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Greenway-Based Bicycle Commuting in Medium Cities: A Case Study of Qingfeng Greenway in Jinhua, Zhejiang Province

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Abstract: The bicycle commuting distance is closely related to the urban greenway-built characteristics in medium cities. Bicycle commuting on greenways has become one of the residents' travel modes, which positively impacts individuals' well-being and city development. With Qingfeng Greenway in Jinhua City, Zhejiang Province as an example, the paper investigates the travel characteristics, commuting demands and commuters' travel expectation through field observation, surveys, and interviews. The in-depth analysis of the greenway construction, operation and management, and coordinated development with the surrounding built environment is conducted, which reveals the main problems of vaguely defined right-of-way, inadequate facilities along greenway, lack of smooth connection with residential areas and urban street network. Based on bicycle commuting demand and a hierarchical classification of greenway, the paper provides suggestions on improving greenway development in several aspects: right-of-way allocation and connection, facilities development along greenway, connection with surrounding residential areas and non-motorized roadway network, travel services improvement, etc. **DOI:** 10.13813/j.cn11-5141/u. 2020.0609-en

Keywords: bicycle transportation; urban greenway; commuting; right-of-way allocation; connection; Jinhua City

0 Introduction

In recent years, the construction of greenways has been promoted in many cities in China. Greenways serve as corridors with natural ecological and cultural resources along the line, facilitating residents' recreation and fitness, green travel, and wildlife migration. "Guidelines for Greenway Planning and Design" classifies greenways into two types, urban and country, according to their locations and environmental landscape. Urban greenways are constructed on the basis of urban roads, water system, or green space in public parks, with functions including but not limited to promoting green travel [1]. Observation in many places has suggested that users on urban greenways (especially on roads connecting urban periphery and central district near water system or green space in parks) with recreation and fitness purposes mainly appear on weekdays before morning peak hours (6:00–7:00), after lunch break (14:00–15:30), at nighttime (19:00–21:00), as well as on weekend and holidays. They rarely appear during the weekday morning and evening commute hours. Therefore, space resources of greenways are not fully utilized in terms of time.

On the other hand, bicycle transport (including man-powered bicycles and eligible electric bicycles) has been gradually recognized by the whole society, given that it adapts well to short- and medium-distance travel, has positive significance in alleviating traffic congestion, and enhances traffic justice. The Ministry of Housing and Urban-Rural Development of the People's Republic of China carried out a demonstration project for the pedestrian and bicycle transportation system in 2010. "Guidelines for Planning and Design of Urban Pedestrian and Bicycle Transport Systems" was published in 2013. Bike sharing rose rapidly in large and medium cities in 2016. All of the above strongly proves that bicycle transportation is in the stage of comprehensive renaissance. However, in the central districts of cities where redevelopment of existing land is the focus, road space resources are extremely limited. Due to the constantly strong growth of motor vehicles and the persistent pursuit of car-oriented lifestyle in the short term, the improvement of cycling environment continues to be difficult. Cities such as Beijing and Xiamen have invested heavily in the construction of elevated bicycle-only roads, but the service efficiency in different segments and time as well as user's feedback varies substantially.

Since urban greenways serve green travel, can we introduce the idea of resource sharing with the consideration of time distributions of greenway usage, and design and manage the greenways as bicycle-only commuting roads during morning and evening peak hours? Admittedly, compared to mixed-use traffic roads, the greenways can be constructed at a much lower cost and have higher bicycle travel efficiency and greater environmental benefit.

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1 Feasibility analysis of greenway-based bicycle commuting in medium cities

1.1 Characteristics of urban space and transportation

Medium cities (defined in this paper as cities with urban permanent population between 1 and 1.5 million), except for those with special terrain constraint, usually have a single-center structure. The Central Business District (CBD) or Central Activity Zone (CAZ) is often located close to water resources or at the confluence of several rivers; greenways along the river become one of the shortcuts between urban centers and the periphery areas.

"Commuting Monitoring Report of Major Cities in China in 2020" shows that, in Type II large cities, the population with commuting distance less than 5 km accounts for approximately 58%; this proportion is even higher in smaller-sized cities [2]. Bicycle commuting is a great option for the distance less than 5 km. Significant passenger flow exists during morning and evening peak hours in single-center cities, which results in high volume of motorized and non-motorized traffic with frequent traffic congestion on main corridors. If residents within 1 km or more around greenways can be attracted to choose bicycle transport, traffic structure and travel environment will be improved and traffic congestion can be effectively alleviated.

1.2 Advantages of greenway-based bicycle commuting

1.2.1 Perspective of cyclists

The sound environment on both sides of the greenway in parks or along the river (the average noise level at about 40 dB) is rather better than that along a traffic corridor (the average noise level at 60–70 dB); therefore it provides cyclists a quieter environment. Greenway, as a special corridor for walking and biking, enables users to stay away from motor vehicle exhaust and greatly reduces conflicts between motorized and non-motorized traffic. Thus, the comfortableness and safety on greenways are much better than those on urban arterial roads with large traffic flow and many intersections (regardless of certain roadways with divided motorized and non-motorized traffic). Meanwhile, biking has also been recognized as an effective healthy travel mode. According to the research by the British Heart Foundation, regular biking activities (e.g., 32.2 km per week, equivalent to 3.22 km one-way commuting travel) can reduce the risk of heart disease by up to 50% [3]. Biking on greenways can promote the development of a healthy lifestyle, which plays a role of improving residents' health level and enhancing physical fitness.

1.2.2 Perspective of cities

The capacity of a non-motorized traffic lane on roads with intersections is about 800–1 200 $veh \cdot h^{-1} \cdot m^{-1}$, whereas the capacity of a bicycle-only road without intersections can reach 1 800–2 100 $veh \cdot h^{-1} \cdot m^{-1}$. If the right-of-way separation from pedestrians on greenways could be achieved during morning and evening peak commuting hours, greenways can use less road space resources and have higher traffic efficiency to carry the same amount of bicycle traffic.

High-quality biking environment is an important foundation for improving the sharing rate of bicycle travel. The improvement in physical facilities and service quality based on commuting cyclists' demand can shift vehicle users to biking for medium- and short-distance trips. It is highly beneficial for traffic structure optimization, energy saving, emissions reduction, and intensive use of road space resources.

2 Surrounding areas of Qingfeng Greenway and basic travel characteristics of bicycle commuting in Jinhua

A comprehensive observation of the greenways along the three rivers and six banks in Jinhua City, Zhejiang Province from March to June 2019 suggested that some residents independently chose bicycle commuting on greenways during weekday morning and evening peak hours, which proved feasibility of temporally sharing resources. Incompatibility of greenway use for bicycle commuting is observed, given the difference between their construction functions and service objectives. Multiagency collaboration (e.g., among departments of gardening and afforestation, urban administration, transportation, and urban construction) is required with shared responsibilities and benefits to effectively serve residents' green travel needs and improve the service quality of bicycle commuting. This paper, taking the greenway of Qingfeng Park as an example (hereinafter referred to as Qingfeng Greenway) and using field data from observations, surveys, and interviews, analyzes bicycle commuters' travel characteristics, selection of the greenway for commuting, travel demand, and existing problems. Potential ideas and detailed plan for quality optimization are proposed.

2.1 Surrounding areas of Qingfeng Greenway

Qingfeng Greenway is one segment of the three-river and six-bank greenways in Jinhua City, connecting the residential area in the northeast part of the city and the urban center to the north of the Wujiang River. With a length of approximately 1.6 km (Fig. 1), it runs from Huancheng East Road in the east, connecting the greenway of Architectural Art Park, to the Ancient City Historic District in the west, joining the greenway of Bayong Park. The greenway was built as a part of the Wujiang River embankment project and opened to public in 2017, which was the earliest built and opened segment among all three-river and six-bank greenways.

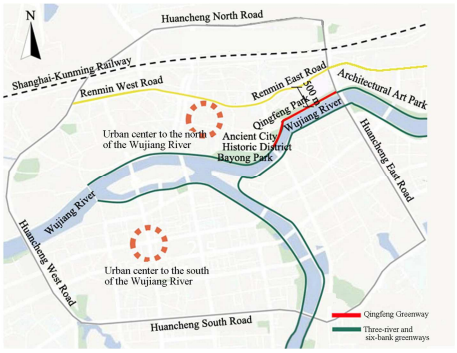


Fig. 1 Location of Qingfeng Greenway

Due to the separation by Wujiang River on the south and a railway on the north, commuters from the northeast part of the city to the urban centers rely entirely on the east–west arterial road, Renmin East Road, before the greenway's opening. The road has been widened by removing almost all the isolation belts, but it is still unable to carry the growing commuting passenger flow; its biking environment is bad, given the mixed motorized and non-motorized traffic (Tab. 1). The area between Renmin East road and Qingfeng Greenway is mainly for residential use. All transit bus stops serving residents in this area are located on Renmin East Road, which covers only 66% of the area with a radius of 300 m (Fig. 2).

Tab. 1 The locations affecting cycling safety along Renmin East Road (Dongshi North Street–Huancheng East Road)

Road segment	Entries of enterprises along the road	Bus stops	Roadside parking strips	Intersections	Total influencing scope
Renmin East Road (north)	9, influencing scope of 270 m	3, influencing scope of 126 m	2, influencing scope of 210 m	5, influencing scope of 260 m	741 m (including repetition), accounting for 46.3% of the total road length
Renmin East Road (south)	5, influencing scope of 150 m	3, influencing scope of 126 m	1, influencing scope of 110 m	5, influencing scope of 260 m	646 m (including repetition), accounting for 40.4% of the total road length

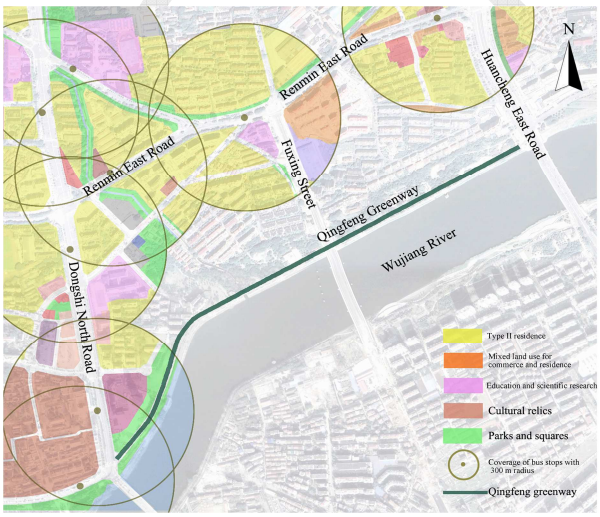


Fig. 2 Coverage of bus stops within 300 m-radius in surrounding areas of Qingfeng Greenway

The cross-section width of Qingfeng Greenway is 5.5 to 7.8 m. The whole road is relatively flat with the longitudinal slope within 0.3%, except for the underpass at the river-crossing urban roads with concave curve or other sections cause by elevation difference. Qingfeng Greenway is connected with several urban minor arterials and branch lines on the north of the residential area through the local roads in Qingfeng Park. To the east of Fuxing Bridge, in addition to the riverside greenway, there is also an east–west park trail inside Qingfeng Park to the north of the greenway (Fig. 3), with a width of 1.5–2.5 m. Current users include pedestrians and cyclists and their mutual interference is intense when the traffic is heavy.

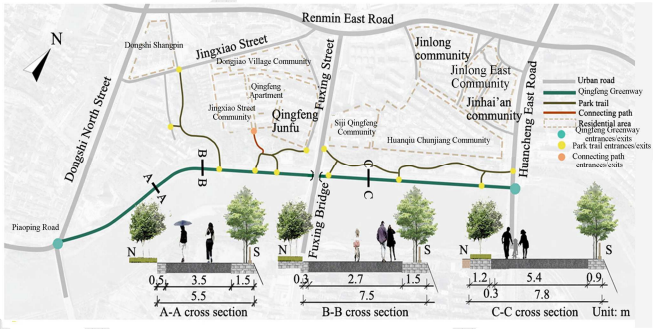


Fig. 3 Cross section of Qingfeng Greenway and connection with surrounding streets and residential areas

2.2 Travel characteristics of bicycle commuting

According to the continuous observation between March and June 2019, the commuting flow of one-way non-motorized traffic (in the direction at a high flow rate) during morning and evening peak hours on Qingfeng Greenway was between 180 and 230 vehicle·h^{-1}. In this paper, a typical workday with a fine weather is selected to collect questionnaire feedback from 75 bicycle commuters through random sampling. Results have demonstrated that cyclists mainly consist of people aged 18–60 with middle or low income. Cyclists' residence is concentrated within 2.7 km from the center of Qingfeng Greenway. The average one-way commuting distance is 5.1 km with an average nonlinearity coefficient of 1.45 of the biking path. The cyclists' workplaces have suggested a distribution of 31.8% in the business and commercial district to the north of Wujiang River, 10.6% in the commercial district to the south of Wujiang River, and 57.6% in places other than the above two job centers (Fig. 4).

Among all interviewed cyclists, 34.9% have to take a detour to reach Qingfeng Greenway. They consider the attractive characteristics of cycling on greenway, include noise-free environment, smooth road surface, separation between motorized and non-motorized traffic, and good air quality. The total travel time after the detour does not increase much or even decreases, which suggests high efficiency of bicycle commuting on greenways.

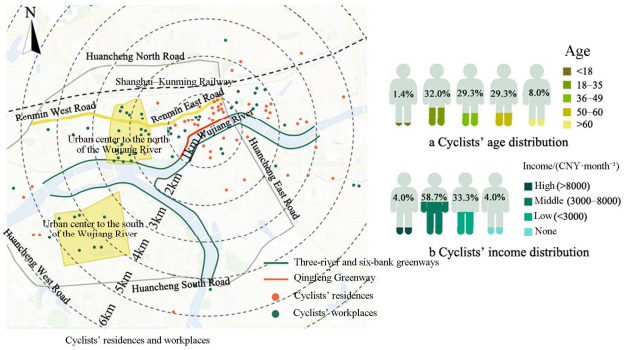


Fig. 4 Distribution of incomes, ages, residences and workplaces of bicycle commuters

The shift of bicycle commuting travel from urban arterial roads to greenways increases the efficiency of greenway use during morning and evening peak hours; in addition, this shift results in significant positive environmental benefits by improving the comfortableness, safety, and health of commuters. Nevertheless, the survey also reflects the greenway commuting cyclists' dissatisfaction with the current road design, facility supply, and operation management. Improvements in these aspects will contribute to a higher proportion of travel modes in green transportation, which is worthy of further study.

3 Problem analysis

3.1 Right-of-way determination and connection of greenways

3.1.1 Right-of-way determination

Since greenways are constructed to serve pedestrian and bicycle travel for leisure and fitness purposes, their design adopts a cross-section of mixed travel for pedestrian and non-motorized traffic, with the consideration of insignificant velocity difference between the two modes (Fig. 5). Bicycle traffic has a higher speed in commuting due to visible time constraints. Currently, the maximum traffic flow on Qingfeng Greenway during peak hours is around 230 vehicle·h^{-1}, which is far less than the traffic capacity, and no evident conflict between pedestrians and non-motorized traffic has been observed. However, the survey results suggested that 18.7% of the cyclists recognized one of the important potential problems as the lack of isolation measures between pedestrians and bicycles. Amid the improvement in the bicycle road system in the future, the increase in the number of commuting cyclists on Qingfeng Greenway is expected to result in conflict between pedestrians and non-motorized traffic to a certain level, which requires proactive schemes for solutions.

In addition, although the park trail parallel to Qingfeng Greenway between Fuxing Bridge and Huancheng East Road (only 1.5–2.5 m wide) is narrower than Qingfeng Greenway

Fig. 5 Qingfeng Greenway

(Fig. 6), it attracts some cyclists because of its convenience of connection with surrounding roads (e.g., Huancheng East Road and Fuxing Street). As a result, there are mixed travel and interference between pedestrians and non-motorized traffic, with a substantial deterioration in safety and comfortableness. Cyclists recognize no significant difference between the park trail and the Qingfeng Greenway. Differentiated service standards and target groups can be planned later through pavement design, cross-section programs, facilities allocation along the greenway, and access management to standardize travel paths of pedestrians and cyclists.

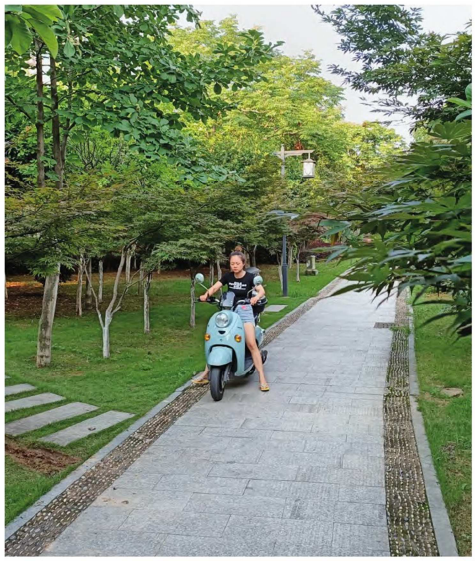


Fig. 6 Park trails

3.1.2 Connection of greenways

Riverside greenways in the city are usually constructed

and opened by segment after the existing river-crossing urban roadways are open to traffic. Therefore, the node connection between different greenway segments is inevitably limited, especially for the elevation and longitudinal slope at the interchange with river-crossing roads and for the altitude difference linking different greenways. Without precise design, the connection may appear sharp, failing to ensure cycling safety and comfortableness due to a steep longitudinal slope.

Qingfeng Greenway is taken as an example. Because the urban river-crossing arterial road has the same height as the riverbank, the interruption on greenways by river-crossing roads is common. The greenway underpasses Fuxing Bridge through an 8% longitudinal slope, which is much greater than typical slope limit for non-motorized traffic lane from the *Code for Design of Urban Road Engineering* (CJJ37-2012)(2016 edition). Cyclists' perception is usually erroneous from visual judgement; both emotional tension and slow reaction due to overestimation of the slope and negligence and speeding due to underestimation of the slope may increase the probability of accidents. Approximately 40% of the respondents in the cyclists survey have reported that the slope of the greenway segment intersecting river-crossing roads is too steep and needs to be improved to ensure safety. Likewise, the current connection to the Architectural Art Park Greenway on the east relies on a barrier-free ramp to address different altitudes between the platform underneath the bridge and the greenway; the ramp has a width of only 1.2 m, with twists and turns, so it is hard for cyclists to push bicycles. The current way of connection to Bayong Park Greenway on the west follows the pattern of steps plus ramps to pass Dongshi North Street (an arterial river-crossing road) underneath (Fig. 7). None of the nodes mentioned above has achieved the goal of supporting continuous, safe, and comfortable cycling, which has become a potential safety hazard for bike commuting on greenways.

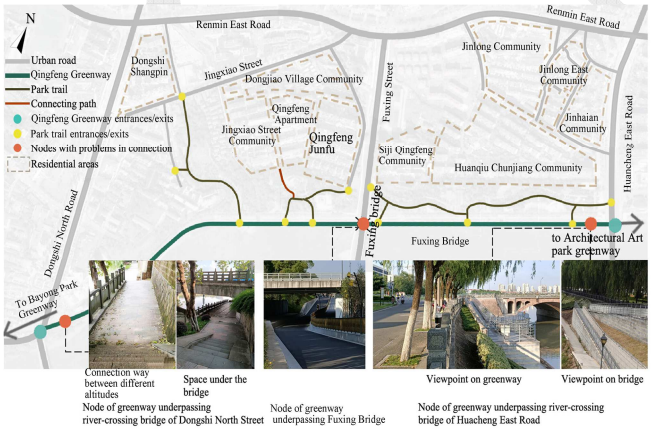


Fig. 7 Connections between Qingfeng Greenway and the river-crossing urban roadways

3.2 Facility distribution along greenways

Cyclists' demand for facility distribution varies at different service levels, which can be roughly classified into three categories: elementary, intermediate, and advanced (Tab. 2). When the lower-level demand is met, higher-level demand will be desired. In general, the current situation of Qingfeng Greenway has revealed problems including the imperfect facility distribution corresponding to the elementary demand and a lack of pre-control of the facility land corresponding to the intermediate or advanced demand (Fig. 8).

Tab. 2 Level of cyclists' demand for facilities along the route

Demand level	Facility type	Specific facilities
Elementary	Frequently-needed transportation services during cycling	Traffic signs, rain shelters, and bicycle parking areas
Intermediate	Occasionally-needed transportation services during cycling	Charging piles for e-bikes and bicycle repair stations
Advanced	Occasionally-needed social amenities during cycling	Small catering spots and vending machines

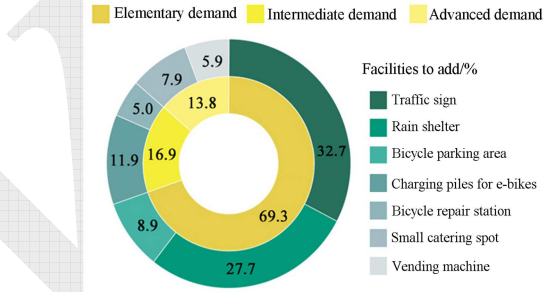


Fig. 8 Facility allocation problems reported by bicycle commuters

3.2.1 Facilities corresponding to elementary demand

The lack of traffic signs (e.g., warning signs on segments with large slope changes) on Qingfeng Greenway increases the biking traffic hazard. There has been a long-standing conflict between pedestrians and non-motorized traffic in some segments, because access management for different travel modes, right-of-way division between the park trail and riverside greenway, and traffic signs to clearly distinguish right-of-way of pedestrians and bicycles are not available.

In addition, according to the greenway design standard, a rest stop is set on Qingfeng Greenway, which can be used as a temporary rain shelter. However, for commuting cyclists with fixed travel needs, they are more likely to be concerned of unexpected rain or snow. If it is difficult for bike commuters to take the nearest rain shelter within 1–2 minutes, the unpleasant cycling experience may greatly reduce commuters' willingness to choose greenways in the future.

Qingfeng Greenway is connected to the surrounding residential areas and facilities through urban access roads (e.g., food markets, primary and secondary schools, etc.) and park trails. However, no bicycle parking space is available at the nodes where park trails are connected with the entrances/exits of residential areas or public buildings. As a result, it is difficult to meet a reasonable demand for parking at starting and ending points of a commuting trip or in the middle of a shopping trip.

3.2.2 Facilities corresponding to intermediate and advanced demand

According to the survey results, commuting cyclists have no strong willingness to increase the number of facilities corresponding to intermediate and advanced demand; however, with the elementary demand being met, they would prefer higher service quality. For example, bike commuters hope that bike repair services are available along the greenway and they can also buy breakfast, tea or basic daily necessities and medicines during the commuting trip. The potential demand for the above services needs to be met through land control and planning. Given that travelers for leisure and fitness served by greenways also have similar demand, these facilities should be developed to allow efficient utilization and sharing of resources.

3.3 Connection between greenways and residential areas

Nearly 10 residential areas are located next to the north of Qingfeng Park, including Jingxiao Street Community, Qingfeng Apartment, Siji Qingfeng Community, and Huanqiu Chunjiang Community. Although these communities are in close proximity to Qingfeng Greenway, bicycle travel is not easy for residents. The number of entrances and exits for non-motorized traffic in these residential areas linking to Qingfeng Greenway is insufficient; among the current three entrances/exits, two are located to the east of Fuxing Bridge and have been closed for a long time (Fig. 9). Cyclists have to take a detour to reach Qingfeng Greenway. Survey results have shown that 56.3% of the respondents (mainly from residential areas to the east of Fuxing Bridge) believe that the two entrances/exits should remain open for convenient travel. The third entrance/exit is located at the west of Fuxing Bridge. Although it is open, there is a significant elevation difference between the connecting path and Qingfeng Greenway; the current connection is through steps, which become a barrier against the continuity and smoothness of cycling. Survey results have suggested that 43.7% of respondents (mainly from residential areas to the west of Fuxing Bridge) consider the connection to be unacceptable.

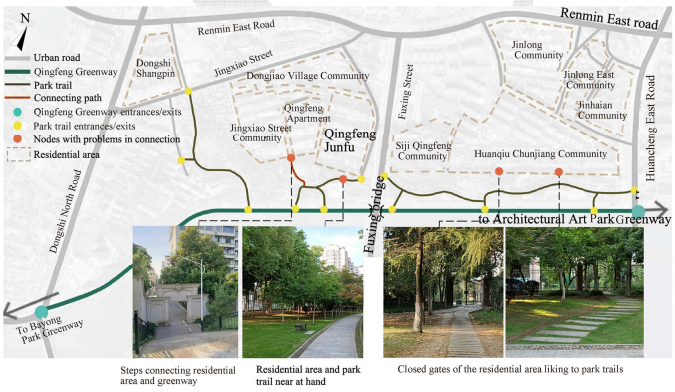


Fig. 9 Locations of greenway (park trails) and residential areas and the problems in connections

The first and last 50 m between the residential areas and commuting greenways are the most easily ignored sections in a precise design; such ignorance may result in substantial inconvenience and even directly compromise the willingness of cycling. Many agencies, such as property management companies, park management departments, and departments are involved; the coordination among these agencies bears certain transaction cost. However, cutting the connection or simply using steps for connection is contrary to the people-oriented development. In the subsequent optimization design, on the basis of consolidating interests of all departments, bicycle entrances/exits to Qingfeng Greenway should remain opened or new ones should be added. Connection via steps should be transformed into a continuous cycling ramp, so that a direct connection path to Qingfeng Greenway can be constructed to facilitate the distributing of commuting cyclists.

3.4 Connection between greenways and urban non-motorized roadway network

Greenways, together with urban non-motorized road network, provide cyclists with a safe, convenient, and comfortable commuting travel. Because riverside greenways and the existing non-motorized lanes on urban roads have different contractors and construction sequences, it is common that they have poor connection. Qingfeng Greenway is an example, which only links to one side of the non-motorized lane in connection with Huancheng East Road (river-crossing arterial road with street medians) and has a serious problem of cyclists' travelling to the opposite direction. No corresponding passageway is designed at the junction with the road under Fuxing Bridge (Fuxing Street). The current connection relies on the park trail of only 1.5 m wide, which is the bottleneck in the road network and reduces the travel efficiency (Fig. 10). Survey results have suggested that 51% of the respondents recognize that the inconvenient connection to non-motorized lanes on urban roads is a typical problem encountered in cycling.

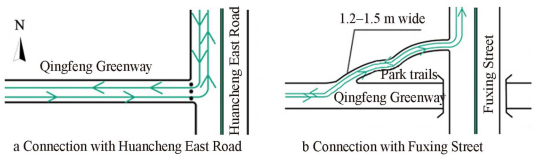


Fig. 10 Connections between Qingfeng Greenway and bicycle lanes on urban arterial roadways

4 Optimization ideas and plans

4.1 Cycling demand levels and greenway classification

In this study, cycling demands are classified into five levels, namely feasible cycling, safe cycling, convenient cycling, comfortable cycling, and free cycling, based on

Maslow's hierarchy of needs. Feasible cycling and safe cycling correspond to the elementary demand; convenient cycling and comfortable cycling indicate intermediate and advanced levels of demand of residents; free cycling suggests the ideal condition. Currently, Qingfeng Greenway can meet the elementary cycling demand, except that some individual nodes and segments have certain deficiencies to be addressed to ensure safety.

In design, operation, and management of the greenway redevelopment, a more reasonable allocation of pedestrian and cycling spaces is needed. According to research findings of environmental psychology, the texture change in interfaces can be taken as a reference to divide space and control behavior [4]. Through changing paving materials, properly adding steps or blocking piles, and setting guide signs, we can prohibit non-motorized traffic from using the park trails that are transformed into a pedestrian-only space. Riverside greenways are transformed into a bicycle-oriented and pedestrian-friendly corridor, which is reflected in the road cross-section design. Greenways that meet bicycle commuting demand are reclassified into two categories: greenway mainlines and greenway connectors. The coherent riverside greenways, as the greenway mainline, serve as major corridors for bicycle commuting, which should meet the demand of comfortable cycling. Access segments to other urban roads, bus stops, entrances/exits of communities, as the greenway connectors, serve collecting and distributing functions, enabling convenient cycling. Specific improvement measures can be gradually implemented in the near- or long-term according to the urgency of residents' demand with timely feedback and adjustment, to obtain high social, economic and environmental benefits at a low cost.

4.2 Right-of-way allocation and connection of greenways

4.2.1 Right-of-way allocation of greenways

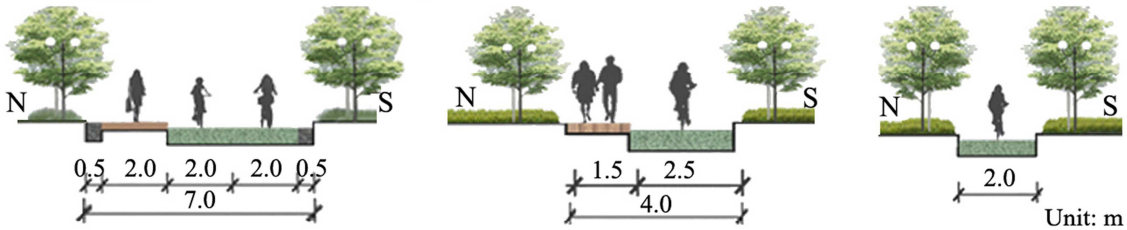
For the smooth cycling on the greenway mainlines and reduce the interference with pedestrians, part of Qingfeng Greenway will be widened by some space in the park to form 4.5 m wide two-way non-motorized lanes at the south side and a 2.5 m wide sidewalk at the north side. A 15 cm elevation difference is set between the sidewalk and non-motorized lane and different materials of pavement are used to separate pedestrians from non-motorized traffic to ensure the independent right-of-way for pedestrians and cyclists. A two-way cycling space at least 2.0–2.5 m wide should be maintained on the greenway interconnections. The setting of walking space depends on the specific pedestrian flow and direction (Fig. 11).

4.2.2 Connection of greenways

At the flyover crossing between the greenway mainline and the existing river-crossing road, the greenway is properly cantilevered to underpass the river-crossing road. The cantilever segment is constructed on the protective green space with support columns. The transformed road segment should meet the slope limit requirement for non-motorized vehicles according to the *Code for Design of Urban Road Engineering* (CJJ37-2012) (2016 edition) and the demand for convenience and comfortableness of cycling.

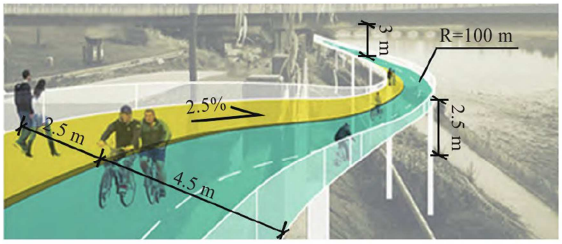
The reconstruction design of Qingfeng Greenway crossing Fuxing Bridge can be taken as an example. The headroom under the bridge after reconstruction is designed to be 3 m and the slope is set at 2.5% with length of 24 m at both sides, which can meet the slope construction standard for non-motorized vehicles (Fig. 12a). The same method is applied to the segment crossing Huancheng East Road and that connecting Architectural Art Park Greenway, with the slope of 2.5% and length of 124 m after reconstruction (Fig. 12b).

The overall elevation of the greenway segment in Bayong Park in the west is 3 m lower than that of Dongshi North Street and 6 m lower than that of Qingfeng Greenway. With the existing underpass below Dongshi North Street for connection, the steps are transformed into a continuous ramp with a width of 4.5 m, slope of 2.5%, and length extending to 240 m, which can meet the slope construction standard for non-motorized vehicles (Fig. 12c).



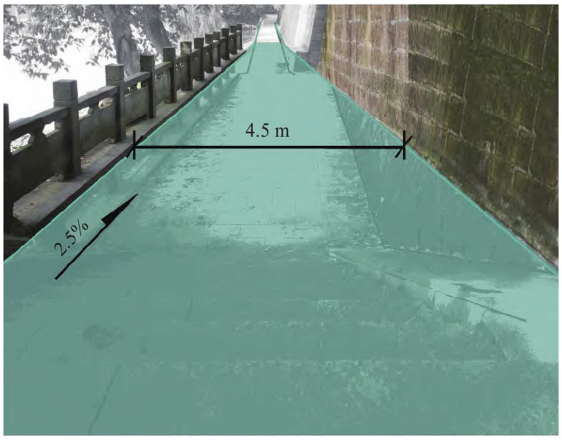
a Greenway mainline　b Greenway interconnections (with sidewalk)　c Greenway interconnections (without sidewalk)

Fig. 11 Cross-section of greenway mainlines and interconnections after improvement



a Node of Fuxing Bridge

b Node of Huangcheng East Road



c Node of Dongshi North Street

Fig. 12 Reconstruction plan of Qingfeng Greenway underpass urban roadway

4.3 Facility allocation along greenways

According to the cyclists' hierarchy of demand, the allocation of facilities will be gradually improved in the short or long term. In the short term, in response to elementary demand, the design should comply with the *Code for Layout of Urban Road Traffic Signs and Markings* (GB 51038-2015), including setting "No Entry" signs for motor vehicles at the entrances/exits to the greenway, setting signs to regulate the right-of-way for pedestrians and non-motorized vehicles on greenway mainlines, setting "No Entry" signs for non-motorized vehicles on park trails and warning signs in front of the cantilevered flyover crossing to remind cyclists of safety and path changes. In terms of allocation of rain shelters, cyclists should be guaranteed to ride to the shelter space within 2 min on greenway mainlines. With the current courier station as the center, new rain shelters should be located every 500 m with the layout of gallery frame. At the nodes that connect residential areas, public buildings, bus stops at greenway interconnections, bicycle parking areas and public bike rental stations should be arranged to facilitate bicycle parking.

The facilities to be allocated in the long term can be implemented in coordination with the subsequent supporting construction of greenways to meet the cyclists' intermediate and advance demand. Examples include setting charging piles for electric bicycles and bicycle repair stations at courier stations, and arranging vending machines, small catering stores, and other service facilities at appropriate spaces along the greenways. In addition, on the basis of information technology such as big data and mobile internet, LED screens should be set at the entrances/exits of all segments of greenways to publish real-time weather conditions, real-time flow on the greenways, cycling comfortableness, emergency alerts and other information; cyclists should be ensured to have access to the above information through their city travel Apps.

4.4 Connection of greenways with surrounding residential areas

Opening the existing entrances/exits of residential areas and adding bicycle-only entrances/exits and interconnections for communities, where cyclists need to detour to Qingfeng Greenway, can ensure convenient travel within all the residential areas near Qingfeng Park being directly linked to Qingfeng Greenway through interconnections (Fig. 13). Bicycle ramps should be constructed at the entrances/exits of the communities with a height difference from greenway interconnections. The current steps of 3.6 m wide at the entrances/exits of Qingfeng Apartment can be transformed into a 0.8 m wide ramp on both sides with anti-slip strips for residents to push bicycles on and off (Fig. 14). In the long run, on the basis of a consensus with the park management, it can be further transformed into a ramp of 2.5% longitudinal slope.

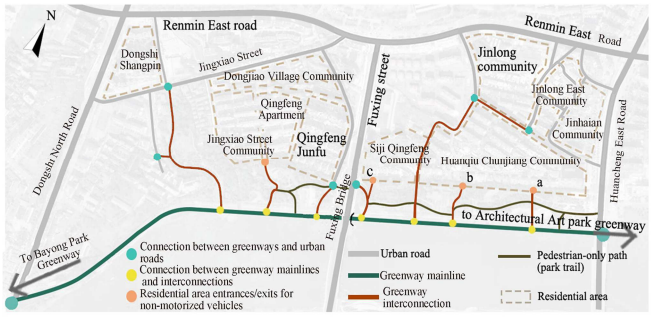


Fig. 13 Improvement in connections between Qingfeng Greenway and surrounding residential areas and roadways

Fig. 14 Connection improvement at the entrances/exits of residential areas

4.5 Connection of greenways with urban non-motorized roadway network

At the intersection of greenway mainlines and urban arterial roads, an underpass is adopted to ensure free movement on greenways. For a continuous road network for non-motorized vehicles in the city, a seamless connection is necessary between the greenway mainlines and the non-motorized lanes on the existing river-crossing roads. To be specific, two approaches can be implemented. One is to use a newly added underpass and directional ramp to solve the connection problem between the greenway and the non-motorized lane on the opposite side (e.g. at the intersection node of Huancheng East Road; see Fig. 15). The other is to connect greenway mainlines and the existing river-crossing roads through greenway interconnections at about 50 m outside the intersection node (e.g. at the intersection node of Fuxing Bridge; see Fig. 13). In both approaches, the width of the ramp or interconnection line should be at least 2.5 m.

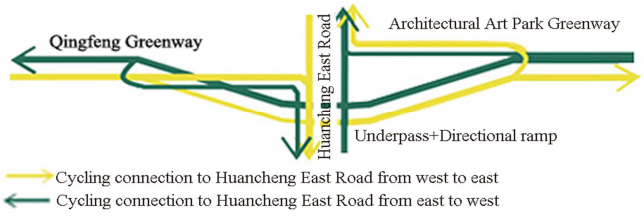
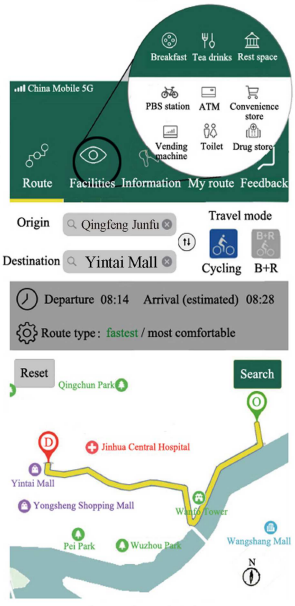


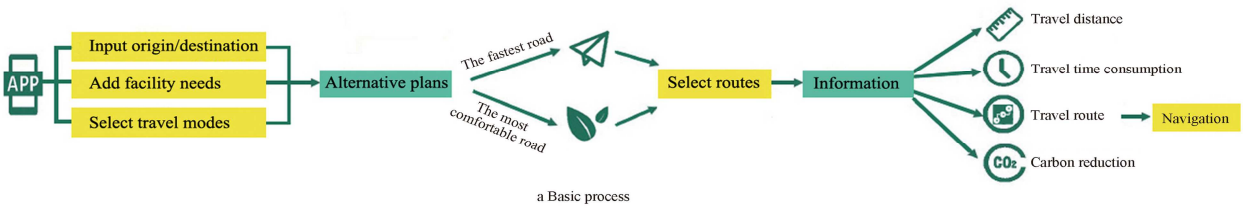
Fig. 15 Connections between greenways and bicycle lanes on Huancheng East Road

4.6 Optimization of bicycle travel service based on MaaS

Convenient and comfortable cycling mainly depends on the improved space design, quality management, and facility allocation. However, in the new era of big data, smart technology, mobile internet and cloud computing, transition from travel-as-transport to travel-as-service is needed to ensure free cycling. Currently, each city has generally designed APPs for travel information query, based on which bicycle travel services can be integrated. After the cyclists input origin (destination), facilities needed along the way (e.g., tire inflation services, places for buying breakfast and daily necessities, and ATM services), and travel mode (cycling only or combined biking and transit use), the travel service system automatically calculates and quickly recommends two choices: the fastest route (least delay and shortest travel time) or the most comfortable route (environment-friendly, easy riding, and acceptable travel time) according to real-time weather and road conditions as well as cyclists' travel requirements. After the cyclists select one mode according to temporal availability, physical strength, and other factors, the system displays specific travel route, distance, time, carbon reduction, and other indicators and provides real-time navigation as needed (Fig. 16). High-quality bicycle travel services will effectively facilitate free cycling.



b Interface sketch



a Basic process

Fig. 16 Flow and interface of bicycle travel service APP

5 Conclusion

Bicycle, as a low-carbon, flexible, healthy, and green travel mode, becomes highly adaptable to the travel needs with an average commuting distance less than 5 km in medium cities. If the travel environment and service quality of bicycle transport can be rapidly improved, more commuters will be expected to shift to the bicycle travel mode in the future and bicycle will even become the dominant travel mode for short- and medium-distance commuting.

In urban central district with scarce resources, riverside greenways serve as the shortcut connecting urban peripheral residential areas in single-centered cities with CBD or CAZ. Further study is required for greenways, given their potential to be used as a bike-only commuting corridor during morning and evening peak hours. The clear classification and right-of-way allocation of greenway mainlines and interconnections, the increasing satisfaction of demand for facilities along greenways in the short and long term, and seamless connection with surrounding residential areas and urban river-crossing road network are important to ensure the improvements in bicycle commuting willingness and satisfaction. It is worth noting that, for a breakthrough in the above aspects, precise system design, interest coordination, collaborative governance, joint construction, and responsibility-sharing by different agencies have all become necessities. Under the guideline for building a city with people's satisfaction, the continuous tracking and investigation of cyclists' travel characteristics and demand for improvements, followed by the gradual enhancement in details, are beneficial to the fundamental improvement in the competitiveness and sharing rate of bicycle travel.

Due to the limitation of work scope, this paper only focuses on one of the most representative segments, Qingfeng Greenway, among three-river and six-bank greenway of Jinhua City. However, the same research method can be applied to other urban greenways serving commuting travel. Other cities can increasingly promote "Greenway Commuting Demonstration Project" in a segment-by-segment manner and coordinate with the construction and transformation of urban non-motorized road network, to ultimately form a high-quality green infrastructure network and travel service system for biking.

References

[1] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Guidelines for Greenway Planning and Design [EB/OL]. 2016 [2020-09-10]. http://www.mohurd.gov.cn/wjfb/201610/t20161014_229168.html (in Chinese).

[2] Urban transportation research branch of China academy of urban planning and design. Commuting Monitoring Report of Major Cities in China in 2020 [EB/OL]. 2020 [2020-09-10]. https://mp.weixin.qq.com/s/Zl950v1VQHl9Fg6JsYKYKg (in Chinese).

[3] Anonymity. 数据告诉你: 骑车上班的五个理由 [J]. 中国自行车, 2014 (11): 108–110 (in Chinese).

[4] Hu Zhengfan, Lin Yulian. Environmental Psychology: Study of Environment-Behavior and its Design Applications [M]. Beijing: China Building Industry Press, 2018 (in Chinese).

