DEVELOPING BUS RAPID TRANSIT IN A HIGH-DENSITY METROPOLITAN AREA: A CASE STUDY IN GUANGZHOU, CHINA

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ABSTRACT

The practice in China showed that developing Bus Rapid Transit (BRT) in high-density metropolitan areas needs innovation on the system. Taking Guangzhou BRT pilot line, one of the most successful BRT systems in Asia-Pacific region, as an example, this paper analyses how the Express Corridor plus Flexible Routing (called Guangzhou Mode for short) system makes full use of the speed and flexibility advantages of BRT vehicles to meet travel demand in a high-density megacity. We briefly introduce the core ideas of Guangzhou Mode, including its objects, three key elements and two aspects of advantages. The characteristics of the new innovative system have been investigated with quantitative analysis from its influences on passenger transfer and passenger volume. The analysis shows that Guangzhou Mode has distinct advantages in saving travel time and meeting travel demand while applied in high-density metropolitan areas. Specifically, Guangzhou Mode system performs better in optimizing passenger transfer organization and using system resources than the traditional ones. This will lead greater improvement on BRT attractiveness and system operation efficiency. The study also find that Guangzhou Mode will only give full play to its potential with all of the three key elements, and lack of any one element will significantly reduce the system performance. The study gives a full-scale theoretical analysis of Guangzhou Mode and reveals its foundations for success in high-density metropolitan areas. Our findings suggest a way of intensive transport and high resource utilization in BRT development, providing rapid, efficient and convenient high-quality bus transit service.

Keywords: urban public transport; bus rapid transit; high-density city; express corridor; flexible routing; high-quality bus transit service

INTRODUCTION

China is trying to ease urban traffic problems and achieve sustainable development via the development of public transport. Bus Rapid Transit (BRT) is a newly introduced public transport mode in China and given high hopes. It is a public transport mode between rail transit and normal bus transit. BRT has larger capacity than normal bus transit, and provides faster and more comfortable service. On the other hand, BRT is more flexible and economic than rail transit, and has lower construction costs and shorter construction periods. Because of the advantages mentioned above, BRT has been widely developed around the world since the first system was born in Curitiba, Brazil in 1970s (Demery 2004). In China, more than ten cities have opened their BRT systems since 2004. These new BRT systems are playing positive roles in improving local public transport service. However, for a developing country in high-speed urbanization with 1.3 billion people, simply copying foreign success stories is obviously difficult to succeed. The application of BRT is still facing big resistance. One of the biggest problems is the land for roads. Most of the cities that are planning a BRT system in China are high-density cities with a shortage of land for roads, especially in downtown areas. When making decisions, the government will consider more about how to avoid low occupancy of BRT facilities and reduce the negative effects on other traffic than the efficiency and cost effectiveness brought by the system. Many of the decision makers are not willing to risk building traditional rail transit style BRT corridors because it usually means high speed but low occupancy of facilities and fewer lanes for other traffic. So new ideas are needed while developing BRT in high-density metropolitan areas.

Guangzhou is the 3rd biggest city of China. There are more than 8 million people living in the 549 km^2 central city area. Guangzhou is a typical high-density city. Its population density is 14.6 thousand per km^2 in central city area and 34.2 thousand per km^2 in the downtown. The Guangzhou BRT pilot line system was first proposed in 2004. After a long-term repeated proof, the system was put into operation in early 2010. It is located in Zhongshan Boulevard corridor, a main east-west transit corridor in Guangzhou. This new BRT system was developed based on an innovative Express Corridor plus Flexible Routing Mode (or called Guangzhou Mode) instead of the widely adopted Rail Transit Mode. Although the BRT corridor has only 22.9 kilometers and 26 couples of BRT stations, the BRT system is a very big one that connecting another 750 couples of bus stops by the 46 BRT lines. The bus stops covered by BRT lines are about 15.6% of the total bus stops in the main city of Guangzhou.

This efficient and flexible BRT system shows good prospect and adaptability in high-density urban areas. The post-project evaluation after ten months of operation in late 2010 showed Guangzhou BRT system had made a big breakthrough in passenger capacity compared other systems in China. There were about 25 thousand one-way volume and 340 buses per hour during the peak hours in late 2010(Ning et al. 2010), and later the number grew to 30 thousand in 2012. The average daily volume through the corridor increased by 50% from 520 thousand(Guo et al. 2008) (all 87 bus lines before BRT operation) to 780 thousand(Ning et al. 2010) (in late 2010 with the BRT system), and further to 843 thousand(ITDP 2012) (in late

2011). In addition, the average speed of buses in the BRT corridor reached 23 km/h, increased by 84% than before (without BRT)(Ning et al. 2010). The BRT corridor now is acting as a citywide public transport hub corridor and providing higher quality public transit service. In 2011, Guangzhou won the Sustainable Transport Award for its success in developing a remarkable BRT system.

The purpose of this study is to discuss what kind of BRT system a high-density city should develop to make full use of the advantages of BRT and improve its public transport system. The core ideas, the characteristics and the applicable scope of Guangzhou Mode were investigated and analysed.

CORE IDEAS OF GUANGZHOU MODE

Objects

As we know, the first feature of BRT is rapid. But when we are pursuing the rapidness, it should not be ignored that BRT is also a kind of bus transit. Bus transit which provides intensive public service was born to share public resources and reduce traffic congestion. The traditional rail transit style BRT system has greatly increased the speed of buses. The next point is how to increase the capacity without slowing down the buses. As mention above, this problem is particularly important when developing BRT in high-density cities. Guangzhou's Express Corridor plus Flexible Routing BRT system was proposed in this context.

Guangzhou Mode is indicating a bus priority concept with high-quality public service. The BRT system was designed to provide more flexible services to meet the public transport demand actively while keeping the buses running with a high speed in BRT corridors. As a result of that, the BRT facilities and buses can be used more efficiently and the system will attract more people to take buses.

Key Elements

Generally, a BRT system includes running ways, stations, vehicles, services, fare collection, Intelligent Transport System (ITS) and branding elements(Diaz and Hinebaugh 2009). In Guangzhou BRT pilot line system, the running ways, stations and services are three key elements. Specifically, it has an express corridor (running ways) as the basis, flexible routing (services) as the core, and efficient stations as the support.

Express Corridor

Guangzhou Zhongshan Boulevard corridor for BRT operation was planned as an express corridor for bus transit. Zhongshan Boulevard, a two-way arterial road with eight motor vehicle lanes was redevelopment with the construction of BRT corridor. One median BRT lane was separated for both directions along the 22.9 km long corridor (Figure 1). At the same time, four supplementary measures were implemented to ensure the buses run with a high speed in the corridor and the facility has enough capacity, as follows:

1. Strict right-of-way control. The BRT lanes are only open for BRT lines and some special vehicles (such as ambulances and fire trucks).

2. Separated pedestrian crossings. In the 36 pedestrian crossing facilities, 26 are grade-separated facilities and the rest ones are signalized crossings.

3. Bypass lanes at stations. One more BRT lanes were set up as bypass lanes within station areas to avoid the buses blocking each other and make it possible to use skip-stop operation measures.

4. Comprehensive traffic facilities improvement. The road and intersections along the corridor were redesigned and the signal plans were optimized for buses.

Figure 1 Guangzhou Zhongshan Boulevard BRT Pilot Line

Flexible Routing

There are commonly two types of BRT service. One is known as trunk-feeder service and the other is direct service. What service a BRT system provides is related to its operation mode, namely how the BRT lines are organized.

The system providing trunk-feeder service usually has trunk lines running in the corridor and feeder lines running out (Figure 2a). The trunk lines act like rail transit and the feeder lines act like normal bus transit. There would be set a number of hub stations along the corridors for passengers to transfer between trunk lines and feeder lines. Because the BRT lines are organized similarly to the rail transit and the trunk lines and the hub stations are relatively fixed, we call this operation mode as rail transit mode or fixed routing mode. Fixed routing mode is the earliest and most widely used operation mode around the world.

The system providing direct service is usually organized like a normal bus transit system (Figure 2b). BRT lines directly connect different origins and destinations. Most of these points are located out of the corridors, so the BRT lines will only use a part of the corridors. We call this operation mode as direct routing mode.

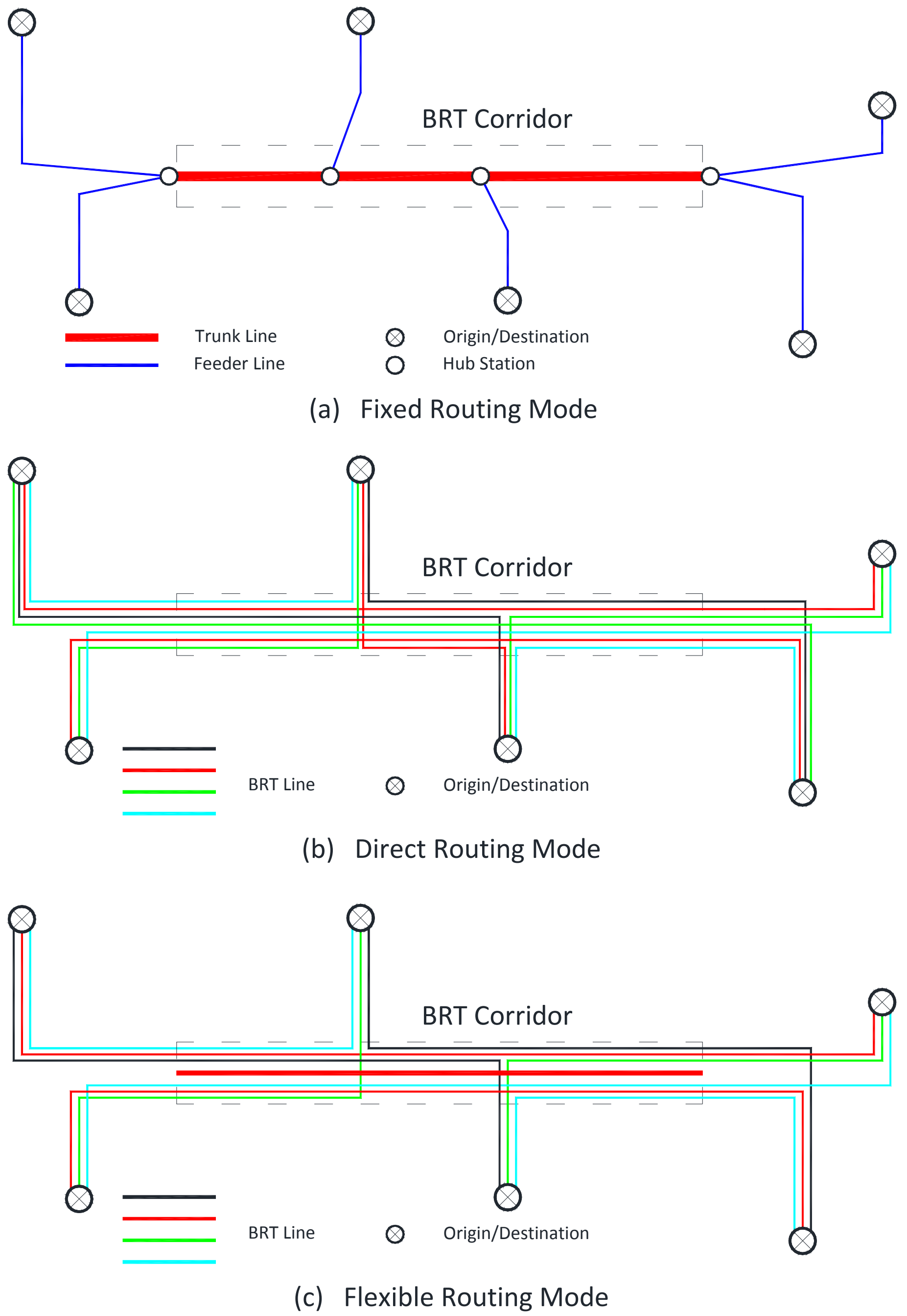


Figure 2 Illustration of the Organization for BRT Routes

Guangzhou BRT pilot line system uses an innovative flexible routing mode to provide both trunk-feeder service and direct service (Figure 2c). In the new system, the two modes mentioned above were integrated into one. There are both trunk lines that only running in the corridor and direct lines that only pass by a part of the corridor. Every station has several different BRT lines and passengers can transfer among these lines for free. So hub stations are not very necessary in this system. On the other hand, the lines organization and passenger transfer are very flexible.

With the implementation of the BRT pilot line, the bus lines related to the corridor were reorganized and optimized. The 87 bus lines were integrated into 46 (Figure 3). There are three types of lines with different operating measures:

1. 31 normal lines with non-skip-stop operation;
2. 9 express lines with skip-stop operation;
3. 6 branch lines as a supplement to the normal lines with non-skip-stop operation.

Most of the 46 BRT lines were not designed to go through the whole corridor. There are 15 lines with 11 stops and over, 16 lines with 5 to 10 stops, and 15 lines with 4 stops and less.

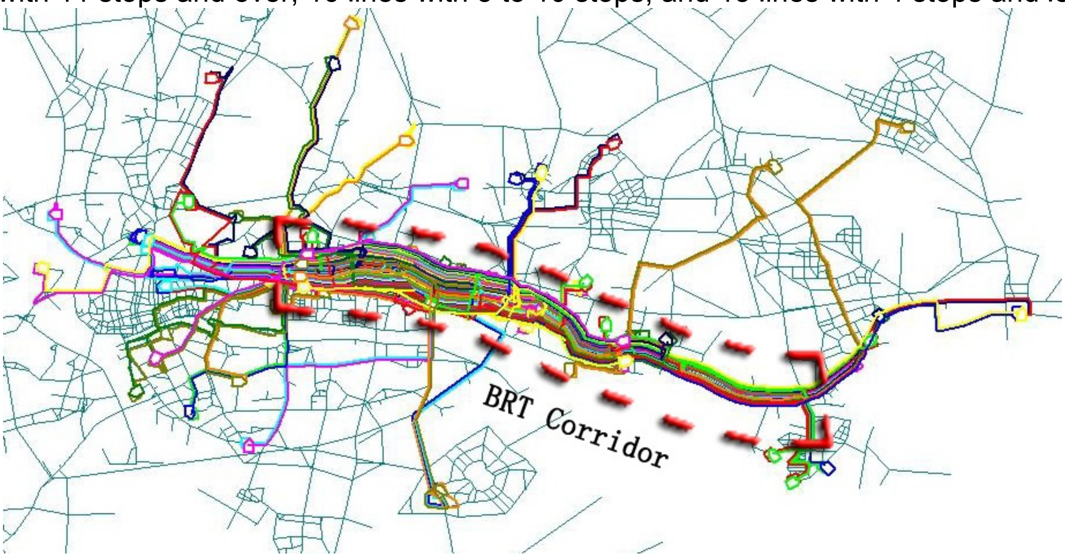


Figure 3 Guangzhou BRT Pilot Line Network

Efficient Stations

Guangzhou BRT pilot line system provides efficient services at stations. The stations were designed to integrate with the current roads and buses.
To improve the efficiency of buses at station, four supplementary measures were implemented, as follows:

1. The median side platforms were used to be compatible with the current right-handed buses;
2. The scale of stations were mainly decided by passenger demand (the biggest station is 285 meters long);
3. Enough space was reserved between loading areas to make buses enter and leave more convenient;
4. The loading areas were reasonably allocated based on the passenger flow and departure frequency of different lines.

To improve the boarding and alighting efficiency of riders, three supplementary measures were implemented, as follows:

1. Tickets were designed to be sold outside the buses;
2. An intelligent guidance system was built to help riders find their buses;
3. Level boarding and alighting were achieved to reduce the delay.

Advantages

Saving Travel Time

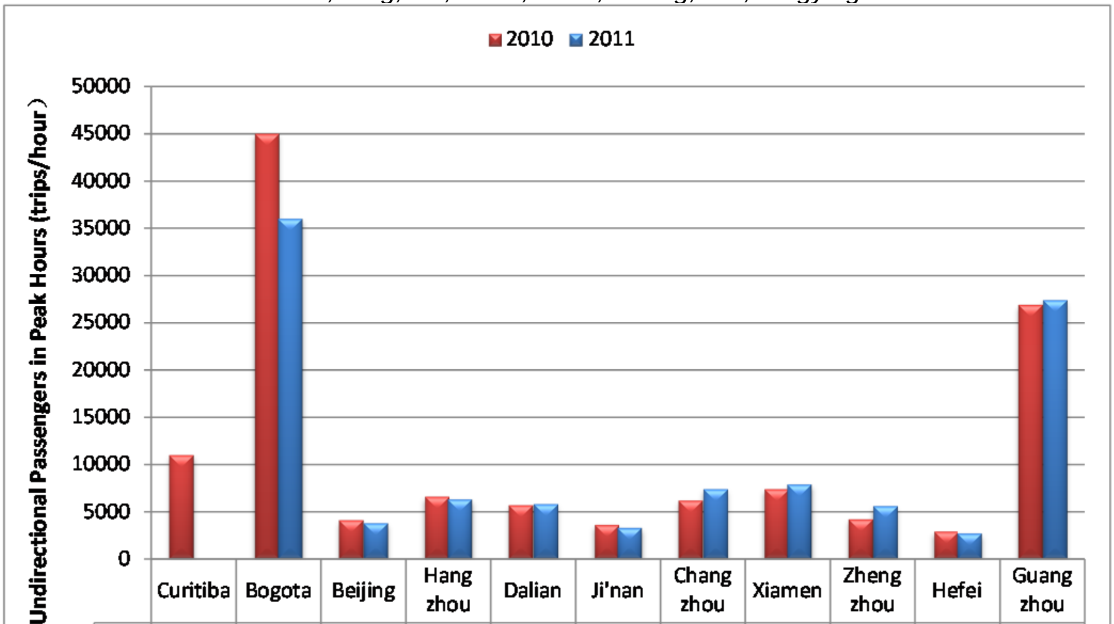
In a bus trip, the travel time between the two bus stops near origin and destination mainly depends on the bus system's operation and traffic condition. It is consist by four parts: waiting time, boarding/alighting time, riding time, and transfer time. The three key elements have great contributions on saving travel time by reducing these four parts of time.

Express corridor greatly increases the speed of BRT buses by eliminating the interferences from other vehicles. The waiting time and riding time are reduced. Flexible routing greatly increases the departure frequency of BRT buses by setting multiple origin stations. The waiting time and transfer time are saved. Efficient stations have remarkable contributions on boarding/alighting time and transfer time by selling tickets outside the buses.

Meeting Travel Demand

The adaptability between BRT system and travel demand is mainly embodied on the organization of lines and the service it provides. They are all decided by its system mode. The cities that developed BRT earlier, such as Curitiba(Demery 2004) and Bogota(Alasdair Cain 2006), were trying to improve the operation speed of bus transit and use BRT system instead of rail transit. So they usually used the rail-transit-like fixed routing mode to operate BRT systems.

In China, most of the earlier BRT systems were also choosing the fixed routing mode. Almost all the cities that developed BRT systems are high-density ones. Although these systems gave good examples in the improvement of public transit service, there are still a far cry between China's BRT system (except Guangzhou) and foreign successful systems on passenger volume (Figure 4)(ITDP 2012).



	Curitiba	Bogota	Beijing	Hang zhou	Dalian	Ji'nan	Chang zhou	Xiamen	Zheng zhou	Hefei	Guang zhou
2010	11000	45000	4100	6600	5700	3600	6200	7400	4200	2900	26900
2011	0	36000	3800	6300	5800	3300	7400	7900	5600	2700	27400

Figure 4 Comparison of the Passenger Volume in BRT Corridors during the Peak Hours

After an investigation about these cities and their BRT systems, it is found that there are two influencing factors that lead the big gap:

1. Travel distribution. The cities like Curitiba and Bogota have a distinct zonal (Figure 5b) or radial (Figure 5c) city form. Most of the travel distributes along the BRT corridors. But many high-density cities in China have a strong center area and the people gradually spread outside. Their city form and travel demand are like planar (Figure 5a) or mixed (Figure 5d) distribution. The travel demand is very complicated and strong, but without clear direction.

2. BRT corridor network. Compared with Curitiba and Bogota's large scale BRT corridor network, most of the BRT systems in China are still at experimental stage. Many cities have only an isolated rail transit style corridor, without network.

The two problems make it hard to bring out the advantage of BRT on capacity(Lu and Wen 2006). Guangzhou's exploration and practice on new BRT system shows that the Express Corridor plus Flexible Routing Mode has big advantages on meeting travel demand, especially in high-density cities.

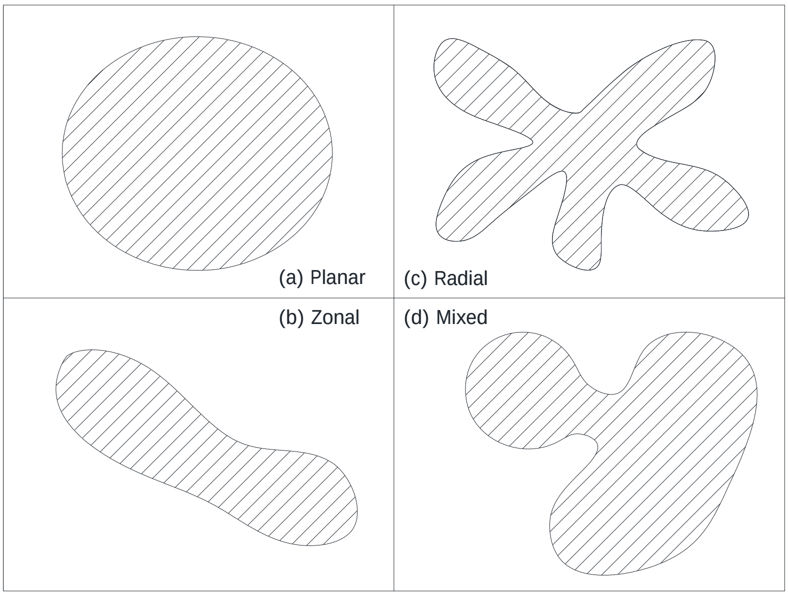


Figure 5 Illustration of the Travel Distribution in Different City Forms

CHARACTERISTICS OF GUANGZHOU MODE

The most important issues for passengers and operators are travel efficiency and passenger volume. They determine the quality of a BRT system. The travel efficiency depends on bus speed and transfer delay. When we have express corridor, transfer delay is the main influencing factor for travel efficiency. The passenger volume is related to the system capacity, system mode and travel demand. In this section, we discuss the characteristics of Guangzhou Mode by analysing its influences on passenger transfer and passenger volume.

Influences on Passenger Transfer

Transfer Organization

There are mainly two transfer styles for BRT systems. One is fixed point transfer and the other is multipoint transfer. Under the fixed routing mode, to transfer between a trunk line and a feeder line uses fixed point transfer, while to transfer between trunk lines uses both of the two styles. The flexible routing mode system usually uses multipoint transfer. The passengers can choose different route combinations and transfer stations. Figure 6 shows the transfer organization of the two operation modes. It also determines the service area of them. The fixed routing mode has much bigger service areas near terminals and hub stations than other stations along the corridors. It is more like a Point-Line transfer organization. The service area of flexible routing mode spreads evenly along the corridors. It is more like a Point-Plane transfer organization.
Because the flexible routing mode has multi-point and multi-choice characteristics on transfer organization, the BRT corridors may act as a citywide or regional public transport hub corridor. The passengers can share the transfer capacity of the whole corridor and avoid excessive concentration in several hub stations.

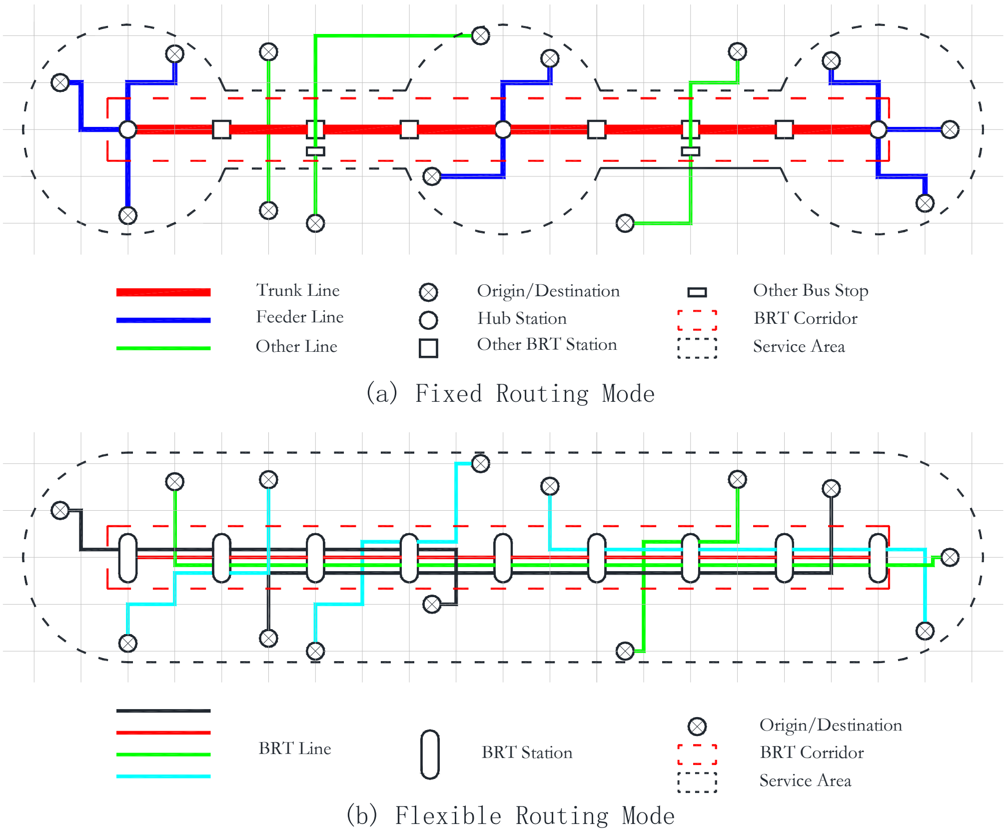


Figure 6 Illustration of the Transfer Organization

Transfer Frequency and Style

According to the analysis of transfer organization, it is easy to get a conclusion that the transfer frequency of the flexible routing mode is no more than the fixed routing mode (Table 1). The former mostly uses multipoint transfer with a relatively dispersive flow, while the later mostly uses fixed point transfer with a relatively intensive flow. Because the feeder lines usually do not enter the corridor and there may be too many lines at hub stations, in many cases the transfer between a trunk line and a feeder line for the fixed routing mode cannot finish in the same station. Some fixed routing BRT system made it by using island platform and double-hand door buses.

Table 1 Comparison of the Transfer Frequency and Style

Travel OD		Fixed Routing Mode		Flexible Routing Mode	
Origin	Destination	Frequency	Style	Frequency	Style
In the corridor	Out of the corridor	1	Fixed Point, Mostly Different Stations	≦1	Multipoint, Mostly Same Station
Out of the corridor	In the corridor	1	Fixed Point, Mostly Different Stations	≦1	Multipoint, Mostly Same Station
Out of the corridor	Out of the corridor	2	Fixed Point, Mostly Different Stations	≦2	Multipoint, Mostly Same Station

Transfer Costs

The transfer cost mainly depends on ticketing times. Transferring in different stations usually needs to buy a new ticket, while it is not necessary when transferring in the same station. Guangzhou's practice shows that the flexible routing mode is easier to reduce the transfer costs. After the opening of Guangzhou BRT system, the travel costs also reduced. The price of all BRT tickets for one trip was adjusted to 2 Yuan, including 17 bus lines whose tickets were at least 3 Yuan.

Influences on Passenger Volume

The BRT system mode and the passenger volume are mainly connected by the passenger transport efficiency. It is defined as the ratio of the passenger volume to system capacity, reflecting the utilization of the system resources.

Person Capacity

The most important indicator of BRT system capacity is the person capacity of the corridors. The person capacity, which is a desired value, has two decisive factors: the bus capacity of BRT corridors and the passenger loading capacity of buses. The former depends on the corridor facilities and the later depends on the bus selection.

Bus Capacity of BRT Corridors

The bus capacity of a BRT corridor is the number of buses that can use the corridor during a given period of time (usually 1 hour) under normal circumstances. BRT corridor is a system consisted by running ways, intersections, stations, crossings, signals and other facilities. The bus capacities of different sections in a BRT corridor vary from each other. Generally, there are three types of sections with differentiation on bus capacity: road segments, intersections and stations.

The bus capacity of any section in a BRT corridor is the ratio of the effective passing time to the minimum time headway of BRT buses, as shown in (1):

$$C_{bus} = \frac{T}{H} = \frac{\alpha T_0}{h/n} \quad (1)$$

Where, C_{bus} is bus capacity (bus/h); T is the effective passing time (s/h); H is the minimum time headway of BRT buses (s/bus); α is the reduction coefficient for passing time: it equals 1 for road segments and stations without any driving restrictions, and equals the green ratio of BRT buses for signalized intersections or stations with a downstream signal. T_0 is number of seconds in 1 hour (s/h), it equals 3600; h is the average minimum time headway for a facility unit (s/bus), such as a single lane for road segments and intersections, or a single loading area (Kittelson & Associates et al. 2003) for stations; n is the effective number of the facility units, such as lanes or loading areas.

Generally speaking, the capacity of intersections and stations are both less than road segments because the capacity of a single facility unit at intersections and stations may far less than road segments. If there are no preferential treatments, intersections and stations will play the role of bottlenecks in a BRT corridor.

Many measures applied in Guangzhou Mode, such as strict right-of-way control, separated pedestrian crossings, bypass lanes at stations, comprehensive traffic facilities improvement, demand-based large-scale stations, and reserved space between loading areas, have great contributions in increasing the capacity of the BRT corridor.

Passenger Loading Capacity of Buses

The passenger loading capacity is dependent on the size and type of vehicles selected as the BRT buses. Three types of buses are frequent used:

1. Normal Size. It is about 12 meters long, carrying 60 to 90 passengers.
2. Large Size. It is articulated and about 18 meters long, carrying 120 to 180 passengers.
3. Extra Size. It is articulated and about 24 meters long, carrying 240 to 270 passengers.

Efficiency

In practice, besides securing the BRT system has enough person capacity, another core problem is how to turn this theoretical value into real passenger volume as much as possible. In other words, we should always try to improve the system efficiency and reduce the waste of system capacity. There are two ways to improve system efficiency: increasing facility utilization rates and bus loading rates. These two factors are directly reflecting the efficiency of a BRT system.

Based on the statistical data (collected in 2010) in peak hours of the main BRT systems in China, we calculated the factors for different systems. It is shown in Table 2 that the facility utilization rate and bus loading rate of Guangzhou BRT system are all above 80%, apparently higher than other systems in China.

Table 2 Peak Hour Efficiency Factors of the Main BRT Systems in China

City[1]	Passenger Loading Capacity[2] (person/bus)	Unidirectional passenger volume (person/h)	Unidirectional bus volume		BRT facility utilization rate[3] (%)	Average bus loading rate (%)
			(bus/h)	(PCU/h)		
Beijing	170	4100	55	220	26.8	43.9
Hangzhou	140	6600	67	228	27.8	70.4
Dalian	125	5700	75	225	27.4	60.8
Ji'nan	140	3600	40	131	16.0	64.3
Changzhou	170	6200	70	280	34.1	52.1
Xiamen	110	7800	90	234	28.5	78.8
Zhengzhou	110	4200	50	138	16.9	76.4
Hefei	90	2900	60	120	14.6	53.7
Guangzhou	**90**	**26900**	**340**	**680**	**82.9**	**87.9**

SOURCES: Institute of Transportation Development & Policy(ITDP 2012)

NOTE: 1. All systems have only one BRT lane per direction in the corridors; 2. It is calculated based on the vehicle composition of BRT systems respectively; 3. It is the ratio of unidirectional bus volume to bus capacity of the corridor, where we use 1640 PCU/h as the basic capacity and 0.5 as the reduction coefficient.

Naturally, it is wondered whether the improvement of system efficiency is due to the new system mode, because all of the BRT systems listed in Table 2 except Guangzhou are developed based on the traditional rail transit mode. In order to make this problem clear, we theoretically analyse how Guangzhou Mode influences the facility utilization rate and the bus loading rate.

BRT Facility Utilization

Take a BRT corridor with 6 stations and 5 nodes (intersections or at-grade crossings) as an example. As shown in Figure 7, the indented capacity curve is the envelope curve of the BRT bus volume. Whatever modes are the BRT system used, the volume curve will not go out of the capacity curve.

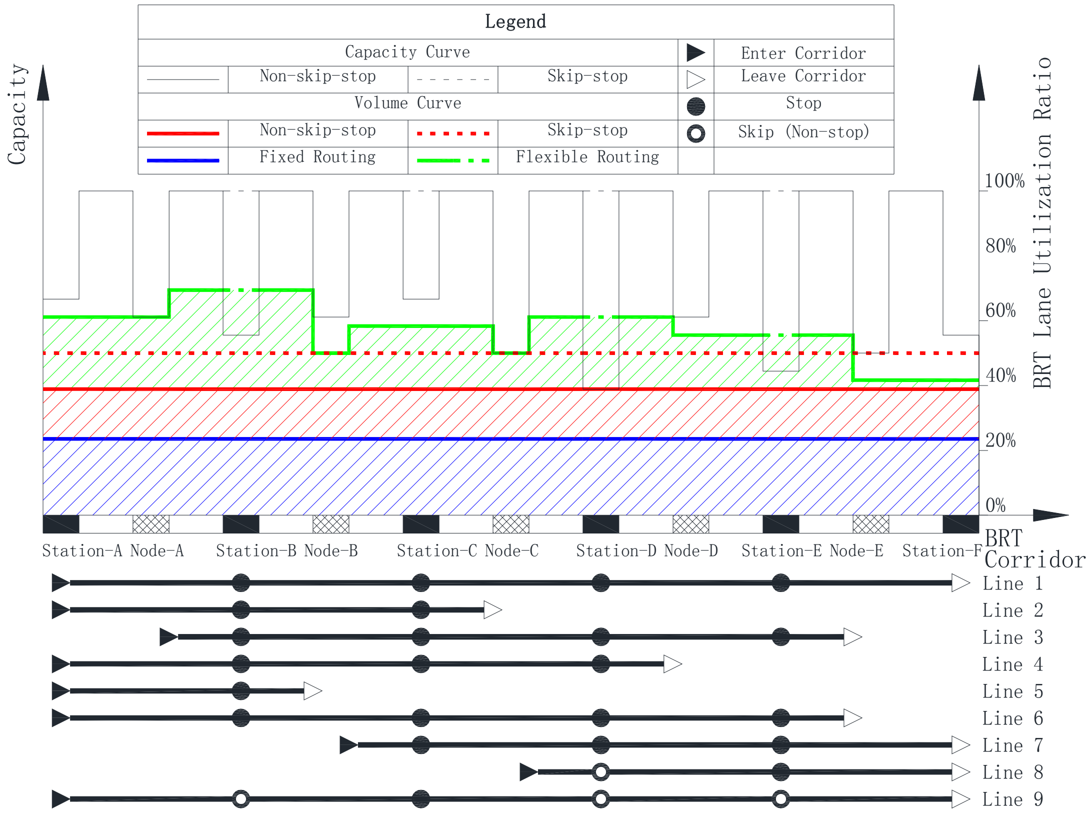


Figure 7 Illustration of Bus Capacity in the example BRT Corridor

If all the buses are designed to run through the whole corridor and stop at every station, the corridor capacity will determined by the sections with the minimum capacity (Station D in Figure 7). If some of the buses run with a skip-stop operation (such as express line), the nodes with the minimum capacity (Node C and E) will be the benchmark.

For a fixed routing mode BRT system, the trunk lines will run through the whole corridor, then its envelope curve narrows to the red solid line Figure 7 (or red dash line with skip-stop operation). Moreover, this narrowed envelope curve is just a theoretical value. In practice, the departure interval of buses at a bus terminal is about 2~3 minutes in peak hours, sending out 20~30 buses per hour. On the other hand, the number of terminals for the trunk lines of a fixed routing mode BRT system is very limited, usually no more than three for one corridor. It is calculated that a BRT corridor with fixed routing can send out 20~90 buses in an hour. By the restriction of bus departure ability, the utilization ratio of BRT corridors with fixed routing is often lower than 30%, as the blue solid line shown in Figure 7.

For a flexible routing mode BRT system, there are usually a number of lines from different terminals running in the corridors. It means there could be a number of terminals sending out buses to a BRT corridor at the same time. Compared with fixed routing mode, flexible routing mode is making better use of the capacity of different sections of a BRT corridor. An example of flexible routing mode is illustrated in Figure 7. The green line (solid and dashed) is the volume curve overlaid by 9 BRT lines running in the corridor. The average utilization ratio of the corridor is higher than 50%. In Guangzhou's case, there are 46 flexible lines running in Zhongshan Boulevard corridor and the utilization ratio is higher than 80%.

Bus Load Factor

The bus load factor in a BRT system is mainly dependent on the distribution and intensity of travel demand. It is also influenced by the system mode. Take a BRT corridor with 7 stations as an example. For a fixed routing mode BRT system, it is designed that most of the passengers board and alight at the terminals and hubs. As shown in Figure 8, when the travel demand is zonal distributed, most of the trips are between terminals (Station A and G) and hubs (Station D). In this case, the bus load factor of the corridor will be stable and at a high level (red solid line in Figure 8). When the travel demand is planar demand, the trips between stations would be similar. In that case, the bus load factor will be lower, especially near the terminals (blue solid line in Figure 8).

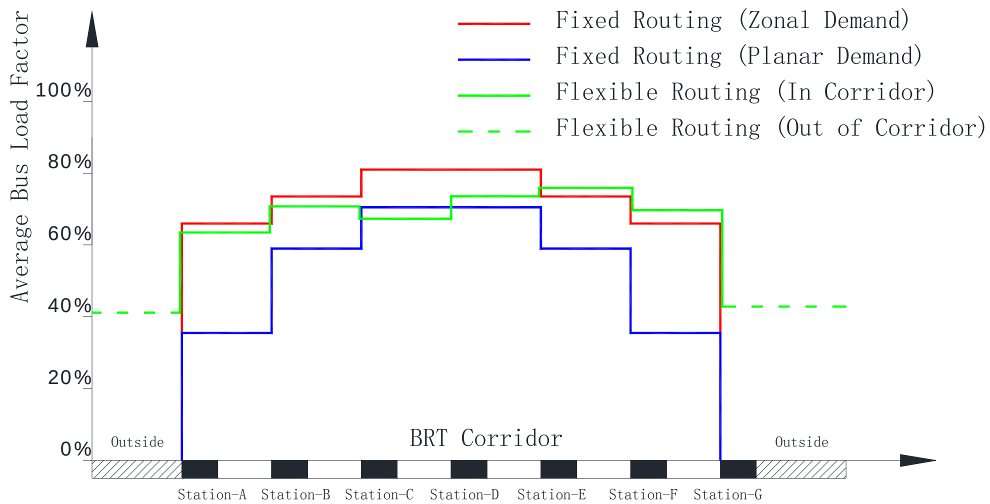


Figure 8 Illustration of Average Bus Load Factor

For a flexible routing mode BRT system, every station in BRT corridors can act as a hub that has a relatively high transfer volume of passengers. Passengers can take a BRT line outside and run into the BRT corridors with the bus, then choose a best transfer site among several stations. This characteristic of flexible routing mode can balance the passenger flow between stations and lines, preventing the buses from too empty or too crowd in peak hours and keeping a stable full load when running in the corridors (green solid and dashed lines in Figure 8).

Brief Summary

In conclusion, the new Guangzhou Mode, namely the Express Corridor plus Flexible Routing mode, has better adaptability to travel demand and more suitable for high-density cities than traditional modes of BRT systems. Guangzhou Mode can make a good use of the system resources by improving the matching of the capacity of BRT facilities with the passenger flow, increasing the passenger volume and efficiency of the system and reducing the transfer frequency and costs.

According to the analysis above, it is summarized the performance of a Guangzhou Mode BRT system is closely linked with the key elements (Table 3). Only if the three key elements appear at the same time, a Guangzhou Mode BRT system can reach a high level in speed, convenience, capacity and efficiency simultaneously. Lack of any element will significantly lower the system performance. In Guangzhou's case, by integrating the three key elements, the BRT pilot line system made breakthroughs in improving passenger transfer and volume while giving consideration to both trunk-feeder service and direct service in a high-density metropolitan area.

Table 3 Relationship between the Key Elements and the Performance of Guangzhou Mode

Key Elements			System Performance			
Express Corridor	Flexible Routing	Efficient Stations	Speed	Convenience	Capacity	Efficiency
●	●	●	☆☆☆	☆☆☆	☆☆☆	☆☆☆
●	●	○	☆☆	☆☆	☆☆	☆☆
●	○	●	☆☆☆	☆☆	☆☆☆	☆
○	●	●	☆	☆☆☆	☆☆	☆☆☆

NOTE: ● = Yes; ○ = No; ☆☆☆ = good; ☆☆ = normal; ☆ = bad.

APPLICABLE SCOPE OF GUANGZHOU MODE

Transportation Applicability

Guangzhou's practice showed that Guangzhou Mode is very suitable for high-density metropolitan areas. In addition, it is found that Guangzhou Mode is a relatively free mode with malleable service. By routing the lines flexibly, the BRT system will have good adaptability to different travel distribution forms.

There are mainly three scenarios based on different travel distribution forms:

1. Planar distribution. The system should provide more direct services by planning more direct lines.

2. Zonal, radial or group distribution. The system should provide more trunk-feeder services by planning less direct lines.

3. Mixed distribution. The proportion of trunk-feeder service and direct service should be determined and optimized flexibly based on the situation.

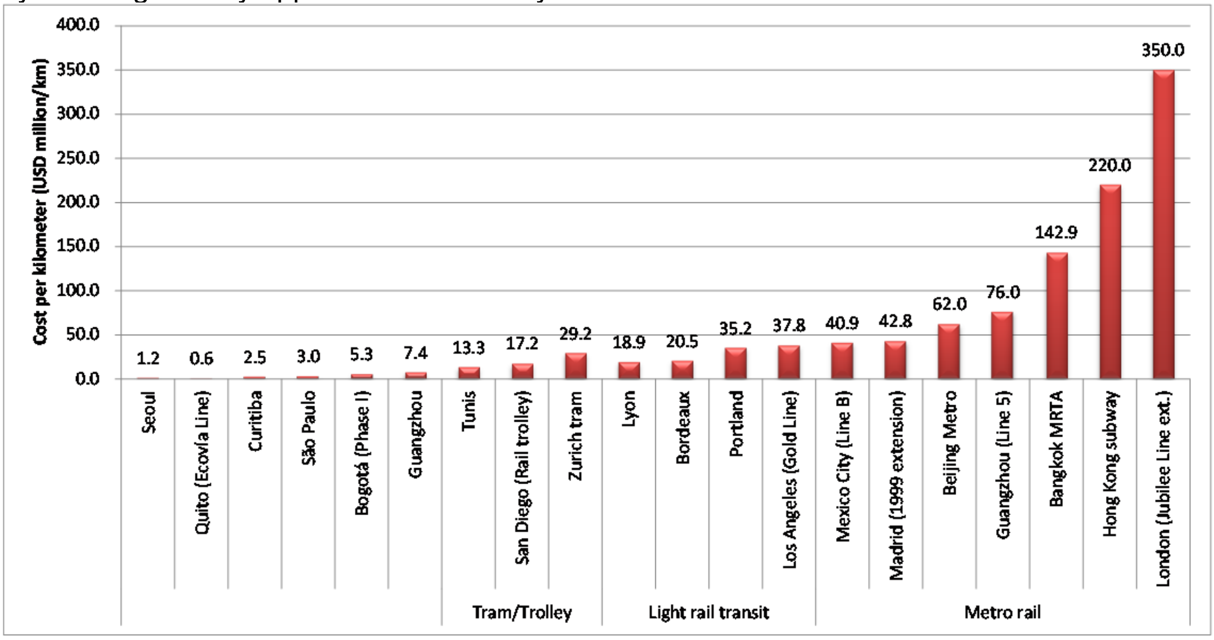
In other words, the transportation applicable scope of Guangzhou Mode is wide. In some cases, Guangzhou Mode may replace the rail transit mode and the direct mode. The constructed rail transit mode or direct mode BRT systems can also be turned into Guangzhou Mode with some improvement measures, to further increase the efficiency and adaptability of the system.

A remarkable point is that it is not the more lines running in BRT corridors the better. More lines may bring more passengers, but too many lines will lower the level of service. So the number of lines should be controlled in a reasonable scale and compatible with the facilities and the travel demand.

Economy Applicability

As mentioned above, BRT is a relatively economic option for developing mass transit systems. It is shown in Figure 9 that the developing BRT systems are much cheaper than other mass transit options, including tram, trolley, light rail transit and metro rail.

In a high-density metropolitan area, the price of land is higher and the economic issues usually are critical to the decision of the city in building or improving its transport systems. Although urban rail transit is more efficient and reliable than most bus transit, few cities can afford to build a large enough metro rail or light rail transit system. Instead, building a BRT system is generally applicable in economy because of its low infrastructure cost.



Source: Guangzhou: (Ning et al. 2010) and others: (Wright and Hook 2007)

Figure 9 Infrastructure Cost Comparisons of Different Mass Transit Systems

CONCLUSIONS

Guangzhou Mode is a new innovative mode which has been explored when developing BRT in a high-density metropolitan area. It was proposed based on an essential idea of public transport priority and sustainable development. The ideas of Guangzhou Mode will promote

the applicable scope of BRT and its competitive power as a promising transportation option. The study gives a full-scale case-based theoretical analysis of Guangzhou Mode and reveals its foundations for success in high-density metropolitan areas. We find that Guangzhou Mode has a distinct advantage in saving travel time and meeting travel demand. Our findings suggest a way of intensive transport and high resource utilization in BRT development, providing rapid, efficient and convenient high-quality bus transit service. This case study also provides ideas and references for the cities in developing countries that are trying to build a good, healthy and sustainable transport system.
New idea brings changes but also challenges. With the new Guangzhou Mode, there are still a lot of new questions to be answered. For example, with the extension of BRT corridor networks, how to optimize the lines dynamically with the change of travel demand, how to provide real-time intelligent transfer guidance and management, and how to coordinate the development of BRT and other forms of public transport are all important issues that deserve further study.

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