Characteristics and construction of stations under transit-oriented development planning

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Abstract. The purpose of this article is to study the characteristics of stations under TOD planning and provide experience for future construction of transportation network planning and surrounding buildings based on station characteristics. Starting from the development stage of TOD theory, the article analyzes the definition of TOD and its main objectives such as traffic efficiency, life choices, and road network construction. Using examples and comparative argumentation methods, the characteristics of station classification, functional height collection, combination of digital technology, and multi-dimensional spatial structure under TOD planning were obtained. To further demonstrate the characteristics of the station, this article takes Baiyun Station as a case study and analyzes it from the perspectives of BIM technology application, functional layering, structural form, construction plan, etc., proving the universality of research on station characteristics under TOD planning. In the summary section, suggestions are made for road network planning and surrounding building construction based on the performance characteristics of the station.

Keywords: Transportation, TOD, Baiyun station, digital technology.

1. Introduction

TOD theory is a public transportation-oriented urban planning method, proposed to address issues such as land resource waste, traffic congestion and chaotic urban layout.

The TOD theory originated in the United States in the 20th century [1]. During this period, the main modes of transportation in the suburbs of the United States were railways and trams. These two modes of transportation are both components of rail transit and require vehicles to operate on specific tracks, which imposes requirements on the quantity and carrying capacity of track construction. At the same time, there are differences between railways and trams in terms of driving speed, natural environmental impact, and economic driving capacity, which puts forward higher requirements for the adaptability of transportation to the natural and cultural environment. To address this issue, the US government adopted the tram system as the main guide and issued policies to improve population distribution, urban spatial planning, and transportation station layout. Ultimately, a city form centered around transportation stations and surrounding areas was formed, with fully compact functions and friendly walking distance.

The TOD theory shows obvious phased development [2]. In the early stages of theoretical development, TOD mainly focused on the micro level. During this period, the economic development of the station and surrounding areas was the main goal, with less consideration given to environmental impact and development continuity. With the further improvement of the theory, the research perspective of TOD theory has further developed from a macro perspective, shifting from the economic development of stations and surrounding areas to research on the development of public transportation, land use, and resource management of the entire city. At the same time, the development of new technologies has also provided more efficient means for the evaluation and implementation of TOD. The application of digital technology, IC card detection, and other technologies has enabled TOD technology to flourish in the new era. This article summarizes the characteristics of stations under the guidance of TOD and takes Baiyun Station as an example to study the specific technologies and characteristics of station construction.

2. Explanation of TOD Definition and Planning Objectives

TOD means transit-oriented development. There are multiple interpretations of this definition.

TOD planning represents compact urban space utilization, highly functional aggregation, and pedestrian-friendly pedestrian-accessible transportation stations [3]. It is a means to promote the intelligent transformation of cities, improve urban employment and living conditions, and further promote the green and low-carbon development of residents' lifestyles [4]. What's more, TOD is a development method that combines regional construction planning, urban economic recovery, edge zone development, and the construction of convenient and unobstructed communities, achieving the integration of transportation, economy, architecture, and other fields. Not only does it help to further diversify the internal elements of the urban and rural transportation system, but it also closely integrates communities, enterprises, and cities, constantly giving birth to new forms of development [5].

In these TOD definitions, there are common areas of concern: pedestrian-friendly distance, versatility, regionality, etc. This indicates that TOD is not only a public transportation-oriented urban planning, but also a systematic planning method that enhances regional economic benefits, improves natural and cultural landscapes and improves work and living conditions. This plan takes traffic efficiency, lifestyle choices, and road network construction as its main objectives [6]. By changing the station's spatial layout, optimizing surrounding building planning, and issuing incentive policies, it ultimately achieves comprehensive optimization of transportation, economy, and culture.

3. Characteristics of Stations Under TOD Planning

Under TOD planning, stations mainly exhibit the following planning characteristics.

3.1. CLASSIFICATION of Urban Rail Transit Stations in TOD Mode

Based on the function-oriented classification method, the railway transit stations are divided into three categories according to the function of the land around the station and the role of the city. The central type is based on the urban public activity center, the residential type is based on the urban residential area, and the hub type is based on the transportation hub stage. This division has an obvious guiding effect on land use planning and development around the station. Table 1 explains the functions of three types of stations.

Table 1. CLASSIFICATION of urban rail transit stations

	Central type	Residential type	Hub type
Rail transit station classification based on function-oriented classification	Based on the urban public activity center, including commercial, office, etc. with higher population flow.	Based on the urban residential area, mainly provide living ability, including pubic activity center.	Based on the transportation hub stage, mainly provides transportation ability.

3.2. Limited Area Multifunctional

With the continuous development of urbanization, major cities in countries such as the UK, France, and the United States have generally entered the third stage of the S-shaped curve, transitioning from a period of rapid growth to a stage of slow development or stagnation [7]. At the same time, the basic proportion of urban residential land, industrial and commercial land, public service, and facility land remains unchanged, further limiting the use of railway station land. To meet the various requirements of passengers and society for transportation, TOD-guided stations continuously develop their functions within a limited area, while forming different areas.

In the TOD plan, the station and the surrounding area have different functional zones: the core business district, which focuses on consumption and entertainment and solves the basic needs of residents; the office area, which changes the separation pressure of living and employment; residential

area, contains a mixture of different types of housing; public spaces, include parks, green spaces and other public areas for people to walk and communicate, as well as peripheral sub-the area waits to be developed.

3.3. Integration of Digital Technology

Digital technology is a technology that evaluates the design, on-site construction, comprehensive management, and other aspects of a project or project through shared data information, to ensure the reliability and accuracy of decision-making. With the vigorous development of digital technology, design methods combined with it in TOD construction continue to emerge [8]: In the layout of station networks and the development of station surrounding areas, virtual reality technology can use virtual networks, GIS, 3D visualization and other technologies to convert real street scenes and road surrounding building facilities into computer content, enabling staff to better understand relevant data, Establish relevant 3D models and conduct further analysis [9]; After establishing physical and mathematical models through virtual reality technology, digital technology can further optimize the analysis of relevant data. Taking the development and utilization of land space on both sides of the TOD corridor as an example [10]: When researching the development of this area, the first step is to use a systematic approach to integrate various influencing factors of land development and construction. Then, combined with different locations and environmental conditions, and considering the adaptability of different regions to income, demand, and derivative elasticity, a reasonable development range is determined to further complete the allocation of industries and facilities; In addition, digital technology plays an increasingly important role in the evaluation of TOD construction. When evaluating the effectiveness of TOD rail transit construction, technologies such as cellular automata can establish land simulation models and compare relevant standards of various policies. At the same time, digital technology can further quantify the energy consumption and natural environmental impact of TOD construction, thereby better evaluating the impact of TOD on sustainable development and conducting related construction and planning.

3.4. Multidimensional Spatial Structure

The transportation network under TOD planning has the characteristics of dense station distribution, complex spatial structure, and large flow changes. As the urbanization process of major countries around the world generally enters the third stage of the S-shaped curve, the total amount of urban land tends to stabilize. To ensure the basic proportion of residential land, public service, and public facility land, industrial and commercial land, and to pursue higher transportation network efficiency and computing capacity, it is necessary to further optimize the internal structure of transportation stations and enrich their functions within the limited land occupation. Taking the TODTOWN project in Xinzhuang as an example [10]: The core area of the station has three different functional zones, namely railway and platform, comprehensive transfer hall, and roof section. While meeting the functions of the station, space utilization has been improved through high-density construction in the vertical direction. While maintaining high density in the internal structure of the station, the external facilities of Xinzhuang Station also have a compact spatial structure [11]. Centered around a transportation hub, retail malls, garden landscapes, public spaces, etc. are seamlessly connected, meeting daily needs while reducing the occupancy of urban land and facilitating the next step of urban development.

4. Characteristics of Baiyun Station Construction

In this report, Baiyun Station is a case study to demonstrate the performance characteristics of the station under TOD planning.

4.1. Geographical Location and Plan of Baiyun Station

Baiyun Station is in the Beijing-Guangzhou Line of Baiyun District, Guangzhou City, Guangdong Province, is one of the main passenger stations of the Guangzhou Railway Hub Planning "Five Main and Four Auxiliary" Passenger Terminal, With a total construction land area of 453000 square meters, a station scale of 11 sets and 24 lines. It not only serves as a long-distance passenger transportation center, city, and tourist bus station; but also serves as a tourist center, demonstrating significant characteristics of transportation integration and functional integration. At the same time, the comprehensive transportation hub emphasizes ecological and intelligent integration, and implements new TOD planning, making it one of the largest train station complexes in Asia. Figure 1 shows the spatial location of Baiyun Station

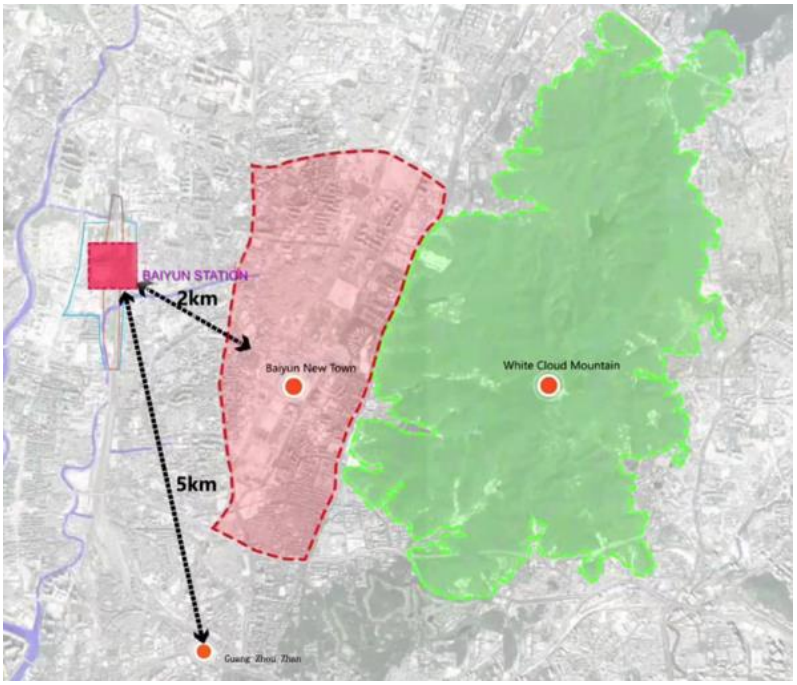


Figure 1. Location of Baiyun Station (Picture credit: Original)

4.2. Diagram of the station building and surrounding facilities Location map of Baiyun Station

According to the needs of information management and BIM application, Baiyun Station follows the unified BIM application specifications, starts from the aspects of BIM standard system construction, BIM platform construction, and construction BIM application, and uses the self-developed construction information management platform to manage the resources, safety, quality, progress, archive data and other aspects of the foundation pit project, the main structure of the station building and other synchronous implementation projects of Baiyun Station. According to the civil BIM application requirements of Baiyun Station, the platform functions are expanded, and BIM technology is effectively applied to the construction process of Baiyun Station, improving project quality and construction efficiency, and laying the foundation for digital operation and maintenance. The overall technical route of informatization and BIM application of this project is shown in Figure 2.

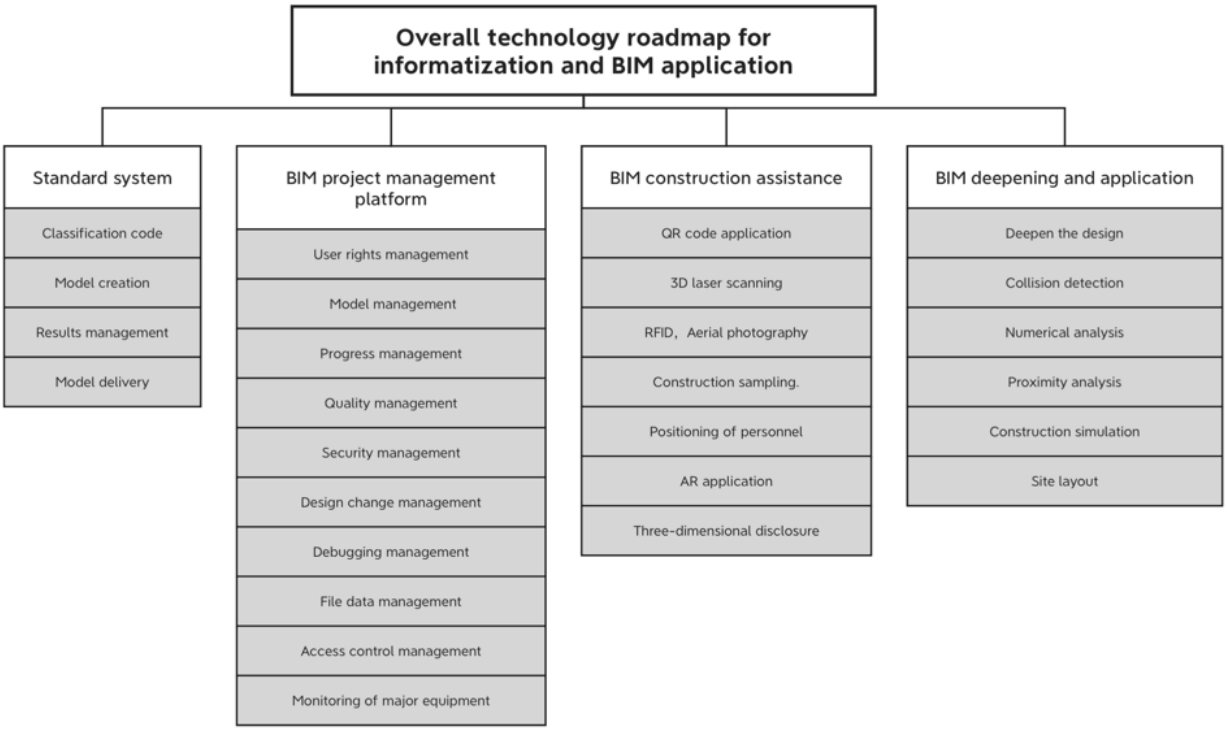


Figure 2. Overall technology roadmap for information and BIM application (Picture credit: Original)

4.3. Diagram of Each Floor of the Baiyun Station Building

The Baiyun Station building has obvious functional layering, from top to bottom: Roof layer, Elevated platform level, Elevated floor, Platform floor, Outbound layer, and Reserved foundation pit for the subway. Figure 3 shows the relationship between the various floors of the Baiyun Station building.

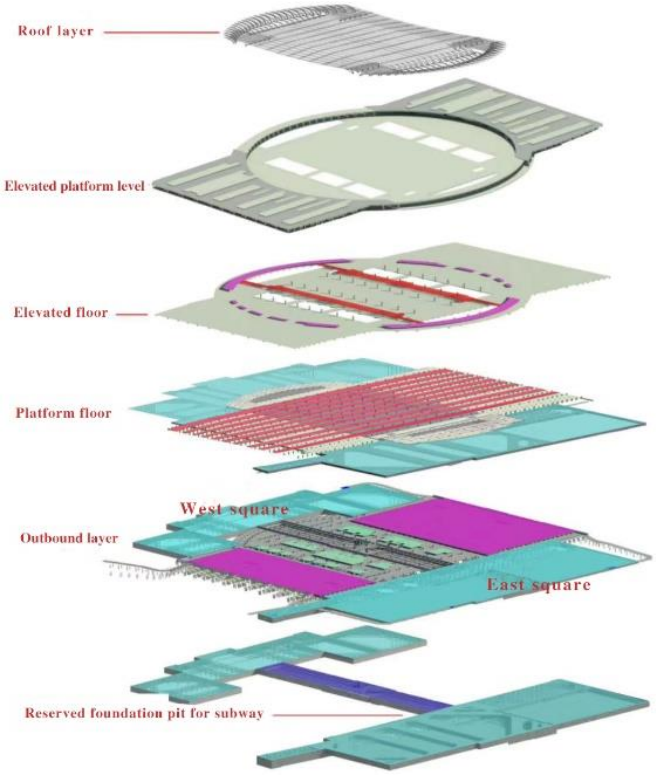


Figure 3. Relationship diagram of each floor of the Baiyun Station building (Picture credit: Original)

4.4. Main Structural Forms of Baiyun Station

Under the guidance of TOD construction, Baiyun Station has a multi-level spatial three-dimensional structure, mainly composed of three parts: track bearing layer, elevated mezzanine layer, and roof.

In track bearing layer, A2 zone adopts the construction method of steel reinforced concrete columns, prestressed concrete beams, and cast-in-place concrete floors, while A1, B, and C zones use materials of steel reinforced concrete columns, reinforced concrete columns, reinforced concrete beams, and cast-in-place concrete floors.

Elevated mezzanine is mainly constructed using steel tube concrete columns, steel tube columns, steel beams, and reinforced truss floor support plates. The outdoor circular corridor adopts a reinforced concrete frame structure.

In Roof, Steel truss and grid structure are used, while Optics Valley adopts a combination of truss petals, rigid ring beams, and solid web arches.

Figure 4 is a schematic plan of the structure of Baiyun Station.

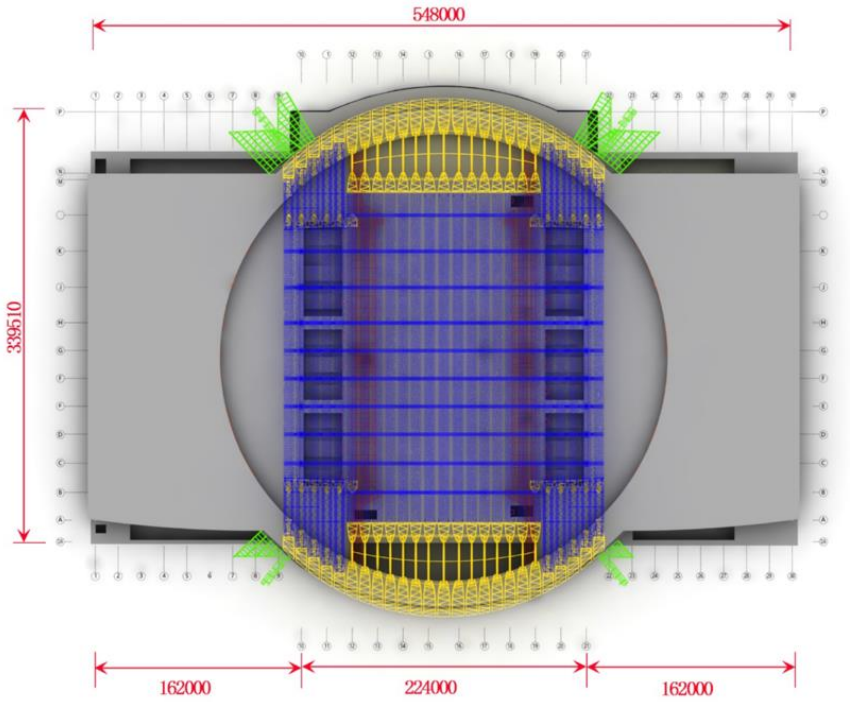


Figure 4. Horizontal schematic diagram (Picture credit: Original)

4.5. Construction Plan for Various Parts of Baiyun Station

The construction of Baiyun Station fully combines the guidance methods of digital technology and adopts different construction methods for different components from aspects such as material properties, economic value, and resource impact.

4.5.1. Column base part

The steel columns all adopt embedded column bases, with a larger cross-sectional size thicker plate thickness, and a weight of about 3t per linear meter. According to the burial depth of the column base, which is twice the height of the column section, and considering that the column base extends 1m above the bearing platform, the weight of a single column base is within 15t. If the column base is lifted within the lifting performance range of the tower crane, it will be lifted by the tower crane. For other tower cranes outside the lifting performance range, it is planned to use a 50t crawler crane to enter the interior of the foundation pit for lifting.

4.5.2. Steel structure columns, beams, and lifting area roof

The lower steel structure beams and columns of the roof include the track layer frame beams and columns, the waiting layer frame beams and columns, and the lifting area roof. After the basement raft foundation construction is completed, a roadbed box is laid on the large bottom plate, and the foundation pit is lifted inside the large bottom plate using a crawler crane. Using a 250t crawler crane for lifting the floors below 10m in Zone B and Zone C, and a 110t truck crane for lifting the 10m platform on the 17m upper cover platform. In Zone A, due to the large impact area of the subway, the lifting radius reaches 36m, and the large partition of the roof grid in the lifting area, four 350t crawler cranes are used for lifting.

4.5.3. Roof lifting area

The roof truss and grid structure in the central lifting area will be assembled and lifted after the construction of the elevated floor slab is completed and reaches its strength. The lifting area adopts a 25t truck crane for loose assembly on the elevated floor. The lower chord of the truss is disconnected at the steel column position, and the upper chord is connected and located on both sides of the steel column. The lifting bracket is set up on the top of the column and above the truss to lift the lifting area truss, and the grid frame is installed in place together with the lifting of the truss.

4.5.4. Optic valley belt

The Guanggu strip steel structure is planned to adopt the installation concept of setting up temporary support frames and lifting large crawler cranes in blocks. The maximum weight of a single petal-shaped column in blocks can reach about 20t, and two 350t crawler cranes are planned to be used for installation. Install lifting and transportation channels on the side of the 9.8m waiting layer near the optical valley belt and reinforce them. The flower petal-shaped columns on both sides of the Optics Valley belt are installed in pairs, and the lifting sequence starts from the middle to both sides. After the lifting of the Optics Valley belt is completed, the roof grid above the channel will be installed and divided into blocks.

5. Conclusion

This article reviews the development history of TOD theory and summarizes the focus of TOD theory in two different stages: early development and theoretical improvement. After explaining the definition and pursuit goals of TOD, the article further analyzes the characteristics of station classification, functional high integration, digital technology integration, and multi-dimensional spatial structure under TOD planning. Taking Baiyun Station as a case study, the article analyzes the characteristics of stations under TOD planning from the perspectives of BIM technology application, functional stratification, structural form, and construction plan.

The characteristics of stations under TOD planning provide a development direction for the planning of transportation networks. When setting up stations, full consideration should be given to the main types of facilities in the area. For residential areas, public activity centers, and transportation hub areas, residential, central, and hub stations will be constructed separately. Simultaneously allocate and adjust the traffic flow in the region based on the capacity and processing capacity of the three types of stations.

The characteristics of the station under TOD planning also guide the construction of surrounding buildings. When constructing buildings around transportation stations, full consideration should be given to the impact of the multi-dimensional spatial structure of the station in terms of floor area and function. The total floor area of the station and surrounding buildings should not hinder the construction of other land and facilities, while achieving rich and complete functions, maximizing the use of land and human resources, and promoting the economic development of the surrounding areas.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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