EXPLORING THE POSSIBILITIES OF ADOPTING BRT IN HISTORIC CITIES

SUZHOU DEVELOPMENT MODEL

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Chapter One Introduction

The purpose of this paper is to examine possibilities of adopting BRT in historic cities to relieve traffic congestion in an old city, Suzhou, China. Located half an hour drive time from Shanghai, Suzhou is a famous historic city and best known for its Wu culture, architecture heritages of rock gardens and stone bridges, and water features. It is using both roadways and waterways from the ancient time compared with the most prevalent transportation modes - roadways. The checkerboard layout both having roadways and waterways is one of its specializations. Historic buildings are standing by the waterside and facing alleys and bridges on the other side. Therefore, it is also known for the ‘East Venice’.

However, the beautiful scene of using both waterways and roadways has changed since China’s Reform and Opening up. Many Rivers and lakes were filled to obtain more land spaces for accommodating houses when there was a significant demand for economic development and less demand for waterways uses. The primary tool for getting around has become the auto vehicles when China began to catch up with the world trends. Thus, the way of using waterways was abandoned gradually. All these changes have lead to serious results on the existing road network, with increased congestion and deteriorating infrastructure. Old Town Suzhou uses methods of expansion as a
response, such as widening roads or building new ones. For example, Ganjiang Road central cross the old town Suzhou was widened to accommodate more travel through traffic flow to connect two industry zones on the two ends. The widening action has destroyed the historic city fabric and led to rejection when Suzhou applied for status as World Heritage of Historic Cities.

Figure 1.1-1 Images of Waterways in Suzhou Photo by Wenya Hou 2008
A new way of thinking needs to be advocated. It is obvious that widening roads is not a good way in solving congestion, only lead to the result of more autos driving in, and further lead to urban fragment. Thus, Many cities look into ways of encouraging effective mass public transportations. Bus Rapid Transit (BRT), the newly emerged mass public transit model, is increasingly recognized as a cost-effective solution to mass transit problems. (Annie, 2011) It is emphasizing the priority of buses movement by providing dedicated bus lanes and keeping bus characteristic of feasibility at the same time. It combines the capacity and high speed of rail, but low in capital investment. Therefore, BRT systems enable cities with even low-income to have a high quality and effective
mass transit system in their city areas. (Lloyd, 2007) This is probably one of the most important reasons that BRT has become increasingly popular in recent years. It has been widely applied in Europe (like Paris), America (like Los Angeles, Pittsburgh, Cleveland), and China (like Beijing, Xiamen, and Guangzhou).

Suzhou looks at ways in which local government is attempting to implement related policies to encourage public transportation development. It is a vital period for the transportation development of Suzhou, facing challenges of rapid economic development, urbanization, motorization, and ecological impacts on historic preservation. Therefore, Suzhou Government has made the decision to develop a multimodal transportation system combining light rail system with BRT system. As light rail system cannot be completed in a short term (the construction of one line already started from 2010, estimated complete on 2018), BRT system becomes the main construction for the short term (One line already started, connecting High New Technology Development Zone with Singapore Industry Park). This paper is trying to explore the possibility of adopting BRT on the existing road systems of old town to help solve the issue of traffic congestion, and thereby providing information input for Suzhou transportation planning.

Hypothesis

Rapid bus transit system can be adopted to the existing road network system of historic cities by changing several operation approaches. Combining Bus Rapid Transit with other public transportations into an integrated transit system will help relieve traffic congestion.
Assumption and Research Horizon

Suzhou is chosen to be the studied city as I had stayed there for over five years and can provide detailed information from my first-hand experience. My premise here is that only an integrated mass transit system will help relieve traffic congestion. This paper aims to use Suzhou as a model to explore the way of applying BRT on existing road system of historic cities. Some questions will be addressed in this research: What is the root cause of traffic congestion in old town Suzhou? Under which condition, can BRT be the solution to these traffic issues? Can BRT be applied in old cities that have narrow road network systems and high density of houses? If it can, what specific modification and construction are needed? This paper will provide important preliminary research for BRT system applying in Old Town Suzhou to promote the fundamental goal of developing a sustainable urban future. The research result will contribute to transportation development of Suzhou, and can be seen as a reference of applying BRT system in historic cities.

The scope of the research paper is discussing how the Bus Rapid Transit system can go beyond traditional experiences and approaches to be applied to the specific content of old cities. The necessity, suitability and feasibility will be discussed based on the research of BRT and current condition of Old Town Suzhou. Some operation standards may be modified to fit the specific requirements of old cities. The method of adopting BRT to a transport integration system will be explored as one of the transportation development strategies. A corridor in the old town Suzhou is chosen to study by giving detailed design strategies to develop the guidelines of applying BRT in historic cities.
The overall aim of this research is to gain new insights into BRT system through literature review, case study and analysis by identifying how these system operation guidelines and regulations can be applied on current road network system of old cities. The main question to be answered in this research is: Under which conditions can BRT system be successfully be applied in old cities? Here the “success” can be defined as an achievement of reducing travel time and travel cost of BRT system impacted area and attracting passengers from other modes.(Annie, 2011)

This paper is not intended to criticize Suzhou’s current city development strategy. Indeed, provisions made in Suzhou’s more recent transportation planning strategies clearly showing a shift towards transit-oriented development. However, it is also important to note that the transportation strategies need to be done better than before as traffic issues rising significantly throughout the city. The purpose of this thesis is to explore ways in which integrated transportation system can be formed, so that Suzhou can continue to the pathway of a more sustainable urban future.

**Summary and Paper Outline**

Development versus historic preservation is a familiar struggle. City planners need to be aware of the sensitive and valuable factors of historic cities. Historic buildings are standing as history, culture, and identity. Any action taken without careful consideration may lead to serious results. Some cities built high-rise building blocks by pushing down old buildings to obtain some spaces. Some cities maintain their historic buildings and features at the expense of absence of new buildings, which amounts to a regression rather than progress. These solutions may meet the short-term economic goals but have
negative impact to further development. When facing the traffic issue in historic cities, neither widening roads nor banning auto-vehicles has direct impact to the roots of congestion.

Integrated public transit system is recognized as the ultimate method of solving traffic congestion. The typical transit system is using light rail as the backbone public of transit and BRT as the extension or supplement. Many cities in China are seeing BRT as a better solution than light rail in less construction cost and shorter completion time. As Lee Schipper from the World Resources Institute said: ‘if Chinese cities continue the momentum they have gained in the past few years, transport will serve city development, the strangulation by smaller vehicle seen elsewhere will be avoided and Chinese cities will move a large step towards sustainability.’ (Newman, 2008)

This paper focuses on exploring the possibility of adopting BRT on the existing road system to achieve historic preservation. Chapter 2 will discuss BRT from its definition, design features, and practice experiences in the United States. Lessons learned from these studies can help explore way of adopting BRT in some specific situations. A case study of Beijing BRT corridor is conducted to help better understand the context of adopting BRT in historic cities. Chapter 3 will provide a general image of Suzhou in location, city form, transportation planning and activities of local residents. This information provides input for the BRT corridor study. Chapter 4 will explore the way of adopting BRT in using a specific corridor- Renming road in the Old Town Suzhou. The main concern of implementing BRT is how to apply it on existing road conditions and how to combine with other public transportation system and local city’s characteristic to form an integrated mass transit system. Linking transportation and land use is another
concern. Housing may expand near transit station and surrounding property value will go up when the transit station is proposed. The current road condition will be studied and detailed design of BRT will be demonstrated in this chapter. Conclusion about BRT guideline will be drawn from the corridor design.
Chapter Two Introductions to Bus Rapid Transit (BRT)

System

BRT has become increasingly popular throughout the world, especially among Asian cities since 2000. The first BRT corridor was launched in Beijing at about five kilometers on December 2004. (Matsumoto) It serves as a contemporary supplement of subway system and crosses through central Beijing, places where old districts are. BRT is also popular in Cities of Delhi and Ahmadabad in India. A twelve-kilometer BRT corridor, connecting both old and new city areas in Ahmadabad opened on 15th Oct 2009. (Transit Cooperative Research Program, 2003)

Definition

There are various definitions about BRT.

It is defined as “a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways and ITS elements into a fully integrated system with a strong image and identity.” by the U.S. Transit Cooperative Research Program. (Transit Cooperative Research Program, 2003)
“A high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service.” (Lloyd, 2007)

“An enhanced bus system that operates on bus lanes or other transit ways in order to combine the flexibility of buses with the efficiency of rail…. It also utilizes a combination of advanced technologies, infrastructure, and operational investments that provide significantly better service than traditional bus service.” (Federal Transit Administration)

A more specific definition is from a most recently report “Recapturing Global Leadership in Bus Rapid Transit---A Survey of Select U.S. Cities”. (Annie, 2011) It developed a score system, called BRT standard, to rank the BRT system as gold, silver or bronze. The standard is weighting by many categories, including service planning, infrastructure, station design and station-bus interface, and quality of service and passenger information system.

**BRT Features**

There are significant differences among BRT facilities from region to region. Many cities have built their own BRT systems based on local road conditions and fiscal budget. Five basic elements are generally identified to form a standard BRT system, including running ways, stations, fare collection, vehicles, and intelligent transportation systems (ITS).
• Running Ways

Running way is a basic element for BRT, with options from general travel lanes to dedicated bus lanes. Dedicated running ways enable stable bus travel speed and improve travel safety by providing ‘private room’ for buses. In addition, dedicated running ways not only increase the independence and reliability of buses, but also achieve the key transport goal. The goal of transportation system is to serve for people instead of vehicles by giving travel priority to the majority of people.

Practices of BRT running ways are various, from mixed traffic lanes, HOV lanes, busways on separate right-of-way, bus tunnels to median arterial busways. (Transit Cooperative Research Program, 2003) Dedicated bus ways dominate North American and Australia while median arterial bus ways are found widely throughout South America. (Transit Cooperative Research Program, 2003) Many European cities use arterial street bus systems, while reserved freeway lanes for buses are operated only in America. (Transit Cooperative Research Program, 2003)
The total lane width of a typical median station is about 80 feet, including four travel lanes and a station-side platform. Bus lanes are commonly from 11 to 12 feet wide. For example, arterial median bus ways of Curitiba including stations and bus lanes are around 75 feet wide. (Transit Cooperative Research Program, 2003) BRT systems can take the maximum advantages from median busways. First, traffic flows on the side of travel lanes are more affected on intersections than traffic inside. Second, buses on two directions can share the same median stations. But median bus lanes decrease passengers’ accessibility and requires a wide median for stations, which are the limitations of adopting to cities with narrow road systems.
Route design determines modes of transit service, ranging from feeder service (door to door) and trunk service (see figure 2.2). The BRT route design is always based on local road conditions and passengers’ demand. Successful BRT system would integrate with local public mass transit to spur local land use development.

Figure 2.2 BRT Route Service- feeder service (Left) and trunk service (Right)

- Stations

Stations, as the entry point of the whole BRT system, affect accessibility, safety and security as well as the BRT image. The station design has options from closure to semi-closure stations to accommodate fare collection system and large number of passengers. The spacing of stations along arterials is ranging from a minimum of 100 feet in urban area to 5,000 feet in suburban area. (Transit Cooperative Research Program, 2003)
Platform height – platform height affects the accessibility of disabled passengers, boarding time and customer experiences. BRT system in Curitiba uses high platforms to provide level boarding, which significantly contributes to the decreasing of dwelling time. However, many new planned and constructed BRT systems choose to use low platforms based on existing road conditions to eliminate land construction. They use special low-floor buses to provide level boarding.

Platform layout – it affects ways of vehicles’ landing and passing and passengers’ activities to board. Station envelope usually has two to three lanes to enable other buses’ passing and to avoid station delay. The platform layout is also related to the design of pedestrian lanes.
• Fare Collection

Fare collection methods include pay-on board method and pre-payment with electronic fare media like smart cards. Different methods of payment affect various customer experience, accessibilities, and bus dwelling time. Bogota, Curitiba and Quito, for example, have off-vehicle fare collection, which contribute to increase boarding speed and less station dwelling time. (Transit Cooperative Research Program, 2003) Beijing BRT uses pay-on-board system to collect travel fare, which is based on local conditions.

• Vehicles

BRT systems can utilize a wide range of vehicles, from standard bus (40-foot), articulated bus (60-foot), to specialized vehicles. (Kittelsoon & Associates, INC, 2007) The TCRP Report 90 noted that almost every city having BRT system operates articulated vehicles in the United States and Canada. It also indicates that an increasing number of systems operate low-level floor vehicles to make passenger boarding and alighting easier.
Intelligent Transportation Systems (ITS)

Intelligent Transportation systems are increasingly popular nowadays and are highly recommend by local transportation planners. ITS include vehicles operations and management, passenger information, safety and security system. They can be adopted into BRT systems to enhance the performance of travel speed, travel time, reliability, passenger experience and safety and security.
History of BRT

The first successful BRT project started in Curitiba (Brazil) in 1974. Since then, Curitiba’s experience has become the best example in inspiring other cities to develop similar bus transit systems. Before the 1970s, heavy rail was the most popular transportation model that many cities would choose although BRT had successful applications in Pittsburg and Ottawa. After the 1990s, people’s vision began to change to BRT due to the successful experience of BRT application in Curitiba. BRT systems were operated in many American cities, including Alameda (California) Albany (New York), Boston (Massachusetts), Chicago (Illinois), Cleveland (Ohio), Los Angeles, and Las Vegas (Cliff Henke).

BRT systems have started to spread quickly throughout the region of Asia since 2004. In 2004, the TransJakarta BRT system was started passing through the City Centre. (Hidalgo, 2009) On 25 December 2004, the first BRT corridor was launched in Beijing, China. (Matsumoto) In 2008, a corridor totaling about 5.6 km was installed in Delhi, India. (Scott, 2008) By 2008, there were 21 BRT systems in Asia, eight of them in China and two in India. (Matsumoto) Other 51 BRT systems are planning or under construction.

With the first BRT system started in Beijing in 2004, the number of BRT systems increased rapidly in China. By 2008, eight cities have adopted BRT systems in their city area and at least fifteen cities have developed preliminary BRT plans. (Hidalgo, 2009) Why has BRT become so popular in China? Part of the reason may be because of the changing strategies as the decision makers in China began to give priority to the
development of mass public transit network. Furthermore, the central government began to realize that BRT might be an effective option in combating the impending rise in private vehicle modes in urban areas.

**Literature Review**

The concept of BRT was first mentioned in the United States from the 1930s. Since then research and application studies about BRT continue to evolve in the urbanization process as it strongly links with land use decision-making. There are many researches about BRT in different aspects conducted by transportation institutes and companies. Transportation Research Bureau conducted Transit Cooperative Research Program and published a report called “Bus Rapid Transit” in two volumes in 2003. (Transit Cooperative Research Program, 2003) Volume one is case studies that introduced BRT system applications in 26 cities among North America, Europe, South America and Australia. Every case is demonstrated from the aspects of system organization, system design, operation and financing. Volume two explored the BRT implementation guidelines. (Transit Cooperative Research Program, 2003) Another valuable resource is the “Bus Rapid Transit Practitioner’s Guide” published by Transit Cooperative Research Program (TCRP) in 2007. (Kittelson & Associates, INC, 2007) This guide concludes that BRT can be seen as a catalyst that increases housing density around transit nodes.

In addition, experts and scholars have made detailed research studies about BRT in the aspects of capital and operating costs, operation capacity and corridor design. A paper called “Bus Rapid Transit as a Substitute for Light Rail Transit” (Sislak, 2000) compared the construction costs between light rail and BRT and concluded that BRT can save up
to 70% of construction cost with the same level of services of light rail. BRT has advantages not only in saving construction cost but also in showing a higher customer satisfaction than that of light rail. Michael R. Bales demonstrated his research process about BRT systems in Miami and Orlando in the report of “Statistical Estimation of the Importance Placed on Specific Elements of Bus Rapid Transit by Customers” in 2003. The report indicates that passengers had a higher satisfaction of rapid transit compared to common buses as BRT provided a high quality of travel service experience. Therefore, BRT is an effective alternative to light rail. (Michael, 2003)

Some experts further did studies about combining BRT with light rail on an urban basis. Timothy Nicholas did the assessment of BRT project on Wilshire Boulevard in Los Angeles in 2003 and concluded that the number of passengers increased significantly after the implementation of BRT system, as the travel time shortened with the faster speed of buses. However, he also concluded that with the attraction of high volume of passengers, BRT would reach its maximum capacity. Therefore, subway constructions need to be further considered. (Timothy, 2003) In the paper “Value of Facilities and Attributes of New Heavy Rail and Bus Rapid Transit Projects in a Developing City” (Martinez, 2002), Manuel J. Martinez conducted research on the adaptability of combined transportation between BRT and rail, where BRT worked as the extension of rail transit system. He collected data to perform the study of transportation forecasting models.

Some other studies have been done about BRT in improving its operating performances and applications. Eric, Holeman proposed a multi-standard assessment method of selecting suitable corridors for BRT development in “Selecting Corridors for Bus Rapid
Transit Using a Multi-criteria Method” in 2004. The method evaluated projects based on taking into account three factors, including passenger capacity, travel time savings, and conflicts to existing transportation services. (Eric, 2004) Yafeng, Yin and Mark, A. Miller defined BRT as a system that integrated vehicles, stations, bus ways and smart buses together and had a great flexibility in “A Framework for Deployment Planning of Bus Rapid Transit Systems” in 2005. This paper explored the methods of how to maximize the benefits of system approaches under constraints of construction funding, rules and regulations, passenger transport corridors and other external constrains. (Yin, 2005)

The most recent research about bus rapid transit is a book called “recapturing global leadership in bus rapid transit” (2011). It created a score system based on observable system characteristics, and ranked BRT projects as gold, silver, bronze or not BRT. The weighting categories are based on passenger travel time, service quality, bus speed, custom comfort and ridership. This report chose several successfully implementation BRT cases to demonstrate its score systems, including Cleveland, Ohio, Eugene, Oregon, Los Angeles, California, Pittsburgh, Pennsylvania and New York. It is concluded that a high-quality mass transit intervention is an assessment of cost effectiveness, indicating a reduction in total travel time and travel cost for the population of transit riders in the project’s impact area; attract new riders from other modes and effectiveness in achieving other public transportation objectives. (Annie, 2011)

The literature review indicated that many studies have compared BRT system with other transportation models, like common bus transit, light rail, and subways. BRT shows high advantages in capital cost, network connectivity, speed of implementation and flexibility. Evidence suggests that BRT model has a positive impact on a cost effective and
environmental-friendly basis to urban area and to solve traffic problems. The key goal of BRT researches is to find out the ultimate way of integrating BRT system with the unique characteristic of each different city. Integrating BRT with other city public transit models forms an effective city mass transit system. The literature review confirmed the need for additional research in the adaptability of BRT system in historic cities as no experts have studied such aspect about BRT system.

**Case Study-Beijing south Axis BRT corridor**

We will examine a BRT corridor in Beijing to explore some of the aspects like design guidelines, vehicle and station facilities, operations and management, how BRT works as the supplement of subways, and how it is integrated with other transportation modes to form a whole transportation network.

**Background**

Beijing is known as one of the most congested cities in China. A report showed that the average traffic speed was less than 15 km/h at rush hour and approximately 40% of travel time above one hour in 2008 in Beijing. The serious traffic problem results from the significant increasing number of private auto-vehicles ownerships with a large number of base quotas. As a response, City of Beijing has devoted great efforts in increasing traffic efficiency by promoting a multimodal transportation system. Its metro system runs almost the overall city area with buses serving the transit mission. Beijing further chose BRT system as a supplement of metro 8, which is the fist BRT corridor applied in China in 2005.
The Beijing south Axis BRT corridor was initially tested and operated in December 2004 and it was in full operation in December 2005. (Darido, 2006) The timeline for planning and implementing the project took only 18 months. The 2008 Olympic games was a significant pressing reason to speed up BRT development and construction project. The basic guidelines of developing a BRT system in Beijing include: (Zhenjiang, 2004)

Figure 2.5 Beijing BRT Corridor Map  Source: BRT in China
- The supplement of rail system—BRT works as transition and substitution or extension of light rail system.

- Integrating with road construction—BRT projects need priority bus lanes and special stations. The short term of implementing BRT projects is to serve urban centers and corridors with high traffic flow demand.

- Upgrading public transportation on the ground—manages the present bus lines and reduces redundant bus routes to form a whole integrated rapid bus network system on the ground.

The BRT line 1 corridor is totally 16 kilometers long, starting from Qianmen station to north direction pass through two districts and ends at Maodezhuang station. The corridor connects Metro line 2 and other six bus stops, linking over 0.2 million residents in eight residential areas and four commercial centers in the southern districts. (China Watch, 2011) The Beijing BRT Company, Ltd., is in charge of the construction and operating of the BRT corridor, which is owned by Beijing General Bus Company and two other private bus companies under the Beijing Transit Group. (Darido, 2006) A joint IVECO-Chinese company supplies the BRT vehicles for BRT Line 1. The BRT vehicle is length at 18-meter and width at 2.55-meter, and can carry as many as 180 people, with three left-side doors, GPS and air conditioning.
Figure 2.6 Beijing BRT at Qianmen Station  Source: BRT in China

Figure 2.7 Beijing BRT Vehicles  Source: BRT in China
The BRT travel lane is using median bus way in two-direction with physical barriers to control traffic. BRT vehicles travel in mixed traffic in downtown area, as it is hard to obtain road spaces in historic districts. The median station, length at about 70-80 meters, width at 5 meters, provides passengers with level boarding platforms, with multiple doors to facilitate boarding. Electronic boards are showing information about bus schedule, stop locations, and line directions. Fare collection is off-board prepayment at stations and also supports electronic fare collection. It charges uniform fare of 2 CNY (around $0.3) per trip, but over 60% of people use monthly fare passes with a discounted fare of 45 CNY ($7) for a monthly pass. The operation schedule for Station of Maodezhuang is from 5am to 10:30pm, and for Qianmen from 5:30am to 11pm. A single trip takes about 40 minutes, with a total of 87 buses serving the corridor. It currently carries around 90,000 passengers per day, up to 220,000 passengers during holiday. (Qiaqing, 2007) A passenger rider survey was conducted in 15, March 2006. The data results are showing at table one and table two. (Qiaqing, 2007)
After starting the operation of BRT corridor, common buses had planned corporately to rationalize routes along the BRT Line 1. Implementation strategies include reducing duplication of routes and enhancing transit connection between BRT and regular buses. It enables provision of passengers for BRT and provides high quality service of public transportation. Before the opening of BRT line1, there were 22 regular bus lines serving approximately 260,000 passengers per day along the corridor. (Zhenjiang, 2004) As bus routes reorganized, eight bus lines were changed. Three regular bus routes were discontinued, four routes were shortened to serve as the feeder lines for the BRT corridor, and one route was realigned to provide bus services for adjacent areas where there were no bus services. As a result, the BRT system saved a total of 400 standard buses along the corridor.
However, several operating problems were caused by decreasing common buses, like overcrowding at BRT stations for a high amount of ridership during peak hours for the test period. As a response, the BRT corridor operation managers decided to restore a parallel regular bus route to reduce the high demand for BRT services. Another twenty regular buses with right side doors were adding to the BRT line during peak hours. (Zhenjiang, 2004) These actions help relieve the heavy burden on BRT line 1.

Having heavy rail transit system in Beijing, the BRT system was chosen for specific applications in some corridors. Some experts questioned that BRT cannot fulfill its function, with only a single line and without the basis of a citywide system, during the meeting of Beijing BRT development, 2006. The secretary of Beijing Municipal government responded that the BRT line 1 was constructed on the route of planned metro line 8. Metro line 8 would not be included in short term and mid-term transportation system planning, so put this section “free” for BRT. Once the line 8 starts, this line would be changed back to subway line. In my opinion, as A Mega-city, its urban transportation system should be an integrated system made up by a variety of transportation models. BRT can play part of roles in the urban traffic system but further research and feasibility studies through a trial basis should be done in further spatial distribution, functional orientation and scales.

Lessons Learned:

Advantages

The biggest advantage of BRT compared to rail transportation is the lower initial cost. BRT system runs on the ground, which needs only a few improvements on present road
network systems and do not need to build tracks. The initial cost of rail is as much as 10 times the cost of BRT. The cost per kilometer for BRT line 1 is $1/15$ that of metro line 4. (Zhenjiang, 2004) The flexibility of BRT is another advantage compared to rail transport systems. Rail can only be operated after the completion of lines, stations, vehicles, fare collection and control system, while BRT can be operated when part of these finished. For example, the BRT line 1 started operating in its early implementation stages. The early stage (from Qianmen station to Muxiyuan station) was started on 25 Dec, 2004 while the late stage was not started till 30 Dec, 2005. (Zhenjiang, 2004)

The actual passenger volume of BRT line 1 carrying is around 10,800 people per hour, which is almost the same as that of metro line 13 and over the capacity of metro 8 (about 9,400 people per hour). (Zhenjiang, 2004) According to a recent report, the BRT line 1 achieved the passenger amounts of 33,000,000 people per year, which is close to the annual passenger volume of metro 13, at 42,600,000, and twice times that of metro 8. (Qiaqing, 2007) Therefore, BRT line 1 shows a strong potential in terms of high capacity.

**Limitations**

BRT systems aim to improve travel efficacy. While the improvement brought by BRT is limited as it is still occupy part of road resources. Although BRT system uses physical barriers and signal priority method, it still causes traffic conflicts in intersections, which limits the travel speed and causes uncontrolled irregular delay. At the same time, as the transportation on the ground, the travel speed cannot be significantly faster than the speed of vehicles, and is unable to be as fast as rail system. Particularly, the speed of BRT line 1 is greatly reduced in downtown area where there is mixed traffic.
Conclusion

BRT is a cost-effective transportation system, but the planning and construction should be based on specific city features, scales prerequisite, fixed conditions and scientific functional orientation. Based on the urban traffic conditions of Beijing and its city scale, the role of BRT system can be an effective structural supplement of rapid rail transit system that needs long period of implementation and expensive cost. It cannot work as the main transportation system in the central area of mega city due to its limitations. This is also the probable reason why Mega-cities like Sao Paulo and Brazil, Beijing as well, have no choice but to build rail transportation system as their backbone transportation system. However, the role of rapid rail transit system cannot be replaced, especially in Beijing, which has large city scale, high density and large population.

This chapter introduced the basic elements of BRT system, and analyzed the reasons for implement BRT in cities, which indicate that different urban areas can have various BRT systems based on their unique circumstances. The case study also revealed that transportation system should be an integrated system made up by a variety of transportation models. One simple transportation model cannot solve all the city traffic problems. In the next chapter, I will address the questions of what is the root cause of traffic congestion in old Town Suzhou and whether BRT can be an option to help relief this problem while working with other transportations.
Chapter Three Introduction to Suzhou

Suzhou is one of the most classic historic cities in China, famous for its checkerboard layout of roadways and waterways double grid transportation system. With this kind of feature, architecture heritage and Wu culture, it has a long history of being a famous tourism city. In addition, rapid industrialization and urbanization and the geographically unique advantages (only 63 km to Shanghai), have given the city the highest income per capita in its province.

Figure 3.1 Suzhou Images of waterways, rock garden, bridge, and arrow Streets with houses on the two sides. Photo by Wenya Hou


**Location, Geography, Climate, and Demographics**

Suzhou is located in the southeast of Yangtze River Delta, Jiangsu Province, China, bordering Shanghai to the east, Hangzhou to the south, Tai Lake to the west and Yangtze River to the north. (Figure one) Shanghai-Nanjing Railway crosses the whole area in the east-west direction and Beijing-Hangzhou Grand Canal in north-south direction. Suzhou has a clear four seasons, warm springs, hot summers, windy falls and cool winters with occasional snowfall. The whole area is quite flat, with rivers and lakes that occupy more than 50% of the total site. It had a population of 2.33 million by the end of 2005, of which 57.3% live in the city and towns.(Wikipedia)

![Figure 3.2: Suzhou in China, Suzhou in Jiangsu Province](image)

**Urban Land Use**

The overall land use pattern shows that residential use is the predominant land use (figure 3.4). A glance at the land use map shows that there are two large areas
containing less residential use: Suzhou High & New Technology Development Zone (HNTDZ) in the west part of the district and Suzhou Industrial Park (SIP) in the east part (figure 3.3). They contribute directly to local economic development. A closer look at Suzhou's land use reveals more non-residential areas: City Avenue’s commercial strips, Suzhou University at Pingjiang Avenue, and the Park just central located in HNTDZ. They are essential uses in different aspects of commercial, education and recreation.

Figure 3.3 Suzhou Urban Forms, Source: Suzhou Planning
Figure 3.4 Suzhou Land Use Map, Source: Suzhou Planning

Figure 3.5 Urban Form of Old Town Suzhou, Source: Baidu Image
Urban Form

Like most cities in China, Suzhou has a high density and mixed-use development. Urbanization has accelerated recently, with an overwhelming from 35.8% of urban population in 1999 to 55.9% in 2005 and an annual growth rate of 2.58%. (Wikipedia)

Along with the advance of urbanization and socio-economic development, the focus of urbanization development changed from the increasing urban population to the quality improvement.

Instead of highly developing the Old Town Suzhou (city core); the city has expanded in two directions to develop two modern industry zones, the east (Suzhou Industrial Park (SIP)) and west (Suzhou High & New Technology Development Zone (HNTDZ)) (see figure3.3). Particularly, SIP is the largest cooperation project between the Chinese and Singaporean governments, located beside the beautiful Jinji Lake. Therefore, Suzhou has developed uniquely, with both old and new in its urban forms. In Old Town Suzhou, the buildings are of Su style. White washed small scale houses with black tile roofs line narrow lanes and overlook the waterways. Buildings are not allowed to build over seven stories high in order to protect the view sight between the classic gardens and pagodas.

In the modern industry zones, high-rise buildings stand one by one along wide roads. Industry zones are home to high-rise offices, residential uses and industrial uses, but also feature several landmarks, such as Hanshan Temple, Xi Garden and the center of science and technology. In terms of the street system, street pattern in Old Town Suzhou has retained a river road parallel checkerboard pattern as well as the water network layout, which can be roughly described like three horizontal and three vertical corridors plus a circle waterways interwoven to be a network.
Access of Citywide

Suzhou maintains excellent accessibility being situated between Shanghai and Nanjing, which is the capital of Jiangsu Province. The Shanghai-Nanjing railroad crosses through Suzhou city area and three of four highways of Shanghai also cross Suzhou. The highway system of Suzhou has initially formed a radial network layout with Shanghai-the network core. The public transportation started in 1959, and a Bus Company was established in 1999 to induce competition, which increased the capacity significantly. By the end of 2005, there were 1731 buses, 119 bus lines, and the total mileage of bus lines reached 2697.3 km. (Suzhou Planning Department, 2008) In recent years, the Public transport capacity has been greatly accelerated driven by market reform and government support.
The pedestrian system includes walking lanes on both sides of roads, commercial strip pedestrian Street, streets overhead or underground and crosswalk. Particularly, two commercial centers, Ping Jiang Street and Guanqian Street (in old Town Suzhou) have enclosed systematic pedestrian systems. But vehicles often occupy pedestrian lanes, as parking lot is inadequate in those high-density centers. Along with the increasing of city scale, the proportion of walking to work has decreased gradually while walking for leisure and shopping has increased.

**Old Town Suzhou**

Old Town Suzhou is located in the central area of Suzhou, at 1420 ha. Planned long-term population is 250,000. (Suzhou Planning Department, 2008) Old town Suzhou is historically functioning the commercial, political, educational, recreational, residential and manufacturing uses, obtaining the highest density and largest population as well (figure 3.3). Due to the historical reason of single city center structure, the old town Suzhou heavily accommodates various land uses, like political center, commercial center, hospitals, and schools. For example, the number of student of old town accounts for 63% of the whole city, the commercial facility of old town accounts for 84% of the whole city, and the number of clinic is at 79% of the whole. (Wikipedia) In other word, the trips to work, school and medical are still attracted to old town, even though many citizens had moved out of the town. Therefore, the traffic demand is increased for the reasons of moving out and functions cluster.
Road Network System Analysis

In SIP, high-tech zones and other outlying areas, the road lanes of motorized vehicle are much wider (at about 5 meters) than that in old Town Suzhou, at only about 2.3 meters. Old Town Suzhou has a checkerboard road system with roadways and waterways paralleling early from the Song dynasty (1127-1276). The city formed like: Moats around city walls, canals inside city walls dotted with bridges, streets built by rivers, and houses built along riverside. The waterways were pretty wide at the ancient time (16 to 33 meters), and functioned as transporting goods and people, while streets were constructed for short trips. All these contributed to the unique traffic system of the old town: waterway played the key role while streets were the supplements.

However, the overall length of river has decreased from 90km to 34.4 km today. Many waterways were filled to meet the high demand of housing construction and fast growth of population. In addition, the width of canals is at 4-6 meters in average, which has already lost the traffic function. The street system plays the transporting role instead, but they cannot meet the motorized demand as the maximum street width at only 6 meters (annual increase rate of motor vehicle ownership at 16.5 percent). With the widening and modifying of several roads, including Renming Road, Ganjiang Road, Daoqian Street, and Ningdun Road, they become the main carriers of road network system in old town.

The traffic flow is overloaded for some major arteries in Old Town Suzhou with the rapid increase of mobility. There are many serious issues emerging, including intersection congestion, low level of safety for drivers, bicyclers, and pedestrians, too many conflicts points and low speed of traffic flow. Obviously, the increasing number of mobility has a
significant negative impact on the road network of Old city area as the traffic issue is becoming extremely serious. Traffic demand always tends to be higher than supply. Without proper guidance, expansion of road system cannot solve the issue fundamentally. Instead, development of large capacity public transportation and improvement of traffic resource utilization will ultimately relieve city traffic pressure.

To sum up, the road system in old town Suzhou has two features:
First, current road network system has an unclear classification. Local street network system is in poor condition with low density, which causes traffic mainly gathering in main arterials. Thus, it cannot organize its traffic flow properly, which means different travel objective cannot be separated and cannot fulfill the function of road classification system. Actually, the layout of internal local streets is clear and connective. The internal streets are developed from ancient neighborhood, has the nature of order, organized and integrity. Parts of these streets even have high value in serving traffic aspects. However, without proper preplan, there are many self-build buildings, which made narrow spaces more limited.

Second, the function of city arterials is unclear which causes the transportation system complicated. The arterials in the old town are the Ganjiang road in east-west direction and Renming Road in south-north direction, which forms a crossing network inside old town Suzhou. Renming road connects with Wuzhong district to the south, with rail station to the north while Ganjiang road connects two industry zones from the east to the west. “The primary function of an arterial road is to deliver traffic from collector roads to freeways, and between urban centers at the highest level of service possible. As such, many arteries are limited-access roads, or feature restrictions on private
access. However, from the collected data, it shows that these two roads serve more in
distribution than transit as they are connecting with many collectors and local streets,
with functioned buildings standing by the sides. Furthermore, the construction of
Ganjiang road destroyed the historic city fabric of Suzhou. Its construction cut the old
town into two pieces at the expenses of pushing down historic buildings and bridges with
over 2500 years’ history.

Residents Ridership Analysis

Old town Suzhou, serves main functions, produces and attracts traffic in Suzhou
according a field survey, reported that 33% production trips and 40% attraction trips of
Suzhou traffic happened in the old town. It also indicates that old town accommodates
overly residential and employment land uses than its capacity. Residents living in the old
town are having lower to middle income, with large amounts of migrant workers.
Because the prices for room rental are reasonable, migrants always choose to live there.
Local Suzhou residents with middle to high income choose to move to SIP to have a
better quality of life. Retail, hospitals and education in the old town attract trips from the
citywide and residents who live in the old town commute to industrial zones to work.
Therefore, over 30% of trips are produced or attracted to the old town.

There were 255 bus lines, 3,246 buses in the city area, the average running distance is
around 400,000 miles per day, and the average passenger volume is 1,480,000 per day
according to a recent report in 2011. However, bus ridership accounted for less than 15%
of overall trips while over 50% of people choose to use cars. According to a survey done
by local transportation department, residents were complaining about the delay of travel time and extremely slow speed of buses. Except the Renmin road and some express lines, the exclusive busways are only a few in downtown areas. Even on some roads that have bus lanes, they don’t have signal priority in the intersection, which causes extreme low speed of buses in mix traffic.

The high amount of motor-vehicle ownership is also a reason for the limited volume of public transportation ridership, at an annual increasing average of 16.5 percent. Non-motor vehicle is the predominate transportation of Suzhou citizens. In recent years, the proportion of bicycle trips decreased, but the proportion of electric bicycle trips increased gradually, which has become the most common transportation according to the transportation census, although road network for electric bicycles is not offered. Various types of motor vehicles made the traffic flow even worse and hard to manage.

**Necessity Analysis of BRT**

From the above analysis, one conclusion can be drawn: the root cause of traffic issue in old town is that poor road system cannot meet the high traffic demand of auto vehicles, particularly the increase of auto-vehicles. With the development of road system outside the old town, the transit traffic will be reduced gradually inside of the old town Suzhou, but trips generated and attracted are still at a high volume and cause severe traffic congestion.
It is obvious that the problem of disproportionate road system classification cannot be solved in a short term, while high traffic demand can be served with updated mass transit network. The implementation of BRT can increase bus travel speed, but also increase passenger capacity of road system. For example, the report of two BRT corridors of Los Angeles showed that rapid buses saving average travel time at 25% compared to normal buses, the amount of passengers also increased at 33 percent and 26 percent to each BRT corridor. It was estimated that 1/3 were new passengers, 1/3 were attracted passengers changed from other transportation models. (Transit Cooperative Research Program, 2003)

The planning and construction of light rail started from 2010 in Suzhou, and will take eight to ten years. Considered from traffic capacity and travel speed, light rail will be a good approach, while BRT has lower capital costs and greater operating flexibility. Therefore, BRT can be a cost-effective way of providing high-quality, high-performance transit to relieve the fiscal burden and it can also work as an extension and transit supplement for light rail in the future.

**Conclusion**

This chapter presented detailed information about city of Suzhou and its old town to allow readers obtain a general view about this historic eastern city. It also analyzed the current road system of Suzhou and public transportation ridership to identify the root cause of traffic congestion in Suzhou. One conclusion can be drawn from above analysis is that BRT can perform a vital and fundamental transportation model for Suzhou- the
middle level city. But it is also recognized that only the integrated public transport system will approach to solving traffic problems successfully in the future. Therefore, in the next chapter, a detailed corridor study will be demonstrated to address issues like how to apply BRT on the existing road system in the old town Suzhou, how to integrate it with common buses and light rail, and what operations need to be modified.
Chapter Four BRT Corridor Design of Renmin Road

Introduction

Renmin Road has been chosen as a test application for a BRT route to consider the problems resulting from the introduction of BRT in an old city area. Renmin Road across the Old Town center connects Wuzhong district to the south and Suzhou Rail Station to the north and it is 4,681 meters long. As the only arterial in the South-North direction in the old town, it accommodates the most bus lines compared to other arterials (see figure 4.1). About six bus lines are occupying the Renmin Road and over 300 buses are using the road at the peak hours, which is accounting for over 30% of overall trips in the road. (Zhou, Zhang, Wang, Dai and Li) The amount of 300 buses across the old town city using the same road always causes station paralysis, traffic congestion and has negative impact on the travel speed of other vehicles.

One of the reasons for traffic congestion results from road widening. It used to be only 3 meters wide before the 20th century and it has been widened to about 40 meters nowadays. It has been adjusted to a four-lane Road. Parts of it have separated bus
lanes on both sides of road. With road widening, it brings in increasing number of trips leading to traffic congestion.

Figure 4.1 Renmin Road at the Old Town Suzhou
Another reason for the congestion is traffic disturbance. There are over 20 urban collectors connecting with the road and many direct openings facing the Renmin Road. Although Renmin Road is defined as the principal city arterial, it has a different function compared with the common definition of city arterial. A city arterial, loading heavy traffic,
works for delivery traffic from urban collector to freeway with limited access. It should avoid excess connections with lower-grade roads and streets to reduce the interference and influence of main traffic flow. Renmin Road serves more like urban collector with a great amount of building blocks along the street and allow auto-vehicles drive into the road directly.

A third reason for the road congestion is because a great number of traffic sources are located close by the road, which has significant negative impact on the road traffic flow and traffic capacity. For example, Guanqian Walk Street and Nanmen Commercial center are both located along the road. As the most popular center for retail, recreation and official uses, these two centers generate huge amount of traffic. The traffic flow on the Renmin road is interfered with a lot by the direct access of autos and pedestrians. Furthermore, many tourist attractions are located close to this road, like Yi Garden, Wen Temple and North Temple Pagoda. Educational uses are also spread along the two sides of the road, like Suzhou Library, Suzhou Middle School and Suzhou University. To sum up, widening road is not a good solution to relieve the traffic congestion in old town, which is drawn from the experiences of current serious situation of traffic in Suzhou.

There are many effective methods that can be taken. First, reclassify and reorganize the road system in old town. The Old town can be divided into many small blocks and each block will allow three to four entrances to the outside, instead of opening in all directions. Alleys can serve the inside traffic flow and must not connect with principal arterials to limit the significant negative impact to the free flow. Second, local zoning ordinance should restrict the relocation of attractive sources inside of the old town. Similar
strategies have been taken in the old town a few years ago, encouraging schools, hospital and recreation to relocate to the outside.

Third, control drive through auto-vehicles by limiting the parking spaces, drive in hours and having signal restrictions. Last, provide integrated effective public transportation system to attract travelers from other modes traveler. Reports have shown that local residents will choose public transportation within 15 minutes of walking and waiting time. Therefore, integrated BRT system with common buses provides convenient and door-to-door service surely attractive to passengers inside the old town. Another strategy is to encourage rickshaw pullers around the Old Town. Travelers and tourists can pay around $6-$1 to rickshaw puller to get to the tourist attractions passing through some narrow alley inside historic districts. It is an environmental friendly transportation model and represents local cultural identity. It is a way of continuing history and memory by enhancing the use of rickshaws. The integrated transportation system of BRT, common buses and rickshaw will serve different demand of local residents, tourists and travelers.

**BRT Corridor Design**

The BRT corridor along Renmin Road will be designed as trunk transit service, going through Renmin Road directly to limit the negative impact of mass transit on historic buildings and districts. Parts of it designed to go through underground using existing underground spaces. Common buses will connect with BRT routes through transit stations to provide feeder service. Current bus lines will be rescheduled based on the serving area of BRT corridor to reduce repeated routes; while maintaining the bus routes
that serve with BRT corridor. Experiences are drawn from Beijing BRT Corridor 1. Many bus routes were cancelled when BRT starting operated but had to recover several bus routes after one month later. Based on existing land uses, there are three main passenger distribution points along the Renmin Road, which are North Temple Pagoda, Guanqian Walk Street, and Nanmen commercial center. (See figure 4.3) These three points are the main attraction of trips and will be designed as BRT stops along the road. Renmin road has been widened to two-way four lines and part of it even has separated bus lanes, which provide a good prerequisite for BRT corridor design.

Figure 4.3 Three main points along Renming Road at the Old Town Suzhou
Section Design

The bus lane design determines BRT operating speed and capacity. Countries in different regions throughout the world have implemented different kinds of BRT system. For example, North America and Australia use HOV BRT system, while South America always uses central BRT bus lane. Some Asian Countries are also using central bus lanes and bus lanes on two side of road as well. The difference is based on road condition, travel habit, and trip demand. Overall, Separated bus lanes are proposed to guarantee bus speed and travel time saving.

The BRT corridor design for Renmin Road should follow the following rules.

1. Side parking along Renmin Road is banned to acquire space for BRT bus lane. Bus lane will locate on two side of road to eliminate construction.

2. Balance the functions between passenger corridor and traffic flow to reduce interference between public transportation and private auto-vehicles.

3. The BRT corridor design should maintain the overall city uniform traffic continuous and integrated with surrounding land use and road sections.

The BRT corridor design can be divided into three sections: 1, 2, and 3 based on current condition of width, amount of trips, and intersections (see figure 4.4).
Section 1

Section 1 of Renming Road has two-direction four lanes totally with bike lane and side parking on both sides. Current Mixed traffic of auto-vehicles and buses has serious congestion and travel delay impacts on buses. As auto-vehicles take advantages in flexibility compared with buses. The design for BRT corridor will be on two sides of road, with spaces obtained from side parking and travel lanes. Travel lanes will be reduced
from 12 feet to 11 feet, which would work well without big vehicles like buses. Bike lanes by side parking lanes will be moved to close to pedestrian lanes. Physical barriers are designed to control traffic speed between bike lanes and BRT corridors.

The proposed section design is 114 feet wide with sidewalk and bike lane on the two sides of road the same as before. Travel lanes still continue the original pattern of two-way four lanes, which is meet the design standard of urban arterial but limited to 11’ feet per lane. BRT bus lane set on the two sides of road with physical barriers from travel lane and bike lane to manage traffic. Spacing is obtained from side parking and travel lanes. A three-foot buffer is set between pedestrian and bike lane to provide a safe, quiet and polluted walking environment. (See figure 4.7)
Figure 4.6 Image of Section 1, Picture Source: web

Figure 4.7 Proposed Design with BRT lanes --Section 1 of Renmin Road
Source of the road section drawing: Wenya Hou
Section 2

Section 2 of Renmin Road loads heavy amounts of traffic and it is the most difficult part in which to implement a BRT corridor. Huge amounts of trips are produced by the most popular commercial and recreation center - Downtown-Guanqian Walk Street. In addition, large space of pedestrian on both sides of road is required. Reports have shown that the numbers of people come to Guanqian Walk Street are around 20,000 to 100,000 during some special festivals. This amount of people generated large demand of public transportation model demand. Current common buses cannot meet this demand as hundreds of people are waiting at the bus stop during peak hours. Current bus stops also cannot deal with this amount of people as many of them are standing on the travel lanes waiting for the bus, which is unsafe and has a negative effect on the free flow of travel lanes.

Figure 4.8 Underground Spaces
Source of drawing: Wenya Hou
The BRT corridor across the section 2 is proposed to go underground. There are several reasons to propose BRT travel underground. First, the current traffic flow is almost saturated. The travel speed is around 20 km/h to 35 km/h on average, which is far below standard of travel speed on urban arterial. Second, there is an existing underground space at the intersection of Guanqian Walk Street. The space is currently used as underground corridor for the intersection as lots of people crossing the road to get into the Walk Street. BRT corridor can construct underground as the extension of the space and set a station there. Pedestrians can still cross the intersection through underground and access BRT bus at the same time. Special provision for ventilation is needed to prevent the air from becoming polluted by bus fumes. Last, BRT travel underground will guarantee its speed when passing downtown area without interference of other auto-vehicles. Station by the Guanqian Walk Street will be considered as the main transit stop. It can provide level boarding and prepay system to decrease the boarding time. Two entrances for BRT to travel underground will be constructed on the edge of section 2. BRT bus still using its separated bus lanes and merge into central lanes after totally
enter the underground section. BRT using Central lane underground can save construction cost and earthwork. The underground corridor can further be used by subway as Suzhou is constructing subway nowadays (2010-2018).

Figure 4.10-1 Proposed BRT Corridor Design for Section 2
Source of the road section drawing: Wenya Hou

Figure 4.10-2 Proposed BRT Corridor Design for Section 2
Source of the road section drawing: Wenya Hou
Section 3

Section 3 of Renming Road has separate bus lanes on the two sides, which provide good prerequisite for the implementation of BRT vehicles. Parts of the road do not have bus lanes. BRT lane space can be obtained by converting one travel lane into dedicated bus lane.

Figure 4.11 Section 3 of Renmin Road, picture source: Baidu image
Figure 4.12-1 Proposed BRT Corridor Design for Section 3
Source of the road section drawing: Wenya Hou

Figure 4.12-2 Proposed BRT Corridor Design for Section 3
Source of the road section drawing: Wenya Hou
**Station Design**

Common bus stops in the old town Suzhou are successfully using Suzhou architecture features. They follow the native Suzhou style and applied in roof, pillar, call box, and bench. This design used to be a popular topic among citizens, planners and outsiders. Some supported this kind of construction and pointed out that bus stops have become one of the most beautiful city scenes. Some against with the concern of capital cost and argue that bus stops in the old style are not fit into the surrounding circumstances. Despite these discussions, these bus stops are already built, standing by the street and serving as waiting spaces.

There are seven to eight bus stops along the Renmin Road (See Figure 4.14). Proposed BRT corridor is on the two sides of the road, therefore, BRT can use common bus stops on a cost-saving basis (see figure 4.15). Particularly, the middle bus stop is proposed underground so it will not use the common bus stop. Passengers can use smart cards or cash to pay for the ride after boarding. This way of payment increases the dwell time compared with prepayment method, but dedicated bus way and signal priority are the two key factors that guarantee stable bus speed in this corridor study. Further research needs to be done in terms of number of passengers waiting at the same time to determine the capacity of closure BRT stops. Walking, common buses and biking will be the main three way to access BRT stops in the old town Suzhou. Auto-vehicles will be considered for transit outside the Old Town, where parking spaces will be required.
Figure 4.13 bus stops along Renming and Ganjiang Road
Source: Website
Figure 4.14 Present Bus Stops along Renmin Road
Source: Wenya Hou

Figure 4.15 Proposed BRT Stops along Renmin Road
Source: Wenya Hou
Signal Design

The travel time saving of BRT is taking advantages from signal priority, which will also be considered to apply along Renmin BRT corridor. BRT will use separate light signal and BRT vehicles are allowed to travel first with the signal. See figure 4.16.

Figure 4.16-1 Proposed BRT Signal Control
Source of drawing: Wenya Hou
The signal for bus lane is first turned green, and BRT buses can travel first without interferences of auto-vehicles.
Conclusion

This chapter conducted a corridor study using a major arterial in the old town Suzhou. This study covers major issues of applying BRT into specific road including route design, station design, road section design and signal design, which can be used as a corridor example of applying BRT in China. Particularly, the BRT corridor was designed and proposed using existing road condition with small constructions.
Chapter five Conclusion

One conclusion can be drawn is that BRT is an effective transportation mode that helps relieve traffic congestion in historic cities with high capacity, stable speed, and flexibility. In addition, it decreases the possibility of using smaller vehicles in China, which has become a trend in other Asia cities like India, Nepal and Thailand. It decreases land construction, which is especially important in historic cities. Because land construction may have negative impacts on foundations of historic buildings, and these historic buildings are too fragile to suffer huge noises.

However, BRT needs to be integrated with other city transportation modes like common buses, light rail and metro to form a whole transit network on a city basis. Some cities are using light rail as the main transit system in the city area and BRT as the supplement connecting the city areas with suburbs on an economic-friendly basis. Apart from financial reason, BRT has its disadvantages in applying in historic cities. Many historic cities follow traditional city development pattern with narrow road network systems and high density of houses. Large vehicles of BRT are difficult to travel around. Its routes are limited to some wide enough corridors. So common buses play the key role in transit network to connect BRT. BRT dedicated lane can be obtained from parking, bicycle and pedestrian lanes when the corridor is not wide enough to accommodate medium BRT
lanes, like Renmin Road BRT Corridor in the research. Newly constructed road can consider about medium BRT travel lane, which has been successfully applied in Beijing, Xiamen and Guangzhou.

Many projects are started with good road conditions by applying BRT in newly constructed cities or roads systems. BRT was hard and rare to be an option for historic cities. Cities are in favor of subway found it saving road resources for auto-vehicles, having higher capacity and travel speed, and representing a good reputation for the city modernized images. However, financing, flexibility and necessity need to be considered, especially when the city is at middle to small-scale level.

This paper provides an alternative for Suzhou transportation plan. Currently, the plan is proposing for subway network system in old town Suzhou and BRT as supplement serving industry parks around. Some expects argued that soil condition in Suzhou, especially for the old town Suzhou is not good enough to construct subways. Lots efforts and funding must have been devoted in solving the soil problems, like water leaking, and soil spongy. BRT can be an alternative to subway on a cost-effect, historic and environmental friendly basis by applying on the existing road network. Suzhou transportation plan can pursue an innovative strategy that BRT works in its old town and the extension -- subway serves in Industry Park zones. The strategy may be on an opposite side to other cities, but it is based on its historic features and unique city form and development of Suzhou. Therefore, BRT can be considered as an option in historic cities with integrating of other transportation modes.
Further Questions

BRT system is saving construction cost by occupying road resources, but related problems may be caused once starting operating. Further questions like how to connect common buses with BRT and how to decrease number of autos need to be addressed. One way to evaluate BRT depends on the achievement of reducing travel time of BRT impact area and attracting passengers from other modes. (Annie, 2011) The evaluation process will contribute to decision making in how to organize common buses working as the transit of BRT, how to organize access of pedestrian, bike and private vehicles, and What related policies can be adopt to reduce private vehicles driving in old cities.

Another possibility for applying BRT travel lane on extremely narrow roads is to form a single direction travel system for auto-vehicles and buses. It allows BRT medium bus lane by decreasing travel lanes. It is another effective approach to solve traffic congestion in areas with high amount of traffic flow, which has been applied in Xinjiekou District (downtown area), Nanjing, China. Single direction system raises problems when drivers are not familiar with the local roads. More efforts can be done into providing enough and obvious signals. This is another approach of applying BRT in historic cities using existing road conditions with further research study of forming a single direction traffic system based on local road network.

To sum up, it is local residents that make the decisions of driving or getting on buses. More efforts for planners, related officials, and local governments to be done to raise awareness of using public transportations, like hosting public education workshops, provide incentives in carpool and set limitations on driving. It will be a main trend of
using transportation modes with low cost, green energy and high quality of service. BRT possesses these characteristics and worth studying to contribute to further environment protection.
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