From the perspective of "station city integration" to "corridor integration" from the perspective of mobile space.TOD.Development theoretical framework and mode optimization

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Summarize: Transit-oriented development (TOD) is a key planning method to meet the challenges of urban sustainable development, but the theoretical mechanism and practical results of the TOD development model still need to be further improved. By tracing back the basic connotation and key mechanism of the TOD concept, it is clear that public transportation andThe integration of land use is the essence of the TOD development model, emphasizing that the fundamental purpose of TOD is not compact, mixed and high-intensity land development, but to improve the competitiveness and attractiveness of public transportation in residents' travel choices, and promote green, low-carbon and sustainable development of cities. In view of the difficulties encountered by the TOD development model in China's practice, it is proposed that "travel behavior" from the perspective of mobile space-Public transport-LandUse the theoretical framework of the model. Based on the empirical results of the community structure of rail transit travel behavior, it is proposed to take the "corridor" as the main planning scenario.TOD optimization mode in order to provide more and more balanced public transportation;The passenger flow provides urban residents with more convenient employment, residence and recreation options for urban residents.

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The dual role of urbanization and motorization has led to a surge in urban traffic demand, bringing great challenges to urban environmental protection, energy security and congestion control. Therefore, public transportation has become a necessary measure to reduce energy consumption, relieve the pressure of traffic congestion, and promote the green and low-carbon development of cities.At the same time, with public transportation stations as the center and the appropriate walking distance as the radius, it emphasizes compact, mixed and high-intensity land development within the radius, so as to improve the bus-oriented urban development model of residents' public transportation travel sharing rate and land use efficiency.(Transt-Oriented Development, TOD) has been widely advocated. The development of public transportation in big cities around the worldOr land development in the station areaThe project often borrows the concept of TOD to promote urban land development and public transportation expansion..Exhibition, and formed extremely rich practical cases. However, yesThe real impact and practical benefits of TOD in urban and transportation development are still controversial, especially there is a significant gap between the actual effect of many TOD projects and the ideal goals, which urgently needs to

be systematically and deeply explored. Based on this, this paper starts from the basic connotation and key mechanism of the TOD concept, combines the difficulties encountered by the TOD development model in Chinese practice, and puts forward the TOD corridor development model from the perspective of mobile space.

1 TODThe basic connotation and key mechanism of the concept

1.1 Basic connotation

The background of the TOD concept stems from the criticism and correction of the United States on the spread of urban suburbs and its external uneconomicity.[One]. After World War II, with the rapid increase in population and the popularization of cars, many cities in the United States entered the process of rapid suburbanization. Because there are almost no external development restrictions in the early suburbanization process,1960Later, the development of urban space in the United States formed a spread pattern characterized by low density and decentralization, and led to a series of urban overspreads such as traffic congestion, air pollution and ecological environment deterioration.The problem of life[2], forUrban curtain extension crisis., by changing the traditional spatial growth mode, promote compact development in specific regions, so as to achieve the "smart growth" of comprehensive goals such as urban and suburban cooperation, enhancing local sense of belonging, protecting natural and cultural resources, and improving development income (smart Qrowth) The development concept began to rise in the United States.[3]. Against this background, in 1993, Karl Thorpe (CalthorpeP.) For the first time, public transportation-oriented urban development was proposed (1) (TOD) concept, that is, "building a new framework for urban development, so that the various elements in development are integrated into highly mixed neighborhoods and communities that are suitable for walking and are public transportation-oriented. It proposes to introduce a new development model in residential and key business areas to create a platform for more diverse travel models and socio-economic activities" [4]]. After that, Karl Thorpe's TOD concept became a new set of land use and public transportation design standards, which was later (Cevero.R.) Equal [5]It can be summarized as density, diversity and pedestrian-friendly..The 3D principle of design. Later, on the basis of the 3D principle, destination accessibility and distance to transit were added, forming the 5D principle.[6-7]. If TOD can be implemented according to these five principles, the per capita mileage will be reduced [8-9] .

Early stageThe TOD development model focuses on the micro level.Site domain development[10], specialIt is not a neighborhood or community unit built around a public transportation station within 2,000 feet (about 600 m) [11], the 3D principle proposed by Severo et al. is actually a spatial design standard, emphasizing the virtuous cycle between the transportation system and land development from the active arrangement of public transportation and land use.[4].. Because it is simple, intuitive and easy to measure, the 3D principle has been widely used after it was proposed.[7], a number of sub-indicators are born in parallel, such as: high-density resident population and employment, volume rate, proportion of various land areas, number of intersections, pedestrian network density, etc. [12].The later TOD development model has been continuously enriched and refined, and its connotation and extension have also been greatly expanded [12]], in the airOn the scale,The TOD development model has expanded from the early community development around the site to the coordinated development of public transportation and urban spatial structure at

the macro level. Such as Severo[1]Extend the TOD development model to transit metropolis, and the positive role of the bus system is no longer limited.In the station domain, and emphasize the integrity of public transportation service and urban space.Work together to promote the realization of urban sustainable development goals, and introduce the successful experience of Stockholm, Copenhagen, Singapore, Tokyo, Curitiba and other bus cities respectively. In the study of TOD categories, TOD has gradually refined from the early 3D universality principle to differentiated guidelines by category and circle layer [13], such as Reconnecting America and the TOD Center for Transi t-Oriented Development) two institutions jointly proposed 7 typical TOD station types such as regional center, city center, suburban center, bus town center, bus community, special function or employment area, mixed function corridor [14], emphasizing.According to the stationCarry out TOD development. In terms of TOD evaluation method, the TOD development model has gradually adopted hierarchical analysis from the early qualitative-based evaluation method [15], complex network [16], nodeOnePlace model [17]And other quantitative methods to improve the scientificity of TOD evaluation and planning methods. In addition, the research on TOD has also been extended to the development system and mechanism [18], land rentPrice impact[19], squire [20] and other aspects.

.In summary,The concept of TOD was born from the criticism and correction of the Gyan crisis in urban suburbs in the United States. Although the design guideles and research topics of TOD are constantly changing, the connotation of TOD still expects to encourage residents to give priority to public transportation through the integrated development of urban public transportation and land use, so as to promote public transportation. Make full use of transportation capacity, intensive development of urban land, and sustainable development of urban and urban transportation. Among them: Land use can be at the micro level.Station area tenThe way of land use can also be a spatial structure involving the macro level. Public transportation is not limited to large-volume subways, but can also be different forms of public transportation such as light rail or express buses.[21]. In its origin, the fundamental purpose of the TOD development model is notStation area tenDevelopment or public transportation expansion, but through compact,Mixed, high intensityLand development in the station area, improve the competitiveness and attractiveness of public transportation in residents' travel choices, so as to effectively alleviate urban traffic congestion, air pollution, environmental deterioration and other "urban diseases", which isThe original intention of the TOD concept [4] .

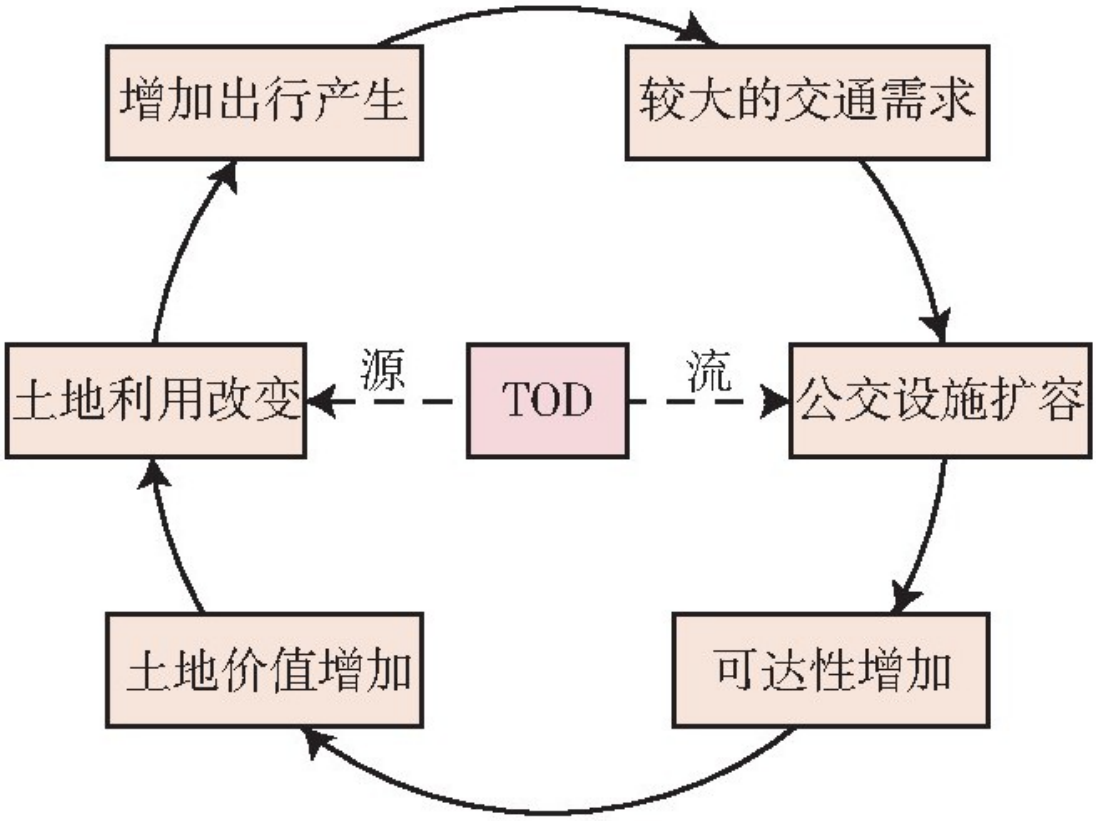
1.2 Key Mechanisms

TOD workFor the urban development model guided by public transportation, the "guiding" effect comes from two positive feedback mechanisms between land use and public transportation. The first positive feedback mechanism is the source mechanism (Figure 1), that is: urban land use provides a spatial carrier for the occurrence of various urban activities; the "source" of travel demand generated by various urban activities determines the production and attraction of transportation [22], and the layout and transportation capacity of the urban transportation system determine urban activities Dynamic spatial accessibility (travel time/distance/price) and affects people's travel choices; the results of selection form a "flow" in the transportation system, which in turn has an impact on the value of urban land [23]. The TOD development model accelerates the speed of land development by nearing the

conversion distance between "source" and "flow"..Rate, ensure the scale of passenger flow of public transportation, forming a comparative advantage over the development models of other cities.

The second positive feedback mechanism is the economy of scale mechanism.(Figure 2). Compared with private cars, public transportation has better efficiency in the utilization of transportation resources, that is, it can transport more passengers in the same space and time, and the average transportation cost decreases with the increase in the number of passengers transported, which has economies of scale. At the same time, the greater transportation energy advantage enables producers to rely on public transportation to serve more market demand, thus supporting the positive externality of compact, hybrid and high-intensity development and thus formed by the spatial economies of scale [24]. Transportation economies of scale and space economies of scale can make TOD from a compact land use model toThe development advantages of the cluster economy change. At this time, TOD can be understood as not only a spatial object, but also a space object that can passTonghe land integration promotes the improvement of economic efficiencyThe subject, and make the organizational characteristics of the factors of production(Such as the dependence of the time-sensitive industry on traffic accessibility) manifested through the spatial characteristics of TOD (such as 5D characteristics) [25] .

Picture1 The source mechanism of TOD



The TOD development model is based on the positive feedback mechanism of these two types of land use and public transportation, which constitutes the relationship between land use, space activities, transportation accessibility and transportation capacity.Ideal

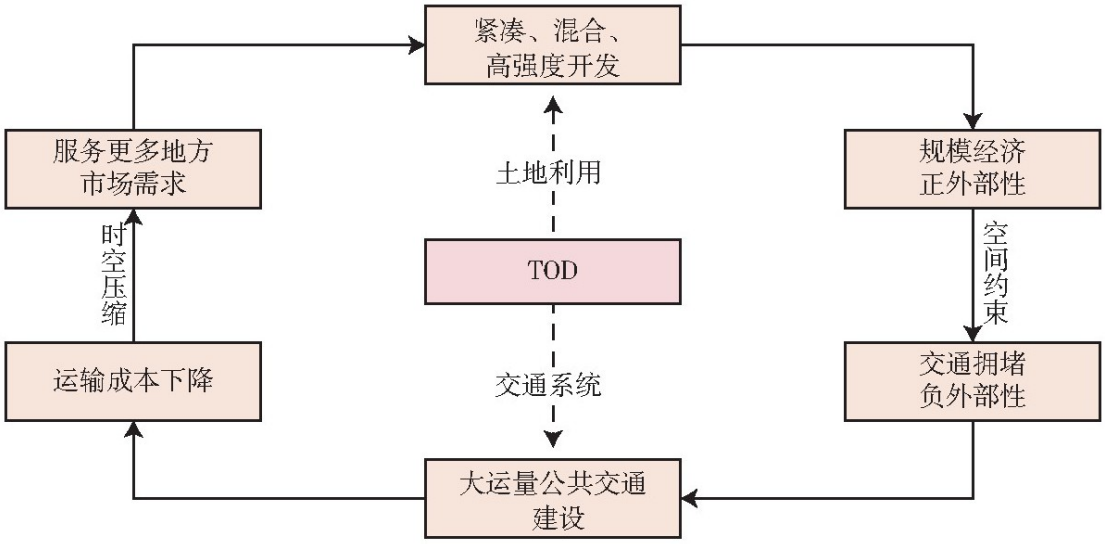
developmentStatus. In practice, pursue this kind ofIdeal developmentThere are roughly two modes of status: one is the "support mode" with the expansion of transportation facilities after the change of land use [26], and the other is the "otation model" with the change of land use after the expansion of transportation facilities [27]. The advantage of the former is that it has a mature basis for transportation demand, but it will lead to a significant increase in the cost and difficulty of transportation construction in the later stage. The advantage of the latter is to reduce the cost and difficulty of transportation construction, but the traffic demand will continue to be weak in the early stage [28] .

2 TOD.The practical dilemma of the development model in China

2.1 The degree of development and concentration is not high

UnhesitatinglyThe TOD development model was introduced to China at the beginning of the 21st century and was widely advocated. However, from the current development results, there is still a large gap between the practical effect of China's TOD and the internationally recognized TOD successful cases in Singapore, Hong Kong, Copenhagen and other countries. This gap is first manifested in the urban track. The clustering of development factors along the transportation corridor is still not obvious [29]. The study [30] shows that the population and job distribution in the surrounding areas of China's major urban rail transit stations are still generally homogeneous, and there is no obvious trend of clustering and distribution along the corridor. Public transportation system, especially rail transit linesThe layout of the network and site is still "following" the development of the city, and has not yet reached the model of "guiding" urban development under the preemption of transportation [31], resulting in the population along China's urban rail transit, the degree and attractiveness of job aggregation are limited[32]. Take Beijing and Shanghai as examples, although the scale of the rail transit network in Beijing's Fifth Ring Road and Shanghai's overseas ring road is twice that of Singapore and Hong Kong, the population coverage ratio within a radius of 500 m around the station is only about 50% of that of Singapore and Hong Kong [30], and there is no obvious land around the rail transit station. The differences in development intensity, mixing degree and site connection convenience (such as the number of exports) have failed to give full play to the urban large-volume track intersection..Economy of scale of transportation.

Picture2 Economy of scale mechanism of TOD



2.2 The intensity of passenger flow in the line network is low

AlthoughTOD emphasizes the guiding role of urban public transportation, especially rail transit, on land use, but because the land development around the rail transit station requires more time and the resistance to the promotion of the project is greater than the construction of rail transit, in.TOD.In practice, the overall speed of rail transit construction is ahead of the speed of land development, which has reduced the overall passenger flow intensity of China's urban rail transit network. In 2019, the average daily passenger intensity per kilometer of national urban rail transit was 0.710,000 people [33], just reached the initial passenger intensity standard required by the State Office's No. 52 (2). Among them, the proportion of cities with a passenger intensity of more than 15,000 people in the country is only about 17%, the proportion of cities with a passenger intensity of less than 70,000 people in the line network is about 46%, and the proportion of lines with a passenger intensity of less than 70,000 people is about 39%.[33], the highest-ranked passenger intensity of Guangzhou subway is also only 17,400, which is still a clear gap with 21,000 in Hong Kong and 29,000 in Tokyo, Japan [34]. This phenomenon of low passenger flow intensity not only leads to a great waste of urban rail transit capacity, but also brings heavy financial subsidy pressure to local governments [35]. In the future, with the introduction of new urban populationThe rate is slowing down, and the new rail transit lines in megacities are gradually extending to suburbs with low population density, and the overall operating efficiency of urban rail transit may be further reduced [36] .

2.3 Uneven distribution of commuter passenger flow

Due to the slow development of secondary employment centers on the outskirts of urban suburbs in China[37] and the single traffic mode of the peripheral radiation corridor and other reasons [38], cities during rush hourSuburbs andThe one-way passenger flow of rail transportation between the city center and the city is serious.Lead to Tongle passenger flowChannel uneven spearShield prominence [39], taking Shanghai as an example, the unevenness coefficient of the commuting channel from Baoshan, Jiading and Songjiang and other peripheral new cities to the direction of Shanghai city center, the southern suburbs of Pudong and the direction of Pujiang Town in Minhang to the central city exceeds 3, QingpuOneHongqiaoOneThe irregularity coefficient of the east-west passenger passage in the direction of the central city is also above 2, forming obvious "tidal" traffic [40],Tongle channelThe imbalance of passenger flow directly leads to the insufficient capacity of the rail transit network in the direction of entering the city in the morning rush hour (the cross-section passenger flow reaches 4Just in case60,000 times/) and waste of transportation in the opposite direction (only 0 in the direction out of the city.5Just in case10,000 times/). Especially in the citySuburbs andThe conversion zone between the city center and the city presents a severely crowded operation state, and even leads to the need to take flow-limiting measures at local operating intervals or stations of the track line.This kind of Tongle channelThe flow of passengersNoBalance is not in line with the original intention of green, low-carbon and sustainable development in the TOD concept. On the contrary, it may form another form of traffic "congestion", which will also lead to higher per capita energy consumption and emissions of the subway than private cars due to excessive empty load rate [41] .

2.4 Simple adplicity of development mode

Be confronted withThere are also trends and risks of simple application of the TOD

development model [12]. Around the walking range of public transportation stations, the TOD development model, which advocates compact, mixed platform and high-intensity development, has been generalized into rail transit stations (or even high-speed railway stations).Site domain developmentThe universal principle, and declare the core planning concept of "building a track is building a city"[42]. However, practice and research prove that not all rail transit stationsDomain space.It is suitable for and should carry out compact, mixed and high-intensity land development. On the one hand, the volume of site land development should be determined by the market demand of site services. Rail transit stations with weak network accessibility and low population and job density in the surrounding areas are not suitable for large-scale and high-intensity development, otherwiseThe risk of idle due to insufficient post-development utilization rate[12]. On the other hand, with the huge impact of e-commerce and remote working on the needs of traditional commercial space [43], it is also debatable whether the land around rail transit stations can be generally developed in a large-scale and high-intensity mode.

ThreeFrom the perspective of fluid space.TOD.Corridor development mode

3.1 The perspective of "place space" to "flowing space"

The integrated development of urban public transportation and land use isThe essence of TOD mode[32]Therefore, how to understand the "integration" between urban public transportation and land use"It has become the key to the TOD development model and the only way to solve the current difficulty of China's TOD practice. From a theoretical perspective, the traditional TOD development model is based on the static material layer.On the basis of the growth of land use and transportation facilities, the fundamental service object of the TOD development model - the behavior of one person is overly ignored.Mull overIn particular, it ignores the impact of the dynamic and east-easted nature of people's travel behavior on the integrated development of public transportation and land use. It is urgent to re-understand the positive feedback mechanism of public transportation and land use from the perspective of more dynamic fluid space (3). Therefore, this article proposes to include "travel behavior" into the TOD development model. In the associated dimension of the formula, build "travel behavior"OnePublic transportOneThe theoretical analysis framework of "land use" (Figure 3), so as to emphasize the emergence of peopleBehavior is not only the choice of individuals to adapt to traffic and space [44], but also a constraint and improvement goal of traffic layout and spatial intervention [38]. On the one hand, the impact of travel behavior in public transportation is specifically reflected in the flow of passengers, and the travel impedance (especially the number of transfers and the connection environment) has a direct impact on the form and layout of the public transportation network.And the facilitiesLayout and service management play a regulatory role in travel behavior; on the other hand, the impact of travel behavior in land use is manifested in the flow of people. The stability of the time budget has a binding impact on the activity space, and spatial interaction (especially the spatial interaction along the corridor) can be for individual living,Activities such as industry and recreation provide more convenient choice space for public transportation.[FourFive] .

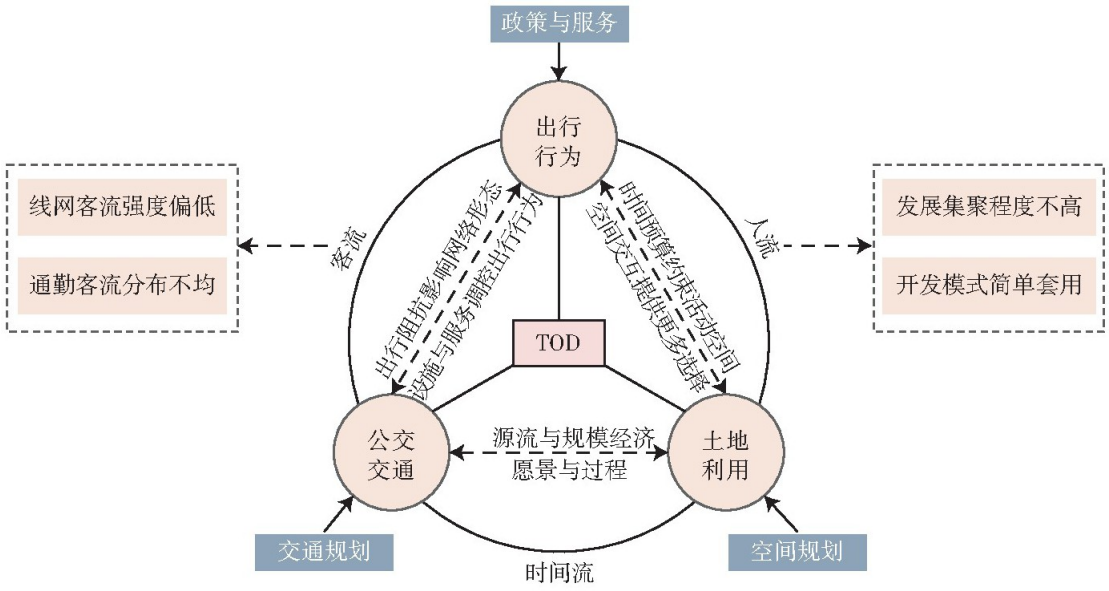
Secondly, the integration of public transportation and land use is not only a vision, but also a process.[46]. As a regulating variable, time will have an impact on the interaction between the two. Therefore, it is necessary to design the TOD development strategy according to the "time" and update the TOD development strategy iteratively according to

different time stages [47]. Compared with the traditional TOD development model, the TOD development model from the perspective of fluid space provides a more explanatory and directional TOD development theoretical framework for TOD (based on human behavior), with 3 related dimensions.Degree hasEach corresponding intervention method provides a new theoretical analysis framework for solving the practical dilemma of TOD development model and expanding the application value of TOD..

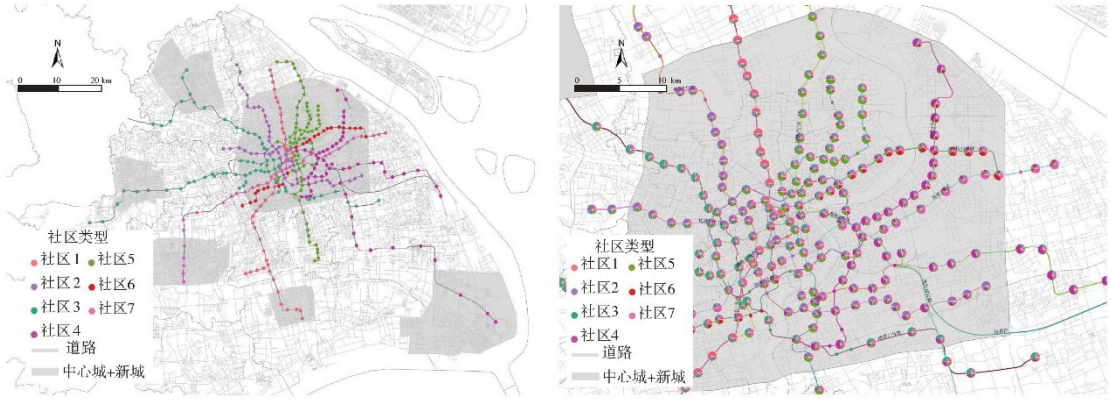
3.2 Mode optimization from "station city integration" to "corridor integration"

Based on "travel behavior"-Public transport-The theoretical analysis framework of "land use", the author applies ShanghaiIn September 2019, the all-day subway swipe data and the Louvain community discovery algorithm (4) carried out flow clustering of Shanghai subway travel behavior (Figure 4) to distinguish the integrated spatial level and scope suitable for public transportation and land use.Empirical analysis results show that although the form of Shanghai's subway network is highly complex, the travel behavior in the cityDomain andThere is a stable community structure in the central city, and the community structure shows obvious "corridor" characteristics, that is, the community structure around the subway line as the main travel space. An empirical study of the London Underground has also confirmed a similar conclusion.[48]. Therefore, compared with the area around the "gudian", the plan is along the "corridor"Unit'sThe TOD development model is more suitable for the integrated development of public transportation and land use. In other words, take the "corridor" as the space unit to coordinate each TOD station.The development mode of the point not only conforms to the basic laws of residents' rail transit travel behavior, but also is more conducive to the spatial interaction intensity and balance adjustment between stations, providing urban residents with more convenient employment and residential selection space under the same commuting time conditions. In addition, the construction of urban rail transit is also planned and built on lines.,The TOD development model with "corridor" as the spatial unit is also more conducive to the overall cultivation and land improvement of the line network passenger flow [49] .

Picture3 Based on "travel behavior"-Public transport-Theoretical analysis framework of "land use"



Picture4 Community discovery and analysis results based on the passenger flow between stations in Shanghai subway swipe data



（a）上海市域市轨道交通站间客流社区类型　　（b）上海中心城轨道交通站间客流社区类型具体构成

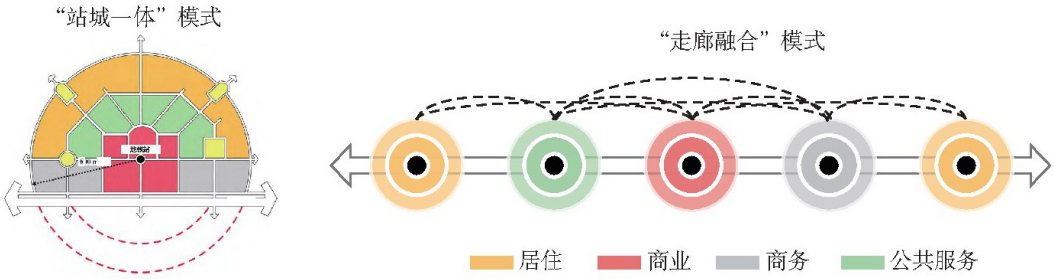
Based on this, this article proposes the "corridor integration"TOD optimization mode (Figure 5), that is, the space-time organization mode to improve the integration of public transportation and land use along the bus corridor. The optimization mode retains the basic connotation of "neighbors and communities suitable for walking and public transportation-oriented" and "creating a platform for more diverse travel modes and socio-economic activities" [4] in the original TOD concept, but the land use function and compact development requirements in the TOD development mode are placed in the traffic "corridor" Arrange it. The proposed "corridor integration" model is not right"Station city body"The TOD model is a comprehensive denial, but based on the laws of residents' travel behavior, the essence of the TOD concept -- the integration of land use and public transportation - is developed in a more suitable space scenario, so as to better realize the full capacity of public transportation.Utilization, intensive land development, urban sustainable development, etc.The original intention of the TOD concept. Table 1 further compares "Station and city integration"The main similarities and differences with "corridor integration".

3.3 Application path and planning cases of "corridor integration" mode

In planning practice, in order to better give full play to the model advantages of "corridor integration", a "circle" can be built.OneCorridorOneMulti-level of "node"THE TOD DEVELOPMENT FRAMEWORK [55] HIGHLIGHTS THE FUNCTIONAL CONNECTION AND COORDINATION VALUE OF THE "CORRIDOR INTEGRATION" MODEL. From a macro perspective, the "corridor integration" model needs to combine the overall location distribution of the city, analyze the size and boundaries of the circle affected by land rent, make a holistic judgment on the attraction direction and flow scale of the corridor, and identify the main connecting areas and scope of the main development corridors in combination with the main functional areas of the city. For example, in the planning and design of the M101 corridor of the sub-center of Beijing City (Figure 6), the corridor determines the layout direction of the corridor from northwest to southwest through the sub-central area according to the overall spatial structure of the sub-center. By comparing the selection of various functional groups and transportation hubs (such as sub-center station and TongzhouWest Railway Station), the importance and functional differences, in accordance with the principle of balanced and coordinated spatial interaction, establishedThe M101 corridor needs functional nodes connected in series. Finally, the corridor combines the

layout and scale of the land, and further implements the station location, route and land use arrangements along the corridor. On the one hand, spatial groups with multiple functional differences provide a certain strength and balanced passenger flow basis for the corridor; on the other hand, functional groups also coordinate the spatial competition through the series of corridors and activate functional areas with development potential.

Picture5 Conceptual diagram of the mode of "station city integration" and "corridor integration"



Surface1 Comparison of two TOD planning models

要素	“站城一体”模式	“走廊融合”模式
目标	促进公共交通使用、促进城市紧凑发展[12]	促进公共交通使用、促进城市紧凑和协调发展、促进客流均衡分布[50]
关注点	围绕站点场所的土地利用[51]	基于交通走廊的空间交互组织
规划原则	公共交通与土地利用在站点周围的局部耦合[52]	公共交通与土地利用在走廊沿线的全局耦合[50]
技术指标	站点周边土地利用密度、强度、混合度[5]、站点客流规模等[53]	走廊沿线土地利用密度、强度、混合度、人口即岗位覆盖率、站点与站间客流规模与均衡性[54]、通勤可达性、站点接驳水平等

Picture6 Beijing City Sub-Center M101 Corridor

Source of information: Beijing Municipal Commission of Planning and Natural Resources, Urban Sub-Center Control Detailed Planning (Block Level), 2016-2035 years

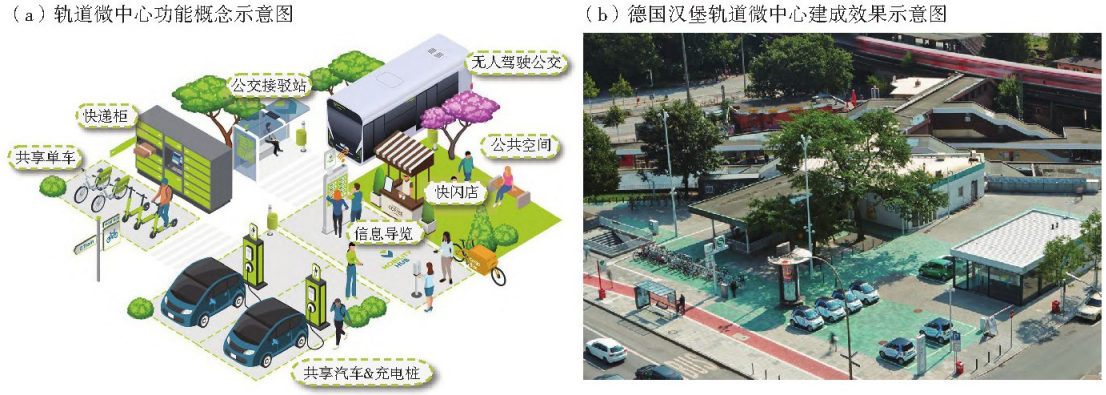
From a micro perspective, the "corridor integration" model needs to expand the attractiveness and service capabilities of the site through compact site development and refined connection service design, and provide more passenger sources for the corridor. Especially for stations that do not yet have the possibility of large-scale development, priority can be given to combining travel services such as shared travel and connecting to public

transportation, expanding the service scope of the station, and improving the convenience of public transportation.For example, some urban applications in foreign countries have been applied.Micro-center(Mobility hub) concept, implanting emerging travel services into rail transit stations (Figure 7). For commercial center-type and transportation hub-type stations, additional car-sharing or customized bus connection services can be considered to improve the station's distribution capacity. For large-scale residential and employment gathering places, you can set up shared bicycles, shared cars and chargingTransfer services such as piles and unmanned buses can improve the efficiency and convenience of residents' travel.[12]. On the one hand,Micro middleHeartWith the help of the development of new travel services,It has increased the attractiveness of public transportation in residents' travel choices, providing more traffic for the TOD development of other stations along the corridor; on the other hand, public transportation alsoCan be a new typeTravel services provide stable customer groups and service strongholds, and improve the service turnover rate and cost-effectiveness of shared travel.

4Conclusion

It has been more than 30 years since the birth of the TOD concept. In the past 30 years, TOD has become an important model for land use development and bus system expansion in many major cities around the world. Although the specific design guidelines and research topics of TOD are constantly changing, the basic connotation of TOD is still expected to pass urban public transportation. Communication and land use oneTo encourage urban residents to give priority to public transportation, so as to promote the full use of public transportation capacity, the intensive development of land, and the sustainable development of cities. However, the current practice of TOD in China still has practical difficulties such as low degree of development and agglomeration, low intensity of line network passenger flow, uneven distribution of commuter flow, and simple application of development mode. Based on this, this paper tries to put forward "travel behavior" from the perspective of mobile space.-Public transport-Land use" TOD theoretical scoreAnalyze the framework. Based on the empirical results of the community structure of rail transit travel behavior, it is proposed to take the "corridor" as the main planning scenario.TOD optimize the mode, in order to provide more and more balanced passenger flow for rail transit, and provide urban residents with more convenient employment, residence and recreation options for urban residents.

Picture7 TOD track microcenter



Source of information: Redrawn according to the "Mobility hub delivery models" report of the

British Co Mo UK agency in 2021

Annotate

(1) "Public transportation" in the text refers to public transportation, mainly urban rail transportation and express bus transportation.

(2) Opinions of the General Office of the State Council on Further Strengthening the Planning and Construction Management of Urban Rail Transit (State Office [2018] No. 52)

(3) Different from Castel (CasteLarge sizeLs M.) The proposed "flow space" (space of Fow) Concept, the "flowing space" in this article refers to the flow of people and the flow of time, which are two key analytical dimensions of dynamics in the development of TOD, which can have an important impact on the interaction between land use and transportation systems.

(4) Considering that the structural characteristics of passenger flow between urban rail transit stations are very close to the concept of "community" in complex networks, this paper borrows the community identification algorithm to solve the problem of large-scale OD flow clustering in urban rail transit. After a certain selection,This paper selects the Louvain algorithm as the analysis method of the structure of the urban rail transit network. The identified communities can represent relatively closely connected spatial units.

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