Traditional Based Innovation:
Integrating Bicycles and Urban Rail Transit in Beijing, China
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ABSTRACT:
As a measure to mitigate GHG emissions in transport sector, it is necessary to revitalize the traditional non-motorized transport mode of bicycles in many cities of developing countries. In this paper, a traditional based innovation of integrating bicycles and urban rail transit is proposed. This integration enlarges the service area of urban rail transit from comfortable walking distance to comfortable bicycle-riding distance, bringing mutual benefits to these two modes of environmental friendly transport.

Beijing city in China is selected as a case city to explore the proposed integrated bicycles and urban rail transit system (BR system), and the bicycle-rail transfer at Wudaokou station of Subway Line 13 in Beijing is selected as a detailed case site. Firstly, the necessity, feasibility and framework of the BR system are presented. Secondly, the existing performance of the BR system is investigated. Thirdly, a bicycle rental company is introduced as a catalyst for the BR system, and its current practice and potential development are discussed. Finally, an action plan to promote the BR system with a catalyst company is brought forward.

KEYWORDS: Integrating, bicycle, urban rail transit, sustainable transport, Beijing

1. INTRODUCTION
Bicycle was a traditional dominant mode of transport in many cities of developing countries. However, the share of bicycle use has declined sharply in these years because of the challenge of private vehicles. This declining trend of bicycle also happened in China. Bicycle used to be a dominant transport mode in most of the cities in China, and China was called as the “Country of Bicycles”. However, as the economic grows and the city expands, the place of bicycle has been gradually taken by more and more vehicles.

Recent years, the disadvantages of private cars as a dominant personal transport mode have been revealed, such as the large amounts of CO₂ emission, the pollution on air, etc. Hence, the use of bicycles gets considerable attention in varies countries again. From the sustainable point of view, bicycle is considered as an environmental friendly and low carbon oriented traffic mode. There have been many researches on enhancing the bicycle riding environment, and varies public policies on promoting bicycle use have been carried out in many countries.

The promotion of bicycle is significant for developing low carbon transport in China. As a developing country, the megacities in China still have great opportunities to reveal “Leap Frog” development towards low carbon urban transport system, avoiding highly car dependence in urban transport system. Whether the merit of “Country of Bicycles” can

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reappear becomes an attractive topic. Among the measures to promote bicycle use, not only the efforts made by municipal government should be addressed, but also the efforts made by private companies and citizens are very important.

Beijing, the capital city of China, is selected as a case study city. In this article, an integrated bicycles and urban rail transit system is proposed. Based on the discussion on the framework of the BR system and the introduction of a private company with bicycle promoting business, a tentative action plan to promote the BR system is brought forward.

2. LITERATURE REVIEW

The strategies for low carbon transport could be classified as “avoid”, “shift” and “improve”. There have been many studies done on low carbon transport. These studies include comparison of different traffic modes (Conor Walsh, et al. 2009), the impact evaluation of different low carbon oriented technologies and policies (Richard S.J. Tol, 2007; Jan Abrell, 2010), the mitigation method for typical countries (Ji Han, et al. 2008), etc. Based on these studies, World Conference on Transport Research Society’s project “Comparative Study on Urban Transport and the Environment (CUTE) (2001-2004)” brought out a matrix of mitigation and adaptation actions (WCTRS, 2007). In that matrix, the strategies for low-carbon transport are mainly classified into 3 parts: “avoiding” transport demand, “shifting” transport demand from high carbon emission modes to other modes, and “improving” vehicle technology to reduce emission rate.

For developing countries, it is highly recommended to start with the “avoid” stage. Based on the strategy matrix, during the WCTRS “Transport and Climate Change” international symposium on 2009 (WCTRS-SIG11, 2009), the difference on strategies for developed countries and developing countries was discussed carefully. It was revealed that in most developing countries, it is still highly possible to “avoid” more transport demand and to “avoid” the dependence on private car use through carefully designing land use and transport infrastructure system.

The role of non-motorize transport mode, especially bicycle, has been set as an important role in the environmentally sustainable transport system. Instead of Transit Oriented Development (TOD), which is considered as one of the most promising way to reach “avoid” target, the concept of Bicycle Oriented Development (BOD) has been raised recently (Haixiao Pan, WCTRS-SIG11, 2009). Lots of case studies have been done on bicycle use in various cities (Piet Rietveld, 2000; Karel Martens, 2004), especially in cities of Netherland, for its typical high mode share of bicycles.

The instruments to promote bicycle use are brought forward by many researchers (Robert B Noland, 1995; Piet Rietveld, 2004; Greg Rybarczyk, et al. 2009). The integrated relationship of bicycle and rail transit is brought out as a promising instrument to enhance bicycle use (M.J.N. Keijer, et al. 1999; Tilman Bracher, 2000). It is also revealed that the use of bicycle can greatly enhance the accessibility of railway stations in Netherland (Piet Rietveld, 2000).

According to these recent literatures, for developing countries like China, there are more possibilities to avoid the increasing high emission motorized transport. The revitalization of bicycle use could be considered as a key point to reveal “Leap-frog” scenario towards low carbon transport system in cities of China. And the integration of bicycle and rail is a promising way to revitalize bicycle use.

3. STUDY AREA AND DATA

In this article, Beijing is selected as a case study city, and Fangzhou Bicycle Service (Beijing) Limited Company is introduced, for it is running a public rental bicycle system, whose operation experience well represents the problem and situation of bicycle use of Beijing.

Beijing is the capital city of China. The major road pattern of Beijing is its ring road system. And there are mainly 9 subway lines which are operating now (Fig. 1). The total
length of the subway line is about 228km. This is the second largest subway system among the cities of China.

Fig. 1 Subway system of Beijing (Source: Wikipedia)

Subway Line 13 is selected to examine the current BR system. It arcs across the north suburban area of Beijing, serving for commuters from Dongzhimen to Xizhimen, connecting with the Subway Line 2 and Line 10. Comparing with other subway lines, Subway Line 13 has a highest share of commuting traffic in Beijing, representing the commuting urban rail transit of Beijing (Fig. 2).

Fig. 2 Trip aim of several subway lines in Beijing (Source: BTRC, 2007)

One more detail scenario study site is a district near Wudaokou Station along Subway Line 13, which is about 16km² (4km × 4km). Wudaokou Station is the third station counting from Xizhimen transfer node. Around Wudaokou Station, there is a typical shopping center along the subway, a cluster of office building, and several typical “Big Yard” systems of Beijing (Fig. 3a). In this study, this area is abstracted to 200m x 200m grid (Fig. 3b).

The bicycle transfer to subway is extremely high in Wudaokou Station, comparing with other subway station along Subway Line 13 (Fig. 17). A questionnaire investigation was taken on the site around Wudaokou Station. 500 questionnaires were hand out, and 480 valid questionnaires were reclaimed. The viewpoint on bicycle parking, riding and accessibility was investigated in the questionnaire.

Fig. 3 Land use and abstract map around Wudaokou Station

Fangzhou Bicycle Service (Beijing) Limited Company is introduced as a promoting case in this article. It operates a public rental bicycle system, with 575 bicycle stations and more
than 10,000 bicycles. It tries to build up an integrated bicycle and rail transit system in Beijing, mainly serving for the commuters. The serving systems for Subway Line 4 and Subway Line 10 in Beijing have been completed. This company brought forward the concept of “Bicycles in Your Pockets”. Citizens in Beijing can easily find out the bicycle station of Fangzhou Company in 1 km radius area around a subway station along those two lines.

The data in this study mainly comes from three sources: the third comprehensive transportation investigation of Beijing in 2005, the investigation and field trip carried out around Wudaokou Station and the interview of Fangzhou Company by the author in 2010.

4. INTRODUCTION OF THE BR SYSTEM

4.1 The necessity of the BR system

Decline of bicycle use in Beijing

Although Beijing appeared to have an urban transport system which was dominant by bicycles in 20 years before, it did not feel proud for that, and considered it as the characteristics of non developed transport system at that time. Therefore, the development of bicycle transport had been ignored for a very long time.

According to the data given by three time comprehensive transportation investigation in Beijing, the share of bicycle use decreased by about 30% in the past 20 years. The share of bicycle in all transport modes (in number of trips) in 1986 is 62.7%. However, in the year of 2005, the share of bicycle only left 28.9% (Fig. 4). It can be found out clearly in Fig. 4 that the former shares of bicycle use were mainly taken by cars and taxi. The share of private & company car in all transport modes increased from 5% in 1986 to 29.5% in 2005. There also appears 8.2% taxi mode in 2005. Hence, the total share of car use reaches 37.7% in 2005.

In person trip distance of average 10,000 person, car accounts for 8302km, shuttle bus accounts for 780km, taxi accounts for 1354km, bus accounts for 4696km, rail accounts for 1687km, and bicycle accounts for 2622km. The share of bicycle is only 13.5%, while the share of car and taxi is 49.6% (Fig. 5a). In trip distance of average 10,000 vehicles, car accounts for 6429km, which is 68.9% in total. The share of taxi accounts for another 18.7% in total (Fig. 5b).

According to these data, it is obviously that the transport mode share of bicycle had a very significant decline in past 20 years.

Traffic and environmental problems raised by car use

When the city began to rapidly grow, Beijing's perception of the modern city traffic
remained in scenes of fast-running cars and spectacular overpasses. At that time, most of Chinese citizens got their impression of Beijing from TV program, in which there are only different shapes of the overpasses besides the ancient Forbidden City and the Great Wall. Soon after the buildup of the second ring road and the third ring road, with the continuous fast expansion of the urban built up area, the fourth, the fifth and the six ring roads were also completed.

However, Beijing’s traffic has not become more smoothly when more road has been built. Instead, it turns out to be more and more crowded. From the statistics, it can be clearly found out the main reason why the road is becoming increasingly crowded. The growth rate of road construction lags far behind the growth rate of the car ownership (Fig. 6). This means the average road length per car decreases constantly. Hence the traffic in Beijing has become more and more crowded.

Moreover, while the car takes a lot of road resources, its transport capacity is far less than public transport. For example, the vehicle kilometer of car accounts for 68.9% in total vehicle kilometers, however, the person kilometer of car is only 42.7%. That means cars occupy 68.9% usage of the road, but only serve for 42.7% of the passenger trip distance. Taxi is the least efficient way referring to road resources. The share of vehicle trip distance for taxi is 18.7%, while the share of person trip distance for taxi is only 0.07%. The ratio of vehicle trip distance and person trip distance shows the car is about 4 times less efficient than shuttle bus and bus, and the taxi is about 6 times less efficient (Fig. 7).

![Fig. 6 Relationship between car ownership growth and road length growth](image)

![Fig. 7 Comparison on efficiency of road usage for transport modes](image)

Not only the traffic jam raised by cars becomes a great problem, but also the car dominant transport system causes high CO₂ emission and other polluting exhausts. The emissions of different vehicles closely link with their mileage. It can be clearly known that car use is the main source of carbon dioxide and other harmful emissions in transportation systems, because the car mileage accounts for most vehicle mileage of the whole transport system (Fig. 5b).

Citizens began to recall good memories of bicycle transport in recent years. However, when the roads in Beijing have become wider and wider, and the urban built up area has expanded more and more, the environment for bicycle riding has declined inadvertently. Many new built roads do not have traditional bicycle lanes, and there are many new roads without shade trees. In newly built up communities, the bicycle parking lots are often in the most inconspicuous location, while those convenient locations are left to the car parking lots on the ground and underground, which are always complained for insufficiency. As the bicycle riding environment is deteriorating in city, the direct consequence is that the citizens are increasingly eager to own a car of their own, to facilitate their trip to every corner of the city more freely.
Advantages for integration of bicycle and rail transit as the BR system

Facing today’s desire for high mobility, it is hardly possible for bicycles to win alone in competition with cars, especially in a megacity like Beijing, where relying only on a bicycle to go around the city is clearly impossible. Therefore, the BR system which combines the bicycle with mass rail transit is recommended.

The BR system can enhance the attractiveness of bicycle use, to make it an important mode to solve current traffic and environmental problems in transportation. Following the rapid urbanization, the traffic demand increases correspondently in many cities of China. It is well known that the new traffic demand should be supplied by public transport, which has lower energy consumption and lower CO₂ emission per passenger km. Among varies public transport modes, rail transit is highly recommended as a mass transit system. And bicycle is considered as an important companion of rail transport, for it could be used for “the last 1 km” from rail transit station to home or to work. The integration of bicycle and rail transit system is a promising idea for better utilizing these two traffic modes.

The BR system can also enlarge the subway station service radius, improving the level of the mass transit services. In general, the comfortable walking distance is considered as within 500-800 meters, and comfortable cycling distance is within 1-2 km. Therefore, if considering of walking transfer to subway stations, the service area of the station is only about 800 meters radius area around. If considering of cycling transfer to subway stations, the service area of the station can reach to about 1-2 km radius area around, which is twice more than walking transfer.

In particular, the city of Beijing has a good tradition of bicycle transport, and the usual bicycle travel distance in Beijing is longer than other cities. According to the transportation investigation, when the residents in Beijing are having cycling trips, the average distance is 4.2km (BTRC, 2007). Therefore, the serving area of subway station can be extended to 4.2 km radius in Beijing if the BR system operates well (Fig. 8).

![Fig. 8 Possible serving radius of B+R system](image)

A simple scenario study is done on a 16 km² site around Wudaokou station, a station of Subway line 13 in Beijing. When considering average walking speed as 5km/h, and average cycling speed as 15km/h, the differences of time needed to get to surrounded subway station is calculated in Fig. 9. Fig. 9a shows the access time of walking, and Fig. 9b shows the access time of cycling. If bicycles are used, subway station can be reached from almost all the meshes in that site within 10 minutes.

When considering not only the subway station, but also the bus stops and the main roads, the impact of enhancing accessibility is almost the same. Fig. 10 shows the access time in each mesh to nearest subway station, bus stop, and main roads. Fig. 10a is the access time of walking, and Fig. 10b is the access time of cycling. There also exist differences between walking and cycling which cannot be ignored.
4.2 The feasibility on carrying out the BR system in Beijing

While the ignorance of bicycle in urban transport system development in the past 20 years has been enumerated, the influence of bicycle on urban transport pattern in Beijing still cannot be underestimated. Although the share of bicycle use in Beijing has decreased rapidly in recent years, when comparing with some European countries, it is surprising that the share of bicycle use in Beijing is still standing on the top level (Fig. 11). The share of bicycle use is just a little less than Netherland. Hence, there is high feasibility on carrying out the BR system in Beijing.

Firstly, many former-built bicycle lanes still exist in the city. When transport infrastructures have been built, they can remain and operate for many years. Thus, once the transport pattern of Beijing city was formed, it could continuous working for a long time.
based on the corresponding transport infrastructures.

Secondly, although the bicycle parking lots have been neglected for long, they still exist in many places. For example, on the site map of new communities or office buildings, although the location of bicycle parking is less and less prominent, the space for locating bicycle parking lot still remains.

Finally, and most importantly, the habit of riding a bicycle for usual life is still there. According to the statistics, for the activities such as the official travel and the trip to pick up someone or something, car use has a higher proportion in modal choice. But for the traditional daily activities, such as going to school, shopping, cycling and walking still accounts for a substantial proportion (Fig. 12). This is the characteristics of transport pattern in Beijing, which is different from most cities in developed countries. This valuable tradition should be carefully kept and developed.

All merits and advantages of bicycle traditions remain in transport pattern in Beijing should be saved and developed as soon as possible, before more and more trips turn into car-dependent.

Once the travel habits are formed, it will be very difficult to change them. Fig. 13 shows the difference of traffic mode share between a car owner family and car-free family in Beijing. For a car-free family, the bicycle trip holds a 41% share. For a car owner family, the reliance of trips on car rapidly rises to the share of 65.5%. In the part of public transport, the 13.5% share of car owner family is significantly lower than the 39.3% share of car-free household (Fig. 13).

To avoid more and more reliance on cars in Beijing, the BR system should be promoted as soon as possible. It should be well treated in the process of new urban construction, and problems in the old infrastructures should be transformed gradually. As Beijing is still in the process of rapid urbanization, the renovation on way of thinking and development model is very important and urgent.
4.3 The framework of the BR system

Based on the discussion before, a traditional based innovation of integrated bicycle and urban rail transit is proposed in this study. This integration enlarges the service area of urban rail transit from comfortable walking distance to comfortable bicycle-riding distance, bringing mutual benefits to these two environmental friendly transport modes.

This BR system includes many related issues, and it can be classified into different parts according to various ways of thinking. Here we suggest classifying this integration system into three levels: connection of two modes, operation of each mode and policies about integration (Fig. 14).

![Fig. 14 Framework of B+R integration system](image)

**Connection: easy transfer on subway station**

Easy transfer between bicycle and urban rail transit is the foundation for the BR system. This transfer part can be improved both for the infrastructure and the operation.

For transportation infrastructure, the bicycle parking at subway station should be improved. The issues should be considered are as follows: whether the existing bicycle parking space is adequate, whether it is quick and convenient to reach the entrance of subway station from the bicycle parking lot, whether the bicycle parking lot has roofs, etc.

For operation and management, how to facilitate passenger’s trips until their final destination should be considered. People can ride their bicycles from home to the subway station, but in general, they do not have a bicycle at the subway station near their final destination. Whether people can get to their final destination conveniently is one of the key problems to be solved for promoting the BR system.

It seems that the easiest way to solve this problem is to allow people to take their bicycles along on the train, so that they can continue to ride their bicycles to reach the final destination. However, this may not be the best way. Because taking a bicycle onto the train will bring other problems, such as security, overcrowding, etc. And this method will obviously not work during rush hours of the day.

If taking a bike onto the train may bring more difficulties, setting up a bicycle rental system on the periphery of subway system can be considered instead. This bicycle rental system will be discussed carefully later in this article.

**Operation of each mode: the riding environment for bicycles and the operating of rail transit**

To enable the BR system running smoothly, both the bicycle transport and the urban rail transit should run well. In this case, the attractiveness of the BR system can be enhanced, and citizens will tend to use this BR system.

For bicycle transport, there are various issues affecting people’s choice on cycling or not. A good cycling environment includes the bicycle lanes on the roads for safety, the shade trees for amenity, the parking in residential and office area for convenience, etc. A questionnaire on ranking the importance for these issues has been done in this study. In accordance with the importance, these issues rank as follows: (1) convenience on bicycle parking, (2) safety for riding a bicycle on the road, this means there are bicycle lanes and those lanes are not occupied by other vehicles, (3) safety of bicycle parking place, this means the bicycle will not be easily stolen when parking, (4) the comfortable environment for cycling, this means there
are shade trees on the road.

For urban rail transit, the subway's serving area, the operation efficiency, punctuality and the convenience of environment in the trains and stations should be improved step by step. Among all of these factors, the serving area of subway is the most basic factor, thus construction of the urban rail network is the most important issue. Whether the subway covers enough area in the city has great impacts on the attractiveness of subway transport mode.

**Policy about integration: promoting the BR system**

To promote the BR system, it is necessary to carry out comprehensive policy sets. The policies could include two kinds. One kind of policy is to promote the development of bicycle and urban rail transit, and the other kind of policy is to curb the development of competitive modes of transport, such as controlling private car use.

To promote bicycle transport, the government needs to invest more resources to improve bicycle riding environment. This does not only refer to the investment of money to build more infrastructures, but also refers to make more efforts to enhance the social environment. For example, the social security level should be improved comprehensively, in order to prevent the large amount of bicycle theft.

To promote the development of the urban rail transit system, government could give financial subsidies to lower the subway fare, carefully design the route of new rail, build more rail lines, etc. These are the possible ways to make urban rail transit more competitive.

The other kind of policy is the measures to control car use. This can be revealed by raising the oil taxes, carrying on car parking control, etc.

**5 EXISTING INTEGRATION OF BICYCLE AND RAIL TRANSIT**

**5.1 Existing transfer between bicycle and urban rail transit**

**Infrastructure of bicycle parking at subway station**

An investigation on analyzing the existing situation of the transfer between bicycle and subway in Beijing was carried out. The investigation was taken along the Subway Line 13, and raised many problems of existing situation.

Beijing Subway Line 13 is a typical commuter route (Fig. 2), connecting two largest dormitory town in northern Beijing with the central City. It has 16 stations in total, among which there are 14 stations have auxiliary parking lots, and 2 stations have not.

According to the investigation, bicycle parking at the subway station are usually very long time. About 1/3 of the parking is more than 5 hours per day. And the trip purposes of riding bicycles to subway station are mainly commuting, shopping and leisure (Fig. 15).

**Fig. 15 Time and purpose of bicycle parking in Wudaokou Station**

From this investigation, it is also found that most of the existing subway parking facilities are very primitive, and under poor management. The diagrams and the photos of the bicycle parking lots at these 16 subway stations are shown in Fig. 16. It could be said that the bicycle parking lot at the subway station has not been well managed.

Most of the bicycle parking lots do not have shelters. And the spaces of the parking lots are not fit with the parking demand. Some of the parking lots are too crowded, so half of the
bicycles have to be parked along the pedestrian lanes. But some of the parking lots are almost empty. For those 2 stations without bicycle parking lots, people have to park their bicycles on some space next to the station randomly.

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For better understanding of the adequacy of bicycle parking spaces, we conducted an investigation on the parking space and the parking bicycle numbers particularly, getting several ideas on this issue. Firstly, the spaces of bicycle parking lot vary from 0m² to 1700m². However, the space variation does not correspond with the parking demand. The Shaoyaoju station has a parking lot of 1500m², but only has 80 bicycle parking. Secondly, the bicycle parking number varies according to the surrounding land use pattern and population density. At the station in multi functional area, the bicycle parking numbers are often higher than the station in only residential area. Thirdly, the bicycle parking is mainly in the daytime (Tab. 1, Fig. 17). Fourthly, in the questionnaire done near the Wudaokou station, 33.6% respondents answer “insufficient” for the parking space, and 30.0% respondents answer “just enough”. This result is consistent with the investigation done for all the 16 stations along Subway Line 13, as bicycle parking lot at Wudaokou station is the most crowded one (Fig. 18).

Tab. 1 Capacity and parking data of bicycle parking lot for subway station

<table>
<thead>
<tr>
<th>Station</th>
<th>Available bicycle parking number</th>
<th>Parking on 12:00 inside</th>
<th>Parking on 12:00 outside</th>
<th>Parking on 22:00 inside</th>
<th>Parking on 22:00 outside</th>
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</thead>
<tbody>
<tr>
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<td>350</td>
<td>140</td>
<td>30</td>
<td>90</td>
<td>20</td>
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<td>400</td>
<td>250</td>
<td>200</td>
<td>80</td>
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<tr>
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<td>Dongzhimen</td>
<td>350</td>
<td>220</td>
<td>0</td>
<td>80</td>
<td>50</td>
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Fig. 17 Parking situation for each station along Subway Line 13
There is also a survey done on the suggestions on bicycle parking lot at subway station. The respondent’s suggestions for improvement are in the following order: (1) covering the parking by a roof to prevent rain and snow, (2) improving the service of parking lot administrator, (3) providing adequate parking space, (4) providing an additional exit directly connected to the entrance of subway station.

**The practice of public rental bicycles**

Beijing has established an incomplete bicycle rental system, which serves mainly along the Subway Line 4 and Line 10 (Fig. 19). This system was not established by the municipal government, but by a private enterprise, Fangzhou public bicycle Co. Ltd., Beijing.

The company was established on the year 2008, just before Beijing Olympic Games was carried out. A bicycle rental network has been built up, with 575 bicycle rental sites and more than 10,000 rental bicycles. It is the largest bicycle rental company in Beijing. The existing bicycle rental sites are mainly located along the subway lines, which directly promotes the BR system. The company's business is to serve the people who use urban rail transit, solving the “final 1 km” transport before getting to their final destination. The concept of "bicycles in your pockets" is put forward, making it possible to find a bicycle rental site at subway stations and its 1 km radius area easily (Fig. 20).

The company's business has attracted attention from Beijing Municipal Government. It may get more supports from the municipal government and have further developments. This case of private capital involving in the BR system brings new ideas and new hopes for the development of low-carbon transport system in Beijing.

**Fig. 18 Questionnaire result on the space of bicycle parking lot**

![Questionnaire result on the space of bicycle parking lot](image)

**Fig. 19 Distribution of rental bicycle sites of Fangzhou Company along subway station**

![Distribution of rental bicycle sites of Fangzhou Company along subway station](image)

**Fig. 20 Photo of several Fangzhou public rental bicycle station near subway stations**

![Photo of several Fangzhou public rental bicycle station near subway stations](image)
5.2 The riding environment of bicycle and the operation of urban rail transit

Comparatively, Beijing's bicycle riding environment is declining. One of the reasons is that the scale of urban built up area is becoming larger and larger, exceeding the ability of bicycle transport. Moreover, the non-motorized transport modes are not well considered in urban design and road design, the trip by walk or by bicycle becomes more and more inconvenient.

The rail transit is well developed in these years. The length of Beijing subway increase year by year. It owns the second longest subway system in China. And after the price down of subway fares, the passenger volume grows greatly. There are still several subway lines under construction.

It can be said that the service level of subway system in Beijing is relatively high and is continuously being improved. The bottleneck for introducing the BR system in Beijing is the declining bicycle transport.

5.3 Policies on promoting the BR system

For promoting bicycle transport, Beijing is preparing the bicycle transport planning of the whole city. The bicycle lane, bicycle parking and other related issues will be considered in that planning. More and more attention has been paid on bicycle transport.

For promoting urban rail transit, the municipal government has given large amount of subsidies to support low fares and construction of more rail transit infrastructures.

For limiting the car use in Beijing, the policy is still weak. The most influential policy on controlling car use in Beijing is travel right control by the plate number. This policy started at the time when Beijing Olympic took place. Now each car is prohibited to go out for about once a week, according to the number of its plate. However, this is only a temporary solution. In fact, this policy is likely to have counter-productive. Some researchers have pointed out that this policy would stimulate the purchase of new cars, because affordable families would consider purchasing a second car to facilitate their trips.

5.4 Analysis on the current situation

Based on the discussions before, the BR system has great potential for better development in Beijing, but there are still bottlenecks which cannot be ignored. The bottlenecks are the inconveniency for cycling environment and the BR transfer, as well as the strong competition of private cars.

Because of those unsolved problems pointed out before, the BR transfer is Beijing has not been well developed. The ratio of riding a bicycle to the subway station is merely about 3%. This ratio is extremely low. The arriving and leaving transport modes for subway station is mainly by walk or by bus (Fig. 21).

As the transfer of bicycles and urban rail transit is still too weak, a better management on the transfer is required. There are still a lot of work can be done to promote the BR system in Beijing.

![Fig. 21 Arriving traffic mode for subway in Beijing (Source: BTRC, 2007)]
6. CATALYST FOR THE BR SYSTEM: A BICYCLE RENTAL COMPANY

6.1 The practice of Fangzhou Company: development with the BR system

Fangzhou Company is a private corporation. It exists as a new comer to the BR system, and takes over the management affairs of the transfer between bicycle and urban rail transit for the BR system. It can be considered as a catalyst to promote the BR system in Beijing.

It is deserving of praise that this kind of private investment tries to contribute to public transport service. During past 2 years, this company accumulated fruitful experiences on how to operate this kind of bicycle service network. They adjusted their business pattern according to changing markets, and have found out proper location choice of bicycle station, cooperation with municipal government, effective advertisement, etc. This company has successfully survived so far, and it is a representative case to reveal that private investments can be well involved in public transport service network.

It was not the original business direction of Fangzhou Company to promoting the BR system. Initially, the company only discovered the potentially market of rental bicycles in Beijing. Based on the opportunity provided by Beijing Olympic Games on 2008, the Fangzhou Company was established and started to operate its business on rental bicycles. At that time, it set up more than 1,000 bicycle rental sites all around the central city of Beijing. The company aimed at building a rental bicycle network in central city, to have at least one rental site within every 300m radius area.

However, the company soon found out problems for this kind of network. Lots of rental sites did not have enough turnovers to support themselves. And the turnovers of those sites near subway stations were significantly higher than other sites. Hence the company quickly adjusted its business strategy, abolished the sites of low turnovers and concentrated existing resources to two subway lines (Fig. 22).

The strategic adjustment process of the Fangzhou Company reflects the rationality and necessity of development for the BR systems to enhance its competitiveness. Bicycle transport should integrate with urban rail transport.

Now the company has 29 formal employees, and more than 500 cooperated employees. It has established a service network of 575 sites and more than 10,000 public rental bicycles. The major service network concentrates along the Subway Line 4 and Line 10, also covering some other subway lines.

6.2 The disadvantages and advantages of a bicycle rental company

The private enterprise like Fangzhou Company to participate in the BR system promotion is a valuable case. It is a good idea to have the private sector to integrate parts of the BR system. There are both disadvantages and advantages of this business.

On one hand, for such private sector participating in public transport, there are several
disadvantages. One of the major disadvantages is the constraints of costs and profits. It may influence on the serving quality. It is really difficult to get high returns from operating this business. Thus, to expand business and improve service quality seems difficult for the company, because it requires high investment and is costly. The company's costs mainly include four parts, including human resource, buying and maintaining bicycles, managing rental sites and propagandizing. The company's profits come from mainly three parts, individual rents, group bicycle renting activities and advertisement on bicycles (Fig. 23). The most important profit is from individual rents, by selling the bicycle rental cards. The bicycle rental cards include year rental cards (120CNY), half-year rental cards (100CNY), monthly cards (30CNY) and normal rental cards (1CNY/hour). During past 2 years, Fangzhou Company has just successfully balanced its costs and profits, and has survived in the market.

Another disadvantage is that it is hard to get trust from citizens for this kind of private enterprise. As there are investments on buying bicycles, the bicycle rental company usually has to require a deposit of 180CNY for each bicycle rental card. However, many citizens do not trust that company, worrying about whether they can have their deposit back, so they are reluctant to apply for a bicycle rental card. This has become a major bottleneck for future development of Fangzhou Company. The identity as a private enterprise is obviously a disadvantage, so Fangzhou Company has to seek for more support from the municipal government.

On the other hand, there are also advantages for such private enterprise to participating in the BR system business. Firstly, the market sensitive of private enterprise is usually high and it is able to adjust its business strategy on time. Secondly, private enterprise will pay more attention to service level, and it could upgrade the bicycle-related service to a high level.

6.3 Potential development on the modal of Fangzhou Company

Fangzhou Company has a promising future. To promote the BR system, it is necessary to establish an entity to work closely with municipal government. It could not only establish a rental bike system, but also integrate the bicycle business related to all BR system. In the near future, the company can do better on its bicycle rental business. In the interim future, the company can try to integrate subway bicycle parking system management and to improve the service level. For further future, it can have further cooperation with the municipal government to improve the city cycling environment.

The integrated bicycle and rail transit network, which Fangzhou Company has built up, promotes the mobility based on low-carbon-oriented public transport. And it may successfully detach the increase of mobility and the increase of energy consumption in transport sector, which are highly related in the current trend. This new integrated network also provides new mode choice for citizens, which is healthier and more environmental friendly.
In the future, this company will keep on upgrading its service quality, and promoting more “Green Transport” related good causes. And more efforts will be made on the field of better cooperation with municipal government and rail transit service network. More supporting policy is necessary for this public renting bicycle network (Fig. 24), to form a reciprocal relationship between Fangzhou Company and the municipal government.

6.4 Developing the BR system with considering bicycle use characteristics in Beijing

The characteristics of bicycle trips in Beijing need to be carefully considered when promoting the BR system.

From the survey data, it can be found that the careers of the groups who often take bicycle trip are mainly workers, service employees, students, retirees, farmers and the unemployed (Fig. 25). Most of them are not high-income groups. This characteristic reminds us that the cost for bicycle renting cannot be too expensive.

In the figure of traffic mode share of different age groups, the groups of age of 13-18, and the age over 36 have a larger proportion of taking cycling trips (Fig. 26). For the aged people tending to use more bicycles, the design details and services of the cycling environment should be prepared well.

Also, there is higher tendency for women to cycle than man (Fig. 27). Hence, the safety of cycling environment is important and secluded corner in parking and riding environment should be avoided.
6.3 Action plan to promote the BR system through the catalyst company

According to the framework of the BR system which has been mentioned before, and based on the experience from Fangzhou Company, a tentative action plan on promoting the BR system through the catalyst company can be brought forward.

*Establishing or improving the catalyst company*

Firstly, a bicycle rental company can be established as a catalyst to start promoting the BR system. This catalyst company can be either a private enterprise or a government subsidized entity. Anyway, it is important to have an entity to promote this issue. The establishing of the catalyst company can start to attract attentions from both the municipal government and the public for low carbon transport.

*Forming reciprocal relationship between municipal government and the company*

Secondly, the mutually beneficial relationship between the catalyst company and the municipal government should be formed well. The municipal government will give policy support for the catalyst company, and even some subsidies. When the catalyst company successfully survives and develops, the BR system develops too.

*Improving the BR system and making BR trip popular*

Thirdly, when the company develops better and better, the business may extend to more fields related to bicycle use. The service quality of bicycle parking in BR system should be raised a lot. The BR trip mode will become popular among citizens.

*Further BR system promoting policies and infrastructure by the government*

Finally, more related policies on the use of bicycles, public transport and private car will be issued. And the infrastructure will be improved for fitting the BR system. With further promoting policies and improved infrastructures for the BR system, the total cycling and parking environment for bicycle use will be enhanced a lot.

7. CONCLUSION AND DISCUSSION

This study proposes a suggestion on establishing an integrated bicycle and urban rail transit system (BR system), from the perspective of bicycle transport development to a way of promoting low carbon transport system.

By analyzing the history and current situation, the necessity and feasibility of establishing the BR system in Beijing is revealed. Based on the investigation of existing performance, the bicycle transport is found as the bottleneck to develop the BR system. Fangzhou Company takes over the issue of enhancing transfer between bicycle and urban rail transit, and it is considered as a catalyst of the BR system development in Beijing. Further discussion on this catalyst company brings forward an action plan to promote the BR system.

As a city in rapid urbanization process, Beijing has a variety of future possibilities. The future path of urban transport development in Beijing is also variable. The improvement of urban mobility does not necessarily correspond to growth of car use and increase of energy consumption. If the environmental friendly traffic modes such as bicycles can be retained as a merit from the tradition, the transport system of Beijing can be of high mobility with low energy consumption, and will reveal the “Leap-frog” development for low carbon transport.

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REFERENCES