

# ***Research on the Integrated Design of TOD and the Relationship with Urban Sustainable Development***

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**Abstract:** This paper mainly discusses the urban TOD planning model and its relationship with urban sustainable development. Based on a comprehensive design study of three different urban cases, the article demonstrates the role of the TOD planning model in promoting sustainable development. Through the analysis of three typical examples in China and a series of urban planning theories, the article puts forward the content, internal connection, and practical effect of the integrated design of the subway station area. Taking Chongqing Longhu Light Year Project, Hangzhou Metro Citizen Center Station, and Beijing Metro Line 11 as research objects, we analyze the impact of function, traffic, and landscape integration. The rationality and status quo of such designs in urban planning are presented. The results show that the TOD planning model is a comprehensive strategy, which can promote sustainable development and solve many social problems in many aspects such as convenient transportation, social equity, economic development, and environmental protection.

**Keywords:** Integrated design, Subway station area, Sustainable development, urban planning.

## **1. Introduction**

With the advancement of urbanization, the scale of cities continues to expand, the land resources are increasingly tense, as well as the population and traffic pressures are also accordingly escalating. Under this circumstance, the importance of the development and reuse of underground space are becoming increasingly apparent. The effective use of underground space has become a current concern of people. As a means of transportation in the new era, the subway is accelerating the development of modernization and has an essential impact on the surrounding commerce, technology, and economy.

With the development of urban rail transit, integrated development and Transit-oriented development (TOD) are being constructed and popularized. The integration of rail transit means that at the beginning of the design, designers regard the rail transit and surrounding buildings as an entirety and then arrange traffic and other functions properly. And TOD identifies the regional development orientation, based on transit systems, thus improving the efficiency of land use and transit operations[1].

Integrated construction plays a crucial role in sustainable development. Three of the target modules of sustainable development are to achieve energy decarbonization and sustainable industries, build sustainable communities and cities, and achieve a sustainable digital revolution[2]. The purpose of subway integration and TOD is to popularize green traffic, build a green environment and integrate functions to increase the economic growth while facilitating transportation. These goals and existing infrastructures serve to promote sustainable development.

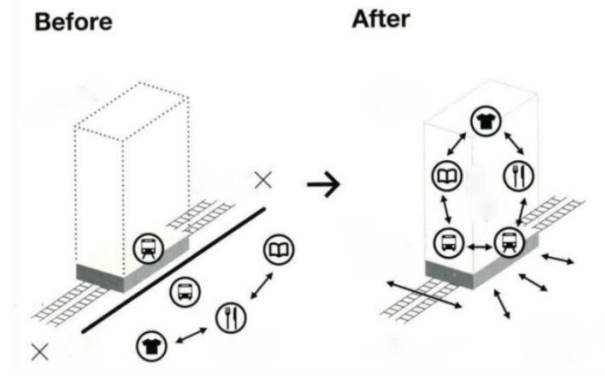


Figure 1: Comparison of TOD and traditional traffic mode.

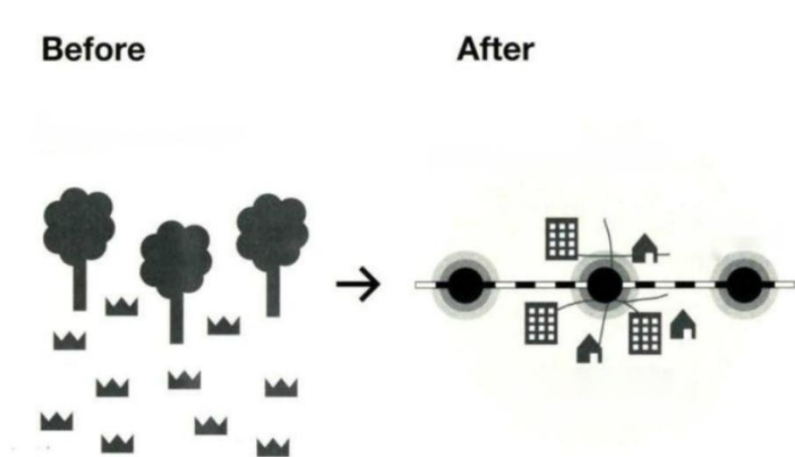


Figure 2: Full utilization of land in TOD.

This paper will mainly study the subway integration and TOD construction cases in three Chinese cities. The first is the Chongqing Longhu Light Year Project, the first high-speed rail TOD (Transit-Oriented Development) complex in China, with rail transit stations as the center to build a compact and harmonious networked development city. The second is Hangzhou Metro Line 4 Citizen Center Station. Due to its unique location, the metro highlights the TOD construction mode and creates a subway business district landscape. The third is Beijing Metro Line 11 New Shougang Station, which is of great significance to improving the level of transportation services and helping the development of the new Shougang industrial comprehensive service area. In the following, we will analyze the unique design of these three cases in detail.

## 2. Methodology

Based on the study of theoretical basis, we selected the three most representative cases of TOD integration construction in China, which are located in Chongqing, Suzhou, and Beijing, and divided TOD integration into three categories that are functional integration, traffic integration, and landscape

integration. To study the relationship between TOD integration and sustainable development, we conducted a full range of data collection and field observations on the cases. We collected the construction situation, specific functions, and current impact of the three cases.

### **3. Functional Integration and Case Studies**

Functional integration is a systematic way of architectural design. Its design goal is to maintain a harmonious and symbiotic relationship between all elements in the system, which needs to pay attention to integrity and complexity. In terms of functions, the integrated design emphasizes the combination of the space inside and outside the subway station, the above-ground and underground space, the subway station and the surrounding area space.

#### **3.1. Functional Integration of Chongqing Longhu Light Year Project**

The project is located in the old urban area of Shapingba District, Chongqing. With the development of the city, the connection between underground and ground, transportation and business in this area become less close, so it gradually becomes out-dated, chaotic and blocked. In the horizontal expansion, a series of public spaces such as medical care for the aged, educational institutions and urban squares are also built around the area. This project focuses on commercial features. Light Year will be an important part of the future pearl business district, with an average of 900,000 people using the high-speed rail, subway and bus systems around the project. Through the four 2.5-ton elevators and escalators in Longhu Light Year, 9,750 people flowed into the business district, thus forming a self-circulating consumption cycle. The perfect existence of various supporting facilities around is also an important feature of this project.

#### **3.2. Functional Integration of Hangzhou Metro Line 4 Citizen Center Station**

Similar to the Project in Chongqing, the subway station of Hangzhou Metro Line 4 is surrounded by ground space with different functions. On both sides of the subway station are the "Sand Boat" commercial street, the Citizen Center and Hangzhou Municipal Government. There are Hangzhou City Planning Exhibition Hall, CBD Park and Hangzhou Grand Theater around, as well as the main river of Hangzhou city, Qiantang River, which integrates politics, science and technology, culture, economy and environment. What is more unique is that the main function of the Citizen Center subway station is to connect the space of different functions in the region from underground[3]. There are 10 exits in the civic Center subway station for direct access, and different exits lead to places with different functions, so that people can switch places at any time.

#### **3.3. Functional Integration of Beijing Metro Line 11 New Shougang Station**

Beijing metro line 11 north Xinan Road station and Shougang station the station also has the same combination mode of metro + business circle, but this time the business circle of design in the underground, formed a between the two standing more than 500 meters long slow underground commercial blocks. Taking the Winter Olympics as an opportunity, Shougang North District combined with the construction of rail transit Line 11, set up the subway service supporting facilities under the west road to connect with the underground space of the surrounding plots to realize regional integration and inject vitality into the development of Shougang North District. The two groups of integrated buildings under the guidance of TOD concept respond to the north and south in the form of portal tower.

### **3.4. The Impact of Functional Integration**

The design of integrated functions of subway stations mostly adopts the mode of subway station + business district, which can quickly bring people brought by traffic into shopping and consumption, realize the combination of traffic + economy, and make the city appear more compact. The integrated design realizes the organic combination of different functional spaces. People travel and consume in the space, while the subway station with integrated functions is the hub of the city center for people. Of course, functional integration also has some shortcomings and disadvantages, such as the concentration of different functional space design for the city will increase the flow of people, increase the burden of space; At the same time, the reconstruction of old urban areas will also lead to a sharp increase in the housing price of new buildings in the region, resulting in the phenomenon of gentrification. Some old surrounding areas that have not been transformed form a sharp contrast with those that have been transformed, highlighting the gap between the rich and the poor in society[4].

## **4. Traffic Integration and Case Studies**

As one of the main components of the TOD model, the second part of the relationship between TOD and urban planning is traffic integration. The so-called traffic integration refers to the simultaneous arrangement of various types of traffic hubs in a station's vertical and horizontal space. To be specific, people can choose modes such as high-speed rail, subway, bus, bicycle, taxi, and private car according to their travel needs within one station.

### **4.1. Traffic Integration of Chongqing Longhu Light Year Project**

As the first TOD site in China, the overall arrangement of this project mainly revolves around the Shapingba transportation hub station, which was called “four tracks in one”. The station has mature public and multimodal transportation capabilities, covering almost all kinds of ground transportation. Additionally, the gigantic transportation hub also connects to the three railway lines of Line 1, Line 9, and Ring Line, realizing the transfer between Shapingba Station and Chongqing. The project has seven floors underground, and each floor has different functions. The first floor to the seventh floor are the bus station, taxi station, pedestrian passage, high-speed rail transfer hall, exit passage, rail station hall and railway line 9 platform. Citizens can conveniently transfer to high-speed rail, rail transit, bus, taxi, and other means of transportation, and the average daily passenger flow is about 900,000.

### **4.2. Traffic Integration of Hangzhou Metro Line 4 Citizen Center Station**

Similar to the case of Chongqing, the Citizen Center Station of Hangzhou Metro Line 4 has the function of transportation interconnection. Citizen Center Station is the transfer station of Hangzhou Metro Line 4 and Line 7, which cover most of Hangzhou's urban areas. Starting from Citizen Center Station, people can easily reach destinations in Hangzhou by subway. In addition, the transportation integration of Hangzhou Metro unfolds the connection between cities. Starting from the Citizen Center, one transfer can take people from Hangzhou to Shaoxing. The rail transit at the Civic Center Station also connects to the ground transportation system. There are three bus stops near the subway entrance, and the station entrance has a large number of shared bicycles.

### **4.3. Traffic Integration of Beijing Metro Line 11 New Shougang Station**

Through specific research, the construction of Shougang Station not only serves people's daily travel but also improves the transportation services in the nearby sports industry demonstration area. For example, the west section of Line 11 transfers to Line 6 and S1 at Jinanqiao Station. To realize three-

line transfer, Jinnanqiao Station has a transfer hall with a span of 30 meters, which is connected to the existing passage to improve transfer conditions. Structurally, the west section of Line 11, Line 6, and Line S1 overlap from bottom to top. Passengers can go to each line through the transfer hall and escalator when transferring. At the same time, there are many shared bicycle points and buses around the station. Citizens can transfer by various means of transportation to easily reach their destinations. Besides, Beixin'an Road Station, a north-south traffic artery in the Shougang area, strengthened the traffic service level during the Winter Olympics and solved the problem of connecting to the subway during the competition.

#### **4.4. The Impact of Traffic Integration**

Within the scope of life covered by above projects, people can reach any destination within 10-15min for daily travel, which is in line with the requirements of the modern 15min city concept for transportation[5]. For sustainable development, these three projects are limited to use for up to 100 years, for the sake of meeting the use needs of at least three generations and the vertical fairness between generations. For this generation, the facilities in the project area are open to all, without any privilege gap, which meets the horizontal equity between generations<sup>[6]</sup>. At the same time, both Chongqing Longhu Project and Beijing Line 11 project involve the reconstruction and renewal of old urban areas or buildings, as well as the capitalized part of commercial land after the renewal, so these measures also reflect the indispensable role of Gentrification in this model to some extent. All of that seems to provide a solution for the contradiction of property conflict between equity, social justice and economic development.

### **5. Landscape Integration and Case Studies**

Today, landscape integration construction has become an indispensable part of subway construction. Citizens consider the renewal of micro landscape space as an effective way to revive the vitality and the sustainable development of landscape resources. The landscape integration construction of the subway pays attention to the unification with the unique features of the surrounding architecture.

#### **5.1. The Landscape Integration of Chongqing Longhu Light Year Project**

Chongqing Longhu Light Year Project stresses environmental protection, building many green infrastructures and energy-saving systems. The project features large ramps, atriums, and plazas at the interface between the subway station. In the balcony area of the shopping mall, the greening rate of the whole project is as high as 35%, with a large area of landscape vegetation and public activity areas. Designers laid lawns, planted green plants, and set up modern intelligent light sources and identification systems in these areas. In the residential area, the greening rate has reached 45%. At the same time, technological properties consisting of temperature, humidity, and light analysis also conform to the requirements of the currently developing smart city.

#### **5.2. The Landscape Integration of Hangzhou Metro Line 4 Citizen Center Station**

Similar to the case in Chongqing, Hangzhou Metro Line 4 Citizen Center Station not only pays attention to landscaping but also adds natural and environmentally friendly settings. Two-way escalators are located at the connection between the atrium and the Sunken Plaza of the commercial area and the top city balcony. At the same time, the planners wrapped glass wall decorations on both sides of the escalator, which increased the sense of spatial hierarchy and consistency[7]. Also, the introduction of natural light provides the fundamental environment for indoor vegetation. At the same time, the decoration style of the subway is full of cultural flavor. For example, the suspended ceiling

of the subway platform is a "starry sky map." Those elements display the city's cultural heritage and bring some physical and mental pleasure to the passers-by.

### **5.3. The Landscape Integration of Beijing Metro Line 11 New Shougang Station**

In contrast to the previous two cases, the landscape integration of Beijing Metro Line 11 pays more attention to the fit with the surrounding environment. Beijing Shougang hosts the 2022 Winter Olympics, and the interior of the trains of Beijing Metro Line 11 is full of Winter Olympics elements. The light strip on the roof is in the shape of snowflakes, and the handrails of the carriage are also integrated into the design of ice hockey sticks. In the periphery of the subway station, the designer combines the ground landscape with the ground industrial workshop to build the overall style and achieve the disappearance of the design landscape. For example, the building colors of the entrances and exits of Shougang Station are brown and gray. There are many low wind pavilions beside the station, which integrate with the surrounding industrial plants.

### **5.4. The Impact of Landscape Integration**

According to the above case analysis, landscape integration promotes sustainable development of green city from two dimensions: optimizing the ecological environment and beautifying the space. The infusion of the subway landscape and the surrounding environment can enhance the viewing experience and create a comfortable environment for passengers. At the same time, the distinctive landscape design can also make citizens feel the charm of history and culture, which can promote heritage and inheritance of history and culture. Besides, the cases of Chongqing and Hangzhou both emphasize that landscape integration improves the greening quality of the surrounding environment. These urban rail transit stations are also enhancing the urban environment through building green infrastructures, such as indoor gardens, vegetation planting, and grass roofs. The appealing interior design of rail transit will also attract more citizens to take public transportation, thereby reducing carbon dioxide emissions and mitigating global warming[8]. Therefore, landscape integration is a long-term and effective method to create a friendly ecological environment and contribute to a green city.

## **6. Comprehensive Evaluation**

In the three cases of using TOD mode, we can find that TOD mode has important innovation and significance for the urban subway station system. Through the vertical comparison of the three cases, we find that TOD mode plays an important role in stimulating the economy, building smart cities, and sustainable urban development. However, there are also some problems and deficiencies in TOD mode that deserve our consideration. First of all, many TOD models have the problem of unclear strategic objectives. Although the planning departments of some cities list a large area of land, due to the different starting points of the government, rail companies and other relevant departments and units, their participation is not enough, and they cannot really form a joint force. As a result, it is often difficult to obtain land and make planning adjustments in the actual process of TOD work the whole process is difficult and complicated. There is also a serious and most important problem, which is the mode of integration of transportation, business district and real estate, which will lead to a series of high risks[9]. For example, the construction of the business district often requires the government to suspend the construction of rail transit. In the case of heavy traffic pressure, it will delay and lag the opening time of the subway station, ignoring the traffic function of the subway itself; At the same time, due to the large volume of the above ground business district and the real estate industry, a large amount of capital needs to be invested to maintain its operation. Because it is difficult to maintain its operation, it is a burden for the region; In addition, the instability of the real estate industry is obvious

to all. Once the real estate industry is depressed, it will be a fatal blow to the TOD model. Finally, the extension of rail transit projects will inevitably accelerate the appreciation of land in the region, thus stimulating the rise of house prices along the line and the massive influx of people in the region, resulting in financial burden and imbalance in cost performance. Even because the expected time is too different from the actual completion time, the advance property payment of the people is huge, and the expectation value drops sharply, resulting in the loss of people's property and the decline of government credibility.

## 7. Conclusion

TOD is an integrated design of urban planning, architecture, landscape and transportation. It is a thinking mode of organic connection and compound planning of various fields through landscape planning and design. At the same time, the integrated design of transportation space is also a method to improve the social, economic and using value of the overall regional space by integrating commercial, residential and landscape design on the basis of emphasizing transportation functions.

From the perspective of sustainable development, Integrated design is undoubtedly an effective method to properly deal with the contradiction between the three elements of sustainable development triangle. This design approach integrates social justice and economic development under the premise of maintaining the greening rate and the large-scale greening of the building platform also meets the demand of urban park in Green City theory. At the same time, it can also increase the sense of connection and cohesion between various traffic spaces[10,11]. On this basis, the integrated design greatly reduces the travel time of people in the area covered by the site. Since the area contains almost all the public functions required daily, the planning scheme brought by TOD also coincides with 15 minutes City theory. Some of the projects are also renovation of old urban areas. The inflow of capital and implantation of electronic equipment further deepen the development of Gentrification and smart city. In future urban planning, such integrated planning and design will be more widely used.

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## References

- [1] Lin, J. J., & Gau, C. C. (2006). A TOD planning model to review the regulation of allowable development densities around subway stations. In *Land Use Policy* (Vol. 23, Issue 3, pp. 353–360). Elsevier BV.
- [2] Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the sustainable development goals. *Nature sustainability*, 2(9), 805-814.
- [3] Li, Z., Lin, X., Han, X., Lu, X., & Zhao, H. (2022). Landscape Efficiency Assessment of Urban Subway Station Entrance Based on Structural Equation Model: Case Study of Main Urban Area of Nanjing. In *Buildings* (Vol. 12, Issue 3, p. 294). MDPI AG.
- [4] Smith, N. (1996). "Introduction" and "Is Gentrification a Dirty Word?" in *The New Urban Frontier: Gentrification and the Revanchist City*. Routledge.
- [5] Moreno, C., Allam, Z., Chabaud, D., Gall, C., & Pralong, F. (2021). Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities*, 4(1), 93-111.
- [6] Campbell, S. (1996). Green cities, growing cities, just cities?: Urban planning and the contradictions of sustainable development. *Journal of the American Planning Association*, 62(3), 296-312.
- [7] Wang, J., & Lu, Q. (2018). Research on space integration design of subway station-Take the citizen center station of Hangzhou Metro Line 4 as an example. *Science and Technology Innovation Herald*, 19.
- [8] Berman, M. (1982). "In the Forest of Symbols: Some Notes on Modernism in New York" in *All That is Solid Melts into Air*. New York: Simon and Schuster.
- [9] Zhong, R., (2020). Problems and suggestions of TOD mode in actual operation. *Money China*, 250-251.
- [10] Singh, Y. J., Lukman, A., Flacke, J., Zuidgeest, M., & Van Maarseveen, M. F. A. M. (2017). Measuring TOD around transit nodes-Towards TOD policy. *Transport policy*, 56, 96-111.
- [11] Ibraeva, A., de Almeida Correia, G. H., Silva, C., & Antunes, A. P. (2020). Transit-oriented development: A review of research achievements and challenges. *Transportation Research Part A: Policy and Practice*, 132, 110-130.