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Failure and Improvement of 3D Principle in Transit-Oriented Development in China: Retrospection on Development along Subway Line 1 in Guangzhou

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Abstract: Guangzhou is the pioneering city in promoting "Transit Oriented Development (TOD) subway + commercial property" concept in China. Over the past 30 years, from the proposing of planning scheme for subway line 1 of Guangzhou in 1988 to the development of "subway + commercial property" along it, we found out that the ideal 3D principle of TOD based on undeveloped land from the US usually failed to be applicable to the center of the old urban area in China's cities, where high density brought about the lack of public space, mixed commercial and business offices in the old urban areas dilutes cultural distinctiveness, and design innovation not easy to be materialized due to the lack of guarantee mechanism. This paper indicated that when constructing rail transit stations in urban built-up areas in China, priority should be given to the development of distinctive functions incorporated with regional characteristics. Moreover, it is advised to take such a strategy featuring high density plus public space, mixed utilization plus characteristic space, and innovative design plus operational mechanism. **DOI:** 10.13813/j.cn11-5141/u.2018.0107-en

Keywords: rail transit planning; TOD; integrated development; 3D+ principles; Guangzhou

0 Introduction

Transit-oriented development (TOD) was proposed in the 1980s and 1990s. The motivation is to solve the issues caused by the auto-oriented development in the US, such as urban sprawl, spatial fragmentation, and shrinking of pedestrian environment and public space [1]. The three major characteristics of TOD are Density, Diversity and Design, also known as the "3D" principle. TOD emphasizes the development of compact urban spatial form, mixed land use, high development intensity, pedestrian friendly streets and environment in the surrounding areas of public transit stations. In other words, it emphasizes higher development intensity to ensure density and economic agglomeration effect required by public transportation. Meanwhile, TOD can meet various demands in daily life through the design of pedestrian space at small scale and mixed land use patterns, therefore can reduce the dependency on autos.

After introduced to China, TOD faced different development environment, land institutions and resident commuting behaviors. In Chinese cities, the primary mission for rail transit construction is usually to mitigate traffic congestion caused by intensive land use and high population density in old urban areas. It is only the secondary mission for rail transit construction to solve the commuting problems between peripheral suburbs and the city center. Since rail transit construction often falls behind urban development in China, TOD confronts built-up with mixed functions, high density, and complicated land ownership, instead of the lack of high density and mixed land use. Therefore, the challenge of applying TOD in China is how to match and coordinate rail stations with existing development and constructions around them. TOD can only be successful when the surrounding areas are renovated continuously.

Guangzhou is one of the pioneer cities in China that explored the application of TOD along rail lines. It initiated the concept of developing rail transit and re-developing the areas along rail lines as early as in 1980s. However, it was found that the traditional 3D Principle was not really achieved when reviewing the practice of TOD on Guangzhou subway line 1 in the past 30 years. Therefore, new development strategies are needed to apply TOD in China so that they can address the special characteristics of Chinese cities.

1 The concept and practice of TOD for subway line 1

In December 1988, during the collaboration between Guangzhou and Lyon, France, the company, Semaly, Metram, Sofretu (S.M.S), generated a final research report,

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Feasibility Study of Guangzhou Underground Railway: The Sample Report [2]. This report pointed out for the first time that the construction of a rail station should promote the development of real estate of its surrounding areas. Meanwhile, both direct and indirect incomes generated by the real estate development should be counted into the investment and operation budget to alleviate the financial burdens of subway operations. This is the predecessor of the concept of "subway + commercial property". Around 1990, Guangzhou started the construction of subway line 1. Inspired by the experience of joint development of Hong Kong Mass Transit Railway and its surrounding areas, and influenced by the financial pressure of subway construction, Guangzhou officially became the first city to propose the concept of "subway + commercial property". This indicated the beginning of joint development around rail stations.

1.1 Phase 1: Re-densification and Property Development to Compensate Financial Loss

Between 1989 and 1999, Guangzhou planed its first railway network (a cross line network consisting of subway line 1 and subway line 2), completed the construction of subway line 1 and started its operation. During the ten years, Guangzhou learned from the "subway + commercial property" practice in Hong Kong to promote the re-development of its central city and to overcome the funding shortage for housing demolitions and relocation along subway line 1. Guangzhou initiated 27 joint development plots along the line to relieve its financial pressure [3]. The construction of subway line 1 promoted the development of commercial properties along the rail line. During the construction period, more than 20 000 households were relocated due to the subway construction. Demolition and reconstruction along the rail line also changed land use patterns. More than 30 new large commercial and business facilities were built, such as Hengbao Plaza and Zhonglv Building. They achieved the re-densification of the subway station core circle (within 200 m of the station) in the old urban areas (see Fig. 1).

1.2 Phase 2: transportation service-oriented utilization of underground space

After the official operation of subway line 1, Guangzhou began to focus on the integrated development of underground space and rail stations to reduce traffic congestion and to optimize the roadway network. For example, Guangzhou constructed underground tunnels around stations, which reduced traffic on the surface roads, and increased the urban capacity. Commercial centers and public spaces were connected together, and city space was extended due to the development of underground space. Guangzhou initiated the development of underground space at seven stations along subway line 1 successively, including Tiyu Xilu, Dongshankou, Martyrs' Park and Gongyuanqian. The total construction area was more than 260 000 m ^{2}(see

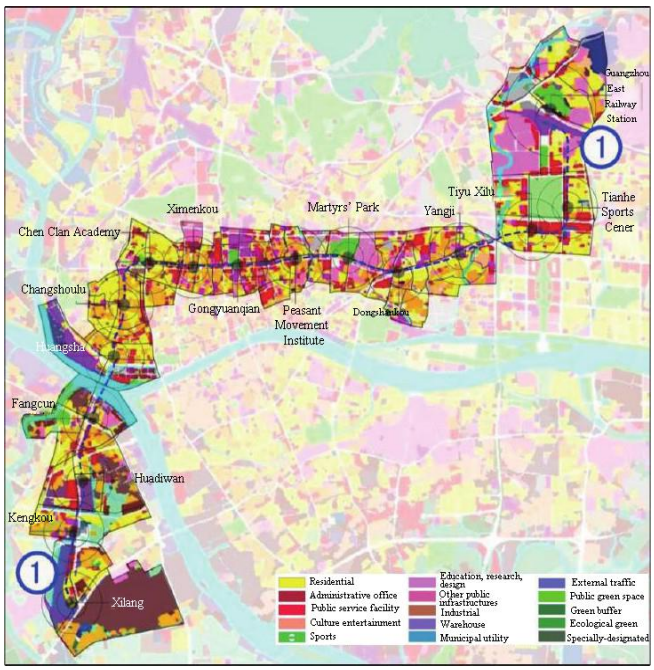

Fig. 1 Land use along subway line 1

Resource: *Research on Comprehensive Development Planning around Guangzhou Rail Transit Station* (in Chinese).

Tab.1). Three-dimensional development of TOD was implemented by connecting station entrances and underground paths with above commercial centers, nodes of public facilities, which optimizes urban space and traffic situation nearby. This practice has promoted the mixed development of land use function in station areas.

1.3 Phase 3: establishment of street network based on the integrated development of hub stations

After the 2010 Asian Games, the rail network in Guangzhou was basically completed, which consisted of a cross and several radial rail lines. Along with the increase in rail line densities, stations became to cluster and impact each other in certain areas. In this period, several hub stations were built on subway line 1 to transfer to new subway lines, and TOD street network was developed around these hub stations. For example, at Tiyu Xilu Station on subway line 1, the underground commercial space and underground tunnels were extended. They were gradually extended to the Tianhe Sports center Station, which was 500 m away. So the underground space at Tiyu Xilu Station grew gradually from a single node to a network. In addition, the underground space network connected TEEMALL, Guangzhou Books center, Victoria Plaza, and Hongcheng Square. They all comprised Tianhe Business center with businesses both on the ground and underground. Another example was Gongyuanqian Station, which was located in the administration district right on the traditional spatial axis of Guangzhou. A large underground complex, the Guangzhou Comic City, was built cantered at the Gonguanqian Station to provide

Tab. 1 Development of underground space along subway line 1

Station	Category	Construction sequence	Connection to stations	Construction area/m²	Main functions	Ownership
Guangzhou East Railway Station	Underground space constructed separately	Constructed after the station was built	Connected through tunnels	150 000	Transportation, business	A state-owned enterprise in Guangzhou
Tiyu Xilu	Underground space constructed with air defense facilities	Constructed after the station was built	Connected through tunnels	1 387	Business	A real estate company in Guangzhou
Dongshankou	Underground space constructed separately	Constructed along with the station	Connected through tunnels	2 767	Business	A railway department in Guangzhou
Martyrs' Park	Underground space constructed with air defense facilities	Constructed after the station was built	Part of the main structure	17 000	Transportation, business	A district air defense office, an investment company in Guangzhou
Gongyuanqian	Underground space constructed separately	Constructed before the station was built	Part of the main structure	32 000	Transportation, business	A railway department, an investment company in Guangzhou
Chen Clan Academy	Underground space constructed with air defense facilities	Constructed after the station was built	Part of the main structure	48 000	Business	A district government in Guangzhou
Fangcun	Underground space constructed separately	Constructed along with the station	Part of the main structure	10 000	Business	A railway department in Guangzhou

exhibition, business, entertainment, dining, parking and other functions. It was also connected to Beijing Road Pedestrian Street via underground paths to prompt the joint development of traditional culture districts and metro commercial circles.

2 Failure of density, diversity and design on subway line 1

The TOD planning theory of the US is not fully applicable to Chinese cities because there are huge differences in the development stage, population density, land ownership, public transportation investment system and cultural backgrounds between China and the US [4]. First of all, the US TOD planning theory originated from the retrospection on the suburban spatial expansion model characterized as low density and single land use. The higher density and land use diversity in the 3D principle were proposed specifically for rapid public transit systems to curb suburban sprawl caused by cars. The American scholar Carl Thorpe suggested that the average population density should be over 7 500 persons/km^2 [5]. However, the average population density of built-up areas in most central urban areas of China was over 10 000 persons/km^2, and up to 30 000 persons/km^2 in the old urban areas of Guangzhou. Obviously, the TOD development of Chinese cities should not pursue excessive density, but should explore how to maintain high quality urban space in high-density situations.

Second, besides the differences in the public transportation investment system and cultural background, the differences in land ownership also profoundly affect the way to practice the TOD in the US and China. Although the zoning laws vary from one city to another in the US, they are all based on the private ownership of lane, ensuring that the development of a plot does not influence the development of its adjacent plots. So the major role for government in TOD is to provide guidance. On the contrary, in China, land is owned by the state or collectively owned by the public, and all urban development and construction are based on state-owned land. The government applies rigid control on the land, thus affecting the urban spatial structure and shape. In this circumstance, the government primarily plays a leading role in TOD.

To summarize, although subway line 1 in Guangzhou has three significant effects on urban development as previously mentioned, extra-high density, mixed land use in old urban areas and design innovation have also brought a lot of challenges to Guangzhou's TOD practice. In particular, the high density has brought about the lack of urban public space, the mixture of commercial and business in the old urban areas has led to insufficient expression of urban cultural characteristics, and design innovation has also been difficult due to the lack of institutional guarantees. These indicate that the high density and mixed land use have never been in shortage in central urban areas in megalopolis like Guangzhou, in which it is difficult to demonstrate the effects of 3D principles shown in the American suburban context. Instead, blindly chasing high density and diversity will lead to the failure of the TOD.

2.1 Node congestion and lack of public space

During the construction of the 27 joint development plots along subway line 1 in Guangzhou, the Hong Kong high-density model was adopted. High floor area ratios (FARs) were allowed when allocating plots, with a maximum of 18.63 and an average of 7.08. Most of these plots were located along streets. They were small, scattered, and irregular, and their cross-sectional depths were small. After setting back the boundary lines from the streets, it was difficult to utilize the plots and implement comprehensive development, and therefore the allocated high FAR was impractical. According to the Literature [3], among the 27 joint development plots along subway line 1, only eight projects were completed, six were cancelled due to idleness, two were changed to greening projects, and the remaining 11 were stopped.

Why are ultra-high-density strategies in TOD not working in central areas of China's metropolis or megalopolis? 1) There was no shortage of high-density areas in the central area of China's metropolis. These high-density areas were able to bring enough passenger flows required by rail transit design, and it was unnecessary to allocate unrealistically high development intensity. Moreover, ultra-high density in old urban areas may also increase the difficulty of development. The reconstruction of Zhongshan 6th Road area, located on the west side of Gongyuanqian Station on subway line 1, was a good example. Although the reconstruction had been promoted for more than 20 years, it was still difficult to implement it. Unreasonable high FAR was one of the main reasons. Among the 19 plots along streets, five of them were granted a FAR of more than 10. The highest FAR was as high as 22, for the parcel located on the northeast side of Haizhu North Road (see Fig. 2). Unreasonably high intensity resulted in difficulties in the joint development plots. 2) The TOD development in the urban center area pursued excessively high intensity [6], which not only increases the congestion at some nodes, but also leads to a loss of attractive urban environment and high quality public space in the urban regeneration process. One of the goals of the joint development of subway line 1 is to compensate the financial loss, so it is inevitable to allocate profit-oriented land in the plan. Among the 27 plots, 17 were planned as commercial and residential combination, and the rest were commercial, hotel and office. Joint development of high intensive residential and office spaces along subway line 1, without reservation of transportation facilities, public spaces and green areas, further increased the environmental stress and infrastructure burden in the old urban areas. It is hard to optimize the function of the old urban areas and the quality of public space. Two plots were later changed to green space, which was a compelling plan adjustment.

2.2 Commercialization-driven and lack of cultural identity

The planning and construction of subway line 1 had promoted the development of real estate and business along the rail line [7]. However, it did not improve the development environment of all stations along the rail line evenly. Instead, various resources, especially business activities, have converged to some advantaged stations. After the operation of subway line 1, the number of large commercial centers around stations increased to some degrees. These commercial centers formed the popular commercial areas along the rail line like grapes on ivy, including commercial business centers like TEEMALL (Tiyu Xilu Station), Lower Nonglin Road (Dongshankou Station), China Plaza (Martyrs' Park Station), Beijing Road (Gongyuanqian Station), Shangxiajiu Pedestrian Street (Changshou Lu Station), etc. This tandem development benefited from the open cut construction method adopted for the entire rail line, as well as the large areas of land acquisition, demolition and reconstruction. For example, the enclosed construction area for the surrounding areas of the Gongyuanqian Station and the allocated joint development plots, was up to 9 hm^2. The demolition area of traditional residential areas and administrative office buildings was about 98 000 m^2. As a result, about 300 000 m^2 of land was provided to this area for the construction of modern commercial and office buildings [8].

Fig. 2 Urban design of reconstruction project in key section of Zhongshan 6th Road

Resource: *Urban Design and Detailed Planning Scheme for Reconstruction Project of Key Sections of Zhongshan 6th Road* ((in Chinese).

During TOD practice on subway line 1, several stations experienced indistinguishable development and excessive commercialization in their surrounding areas, which inevitably resulted in the homogeneity and vicious competition among businesses. For instance, the Gongyuanqian Station, located in old urban areas, was originally planned to be the largest city-level hub station of subway line 1 [2]. To achieve this goal, many traditional streets around the station were demolished. The reservation and cultivation of indigenous urban cultural identity were neglected, and the traditional culture and distinct functions were replaced by homogeneous commercial activities (see Fig. 3). This led to the loss of attractiveness and vitality in this region. Shortly after the operation of subway line 1, Beijing Road Shopping District nearby Gongyuanqian Station was no longer the Number 1 shopping district, and it was replaced by TEEMALL around Tiyu Xilu Station. This case suggested that, diversity of TOD mode in central urban areas should not only be applied to one single station. It also requires different cultural identities and indigenous characteristics to be displayed at stations along the entire line and across the entire region. Otherwise, the building of vitality in the central urban areas would lack continuous motivation, because the absence of urban culture means the absence of sustained vigor.

2.3 Lack of design synchronization and implementation mechanism

Publicity and distinctiveness is the core of good design in the 3D Principle. From good design to good implementation, two key issues are the design of rail transit itself and the plot development around stations. However, in reality, most cities in China are constrained for various reasons, and the lack of effective dialogue mechanism between them has made many designs difficult to implement. For example, during the construction of subway line 1, large-scale land acquisition, demolition and open cutting engineering were implemented, which provided great benefit to the comprehensive development and the use of underground space. However, due to restrictions from the "special funds for special use" regulation and project review and management system, open cut sections of the whole line eventually were backfilled, and even some completed underground spaces were filled. In the end, there were only a handful of underground spaces that were constructed and put into operation in tandem with the subway.

In general, there are two main obstacles in TOD implementation. 1) Lack of design synergy mechanism. Restricted by institutional reasons, the plan, design, review and approval of rail transit and the plot development around stations were incompatible, which makes it difficult to implement good designs. In terms of planning and design, under the current system, the rail transit engineering design and the detailed regulatory planning of urban land development were usually prepared separately. In the detailed

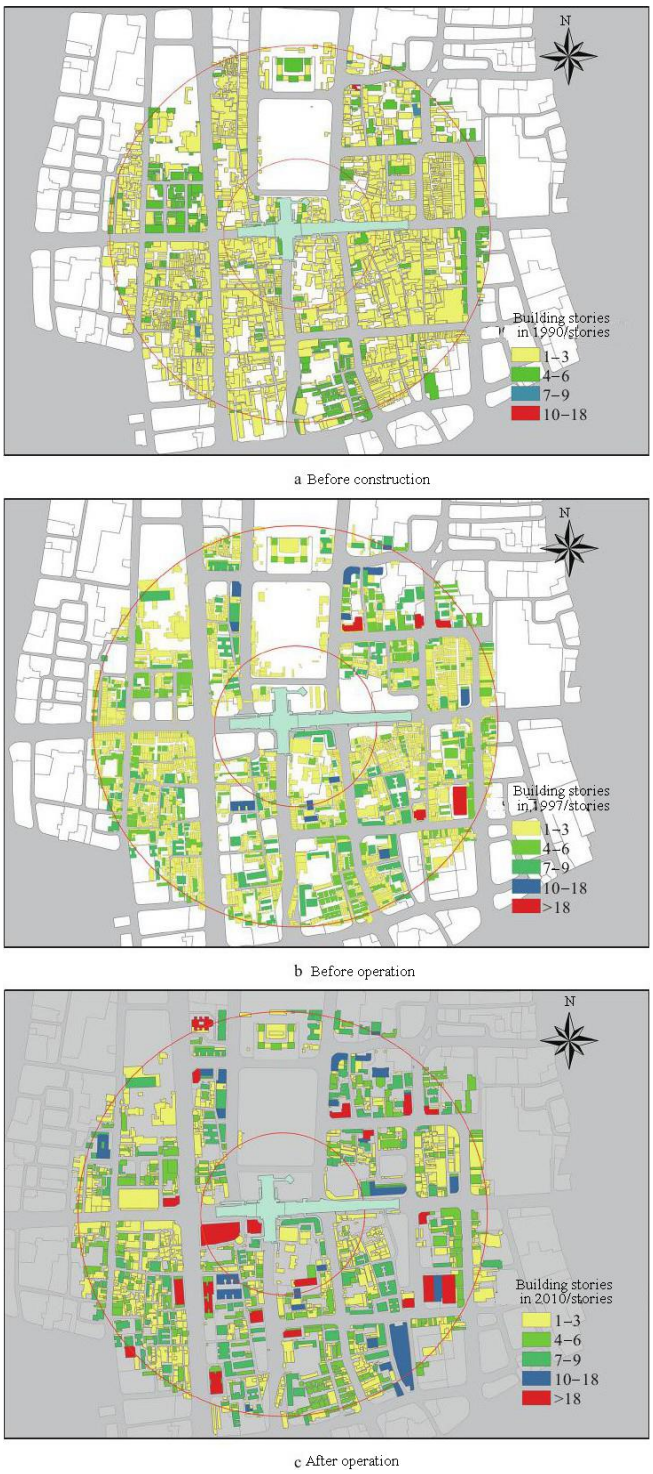

Fig. 3 Development around Gongyuanqian Station in different periods

regulatory planning, rail transit stations were usually treated only as transportation facilities. Nevertheless, considerations were absent in how to connect stations with pedestrian system, and how to set criterion for an integrated development of stations and surrounding areas. This makes it difficult to implement the integrated design. In terms of review and approval, since rail transit investment generally relied

on social and public finances, in principal it did not allow too many profit-oriented properties. In addition, it is basically impossible for a rail transit construction plan to include the content of profit-oriented development and joint development. As a result, it became difficult for rail transit construction projects to reserve the interface with integrated development, which further increases the difficulty of synchronized design. 2) Lack of compensation and profit balance mechanism. First of all, the ownership of existing land around stations in old urban areas was complicated. Unlike in the US, most of the TOD practices were in the undeveloped suburban areas, where it is easy to implement the plan. Second, there were no corresponding land policies and a balance mechanism for revenues from land appreciation nearby stations to propel updates of projects. The development of plots around rail transit stations involved various parties, including rail transit construction parties (they need the revenues from land appreciation along the rail to sustain continuous development of the rail transportation), local governments and land owners. Each party battled for the benefit from the plot appreciation. Before setting up an interest balance mechanism with consents from all parties, or issuing reasonable land policies, the ideal integrated development scheme would only be a fantasy.

3 Constructing "3D+" strategies for China

Considering the prevailing situation of high density and mixed functions in the urban centers of China's cities, directly copying 3D principle around the rail transit stations would inevitably lead to failures to some degree. On the basis of the traditional 3D Principle, the development around rail transit stations in built-up areas should place more emphasis on the protection of publicity, the development of special functions compatible with regional characteristics, and the planning mechanism that supported implementation. These three elements can be interpreted as "3D+" strategy that was suitable for TOD in China.

3.1 High density + public space

According to the 3D principle, high-intensity development was popular in the core circle of rail transit stations. The practice of joint development plot along subway line 1 showed that high FAR was rather a compelling choice to promote the urban regeneration in old urban areas. However, high-intensity development based solely on profit-oriented land may damage the public interests in these areas. Therefore, the top priority to apply TOD in old urban areas was not to pursue high densities, but to achieve the balance between land value and urban space quality under the financial pressure of urban regeneration, in order to mitigate traffic congestion and to improve the level of public service in old urban areas.

Therefore, TOD in central urban areas should promote high-density development with a focus on public space by increasing public space, transportation connection and public service facilities within its core circle of 200 m (see Fig.4). This would help to achieve the traffic optimization and quality improvement in the process of high-density development.

1) Within rail transit stations, a zero-distance transfer to bus stations, Park and Ride parking spaces, taxi stations, etc., should be implemented. Rail transit stations should become organizing centers for various modes of transportation, such as buses, trams and taxis. They should also streamline the flow of people in a fast and orderly manner.

2) Three-dimensional street systems should be established by building air corridors and underground pedestrian tunnels around rail transit stations. Continuous and attractive pedestrian system should be built in the surrounding areas of stations to solve the chaos of mixed pedestrian flows and automobile flows in old urban areas, to improve the quality of pedestrian environment, and to increase the capacity of traffic environment. For example, Hong Kong

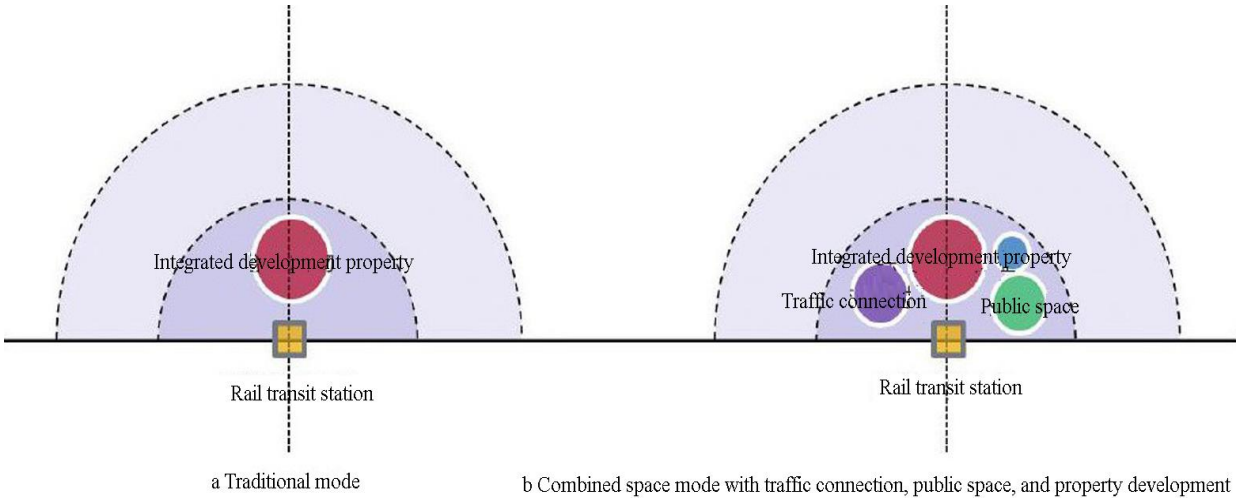

Fig. 4 Comparison of high density principle of TOD and "high density plus public space" mode

resolved traffic conflicts between automobiles and ground-level pedestrian flows by building a three-dimensional pedestrian network centerd on the station. It is therefore called a city without ground pedestrian flows, and it realized a compact urban spatial development mode with well-organized traffic and high density.

3) Public service functions should be strengthened considering the people-gathering characteristics of rail transit stations. The construction of public service facilities in old urban areas often lagged behind the rising population density. For stations in central urban areas, the inner corridors can be built to strengthen the vibrant interactions between commercial business spaces and public spaces in the internal circle, forming a compact station complex. Therefore, public functions were concentrated to facilitate passengers, and the continuous spatial layout was used to strength the function of public center.

3.2 Diversity + characteristic space

Mixed use of land is a primary principle in TOD mode. It is necessary to consider not only the mixed use of land around a single station, but also the integrated development of the entire rail line. The land use patterns of the functional clusters along rail lines often showed diverse characteristics due to the differences in development conditions, major functions and development stages. A successful traffic corridor should consider the cultivation of special features of each cluster along the rail line and strengthen the heterogeneity and complementarity among these clusters. Taking the development of the city rail transit in Arlington, the US as an example, each functional cluster in the corridor had its own emphasis. For example, the cluster of Rosslyn Station focused on high-density business and residence, the cluster of Courthouse Station emphasized administrative and governmental organizations, and the cluster of Clarendon Station highlighted the catering service and the retail industry. These clusters differed from each other in functions, but also complemented each other well.

Clusters along rail transit line should adopt a complementary development model to promote the complementation among clusters. Stations in old urban areas should enhance the excavation of cultural identity, while those in new urban areas should strengthen the cultivation of commercial distinctiveness. The peripheral clusters should improve neighborhood services, play a role of service center within a certain region, and reduce its dependence on the central urban areas (see Fig. 5).

3.3 Good design + operation mechanism

Good design needs to be implementation-oriented, and the execution and implementation of the design plan needs the guarantee from a good operation mechanism. In China, there is a gap between the planning, construction and management of the property development design and the rail transit engineering construction design. On the one hand, it is difficult for rail transit to achieve the space effects of rationally guiding the development of cities. On the other hand, it also makes it difficult for the profit of land value appreciation to effectively feed back into the development of rail transit. Therefore, it is necessary to establish a coordination mechanism for the planning and design of rail transit and cities along the rail line, and to achieve a positive interaction on design and land transfer (see Fig. 6). At the same time, it is also necessary to establish a balance of benefits between the construction of rail transit and the integrated development around stations.

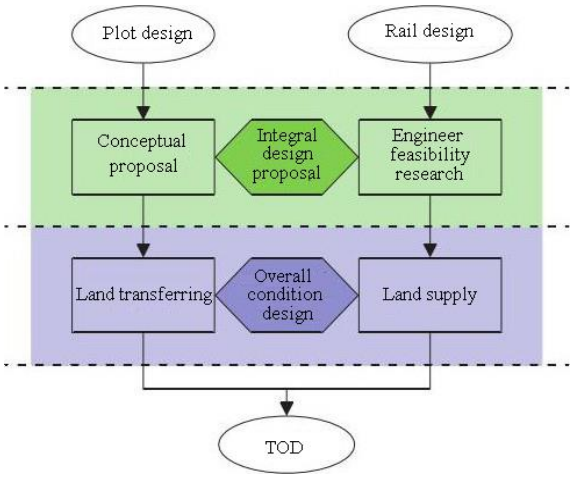

Fig. 6 Coordinated mechanism of plot design and rail transit design

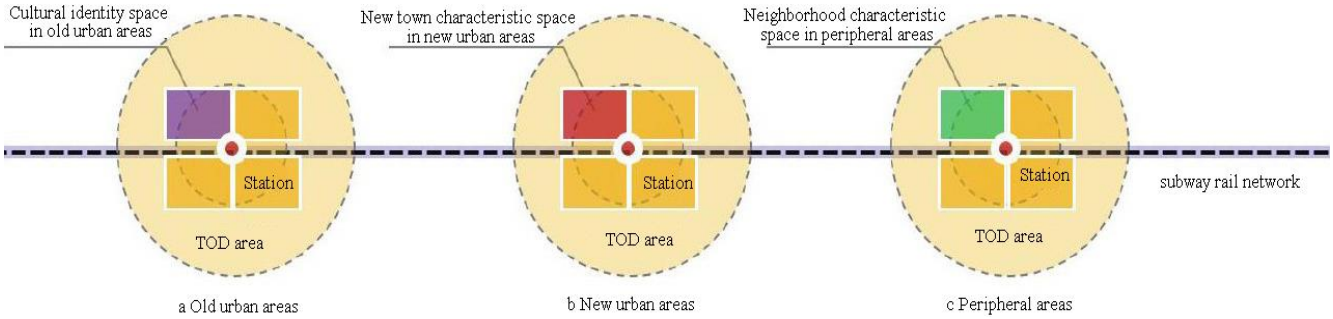

Fig. 5 TOD characteristic space mode in different areas

In order to promote the implementation of a good design, it is necessary to promote the coordination between the rail station design and the plot development around stations from various aspects such as planning and design, land management and policies and regulations. First, a collaborative dialogue mechanism needs to be established between rail transit design and the development of plots around stations through the design integration. For example, in the *"The Implementation Guideline of Integration Construction of Guangzhou Rail Transit Station and the Land Integrated Development along Rail Lines"*, it is clearly required that the integrated conceptual design plan for the joint development of surrounding land should be included in the engineering feasibility study report of the rail transit. This ensured the reservation of land for future joint development before the construction of rail transit projects, and made up for the deficiencies in the previous review and approval procedures. Meanwhile, it is required that this integrated technical plan should be a prerequisite of land transferring for the joint development, and would be bundled up in the form of conditional transfer in transfer stage. This established a vertical collaborative dialogue mechanism from the integrated design to the integrated implementation, and guaranteed the implementation of the joint development of land along the rail line.

Second, an interest balance mechanism should be established around rail transit stations by building a land reserve mechanism and a joint development mechanism. This would promote the coordination between stations and the surrounding areas. The joint development mechanism was a good way for the effective integration of public and private resources. In practice, according to the demand of rail transit facilities, a rail transit construction company acquires the land through the government who hasd reserved the land at the current land price. Then the rail transit construction company can select either companies with good performance and reputation, or owners of land around stations as partners to build properties collaboratively. This created a win-win situation for governments, rail transit companies and joint development partners. Another interest balance mechanism is to allocate the profits from land value appreciation. It requires delineating rail transit integrated development areas on a large scale around stations, adhering to the concept of overall design and comprehensive development, providing development flexibility to subway + commercial property, such as flexibility in mixed land use and FAR, and allowing flexibility on the profits of land value appreciation. A part of profits from land reservation along rail lines can be used to compensate the construction of rail transit. According to the proportion of revenue, the government and related investment entities undertook the development of public space, which promotes the fairness in redistribution and guarantees the implementation of good design.

4 Conclusions

It has been about 30 years since the project of Guangzhou subway line 1 proposed "Subway + Commercial Property". There were successful practical experiences in the development of areas around stations, as well as failures caused by simply imitating foreign planning concepts. The main reason for the failure is the differences in the background of urban development between China and the US, which reflected in the spatial characteristics, cultural identity and institutional environment etc. This indicates that there was a fundamental difference between TOD in built-up areas of China and in the suburbs of the US.

Both traditional American TOD and the 3D principle with high density, diversity and good design paid more attention to land use issues. However, there were weaknesses in the application of the 3D principle in Chinese cities. Hence, in the development of land around rail transit stations in central urban areas, it is necessary to consider the combination of the traditional 3D Principle with publicity, identity and operation supporting mechanism. Excessive emphasis on increasing the development density in the surrounding areas of transit stations was not conducive to the quality of urban space. The top priority for central urban areas in China is to improve the transfer function and urban space through the design of the surrounding areas of stations. To gain benefits from TOD and the integrated development of stations and surrounding areas, efforts should be based on the overall development of the entire city, and development intensity and land ownership should be coordinated for both rail line areas and non-rail line areas.

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