Citation: JIANG Yin, RUI Xiaoli, MEI Rongli, SONG Ruoyuan, ZHENG Haixing. Green Transportation Planning for the Harbor City in Binhai New District of Tianjin [J], Urban Transport of China, 2018 (06): 18–25.

Green Transportation Planning for the Harbor City in Binhai New District of Tianjin

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Abstract: To search for the best feasible development path for the green transportation in Binhai New District of Tianjian, this paper summarizes the main principles of green transportation planning of Sino-Singapore Tianjin Eco-city and Yujiapu Central Business District and challenges in the last 10 years. Taking the development opportunity in reforming and upgrading the Harbor City (bulk area of Tianjin Port), the paper discusses the green transportation development patterns in Harbor City in three levels: the target, strategies and regulations. At the level of target, feasible development goals are proposed according to different development scenarios. At the level of strategies, the paper presents four innovative strategies based on the development background of Harbor City, such as building an 8-minute travel city, developing a three-layer transportation system according to the core of rail transit corridors, constructing pedestrian and bicycle exclusive lanes, and implementing parking strategies of demand guidance plus flexible reservation. At the level of regulation, establishing necessary system for implementation by focusing on regulatory detailed plan and special funds. **DOI:** 10.13813/j.cn11-5141/u.2018.0603-en

Keywords: transportation planning; green transportation; transportation strategies; Transit-Oriented Development; Tianjin New Area of Binhai

1 Research background

Against the backdrop of ever-worsening global ecological environment, the idea of green transportation development has received widespread attention and support since it was proposed by Chris Bradshaw [1] in the 1990s. The *Opinions of the Ministry of Transport on Fully and Deeply Advancing the Development of Green Transport* (JZYF [2017] No. 186) [2], released in November 2017, adopted an overall action plan for green transportation development at the national level.

Since Binhai New District of Tianjin was incorporated into national development strategies in 2006 [3], it has actively explored and practiced the idea of green transportation development in Sino-Singapore Tianjin Eco-city (hereinafter referred to as "the SSTEC") and Yujiapu Central Business District (CBD) (hereinafter referred to as "Yujiapu") in succession (shown in Fig. 1 and Tab. 1). The SSTEC is the first ecological city [4] developed and built jointly by two countries, and Yujiapu is the first low-carbon demonstration town [5] of the Asia-Pacific Economic Cooperation (APEC). Undoubtedly, the establishment of green transportation system is the primary task for both areas.

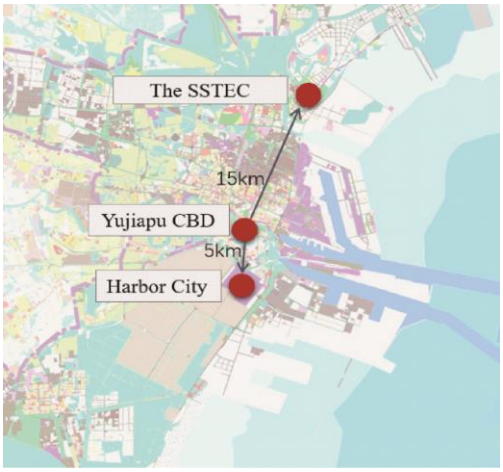

Fig. 1 Location of Sino-Singapore Tianjin Eco-city, Yujiapu and Harbor City

Binhai New District planned to transform the bulk area of Tianjin Port, which is currently used to store dry bulk such as coal, into an innovative, open, livable and intelligent Harbor City in 2007, so as to accelerate the transformation and upgrading of Tianjin Port. Taking the development opportunity in reforming and upgrading the Harbor City, this

Received: 2018-06-06
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paper summarizes the main principles of green transportation planning in the SSTEC and Yujiapu and challenges in the last 10 years, and discusses the green transportation development patterns suitable for the Harbor City in a bid to explore a feasible scientific path for the green transportation development in Binhai New District of Tianjin.

Tab. 1 Land use of Sino-Singapore Tianjin Eco-city, Yujiapu and Harbor City

Name	Area/km^2	Location	The status quo of land use
The SSTEC	30.0	Located between the junction of Jiyun River and Yongding New River and the section of the estuary, about 15 km away from the Yujiapu Railway Station	The majority are vacant lands, except the startup area
Yujiapu	4.0	Located at the CBD of Binhai New District, close to the Yujiapu Railway Station	The majority are vacant lands, except the startup area
Harbor City	12.5	Located to the south of the junction of Dagu Drainage River and Haibin Expressway, about 5 km away from the Yujiapu Railway Station	The majority are the storage yards of dry bulk such as coal

Source: Reference [6].

2 Connotation of green transportation planning

While proposing the idea of green transportation, Chris Bradshaw comprehensively considered transportation priority from various perspectives (shown in Tab. 2).

Tab. 2 Travel mode priority

No.	Type	Priority
1	Mode	1) Walk; 2) Bicycle; 3) Bus; 4) Truck; 5) Car
2	Vehicle Size	1) Small; 2) Large
3	Energy Source	1) Human-powered; 2) Gravity; 3) Solar and wind; 4) Hydrogen; 5) Electric; 6) Hydrocarbon;7) Nuclear
4	Traveler	1) Young Child; 2) Disabled; 3) Senior; 4) Visitors; 5) Adolescent; 6) Adult
5	Trip Purpose	1) To meet people; 2) To reach a special place; 3) To move goods; 4) To reach work; 5) To move information; 6) For recreation/entertainment; 7) For thrills
6	Trip Length	1) Short; 2) Long
7	Trip Speed (considering factors such as safety and wind frictions)	1) Slow; 2) Fast
8	Vehicle Exclusivity	1) Driver and car for hire (higher cost by best match to users' location needs); 2) Shared vehicle; 3) Personally owned and used
9	Vehicle Utilization	1) Full; 2) Empty
10	Trip Segment	1) Access to a property; 2) Through movement

Source: Reference [1]

1) From the perspective of transportation vehicles, three aspects were considered including transportation modes, vehicle sizes and energy sources. The transportation modes with lower energy consumption and pollution should be encouraged.

2) From the perspective of travelers, four aspects were considered including traveler types, trip purposes, trip lengths and trip speeds. Vulnerable groups and mandatory trips should be given higher priority, and long-distance and higher-speed trips should be reduced as much as possible to create a fairer travel environment at a lower cost.

3) From the perspective of transportation efficiency, three aspects were considered including vehicle exclusivity, vehicle utilization and trip segment. Priority should be given to developing transportation modes with higher efficiency, and empty load rates and through trips should be reduced.

Therefore, green transportation is essentially a sustainable transportation system featuring low energy consumption, low pollution, low cost, more fairness and higher efficiency. The core of green transportation planning is to create a green-transportation-oriented travel system through the close integration of the green transportation system and land use. First, travel demands and trip lengths should be controlled from the source by coordinating with land use. Second, more resources should be allocated to public transit and pedestrian and bicycle traffic to improve the accessibility of green transportation. Third, travel cost of motor vehicles should be increased and travel dependence on motor vehicles should be reduced. Finally, powerful policy supports should be provided to ensure the full implementation of these development ideas.

3 Major ideas of green transportation planning

The SSTEC and Yujiapu are the first batch of green transportation test fields initiated by Binhai New District, which have accumulated rich experience in green transportation planning. Based on relevant references [4–5], this paper summarizes four core ideas of green transportation planning.

1) Transit-Oriented Development (TOD). It focuses on conducting high-density development around rail transit stations, strengthening the mixed use of commercial, office and residential lands, reducing the number of trips and trip distances and promoting green travel.

2) Jobs-housing balance. Focusing on the balance between local residence and employment, the layout of public service centers should ensure that services can be provided within the neighborhood and long-distance trips should be reduced.

3) Pedestrian and bicycle traffic priority. On the basis of narrow roads and a dense road network, a pedestrian and bicycle traffic priority network with wide coverage and independent space should be constructed to realize higher accessibility for green transportation than that for cars.

4) Low carbon. From the aspect of functional orientation, the dominant role of green transportation should be clear (the proportion of green transportation is greater than 70% outside the SSTEC and greater than 90% in the SSTEC, and it is greater than 80% in Yujiapu). From the aspect of transportation modes, new-energy buses and cars should be promoted actively to reduce greenhouse gas emissions. From the aspect of transportation policies, green transportation should be promoted to control the demand for cars.

4 Challenges of implementing green transportation planning

It has been about 10 years since the launch of the SSTEC and Yujiapu, and the startup area has been basically completed. Judging from the implementation status, there are three major challenges for green transportation.

1) Mismatched rail transit lowers the service level of public transit and constrains the development of the TOD mode.

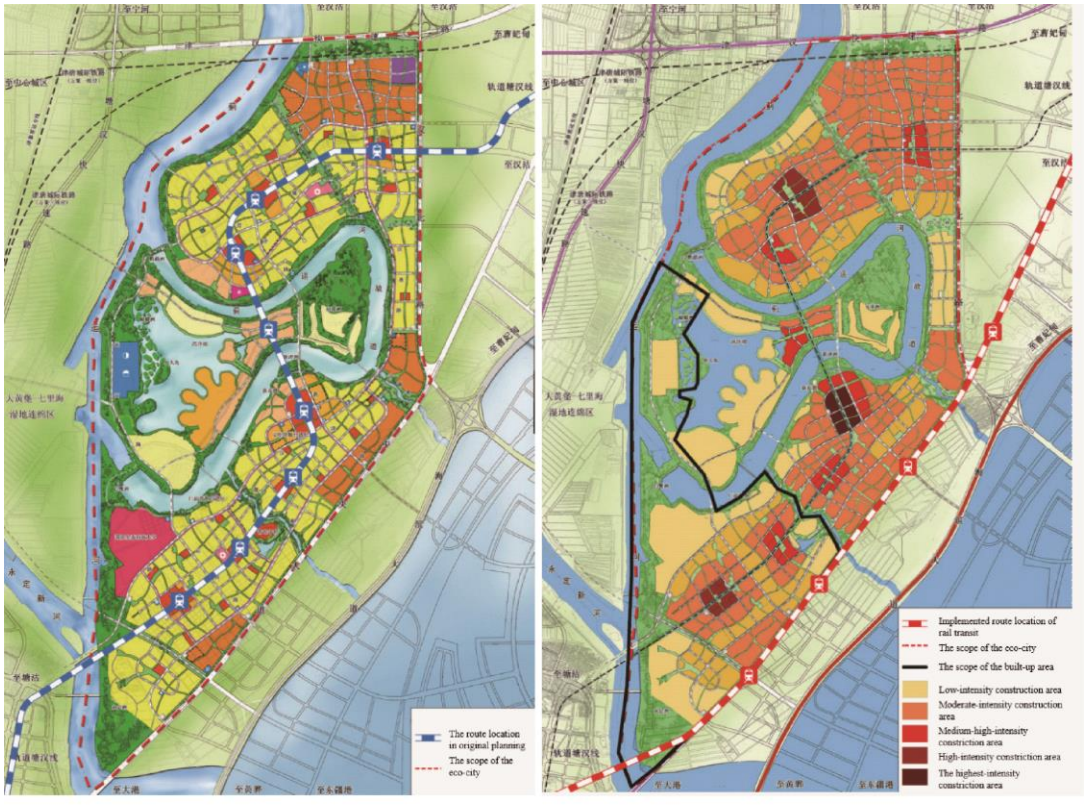
The TOD mode is one of the core ideas of the SSTEC and Yujiapu. However, due to the restrictions of various factors, the actual rail transit is mismatched.

In the overall planning stage, the SSTEC adopted a plan to construct the rail transit line along the Ecological Valley (shown in Fig. 2a). However, due to a series of adjustments of the upper-level plans (the master plan of Binhai New District and special plans for rail transit), the rail transit line was finally moved to the edge of the SSTEC. Consequently, most rail transit trips between the SSTEC and the outside can only be made through transfers, which reduces the service level of rail transit. The adjustment of the rail transit line eventually led to the loss of interaction between the originally approved land development intensity and rail transit stations (shown in Fig. 2b).

Yujiapu's rail transit network planning is relatively complete (shown in Fig. 3a), but it is mismatched with the actual land development in its implementation process. There is a serious lack of interaction between rail transit Lines B1 and Z4 whose construction began recently and Xiangluowan Business Area and Yujiapu's startup area whose construction is almost complete (shown in Fig. 3b).

2) The operation mode of traditional closed street blocks greatly restricts the development level of pedestrian and bicycle traffic.

The development mode of the residential land in the SSTEC's startup area still falls into the category of traditional closed street blocks. This mode has a serious impact on the pedestrian and bicycle traffic planning system in the eco-city, mainly reflected in three aspects. ① The construction of the startup area deviates from the scale requirement of 150 m × 150 m for small blocks in the overall plan, and the actual blocks are mostly 300 m × 400 m. Although the originally-planned pedestrian and bicycle traffic system is constructed as required in the large blocks, its passage function cannot be realized because of the closed



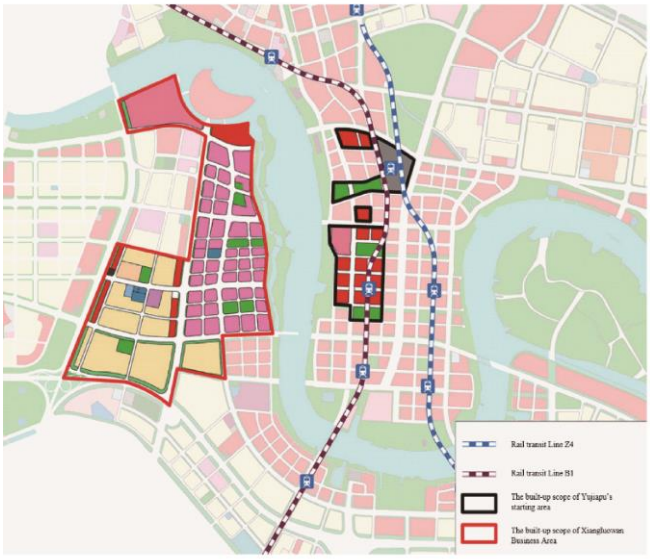
a The original overall plan

b The relation between approved rail transit routes and land development

Fig. 2 Relationship between rail transit and land use in Sino-Singapore Tianjin Eco-city

Source: Reference [6].

a Rail transit network planning



b Yujiapu's startup area and recently-constructed rail transit routes

Fig. 3 Relationship between rail transit lines and land use in Yujiapu

Source: Reference [6].

operation of communities (shown in Fig. 4a). ② Most of streets have closed communities and continuous green belts on both sides. The function is single with no rich and diversified urban activities, and city vitality along the streets is lacking. ③ The sidewalk and the non-motorized vehicle lane are built next to each other with no sufficient isolation between them, so it is easy for walkers and bikers to mix, resulting in the reduction in the quality of pedestrian environment and the increase in safety hazards (shown in Fig. 4b). The interaction design also fails to consider bicycle traffic demand in the situation of mixed pedestrian and bicycle traffic, causing great inconvenience for bicycles to cross streets (shown in Fig. 4c).

a Roads blocked by fences

b Road section shared by pedestrians and non-motorized vehicles

c Intersections shared by pedestrians and non-motorized vehicles

Fig. 4 Existing problems of non-motorized vehicle lanes in Sino-Singapore Tianjin Eco-city

Source: Reference [6].

Yujiapu's startup area mainly includes financial office buildings, and it has well carried out the idea of narrow roads and a dense road network. However, there still exist a series of problems caused by the insufficient isolation between sidewalks and non-motorized vehicle lanes, similar to those in the eco-city.

3) The travel targets are high, but they lack effective support of matching transportation policies.

Based on a small sample transportation survey [7] in Binhai New District in 2016, the proportion of green travel in the SSTEC's startup area was 67.3% (the planned target was greater than 70% for trips in and out of the SSTEC and greater than 90% for trips within the SSTEC), while the proportion in Yujiapu's startup area was 45.3% (the planned target is greater than 80%). One of the reasons for the large gap with the expected targets is that bicycle travel environment is poor since the rail transit is still under construction. Another reason is the lack of supporting transportation policies to control car ownership and usage. Both the construction standards for parking facilities and the parking rate standards are implemented in compliance with relevant policies of Tianjin, which are incompatible with the high green travel targets.

5 Exploration of green transportation planning in Harbor City

Based on the green transportation development experience of the SSTEC and Yujiapu, this paper actively explores how Harbor City should carry out the development ideas of green transportation from three levels: targets, strategies and regulations.

5.1 Target level

The general development vision of Binhai New Area is to build an innovative, open, livable and intelligent Harbor City [8]. Its function is positioned as an ecologically livable and innovative residential area with supporting facilities. Together with Yujiapu, they will form a situation in which their developments are supporting each other with good interactions. In order to support the ecological livability goal of Harbor City, the transportation development vision of Harbor City is to build a green transportation oriented, healthy, vigorous, intelligent and efficient sustainable transportation system [6].

A reasonable green transportation development target is the basis and premise for developing green transportation development strategies. By considering various transportation supply conditions and comprehensively judging factors such as trip purpose, trip distribution and trip length, corresponding transportation structures are obtained (shown in Tab. 3). In light of the analyses of various scenarios, the long-term green transportation-oriented transportation development target for Harbor City is for public transportation to dominate trips going in and out of the area, for pedestrian and bicycle traffic to dominate trips within the area, and to achieve a proportion not less than 70% for green travel.

Tab. 3 Travel mode sharing under different scenarios

Scenario	Travel mode		
	Public transit	Pedestrian and bicycle	Car
No rail transit at the early stage (assuming 30% of development)	30	19	51
Rail transit lines Z4 and B1 are completed (assuming 50% of development)	38	26	36
Rail transit lines Z4 and B1 are completed + bus only lanes are networked (assuming 100% of development)	42	28	30
Rail transit lines Z4 and B1 are completed + bus only lanes are networked + rail transit line B5 is completed (assuming 100% of development)	47	26	27

Source: Reference [6].

5.2 Strategy level

Based on the development target and the characteristics of Harbor City, four major strategies for innovative development are proposed as follows.

1) Building an 8-min city to reduce the number of trips and trip lengths

To avoid becoming a "dormitory town", Harbor City plans to introduce port-based service industry and entrepreneurial and innovative enterprises, which will increase the job-housing ratio so that 40%–50% of working population can find jobs within the area and long-distance commuting trips can be reduced.

Meanwhile, more efforts should be made to build an 8-min city and construct more facilities to provide convenient local services. Within 8 min, residents should be able to reach major service facilities such as stores, educational institutions, office buildings, cultural centers, and public transit stops. It is urgent to create a new mode of urban life, enhance the internal connections within a community, improve the city's vitality, control travel demands from the source, reduce unnecessary trips and shorten trip lengths.

2) Introducing the TOD mode of Curitiba of Brazil in an innovative way to form a three-layer transportation system centered on the vigorous corridor of rail transit

Compared to the SSTEC and Yujiapu, the biggest advantage of Harbor City is that the rail transit lines Z4 and B1 which are under construction will pass through Harbor City. This advantage provides favorable conditions to implement the TOD mode for the simultaneous development of rail transit and the city, and avoids the issue of mismatched and lagged rail transit.

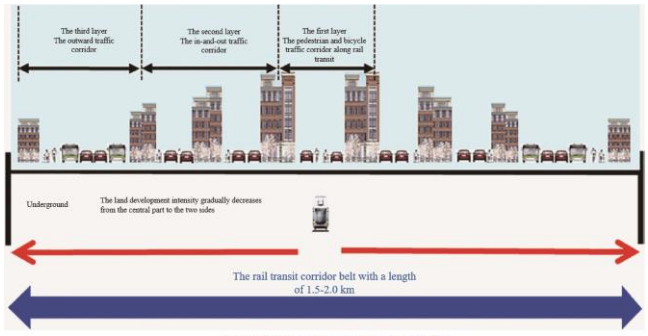
With the TOD mode, the land use layout of Harbor City is to implement medium- and high-intensity development within 200 m on both sides of rail transit routes, which focuses on the mixed land use of commercial finance, business office and residential buildings. Medium- and low-intensity

development should be implemented outside of 200 m on both sides of rail transit routes, and focus on residential buildings with a consideration of stores on the ground floor along the routes (shown in Fig. 5).

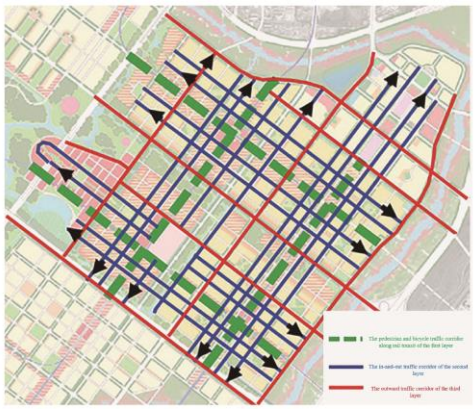
Fig. 5 Land use in Harbor City

Source: Reference [6].

The land use layout pattern of Harbor City is very similar to that along Curitiba's bus rapid transit corridor. Hence, the transportation planning of Harbor City breaks the traditional four-class road system, and innovatively introduces Curitiba's classical "trinary road system" [9] to build a three-layer transportation system with the rail transit corridor as the core (shown in Fig. 6a).



a The overall transportation organization ideas



b The overall transportation organization plan

Fig. 6 The three-layer transportation system in Harbor City

Source: Reference [6].

The first layer consists of four pedestrian and bicycle traffic corridors (shown in Fig. 6 b) along rail transit routes, which are the most vigorous streets in the area with the best pedestrian and bicycle travel environment. Referring to the vibrant La Rambla in Barcelona, Spain, a 20-m-wide landscape belt is planned in the middle of the corridors, with subway entrances and exits and small leisure service facilities scattered in the belt. In addition, commercial corridors or leisure corridors will be built along the rail transit, depending on the nature of land use. Outside of the corridors are auxiliary roads and sidewalks (shown in Fig. 7a). The design of the road cross section should coordinate road boundary lines, greenbelt control lines and building boundary lines. An open block management mode should be implemented to avoid the problem of lost vitality on both sides of the roads in a closed community. The auxiliary roads should mainly organize arriving and departing motor vehicles along the central landscape belt, with a speed limit of 30 $km \cdot h^{-1}$ to ensure the safety of pedestrians going in and out of the belt.

a Pedestrian and bicycle traffic corridor along rail transit routes

b In-and-out traffic corridor

c Outward traffic corridor

Fig. 7 Cross-section design of the three-layer transportation system in Harbor City

Source: Reference [6].

The second layer consists of in-and-out traffic corridors, which are 8 pairs of one-way streets for motor vehicles on both sides of rail transit routes (shown in Fig. 6b). It improves the efficiency of transportation organization on dense road networks with narrow streets. Pedestrian and bicycle traffic can travel in both directions and have independent right of way, which guarantees the priority of pedestrian and bicycle traffic from the aspect of space (shown in Fig. 7b).

The third layer consists of outward traffic corridors (shown in Fig. 7c), which realizes the accessibility and connection between the inside and outside areas of Harbor City and also serve as the main corridors for bus traffic.

The motor vehicle traffic organization function of the three-layer transportation system in Harbor City is gradually reduced from outside to inside, while the pedestrian and bicycle traffic organization function is gradually enhanced. The road network density is 10 km·km^{-2}. Public transit transfer hubs and connection routes will be provided at main rail transit stations to ensure that public transit can be accessed within 500 m at any location in the area.

3) Embedding diagonal roads for pedestrian and bicycle traffic to create a convenient, safe and attractive pedestrian and bicycle traffic priority system

Although Harbor City is only 5 km away from Yujiapu in the north, there are two rivers, a railway and an express road to cross, and many obstacles exist for bicycle trips. In order to effectively implement the priority development of pedestrian and bicycle traffic, Harbor City plans to embed diagonal roads for pedestrian and bicycle traffic (shown in Fig. 8) on the basis of three-layer transportation system. The total length is 10.2 km, and their main functions are as follows.

Fig. 8 Elevated bicycle lanes and pedestrian and bicycle transportation priority system in Harbor City

Source: Reference [6].

The first function is to shorten the distance and travel time of bicycle trips from Harbor City to Yujiapu. After diagonal roads are introduced from the south end of Harbor City to Yujiapu, the trip distance will be 7.9 km, reduced by 1.4 km or 15%. Meanwhile, 70% of the bicycle paths are elevated, which will increase the travel speed by about 20% and reduce the travel time by 30%–40%.

The second function is to significantly shorten the distance of pedestrian and bicycle trips along the rail transit routes, since the diagonal roads for pedestrian and bicycle traffic are connected to major public centers and rail transit stations in the area. For trips going to the subway, work, shopping, leisure and entertainment, diagonal roads will be the preferred path for pedestrian and bicycle traffic in the area along the routes due to their distance advantages. The aggregation of pedestrian flow will provide development potential for commerce along the routes, and the good commercial environment will attract more pedestrian flow in return. Therefore, the diagonal roads for pedestrian and bicycle traffic and the corridors along the rail transit routes will become the most vigorous corridors in the area.

With the pedestrian and bicycle corridors and diagonal roads along rail transit routes as the skeleton network, a convenient, safe and attractive pedestrian and bicycle traffic priority system (shown in Fig.8) will be built in this area, which consists of greenways along rivers and in parks and pedestrian and bicycle traffic system along roadways.

4) Implementing the parking strategy of "demand-based guide + flexible reserve" to control the ownership and use of motor vehicles

High-level green transportation and policies to regulate demands on motor vehicles supplement each other. Controlling off-road parking supply to curb motor vehicle ownership and rigorously controlling on-road parking to reduce motor vehicle use and ensure the traffic order are regional policies widely adopted by overseas metropolises to regulate motor vehicles.

In accordance with Tianjin's parking facility standards, on average 1.5 parking spaces should be built for each household in Harbor City. To reach the development goal of green transportation, the plan proposes 1.0–1.2 parking spaces for each household and proposes to reduce the parking space requirements moderately for public buildings.

A public parking facility should be reserved in each planned plot (about 400 m × 600 m) to ensure parking spaces for P & R, to provide enough temporary parking in public buildings, and to moderately meet the parking demands of households with two or more cars. The gradual development strategy should be adopted to develop the public parking facility from a green land to a surface parking lot to a parking garage. In this way, the development potential of the public parking facility is flexibly reserved.

In order to strength on-road parking control and promote off-road parking space sharing, the establishment of an

intelligent parking system that covers on-road and off-road parking should be actively promoted to integrate and coordinate parking resources, improve the utilization of parking spaces and ensure traffic order.

5.3 Regulation level

In order to ensure the smooth implementation of the green transportation system, it is suggested to establish a necessary protection system from two aspects.

1) Protection of the development space with a detailed regulatory plan as the starting point

Since the construction of rail transit in Harbor City has already started, the mismatch of rail transit and land use is no longer an issue. Therefore, the emphasis at the implementation level is to avoid the similar situation of the eco-city in which the infrastructure construction and operation management of green transportation is out of control. It is thus suggested that all pedestrian and bicycle traffic networks such as the diagonal roads should be included in the detailed regulatory plan as municipal roads to protect the development space of green transportation.

2) Protection of funding with special funds as the starting point

The Harbor City's parking strategy of "demand-based guide + flexible reserve" can curb the demand for motor vehicles to some extent. To further improve transportation supporting policies and give priority to green transportation development, it is suggested that funds saved by land developers in the construction of parking facilities should be taken as a special fund for transportation managed by the government. In the near term, the fund should be mainly used to improve the service level of public transit and pedestrian and bicycle traffic, and to build P & R parking facilities. In the long term, this fund should be used to construct public parking facilities. At present, the Tianjin Municipal People's Government is actively promoting the supervision measures for the special guidance fund for parking facilities, which provides policy support [10] for the parking strategy of "demand-based guide + flexible reserve".

6 Conclusion

Binhai New District's exploration and practice on green transportation in the SSTEC and Yujiapu showed that the development of the green transportation system faced many challenges. In order to search for the scientific development path for green transportation in Binhai New District under the new situation, this paper takes the transformation and upgrading of Harbor City as an opportunity, and innovatively introduces Curitiba's TOD mode based on the Harbor City's innate advantages of simultaneous construction of its rail transit and the city. This paper systematically explores the development of the green transportation system in Harbor City from three levels: targets, strategies and regulations.

There is still a long way to go for the development of the green transportation system. Besides, the situation varies widely from place to place, and no modes can be applied everywhere. Therefore, Harbor City must follow the development route of practice, summarization and practice, and constantly adjust its development targets and strategies, so as to create a green transportation development mode suitable for Harbor City.

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