

**Building Bus Rapid Transit into the existing public transit system:
Competition and Integration of BRT and the Urban Rail Transit in Cities
of China**

By

Yun Zhan

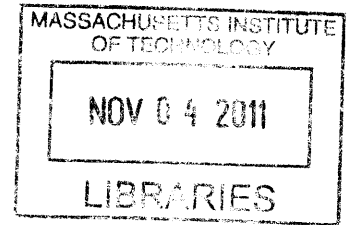
B.E. in Urban Planning and B.A. in Economics
Peking University, Beijing 2009

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degree of

Master in City Planning

at the
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ABSTRACT

BRT is a new type of bus transit with high speed and capacity. With its advantages and benefits, BRT is getting popular in the world, including China. Since BRT and urban rail transit (URT) are both rapid public transports, the comparisons between the two will be inevitable. Generally speaking, BRT could theoretically reach the speed and capacity of light rail, but there is still a gap in abilities between BRT and metro. Though for construction investment, BRT is much lower-cost than the same-length metro, if considering the land value and exclusive effects altogether, the total cost of a BRT system could increase faster with the raise in passenger numbers. Therefore, depending on different development stages, cities should choose the right mode with highest efficiency as the dominant public transit. Sometimes, both of the systems should work in corporation for the best effectiveness. Though there are competition and substitution between BRT and URT, compatibility and complementarity also exist. The integration between the two will bring us a new understanding on the developments of the urban transit system.

For integration of BRT and URT, thoughtful network planning is the first step. Second, the service quality and efficiency of transfers between the systems should be emphasized. Also important, a cooperative management will be necessary. At the same time, land development opportunities should be considered with this integration trend.

Thesis Supervisor: Ralph Gakenheimer

Title: Professor of Urban Planning, Emeritus

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Boston is destined to be a memorable city.

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CHAPTER 1. INTRODUCTION

1.1. Research Background

Comparing to private transit, public transits always have some inherent disadvantages, such as lack of flexibility of routes and hours, comparatively lower commuting speed and comfort in trips, inevitable walking distances on endpoints and waiting time on stops, and troubles for transfers and squashes in peak hours (*Lei Chen, 2006*). In addition, the construction of a public transport system, especially a metro system, normally costs a lot of funds fixedly in the first stage. As a result, in most of the developed countries in the world, especially the United States, the automobile transport is still the mainstream for transit. In the developing regions, the shares of private cars are also increasing sharply with the rapid urbanization process. In this motorized world, traffic congestion, high accident rate, and air pollution have gradually grown into widespread and serious problems that finally got noticed by professionals and the societies.

To deal with all the troubles caused by the explosion of private cars, a new public transport mode, Bus Rapid Transit (BRT), was born and quickly popularized as a sustainable solution.

1.1.1 The Concept of BRT

What's BRT?

Bus Rapid Transit (BRT) is a term specifically describing a new category of urban bus transit system with high capacity, performance and sustainability. Generally speaking, it is a “3rd kind” of public transit which combines the speed, reliability and amenities of the rail transit and the flexibility and cost savings of buses with a quality image and a strong identity¹.

The concept was first raised by *Chicago* city of United States in 1930s (Figure 1.1-1). The first BRT project was implemented by Brazil government in *Curitiba* in 1970s. The expression started to be mainly used in North America by the later 20th century, and have become very popular in the whole world since 2000. Until now, the concept has developed maturely with clear and practical meanings.

¹ “*What is Bus Rapid Transit?*” from Select Bus Service website, NY Metropolitan Transit Authority. [<http://www.mta.info/mta/planning/sbs/whatis.htm>], 03-05-2011; “Bus rapid transit”, From Wikipedia, [http://en.wikipedia.org/wiki/Bus_rapid_transit]

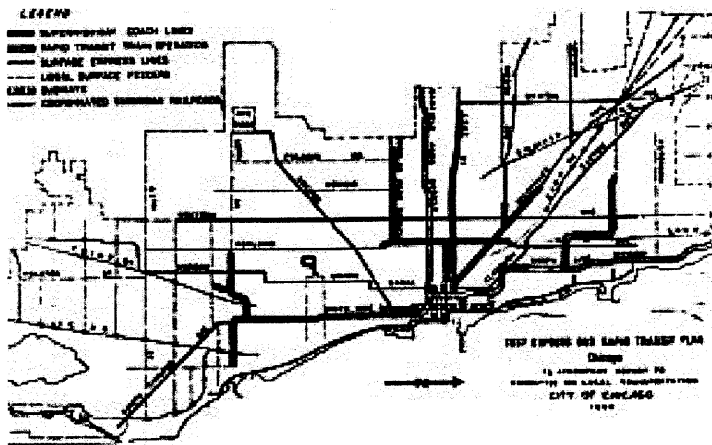


Figure 1.1-1:
1937 Express Bus
Plan—Chicago

Source: Herbert S. Levinson,
Samuel Zimmerman and
Jennifer Clinger, *Bus Rapid
Transit: An Overview*

A BRT system normally has its own right-of-way, multiple-car trains at short headways and longer stop-space than traditional streetcars and buses². Based on the definition by Federal Transit Administration of United States, a Bus Rapid Transit system generally consists of several *major elements: Running Ways, Stations, Vehicles, Fare Collection, Intelligent Transportation Systems (ITS), and Operations Planning*³.

To be clearer, according to Professor *Ralph Gakenheimer* from *Massachusetts Institute of Technology*, there are *minimal essences* to satisfy for distinguishing BRT from the normal bus transits: (1) *dedicated lane(s) for buses*, (2) *stations for prepayment of fares*, (3) *large doors for short stops*, (4) *and passing priority at the intersections*⁴. In another words, though other optional elements and technology could be included, a BRT system should at least have all these feature as the basic conditions. Beyond that, each BRT application could be designed differently to some extent in practice to meet the specific needs and characteristics of the region⁵.

BRT, a Revolution of Sustainability in Urban Transport

The major high-speed-and-comfort elements and the high circumstance adaptability guarantee BRT a great performance in transportation services. With its strengths in service, BRT has competitiveness in commuting speed and quality, not only in contrast with the tradition bus transit, but even comparing to automobiles and two-wheelers, which are exploding across the world with perilous consequences to traffic safety, greenhouse-gas emissions and traffic congestion. Therefore, BRT is regarded as a way to change the current private-transport-dominant reality by

² "Bus rapid transit" From Wikipedia

³ *Characteristics of BRT for decision making*, 2004, Federal Transit Administration

⁴ Ralph Gakenheimer, 2010, in conversation

⁵ "What is Bus Rapid Transit?"

increasing the share of public transits, reducing the trips by private motors and then alleviating the traffic pressures on the roads.

Adding its characteristics to be built quickly, incrementally, and economically, its sufficient transport capacity to meet demands in even in the largest metropolitan regions⁶, and its links to land use densification and Transit Oriented Development (TOD),⁷ BRT is always popular in countries and recognized as a key to open the door into a more sustainable future. As a new sustainable transport mode, BRT is certainly gaining a leadership in the urban transport renewal and will definitely bring changes into the urban transport system both spatially and culturally.

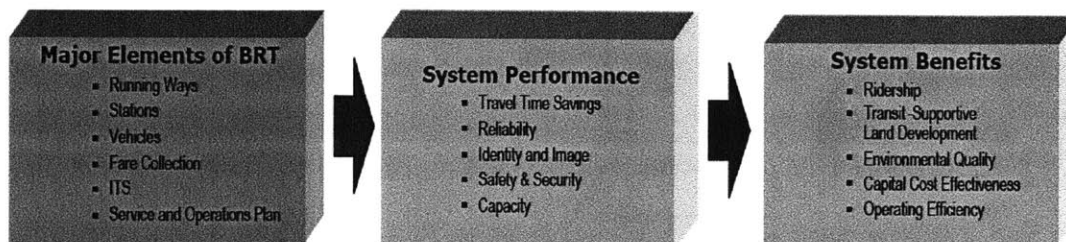


Figure 1.1-2: BRT elements, system performance and system benefits

Source: *Characteristics of BRT for decision making, 2004, Federal Transit Administration*

1.1.2 BRT in the world

The United States -- a major experimental field for BRT

The United States was the first country bringing out the concept and plan of “Bus Rapid Transit” (1937, Chicago city, though didn’t get implemented) and also a major experimental field for BRT constructions before 2000. U.S has now become the country having the largest number of BRT routes in the world. However, among all the projects, a wide variety exists because of different regional contexts and only a few of them reached all the minimal essences (Table 1.1-1). For instance, diverse types of rights-of-way have been incorporated in different cities: mixed flow arterial in Los Angeles, mixed flow freeway in Phoenix, dedicated arterial lanes in Boston, at-grade transit ways in Miami, and fully grade-separated surface transit ways in Pittsburgh, and subways in Seattle.⁸

⁶ Herbert S. Levinson, Samuel Zimmerman and Jennifer Clinger, *Bus Rapid Transit: An Overview*, [<http://www.nctr.usf.edu/jpt/pdf/JPT%205-21%20Levinson.pdf>]

⁷ Ralph Gakenheimer, 2010, in speech

⁸ *Characteristics of BRT for decision making*, Federal Transit Administration, [http://www.nbrti.org/docs/pdf/Characteristics_BRT_Decision-Making.pdf]

Table 1.1-1: different Elements of BRTs in US

Elements of Bus Rapid Transit in the FTA Demonstration Projects										
	Boston	Charlotte	Cleveland	Washington, DC	Eugene	Hartford	Honolulu	Miami	San Juan	San Jose
Busways		•			•	•		•		
Bus Lanes	•	•	•			•		•		
Bus on HOV-Expressways		•		•			•		•	
Signal Priority		•	•	•	•		•			
Fare Collection Improvements			•	•	•					•
Limited Stops	•		•	•	•		•	•		•
Improved Stations & Shelters		•	•	•	•	•		•		•
Intelligent Transportation Systems	•	•	•	•	•	•	•	•	•	•
Cleaner/Quieter Vehicles	•		•		•					

Source: *Bus Rapid Transit 101*, Center for Transportation Excellence [<http://www.cfte.org/trends/brt.asp>]

Though most of the BRT projects help to reduce the commuting time in the cities, like the ones in Pittsburgh and Los Angeles maximally bringing the cities 25~50% commuting time saving than the old bus transit, but the efficiency and effect of them are various and to some projects the actual speed is not much more rapid than usual bus transit. Therefore, Professor *Vukan Vuchic* at the *University of Pennsylvania* challenges the word “Rapid” in the name Bus Rapid Transit for some US-style BRT projects, instead offering the term “*Bus Semi-Rapid Transit*” and arguing that “Rapid” should only be used when referring to exclusive-right-of-way transit. ⁹

Latin America

Comparing to the reality in North America, the developments of BRT in South America are more thorough, typical and successful.

Curitiba, Brazil -- the first BRT system

In regards to the previous experiences, Brazil has the earliest and most developed BRT system. “*Rede Integrada de Transporte (RIT)*” ¹⁰ System (Figure 1.1-3, next page) built in 1974 in *Curitiba*, Brazil was the first BRT system implemented¹¹ and one of the most heavily used, yet low-cost, transit systems in the world. Until now, this BRT system there is still regarded as one of the most successful models for Rapid

⁹ *Bus Rapid Transit 101*, Center for Transportation Excellence, [<http://www.cfte.org/trends/brt.asp>]

¹⁰ “*Rede Integrada de Transporte (RIT)*” means Integrated Transportation Network in Portuguese

¹¹ “*Rede Integrada de Transporte*” from Wikipedia, [http://en.wikipedia.org/wiki/Rede_Integrada_de_Transporte]

Transit: The buses run as often as every 90 seconds in the dedicated lanes and stop at cylindrical, clear-walled tube stations with turnstiles, steps, and wheelchair lifts. Passengers pay reasonable fares as they enter the stations, and wait for buses on raised platforms. Instead of steps, buses have extra wide doors and ramps that extend out to the station platform when the doors open (for same-level entry). A typical dwell time will be no more than 15 to 19 seconds at a stop.¹²

Great efficiency brought acceptance and popularity in the public. According to previous researches, until now, around 70 percent of Curitiba's commuters use the BRT to travel to work, and 28 percent of the BRT riders previously traveled by car. Based on former survey results, the introduction of the BRT brought a reduction of about 27 million auto trips per year, saving about 27 million liters of fuel annually, resulting in congestion-free streets and pollution-free air for the 2.2 million inhabitants of greater Curitiba.¹³

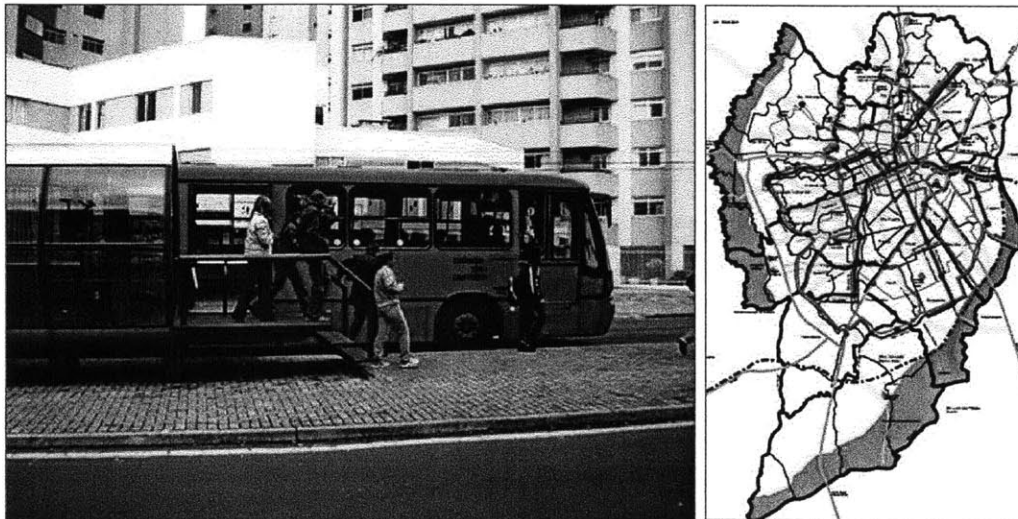


Figure 1.1-3: the bus stop and routes of RIT system (BRT) in Curitiba, Brazil

Sources: The right: <http://www.vatransit.com/practices/task3.htm#b11>

The left: <http://www.treehugger.com/files/2009/03/curitiba-brazil-bus-rapid-transit-video.php>

Bogotá, Colombia-- another significant milestone

As another significant milestone in the history of BRT since the new century, a bus rapid transit system named “*TransMilenio*” was opened to the public in December 2000 in *Bogotá*, the capital of *Colombia*. (Figure 1.1-4, next page) Based on the model used in Curitiba, Brazil, *TransMilenio* totally runs for 84km (54 miles) throughout the city.

¹² Joseph Goodman, Melissa Laube, and Judith Schwenk, *Curitiba's Bus System is Model for Rapid Transit*, [<http://www.urbanhabitat.org/node/344>]

¹³ Joseph Goodman, Melissa Laube, and Judith Schwenk, *Curitiba's Bus System is Model for Rapid Transit*, [<http://www.urbanhabitat.org/node/344>]

Usually, four lanes down the center of the street are dedicated to bus traffic. The whole BRT system consists of 9 interconnecting BRT lines. Each composed of numerous stations in the center of a main avenue, and passengers typically reach the stations via a bridge over the street. Further, the buses used have a capacity of 160 passengers, and got updated to a capacity for 270 passengers in May 2007. As of May 2010, up to 1,500 buses were circulating on the main-avenue system, and an additional set of 410 regular buses, known as "feeders" service for commuters from certain important stations to many different locations that the main route does not reach.¹⁴

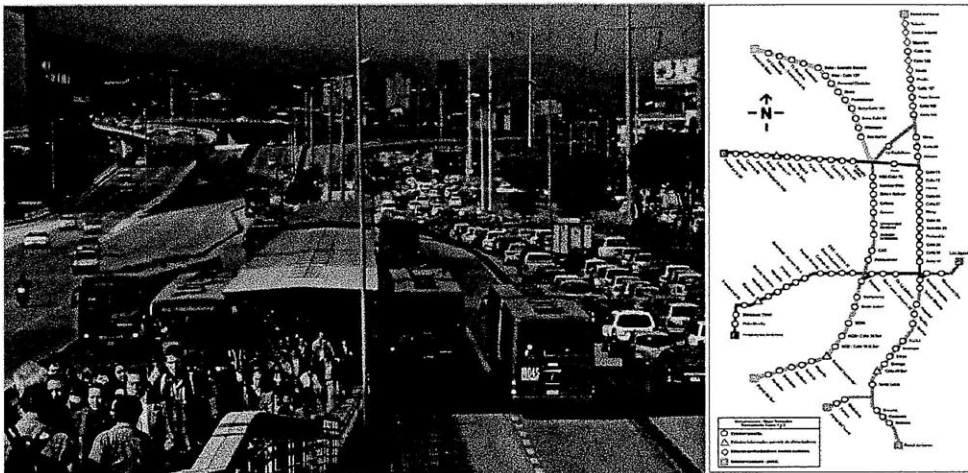


Figure 1.1-4: the "TransMilenio" system in Bogotá, Colombia

Sources: The Right: "TransMilenio", From Wikipedia, [<http://en.wikipedia.org/wiki/TransMilenio>]
 The left: Scott Dalton, NY Times, [<http://www.sustainablecitiesnet.com/models/bus-rapid-transit-bogota/>]

Encouraged by the huge success in Bogotá, there are an increasing number of BRT systems are being constructed, implemented, and also planned all over the world since the new century. Following the classical cases from North and South America shown above, dozens of cities additionally from America, and from Europe, Africa, Asia and Australia have been involved in this fresh planning-and-constructing-for-BRT wave.

BRT in Asia

In Asia specifically, in response to a generally dramatic motorization and a common decline in public transport mode share, BRT mode was introduced and recommended as a viable alternative to traditional rail public transport, and an urban transport solution for the economic and environmental problems.¹⁵

¹⁴ "TransMilenio", From Wikipedia, [<http://en.wikipedia.org/wiki/TransMilenio>]

¹⁵ *Bus Rapid Transit Systems in Asia*, Clean Air Portal, CAI-Asia Publications, CAI-Asia Factsheet No. 11, August 2010, [<http://cleanairinitiative.org/portal/knowledgebase/publications>]

The first stage of BRT constructions happened in *Transjakarta, Jakarta, Indonesia* (opened in 2004) and *Seoul, Korea* (bus system reform in 2004), and currently, there are over 80 BRT systems under development in Asia¹⁶. (Figure 1.1-5)

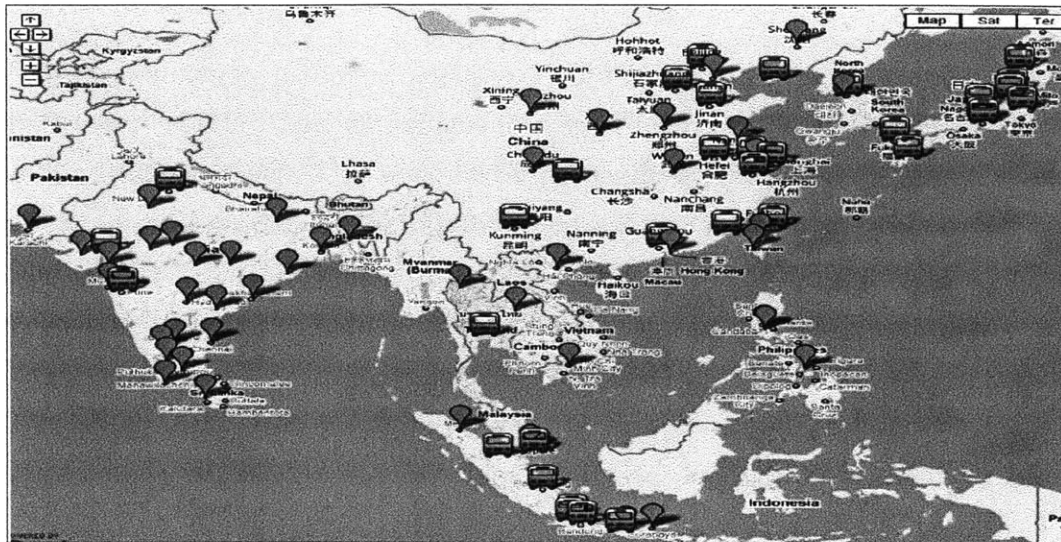


Figure 1.1-5: BRTs in Asia (CAI-Asia, 2010)

*Blue Buses indicate in-operation BRTs and Red marks indicate ones under construction.

Source: *Bus Rapid Transit Systems in Asia*, Clean Air Portal, CAI-Asia Publications, CAI-Asia Factsheet No. 11, August 2010, [<http://cleanairinitiative.org/portal/knowledgebase/publications>]

1.1.3 BRT in China

Necessity of BRT in China

In the developing areas, private cars have rarely gotten an absolute dominance in transport. The popular urban transport ways are normally comparatively inefficient but cheaper than private cars, such as motorbikes, bicycles, and some low-quality public transits. In China for instance, though motorization has been blooming in all of the big cities, according to the statistics from Department of Housing and Construction of China in 2009, the main trip modes are still walking and bicycling in average share across the country, which call for around 50%~ 60% of the daily trips¹⁷. This means a real overall motorization hasn't still come yet.

However, with the process of urbanization and economic development, the ownership of motor vehicles and the share of private cars have been and will continuously be enlarged dramatically, especially in the major big cities, since the increases in income make the price of vehicles look more affordable and the people now care more about

¹⁶ *Bus Rapid Transit Systems in Asia*, Clean Air Portal, CAI-Asia Publications, CAI-Asia Factsheet No. 11

¹⁷ From: 163 news, [<http://news.163.com/09/0902/21/51840IRQ000120GR.html>]

efficiency and comfort in the commuting trips, and also because in the modern Chinese culture, owning a private car means more than a change in transport mode, but also somehow an important symbol to show an upgrade in life quality and social status.

There are more than 50 cities in China containing an urban population above 1 million, and more than 20 of them have a population above 2 million¹⁸. For some mega cities like Shanghai and Beijing, the urban populations are around 10 million and administrative population are reaching 20 million. As the one of the fastest growing regions full of the busiest group, the big cities in China are heading into a motor-dominant urban transport world with no hesitation. Taking Beijing as an example, which used to be a domain of bicycling, until 2009, the automobile ownerships of the whole city reached 4 million¹⁹ (Figure 1.1-6), which is about 18 times of the total capability of the main three ring roads (*2nd, 3rd and 4th Ring*).

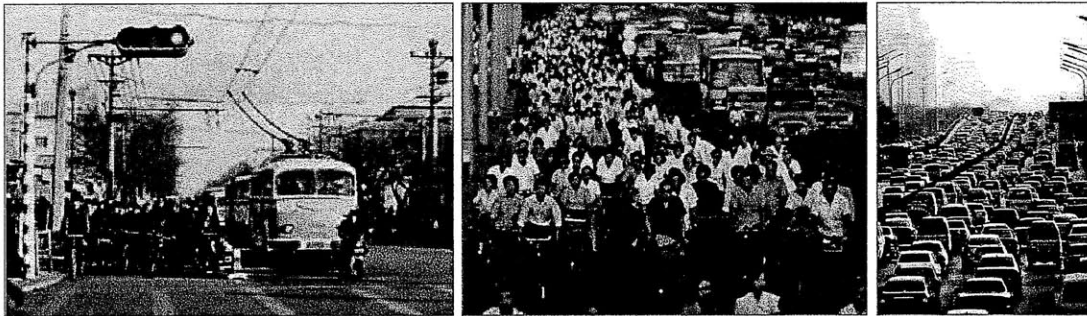


Figure 1.1-6 the photos showing the traffic on street in 50s (left), 80s (middle), and 2000s (right) in Beijing, China

*1950s: A Bicycling-dominant Age; 1980s: A Bicycling-and-automobile-mixing Age; 2000s: An Automobile-dominant age; Source: <http://www.chinautc.com/information/picture.asp?classid=6;>
http://www.estall.cn/news_display.asp?newsid=3687

The transportation “evolution”, motorization, not only brought spatial changes on the urban form, but also came with continuously worsening traffic conditions on the roads and also serious air pollutions at the same time. For most of the super major cities, traffic congestions and vehicle exhausts have become a part in the residents’ life, which is hard to be tolerated and ignored.

Where the transportation space in the cities is limited, the only way to solve these problems is to widely develop and advocate public transits. Comparing to the space

¹⁸ From: http://en.wikipedia.org/wiki/List_of_cities_in_China. Statistics on urban population are variable according to the differences of sources and methods of investigation.

¹⁹ From: <http://stock.stockstar.com/JL2009122400000830.shtml>

on roads requested by private cars, the space for the same capacity asked by public transits could be much more compact (Figure 1.1-7).

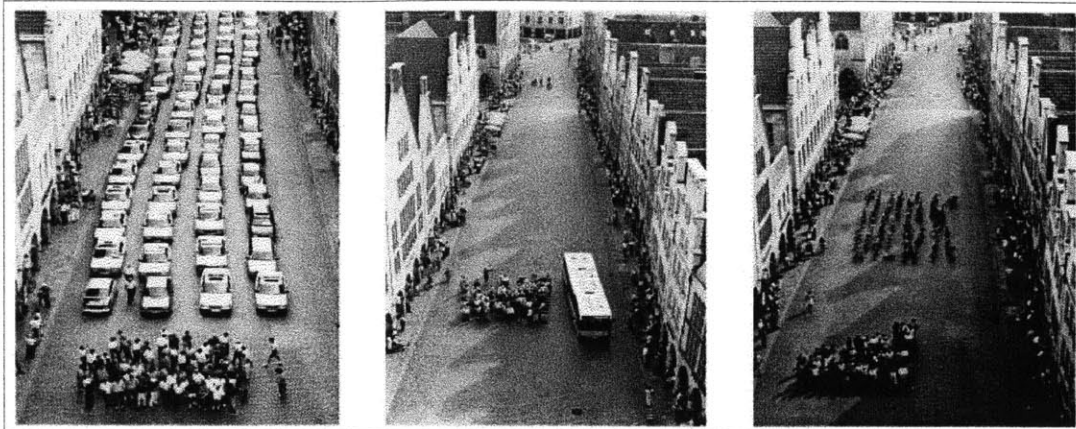


Figure 1.1-7: Amount of space required to transport the same number of passengers by car, bus or bicycle.

Source: Press office, City of Münster, Germany. Copied from [http://pedshed.net/?p=240]

However nowadays, the developments of public transits, especially urban bus operations, are lagging much behind the economic growths in China. Though the governments are investing huge funds every year into the constructions of public transport, most are on rail transits and the outcomes are not very pleasing. According to the previous data, between 2001 and 2004, the number of public transport vehicles in China has only increased around 30% and the total capacity rose about 20% (Figure 1.1-8), comparing to the nearly one-time increase in ownership of automobiles in the same period.

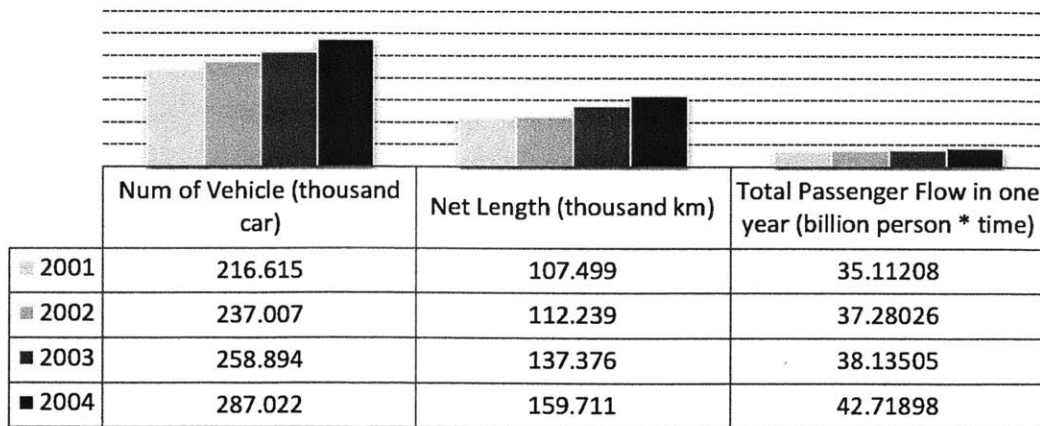


Figure 1.1-8: the development of public transport between 2001 and 2004

Source: Jingxia Wang, Summary of urban transport development strategy in China, 2006, http://www.chinautc.com/information/newsshow.asp?newsid=271

For bus transit specifically, the developments are even slower with less passion and spur from the government, which cause an unfavorable quality in service and weak passenger attractiveness in daily transit. Among the cities of China, the share of transit by bus is in 6%~25%, and for more than 600 of them, the share is under 10% (Min Yang, Xuewu Chen, Wei Wang, 2003). Worse, according the data in 2006, the utilization ratio of bus transit was going down in several sampled major cities (Figure 1.1-9), which shows a continuous decline in bus transit popularity.

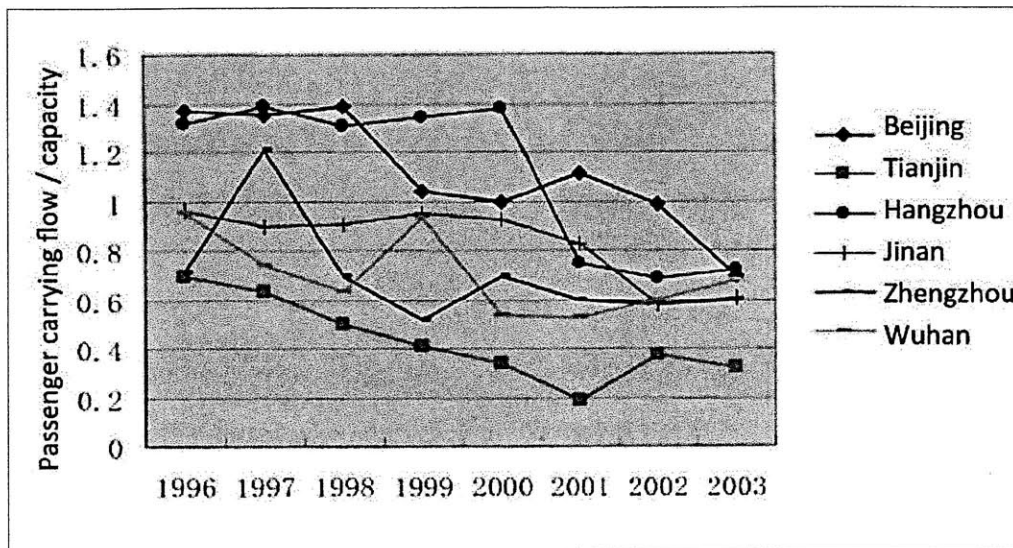


Figure 1.1-9: the changes in utilization ratio of public buses between 2001 and 2004

* *The utilization ratio: The rate of the total passenger carrying flow divided by total capacity of the buses, which is an efficiency index of the system*

Source: Jingxia Wang, *Summary of urban transport development strategy in China, 2006*, <http://www.chinautc.com/information/newsshow.asp?newsid=271>

Regards to the reasons of the depression, the declining efficiency and worsening service quality of public buses are both widely effecting problems: *First*, the traditional bus service has a smaller servicing radius, a slower operating speed and a more unstable schedule than other urban transits; *Second*, with a limited capacity comparing to the huge population, public buses and their stations are always very crowded in China, so that the commuters would rather choose the more flexible and comfortable especially when the time and financial costs are closed. *Third*, bus routes should be fixed in a certain period, but the expansion of urban space and decentralization of residences happened so rapidly in China, which left the bus services less time to adjust and extend in time for reaching all the places with needs. (Qinshui Chen, 2004) To solve all these problems in traditional bus transit and to change the idea and status of on public transit, Bus Rapid Transit should be introduced in the big cities of China.

Developments of BRT in China

The concept of BRT got into China at the end of 20th century. According to the high-population-density reality in cities of China, there are always desires of a new transport mode which could mitigate the burdens on daily public transits and resolve the worsening traffic problems. In 1994 then, an academic team headed by Ximing Lu primarily brought the idea of building a separately fast-lane bus system to relieve the serious traffic congestions in city areas, and till 2003, the expression of Bus Rapid Transit (BRT) was first referred in the yearbook of China Buses and Coaches.²⁰

In 1999, the earliest segregated median busway in China was built in *Kunming city*, a central city in southwest China. (Figure 1.1-10)

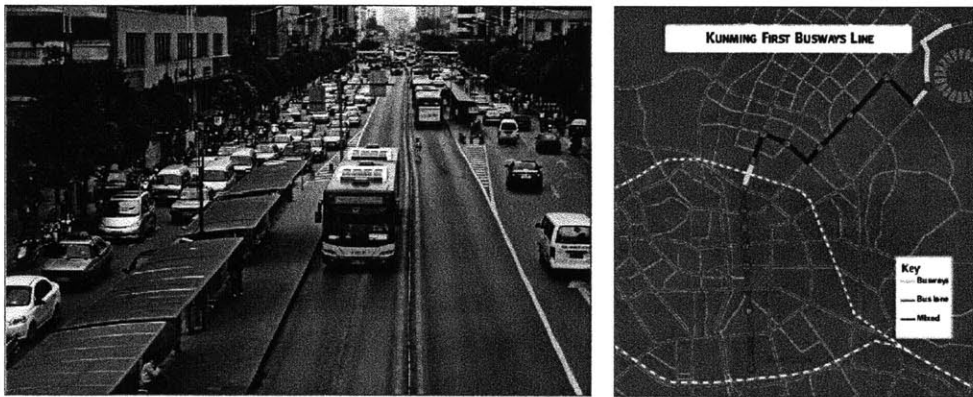


Figure 1.1-10: the median bus lane in Kunming

Source: The left: [<http://www.shenyangbus.com/a/hyzx/ksgj/2010/0729/2084.html>]

The right: Wang Fengwu, James Wang, *BRT in China*, [http://www.gobrt.org/BRT_in_China.pdf];

At that time, it is a dedicated lane for normal bus transit running for around 5km, without special BRT buses, pre-board fare collection, or a significantly improved station environment²¹, so as to be only regarded as a predecessor or rudiment of a BRT lane. However, this median bus lane showed how to accommodate large volumes of buses and bicycles in the same corridor without conflicts, which was important to the transportation development in the city at then²². Later by November, 2006, a 5-km Bus Rapid Transit lane was built as an extension of the existing median bus lane and formed a real BRT in Kunming, which opened in 2007.

In 2004, the first complete BRT path in China was implemented on the south central axis of Beijing City (Figure 7). The path length is 15.8 km, which passes through 3

²⁰ Xingtao Yu, 2006, Tongji University

²¹ Karl Fjellstrom, Bus Rapid Transit in China, Oct. 2010 ,
From [<http://www.atypon-link.com/ALEX/doi/abs/10.2148/benv.36.3.363>]

²² Karl Fjellstrom, Bus Rapid Transit in China, Oct. 2010

districts in Beijing, and included 16 stations. The designed operating speed is 30~35 km/h, and capability of the lane is 215, 000 people per day.²³

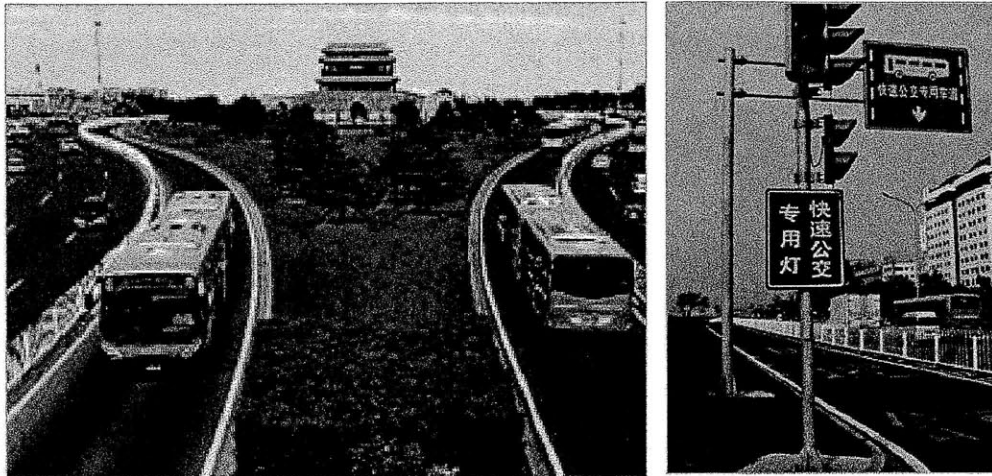


Figure 1.1-11: the dual BRT lanes on the south central axis road in Beijing

*The words on the signs said: “Dedicated line for BRT” (on top), “Dedicated traffic light for BRT” (on left pillar; Source: <http://www.gztpri.com/xs-viewer.asp?id=13>)

Since then, the development of BRT in China has been much advanced. Until now, there are over 10 cities having already built BRT routes, which included Kunming(Segregated busway in 1999, upgraded to BRT in 2007), Beijing (1st lane was opened in 2004), Hangzhou (2006), Dalian(2008), Changzhou(2008), Jinan(2008), Chongqing(2008), Xiamen(2008), Zhengzhou(2009), Hefei(2010), and Guangzhou(2010). (Figure 1.1-12) Several more cities like Wuhan, Tianjin and Nanjing are constructing or planning to construct BRT in the near future.

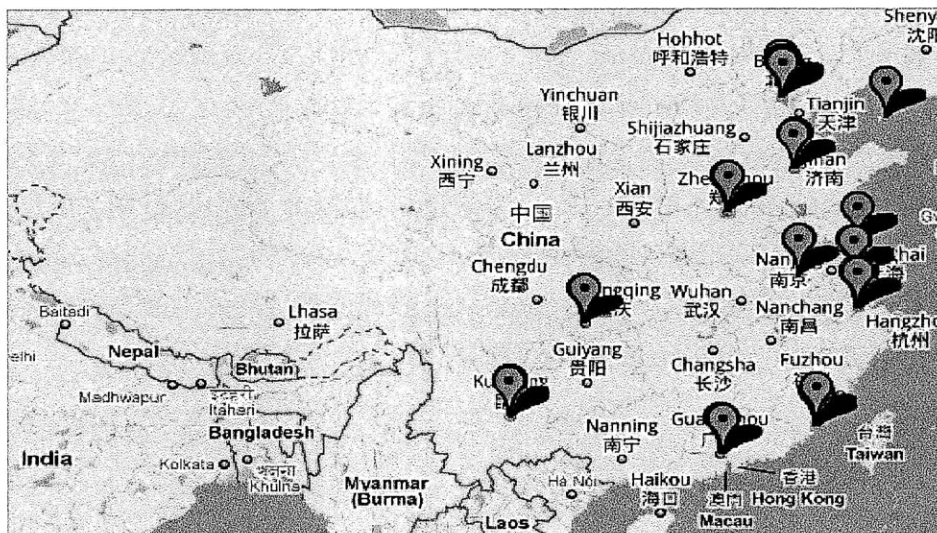


Figure 1.1-12 : The cities in China with BRT

Source: <http://www.chinabrt.org/defaulten.aspx>

²³ Daming Luo, xiaojing Ji, 2005

Along with its dramatic growth in recent years, doubts on BRT's efficiency and feasibility in China have not stopped as well.

First, BRT met its speed crisis in some earlier cases like *Beijing* and *Kunming*. In Beijing for instance, though a exclusive-right-of-way was incorporated in most parts of the route and there was only one bus line operating in the dedicated busway, the actual speed of the BRT could only sustain at around 16 km/h (about 10 mile/h), comparing to the designed speed at 30 km/h (about 17 mile/h) as mentioned. The difficulties for the BRT to be 'rapid' partly come from the time waste for traffic delays in front of the overset traffic lights on the street, since the bus signal priority for BRT hasn't been accomplished in both of the cases.

Moreover, calling for a clear right-of-way and highly-flowing stations, BRT system is occupying new space in the urban land use pattern, which brought new problems and conflicts, especially in the urban areas of big cities with narrow streets. The main complaints of BRT operations came from the private-car drivers, who feel disappointed for the even longer lines in the car lanes on the roads because of the segregation for BRT bus lanes (Figure 1.1-13).

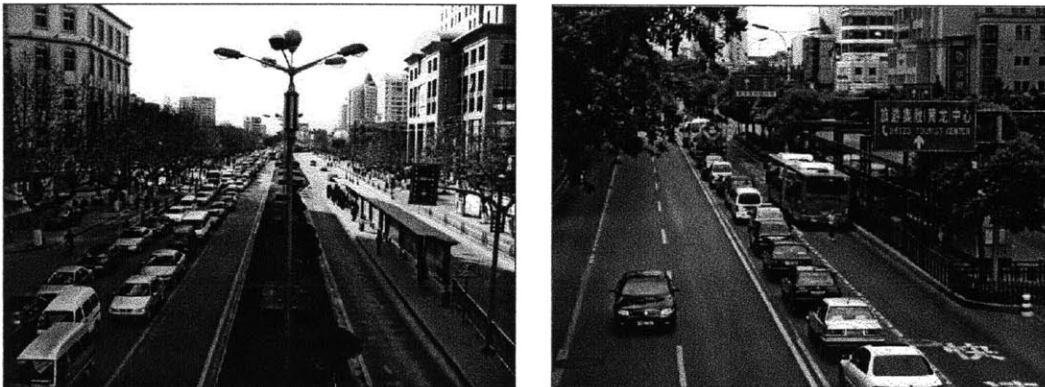


Figure 1.1-13: serious traffic congestions on the car lanes with almost empty BRT lanes
*(left): the BRT lane in Kunming, China, (right): Hangzhou city, China

Sources: <http://www.shenyangbus.com/a/hyzx/kskj/2010/0729/2084.html>;
<http://www.gztpri.com/xs-viewer.asp?id=13>

However, for such apparent advantages in capacity and costs weighing much more than bearing the problems, the Chinese governments still keep a doubtless enthusiasm on implementing BRT systems.

With upgrades in BRT technology and planning as well, the later BRT systems built have been improved in both of the efficiency and feasibility. The most important case recently is the BRT system opened in Guangzhou in 2010 (Figure 1.1-14), of which we will see discussions deeply in the later chapters.



Figure 1.1-14: Guangzhou BRT Shipai Qiao Station, by Karl Fjellstrom

Source: <http://www.transportphoto.net/photo.aspx?id=9900&c=Guangzhou&l=cn>

1.2. Research Topic

Motivation

Though the practices of BRT has been booming in China and the governments are paying two hundred percent enthusiasm to promote the developments of BRT, it does not mean the mode is totally perfect and omnipotent for solving all the problems in traffic. It might better than the old bus mode but still a transport tool essentially, which could bring advantages but also difficulty to the overall transportation situation in the cities. In another words, BRT is not a skeleton key for every problem.

More importantly, as mentioned above, the implementation of the new BRT system in the somehow maturely developed city areas is like inserting a new player in the already-started game, which will definitely bring new relations, competitions and even problems among urban transportation. The new relations, new competitions, new mergence and especially the new chances of development behind it are some interesting topics calling for our concerns.

Topic

Titled as “*Building Bus Rapid Transit (BRT) into the existing public transit system: Competition and integration of BRT and the urban rail transit in cities of China*”, this thesis chose the developments of BRT in China as research objectives.

Beyond discussions on BRT’s characteristics and its adaptability in China, this paper will specifically focus on the comparisons and the interactive relations between the BRT system and the urban rail transit, which mainly refer to the metro system. Not only the compatibility but also competitions will be recognized. Basing on that, I will summarize the integration models for inputting BRT into the urban transit system and try to find better ones letting the new transport pattern orient more sustainable and prosperous economic developments and urban growths.

Key questions

Centering at the main topic, there are several questions need to be answered in this paper, which include:

- What is the difference between BRT and the traditional public transit modes including the original bus service and the rail transit?
- What will constructions of BRT bring to the existing urban rail transit system, competitions, challenges or supplements? And which kind of competitions and challenges BRT will meet in its growth?
- Which one would be the dominant public transit mode in the future, BRT or metro? And what will happen to the other one?
- How to shape the relations between BRT and the urban rail transit in China? And How to connect and integrate the systems with each other (in the space, facilities, fares, management, and even technologies)?
- How to lead and finance the developments of BRT and the urban rail transit in great order step by step? How to handle the managerial and financial relations in their developments?
- What are the most important issues in the transport integration? What are the challenges? And how to solve them?

Methodology & Data

The major studying method in this research is to summarize the previous experiences learn from former lessons and analyze the mechanism behind.

Primarily, the literature and theoretical reviews should be accomplished, and summarizing the experience from previous BRT constructions and practices all around the world will also help; Then narrowing down to China, where a lot of BRT projects is building and planning, comparison between cities and case studies will be a great tool to analyze the rules and mechanisms behind.

Therefore, references to governmental data on planning and construction projects and also previous studies will be necessary. In this process, both qualitative and quantitative analysis would be included, and the data supporting behind will be generally the statistics, planning reviews and even construction summaries of BRT projects and other transportations in China.

1.3. Organizing Logic and Structure in this paper

Chapter 1: Introduction already brought us some basic backgrounds in the topic.

Following, ***Chapter2: the System of BRT*** will first bring us some brief knowledge about the characteristics of the BRT system.

Then, in ***Chapter3: BRT V. Urban Rail Transit***, detail discussions will be provided on the compares, competitions, compatibility and cooperation between BRT and Urban Rail Transit (URT).

Finally, in ***Chapter 4: Integration of BRT & URT***, based on the understandings of the differences between BRT and URT, we will discuss the methods and crucial issues in integrating BRT and URT systems and work together efficiently with other modes in public transport services.

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CHAPTER 2. THE SYSTEM OF BRT

2.1. Distinguishing characteristics of BRT

2.1.1 Advantages of BRT

As mentioned, comparing to private transit, traditional public transits always have some inherent disadvantages, such as *lack of flexibility, comparatively lower commuting speed and comfort in trips, inevitable walking distances on endpoints and waiting time on stops, and troubles for transfers and crushing crowds in peak hours* (Lei Chen, 2006). In addition, the construction of a public transport system, especially a metro system, normally costs a lot of funds fixedly in the first stage.

However, BRT, as a new sustainable transport mode, is different with traditional public transits. According to previous summarization by US Federal Transit Administration, there are concrete improvements of BRT in the urban transport services comparing to the traditional public transits: ²⁴

1) Travel Time: BRT could bring travel time savings to the urban commuters. Among all, BRT projects with more exclusive running ways generally experienced the greatest travel time savings compared to the local bus route. Exclusive transit-way projects operated at a travel time rate of 2 to 3.5 minutes per mile, and arterial BRT projects in mixed flow traffic or designated lanes operated between 3.5 and 5 minutes per mile.

2) Reliability: Passenger surveys indicate that reliability is important for attracting and retaining passengers. BRT services normally go with intelligent-technologic control systems behind tracking the buses, such as automated vehicle location systems, which would bring more efficiency and reliability in the service. As expected, systems with more exclusive transit-ways demonstrated the most reliability and the least schedule variability and bunching.

3) Image and Identity: A successful transport system should be able to achieve a distinct identity and position in the respective region's family of transit services. Performance in achieving a distinct brand identity for BRT has been measured by in-depth passenger surveys in US, and according to the surveys, BRT passengers generally had higher customer satisfaction and rated service quality higher for BRT systems than for their parallel local transit services, which could help the public transit system to attract a bigger share in the passenger resources.

²⁴ Mainly from: Federal Transit Administration (FTA), US, Characteristics of BRT for decision making, 2004

4) **Safety and Security:** Data from Pittsburgh suggest that BRT operations on exclusive ways have significantly fewer accidents per unit (vehicle mile or vehicle hour) of service than conventional local transit operations in mixed traffic.

5) **Capacity:** First, the large-capacity type of vehicles usually used in BRT system bring the carrying capability per bus up, and more importantly, the exclusive transit ways and some special priority rights on the road make sure the implementation could run faster to transit more passengers per hour, which results in a similar carrying capacity comparing to a metro system.

Because of its advantages in service efficiency and quality, some benefits of BRT system implementation are now being felt. The most tangible related benefits are:²⁵

1) **Additional ridership:** There have been significant increases in transit ridership in virtually all corridors where BRT has been implemented. Ridership gains of between 5 and 25% are common. Aggregate analyses of ridership survey in US results suggest that the ridership increases due to BRT implementation exceed those that would be expected as the result of simple level of service improvements. This implies that the identity and passenger information advantages of BRT are attractive to potential BRT customers.

2) **Capital cost effectiveness:** Recently implemented BRT systems have focused on less capital-intensive investments. Depending on the operating environment, BRT systems are also able to achieve service quality improvements. Furthermore, BRT systems are able to operate with lower ratios of vehicles compared to total passengers. Thus, BRT demonstrates relatively low capital costs per mile of investment.

3) **Operating efficiencies:** Experience shows that when BRT is introduced into corridors and passengers are allowed to choose BRT service, corridor performance indicators (such as passengers per revenue hour, subsidy per passenger mile, and subsidy per passenger) improve. Furthermore, travel time savings and higher reliability enables transit agencies to operate more vehicle miles of service from each vehicle hour operated.

4) **Increases in transit-supportive land development:** In places where there has been significant investment in transit infrastructure and related streetscape improvements, there have been significant positive development effects. TOD chances will also increase related to the developments in public transports. Experience

²⁵ All from: Federal Transit Administration (FTA) US, Characteristics of BRT for decision making, 2004

is not yet widespread enough to draw conclusions on the factors that would result in even greater development benefits from BRT investment, although the general principle that good transit and transit-supportive land uses are mutually reinforcing should hold.

5) ***Improvements in environmental quality:*** Documentation of the environmental impacts of BRT systems is rare. Experience does show that there is improvement to environmental quality due to a number of factors. Ridership gains suggest that some former automobile users are using transit as a result of BRT implementation. Transit agencies are serving passengers with fewer hours of operation, potential reducing emissions. Most importantly, transit agencies are adopting vehicles with alternative fuels, propulsion systems, and pollutant emissions controls.

(Refer to FTA, 2004)

2.1.2 Essential components

BRT systems are commonly described in terms of a set of elements, or at least a range of considerations for a number of standard elements. These include:

- ***Running Ways:*** Options range from general traffic lanes to fully-grade separated BRT transit ways;
- ***Stations:*** BRT stations vary from simple stops with basic shelters to complex intermodal terminals with many amenities.
- ***Vehicles:*** Options vary in terms of size, propulsion system, design, internal configuration, and horizontal/longitudinal control, all of which impact system performance, capacity and service quality.
- ***Intelligent Transportation Systems:*** ITS options include vehicle priority, operations and maintenance management, operator communications, real-time passenger information, and safety and security systems.
- ***Fare Collection:*** Options range from traditional pay-on-board methods to pre-payment with electronic fare media.
- ***And Service and Operation Patterns:*** Designing a service plan should meet the needs of the population and employment centers in the.

	System Performance				
	Travel Time Savings	Reliability	Identity and Image	Safety and Security	Capacity
RUNNING WAY					
Running Way Segregation	●	●	●	●	●
Running Way Marking			●		
Running Way Guidance	●		●	●	
STATIONS					
Station Type	●		●	●	●
Platform Height	●	●	●	●	●
Platform Layout	●	●			●
Passing Capability	●	●			●
Station Access			●	●	
VEHICLES					
Vehicle Configurations	●	●	●	●	●
Aesthetic Enhancement			●	●	
Passenger Circulation Enhancement	●	●	●	●	●
Propulsion Systems	●		●		
FARE COLLECTION					
Fare Collection Process	●	●	●		●
Fare Transaction Media	●	●	●	●	●
Fare Structure	●		●		●
INTELLIGENT TRANSPORTATION SYSTEMS					
Vehicle Prioritization	●	●	●		●
Driver Assist and Automation Technology	●	●	●	●	●
Operations Management	●	●		●	●
Passenger Information	●	●	●	●	
Safety and Security technology				●	
Support Technologies					●
SERVICE AND OPERATING PLANS					
Route Length		●			
Route Structure	●		●		
Span of Service		●			
Frequency of Service	●	●		●	●
Station Spacing	●	●			

Figure 2.1-1: Relations between elements and system performance

Source: FTA, US, *Characteristics of BRT for decision making, 2004*

As mentioned in Chapter 1, to distinguishing BRT from the normal bus transits, there are *some essences* in all the elements to satisfy for (Prof. Ralph Gakenheimer, Massachusetts Institute of Technology): *1.Dedicated lane(s) for buses; 2.Stations for prepayment of fares; 3.Large doors for short stops; 4.Passing priority at the intersections; And 5. High-tech communication and operation control in the system*²⁶.

²⁶ Last one was added by author

Though not all the BRT systems in different cities around the world could satisfy in all of the conditions, in most of the successful cases of BRT constructions and implementations, these core and essential components did play key roles for the whole system's efficiency and achievements.

- ***Dedicated Busway***

Reserving dedicated lanes for BRT specifically is the most effective way to keep the transit services from the interrupts from other road transports and also traffic congestions to guarantee the operation speed and safety.

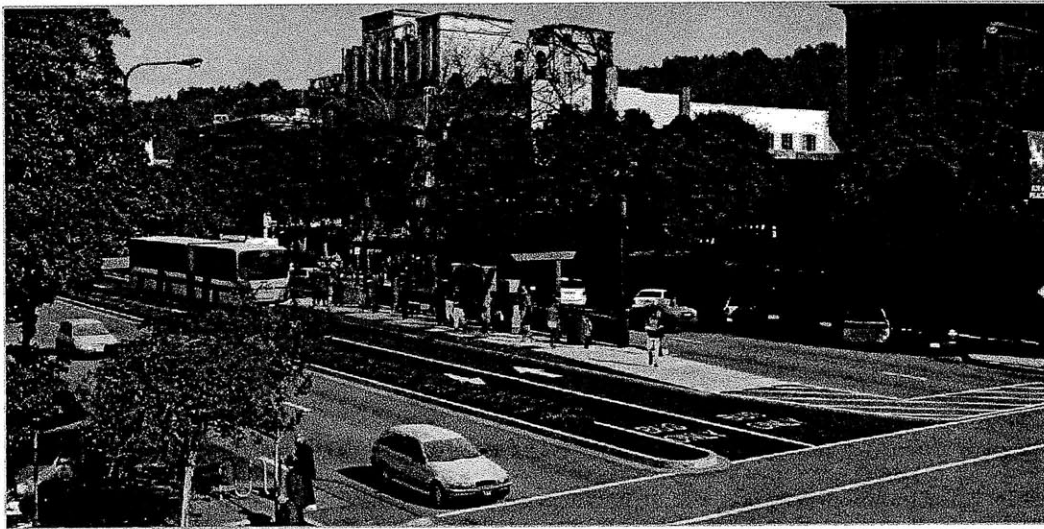


Figure 2.1-2: Schema of Bus-Only Lanes in street (Dedicated busway)

Source: [<http://www.thetransportpolitic.com/2010/04/22/east-bay-bus-rapid-transit-receives-support-from-oakland-as-berkeley-hesitates/>]

In more detail categories, two types of dedicated busways are often seen in different areas.²⁷

1. *Designated (Reserved) Arterial Lanes*

Designated (Reserved) Arterial Lane is the most common busway can be seen in the world for BRT busways. In corridors where the alignment of the BRT route follows an existing arterial roadway, designated lanes can provide BRT vehicles with a fast, reliable alternative to mixed flow traffic lanes. Other vehicles are restricted from using the lane. This is enforced through a *physical barrier* or through *police*

²⁷ The names of types refer to FTA, US, Characteristics of BRT for decision making, 2004, but in that paper, three types were introduced based on US situations.

enforcement. BRT vehicles thus face minimal congestion delay between intersections. With designated lanes, BRT vehicles are not delayed in the approach to a station by a queue of other vehicles. Designated lanes thus reduce travel times and improve reliability. Based on the survey in US, the Cost of this implement is about \$2.5 - \$2.9 million per mile per lane (excluding ROW acquisition), which is cheaper than totally-separated transit way.²⁸

As an additional advantage, this type of busways has the flexibility to transfer and mix up between Designated Arterial Lane and mixed flow lanes with no reservation lane for BRT. The city will choose to reserve some busy divisions of the lines to be Designated Arterial Lanes and others could still keep them in mixed flows.



Figure 2.1-3: The entrance of a dedicated busway in Guangzhou

Notice: On viaducts, the busway will only be dedicated to BRT in commuting peak hours (5:30-7:00 pm)

Sources: Karl Fjellstrom, ITDP, 2010;

To some extent, the performances of these designated busways also depend on the separating grade between lanes. In some cities, the busways are nearly totally separated from other lanes by fixed and firm physical barriers through the entire route. In some others, with little physical barrier, the restrictions will mostly effect through police enforcements. In some cases, only the policy barriers could work not as well as physical barriers.

²⁸ FTA, US, Characteristics of BRT for decision making, 2004

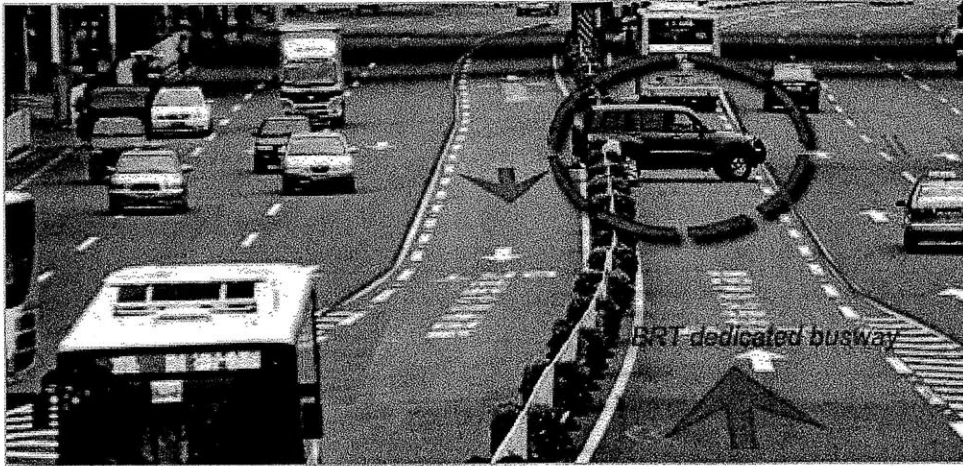


Figure 2.1-4: Rule breaker driven into BRT lane in Guangzhou

Notice: In the first 10 days of operation, four accidents were caused by rule breakers in BRT lanes.

Source: [<http://news.bitauto.com/jiaotong/20100221/0805102726.html>]

2. Fully Grade-Separated Exclusive Transitways

The running way type with the greatest level of separation is the grade-separated exclusive transitway. These facilities can either be stand-alone (as in the use of former railroad rights-of-way) or be on a major highway (either running along the side or in the median of a freeway or in a separate elevated or underground viaduct). Grade-separated exclusive transitways allow BRT vehicles to operate unimpeded at maximum safe speeds between BRT stations.

The most famous example of fully grade-separated exclusive transitways in China is the BRT system running in Xiamen City, which was built on a viaduct line for the entire route. (Figure 2.1-5)

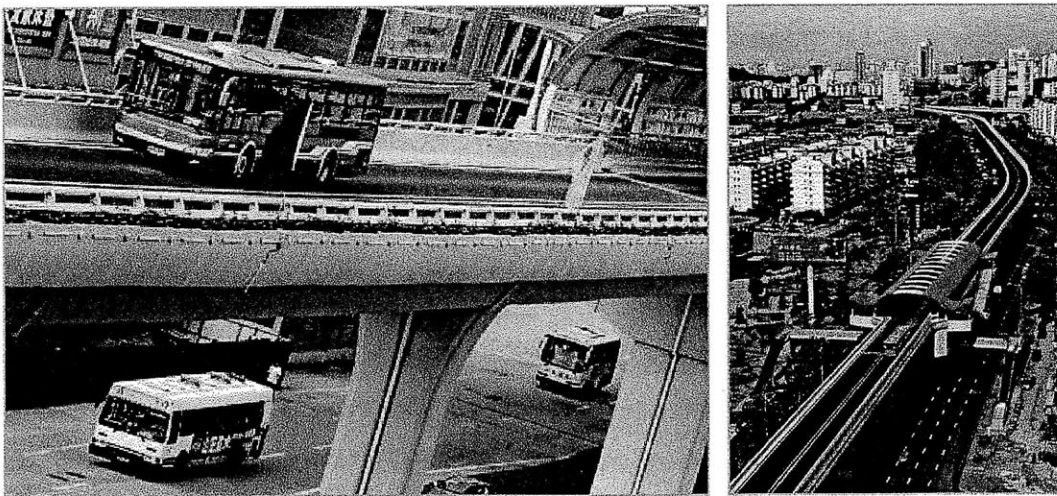


Figure 2.1-5: BRT lanes on viaduct in Xiamen city, China

Sources: (left) [http://house.xmnn.cn/housenews/xwzx/bdxw/200811/t20081106_5828.htm]

(Right) [<http://auto.sina.com.cn/news/2008-09-11/1529409341.shtml>]

- ***Stations for prepayment of fares***

Off-board fare collection system supporting prepayment of fares on platform is helpful to shorten the stop-and-pick up time of buses by saving the fare-paying time for everyone on board and allowing passengers to use all 3 doors to enter and exit the bus²⁹.

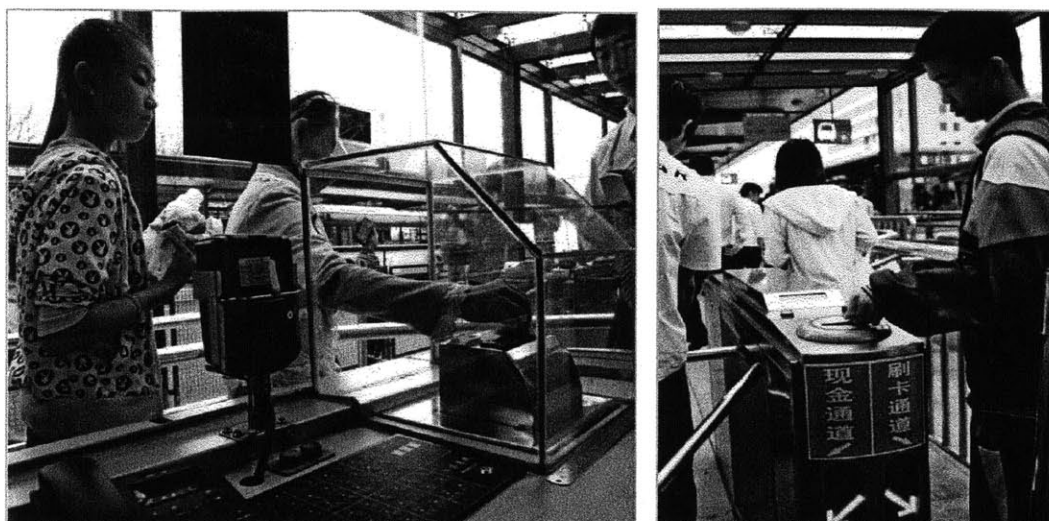


Figure 2.1-6: Off-board fare collection systems supporting prepayment of fares in Guangzhou

Source: GIT, China, Operations management of the BRT pilot line on Zhongshan Road in Guangzhou, 2010

Nowadays, most of BRT systems in China still preserve on-board fare collection methods, but off-board fare collections have been becoming better known and is the trend for the future. Detailed introductions on fare collection methods in BRT system could be found in Chapter 4, 4.3.2 Compatible fare collections (page 115).

- ***Large doors for short stops;***

Large doors of the vehicles (and also gates on the stations if there is any) will also be good for shortening the boarding time, so as to make the stop and pick-up of buses become more efficient.

Taking the *TransMilenio* system in Bogota as a successful example, not only the vehicles in the BRT system was designed with multi double-size two-sashed doors (Figure 2.1-7), but also the BRT stations matching with the buses also have enlarged gates for quicker boarding of passengers.

²⁹ Refer to [<http://www.nyc.gov/html/brt/html/faq/glossary.shtml>]



Figure 2.1-7: The vehicle and the double two-sashed doors in TransMilenio system

Notice: Comparing to the doors on normal bus, the width could be at least double

Source: [<http://www.skyscrapercity.com/showthread.php?p=51593709>];
 [<http://www.transportphoto.net/photo.aspx?id=1569&c=Bogota&l=en>]
 [<http://news.sina.com.cn/c/2009-06-06/040315743522s.shtml>]

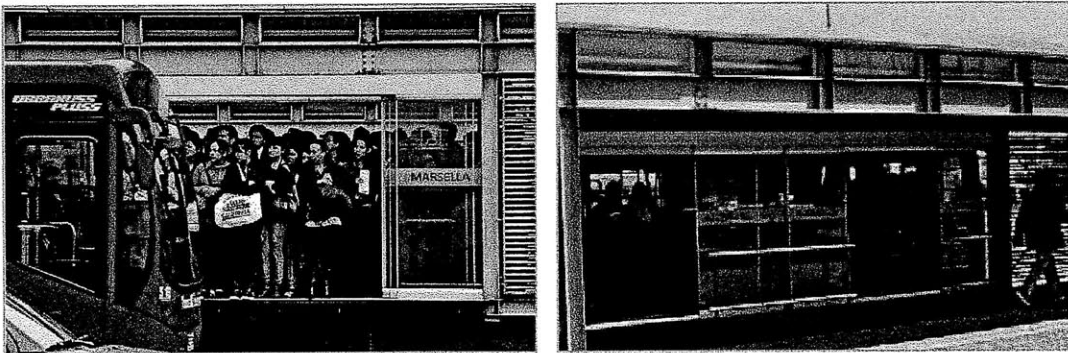


Figure 2.1-8: Enlarged sliding gates on BRT platform in TransMilenio system

Notice: The width of the gates just matches with the one of the bus doors.

Source: (Left)[<http://thecityfix.com/blog/transport-and-inequality-in-latin-america-and-the-caribbean/>]
 (Right)[<http://www.skyscrapercity.com/showthread.php?p=51593709>]

Also importantly, large doors with facilities like wheelchair lifts will be good for convenience of the disabled. (Figure 2.1-9)

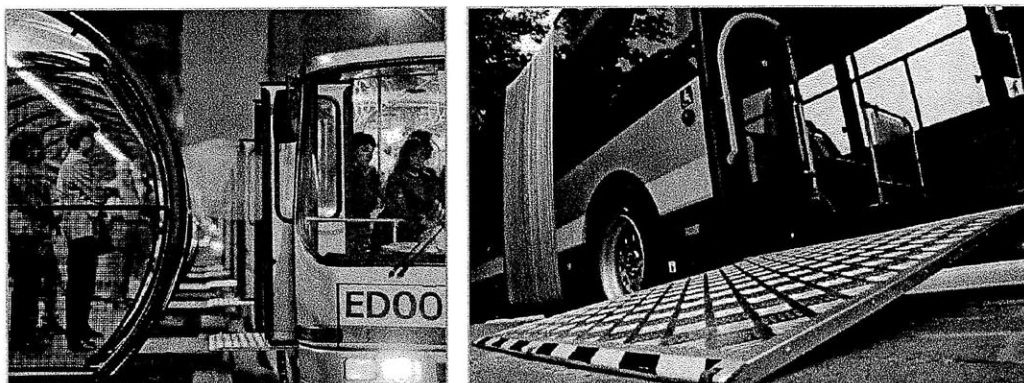


Figure 2.1-9: disabled-accessible bus doors of BRTs in Curitiba (L) and Guangzhou (R)

Source: [<http://inhabitat.com/transportation-tuesday-curitiba/>] [<http://china.rednet.cn/c/2007/09/04/1310821.htm>]

- *Passing priority at the intersections*

Intersection is one of the key points in BRT system. Unreasonable designs and managements on intersections will lower down the operation efficiency of the whole system. A great design should comprehensively consider the needs and safety of all the transits and pedestrians on the road and make the best balance between them to guarantee a safe but efficient transport system.³⁰

For BRT system specifically, because all the buses will need to spend time on stopping in front of stations, discharging and picking up passengers, so they are easier to meet more red lights comparing to mixed car flow. How to reduce the time spending on waiting for green light is one of the big issues for increasing the system efficiency. Especially in the developed western countries, BRT systems normally have lower-flows and passenger-capacities but will meet more intersections, this kind of red-light delays are more apparent.³¹

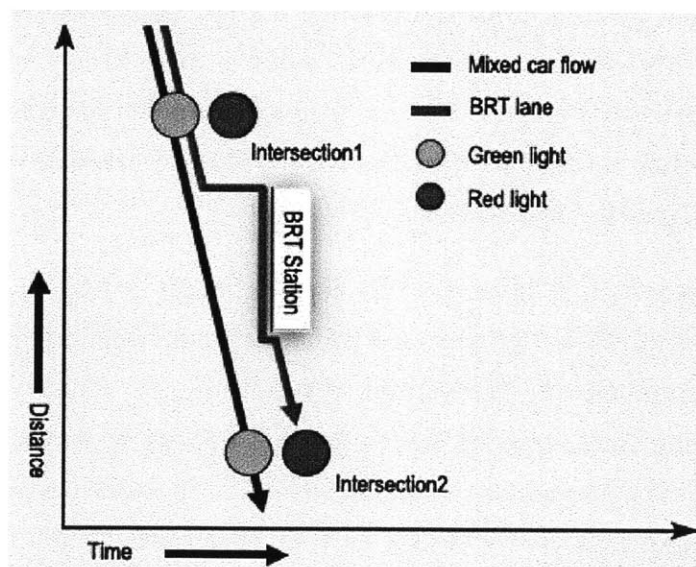


Figure 2.1-10: Compare between BRT and mixed car flows on speed of passing intersections

Notice: In the same green-light period, the mixed-car flow could pass two intersections, but buses in BRT lanes might only be able to pass one because of the stop time in front of stations.

Source: China UTC, *Guidebook for Planning and Design of BRT, Chapter9. Intersection and Signal Control, 2007*

Several ways could be used to reduce the waiting time before intersections. One is to build up multi-layer intersections with express tunnels or viaducts only for BRT buses. (Figure 2.1-11) This way is most effective to keep the BRT lanes away from any interrupt by traffic controls and lights. However, it is very expensive to build up, not economic enough for regular cases in most of the areas.

³⁰ China UTC, *Guidebook for Planning and Design of BRT, Chapter9. Intersection and Signal Control, 2007*

³¹ China UTC, *Guidebook for Planning and Design of BRT, Chapter9. Intersection and Signal Control, 2007*

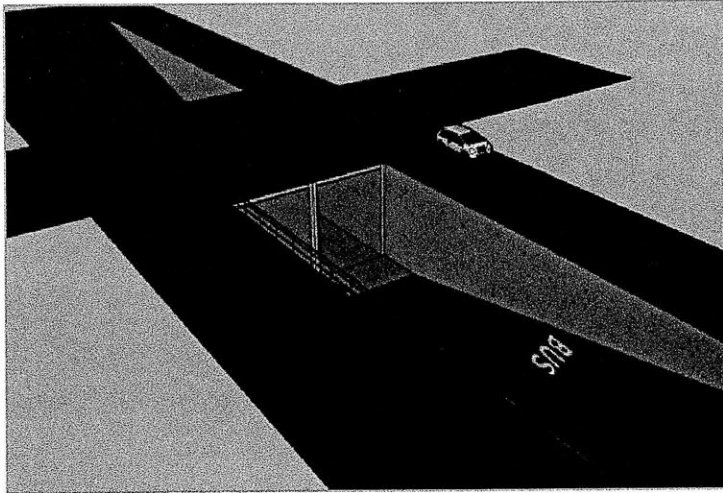


Figure 2.1-11: Schema for the underpass only for BRT buses before intersection

Source:
 [http://praja.in/en/discuss/2008/01/brts-right-all-cities]

Bus priority signal is another popular way for the same purpose. Various signal priority schemes have been developed and implemented in many countries. By adjusting signal timing, the system gives priority to BRT that allows buses to pass through intersections more quickly: Sensors could track when a bus nears an intersection, and turns traffic signals turn green sooner, or keeps them green longer. This keeps the bus moving, speeding up the bus trip. This way will also effectively shorten waiting time of buses at signalized intersections.³²

The selected signal priority approach that gives priority just for buses satisfying particular criterion may be a way to relieve the potential problems under congested network condition. Since the magnitude of disadvantage for non-priority vehicles depends on the frequency of giving signal priority, selected signal priority approach gives less influence on other vehicles. In addition, each priority event is expected to be more effective because the approach gives priority only to buses that need it. Furthermore, depending on specified criterion, the selected signal priority strategy can derive other benefits such as reliability enhancement and headway regularization of buses.³³

The whole process for providing priority signal to BRT buses is illustrated in Figure 2.1-12. Four main steps, including Detection, estimation, request-applying and application processing, will need to accomplish for every priority signal provision. For the signals, both of the transmitting terminal and the receiving terminal will be essential. In facilities, the signal-calling equipment on buses and backstage answering

³² Refer to Suhyeon Kim, Mincheol Park, and Kyungsoo Chon, A bus priority signal strategy for regulating headways of buses, 2005 and [http://www.nyc.gov/html/brt/html/faq/glossary.shtml]

³³ Suhyeon Kim, Mincheol Park, and Kyungsoo Chon, A bus priority signal strategy for regulating headways of buses, 2005

and control center will also be necessary. Therefore, it requires a technical upgrade in the whole system. The performance of the priority signals will be affected by the reliability and calculating speed of backstage technologic operations. As a result, this passing priority signal controlling system cannot be low-cost. The first stage investments for all the equipments (ex. Sensors, signal-controlled traffic lights, etc) will be considerate, and even the following maintenance expenses will not be cheap.

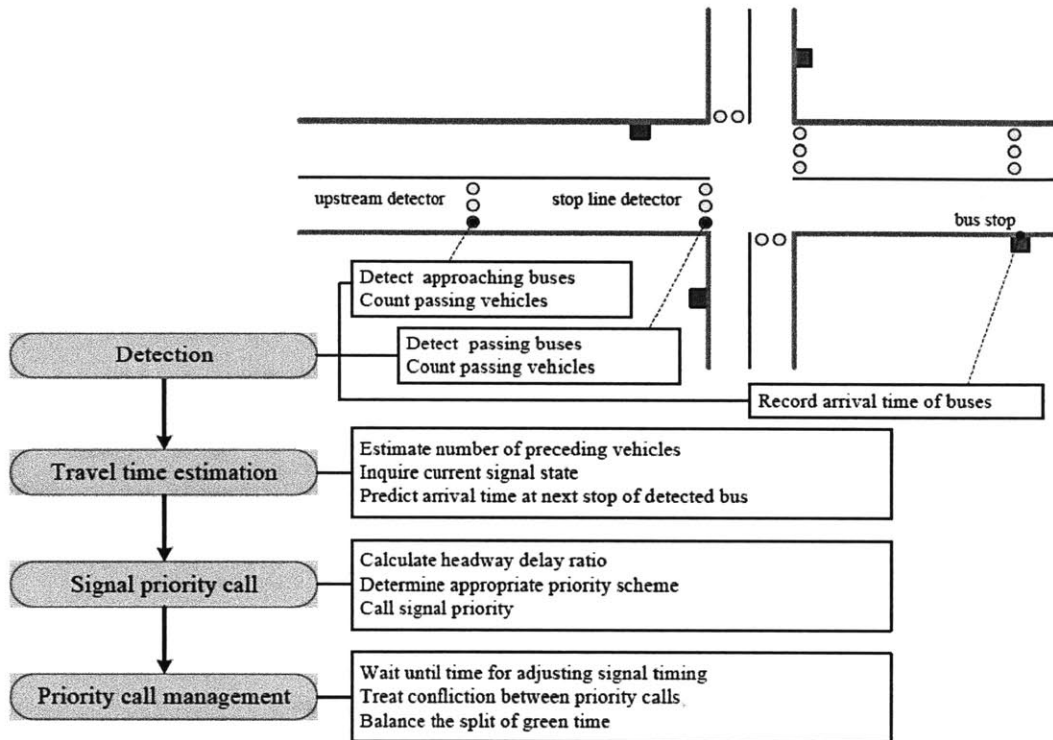


Figure 2.1-12: Expected Process of signal priority provision

Source: Suhyeon Kim, Mincheol Park, and Kyungsoo Chon, *A bus priority signal strategy for regulating headways of buses*, 2005

Therefore, to get persuasive reasons for introducing bus signal priority, many aspects like travel time, waiting time, operating cost and emission of pollutant of all the travelers or vehicles should be considered. Comprehensive measurements of spending and saving and estimation of necessity before constructions should be made. For example, for most of the developing areas like China, different with developed countries, BRT system is facing high-flow and burden of passenger transits. The reasons behind traffic jams are more complicated. Some congestion even happens in dedicated busway. There are a lot of issues waiting for improvements and upgrades, and passing priority control at intersections is only one of them. Which one is more urgent, more necessary under current situation should be figured out when the budget is limited.

- **High-tech communication and operation control**

As a new-age transit, BRT is expected to operation with signal priority, operator lane assist, reduced headways between vehicles, and real time information may need both more frequent updates and more types of data than normal operations.³⁴ Therefore, supporting and cooperating with the vehicle priority signal and other functions, a high-tech communication and operation control system will be important and imperative in BRT service, the core of which is intelligent technology.

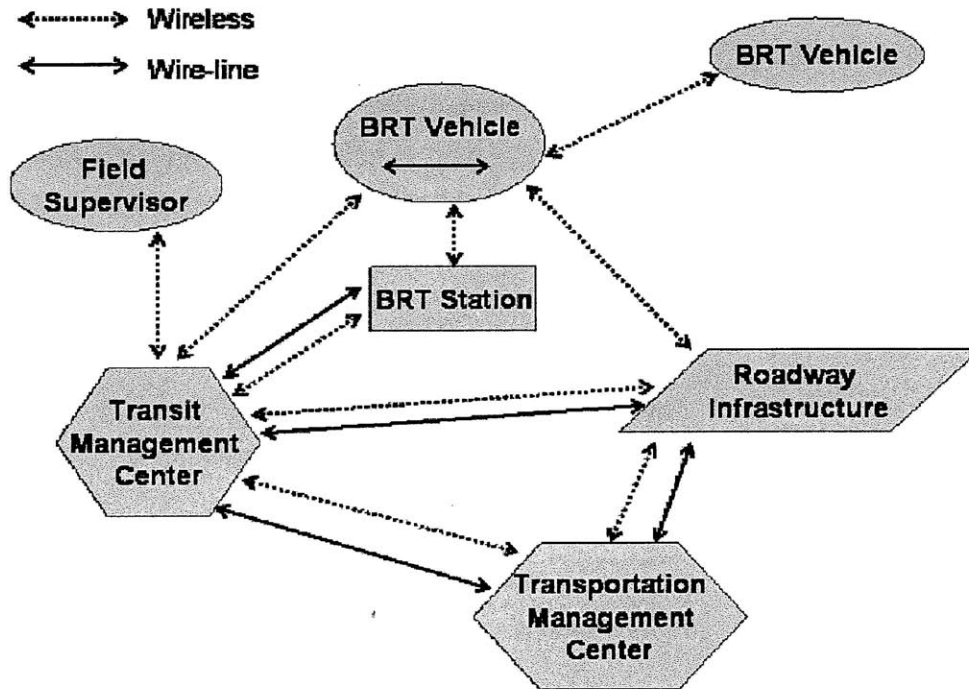


Figure 2.1-13: Schematic BRT Advanced Communication

Source: FTA, US, Characteristics of BRT for decision making, 2004

Ideally, the communication system based on intelligent technologies can transmit both voice and data as an integrated system. It is not focused purely upon the communications between the BRT vehicle and the transportation management center. As shown in Figure 2.1-13, Communications and information interaction keep frequently between various elements of BRT system, either via wire line or wireless.³⁵ This high-tech communication and operation control on BRT system will be meaningful to make sure the transit service operating efficiently and orderly. Additionally, it will also be helpful for further information and management integration between BRT and URT, which will be discussed in later chapters.

³⁴ Federal Transit Administration (FTA), US, Characteristics of BRT for decision making, 2004

³⁵ Refer to: Federal Transit Administration (FTA), US, Characteristics of BRT for decision making, 2004

2.2. Different patterns in operation of the BRT system

According to the previous experiences, there are several different patterns to build up BRT systems. The underlying relations between BRT and the urban transit system bring various roles and importance of BRT (Lei Gao, Wei Wang, Jun Dai, 2006):

1) Build BRT as the central mode in public transit;

To follow this mode, a complete and widespread BRT network should be built up, which could be regarded as an alternative for a metro system. (Lei Gao, Wei Wang, Jun Dai, 2006) As a result, this mode could be only operated in the cities where a metro system hasn't been constructed or hasn't become the major public transit. Normally, it is suitable for middle or secondary-scale cities where the population and transportation needs are not big enough to balance the costs of the construction of a metro system.

4) Build BRT as a cooperator with the metro or light rail system;

This is a mode popular in some very developed mega or big cities like Hong Kong or Taipei. It could bring the maximum utility of BRT system and also could possibly save part of the investments on constructions and operations. This mode requires rapid and fluent connections and transfers between the metro and BRT lanes and stations. To reach this, the cities should do a comprehensive transportation planning at the very front to consider the cooperation between different transit systems. (Lei Gao, Wei Wang, Jun Dai, 2006)

2) Build BRT as a supplemental branch linked to the central rail system;

This mode could work in the big cities where a metro or light rail system has already be built up but the service radius hasn't reach the whole city area and on the edge of urban area or in the new developing zone in the suburb, the transportation demand is not that big as the one in the central area, so that building a cheaper BRT lane will be more economically practical than adding a new metro rail. (Lei Gao, Wei Wang, Jun Dai, 2006)

3) Build BRT temporarily as a transition to an urban rail system in the future;

For the cities that are planning to build an urban rail system eventually but doesn't totally get ready financially or spatially, it is a good choice to build BRT first, which could satisfy the transport needs more in time and save some transportation corridor for the future (Lei Gao, Wei Wang, Jun Dai, 2006). Later when everything is ready,

the metro system could be constructed, sometimes even under the BRT corridor. This is a mode suitable for some comparatively smaller-scale cities in their starting stage of growth.

5) *Build BRT exclusively isolated from the existing public transit system.*

This is a very unique mode calling for an independently development of BRT. It basically refer to the plan that to build totally exclusive or isolated BRT lanes without connections to the urban rail transit. It normally got implemented in the preliminary stage of constructions or for a special use. (Lei Gao, Wei Wang, Jun Dai, 2006)

However, no matter which developing mode is chosen, when the city decide to squeeze BRT and the original public transit system altogether into the limited transportation zoning space, the new constructions and changes will inevitably bring new relations, competitions and even problems among urban transport system at the mean time. Especially, in the progress of inputting BRT, the compare and competition between BRT system and the urban rail transit, both as suppliers of passenger transit service, will be raised, no matter in space or financially. Though, on the other side, there might also be compatibility and cooperation, and even the chance of the public transportation integration. In the following Chapter 3, all of these issues will be covered.

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CHAPTER 3. BRT V. URBAN RAIL TRANSIT

BRT and Urban Rail Transit are both public Transit with high capacities. To some extent, the two services are substitute for each other. (Though in most of the cases, there might be complementary and substitution effects simultaneously.) Therefore, there inevitably are some *comparisons and competitions* between the two. For a better understanding on relations between BRT and urban rail transit, this Chapter tries to get these topics included in our discussions.

3.1. Compares

As different fast public transit modes, BRT, light rail transit (LRT) and Metro, they each have a variety of advantages and disadvantages.

Qualitatively speaking, comparing to urban rail transits, BRT most importantly has more flexibility in construction and service. In construction, it could be built in phases or together to knit the whole transit network for the city, but also could be considered as an interim stage or transition to a rail transit finally. In service, the bus capacity, route, operation time could be extended or changed according to the developing or varying needs in urbanization.

Comparatively, for urban rail transit, because of the complexity and huge investments in early-stage constructions, it cannot be built and used in the same period, and all the routes, stations and operations could be hard to change. For reducing the average cost and increasing efficiency also, building an urban rail system (no matter LRT or metro) will tend to motivate more constructions for additional rail lines, but the efficiency for new branches in lower-density zones can hardly be kept in the same level with the earlier network formed in the higher-density areas of the city.

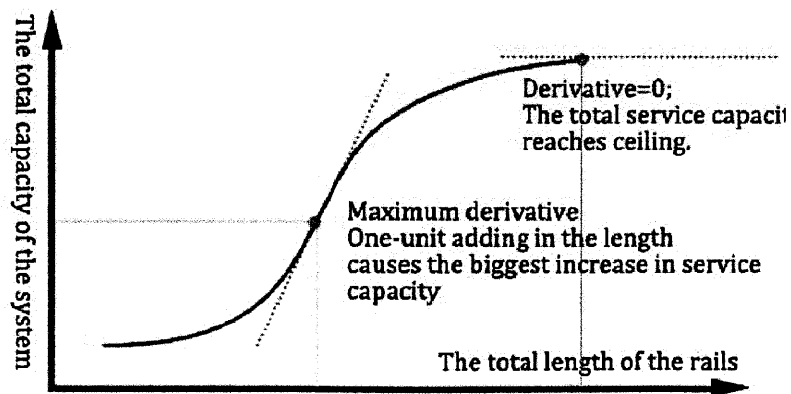


Figure 3.1-1:
Sketch the simple relationship between the total length in the urban rail transit system and its service capacity

(Source: Author)

A former study in Guangzhou shows that the average trip distance by public buses is 7.46km, while the one by metro Lane 1 is 5.33 km, and by metro Lane 2 is 4.93 km (Feng Jin 2008). From Figure 3.1-2 also, the biggest share of service by metros in the whole public transit system happened on the trips between 4 and 6 km, and its share will decline subsequently with an increase in trip distance. This shows the “huge-capacity, short, concentrated” characteristics of metro services, which is not very suitable for long-distance travelers or commuters who need more flexible transport service to approach their homes.

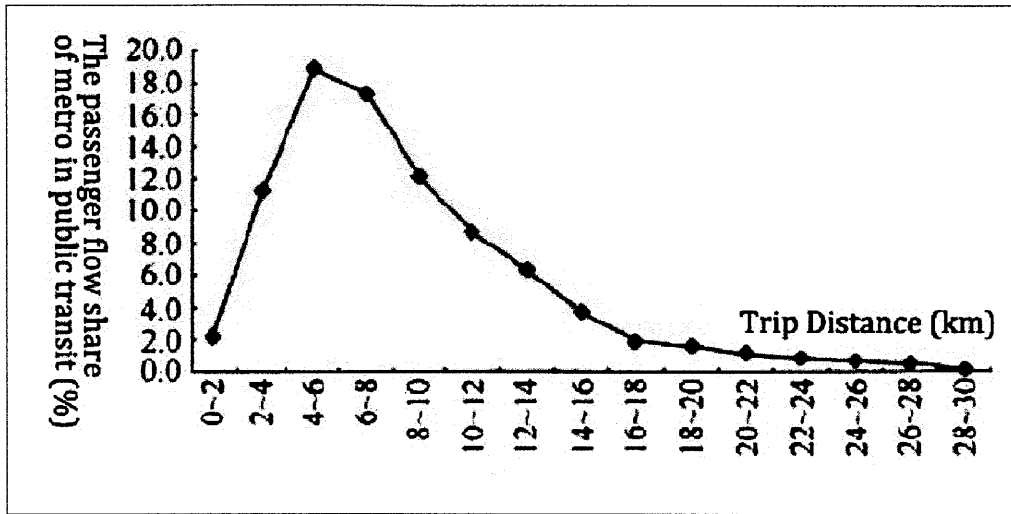


Figure 3.1-2: The distribution of passenger flow share of metro in public transit on trip distance in Guangzhou (By regression)

Source: Feng Jin, 2008

However, urban rail transits still have advantages in some aspects comparing to BRT. First, urban rail transits especially metros underground could save more space on the roads than BRT. For BRT, since the bus lanes are generally arranged on road (except some cases locate underground or at viaduct), sometimes even dedicated from the existing road lanes, it will affect and be involved in the road traffic to some extent.

Also, urban rail transits could have higher stability and reliability in service safety and schedule. Because BRT is still involved in road traffic, though with some priority at crossing in some cities, the service cannot be fully isolated from the traffic condition and also safety performance in the whole road transport system, so its service stability and time reliability cannot be highly guaranteed like metros or light rails.

Besides this qualitative awareness, we would also like to know more about the differences in more quantitative and detail way.

To do the comparison quantitatively, Table 3.1-1 first shows a comparison between them on general service features by a Chinese scholar based on 2006 data.

Table 3.1-1: Compare the General Features between BRT and Urban Rail Transits.

Index	BRT	Light Rail (LRT)	Metro
Feature	Dedicated busway or mixed-up lanes	Dedicated busway or mixed-up lanes	Dedicated corridor
Distance between stations	350~800 meter	350~800 meter	500~2000 meter
Capacity per carriage	40~120 p	110~250 p	140~280 p
Normal speed*	20~40 km/h	20~45 km/h	25~60 km/h
Safety	High	High	Very High
Construction cost per km*	\$ 6~15 Mil	\$ 12~34 Mil	\$ 120~180 Mil
Minimum City Population	750,000	1,000,000	2,000,000
Minimum City Center Scale (Population)	400,000	500,000	700,000

Source: Lei Chen, 2006.

*The amount ranges of speeds and construction costs are very various according to different sources and between diverse regions.

Following, I would also like to give analysis in detail on some important aspects like *Speed, Capacity, Cost, Energy efficiency and Sustainability*.

Speed

Theoretically, a comparatively-complete-and-upgraded BRT system can reach a similar operation speed to a light rail transit system (LRT), but for the situation of metro systems, the railways still have advantages in speed than buses on road. As Table 3.1-1 above illustrates, the general speed of BRT operations in theory is between **20~40 km per hour (12~25 mile per hour)**, closed enough to the speed in **20~45 km/h (12~28 mile/h)** of light rail, even still having distance to the **60 km/h (37 mile/h)** maximum speed of metros. A research on BRT³⁶ systems in US (in 2001) even showed that for most of the studied cities with BRT projects in US, the average speed of BRT is higher than the light rail services. (Figure 3.1-3)

³⁶ Notice: The BRT project in US normally has a comparative lower speed than a typical BRT, so as to be called Bus Semi-Rapid Transit (BSRT).

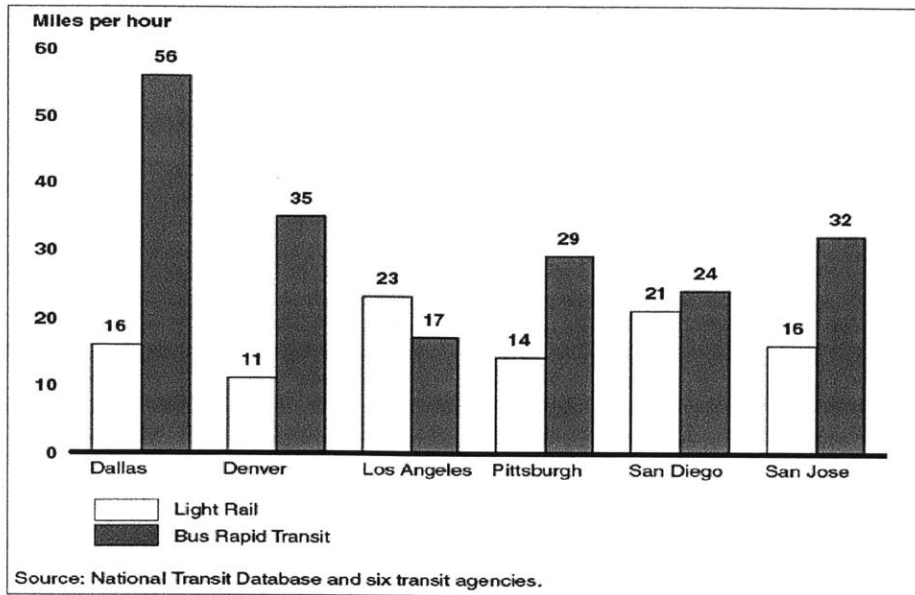


Figure 3.1-3: Average Speeds of BRTs and LRTs in different cities in US, 1999

Source: GAO, Bus Rapid Transit Shows Promise, September 2001

Notice: The BRT and LRT projects in US normally have lower operating speeds with lower passenger density comparing to some countries in Latin America or Asia.

However, depending on traffic conditions, the upper-bound speed of BRT cannot be always reached, especially in peak hours in the city area. According to the data from ITDP China, the average value of peak-hour speeds of BRTs in center areas of different cities is around **21 km/hr (around 13 mile/hr)**, which is actually the lower bound of the theoretical speed range. (See Figure 3.1-4)

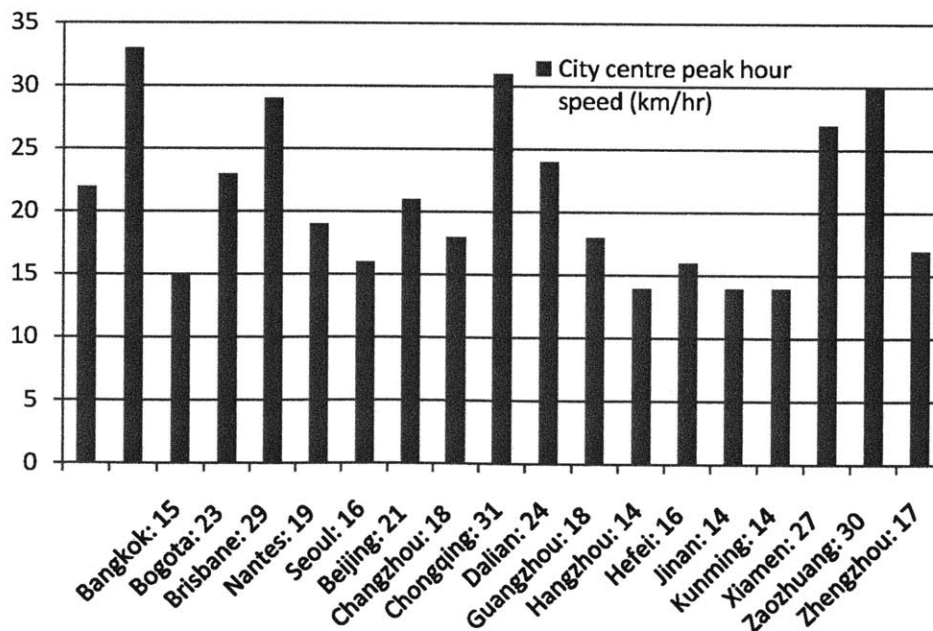


Figure 3.1-4: Peak-hour speeds of BRT in city centre areas (km/hr)

Source: <http://www.chinabrt.org/en/cities/param-quan.aspx?param=3>

Therefore, speaking to speed, urban rail transits including LRT and metro, still have some comparative leads to BRT because they could always be segregated from troublesome road traffic.

For BRT, to ensure its working speed and efficiency, it is better for BRT projects to adopt dedicated busways than mixed-up lanes with other modes, especially in the city central zones. Only in comparative low-density area, when the traffic situation is comparative fluent, the mixed-up lane could be considered as a choice for saving the money and time to build up segregated lines and stations.

Capacity

General speaking, BRT is a public transit with medium-high-capacity of passengers. As a specifically-defined new and sustainable public transit, Bus Rapid Transit (BRT) means to work with high capacity in nature of bus transit, but with limitation as a bus transit, it is still hard to upgrade it into a metro speed and total capacity. As an average, a BRT system could afford an hourly passenger flow strength at **15~35 thousand people**, which is already close to the capacity of a medium-level light rail. Though there is still distance comparing to a metro system. (Figure 3.1-5)

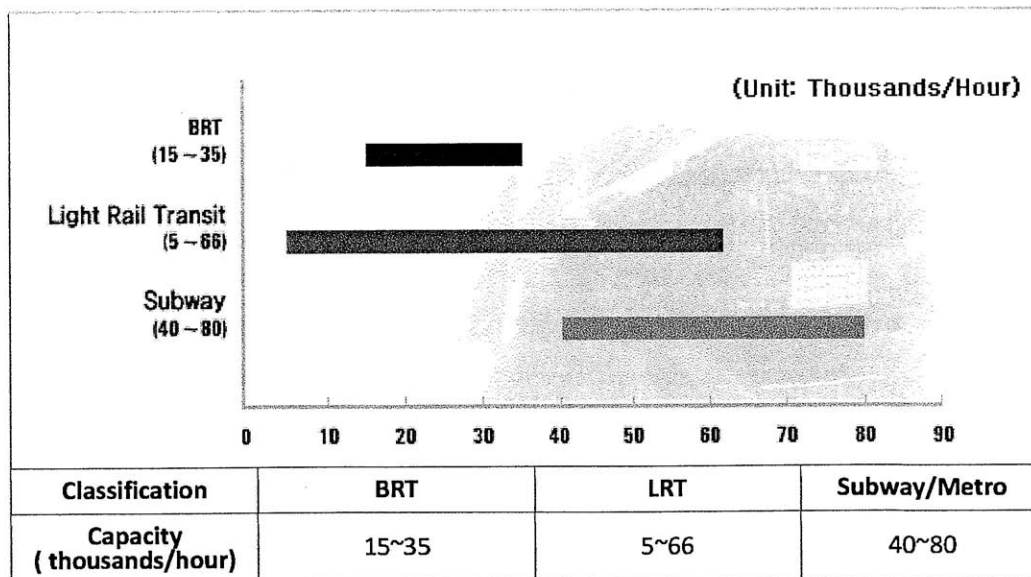


Figure 3.1-5: Compare Transport Capacity between BRT and URTs

Source: <http://www.mta.go.kr/english/brt/comparison.jsp>

Though the brilliant performance of BRT in capacity is a common sense, the real statistical data from practices actually proved there are huge gaps in capacity between BRTs in reality: depending on its facilities and designs, a BRT could undertake a

city's transit demands with peak flows between 4 and even 50 thousand passengers per hour per direction (Table 3.1-2).

Table 3.1-2 Comparison of Capacity between BRTs and metro systems in different cities

Location	System	Peak Flow (k passenger/ hr/direction)	
Beijing*	BRT	4.1	4
Seoul*	BRT	6.7	7
Curitiba	BRT	15	15
Guangzhou*	BRT	21	21
Bogota **	BRT	53 / 42	42
London	Metro	25	25
Sao Paulo East	Metro	60	60
Hong Kong	Metro	81	81

Source: Lei Chen, *The research on the application of Bus Rapid Transit in big cities of our country*;

* The data for Guangzhou, Seoul, and Beijing is from <http://forum.home.news.cn/detail/74094785/1.html>

** The statistics on TransMilenio in Bogota is different, 53k pphpd is from Leichen; 42k pphpd is from Bus Rapid Transit Policy Center; <http://www.gobrt.org/Transmilenio.html>. Here, we trust more on the latter one.

Capital cost

About construction costs in BRT and urban rail transit projects, the amounts and ranges are very various among different countries, regions and cases, and even based on different sources to refer. However, all the data until now have showed that constructions of BRT will cost much less money than building a metro or a light rail in general average level, on per unit-distance base. According to Table 3.1-1 above, which is the data from China in 2006, the construction cost of BRT is in the range of **\$6~15 million per kilo meter (around \$9.7~24 million per mile)**, for light rail is **\$ 12~34 million per km (around \$19~55 m per mile)**, and for metro is **\$120~180 million per km (around \$193~290 million per mile)**³⁷.

The data from US shows a bigger-range and averagely higher capital expense on all these transport infrastructure constructions, partly might because of the varied price indexes. Referring to the statistics from *streetsblog.org*, the construction fee range for BRT is **\$5~55 million US dollar per mile**; Light rail is **\$30~100 million per mile** and metro is **\$200~350 million per mile**.³⁸ More in detail, according to the study from *United States General Accounting Office* (as Table 3.1-3 below shows), the capital cost of a BRT project could be very different depending on its type and facilities involved, normally with an average value changing between 0.68 million~ 13.5 million per mile, comparing to 34.8 million per mile for the capital cost of Light rail.

³⁷ In *Xiaoqiang Luo and Kuanmin Chen, 2010*, it is said that for metro, the comprehensive construction cost is 600~ 800 million Yuan per km, equal to around 90~150 million US dollar per km (\$145~240 million per mile).

³⁸ [<http://dc.streetsblog.org/2011/03/08/can-the-u-s-make-bus-rapid-transit-work-as-well-as-latin-america/>]

In all the types of BRT, the costs of the ones with dedicated busways are highest, normally asking for \$ 7~55 million. Comparatively, the BRT lanes on city streets only need \$0.2~10 million to build (Table 3.1-3).

Table 3.1-3 Compare the construction costs for BRT and light rail projects in US.

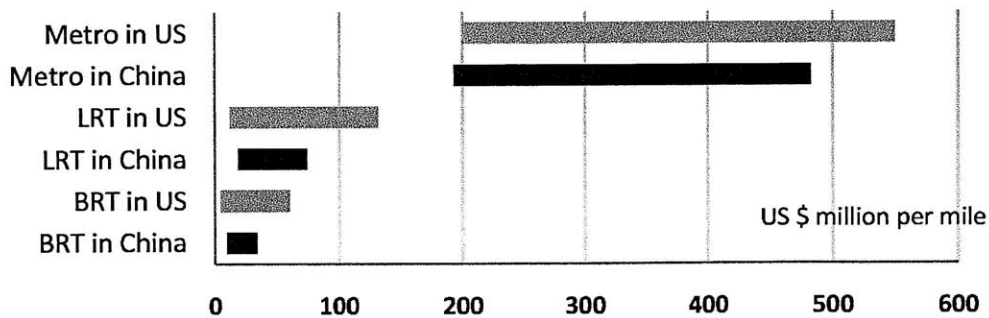
Project type	Number of facilities examined	Capital cost per mile	
		Cost range	Average cost
Bus Rapid Transit			
Busways	9	\$7 million to \$55 million	\$13.5 million
HOV lanes	8	\$1.8 million to \$37.6 million	\$9.0 million
Arterial streets	3	\$200,000 to \$9.6 million	\$680,000
Light Rail	18	\$12.4 million to \$118.8 million	\$34.8 million

Notice: Most of the US BRTs, though are called BRT, but are usually without dedicated lanes, so as to be different with the typical BRT defined in the world.

Source: GAO, *Bus Rapid Transit Shows Promise*, September 2001; the data was supplied by FTA and local transit agencies.

To combine all the varied ranges collected, we could get more a reasonable comparison on the construction costs between BRT and urban rail transits, which has been shown in Figure 3.1-6. According to Figure 3.1-6, we could conclude that, though the cost of building BRT or urban rail transits might be various in different countries and cases, building one-meter or one-mile BRT is always cheaper than building the same length rail transit.

Figure 3.1-6 the Construction cost ranges of BRT, light rail and metro projects in China and US



	<i>BRT in China</i>	<i>BRT in US</i>	<i>LRT in China</i>	<i>LRT in US</i>	<i>Metro in China</i>	<i>Metro in US</i>
lower bound	9.7	5	19	12	193	200
Upper bound	24	55	55	120	290	350

Unit: US \$ million per mile

Though the comparison based on unit distance could bring us basic understandings on the differences between the costs of transit modes, in most of the cases, the evaluation or preference of a transit depends more on its average capital cost based on unit service ability. Therefore, for more significant comparison, we would also like to see the difference between capital costs of BRT and urban rail transits per service unit. Here, we define it as *Passenger Mile*.

A study cased in Vancouver in 2010 provides some threads of the issue. According to the comparison on capital cost per passenger mile (the cost of moving one person one mile) in the research, we could find that for BRT, the capital cost per passenger mile is **\$1.12**, comparing to **\$2.34** for the Rapid Rail Transit system *Skytrain* in the city, and even less than the **\$1.27** for Light rail transit (LRT). (See Figure 3.1-7)

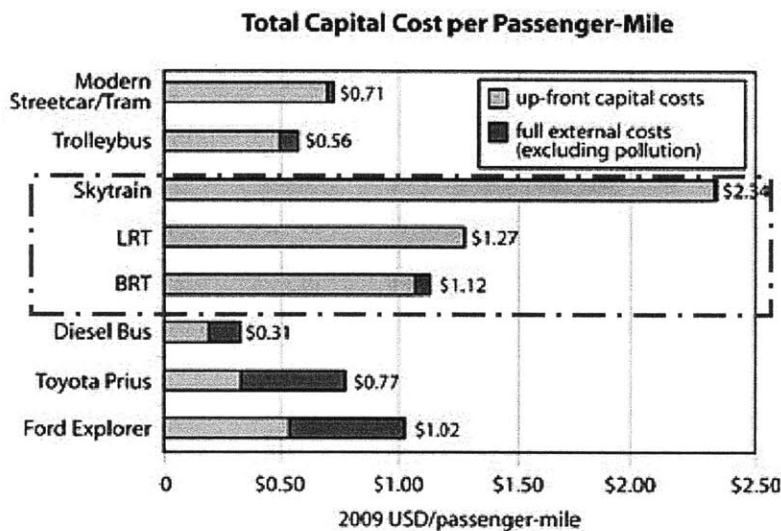


Figure 3.1-7:
Total Capital Cost per Passenger-Mile

*"Skytrain" is an urban rapid transit system in Metro Vancouver, British Columbia, Canada.
From:
[[http://en.wikipedia.org/wiki/SkyTrain_\(Vancouver\)](http://en.wikipedia.org/wiki/SkyTrain_(Vancouver))]

Source:
Patrick M. Condon, 2010

* External costs: Many costs associated with personal automobile, local bus service and to a lesser extent bus rapid transit and trolleybus are more difficult to determine because they operate on existing roadways, *the construction and maintenance of which are not included in most cost calculations for these modes*. For this reason external costs that begin to place a value on the land and resources dedicated to automobile infrastructure are necessary to accurately represent the true costs of the system. (Patrick M. Condon, 2010)

Energy efficiency and environmental sustainability

With all the advocacy and attention-paying on *Green Transport* raised in recent years, energy efficiency and environmental sustainability are both starting to be included into considerations in evaluations of different transit modes.

As a sustainable transit mode, BRT has advantages in these aspects as well: The new high-tech BRT vehicles are designed with low-energy-cost and low-discharge targets. Also, the high-speed feature of BRT could prevent energy waste in traffic jams. According to the statistics, the BRT system in *Curitiba* could save fuel consumptions

by 30% than its traditional bus system, and the *TransMilenio* BRT system in *Bogotá* could help to reduce pollution by 40% than the old bus system. More than that, according to a research by Energy Foundation in 1999, BRT could work with lower fuel consumption and greenhouse gas releases for same passenger transport capacity even comparing to urban rail transits (Table 3.1-4). (Lei Chen, 2006)

Table 3.1-4: Difference on Pollution and Energy efficiency between transit modes

Unit: per 1 million people

	Motorcycle	Private Car	Normal Bus	BRT	Rail transit (electric)
CO₂ (ton)	62.0	140.2	19.8	4.7	7.5
NO₂ (kg)	90.0	746.0	168.4	42.0	17.5
Oil Wear (ton)	21.8	49.2	6.9	1.6	2.6

Source: Lei Chen, 2006.

According to the study on transits in Vancouver in 2010, though the operating cost, energy cost, the future increase in energy cost, and the total cost of BRT are all slightly higher than Light Rail Transit, the total cost of BRT is still cheaper than the Rapid Rail Transit, *SkyTrain*, either per passenger-mile or per trip. (Figure 3.1-8 & Figure 3.1-9) Because of different demographic and economic situations in China and also the unlike passenger behavior patterns, we could believe the amounts of all the costs referred here will be much different and might be all cheaper if in China, but the cost-saving feature of BRT should be aware.

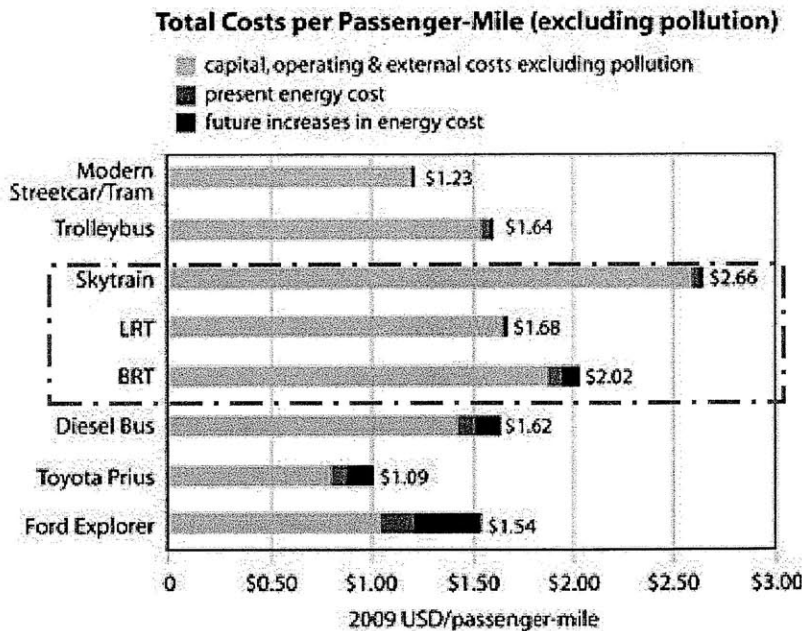
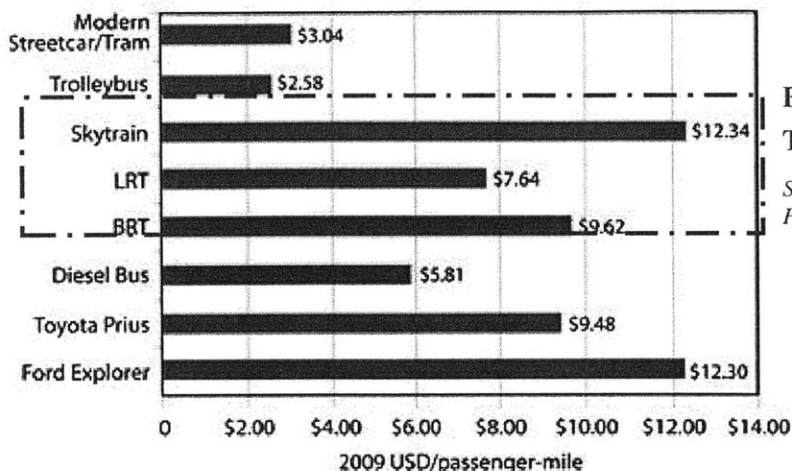


Figure 3.1-8:
Total Capital,
Operating Cost and
Energy Cost per
Passenger-Mile

Source:
Patrick M. Condon, 2010

* The bars show the scale of the on-going operation and maintenance expenses for different mode. Energy costs are isolated from the operating expenses and shown separately according to present energy costs for each mode as well as the future increase in energy costs that can be expected as non-renewable fuels such as oil become scarcer. (Patrick M. Condon, 2010)

Total Cost per Trip (full external costs excluding pollution)



**Figure 3.1-9:
Total Cost per Trip**

Source:
Patrick M. Condon, 2010

3.2. Compatibility and Competition

3.2.1 Compossibility in Space

The competition between BRT and Urban Rail Transit in space still exists to some extent, but is comparatively less than in the other aspects, since the two systems can generally concur in the same or partly overlapping transport corridor when BRTs can be operated on ground and metros can be built underground when both of them are needed. In some cases, even BRT and LRT lanes can have interfaces or be partly merged into a shared corridor. (Figure 3.2-1)



**Figure 3.2-1
Saarbrücken transit
system in Germany:
LRT-Quality Bus
(BRT) interface**

Source: Stefan Baguette,
Copies From
[[http://www.lightrailnow.org/
features/fj_brt_2005-01.htm](http://www.lightrailnow.org/features/fj_brt_2005-01.htm)]

In fast urbanization, BRT, sometimes called as a pre-rail transit, is in some cases regarded as a temporary demand-satisfying transport and also a corridor-keeping strategy for future rail constructions, and can be upgraded into a LRT lane along with

further developments and expanding needs in the city. For instance, in Xiamen city, China, the government (Xiamen City Planning Bureau) proposed an upgrading project from BRT system to LRT system in the original built BRT corridor in 2010. (Figure 3.2-2) The proposal had been first issued and turned down in 2006 but got relaunched again recently, partly because the increasing transportation needs in the city has really started to outweigh the capacity of some routes of BRT in peak hours especially, and it seemed to be the right time to build an LRT to meet the expanding commuting demand.³⁹

However, this kind of upgrading cannot be randomly decided and also not easy. First, the biggest characteristic of the BRT in Xiamen is that the lanes were mostly built on viaducts which minimized the effects on road traffic and also reserved perfect lanes for LRT. Also, the possibility of the upgrading had been considered and preserved since the very beginning in the constructions of the BRT corridors. The road surface and ground setup had been designed and paved with reaching the LRT standards in bearing capacity and so on for future feasible engineering projects on railways. To save reconstruction costs still, the government now is considering a *Translohr* system⁴⁰ to apply than a traditional heavy light rail system.⁴¹ It can be seen that the transition from BRT to LRT is definitely not a relaxing and easy job.

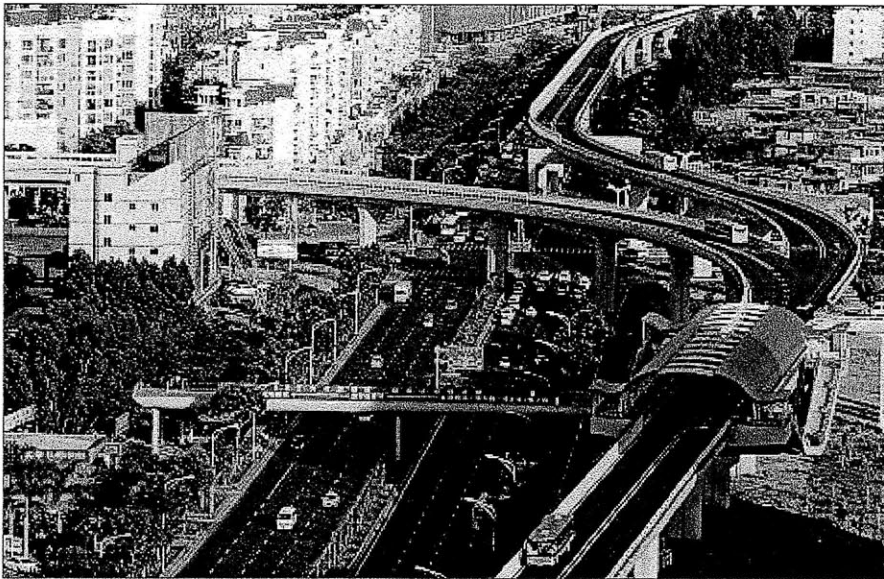


Figure 3.2-2 BRT Corridor in Xiamen

Source: [<http://www.whatsonxiamen.com/news14594.html>]

³⁹ From: [<http://www.whatsonxiamen.com/news14594.html>]

⁴⁰ Translohr is a kind of light rail system which runs on rubber tires and is guided by a single central rail. It originally comes from France, and has been practically applied in Tianjin, China.

⁴¹ From: [<http://bbs.xmfish.com/simple/?t1740269.html>]

3.2.2 Substitution and Complementarity in Service

Theoretical model referring to classical economics

Consumer choice is a theory of microeconomics that relates preferences to consumer demand curves. The link between personal preferences, consumption, and the demand curve is one of the most complex relations in economics. The models that make up consumer theory are used to represent prospectively observable demand patterns for an individual buyer on the hypothesis of constrained optimization. Prominent variables used to explain the rate at which the good is purchased (demanded) are the price per unit of that good, prices of related goods, and wealth of the consumer.⁴²

The fundamental theorem of demand states that the rate of consumption falls as the price of the good rises. This is called the *substitution effect*. Clearly if one does not have enough money to pay the price then they cannot buy any of those items. As prices rise, consumers will substitute away from higher priced goods and services, choosing less costly alternatives. Subsequently, as the wealth of the individual rises, demand increases, shifting the demand curve higher at all rates of consumption. This is called the *income effect*. The income effect results from an increase or decrease in the consumer's real income or purchasing power as a result of the price change. As wealth rises, consumers could choose to substitute away from less costly inferior goods and services, choosing higher priced alternatives. The sum of these two effects is called the *price effect*.⁴³

Also in classical economic terminology, *substitutes* and *complements* are defined as two types of goods or relations between goods. One way we classify goods is by examining the relationship of the demand schedules when the price of one good changes. This relationship between demand schedules leads economists to classify goods as either substitutes or complements. As *substitutes* for each other, which means to replace each other in use (or consumption), the demand of one will move in same direction when the price of the other one moves, while as *complements*, the demand will move in the opposite direction.⁴⁴

There are two extreme situations call *Perfect substitute* and *Perfect complement*. *Perfect substitutes* may alternatively be characterized as goods having a constant marginal rate of substitution. In this case, goods X and Y can be consumed in different quantitative proportions, but the consumer obtains the same level of utility

⁴² From: [http://en.wikipedia.org/wiki/Substitution_effect#Substitution_effect]

⁴³ Refer to [http://en.wikipedia.org/wiki/Substitution_effect#Substitution_effect] and [<http://courses.ttu.edu/econ3320-kdesilva/lecture7.ppt>]

⁴⁴ Refer to: [http://en.wikipedia.org/wiki/Substitute_good] and [http://en.wikipedia.org/wiki/Substitute_good]

along all points of the indifference curve. (Figure 3.2-3 (a)) Alternative types of soft drinks are commonly used as an example of perfect substitutes. As the price of Coca Cola rises, consumers would be expected to substitute Pepsi in equal quantities, i.e., total cola consumption would hold constant. **Perfect complement** on the other hand, is another kind of goods that have to be consumed with another good. The indifference curve of a perfect complement will exhibit a right angle. (Figure 3.2-3 (b)) Few goods in the real world will behave as perfect complements. One example is a left shoe and a right; shoes are naturally sold in pairs, and the ratio between sales of left and right shoes will never shift noticeably from 1:1.

However, in common situations, imperfect substitutes are more often to be found. **Imperfect substitute** means that it cannot perfectly or completely substitute for the other good on utility, which means the two goods have both substitution and complementarity. Imperfect substitutes exhibit variable marginal rates of substitution along the consumer indifference curve. The consumption points on the curve offer the same level of utility as before but the compensation now depends on the starting point of the substitution. (Figure 3.2-3 (c))

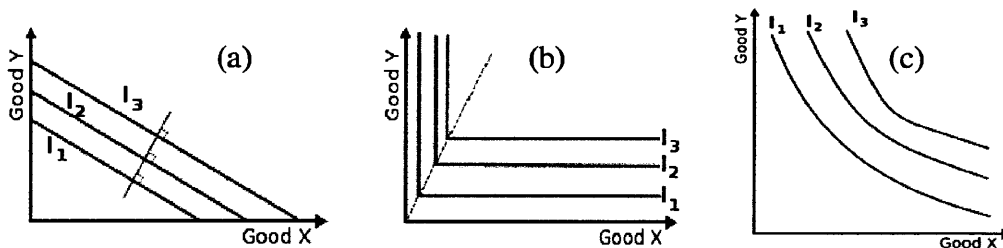


Figure 3.2-3 (a): Indifference curve for perfect substitutes (b) Indifference curve for perfect complements (c) Indifference curve for imperfect substitutes

Source: http://en.wikipedia.org/wiki/Indifference_curve

Referring to these notions in classical Economics, we could analyze the relations between BRT and urban rail transit (URT) in service (or demand in another word) under this *Substitution-and-Complementarity* model.

First, BRT and URT are both fast, efficient, big-capacity urban public transits in the modern time. In the relationship between them, substitution in service is always natural and easy-to-understand, since they are supplying similar transit services generally for the-almost-same-group people with trip demands in public transit.

However, complementarity could also exist simultaneously, at least theoretically. The attraction, quality and efficiency of the two services can improve altogether if they are working interactively in connections and even integrating into a whole comprehensive

and well-organized public transport system. Now the passengers could more easily complete their trip purposes by quick transfers between the BRT and URT lines, and more urban travelers might choose to take public transit instead of private cars for commuting, and then the share of all public transits will go up.

Therefore in this case, the relationship between BRT and URT has both substitution and complementarity, so they are *imperfect substitutes*, which could be represented with a smoothly curving utility indifference curve shown below in Figure 3.2-4 ⁴⁵.

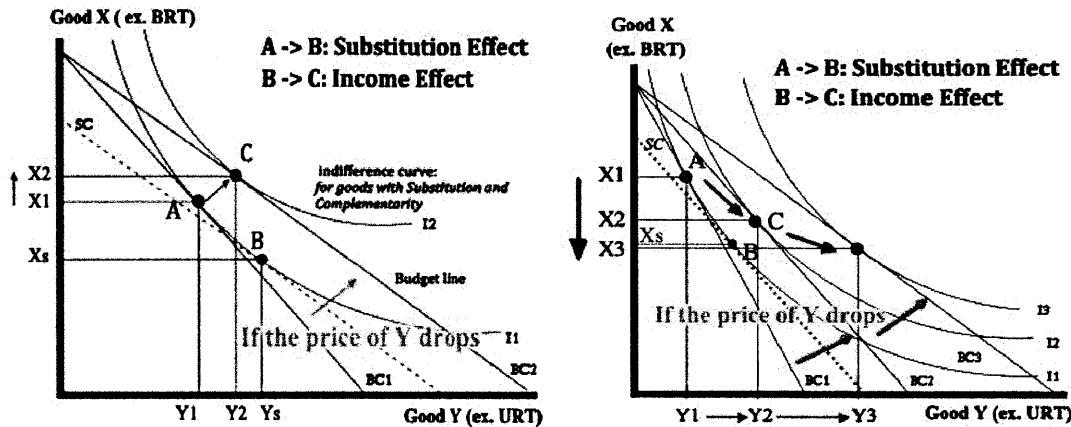


Figure 3.2-4 Hicksian Substitution model

Notice: The figure shows two possibilities:

1. (Left) When the price of Y drops, the demand of X increase (Income effect > Substitution effect);
2. (Right) When the price of Y drops, the demand of X decrease (Income effect < Substitution effect).

There is also a third possibility: When the price of Y drops, the demand of X is unchanged. (Income effect = Substitution effect).

Source: The figures are originally from [http://en.wikipedia.org/wiki/File:Hicks_Substitution_effect.svg] and [http://en.wikipedia.org/wiki/File:Found_demand.svg]

When the price of URT (could be transit fee for the passengers and also could be the construction expense faced by the government) drops, the demand of URT will definitely increase, but the change of BRT could be uncertain.

Because of *substitution effect*, since the price of URT drops, the demand on URT will increase and the demand on BRT will decrease if under the same budget, but with *income effect* at the same time, as the price of URT drops, which is indirect equal to a rise in budget (the budget line pivots out), and because of the improved budget, both of the demands will increase. Therefore, for URT, the need will certainly increase, but for BRT, whether the demand will rise or drop will depend on the shape of the indifference curve and which effect is stronger and more effective.

⁴⁵ In Figure 3.2-3, it also show the *Hicksian Substitution model* which is used to analyze what could possibly happen when the price of y (ex. URT) drops (or increases in opposite). Basically, both of substitution effect and income effect are going to give influence on the result, which brings uncertainty on the demand of X. If substitution effect is bigger than income effect, the demand of X will decrease, if income effect is bigger, then the demand of X will also increase, which is the exact situation represented in Figure 3.2-3 here.

Facts in China ---Substitution until now, Complementarity in the future

There are **9 cities** in mainland China having an operating metro system until now⁴⁶ (listed in Table 3.2-1), and as we concluded in *Introduction* (1.1.3), there are also **11 cities** which have already built BRT routes (listed in Table 3.2-2). However, we could easily find that there are only two cities, *Beijing* and *Guangzhou*, having them both, and even for Beijing and Guangzhou, there are both more-than-10-years gaps between the constructions of BRTs and metros.

Besides *Beijing* and *Guangzhou*, most of the cities having BRTs are second-tier in scale and economy in China. They mostly don't have a metro system, but are building or planning it right now (Table 3.2-2).

Provisions from Construction Ministry on URT construction

One of the reasons behind is that all the constructions of urban rail systems including metros and light rails should get building approvals from China's Construction Ministry, and Construction Ministry has some rigid requirements on economic index before applying for the approval.

The basic conditions for building a metro include: ⁴⁷

- Local general budget revenue of the city is over **10 billion Yuan**;
- Total GDP of the city should reach **100 billion Yuan**;
- Urban population scale is bigger than **3 million pop**;
- And the peak-hour passenger flow per direction on the planned routes is more than **30,000(pop/h/direction)**.

For light rail, the conditions are: ⁴⁸

- Local general budget revenue is over **6 billion Yuan**;
- Total GDP should reach **60 billion Yuan**;
- Urban population is over **1.5 million pop**;
- And the peak-hour passenger flow per direction on the planned routes is more than **10,000 (pop/h/direction)**.

Also, Construction Ministry states that the applications from the cities with better economic bases and seriously bad traffic conditions will be given priority.⁴⁹

⁴⁶ Based on data at the end of 2010, From [<http://zhidao.baidu.com/question/252050822.html>]

⁴⁷ From: <http://zhidao.baidu.com/question/124326596.html>

⁴⁸ From: <http://zhidao.baidu.com/question/124326596.html>

⁴⁹ From: <http://zhidao.baidu.com/question/124326596.html>

Table 3.2-1 The current existing metro systems in Mainland China

City	Open year	Total operation mileage (km, until 2010)
Beijing	1969	336
Hongkong	1976	168
Tianjin	1984	71.6
Shanghai	1995	410 (until 2010.4.20)
Guangzhou	1997	222
Shenzhen	2004	59.2
Nanjing	2005	85
Chengdu	2010	31.6
Shengyang	2010	27.9
Cities got approval for building metros: Changchun, Dalian, Chongqin, Wuhan, Hangzhou, Haerbin, Xian, Suzhou, Qingdao, Changsha, Wuxi, Fuzhou, Dongguan, Ningbo, Jinan, Xiamen, Changzhou, Zhengzhou, Nanchang and Hefei.		

Source: <http://zhidao.baidu.com/question/252050822.html>

Table 3.2-2 The current existing BRT systems in Mainland China

City	Total Length (km)	Peak hourly flow (per direction)	Year for operation	Having metro?	Expected open of Metro
Beijing	54	3800	2004	Yes	/
Xiamen	51	7900	2008	Planning	Unknown
Hefei	15	2900	2010	Permitted	Unknown
Dalian	13.7	5800	2008	Building	2012
Changzhou	44.9	7400	2008	Planning	2018
Guangzhou	22.5	26900	2010	Yes	/
Kunming	46.7	3500	1999	Building	2012
Hangzhou	55.4	6800	2006	Building	2012
Jinan	34.4	3300	2008	Building, Permitted in 2009	2013
Zhengzhou	30.5	5600	2009	Building, Permitted in 2009	2013
Chongqing	11.5	600	2008	Building from 2008	2012

Source: chinabrt.org and search engine: Baidu.com

From the facts, we could find that there is a stronger substitution effect between BRT and URT in the reality in China until now. Most of the cities chose BRT because they didn't reach the required scale or didn't get financial resources prepared for a metro system at that time, but they hope to construct a metro system finally or even replace the BRT system by URTs (ex. Xiamen) for higher capacity. Although on the other hand, we could predict a more complementary future. Since most of the cities having

a BRT now is planning or building URT lines, and in most of the cases they are planning to keep both BRT and URT lines at the same time in their transport system, we could expect that there will be around 10 cities evolved having BRT and URT together in 10~20 years.

To conclude, in China, BRT is currently more like an interim choice for cities with secondary-urbanization and demands, which might eventually meet the transition or union into the metro age.

3.2.3 Competition in Finance

Both as very expensive infrastructure investments normally funded by government, the competition between BRT and URT in financial resources are inevitable with a limited annual budget faced by most of the cities. Additionally, both of the systems require internal integrity in constructions and facilities to some extent, which means, though some junctions between the two could be acceptable, it is unreasonable and diseconomic to randomly design a system with half BRT and half URT. Therefore, the relationship is more than a competition. In fact, it is actually nearly alternativeness between the two in smaller scale.

The unwilling choice between BRT and URT in *Edmonton, Canada* is a good example for this kind of exclusive alternativeness in finance (Figure 3.2-5). Since the budget of the city is limited, Edmonton should make a decision on whether extending the existing light rail line or building a BRT system in a more extensive range. After over three years of study since 2004, Edmonton's transportation department finally decided to drop plans to introduce a BRT system, but to focus on the extension on the existing LRT in the city for short term.⁵⁰ No matter if the decision in Edmonton is right or wrong, the competition between BRT and URT in finance is doubtless and inevitable.

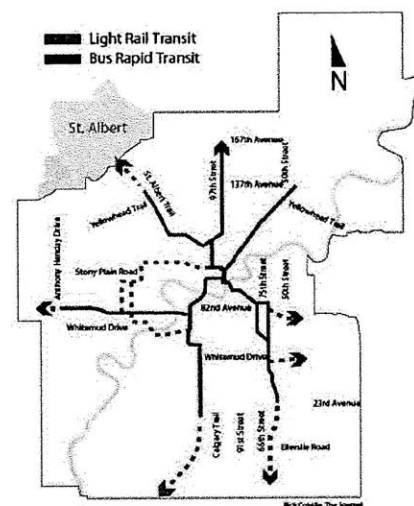


Figure 3.2-5: The alternative transport plans in Edmonton

Source:
[<http://www.getsthere.com/?p=22>]

⁵⁰ City Hall axes bus rapid transit, *The Edmonton Journal*, Dec. 13.
[<http://www.canada.com/edmontonjournal/story.html?id=2cb06782-bd89-4758-aada-e0d61e607cc1&k=32946>]

3.3. Transition between BRT and urban rail transits

3.3.1 The dominant transit in urban development

An important study on 84 "global cities" by Newman and Kenworthy (2003) statistically proved that there are significant interactions between urban density and the shares between different transit modes and also transport-related energy consumption (Figure 3.3-1, Table 3.3-1).

Figure 3.3-1: The Newman and Kenworthy hyperbola: Urban density and transport-related energy consumption

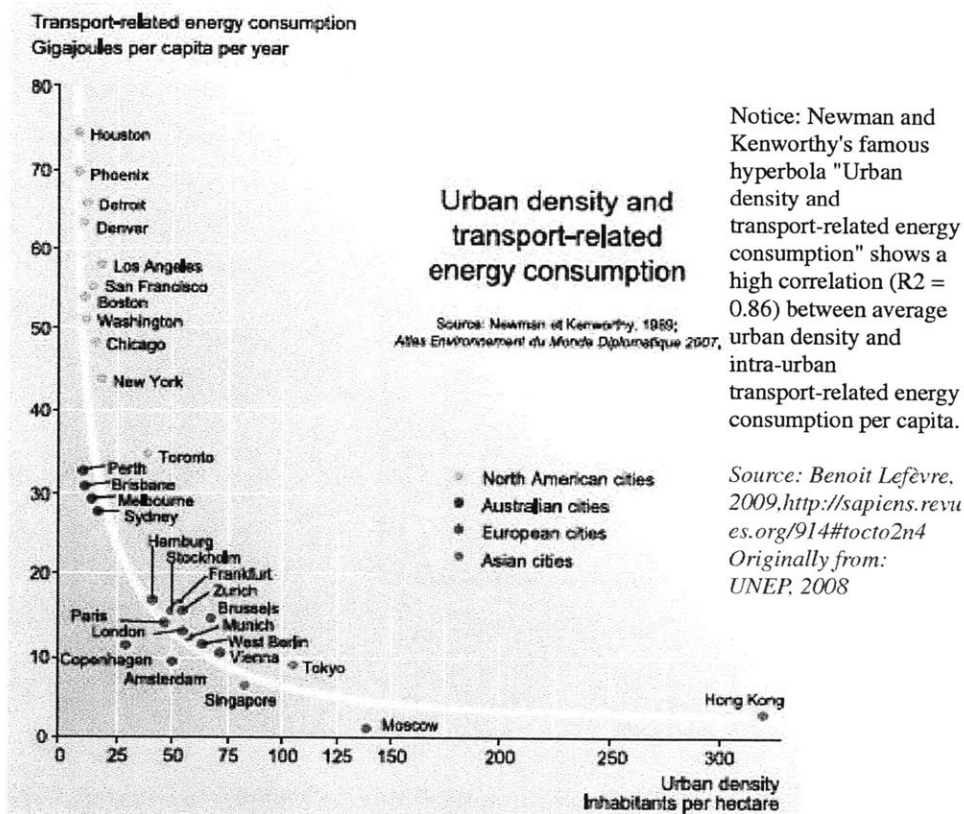


Table 3.3-1: City typology based on average urban density and transport

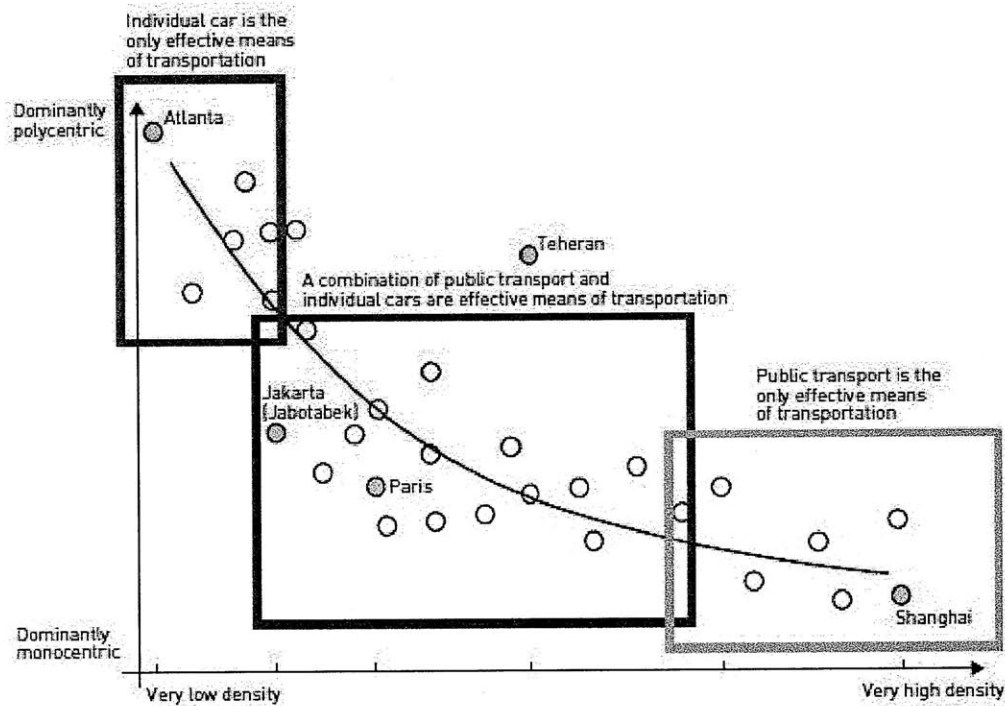
Global urban density	Low < 25 hab/ ha	Medium 50 – 100 hab / ha	High > 250 hab+/ ha
Modal distribution	MPT: 80% PT: 10% NMT: 10%	MPT: 50% PT: 25% NMT: 25%	MPT: 25% PT: 50% NMT: 25%
Automobile use (km / pers / yr)	> 10 000		< 5 000
Public transport use (trips / pers / an)	< 50		> 250
Petrol consumption for transport (MJ / pers / an)	> 55,000	35,000 – 20,000	< 15,000
Representative positions	North American and Australian cities	European cities	Asian cities

Notice: MPT: Motorised Public Transport; PT: Public Transport; NMT: Non Motorised Transport. Density: number of inhabitants and jobs per hectare of net urban surface (omitting green and water surfaces).

Source: Benoit Lefèvre, 2009, <http://sapiens.revues.org/914#tocto2n4>
Originally from: Newman and Kenworthy, 1999

Moreover, there is a strong correlation between urban density and structure and the efficiency of different transit modes, which means, the most effective transport mode might switch between cities with different densities and mono or polycentric spatial structures (Figure 3.3-2). As shown below, for high-density and dominantly mono-centric cities, which is the most often urban pattern in Asia, public transport is the only effective mode.

Figure 3.3-2 Relationship between spatial structure and the effectiveness of public transport



Source: Benoit Lefèvre, 2009, <http://sapiens.revues.org/914#tocto2n4>
Originally from: Bertaud and Malpezzi, 2003.

For public transport specifically, as Benoit Lefèvre (2009) evaluated, it is incompatible with low density and dominantly polycentric urban structures, since bus stops and railway stations must be easily accessible by walking no more than 10 minutes, and investment in public transport infrastructure is only economically justifiable if housing and employment density is sufficient within the catchment area of the stops. According to a consensus, a density pertinence threshold for public transport of approximately *30 inhabitants/ha*.⁵¹ When density is higher than that, public transport could trend to be more efficient than private transport. Therefore, for the cities in China or even the whole Asia, as we introduced in Chapter 1, that is the only choice for sustainability.

⁵¹ Benoit Lefèvre, 2009, [<http://sapiens.revues.org/914#tocto2n4>]

Then in public transport category, BRT and URT are two main options to be the core stem in the network. As we talked in 3.2.2 as well, the current facts in public transport in China show that there is more substitution than complementarity in service between BRT and urban rail transit (URT), partly because of the institutional thresholds of URT constructions put by the government, also might rooted from the competition in financial resources between the two. If BRT and URT are more like substitutes than complements, then the next questions will be: In the public transport realm, for BRT or URT, which will be the more dominant transit? Could bus really replace rail?

3.3.2 The different effective areas of BRT and URT

To really answer the question that if it is possible for BRT to replace a rail system, we might need to analyze facts in the single city case by case. Because of different characteristics in speed, capacity and finance, BRT and metro will suit different kind of cities. There is no absolute efficient mode, but different effective areas of BRT and URT instead.

Theoretically, we could follow the method in 3.3.1 above and similarly use urban density or some other economic, demographic indexes to find the general division between the effective areas of the two, which is also the turning point between their relations in unit cost of service (Figure 3.3-3).

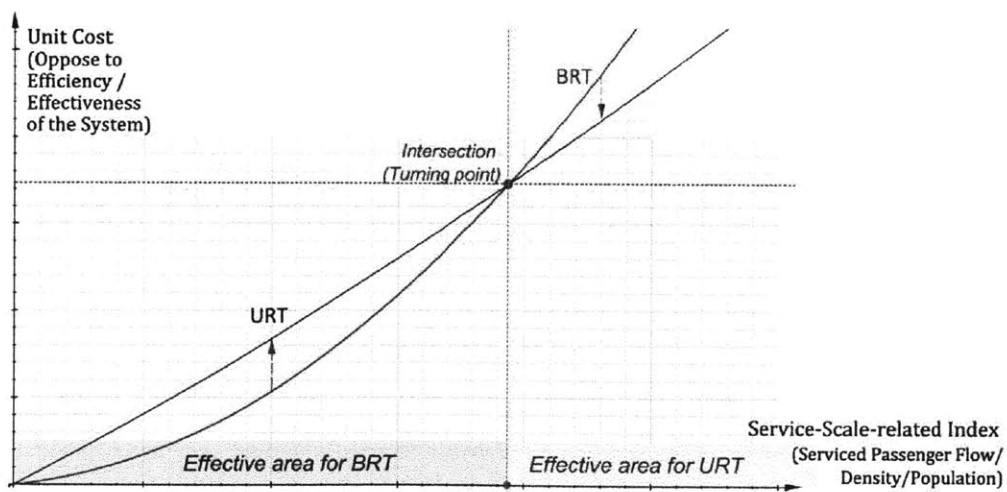


Figure 3.3-3: The unit cost curve of BRT and URT

Notice: The intersection decides the turning point between the effective areas. Before it, the unit cost BRT is lower, which means BRT is more efficient, and after that, URT has a lower unit cost and turns to be the more efficient transit. The reason is that the capacity and speed of BRT is generally lower than URT (Metro), when transit demand (Passenger number) increase, the internal cost (ex. expense for purchasing vehicles) and external cost (effects on roads, values of the land occupied) will rise more quickly.

Source: Author

Where is the critical threshold in capacity?

One of the most apparent critical thresholds exists in capacity. As we analyzed in 3.1, BRT is a public transit with medium-high-capacity of passengers. Generally speaking, the capacity of BRT is still lower than urban rail transit (URT, including both light rail and Metro), especially metro systems. Just like what we showed in Figure 3.1-5, the general boundary between the hourly passenger capacities of BRT and metro is about **40,000 people per hour**⁵².

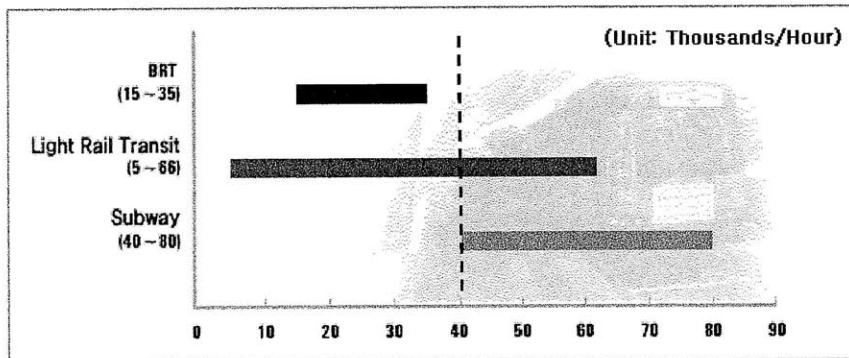


Figure 3.1-5:

Compare
Transport
Capacity
between BRT
and URTs

Source:
[<http://www.mta.go.kr/english/brt/comparison.jsp>]

If the maximal hourly capacity of BRT is about *40,000 people per hour*, the absolute maximal daily capacity will be **960,000 people per day** (which is $40,000 * 24$ hour). However, normally the passenger flow in the well-operated system can hardly always reach the maximum capacity. If we assume, usually there will be 4 hours (normally 2 in the morning and 2 in the afternoon) when the system works at its full capacity, and for the rest 20 hours in the day, the system works averagely at its half capacity, which will maximally be *20,000 people per hour*, then we could deduct that the *normal maximum daily passenger capacity* of BRT is about **560,000 people per day**, which means for the cities having a daily passenger transit demand bigger than that, they should consider to build a metro system.

Regression model: Link daily passenger flow to the city scale and urbanization level

Since eventually we would like to know which stage, size or demographic or economic level will be the threshold for a city in developments to switch from bus transit into rail transit, the next step is to link the daily passenger transit flow (demand) to the level of city developments.

⁵² This means that the maximum hourly capacity of BRT and the minimum hourly capacity of metro are both about 40,000 people per hour.

To find the link, I start from data modeling based on a regression by using some transportation and also economic data of the administrative regions (provinces and autonomy cities) in China (Table 3.3-3). According to the regression results returned by MS-EXCEL (the detail process will be omitted here because of length limitation), the best statistical model we could get is: Q (*million passenger flow*) = $a + b_1 * Population$ (*million people*) + $b_2 * GDP$ value of *Secondary industry* ($\$$ billion) + $b_3 * GDP$ value of *Tertiary industry* ($\$$ billion), while the values of a , b_1 , b_2 , b_3 could be found in the Table 3.3-2 below:

Table 3.3-2: Regression result

	Coefficients	Standard Error	t Stat	P-value
a	0.528148	0.724165	0.72932	0.472086*
b_1	0.056268	0.023682	2.376019	0.024855
b_2	-0.07361	0.014487	-5.0813	2.45E-05
b_3	0.129914	0.014293	9.089465	1.06E-09

* Notice: Here, the t-test of the intercept is actually cannot pass under a common 95% confidence level, but normally, intercept is not the key issue we care, we could comparatively easy the requirements.

Table 3.3-3: The data on public-transit passenger flow and other indexes of the administrative regions in China

Regions	Q	Population	2indus	3indus	Regions	Q	Population	2indus	3indus
Unit	Million	Million	\$	\$	Unit	Million	Million	\$	\$
	Pop	pop	billion	billion		Pop	pop	billion	billion
Beijing	18.05	17.55	43.27	139.08	Hubei	8.39	57.20	91.49	77.68
Tianjin	3.33	12.28	60.42	51.59	Hunan	5.45	64.06	86.17	81.86
Hebei	4.57	70.34	135.76	91.94	Guangdong	19.63	96.38	294.24	273.52
Shanxi	2.74	34.27	60.51	43.74	Guangxi	3.65	48.56	51.24	44.23
Inner Mongolia	1.76	24.22	77.48	56.01	Hainan	0.84	8.64	6.72	11.34
Liaoning	10.43	43.19	119.79	89.26	Chongqin	3.99	28.59	52.25	37.49
Jilin	4.29	27.40	53.67	41.76	Sichuan	7.57	81.85	101.70	78.77
Heilongjiang	5.60	38.26	61.53	51.09	Guizhou	11.11	37.98	22.37	28.57
Shanghai	11.03	19.21	90.94	135.32	Yunnan	3.34	45.71	39.13	38.18
Jiangsu	10.54	77.25	281.31	206.50	Xizang	0.15	2.90	2.07	3.65
Zhejiang	8.79	51.80	180.43	150.28	Shanxi	5.44	37.72	64.19	47.63
Anhui	5.00	61.31	74.32	55.49	Gansu	2.00	26.35	23.14	20.66
Fujian	4.82	36.27	90.99	76.49	Qinghai	1.16	5.57	8.72	6.04
Jiangxi	3.08	44.32	59.39	39.96	Ningxia	0.74	6.25	10.04	8.54
Shandong	9.19	94.70	286.39	178.31	Xinjiang	3.26	21.59	29.24	24.06
Hebei	5.48	94.87	166.83	86.38					

Notice: (Continue in next page)

*Q is Average daily public-transit passenger flow;

Here, we only show a section of it, including a few key variances closely related to the regression model I finally build up. The complete data can be found in Appendix I:

* '1indus', '2indus', '3indus' here represent the real values (\$ billion dollar, converted from the million number from Appendix I) of the GDP shares of Primary Sector, Secondary Sector and Tertiary Sector of the Economy.

Primary Sector of the Economy involves changing natural resources into primary products, which basically means general agriculture, also known as **Primary Industry**.

Secondary Sector of the Economy, or alternatively called **Industrial Sector** or **Secondary Industry**, generally is related to manufacturing, and includes production and construction sector in economy.

Tertiary Sector, also known as **Third/Tertiary industry** and **Service Industry/Sector**, consists of the "soft" parts of the economy.

* Data here is all for 2009. All the amounts of money were in RMB Yuan, but got converted into \$US dollar by an exchange rate of 1/6.6.

*Sources: The data on average daily public-transit passenger flow (people * time), from [http://www.chinautc.com/information/newsshow.asp?newsid=3384]; All the data on economy sectors are from: [http://www.chinautc.com/information/newsshow.asp?newsid=3377]*

The model makes sense with common knowledge, since we expect the daily public transit flow will related to the scale (population) and the economic developments (GDP and economic structure) of the cities. Also, for the correction of the regression model, R, F, T-tests, Standard Error test and also DW test have been passed. (The detail model testing process could be found in Appendix II.)

However, in the model, Q is the total daily passenger flow in the whole public transit system, instead of the daily flow in BRT or metro system.

Therefore, we should further find out the normal share of BRT or metro system in the whole public transit system. (The rest could be taken by normal bus service, shuttles and etc.)

Based on the data we have on 2009's amounts in all the provinces and autonomy cities having a URT service (Table 3.3-4), we could find out that the distribution of the share itself is widespread (with an average on 8.56%, Figure 3.3-4 A), but there is a general correlation between the share and the population density of the area (Figure 3.3-4 B).

Table 3.3-4: Daily passenger flow Share of URTs in public transit and other indexes

Regions	Q (Whole Pubic Transit)	Q-URT (URT in Public Transit)	Share of URT (Q-URT/Q)	Population density (Pop/ Area)	Ratio of 3indus*	Ratio of 2indus*
Unit	Million Pop	Million Pop	%	Pop / sq km	%	%
Beijing	18.05	3.90	21.60%	1045	75.5	23.5
Tianjin	3.33	0.15	4.44%	1087	45.3	53.0
Liaoning	10.43	0.19	1.81%	296	38.7	52.0
Jilin	4.29	0.08	1.89%	146	37.9	48.7
Shanghai	11.03	3.61	32.76%	3049	59.4	39.9
Jiangsu	10.54	0.31	2.95%	753	39.6	53.9
Hubei	8.39	0.04	0.43%	308	39.6	46.6
Guangdong	19.63	1.63	8.32%	535	45.7	49.2
Chongqing	3.99	0.11	2.87%	347	37.9	52.8

Notice: "Ratio of 3indus" and "Ratio of 2indus" are GDP shares of Third and Second Industries.
 Sources: Originally from [<http://www.chinautc.com/information/newsshow.asp?newsid=3384>]. Numbers got exchanges in units.

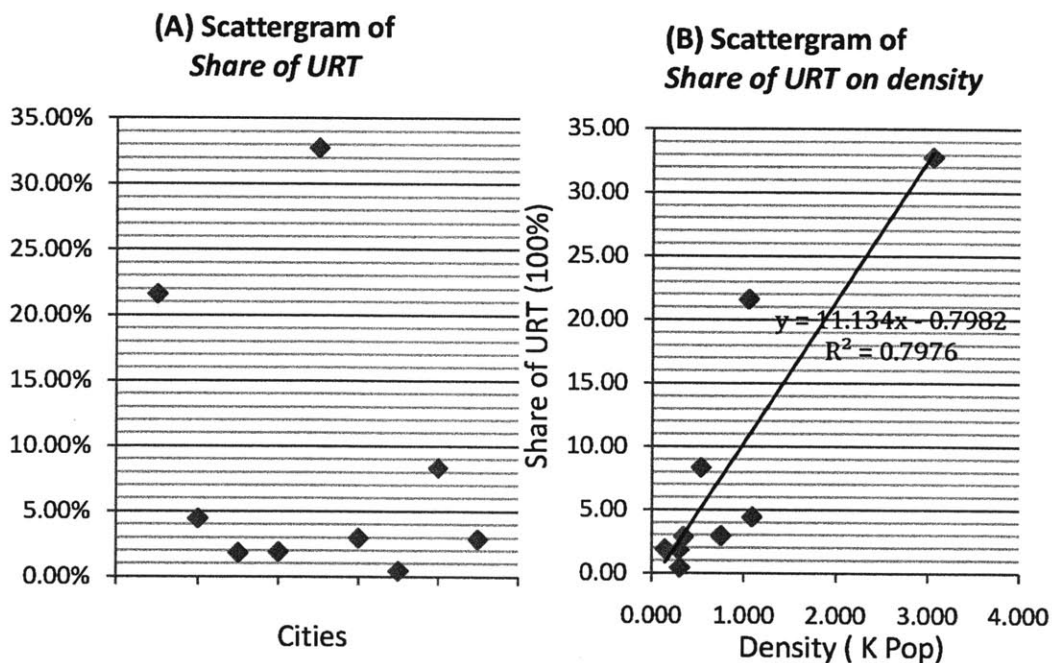


Figure 3.3-4 Scatter diagrams of the Share of URT

Source: Based on Table3.3.4

The equation [$Share\ of\ URT\ (100\%) = 11.134\ Density\ (Pop\ /\ sq\ km) - 0.7982$] gotten by line fitting above is a great plug-in tool to complete the original model.

Now, the whole model is ready:

- Once we know a city's population, GDP in 2nd industry and 3rd industry, we could use $[Q \text{ (million passenger flow)} = a + b_1 * \text{Population (million people)} + b_2 * \text{GDP value of Secondary industry (\$ billion)} + b_3 * \text{GDP value of Tertiary industry (\$ billion)}; a=0.528148; b_1=0.056268, b_2= -0.07361; b_3= 0.129914]$ to predict a city's public transit flow.
- Also, we could use $[\text{Share of URT (100\%)} = 11.134 \text{ Density (Pop / sq km)} - 0.7982]$ to general predict a city's Share of URT in public transit flow once we know the density of the city.
- Finally, we could deduce a city's **URT passenger transit flow Demand (Q-URT)**, which equal to $Q * \text{Share of URT}$. As we talked before, if Q-URT is bigger than the critical threshold of BRT's capacity, which is generally around 560,000 people per day, then the city might want to consider a metro system, otherwise, BRT system might has the ability to replace URT service.

Prediction testing by the model: Link the urbanization reality in the city to its dependency on URT

According to the model built up above, as long as we have the data on a city's population, density, and GDPs in 2nd industry and 3rd industry, we could generally predict the passenger transport flow/demand in a potential BRT or URT system. Then, comparing to the critical threshold of BRT's capacity, we could decide if the city could use BRT to replace URT.

As an example and to test our model, there are some real demographic and economic data of 35 major big cities in China ⁵³ from 2009.

Table 3.3-5: Demographic and economic data of 35 major big cities in China

Cities	Population (million pop)	GDP 2nd Indus (billion \$)	GDP 3rd Indus (billion \$)	Density1 (of the whole administrative city) (Pop/ sq km)	Density 2(excluding the admin-affiliated counties) (Pop/ sq km)
Beijing	12.46	43.3	139.1	759.14	963.84
Shanghai	14	90.9	135.3	2209.31	2583.28
Guangzhou	7.95	51.6	84.3	1068.9	1703.37
Shenzhen	8.91	58.0	66.2	1234.74	1234.74

(Continue in next page)

⁵³ All the cities are central cities in each province.

Cities	Population (million pop)	GDP 2nd Indus (billion \$)	GDP 3rd Indus (billion \$)	Density1 (of the whole administrative city) (Pop/ sq km)	Density 2(excluding the admin-affiliated counties) (Pop/ sq km)
Chongqing	32.76	52.3	37.5	395.48	592.44
Tianjin	9.8	60.4	51.6	833.2	1085.15
Chengdu	11.4	30.3	33.8	940.21	2398.07
Wuhan	8.36	32.5	35.3	983.69	1894.67
Hangzhou	6.83	36.2	38.0	671.89	3606.16
Harbin	9.92	17.4	24.9	186.85	669.91
Nanjing	6.3	29.3	32.9	956.81	1155.98
Jinan	6.03	22.0	25.9	697.36	2486.05
Qingdao	7.63	36.7	33.4	693.7	1373.3
Xi'an	7.82	17.3	22.3	773.32	1567.78
Shenyang	7.17	32.2	29.3	552.04	1475.74
Dalian	5.85	32.2	28.9	465.09	1250.56
Fuzhou	6.38	16.8	19.0	746.1	1455.82
Changsha	6.52	28.7	25.3	551.31	2523.04
Hohhot	2.27	9.0	14.7	132.01	578.33
Nanning	6.98	8.0	11.9	315.81	414.36
Shijiazhuang	9.77	22.5	18.3	616.74	5324.12
Zhengzhou	7.31	27.1	21.5	982.37	2821.88
Ningbo	5.71	35.8	27.0	304.83	1082.51
Changchun	7.57	21.9	17.9	367.16	756.57
Taiyuan	3.65	10.2	12.7	524.37	1953.15
Kunming	5.34	12.5	13.2	254.1	609.6
Xiameng	1.77	12.4	13.6	953.21	1390.8
Urumqi	2.41	6.9	9.5	174.93	243.39
Guiyang	3.67	6.0	8.0	456.91	910.11
Hefei	4.91	16.7	13.5	737.76	1062.68
Haikou	1.58	1.8	5.1	686.51	686.51
Lanzhou	3.24	6.6	7.0	247.28	1289.64
Nanchang	4.97	15.4	10.7	411.77	1399.74
Xining	1.94	3.8	3.5	253.02	3003.42
Yingchuan	1.56	4.3	3.9	162.79	395.59

Original data from: [<http://www.chinautc.com/information/newsshow.asp?newsid=3380>]; and [<http://www.chinautc.com/information/newsshow.asp?newsid=3663>]

From the data in Table 3.3-5 and using the model created above, we could calculated all the model-forecasting values of the daily public transit flow, Percentage Share of BRT in public transit, and eventual the potential daily public transit flow in URT/BRT system. (The histogram could be found in Appendix III.)

Table 3.3-6: Model-forecasting values

Cities	Q (million pop)	Share1* (100%)	Share2* (100%)	Q-URT1* (million pop)	Q-URT2* (million pop)
Beijing	16.113	7.654	9.933	1.233	1.600
Shanghai	12.201	23.800	27.964	2.904	3.412
Guangzhou	8.123	11.103	18.167	0.902	1.476
Shenzhen	5.358	12.949	12.949	0.694	0.694
Chongqin	3.396	3.605	5.798	0.122	0.197
Tianjin	3.334	8.479	11.284	0.283	0.376
Chengdu	3.332	9.670	25.902	0.322	0.863
Wuhan	3.195	10.154	20.297	0.324	0.648
Hangzhou	3.190	6.683	39.353	0.213	1.256
Harbin	3.039	1.282	6.661	0.039	0.202
Nanjing	3.001	9.855	12.072	0.296	0.362
Jinan	2.614	6.966	26.881	0.182	0.703
Qingdao	2.595	6.925	14.492	0.180	0.376
Xi'an	2.583	7.812	16.657	0.202	0.430
Shenyang	2.366	5.348	15.633	0.127	0.370
Dalian	2.242	4.380	13.126	0.098	0.294
Fuzhou	2.119	7.509	15.411	0.159	0.327
Changsha	2.074	5.340	27.293	0.111	0.566
Hohhot	1.909	0.672	5.641	0.013	0.108
Nanning	1.878	2.718	3.815	0.051	0.072
Shijiazhuang	1.790	6.069	58.481	0.109	1.047
Zhengzhou	1.740	10.140	30.621	0.176	0.533
Ningbo	1.726	2.596	11.254	0.045	0.194
Changchun	1.671	3.290	7.625	0.055	0.127
Taiyuan	1.636	5.040	20.948	0.082	0.343
Kunming	1.621	2.031	5.989	0.033	0.097
Xiameng	1.475	9.815	14.687	0.145	0.217
Urumqi	1.390	1.149	1.912	0.016	0.027
Guiyang	1.331	4.289	9.335	0.057	0.124
Hefei	1.321	7.416	11.034	0.098	0.146
Haikou	1.144	6.845	6.845	0.078	0.078
Lanzhou	1.136	1.955	13.561	0.022	0.154
Nanchang	1.070	3.786	14.787	0.041	0.158
Xining	0.817	2.019	32.642	0.016	0.267
Yingchuan	0.809	1.014	3.606	0.008	0.029

Notice: (Continue in next page)

* Q is the total daily passenger transit flow in public transport system.

$Q(\text{million people}) = 0.528148 + 0.056268 * \text{Population (million people)} - 0.07361 * \text{GDP value of 2nd industry (\$ billion)} + 0.129914 * \text{GDP value of 3rd industry (\$ billion)}$

* *Share* is share of BRT in public transit. $\text{Share of URT (100\%)} = 11.134 \text{ Density (Pop / sq km)} - 0.7982$
Share1 was calculated based on *Density1* (Density of the whole administrative city), *Share2* was on *Density2* (Density of the city area excluding the admin-affiliated counties). Since *Density2* is basically not less than *Density1*, *Share 1* is always not less than *Share2*. ***Share1* is more close to the current reality generally based on the average urbanization level in the whole city, while *Share2* reflect some more developed level in the future while the city is more mutually urbanized.**

* *Q-URT* is the potential daily passenger transit flow (demand) on a BRT or URT. $Q-URT = Q * \text{Share}$.
Q-URT 1 & 2 based on *Share 1&2*. **Therefore, *Q-URT1* is more close to the current demand generally based on the average urbanization level in the whole city, while *Q-URT2* reflect some more developed demand in the future while the city is more mutually urbanized.**

Source: Calculations under the statistical model.

Explain the results

Tier1--- Beijing, Shanghai, Guangzhou, and Shenzhen

According to the final results on *Q-URT1*, we could find out there are only 4 cities including **Beijing, Shanghai, Guangzhou, and Shenzhen** generally having predictive passenger flows in BRT/ URT higher than the critical threshold of BRT's capacity (560,000 people per day) currently. Since *Q-URT1* reflects the current demand based on the average urbanization level in the whole city, this means that the transit demands in these cities are averagely over the capacity of BRT system, so these four cities definitely need a developed and widespread urban metro system no matter if BRT will be built or not. In this kind of cities, ***BRT cannot replace metro***. We could define them as *Tier1*. In fact, all of these four metropolises have already had metro systems developing and operating for a long time, which side-supports the result from the model.

As characteristics in Tier 1 (though all the factors interactively affect the final classification, but general speaking):

- the total population of the city should be at least about 8 million;
(Reflecting the huge scale of the city)
- the density of the whole city is reaching 1000 pop/sq km;
(Reflecting the super-high urbanization level)
- the GDPs of second and third industries should both be at least \$50 billion;
(Reflecting the most powerful economic strength)
- and the GDP of third industries should be higher than the GDP of second industries. (Reflecting the post-industrization stage of urbanization)

Tier 2--- Hangzhou, Shijiazhuang, Chengdu, Jinan, Wuhan, and Changsha

According to the final results on *Q-URT2*, There are another 6 cities besides *Tier 1* having potentials for a threshold-beyond average BRT/URT passenger flow in the city, which include **Hangzhou, Shijiazhuang⁵⁴, Chengdu, Jinan, Wuhan, and Changsha**. Since *Q-URT2* reflects some more developed demand in the future while the city is more mutually urbanized, these cities have the potentials and trends for a huge transit demand in short-time growths which BRT might not be able to support alone. In this kind of cities, Metro system should also be considered, preparing for the needs in short-term future. We could define these cities as *Tier 2*. In *Tier 2*, BRT cannot replace URT either, but could be a transition before URT temporarily.

In these cities currently, only Chengdu has an operating metro system, others like Hangzhou, Jinan, Wuhan, and Changsha are having a metro system under developments (Got approved already). Shijiazhuang is the only city doesn't have a plan on metro until now.

General speaking⁵⁵, to be classified in Tier 2:

- the total population of the city is around 6 million~10 million;
(Reflecting the big scale of the city)
- the density of the whole city is reaching 500 ~1000 pop/sq km;
(Reflecting the certain-high urbanization level)
- the density of the city area excluding the affiliated counties is at least reaching 2000 pop/sq km;
(Reflecting the high urbanization level in the central area)
- the GDPs of second and third industries should be \$20 billion~\$35 billion;
(Reflecting the certain economic strength)
- and the GDP of third industries should be higher than the GDP of second industries. (Reflecting the post-industrization stage of urbanization)

Tier 3--- Other big cities.

For other big cities, which have a lower average BRT/URT passenger flow, BRT might be able to take the major transit-servicing job in the city without needing a URT system in short term (5-10 years).

Worth a notice, the analysis here is only based on the average level of density and other indexes in the whole city, which reflects a general/average stage in

⁵⁴ The data shows Shijiazhuang has an unusual extremely high density on Density2 (Density of the city area excluding the admin-affiliated counties), which caused the *Share2* and *Q-URT2* of the city is also higher.

⁵⁵ All the factors interactively affect the final classification, so the range are not very exact.

developments and transit needs of the city but cannot indicate the real distribution of urban growth and transit needs everywhere in the city.

Because of the different urban structural and distribution pattern, some lower tier cities might also have a higher transit demand in the central and other population-highly-aggregated areas, which also could result in a dependency on metro systems. Therefore, the modeling and analysis is only a first step to refer before our judgments.

3.3.3 Possible cooperation patterns

As previously introduced in CHAPTER 2, there are several different ways to build the cooperation between BRT and URT (*Lei Gao, Wei Wang, Jun Dai, 2006*):

- 1) Build BRT as the central mode in public transit;
- 2) Build BRT as a cooperater with URT system;
- 3) Build BRT as a supplemental branch linked to the central rail system;
- 4) Build BRT temporarily as a transition to an URT planned in the future;
- 5) Build BRT exclusively isolated from the existing public transit system.

For tier-1 cities, the central metropolises in China like *Beijing, Shanghai, Guangzhou, and Shenzhen*, since BRT cannot afford the total transit demand alone, metros are necessary, but the service radius of metro system could hardly reach the whole urban area. In this kind of cases, pattern 3 is a better choice. In pattern 3, BRT could be a supplemental branch in the suburbs to concentrate flows in different directions into the metro system. With high flexibility in construction, it could also be used in the new developing areas, where the transportation demand is increasing but metros could hardly reach in short term. (Ex. Figure 3.3-5)



Figure 3.3-5: Map of the new BRT line built in Guangzhou

Source: Base map from: [<http://www.chinabrt.org/maps/maps-guangzhou.aspx>]; Graphing: by Author.

For the big cities in Tier 2 like *Hangzhou*, *Jinan*, and etc. (Basically the developed provincial capitals, or the most central cities in each of the metropolitan areas), since both of the city itself and also the transit demand are growing with the potential to exceed the capacity of BRT system, pattern 2 and 4 might be suitable alternatives.

- *Pre-metro BRTs:*

For the cities hasn't built metros but are planning to build an urban rail system eventually, like *Hangzhou*, *Jinan*, and etc, BRT could be built first as a temporary substitute in service (pattern 4). When the city growth reaches the threshold later, we could transform into pattern 2 or 3.

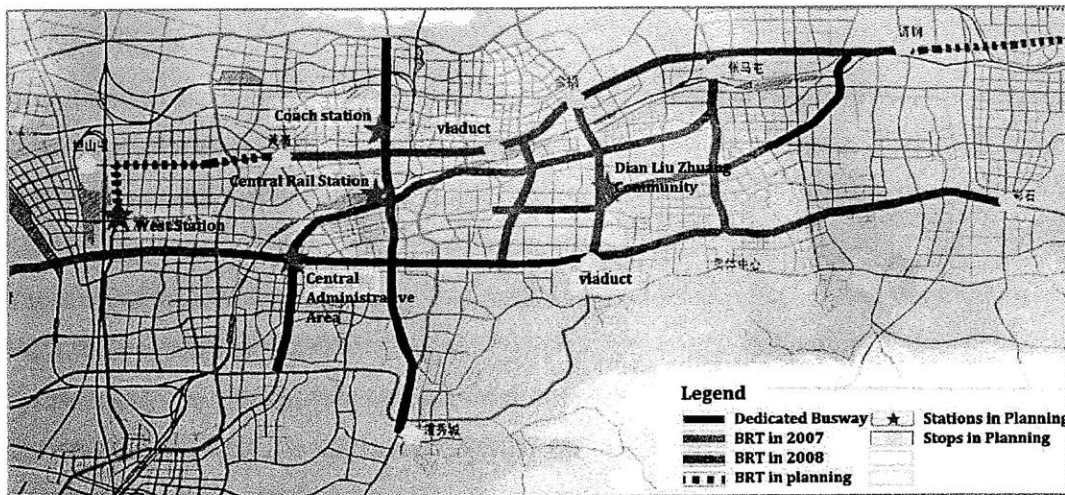


Figure 3.3-6: Transportation Planning on BRT system in Jinan city in 2009

Source: Originally from: [<http://sd.house.sina.com.cn/news/2009-04-29/095246167.html>]

- *Post-metro BRTs:*

For the cities which has a metro system already constructed or under construction, BRT could be operated as a cooperater under pattern 2. Like *Chengdu*, the city has already have a metro line opened (Line 1) and are doing planning for extending the metro system for future developments (Figure 3.3-7). In this kind of situation, BRT could be imported into consideration as a cooperater with the metro system. In some areas, BRT could be more efficient and cost-saving, so all the alternatives of their interrelated assembly should be thought through in planning, base on the ideas of integration of the system.

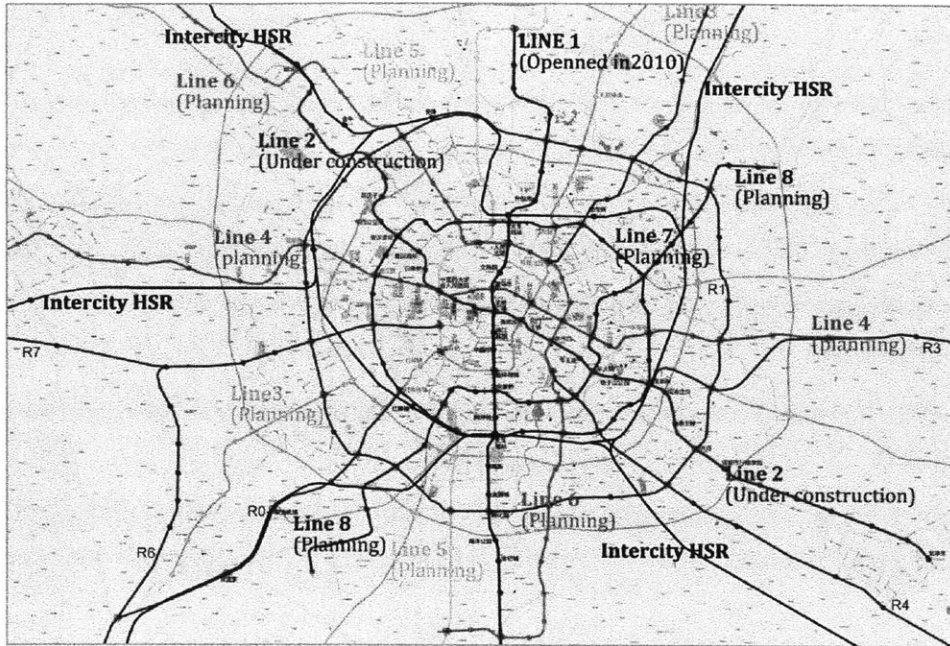


Figure 3.3-7: Master Planning on Metro system in Chengdu

Source: Original map from: [http://chengdua.com/hot_view.asp?id=1]

For other developing mid-big cities in tier 3 (which normally are capitals in some developing provinces or secondary central cities in each of the metropolitan areas), Pattern 1 could be a smart choice. Since the transit needs are comparatively lower than the bigger central cities, metro or light rail system might not be very efficient and will be expensive to them in at least 5- 10 years. At the same time, the city is growing and the normal bus service might hardly afford the flows and cannot satisfy the commuting speed required by the residents. In these settings, BRT would be a perfect option to plan the central role in the whole public transit system.

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Appendix I: The detail data

Regions	Q	Population	GDP	GDP/ Pop	Area	Pop Density	1indus	2indus	3indus	Ratio of 3indus	Ratio of 2indus
Unit	Million Passenger	Million pop	US\$ Million	US\$	Sq Km	pop / sq km	\$ million	\$ million	\$ million	%	%
Beijing	18.05	17.55	184136.82	10492.13	16800	1045	1792.27	43265.91	139078.64	75.5	23.5
Tianjin	3.33	12.28	113967.42	9280.73	11300	1087	1952.27	60421.82	51593.33	45.3	53.0
Hebei	4.57	70.34	261143.64	3712.59	187700	375	33444.55	135755	91944.09	35.2	52.0
Shanxi	2.74	34.27	111489.55	3253.27	156300	219	7236.21	60512.12	43741.21	39.2	54.3
Inner Mongolia	1.76	24.22	147579.55	6093.29	1183000	20	14084.85	77484.85	56009.85	38.0	52.5
Liaoning	10.43	43.19	230492.27	5336.70	145900	296	21437.88	119793.03	89261.36	38.7	52.0
Jilin	4.29	27.40	110284.09	4024.97	187400	146	14857.12	53665.45	41761.52	37.9	48.7
Heilongjiang	5.60	38.26	130106.06	3400.58	454800	84	17489.85	61526.06	51090.15	39.3	47.3
Shanghai	11.03	19.21	227976.52	11867.60	6300	3049	1724.55	90936.06	135315.91	59.4	39.9
Jiangsu	10.54	77.25	522080.30	6758.32	102600	753	34270.61	281308.64	206501.06	39.6	53.9
Zhejiang	8.79	51.80	348338.64	6724.68	102000	508	17622.42	180431.67	150284.55	43.1	51.8
Anhui	5.00	61.31	152466.97	2486.82	139700	439	22658.33	74321.52	55487.12	36.4	48.7
Fujian	4.82	36.27	185401.97	5111.72	121300	299	17920.3	90989.39	76492.27	41.3	49.1
Jiangxi	3.08	44.32	115987.58	2617.05	167000	265	16646.36	59385.61	39955.61	34.4	51.2
Shandong	9.19	94.70	513585.61	5423.29	153800	616	48888.48	286391.36	178305.76	34.7	55.8
Hebei	5.48	94.87	295158.48	3111.19	167000	568	41955.3	166825.76	86377.42	29.3	56.5
Hubei	8.39	57.20	196380.30	3433.22	185900	308	27210.61	91486.06	77683.64	39.6	46.6

Regions	Q	Population	GDP	GDP/ Pop	Area	Pop Density	1indus	2indus	3indus	Ratio of 3indus	Ratio of 2indus
Unit	Million Passenger	Million pop	US\$ Million	US\$	Sq Km	pop / sq km	\$ million	\$ million	\$ million	%	%
Human	5.45	64.06	197874.09	3088.89	211800	302	29843.79	86169.55	81860.76	41.4	43.5
Guangdong	19.63	96.38	598220.61	6206.90	180000	535	30458.64	294237.88	273524.09	45.7	49.2
Guangxi	3.65	48.56	117563.03	2420.98	236000	206	22098.33	51235.45	44229.24	37.6	43.6
Hainan	0.84	8.64	25063.79	2900.90	34000	254	7002.88	6718.64	11342.27	45.3	26.8
Chongqin	3.99	28.59	98939.55	3460.63	82300	347	9193.94	52254.09	37491.52	37.9	52.8
Sichuan	7.57	81.85	214413.33	2619.59	481400	170	33948.64	101695	78769.7	36.7	47.4
Guizhou	11.11	37.98	59283.03	1560.90	176000	216	8337.42	22373.03	28572.58	48.2	37.7
Yunnan	3.34	45.71	93481.06	2045.09	383300	119	16175.76	39129.24	38176.06	40.8	41.9
Xizang	0.15	2.90	6687.27	2305.96	1228000	2	967.88	2070.15	3649.24	54.6	31.0
Shanxi	5.44	37.72	123784.85	3281.68	205600	183	11964.24	64188.18	47632.42	38.5	51.9
Gansu	2.00	26.35	51326.67	1947.88	454400	58	7531.06	23140	20655.61	40.2	45.1
Qinghai	1.16	5.57	16382.88	2941.27	722300	8	1627.27	8717.12	6038.48	36.9	53.2
Ningxia	0.74	6.25	20504.70	3280.75	66400	94	1928.03	10035.15	8541.52	41.7	48.9
Xinjiang	3.26	21.59	64803.79	3001.56	1660000	13	11511.21	29236.21	24056.36	37.1	45.1

Notice and Source:

* Regions here are the administrative divisions on province-level in China, including provinces and directly-governed municipalities

* Data here is all for 2009. All the amounts of money were in RMB Yuan, but got converted into \$US dollar by an exchange rate of 1/6.6.

* Q here is the data on average daily public-transit passenger flow, from [<http://www.chinautc.com/information/newsshow.asp?newsid=3384>]

* 1indus, 2indus, 3indus here represent the real values (\$ million dollar) of the GDP share of primary industry, secondary industry, tertiary industry. The Ratio of 3indus and Ratio of 2indus present the share percentage (100%). All the data related to GDP are from: [<http://www.chinautc.com/information/newsshow.asp?newsid=3377>]

* The data of Population is from [<http://www.doc88.com/p-59658810757.html>];

* The data of Area is from: [<http://zhidao.baidu.com/question/110559596.html>].

Appendix II: The Model Testing

T-test

T-values is an important index for choosing the right variances into the model, here, with all of the P values of b_1, b_2, b_3 is smaller than 0.05, T-test could passed basically under a 95% confidence level (except for *intercept*, but since our focus is put on the relation between the variables, so we could release it).

	Coefficients	Standard Error	t Stat	P-value
a	0.528148	0.724165	0.72932	0.472086*
b_1	0.056268	0.023682	2.376019	0.024855
b_2	-0.07361	0.014487	-5.0813	2.45E-05
b_3	0.129914	0.014293	9.089465	1.06E-09

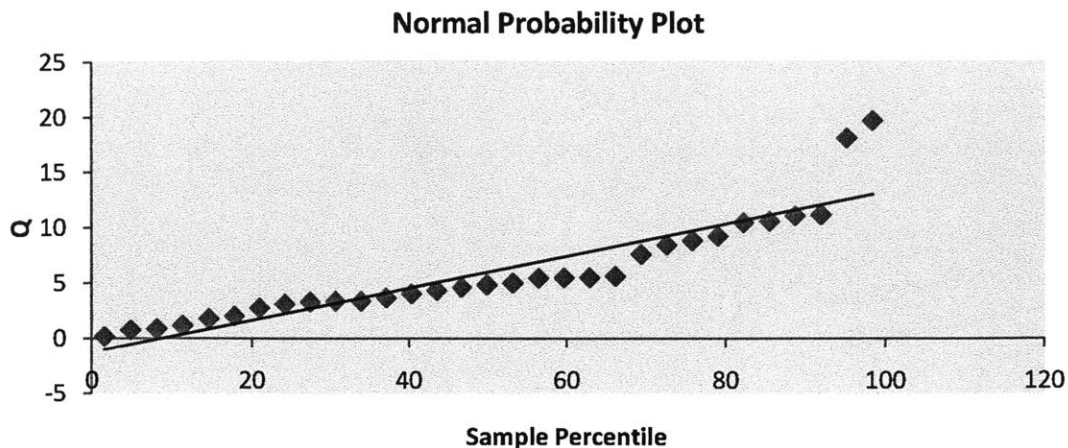
* Notice: Here, the t-test of the intercept is actually cannot pass under a common 95% confidence level, but normally, intercept is not the key issue we care, we could comparatively easy the requirements.

R, F test

Both of the R and F values is higher than requirement. The R, F tests could also pass.

Regression Statistics		ANOVA					
Multiple R	0.921721		df	SS	MS	F	Significance F
R Square	0.84957	Regression	3	549.461	183.15	47.61	6.49E-11
Adjusted R Square	0.826427	Residual	27	103.8576	3.8466		
Standard Error	1.944207*	Total	30	653.3186			
Observations	31						

The Normal Probability Plot also looks closed to linear diagonal, which is normal.



DW test

The DW value is around **2.26**, around 2, which is also fine.

Limitations

The only concern is the over-big Standard Error, which is 33% of the mean value of Q. However, because limitations on data, this is the best we can get based on the information we have.

So generally, the regression model can be trusted under the common 95% confidence level.

Q (million people) = a + b₁ * Population (million people) + b₂ * GDP value of 2nd industry (\$ billion) + b₃ * GDP value of 3rd industry (\$ billion).

a=0.528148; b₁=0.056268, b₂= -0.07361; b₃= 0.129914

Appendix III: The Modeling result

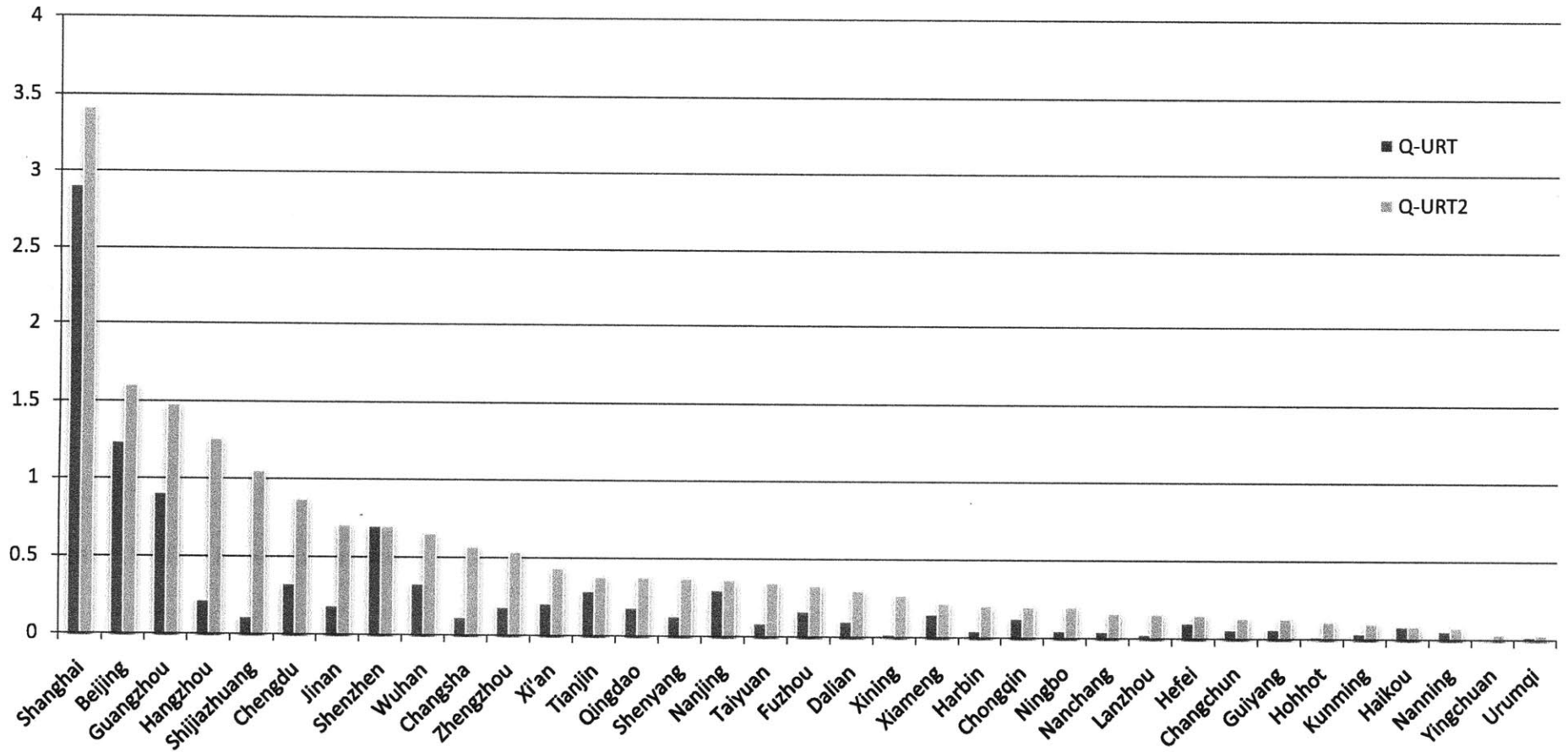


Figure Apx3: Model-forecasting values on daily passenger transit demand for every city

CHAPTER 4. INTEGRATION OF BRT & URT

Transportation has close interactions with land use, economy, environment, and energy consumption. An efficient comprehensive transport system should have compatibility in developments of different modes and also integration between them by effective connections, so as to guarantee the daily activities in the city and also promote the economic developments in more sustainable way.

A compatible and efficient public transport system with sustainable developments should satisfy some conditions (Chuanping Dan, 2008):

- **Systematic:** Public transport is different from private transport modes. The coordination includes multi-parts. It not only requires a tight internal connection between URT, BRT and the normal bus network, but also refers to a lot of non-transport elements. These elements all join together to constitute an entire system. As a system, should always keep the organization property and a high openness.
- **Comprehensive:** Comprehensiveness requires both breadth and depth. First, public transport should have a broad service-covering area and multi-scales. Also, in the structural and functional natures, the system should be complex but organic with abundant choices adapt to different demands and to provide service with flexibility.
- **Dynamic:** There is rarely a city with no growth or change by time. As a service in active city area, the arrangements in public transport should have certain adjusting ability to follow the pulses in urban developments. Therefore, the public transport should be a dynamic system, with additions, revisions, and deletions after frequent review.
- **Layering:** Public transit system is also a multi-layer organization, with subsystems of BRT, URT and normal bus network. Each of them has their own nodes, lines and networks. The connection between these layers is the key in the coordination of the system.
- **Integrative:** Not only the system should have complete elements, but each of the subsystem should be complete and sympathetic to guarantee the functionality in the whole system, and to create a higher effectiveness under the integration than under separate operations. (Chuanping Dan, 2008)

Between BRT and URT, coordination and integration are especially crucial, since they are both the central stems supporting the whole public transport system. The efficiency in and between them will directly affect the performance of public transport in the whole city and will also decide the preference by passengers, the share of public transport and eventually the energy consumption. Certainly, compatibility and integration not only refer to geographical location and physical installation, but also include the coordination in management, uniform pricing, and conscious planning.

For economic and sustainable public transport, the role of BRT in the public transport system should be given careful attention. When it fits the development progress, the BRT should be favored. There are several environments where BRTs could work especially well (Chuanping Dan, 2008):

- In the central zone, where the multi-lane major roads have already built and have some space for dedicated busway;
- On axial roads connecting central zone and suburbs;
- On axial roads from central zone to surrounding towns;
- In some developing new towns or satellite towns;
- On corridors saved for rail construction in the future.

Therefore, though URT is a dominant mainstream choice among public transport modes in most of the big cities in China, the planning, construction and developments of BRT should not be neglected. As a country offering major guidance and supervisions from government, this sense of emphasis should be set up as general standards. The collaboration between these two key modes is an important goal, which is good for sustainability and efficiency in city growth.

4.1. Merging the Networks

The first issue in the integration between BRT and URT is the combination in network. To reach this, **long-sighted planning** for a comprehensive system is specifically important. The following chart shows a systematic planning process.

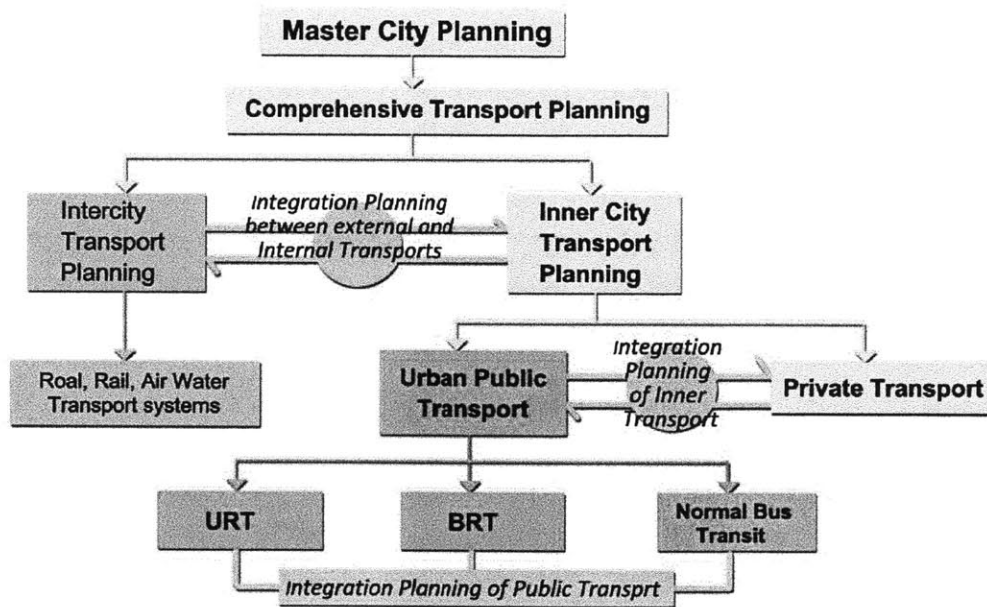


Figure 4.1-1: Flow chart of Planning Process for a comprehensive transport system

Source: Refer to Cailiang Jiang, 2004.

4.1.1 Comprehensive Transport Planning: strategy in developments

Comprehensive Transport Planning is an important and required step which should be included in master planning of every city. It is a general guide on transport developments in the area and also strategy understanding on the relationship between this area and the surrounding region. In this planning, a broad arrangement will be issued on service targets, tasks and scales between transport modes, and also, an initial draft about the future focusing objects in infrastructure investment and construction will be noticed for both short-term (10~20 years) and long-term (20 ~50 years). Therefore, the macro-strategy on dealing the relationship between BRT and URT will be first guided in this planning document.

In comprehensive transport planning, the city needs to decide the suitable core mode in urban transport system, either BRT or URT or even only normal bus transit (for small cities), and also their cooperation pattern. The decision should not be randomly subjective, but need to be rationally based on facts in the city. It should not only base on the current situation and demand, but also need to consider the trend of developments in the future.

If refer to the model resulted in CHAPTER 3 (3.3.2 & 3.3.3), then we could forecast the future demand with predicted economic and demographic indicators. For example,

if a city now has only a population of 6 million people and a density of 600 pop/sq km, and its GDP in 2nd and 3rd industries are around 30, it will not reach the current threshold for building a metro system (Based on the requirements of *Tier1*, refer to 3.3.2). However, we might expect a high-speed growth in this city. After prediction, we believe its population and density could reach 8 million and 900 pop/sq km in 20 years, and more importantly, the density in central zones would reach 4000 pop/sq km. Also, the GDP of 2nd and 3rd industries in the city could further reach 40 and 50 billion. In this case, the city might need a metro system soon, and pattern 2, 3 or 4⁵⁶ will be better choice for the city: In pattern 2 or 3, we could consider starting to plan some metro lines in the central urban areas beforehand, since the planning and approval procedures and the infrastructure construction are all time-consuming.

For the other outer areas, BRT or normal bus service could be also planned also depending on the predicted needs. (Based on *Tier 2*, refer to 3.3.2). Or, we could also follow pattern 4⁵⁷, to build BRT first as a temporary substitute in service and when the city growth is closed to the threshold, we then transform into pattern 2 or 3.

4.1.2 Network Planning: Accessibility and efficiency in the system

Network Pattern: Principles of Network Planning

To best organize the activities and trips in the area, the public transport network should have a certain pattern based on the spatial characteristics of the city area.

Except some linear cities, the network of which could simply be shaped in one bunch with only one major axis, for most of the other cities, the most popular one is the “**Emission-axes + Rings**” pattern: First, the system should have major emission-type branches stretching to the edge of the city area, and second, the system should also contain cycle-type belts to connect the emitting branches.

In inland cities with regular square or round shape, it shows as a network with complete symmetry. For example, Figure 4.1-2 shows the proposed network pattern in planning of BRT in *Beijing*. It in total contains 3-class hubs, 2 level corridors: the outskirts corridor (the light green ones) and the urban area corridor (the more interlaced dark green ones). The reason for this BRT network planning looks more square than cycle is because *Beijing* city is in a very rectangular shape with all the squared highway belts (Figure 4.1-3).

⁵⁶ Mode2. Build BRT as a cooperater with URT system; Mode3. Build BRT as a supplemental branch linked to the central rail system, refer to 3.3.3

⁵⁷ Mode 4: Build BRT temporarily as a transition to an URT planned in the future. also refer to 3.3.3

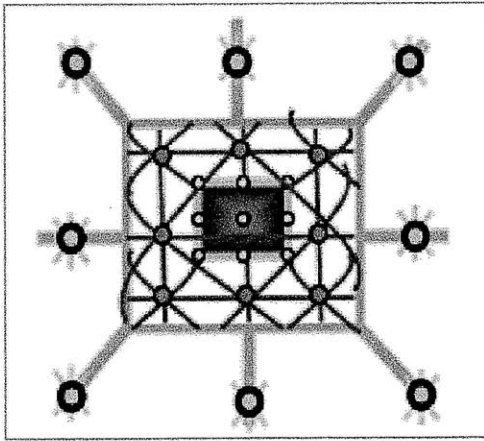


Figure 4.1-2: Principle Pattern in BRT Network Planning in Beijing

Source: U.S. Department of Transportation, FTA, (TRI), Bus Rapid Transit Developments in China 2006

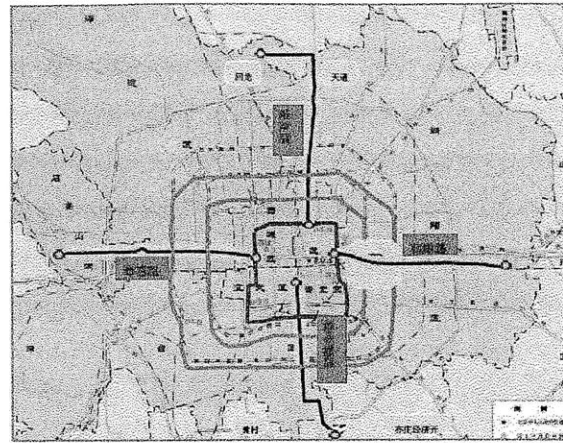


Figure 4.1-3: The Current Highway Rings and the four existing BRT lines in Beijing

Source: Baidu.com, Images. Originally from ggph.com

Meanwhile, for the water-front cities, it could show as a fan-shape network with half symmetry, just like the pattern shown in the BRT planning of Xiamen city (Figure 4.1-4).

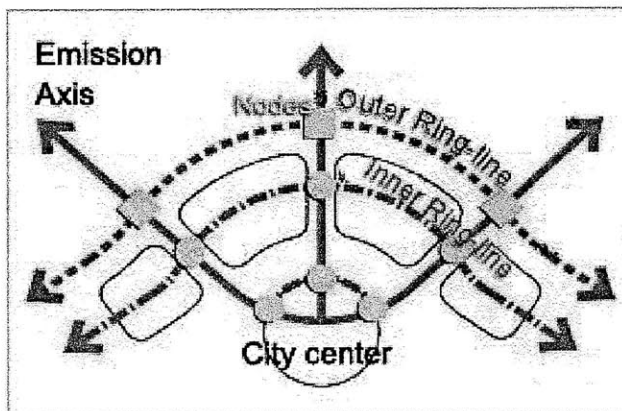


Figure 4.1-4: Principle Pattern in BRT Network Planning in Xiamen

Source: http://www.tranbbs.com/Techarticle/Plan/Techarticle_14339.shtml

Coordinative Strategy in Network Planning: Two patterns, three types

If a city only has a BRT system or a URT system, then the network planning just needs to consider the reasonability of the route arrangements in that one. However, if a city has BRT and URT at the same time, the city needs to have a comprehensive premeditation of the whole system in a broader visual angle.

For the integration of BRT and URT, there are basically two theoretical patterns could follow. As mentioned before, one is Pattern 2, to operate the two as cooperators for

each other, with approximately equal importance. The other one is Pattern 3, to operate one transit (normally BRT) as a supplement to the other more important and mainstream one (Normally metro).

In more details, there are actually **three types** to implement the two patterns.

1. Use URTs (Basically metros) to build up the outer rings, and operate BRTs to fill up the area between and inside with available transit lines and stops.
2. Use URTs (Basically metros) to build up the emission-axes, and run BRTs in cycle to link the axes together
3. Use URTs (Basically metros) to build up the internal or major network and run BRTs as emission branches spreading out.

(See Figure 4.1-5)

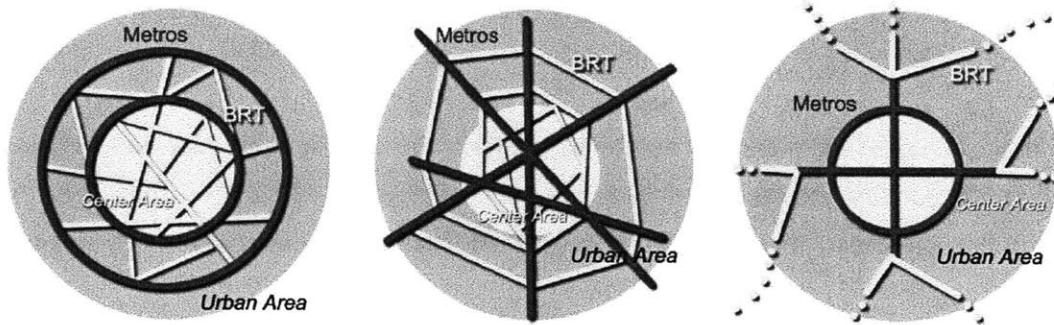


Figure 4.1-5: Three types to organize BRT and Metros together in Network

Notice: The graph here is only a schematic illustration of the three ways above, not means to any specific plan or detail structure.

Source: Author

Certainly, the reality in practice will be more complex, and cities would rarely choose one pure way to operate the systems, so usually the actual pattern will not look so similar to the schemas here, but normally there will still be a major type could be found in the network planning.

An Example of the First Type ----Shenzhen

For the first type, using URTs (Basically metros) to build up the outer rings and using BRTs to fill up the area between and inside, the short-term network planning of BRT and metro systems in *Shenzhen* (2006) is a good example. Since Shenzhen is a water-front city and also facing Hong Kong, there is only a semicircle could be found. (Figure 4.1-6)

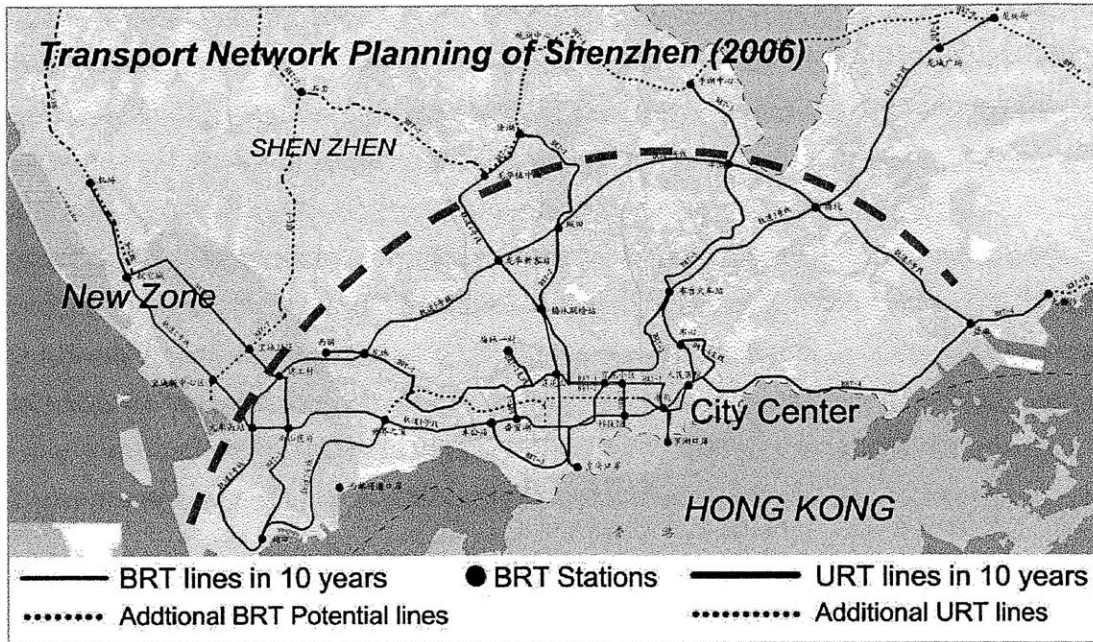


Figure 4.1-6: Transport Network Planning of BRT and URT in Shenzhen (2006)

Source: Original Planning map is from [http://www.tranbbs.com/Techarticle/TPlan/Techarticle_14564.shtml]

The ideas behind this planning are to strengthen the interactions and connections between city centers and the developing new zones, to satisfy the increasing needs on rapid-transit trips, and to efficiently combine BRT and URT to make them engage together.⁵⁸

An Example of the Second Type ---- Zhengzhou

Comparing to Shenzhen's network planning, the network planning in **Zhengzhou** generally looks more like the second Type, using metros to build up the basic axes, and run BRTs in cycle to link the axes together. (Figure 4.1-7)

As you can find in the transport network planning map in Figure 4.1-7, Zhengzhou chooses to use metro lines to be the major branches to link the old town (city center) to other new towns and zones. On the other hand, BRT was designed to increase the connections between the branches and important nodes.

⁵⁸ Refer to [http://www.tranbbs.com/Techarticle/TPlan/Techarticle_14564.shtml]

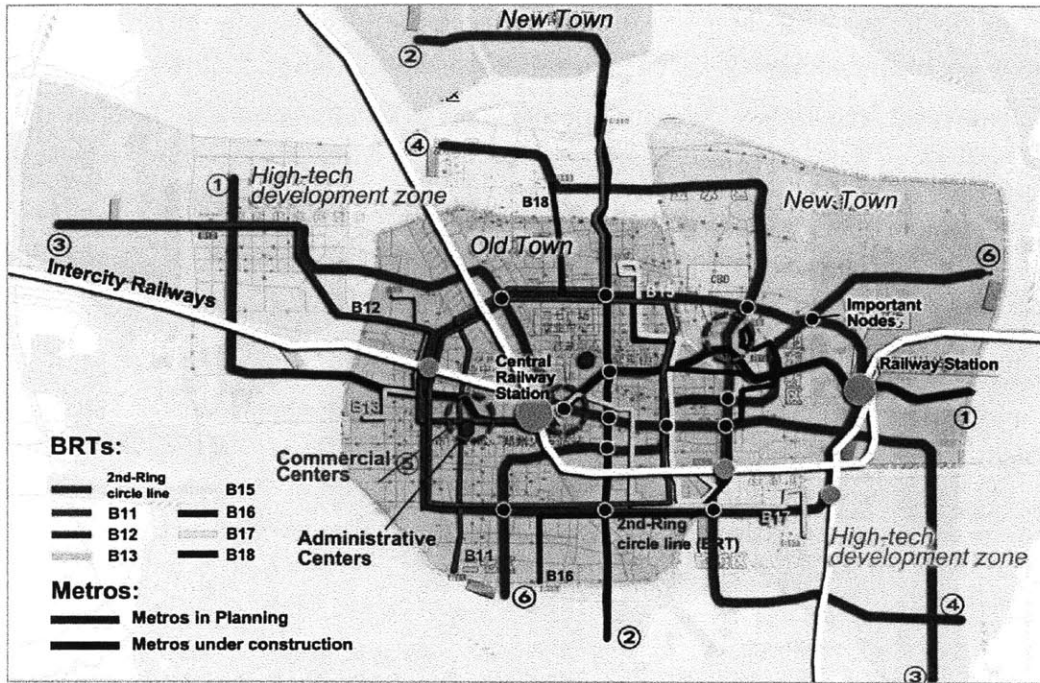


Figure 4.1-7: Transport Network Planning of BRTs and metros in Zhengzhou

Source: Original Planning maps are from [http://www.tripc.net/news/news_info/164230_6/]

An Example of the Third Type ---- Beijing

The short-term planning of BRT network in **Beijing** (2003) is an illustrative example for the third type, which selects metros to build up the internal or major network and runs BRTs as outstretching branches extending from the central area of the city.(Figure 4.1-8)

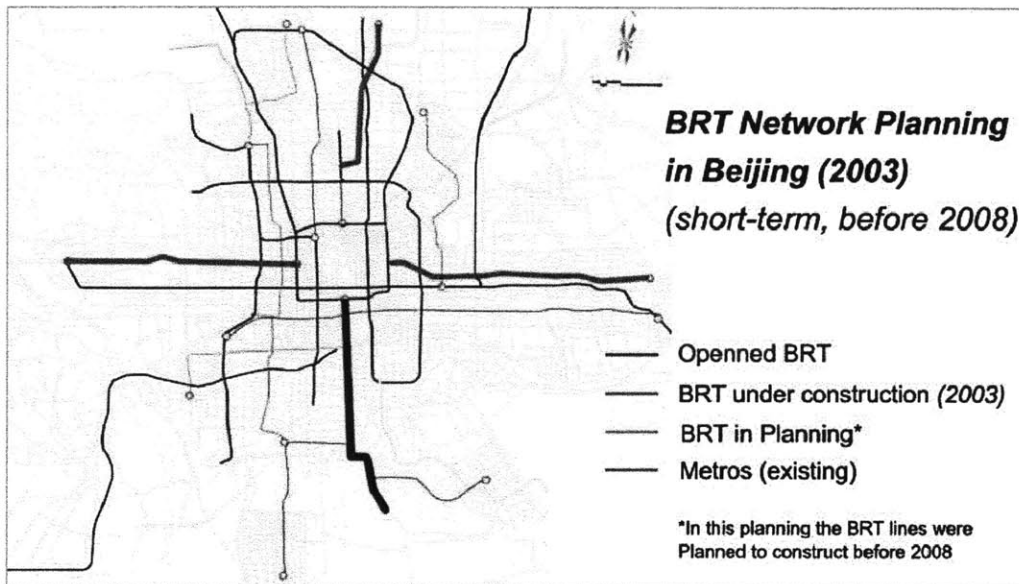


Figure 4.1-8: BRT Network Planning in Beijing (2003) for short term

Source: Original Planning map is from [<http://www.chinautc.com/tresult/manage/photo/20069592263.jpg>]

Meanwhile, different with the short-term plan, according to the long-term plan, the BRT network will eventually evolve into more densely covered co-system with the metros. The form looks more like a combined type with characteristics in both the *First* and the *Third Types* (Figure 4.1-9).

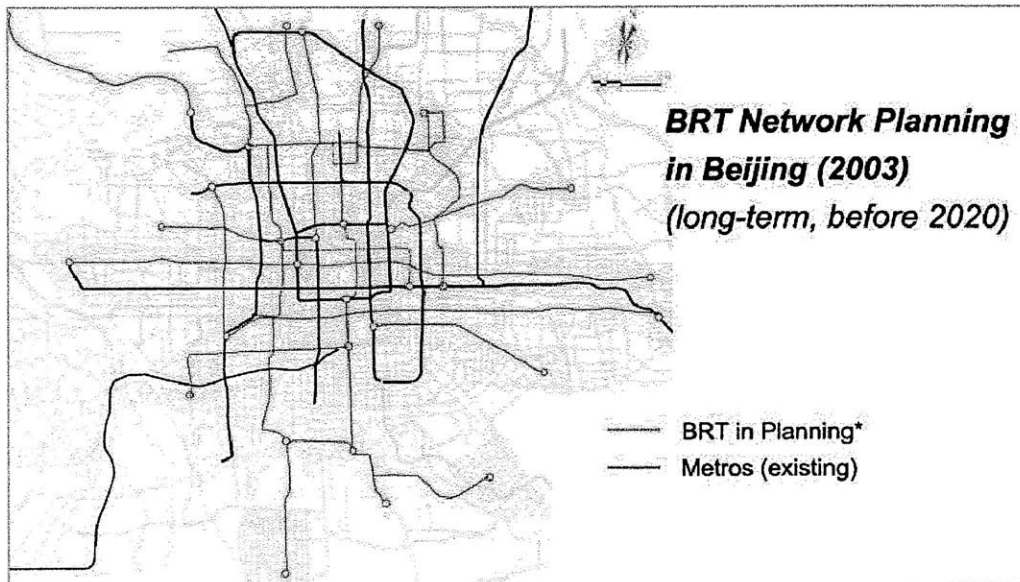


Figure 4.1-9: BRT Network Planning in Beijing (2003) for long term

Source: Original Planning map is from [<http://www.chinautc.com/tresult/manage/photo/20069592262.jpg>]

Network Planning for Pre-metro BRT system ---“#” latticed network

For the cities having BRTs only, which we could call it pre-metro BRT system, the network planning of BRT should consider more on the accessibility and connectivity between important nodes. Since BRT has more flexibility than metros, the lines and stops could be easily set up and upgraded in time to give the most effective connections.

For pre-metro BRT system, the network commonly appears in “#” latticed shape, denser in the city central zone and comparatively sparser in the surrounding area. The density of the network could directly reflect and also interact with the distribution of the demographic density in the city.

Example 1---- Kunming

Kunming has a very typical “#”-shape BRT network under planning and construction. In total length of 70 km, the BRT lanes have 40 km planned in “#”latticed shape

vertically and horizontally crossing the city center area, which could efficiently have a 75% service coverage rate in the city central zone⁵⁹.

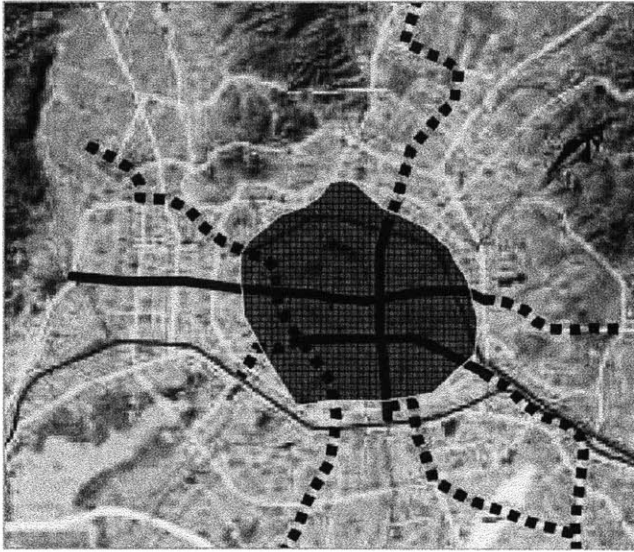


Figure 4.1-10: BRT Network Planning in Kunming city

Source: U.S. Department of Transportation, FTA, (TRI), Bus Rapid Transit Developments in China 2006, Perspectives from Research, Meetings, and Site Visits in April 2006

Example 2---- Jinan

Jinan is another example for a latticed pre-metro BRT system. Since the city evolved between hilly areas, because of the terrain characters, it is a belt-shape urban area, which products a long –shape latticed network in BRT lanes (Figure 4.1-11). Instead of metros, BRT is taking the major burden in daily public transit service.

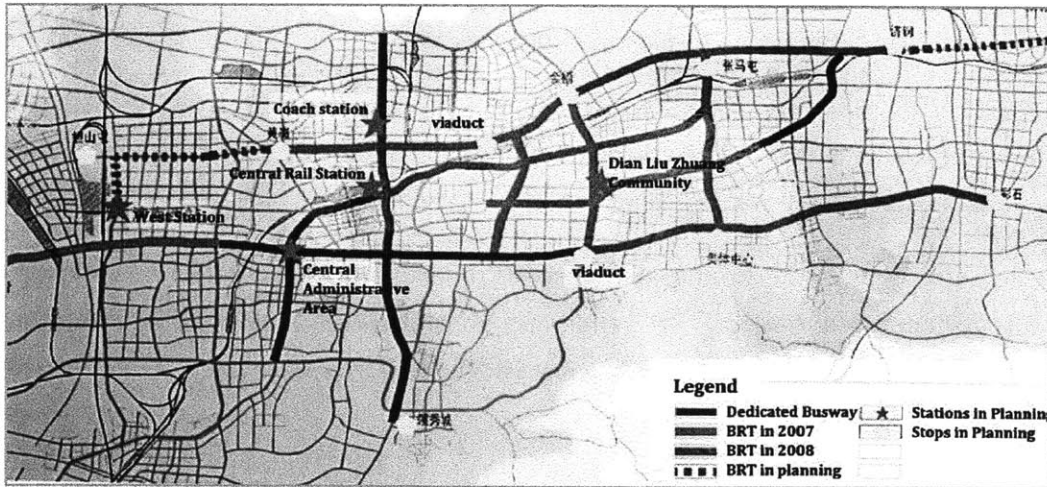


Figure 4.1-11: BRT network planning in Jinan city in 2009

Source: Originally from: [http://sd.house.sina.com.cn/news/2009-04-29/095246167.html]; Also shown as Figure 3.3-6

⁵⁹ Refer to: U.S. Department of Transportation, FTA, (TRI), Bus Rapid Transit Developments in China 2006, Perspectives from Research, Meetings, and Site Visits in April 2006

Example 3---- Xiamen

A strategy sketch plan of BRT lanes in *Xiamen Island* (one zone in Xiamen city) is also an illustration of the “#”-shape pattern in BRT network. One of the advantages in this type of systems is that it would efficiently link the most important nodes and developing areas together, but without too concentrated flows on only one center hub.

In this planning proposal, as you could find in the figure below, the planned BRT lanes tried to misalign a bit to the major roads with highest peak flows. This is a great way to prevent too-heavy transit burdens on one line or too much influence on the original road system.

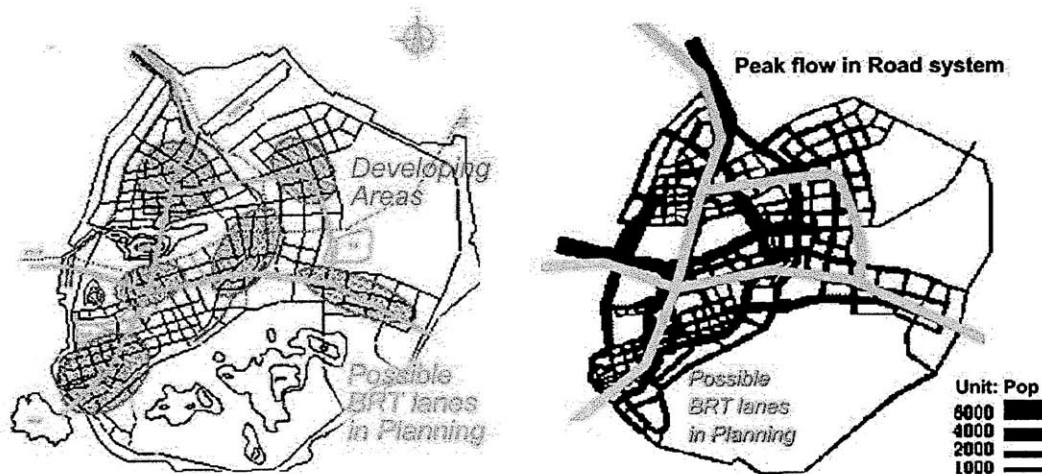


Figure 4.1-12: BRT network planning proposal in Xiamen Island in 2009

Sources: Originally from Xinniao Yang, Xiuzhi Guo, Huapu Lu, 2003,
[<http://www.archdig.com/transportation/transporttransit/200609/7324.html>]

However, besides the discussion on the planning in the island, Xiamen city, the whole urban area, is also a very special case.

Since the city is planning to upgrade some BRT lanes into Light rails, it is a typical example for Pattern 4, building BRT first, and transforms it into an URT in the future. (Figure 4.1-13: Transport Network Planning in Xiamen)

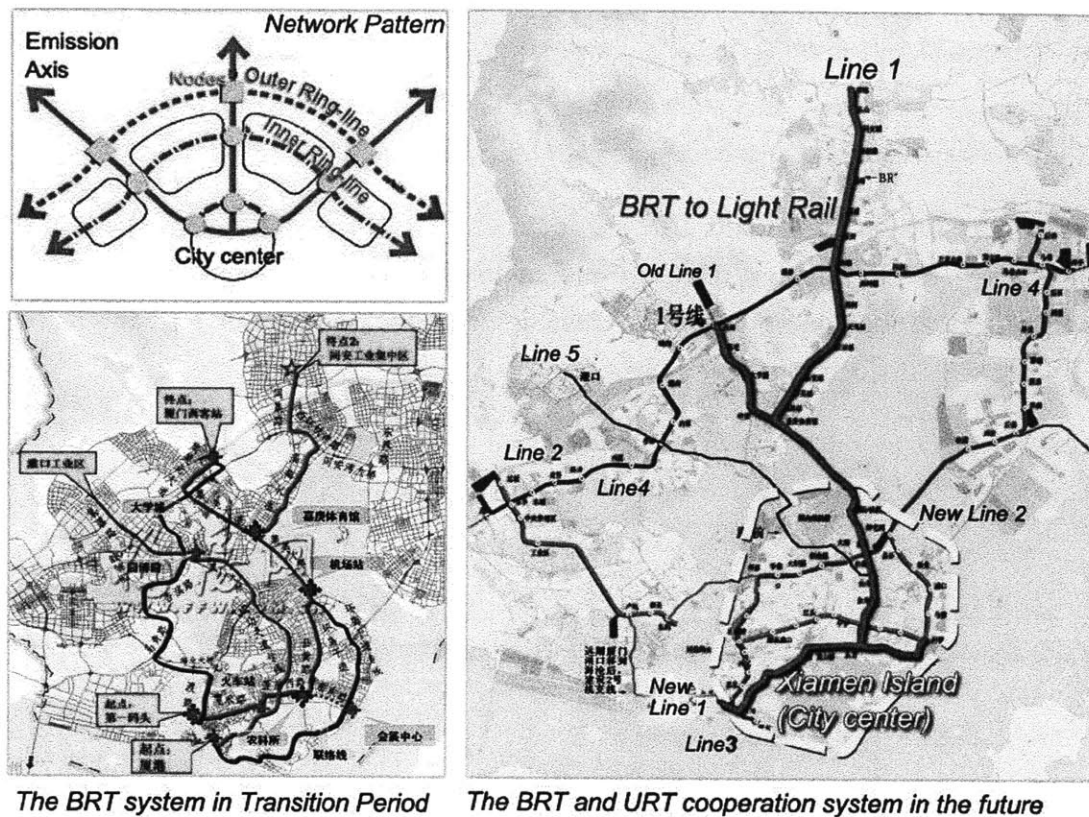


Figure 4.1-13: Transport Network Planning in Xiamen

Source: The Pattern figure is from: [http://www.tranbbs.com/Techarticle/TPlan/Techarticle_14339.shtml]
 The Planning maps are from: [http://blog.163.com/xiamei_trip/blog/static/2010597200972685111264/]

In this planning, we find the strategy of transport development in Xiamen is to build up the North-to-South Axes first, since the connections between the central island and the surrounding hinterland are very crucial. In the future, when necessary, light rail will take the major emission-axial job from BRT, and more BRT lanes will be built up to burden the East-to-West transit, which is the inner and outer rings shown in the network pattern figure (Figure 4.1-13).

This is an unapparent Second Type coordinative strategy introduced previously, which is using URTs to build up the emission-axes and running BRTs in cycle to link the axes together.

4.1.3 Network Development Processing: systematic steps

After having a comprehensive and reasonable network planning, the next task is to implement it with smooth but conscious steps. Being adaptive to different stages in urban development, the network growth and construction should also follow a systematic process with clear short-term and long-term objectives.

Horizontally, the network should be built, extended and interlaced gradually following the tempo in urban developments. Normally, one or two major lanes should be primarily constructed as a stem to connect the most important and central areas, and then, other branches could be added in and the previous ones could get extended.

Texturally, the network should also grow step by step from a simple, single-layer frame into a more complex, abundant and multi-layer system. In Figure 4.1-14, it shows a general idea on an organized development process for BRT or URT lanes, which could be divided into *four stages*.

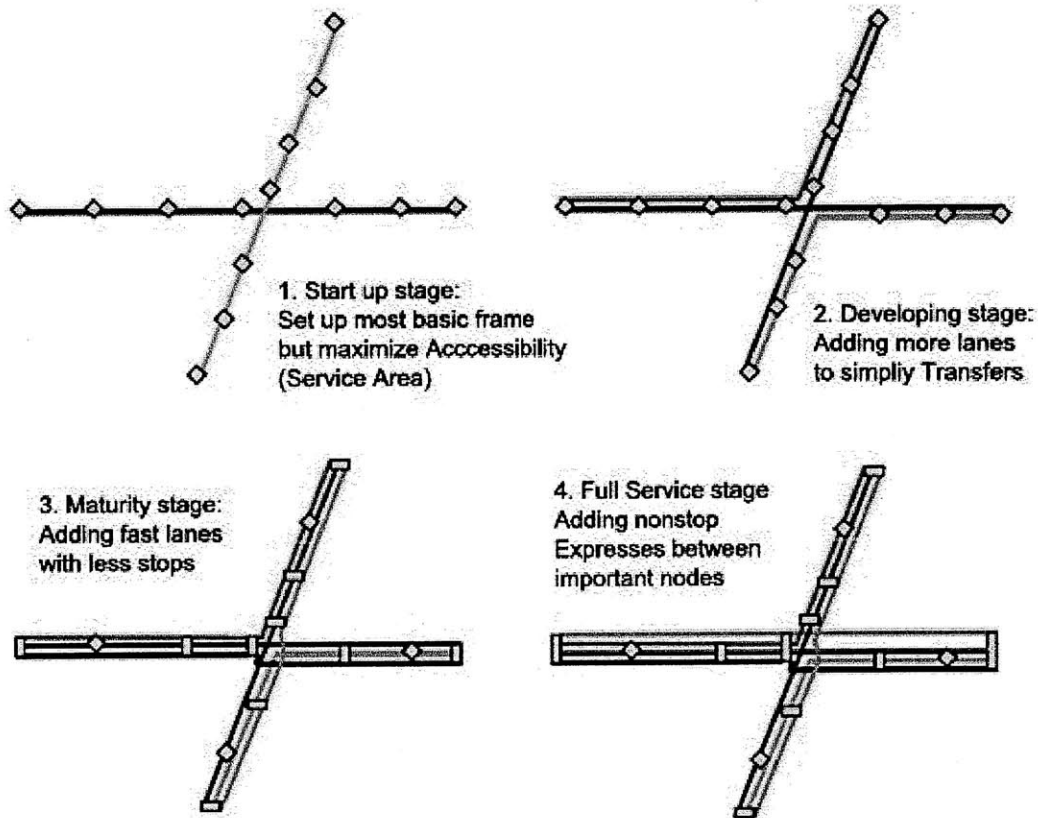


Figure 4.1-14: The Model of Development Process for BRT or URT lanes

Source: China UTC, *Guidebook for Planning and Design of BRT, Chapter7.Network and operation Design*, from: [http://www.chinautc.com/information/manage/UNCC_Editor/uploadfile/20110308165751278.pdf]

- **For start-up stage**, when the city is just reaching the threshold to build a BRT or URT, the most important issue is to build up a basic frame.. Since at that point, these will be the only lines available, the primary task is to maximize the accesibility and capacity of the system. For BRTs specifically, it could mean to set up comparatively more stops, with some-extent compromise on speed.

- After the basic frame is set up and the flows in the system get growing, considerations should be focused more on how to increase the system service quality and efficiency. Therefore, in this *developing stage*, improving the transfers in the whole system will be very crucial. Besides upgrading the transfer centers, one way to raise to the efficiency and comfortability in the service is adding extra lines (basically BRT lines) to omit some complex transfers on some popular directions.
- Then in the *maturity stage*, when the constructions of the whole system have been basically completed, the next step will be to improve the service speed. Fast lanes with limited stops would be a practical option for both BRT or URT lanes, which could separate the passenger groups and give more focus on some major stations/nodes.
- Since there could not be a totally perfect system to build up, after all the developments finished, there should be a *full service stage*. With all the flows stable, we could find out the passenger burdens on some nodes could be too much, or the links between some most important nodes are not enough. In this case, we could set up some express buses only go back and forth between the nodes.

Certainly, since most of the cities in China are growing fast, texturally completing service should never be isolated from the process of horizontal growth of the system. To decide which one is more important currently is a hard task and can only base on the specific facts in the certain city.

4.2. Improving the Transfers

Transfer is always a very popular topic in the studies of public transport. In the multi-layer public transport network consisting of both BRT and URT, no matter exchanges between different modes or shifts between lines in a single mode, which are all called transfer behaviors, should be accomplished in transfer stations or interchange connections (Nannan Song, Xuewu Chen, 2008).

Different choices on transfer modes and organization managements will decide the speed and efficiency of transfers, and the time spent on transfer will directly affect passenger behaviors. That is why choosing the right model, improving the transfer facilities are always important issues in the construction and developments of public transport system.

4.2.1 Classification of transfers

For choosing the right design on a transfer station, we need to first determine the classification in the station system, and evaluate which class the station should be. A reasonable class-definition should comprehensively consider the referred multi-type transit modes, the number of connecting lines and services, and even the current developments in surrounding areas.

There are general three major classes in transfer stations (Chuanping Dan, 2008; Xiaohong Huang, 2006):

- **General Transport Hubs – Intercity level**

General hubs service for both external and internal transport of the city, therefore, should locate on the convergent points for multi-transits both intercity and inner-city. The gross built area of a standard-size general hub will be around or even more than 10000 square meters (Chuanping Dan, 2008).

The hub should not only contain stations for URT, BRT or normal bus service in the city, but also have platforms for intercity coaches, railways, and even ports for water transits in some cases, so that the hub is a comprehensive interchange stage for a lot of transit modes, and also a passenger re-distribution center between the intercity and inner-city transport systems. For example, in Boston, *South Station* and *North Station* are two typical examples for General Transport Hub.

The effective service coverage of general transport hubs is normally broad. Therefore, for medium-scale cities, there will usually be only one or two general hubs. Even for very developed metropolises, the number of this kind of hubs will be limited. To construct such a comprehensive and big-scale transit center, the financial investment will be comparatively considerate, so systematical investigations, researches, planning and design should be done in detail and carefully in every aspect before practice (Chuanping Dan, 2008).

- **Main Interchange Center (Terminal) --- Inter-zone level**

The main interchange terminals or centers normally include the terminals for BRT or URT, the transfer stations between BRT and URT, or the high-flow transfer stations in central zone of the city. The size of a Main Interchange Center or Terminal is normally 3000~5000 square meter (Chuanping Dan, 2008), and the effective service coverage is comparatively big and passing multi-zones and communities.

For the terminals, the major function of the transfer is normally gathering (and splitting) the passenger flows from (and into) different directions in front of a major URT or BRT terminal station (Figure 4.2-1), so the service area is in an open fan shape.

Since most of the terminals locate in suburb areas with lower density in land use, this kind of transfer stations is normally built on the ground, with the outdoor platforms of the ferry lines paralleling to the terminal of BRT or URT. In some cases of URT, the metro lines could be built underground, but still with some on-ground platforms for ferry buses.

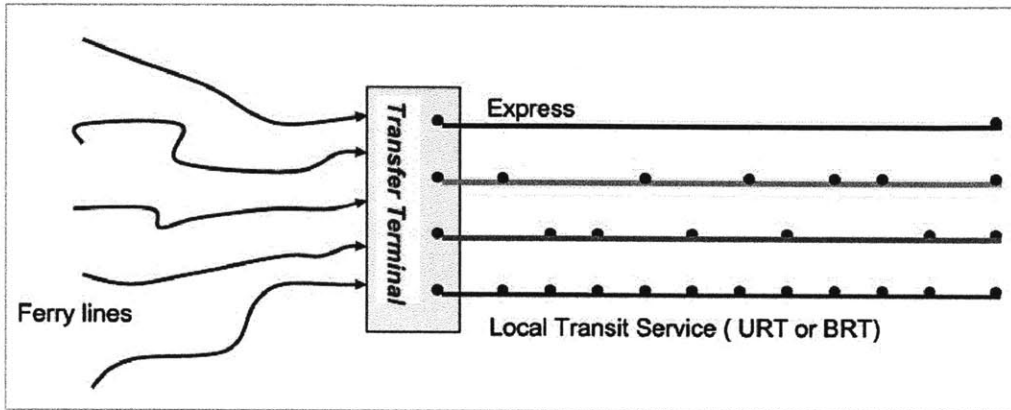


Figure 4.2-1: The Model of Interchange Terminal

Source: China UTC, *Guidebook for Planning and Design of BRT, Chapter7.Network and operation Design*, from: [http://www.chinautc.com/information/manage/UNCC_Editor/uploadfile/20110308165751278.pdf]



Figure 4.2-2: Transfer between ferry bus and BRT bus in the Terminal of TransMilenio in Bogota

Source: China UTC, *Guidebook for Planning and Design of BRT, Chapter7.Network and operation Design*, from: [http://www.chinautc.com/information/manage/UNCC_Editor/uploadfile/20110308165751278.pdf]
Picture originally from ITDP.

The land acreage of terminals in suburbs usually will be extended wherever this is feasible. Sometimes, the parking area, maintenance garage or station of BRT vehicles should also be included in terminal facilities.



Figure 4.2-3: Terminal maintenance station of BRT buses in Bogota

Source: <http://www.transportphoto.net/photo.aspx?id=1246&c=Bogota&l=cn>

For the transfer stations between BRT and URT, or the high-flow transfer station in central zone of the city, the size and acreage could be more compact since the land value in central zone is much higher, but temporary stop space for at least 3~4 buses should be reserved. Overtake lanes for other buses and cars or draw-in stops should be installed for minimizing the effects on the road traffic. For the transfer stations between BRT and URT especially, the walking distance between the entrances should be minimized and at least controlled in 200 meters. The best situation is to be set up in one spot. (Chuanping Dan, 2008)

- **Regular Transfers --- Single-zone level**

Except the higher-class transfer stations, the rest are regular transfers. The service coverage of a regular transfer is smaller, which are normally limited in single zone or community. They could locate between the higher-class transfer stations and service for the interchange simply between two BRT lanes or URT lanes, or between normal bus lines and these two. (Chuanping Dan, 2008) The characteristics of this class transfers is hugely variable depending on the location and the available space for the construction.

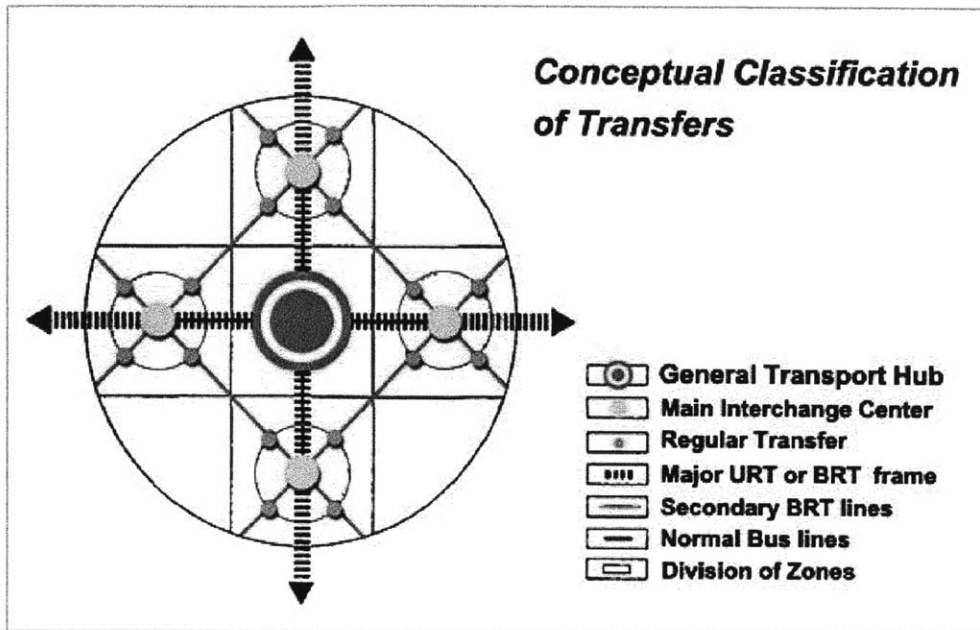


Figure 4.2-4: Conceptual Classification of Transfers

Source: Refer to Xiaohong Huang, 2006, Amended by author.

4.2.2 Categorization of transfers

Based on different characteristic factors, there are several categorization ways to distinguish transfers. For example, depending on which lines are linked in, we could categorize transfers in to *transfer between BRTs*, *transfer between URTs*, *transfer between BRT and URT*, and *transfer between them and other transit*. Referring to the spatial layout, there are normally three types: *planar layout*, *tridimensional layout*, and *mixture* (Xiaohong Huang, 2006), and different on connectivity, there will be: *One-spot transfer*, *adjoining transfer*, *remotely-connecting transfer with passageway*, and *outside-the-station transfer* (Cailiang Jiang, 2004). All the categories are interrelated and could have affiliated subcategories.

Following, I would like to primarily introduce the different spatial layouts of transfers. Since the integration between BRT and URT is emphasized in this paper, I will try to focus more on the integrated transfers between BRT and URT here.

Planar layout

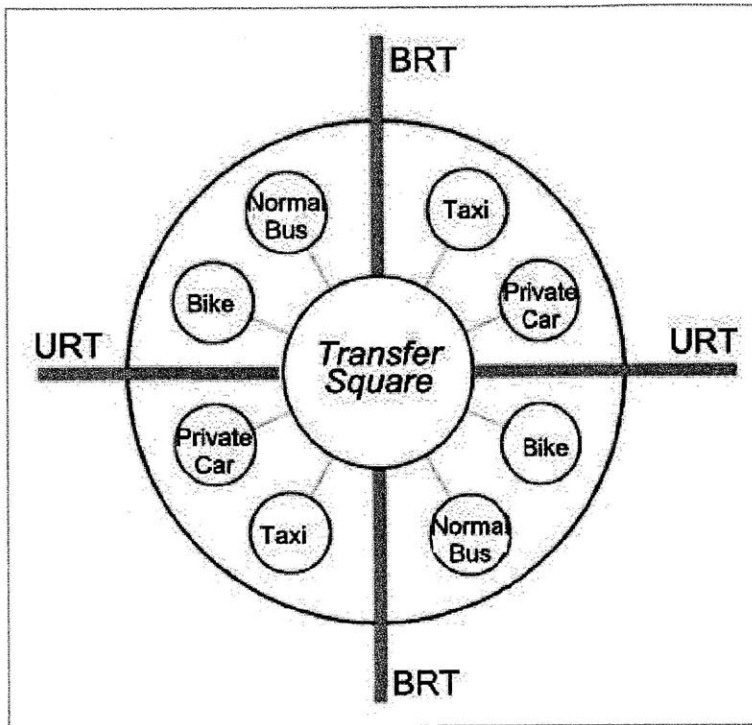


Figure 4.2-5: Ideal planar layout of a comprehensive transfer

Source: Nannan Song, Xuewu Chen, 2008

Having a planar layout means the platforms and facilities of different transport modes in the transfer gets spatially organized in one surface on the ground. This planar-layout way normally costs less in construction expense but requires comparatively bigger land space than tridimensional layout, so as to normally be used in suburbs or secondary cities where there are more available land resources. Furthermore, since metros are underground transport, the planar layout cannot be used in those cases with metro lines involved. Generally, the planar layout is more popular in the transfers between BRTs, the transfers between BRT and light rail, and the transfers between ferry buses and BRT or light rails.

Among planar-layout transfers, different in connectivity between different transports, they can still be subdivided into *one-spot transfer*, *adjoining transfer*, *transfer with passageway*, and *outside-the-station transfer*. For all these kinds, *one-spot transfer* and *adjoining transfer* could provide the highest connectivity and convenience, so they are the most user-friendly layout in planar transfers. Comparatively, channel-connecting transfer will take the commuters some time and walking in the station, but in most of the cases, it is a more practical or economic choice. Outside-the-station transfer is the most inconvenient type with lowest connectivity

between the transports. Ideally, it will only show up temporarily when the station is under construction or maintenance.

- **One-spot transfer**

As it is named, one-spot transfer means to have a single stop or even the same platform for the transfer between lines. One-spot planar layout is very often used for transfers between BRT lines (Figure 4.2-6) and transfers between BRT and the ferry buses (Figure 4.2-2). In some cases, it is also applied for transfer between BRT and light rail, though this is not very common (Figure 4.2-7).



Figure 4.2-6: BRT stop in Beijing
Source: [http://www.gztpri.com/xs-viewer.asp?id=13]



Figure 4.2-7: One-spot transfer between Light rail and BRT in Germany
Source: [http://www.lightrailnow.org/features/f_brt_2005-01.htm]

- **Adjoining transfer**

Adjoining transfer is defined as a kind of transfer stations that have facilities of different transport modes though not in the same stop but arranged adjoining to each other in the same surface (Figure 4.2-8). Adjoining layout is very common in transfer between BRT and light rail and between BRT/light rail and the ferry buses. Adjoining transfer requires not only the neighboring location in space, but also compatibility in access and ticketing.

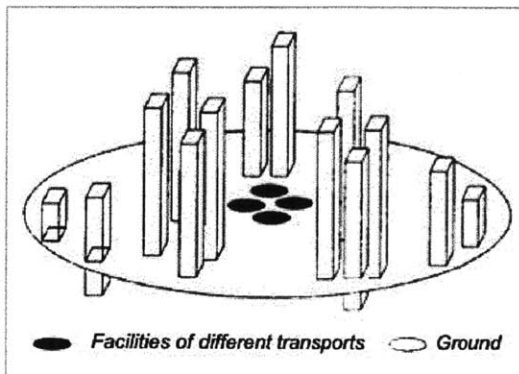


Figure 4.2-8: Schematic illustration of adjoining planar layout
Source: Xiaohong Huang, 2006

- **Remotely-connecting transfer with passageway**

Remotely-connecting transfer with passageway is a kind of transfer stations that have facilities of different transport modes not adjoining or in the same place, so need a passageway to link between them for good connection. In planar layout, the transport facilities are still in the same surface. The installation of passageways is majorly for preventing the interruption on the road traffic from the passenger inputs and outputs in front of the platforms. Two types of passageway could be applied including underpass and pedestrian overpass, but normally, overpass is more common in links between BRT stops.

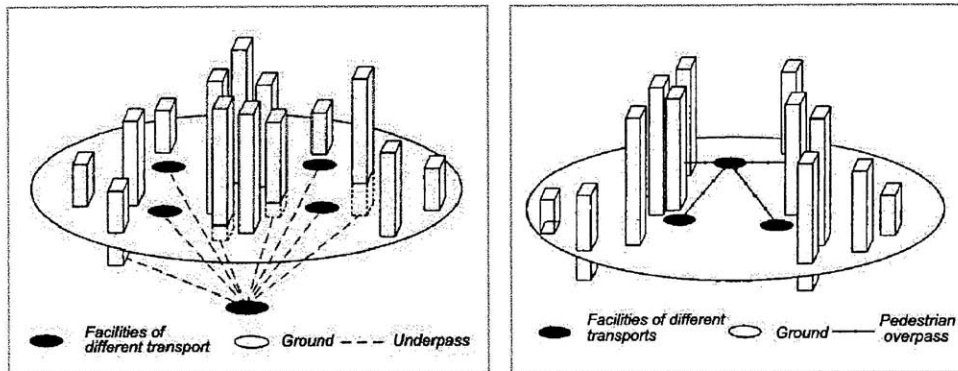


Figure 4.2-9: Schematic illustration of the channel-connecting planar layout

Source: Xiaohong Huang, 2006

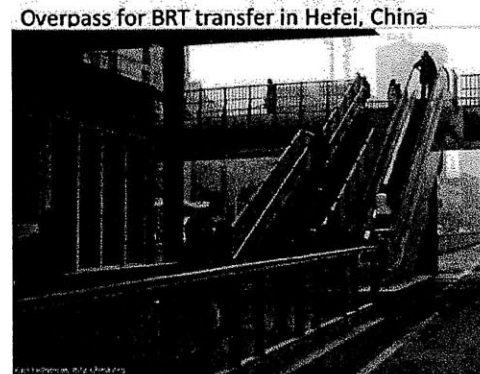


Figure 4.2-10: Transfers with underpass and pedestrian overpass in Bogota and Hefei

Source: ITDP, [<http://www.transportphoto.net/cost.aspx?l=cn&coid=Bogota>]
 [<http://www.transportphoto.net/cost.aspx?l=cn&coid=hefei>]

- ***Outside-the-station transfer***

Outside-the-station transfer is a fairly inconvenient transfer with very low connectivity between the transports. It requires the passenger to exit a stop first and reenter into the system or another system. In some worse cases, the ticketing of the systems is not compatible to each other, which will increase the cost and time spending of the transfers. On average, this type of transfers is not common, usually only shows up temporarily when a station is under construction or maintenance.



Figure 4.2-11: Photos of an outside-the-station transfer in Guangzhou

Source: <http://www.transportphoto.net/photo.aspx?id=9559&c=Guangzhou&l=cn>



Figure 4.2-12: Photos of an outside-the-station transfer in Beijing

Source: <http://www.transportphoto.net/photo.aspx?id=5308&c=Beijing&l=cn>

Tridimensional layout

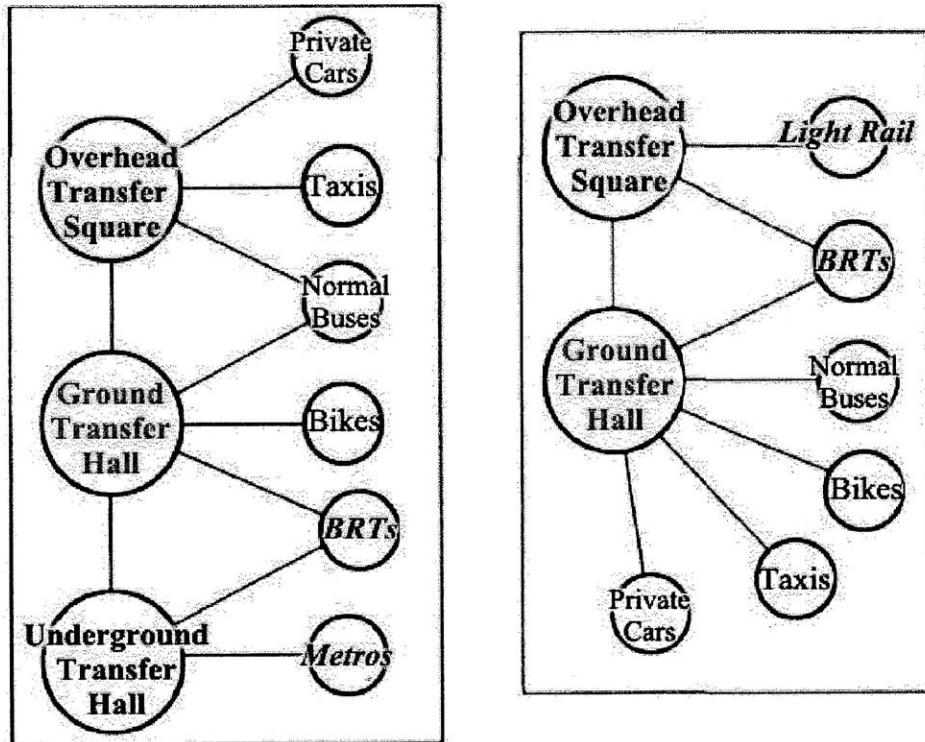


Figure 4.2-13: Ideal tridimensional layout of a comprehensive transfer

Source: Nannan Song, Xuewu Chen, 2008

Nowadays, tridimensional layout is more welcome in the design of transfer station, especially in the high-density urban central areas. The major advantage of tridimensional layout is to compact the acreage and save land resources. Also, with electrical devices like elevators installed, walking distance and time consumption in the transfer could be decreased, and the indoor environment with air conditioner usually will offer comfort feeling for the commuters.

Figure 4.2-13 illustrates two alternatives of organization patterns in tridimensional layout: With metros installed (*The left figure*), underground system will be inevitable. There should be an underground transfer hall or a ground transfer hall but with access to the underground lines. Complementally, the connections between the two and the other transport modes like private cars, bikes and normal buses could be put on the ground or overhead in some cases. If having light rail and BRTs as the core public transports to link instead (*the right figure*), we could build up an overhead transfer platform to import light rails and even for BRT lines. Meanwhile, a ground or overhead transfer hall will be needed to link them to the other transports.

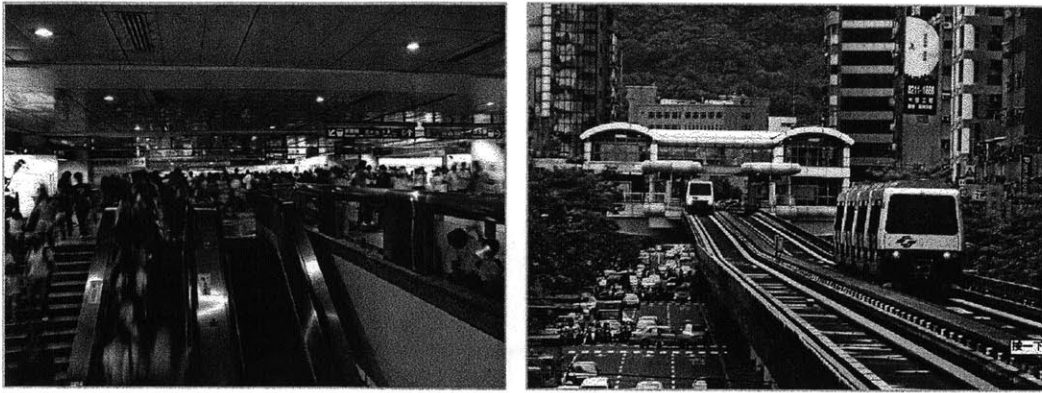


Figure 4.2-14: Tridimensional transfer stations in Taipei

(a) Underground transfer hall;

(b) Overhead station-in-front light rail lines and transfer hall

*Source: (a) http://tupian.hudong.com/a2_21_03_01300000335934124126039346913_jpg.html
 (b) <http://bbs.xmfish.com/read-hm-tid-4988942.html>*

For BRT specifically, there could be three kinds of the installations: The most common and easy one is to put the BRT lines and platforms on the ground and link them with the ground transfer hall, which could make the transfer structure simpler and planar, to save time consumption of passengers in the transfer.

Another way is to set up the station-in-front lines on a viaduct (Figure 4.2-15), and link the platform to an overhead transfer hall by corridors or a ground transfer hall by stairs and elevators. This way could prevent the conflicts between BRT and other transport flows to some extent. (Nannan Song, Xuewu Chen, 2008)

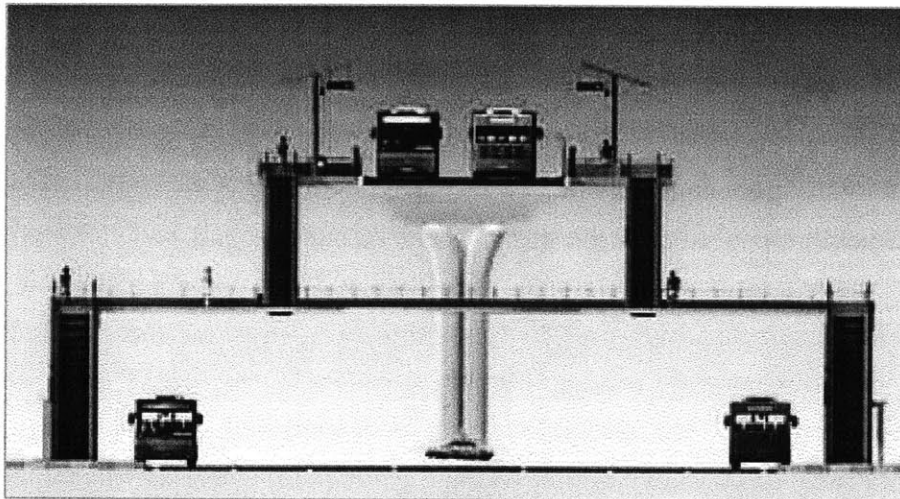


Figure 4.2-15: Tridimensional viaduct to divide BRT and normal bus flows

Source: Google Image, originally from: [<http://yekinglo.bokee.com/6440258.html>]

The third situation is to install the platform of BRT underground. Normally, the cost of underground construction is higher, so it is not very common in BRT station, but if it is an integrated BRT and metro connection, this kind of installation could be possibly applied in a combination with the underground metro system.



Figure 4.2-16: Underground Silverline bus stop at South Station in Boston

Notice: Silver line bus is a semi-rapid bus transit servicing in Boston. It is categorized as a BRT in US definition, but it doesn't enjoy a dedicated busway generally.

Source: ITDP, [<http://www.transportphoto.net/photo.aspx?id=3122&c=Boston&l=en>]

Under tridimensional transfer, different in connectivity between different transports, they can also be subdivided into *one-spot tridimensional transfer (adjoining transfer)*, *remotely-connecting transfer with passageways*, and *outside-the-station transfer*.

- ***One-spot tridimensional transfer --- Transport Hubs or Interchange centers***

One-spot tridimensional transfer (or adjoining tridimensional transfer) means to have all the facilities of different transport modes in multi-layers but in the same station. The station architecture could be on the ground, underground or half-half. Normally, this kind of transfer stations is big-size and functionally comprehensive. It is convenient for the users but high-cost in construction. In most of the cases, the tridimensional station is not only servicing for the transfers between BRT and metro and other transports in the city, but also works as a master station for intercity transports (ex. railway or coaches), which forms a *general transport hub* in the city (Figure 4.2-17). In some other conditions, this pattern could also apply to some major interchange centers of inner-city transports in the city area, even with no intercity transport involved.

A case of comprehensive transport hub: Xiamen North Station

Xiamen North Station is a comprehensive transport hub. It includes a major station of the intercity High Speed Rail (HSR), terminals and stations of BRTs and normal buses, parking space for private cars and stops of other transport modes.

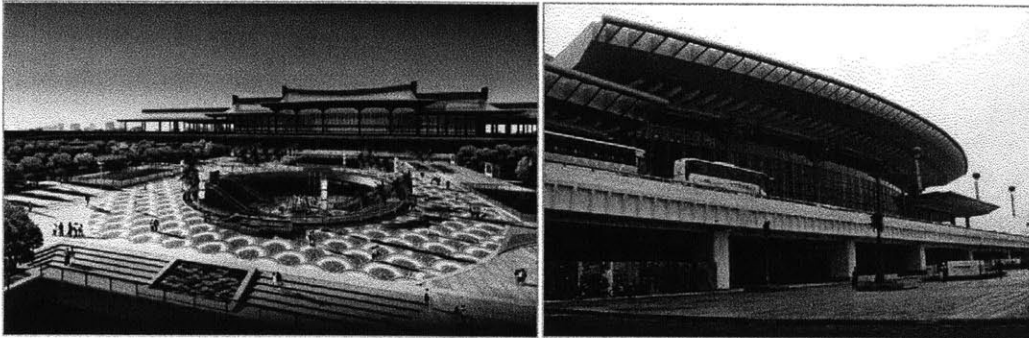


Figure 4.2-17: The design and actual looking of Xiamen North Station

Source: (The left) [<http://www.taihainet.com/news/xmnews/shms/2010-04-25/523807.html>]
(The right) [http://www.whatsonxiamen.com/news_msg_cn.php?titleid=11839]

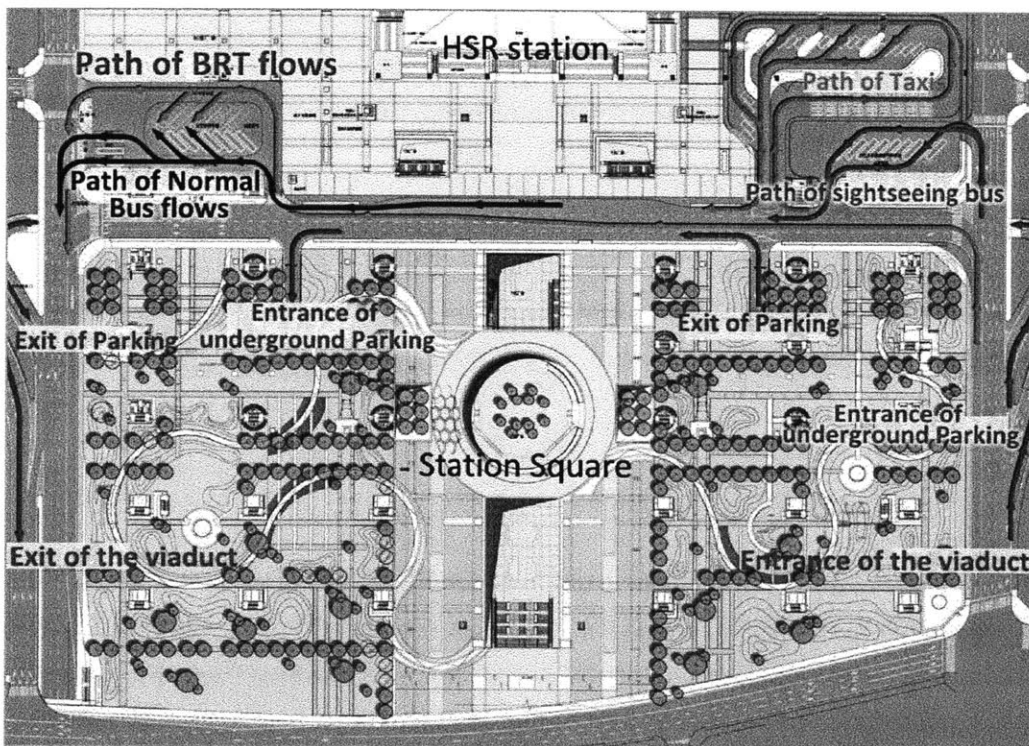


Figure 4.2-18: Site plan and transport plane layout of Xiamen North Station

Source: http://epaper.taihainet.com/newspic/UploadFiles_6334/201004/2010042601085810.jpg

All the transport flows have been organized systematically with their own entrances and exits, to minimize the mutual interruptions and conflicts. (Figure 4.2-18)

Cases of interchange center: ChangZhongLu Metro Station and ZhongShan Park Metro Station in Shanghai

ChangZhongLu Metro Station is under construction in Bao Shan District of Shanghai city. Majorly speaking, it is one of metro stations for the line 7 in Shanghai metro system, but since it also contains stops of BRTs and normal buses and commercial area, it is a great example of a tridimensional interchange center, an intersection node of the inner city transport system.

The site plan of this station is accomplished by *Tongji University*, which is a top and famous design and planning school. The designed architecture is a two-floor building with one extra floor in the basement.

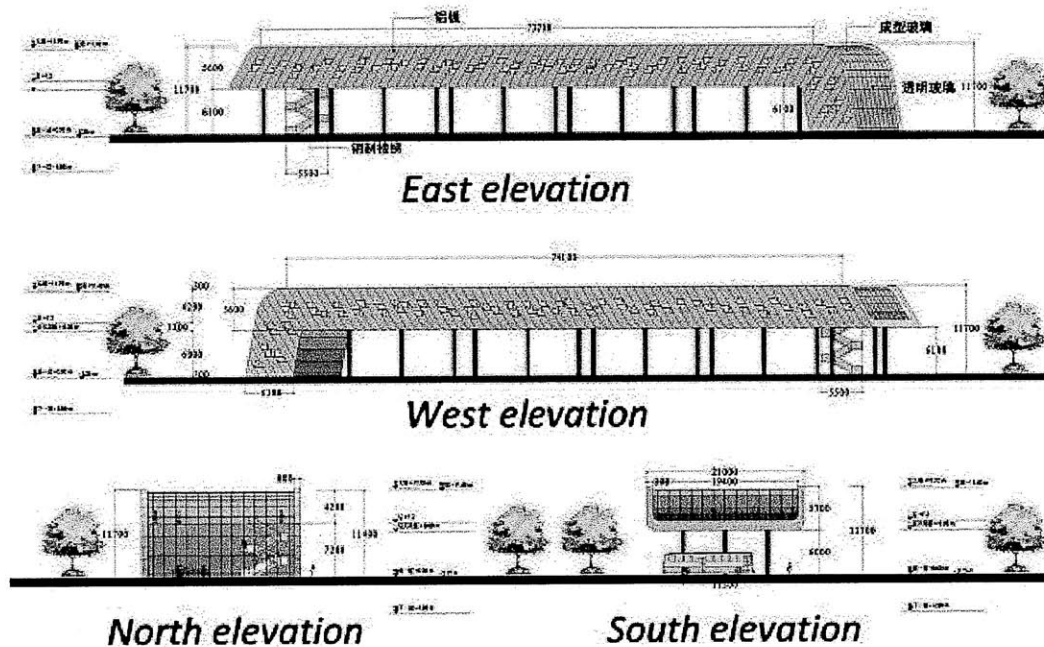


Figure 4.2-19: The elevations of ChangZhongLu Metro Station

Source: [<http://club.metrofans.sh.cn/thread-20405-1-1.html>]

The ground floor contains four major platforms for BRTs and other buses, some other stop points and certain parking space for the buses. The height of the floor is 6 meter. The Second floor is planned to be used majorly as an office area for transport managements. A bit parking space for private cars has been reserved. The basement floor of the building is designed as a transfer hall linking to the metro line, which also has some commercial and office area included (Figure 4.2-20, Next page).⁶⁰

⁶⁰ Refer to [<http://club.metrofans.sh.cn/thread-20405-1-1.html>]

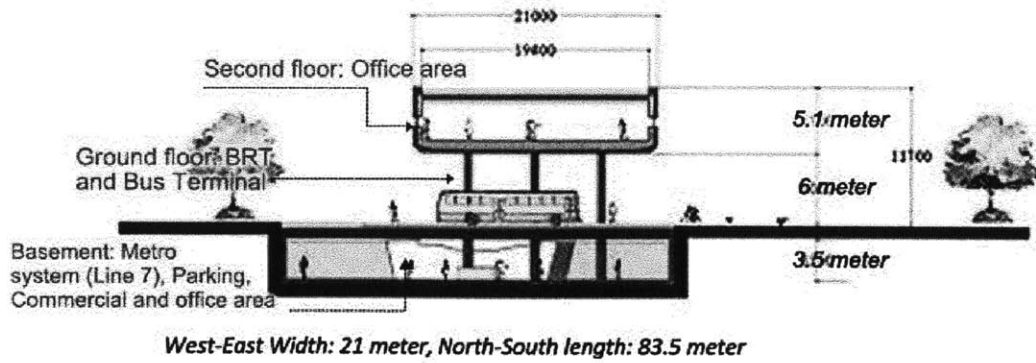


Figure 4.2-20: Section plan of ChangZhongLu Metro Station in Shanghai

Source: [<http://club.metrofans.sh.cn/thread-20405-1-1.html>]

Another example from Shanghai, *ZhongShan Park Metro Station* is an inner-city interchange station between Metro line2 and line3 (light rail) and other transports in use for years.

The whole transfer station has four floors in whole, two of which are on the ground, the other two are underground. The ground floor is a transfer hall for BRT and normal bus lines, and the second floor is the platform for Line 3 (also named as Mingzhu Line), which is a light rail line in Shanghai's URT system. Underground, in first basement, there are stops and waiting areas for taxis and some parking space, and the second basement is the platform for Metro Line 2 of the city.⁶¹

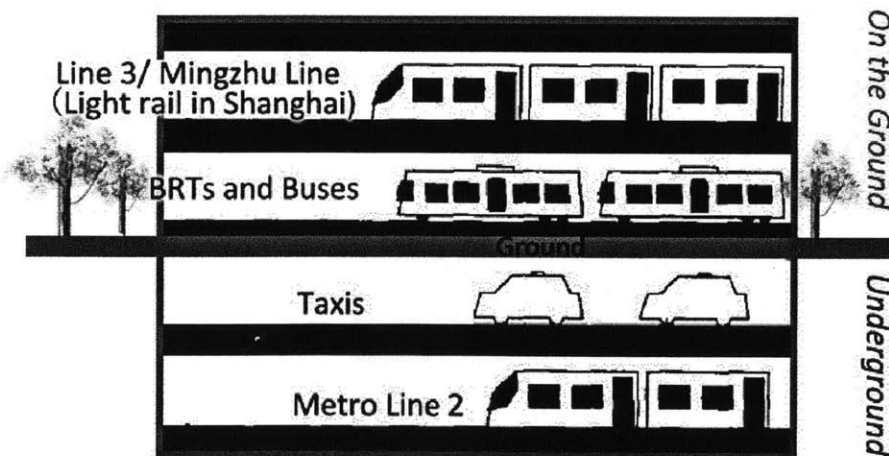


Figure 4.2-21: Section plan of ZhongShan Park Metro Station in Shanghai

Source: Jiawei Shi, Ping Zhong, 2005

⁶¹ Refer to Jiawei Shi, Ping Zhong, 2005

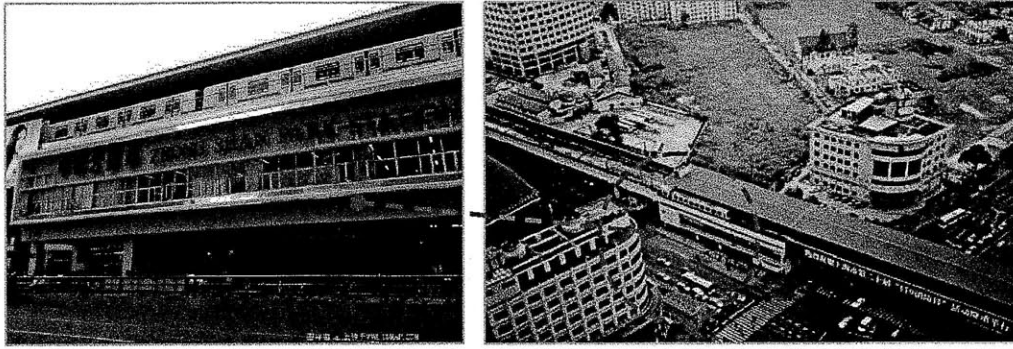


Figure 4.2-22: Real looking of ZhongShan Park Metro Station in Shanghai

Source: [<http://www.ddmap.com/map/21/point-340053-%D6%D0%C9%BD-.htm>];
 [http://club.china.com/data/thread/1011/2720/09/17/6_1.html]

- **Remotely-connecting transfer with passageways**

Different with the remotely-connecting transfer with planar layout, where the transport facilities will still be in the same surface, though the remotely-connecting tridimensional transfer still needs passageways to connect the transport facilities, but the facilities will be in multi-layers, so the passageway will not only mean to prevent the interruptions on road traffic, but also provide great connections between different layers/ floors.

Normally, this type of layout shows up on some transfer cases between BRT and metros. The major advantage of this remotely-connecting layout than the totally separate stations is less interruptions on road traffic and the possibility of integration in ticketing.



**Figure 4.2-23:
 Connecting tunnel
 between metro & BRT
 station at Shipaiqiao
 (shortly before
 opening in 2008)**

Source: ITDP,
<http://www.transportphoto.net/photo.aspx?id=10364&c=Guangzhou&l=cn>

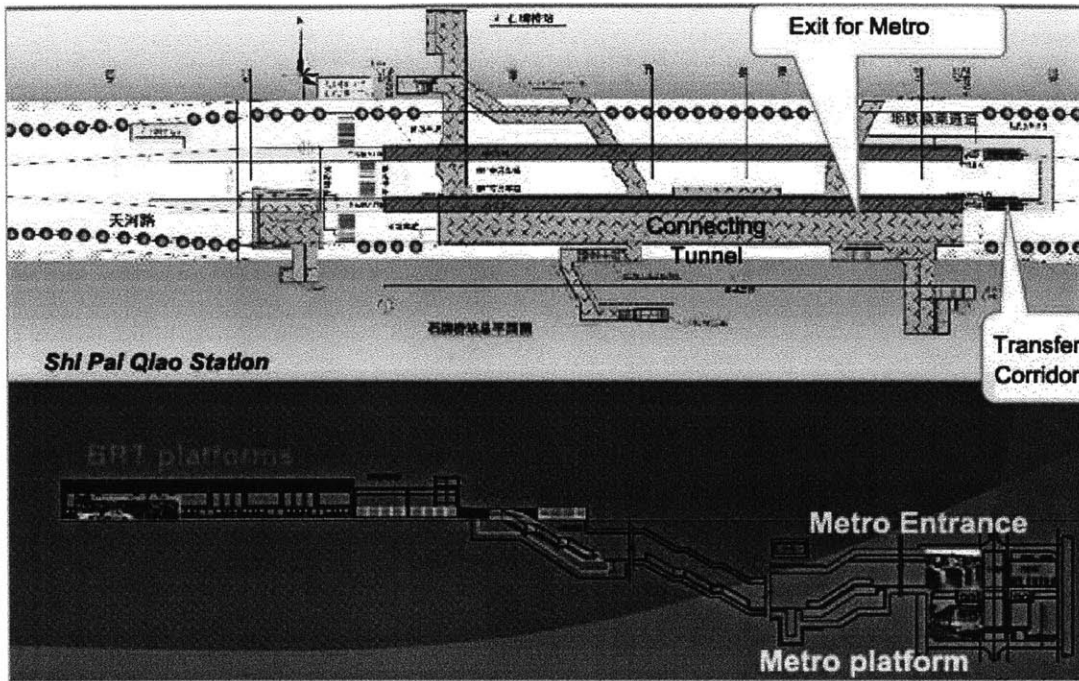


Figure 4.2-24: Design on the Connection between metro & BRT station at Shipaiqiao Station in Guangzhou

Source: <http://www.slideshare.net/EMBARQNetwork/brt-in-china-a-brief-review>

The reasons for not having an integrated one-spot construction could be various, but generally speaking could relate to the restrictions from land use. For example, the metro system has already been built up before inputting BRT lines, and there is no space to install a whole new station on the original metro station, so the new BRT station could only be built in the nearest spot but will have a walkable distance to the metro station.

- ***Outside-the-station transfer***

Outside-the-station transfer basically means totally separate stations. Same as the in the planar layout, it is an inconvenient transfer layout with very low connectivity between the transports and incompatible ticketing management, which is not recommended and advocated.



Figure 4.2-25: Separate ticketing entrance

Notice: This is actually a photo of an entrance for a BRT station in Xiamen. Since Xiamen doesn't have a URT system until now, this picture is only for illustrating the separate ticketing.

Source: <http://bbs.hsw.cn/read.php?tid=2576013>

4.2.3 Designs on transfers

For improving the satisfaction of transport services, besides choosing a reasonable spatial layout, the site planning and actual designs on the transfer stations are also important. Among all the stations, the general transport hub has always been emphasized because of its crucial status in the whole transport system. Correspondingly, the designs on general transport hub should be most considerate. In fact, in all the countries around the world, there have been hundreds of transport hubs built in creative and diverse designs.

Transbay is one of the most famous ones in United States, located in *San Francisco, California*. Transbay is a comprehensive transport hub, which includes stops and facilities for intercity and inner-city rail transit, bus transit, road transit. The total area of Transbay station is over 76600 square meters, and there is more than 70% of the area being used for transfer space between the diverse transport modes.⁶²

The former Transbay Terminal was constructed in 1939 to facilitate rail travel across the Bay Bridge. Following World War II, the lower deck of the Bay Bridge was converted to automobile traffic and the Transbay Terminal became a bus only facility. The bus terminal no longer met current or future transportation needs of the region or State. A new Transbay Transit Center is designed and under construction. It will be built on the site of the former Transbay Terminal in downtown San Francisco and will

⁶² Refer to Nannan Song, Xuewu Chen, 2008

serve 11 transportation systems: *AC Transit* (BRT), *BART* (Metro), *Caltrain* (Metropolitan -area metro), *Golden Gate Transit* (Metropolitan-area bus service), *Greyhound* (Intercity coach), *SamTrans* (Express bus), *Amtrak* (Intercity train), and etc, and a future High Speed Rail from San Francisco to Los Angeles/Anaheim. The new bus and rail facilities and the TOD surrounding will serve as San Francisco's next landmark.⁶³



Figure 4.2-26: The old and new Transbay Transit Center

Sources: [<http://transbaycenter.org/project/terminal-history>] and [http://en.wikipedia.org/wiki/San_Francisco_Transbay_development]

The first phase of the project will create a new five-story Transit Center with one above-grade bus level, ground-floor, concourse, and two below-grade rail levels serving Caltrain and future California High Speed Rail. In addition, there will also be a 5.4-acre public park on the roof of the Transit Center as an extra outdoor floor.⁶⁴

⁶³ Refer to: [<http://transbaycenter.org/project/transit-center>]

⁶⁴ Refer to: [<http://transbaycenter.org/project/transit-center>]

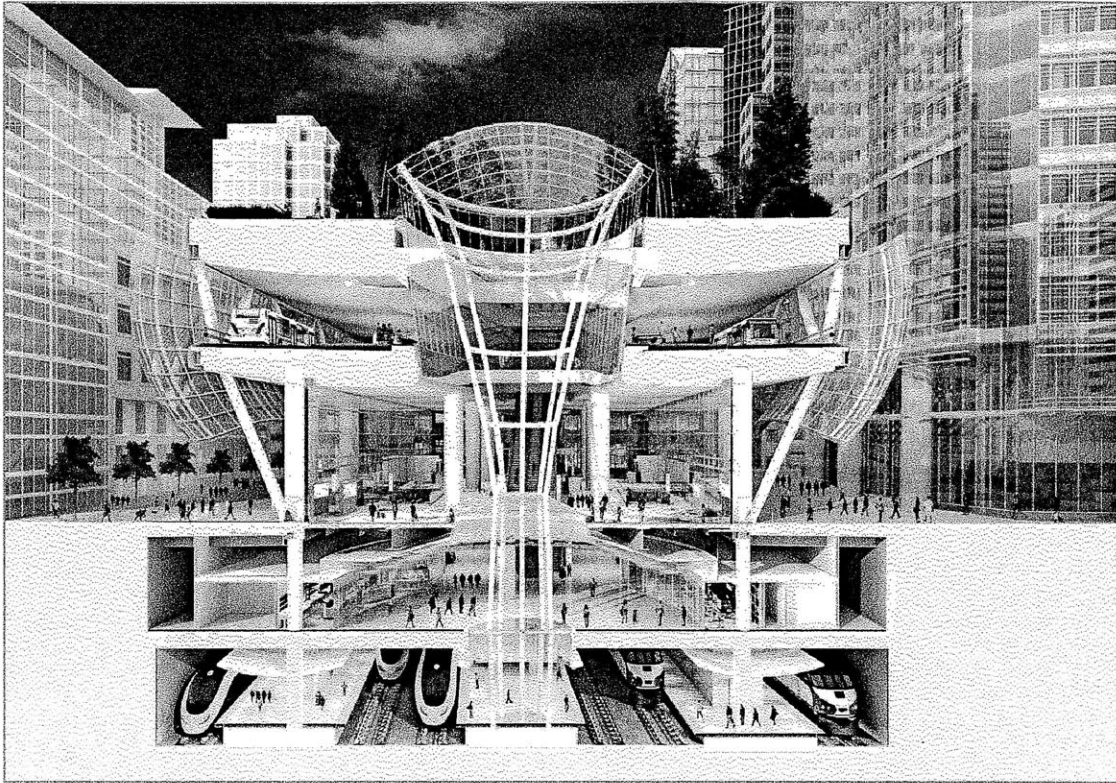


Figure 4.2-27: Section plan of the new Transbay Transit Center

Source: [http://transbaycenter.org/project/transit-center]

The Lowest floor is the second basement, which is designed as a train station platform. The first basement called as lower concourse level in the site plan will serve as the passenger circulation connection between the ground and train station platform. Space will be provided along the public concourse for retail.⁶⁵



Figure 4.2-28: The train station platform and the lower concourse level

Source: [http://transbaycenter.org/project/transit-center]

⁶⁵ Refer to: [http://transbaycenter.org/project/transit-center/transit-center-level]

The ground level will serve as the primary circulation hub of the Transit Center and feature a Grand Hall. The second floor of the Transit Center will provide passenger and visitor circulation as well as administrative offices, space for support services and potential retail. And the third floor is the bus deck level. There are 24 bus decks.⁶⁶ BRTs and Muni buses could load and off-load passengers from the level's central island.

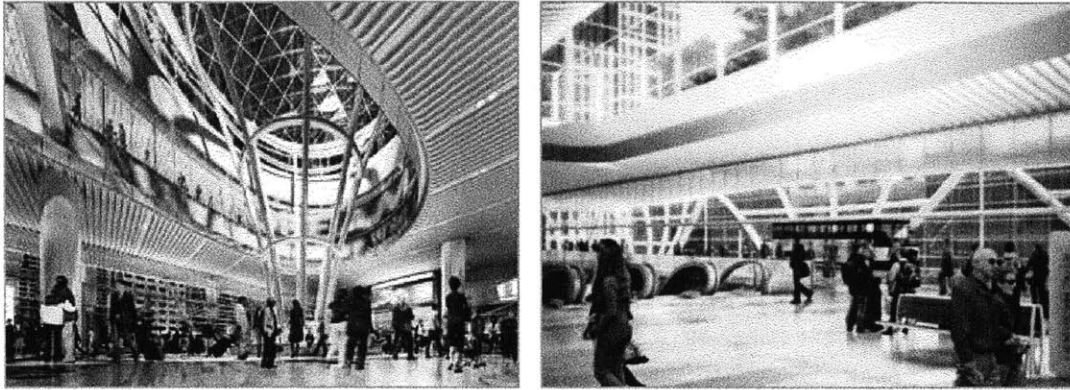


Figure 4.2-29: The train station platform and the lower concourse level

Source: [http://transbaycenter.org/project/transit-center]

Furthermore, the roof of the transit center is planned to be utilized as open space. A 5.4-acre public park that will sit atop the hub and feature a wide range of activities and amenities, including a walking trail, vegetation gardens, lush landscape, lily ponds, an outdoor amphitheatre as well as several retail attractions. This green roof design is a great example and inspiration of sustainable designs on transport center.

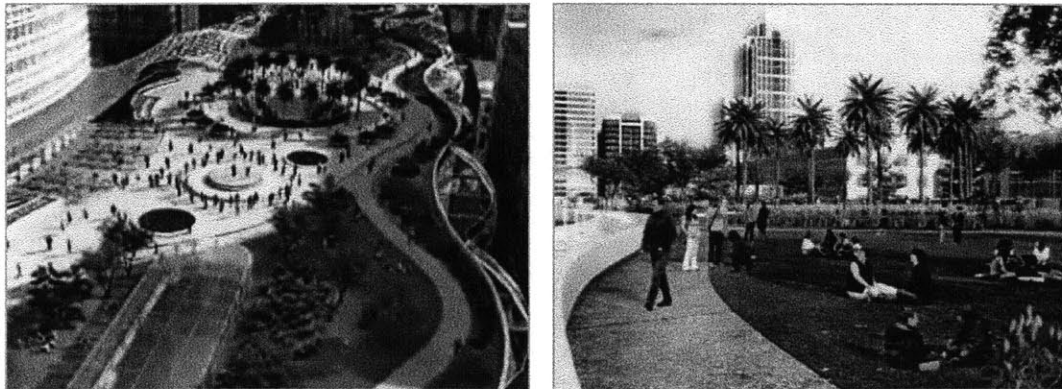


Figure 4.2-30: The green roof and the public park

Source: [http://transbaycenter.org/project/transit-center/transit-center-level/city-park]

⁶⁶ Refer to Nannan Song, Xuewu Chen, 2008

4.3. Unifying the Managements

Integration between BRT and URT not only means to network and spatial compatibility, but requires synergetic management as well. To integrate the managements on the two systems, *coordinative assignment and control, compatible fare collections, unified institutional system* will all be necessary.

4.3.1 Coordinative assignment and control

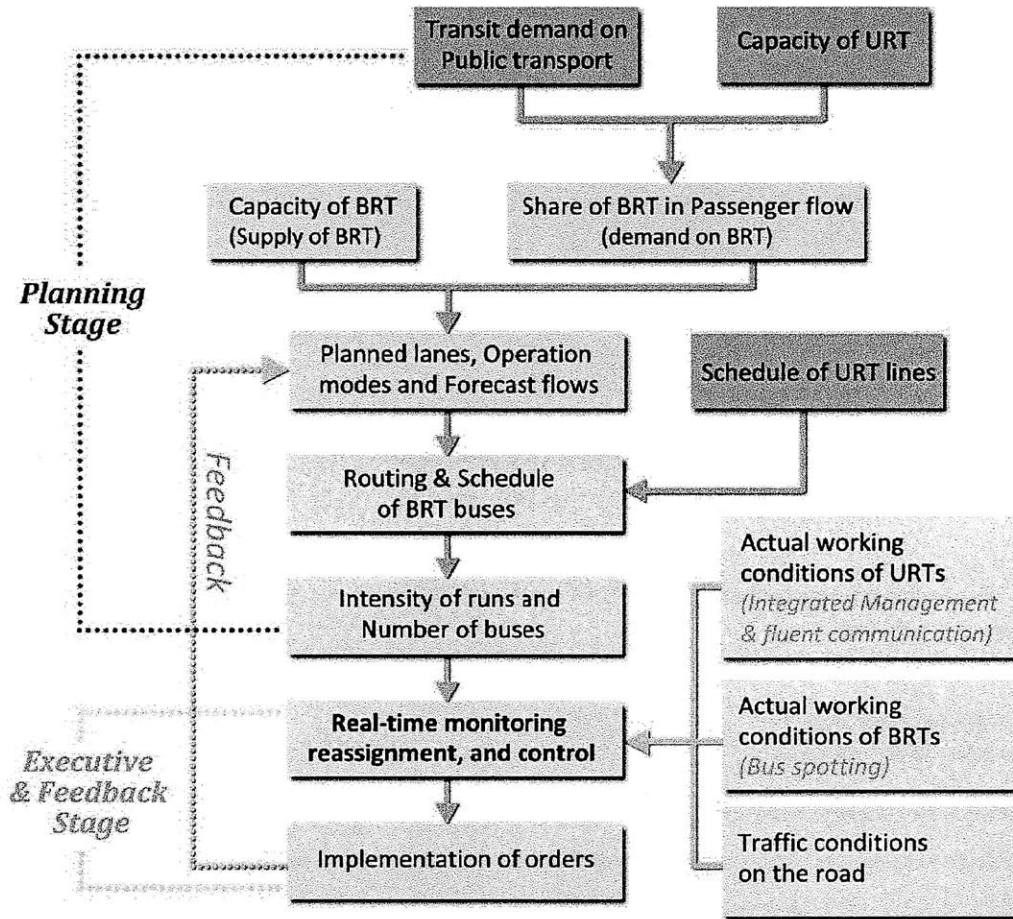


Figure 4.3-1: Schema of coordinative assignment and control of BRT

Source: Author

Primarily, inter-coordinative passenger-flow assignment and real-time control on executions will be one of the most important conditions in management integration. Since the routes and schedules of URT are normally fixed and hardly changeable in short time, it will be more practical to coordinate the routes and timetables of BRT with the URT ones. In Figure 4.3-1 above, it shows the general process of planning and management on BRT system.

Intelligent Real-time Control

In all the procedures, the real time monitoring and control is one of the key steps worth of attentions. The supervision is significant not only on the operations of BRT lines, but also on operations of URT, and even the traffic conditions in the whole transport system on and under the ground. Therefore, spotting all the running vehicles and the in-time and fluent communication between backstage control panels of BRT, URT and even other transports are important. Then, based on the real-time facts, we could give more reasonable responses such as rearrangements of runs and numbers of buses on the road. This interactive application is the core of the management integration.

BRT system in Guangzhou has a very efficient real-time control system by intelligent technology which will monitor and supervise the operations of BRT buses on all the routes. (Figure 4.3-2) Coordinating the information with the traffic conditions monitored by the traffic agency and the records from metro center, the operations of BRT system could be kept in high flexibility and sensibility to the current facts on the roads and the general situation in the whole public transport system.

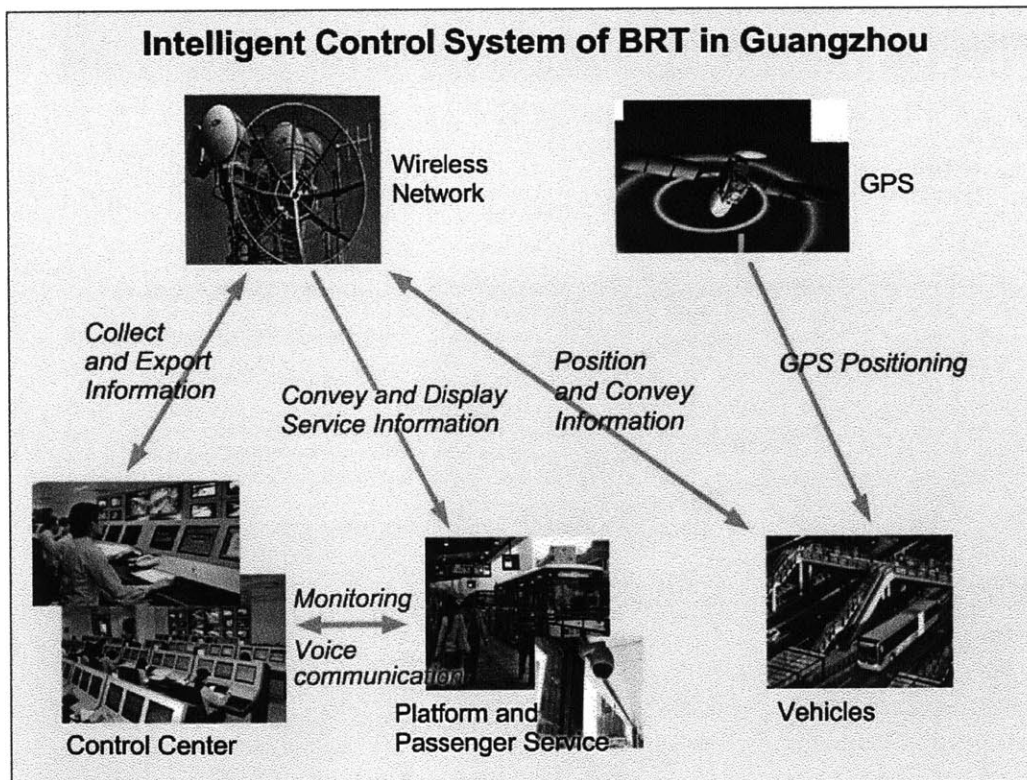


Figure 4.3-2: Intelligent Control System of BRT in Guangzhou

Source: Guangzhou Institute of Transportation (GIT), 2010

In the whole intelligent control system, the role of the BRT control center should be emphasized. It provides the only manual supervision in the system with professional human resources, which works like a brain to give directions in the whole system. (Figure 4.3-3, Figure 4.3-4)

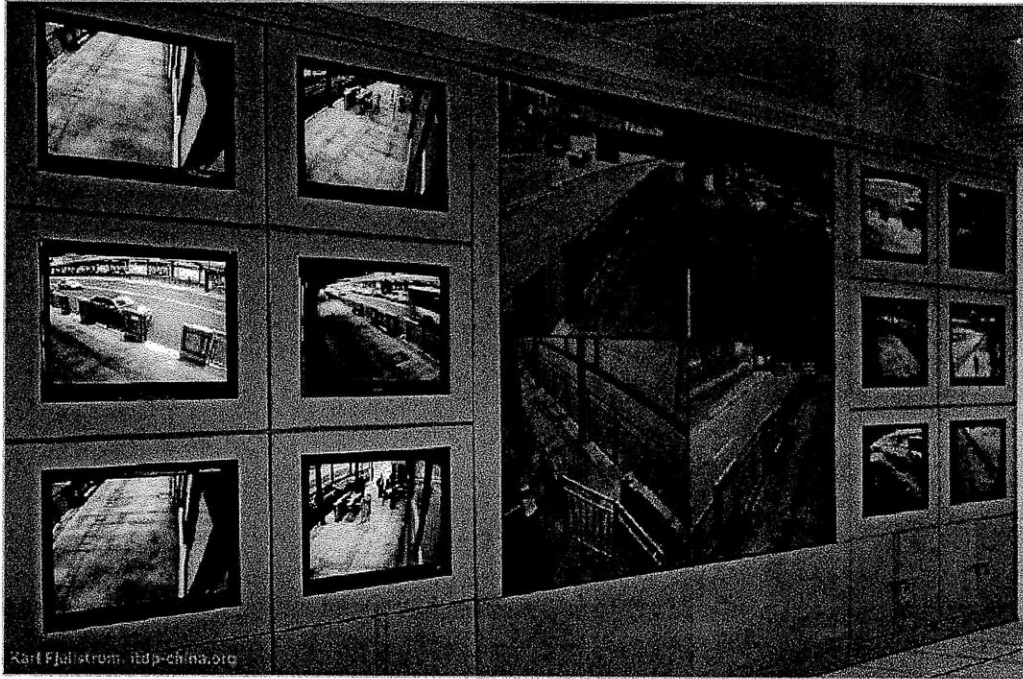


Figure 4.3-3: The monitor wall at BRT Control Center in Guangzhou

Source: Karl Fjellstrom, 2010

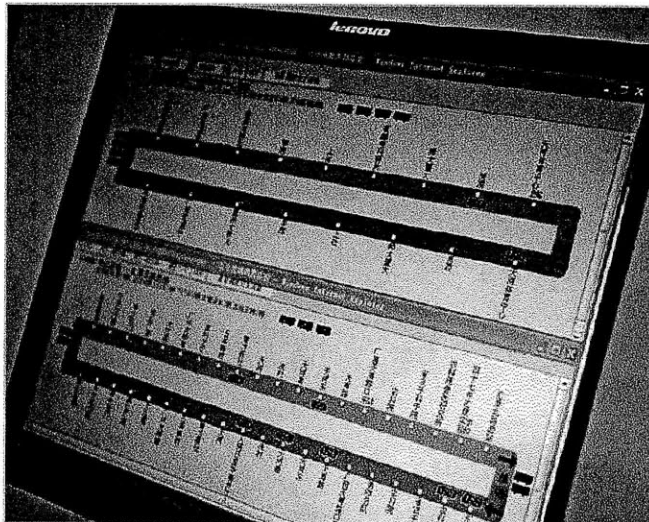


Figure 4.3-4: the real-time bus-positioning system and staff in control center

*Source: Karl Fjellstrom, 2010
Guangzhou Institute of Transportation (GIT), 2010*



4.3.2 Compatible fare collections

A compatible pricing and fare collecting system is extremely essential for the integration of BRT and URT service. Fare collection systems for both of BRT and URT can be electronic, mechanical, or manual, but the key planning objective is to be efficient, especially for the extremely busy services. Factors involved include fare policies (e.g., flat fare versus zone or distance), fare collection practices, payment media and the management system behind.⁶⁷

1. Fare policies

Primarily in fare policies, we need to understand some pricing background in China. For encouraging public transport takings, Chinese governments have restricting provisions on fares and powerful financial subsidies for public transport operations. Because of the influential government interventions, the fares of buses, metros and BRTs are normally much lower than the supposed ones in market economy. The common fares for buses and even BRTs are only around 1~2 RMB, which is \$0.15~0.3 US dollar. For most of the metros, the fare per trip will be controlled in 5 RMB (around \$0.7 US dollar). Even for the most expensive metros, the fare for the longest distance will not be higher than 6 RMB per trip, which is still less than 1 dollar.

Besides the general pricing level, fare policies also include *the fare structure in each of the individual systems*, and *the fare rules for the transfers between the systems*. Both of them will affect the fare processes and technologies a lot.

Individual fare structure

There are two basic alternatives of fare structures for individual systems: *flat fares* and *differentiated fares*. Differentiated fares also include: different by zones, different by time, and different by distance. The decision between them is influenced by the existing or legacy systems of an organization or region and also depends on the kind of the transport mode. Transit agencies may consider a number of design factors including their size, network, organization, customer base, as well as financial, political, and management-related variables.⁶⁸

In most of the existing cases in China, the normal buses in city area are ticketed in flat fare, except some express lines or extremely long line crossing city and suburb areas.

⁶⁷ FTA US, Characteristics of BRT for decision making, 2004

⁶⁸ FTA US, Characteristics of BRT for decision making, 2004

However, the bus tickets are normally one-way only, which cannot stay validated for transfers between bus lines.

Comparatively, metro or light rail systems are usually in differentiated fares, depending on the number of stops and zones passed in the trip, but the transfers in the system will not require another payment (Like *Shanghai*, *Guangzhou*, etc, Figure 4.3-5).

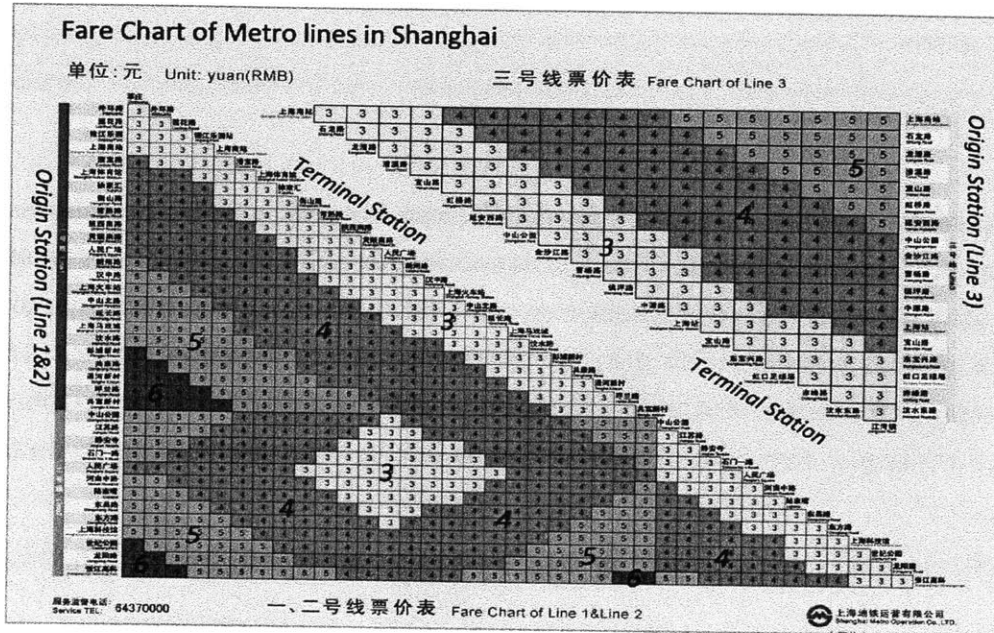


Figure 4.3-5: Fare Chart of Metro lines in Shanghai

Source: [http://shbbs.soufun.com/1210061900--1~2897/19030899_19030899.htm]

There are still some cities choose to have a flat-fare metro system, like *Beijing* (Figure 4.3-6). In *Beijing* currently, the fare is not only flat but also extremely low-price too, which is 2 RMB (around 0.3 US dollar) per time for taking metros, and transfers between different lines in the stations are all free.

However, from a long-term view of the developments in such an international metropolis, this situation might be changed, especially with an increasing inflation in economy of *Beijing*.

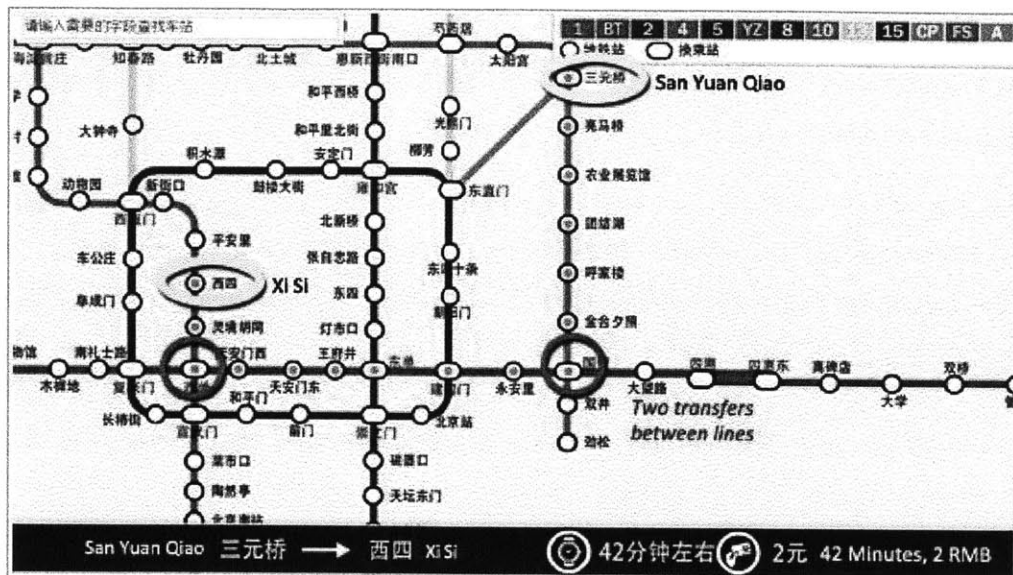


Figure 4.3-6: On-line inquiry system for taking Metros (Time and Fare)

Notice: Fare is always 2 RMB.

Source: [<http://www.explorebj.com/ditie/>]

Different with both of them, BRT is a fresh imported product just getting its status in public transport system. It has some characteristics of buses and also some of metros. Therefore, for BRTs, though most are in flat-fare pricing, the specific policies and rules on transfers could be different.

For the earlier-age BRT, which is the case in most of cities in China (ex. Beijing, Hangzhou, etc), it is more close to a normal bus line in characteristics but with dedicated busway, so the fare policies on it are uniformed under bus system. Normally, the fare is generally unchangeable by distance, but the ticket is for one getting-up-and-down only and cannot keep validated in transfers. For example, in *Beijing*, where the government has policies to support extremely low fares for encouraging public transport takings, the fare of BRT is the same to the fare of a normal bus trip, which is 1 RMB (around 0.15 US dollar) in cash, and if the passenger uses the city's smart transit card to pay, the cost could be as low as 0.4 RMB (6 cents in US dollar) per time, and only half-price for student (0.2 RMB, \$ 3 cent), but after transferring from one line to another, the passengers need to pay the fare again. (It is somehow understandable because of the low price.)

On the other hand, for the modern BRT systems showing up more recently, like the new one in *Guangzhou* opened in 2010, the characteristics are more similar to a metro system, and the ticketing is simpler: For example, in *Guangzhou*, the fare for BRT is 2 RMB (\$0.3 dollar), which is the same to the cost of taking a metro, but at the same time, the in-stop transfers between lines in BRT system by the same platform is free, which is an important symbol of fare integration in BRT system itself. So as the BRTs

in *Hefei, Xiamen, Zaozhuang, Zhengzhou*, etc, where there is no metro system but only BRT lines until now, the ticketing way is also more ‘metro’ style and the transfers in the stops are all free.

For Guangzhou city in addition, there are some discount and rebate policies for regular public transport passengers. After 15 times taking the public transports in one month, the passenger could get a 40% off starting from the 16-time trip.⁶⁹ This policy was enacted to replace the traditional monthly bus ticket (88 RMB) and stored ride metro tickets (55 RMB per 20 rides or 88 RMB per 35 times) used in the city. However, there are still some objection and complaint voices from the residents. For example, if one person has 35 times commute trips per month, normally costing 4 RMB per ride, the old expense will be 88 RMB, but the new expense will be 132 even with the discount, which is still much higher than the old way.⁷⁰ Therefore, the new policy will be beneficial for some commuters (ex. the ones taking normal rides in 2 Yuan), but will still cause some lost in others’ pockets.

Mutual fare rules

Comparatively, the integration on fare collection rules between BRT and URT has difficulties to reach in practice, especially in management and in institution. Since the operation companies could be different and even the administrative agencies related could be separated, the ownership and the administration authority and the distribution of income in the system will be hardly decided. As a result, though there are a lot of cities already built up the integration of fare collections separately in BRT and URT systems, the integration between these two haven’t been reached yet⁷¹. Even for the most modern BRT system in Guangzhou, the ticketing systems of BRT and URT are separated, which means the transfer between them will cost extra expense. Though this ultimate integration is hard to reach in the current reality of China, the target of inter-compatible fare collections should be achieved for the convenience of the travelers. has been coming closer to us with technology progress in fare transaction media and collection process.

2. Fare Transaction Media

Fare collection policies and processes influence the selection of fare payment media and equipment technology. The fare equipment must be capable of handling the

⁶⁹ Refer to [<http://news.tiger-city.net/html/07/n-97807.html>]

⁷⁰ Refer to [<http://www.chinanews.com/cj/news/2009/11-07/1952458.shtml>]

⁷¹ Also partly because there is only one system working now in most of the cities in China: According to 3.3.2 in Chapter 3, only Beijing and Guangzhou have both of the systems

selected fare payment media. The three primary fare media options include: *Cash and Paper Media, Magnetic Media* and *Smart Cards*.⁷²

- **Cash and Paper Media**

Cash (Coins, Bills, and Tokens) and paper media (Tickets, Transfers, and Flash Passes) are the simplest but slowest fare media options because of the necessary transaction time, particularly if exact fare is required. In most of cases, this type of media may require visual verification or manual validation, which will increase labor cost and time consumption.⁷³

For high-tech and efficient systems like metro and light rail, cash and paper media is not a suitable media or at least should not be the major media. For almost all of the modern metro systems in the cities of China, cash and paper media are no longer working. The longest-history paper metro ticket in China is the one used to be applied in metro Line 1 & 2 in Beijing. It was used since the metro system was first opened in 1969 and until 2008 (Though the figure of the paper ticket got changed several times). From June of 2008, magnetic stripe cards officially completely substituted these paper media.



Figure 4.3-7: The old paper metro tickets used in Beijing



Figure 4.3-8: The last paper metro ticket and its owner in Beijing (June.08.2008)

Source: Jian Shuo Wang.2004, *Tickets of Beijing Metro No. 1 and No. 2*, from:
[http://home.wangjianshuo.com/archives/20040216_beijing_impression.htm]
Source: [<http://zhuanti.club.xilu.com/bbs/shehui/newsview-823786-27919.html>]

⁷² From: FTA US, *Characteristics of BRT for decision making*, 2004

⁷³ Refer to: FTA US, *Characteristics of BRT for decision making*, 2004

However, for bus services, which has higher flexibilities but low speed, cash and paper media are always the most necessary and basic option, which cannot be totally removed from nearly any fare system everywhere.

For BRT, which is medium high-speed but with flexibility, cash and paper media is not necessary but could be considered as an accessorial alternative, since cash and paper media have natural compatibility cross different fare systems and even in circulation. To add cash in could increase the flexibility in fare transaction process. In the existing cases of BRT in the Chinese cities, since most of the BRT systems are immature in development, cash and paper media are still important and even inevitable, but it is trending to be no longer the major media in some metropolises.

- **Magnetic Media**

Magnetic media started to show up from the last century, which are important in the developments of transport system. They are key signals of electronic mechanization in transport ticketing equipment from manual conducting. There are two kinds of magnetic media often seen in public transport system.

One is magnetic stripe card. These cards are made of heavy paper or plastic and have an imprinted magnetic stripe that stores information about its value or use.⁷⁴ Magnetic stripe card is a very common pattern for one-way tickets even until nowadays. In some cities, it is also used as stored-value metro card. (Figure 4.3-9)

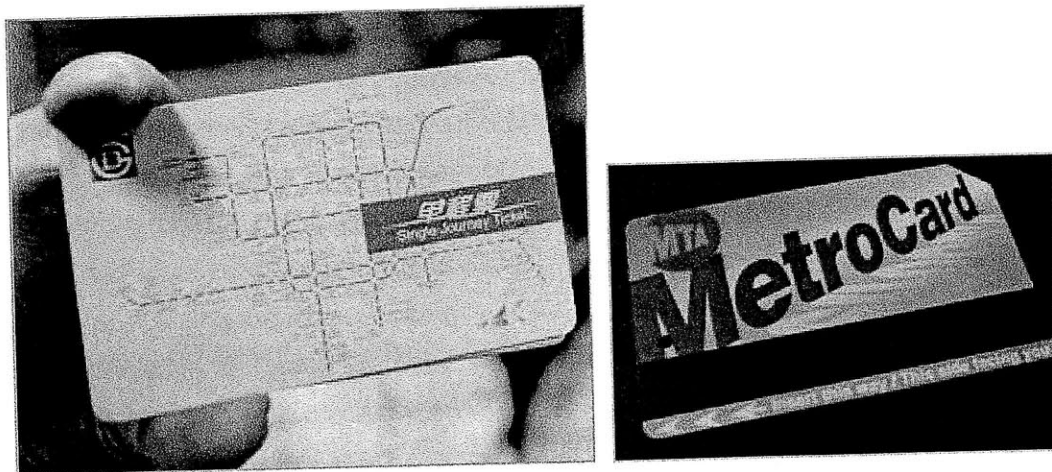


Figure 4.3-9: (1) Magnetic oneway metro ticket in Beijing (left) (2) Magnetic Stored-value metro ticket in Newyork (right)

Source: (left) [http://epaper.voc.com.cn/hnrb/html/2008-06/10/content_30954.htm];
(Right)[<http://www.nileguide.com/destination/blog/new-york/2010/08/26/navigating-the-subway/>]

⁷⁴ Refer to: FTA US, Characteristics of BRT for decision making, 2004

Another one is magnetic token (coin-shape magnetic ticket), which is in general used as a kind of recyclable one-way ticket in metro system. Such as Guangzhou, the city used to have magnetic stripe cards as metro tickets for single journey, but because the wear rate of the magnetic stripe cards is high when passing through the ticket reader, from 2003, the city decided to exchange the cards into contact magnetic tokens with touch reader, and after an upgrading 2009, now the tokens is more sensitive to work faster and better in the station entrances.



Figure 4.3-10: The new magnetic token (one-way ticket) used in Guangzhou metro
Source: [http://www.gzlive.net/bbs/thread-27996-1.html]

Besides metro system, in some special case, this kind of tokens is also used in BRT system as a fare-paying medium, such as in *Xiamen city of China*. (Figure 4.3-11)



Figure 4.3-11: The magnetic token used in Xiamen BRT as ticket

Source: Baidu Image, originally from: [http://bbs.sends.c/c/showthread.php?t=178036]

In general, this type of magnetic media requires electronic readers, which determine the fare payment time and have implications for dwell times depending on the fare collection process and machinery⁷⁵. The costs, especially the one-time investment in the installations of all the machinery equipments will be higher than cash and paper media but lower than smart cards.

However, as a natural drawback, the magnetic media used nowadays are mostly applied for single journey only. For magnetic token, it is hardly kept for multi-time uses, and for magnetic stripe card, since magnetic stripe is quite easy to wear out, it is rarely used for multi-way trips either. Also, the specific magnetic media used in BRT and metros are normally different system by system, hardly to be integrated into the same style and shape, so magnetic media are not the key for keeping the compatibility in fare collection between BRT and URT.

- **Smart Cards**

Smart Cards (or called IC card, or transit card) generally support faster and more flexible fare collection systems. Contactless or Proximity Smart Cards permit faster processing times than magnetic stripe cards or contact smart cards.⁷⁶ Meanwhile, they normally support multi-time uses and can be stored value for a long term, which could save the regular passengers certain time spent on waiting in the line before ticket machines for one-way tickets.

Also, it facilitates processing of differentiated fare structures such as time-based and distance-based fare structures, and more importantly, *fare integration across several modes and operators*.⁷⁷ In a media-integrated system, passengers could use only one card to pass all the entrances and exits in different transport systems, which is very important for the compatibility in fare collection between BRT and URT. Beyond that, this one-card pass will preserve the chance of automatically free charge on transfers.

There are a lot of cities in China having a city smart transit card but with different names (*Beijing, Shanghai, Guangzhou, Shenzhen, Xiamen, Nanjing, Hefei*, and etc). For instance, in Beijing, there is a smart transit card call *Yi Ka Tong*, which means “one card for all”. The card could be used for paying the fares of buses, BRTs and metros. To encourage the residents to switch into using the smart card from cash, as mentioned before, the government determined that the card users could have 60% off for taking buses, which is *0.4 RMB (6 cents in US dollar)* per time comparing to the

⁷⁵ Refer to: FTA US, Characteristics of BRT for decision making, 2004

⁷⁶ Refer to: FTA US, Characteristics of BRT for decision making, 2004

⁷⁷ Refer to: FTA US, Characteristics of BRT for decision making, 2004

original 1 RMB (around 0.15 US dollar) in cash, and for student card users, there is an additional 50% off discount, which turns the fare into 0.2 RMB per time (3 cents).



Figure 4.3-12: The smart card (*Yi Ka Tong*) used in Beijing

Source: [<http://zhuanti.club.xilu.com/bbs/shehui/newsview-823786-27863.html>]

A more successful example is the smart card called *Yang Cheng Tong* broadly used in *Guangzhou city*. Though the integration in fare rules between BRT and metro hasn't been completely reached (transfer between them will still cost extra), but the residents could always use this proximity smart card to pay all the fares in both of the systems and on normal buses. This media-compatibility is at least the first step for integration between the two systems.

After around 10-years developments, the features and functions of Yang Chen Tong are becoming various. Nowadays, Yang Cheng Tong has a lot of different shapes, and editions, and even can be integrated with visa cards and cell phones (Figure 4.3-13, next page). In functions, more than paying for fares of public transports, now the card can also be used as a medium to pay for parking meters and to borrow public bicycles for free out of metro and BRT stations under the city's public bicycle project (Figure 4.1-13, next page), which is good for integration of public transport and bicycling developments. As a beyond-transit, hybrid and comprehensive smart card, the application of *Yang Cheng Tong* in Guangzhou is not limited in transport system, but the stored values in the card can also be spent at *McDonalds* and some retail chain stores for food and groceries.

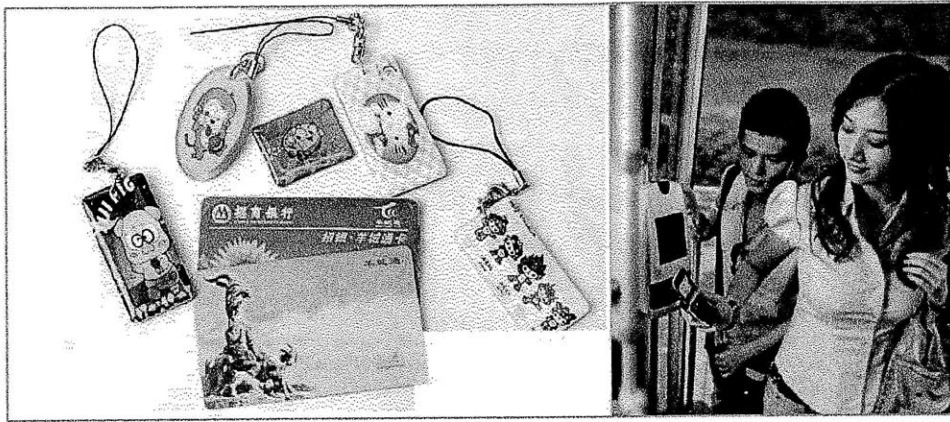


Figure 4.3-13: Multitype looks of Yang Cheng Tong (Smart Card in Guangzhou)

Notice: The Yellow card in the center is the normal looking of Yang Cheng Tong. Yang Cheng Tong has developed into various features and shapes, and even can be integrated with visa cards and cell phones.

Source: <http://www.dc345.com/newsfolder/20079/200792414335888.html>

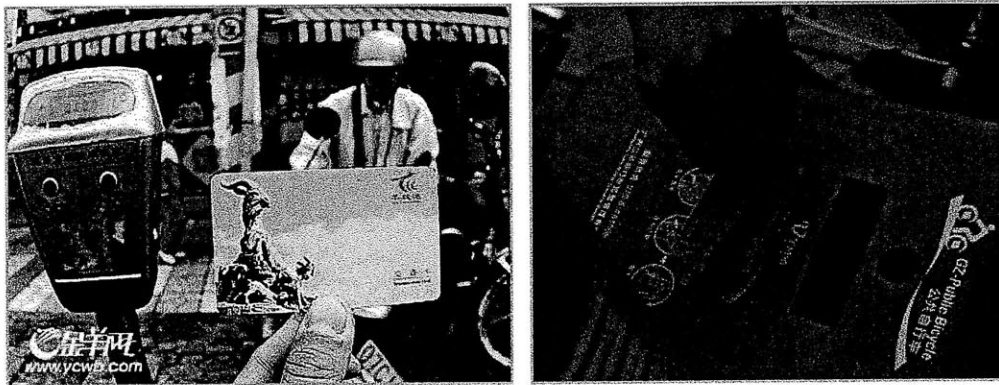


Figure 4.3-14: Extra functions of Yang Cheng Tong

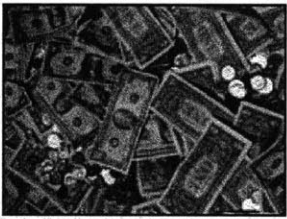
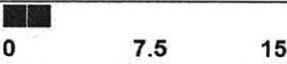

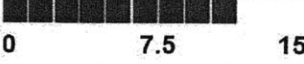


Source: Baidu Image for Yang Cheng Tong,

Originally from [<http://news.163.com/05/1202/17/2402sv940001124t.html>] and [<http://www.yoooo.net/asia/2010/06/24/57592.shtml>]

As a modern circulation media in the new century, smart cards are gradually replacing cash in a lot of places, including but not limited in the city public transport system. ***With high compatibility and efficiency, it is a developing but key medium for the integration of the whole public system.***

Though there are a lot of advantages of smart cards, the cost related is also higher than the other media. Here is a general comparison between the one-time costs of the three major media options for equipment installations and material preparations:

Table 4.3-1: Comparison between the three major media in one-time cost

Cash and paper media	Magnetic media	Smart Cards
 <p>COST PER VEHICLE (\$ thousands)</p> 	 <p>COST PER VEHICLE (\$ thousands)</p> 	 <p>COST PER VEHICLE (\$ thousands)</p> 
<p>Cost: No incremental cost, assuming this is the current fare collection process. \$2,000 (low cost mechanical farebox) - \$5,000 (complex electronic registering farebox)</p>	<p>One-Time Cost: \$10,000 to \$12,000 per validating farebox with magnetic card processing unit (\$5,000 to \$10,000 more than a standard farebox); \$0.01 to \$0.30 per magnetic stripe card; \$10,000 to \$20,000 per garage for hardware/software. May include additional central hardware/software costs.</p>	<p>One-Time Cost: \$12,000 to \$14,000 per validating farebox with smart card reader (\$7,000 to \$12,000 more than a standard farebox); \$1.50 to \$5.00 per smart card; \$10,000 to \$20,000 per garage for hardware/software. May require expenditure on additional central hardware and software.</p>

From: Source: FTA US, Characteristics of BRT for decision making, 2004

As you could find from above, the required investment is generally directly proportional to the performance efficiency. Therefore, even smart cards are more efficient and convenient in use and have important significance for integrating the fare collection media, different types of cities should choose different media based on their current-stage needs and economic strength. For example, for some medium or small cities with no metro or BRT, the cash and paper media would be an economic choice for bus service; for some developing cities with only one of them, magnetic media could be a great transition choice for short term; but for big metropolises facing an integration age of URT and BRT and even the whole public transit system, a function-comprehensive and transfer-facilitating smart card could be more reasonable.

3. Fare Collection Process

There are generally two ways of fare collection, collecting fares on board or advanced off board. For URT systems, there is always advanced ticketing off board. Ticket-purchasing or fare-paying normally happens at the entrance of the station, and only after paying the right fare the passenger could enter the station and take the metros.

For normal buses on the other hand, the ticketing and fare collection usually happen on the bus. There are several ways used in fare collection on board also depending on the media types. The traditional way for the buses in old-time China was to have a *specific conductor* selling and checking the tickets for everyone. The corresponding fare media are cash and paper ticket. Nowadays, this manually-operated way is not that welcome along with the fast developments happening in the cities. As a substitution, a lot of cities started to replace the role of conductors by *fare-boxes on board* to collect the fares *in cash*, the bus driver could take the role of ticketing and supervising so that the position of conductors have been getting cancelled to save labor costs. However, this way only works well with flat-fare structure. When the fare structure is differentiated between zones or distance, this collection way couldn't be suitable. Therefore, in such a big city as Beijing, since there are a lot of bus lines working for long distance crossing the whole urban area, it is hard take a flat rate for both a five-minute trip crossing three blocks and a one-hour trip crossing three zones. In that case, a conductor could be helpful for collecting different fares for the passengers from and go to different places.

Along with the developments in technology, smart cards show up and become as a popular media in a lot of big cities. With smart card, the fare-paying-and -collecting could be accomplished anywhere depending on the location to put the card reader. For normal buses, the card readers are usually installed on board, normally close to the front door. Passengers need swipe or press the card close to the reader to get it sensed and the fare-charging will be mechanically finished. With improvements in electronic technology, even differentiated fare could be settled. According to the experience in *Beijing*, in that case, there could be two readers on both sides of the bus, which will be able to count the number of stops or zones passed. The passengers need to get the card sensed both when they are boarding and getting off, and the reader could automatically count and charge the right fare accordingly. For the buses in modern China, normally both of the electronic fare-payment by smart card and the cash payment are allowed on board. For flat fare structure, there would be both the cash-box and a card reader, and for differentiated fare structure, there could be a conductor and two card readers.

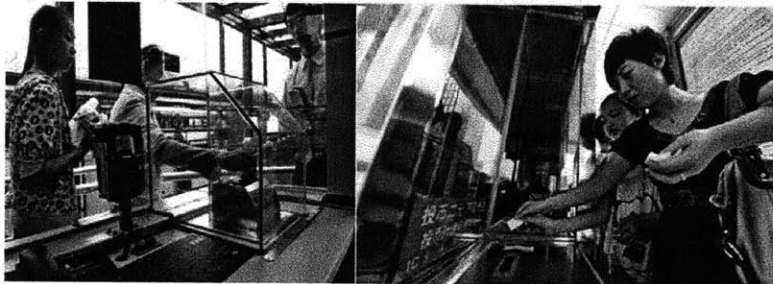
For BRT systems, as a mixture product with the characteristics from both normal buses and metros, the current fare collection methods in cities of China are actually very various: It could be accomplished on the bus or off the bus, with cash, smart card or even magnetic tokens.



Fare Collection Ways On Board (1. Cash Box or 2. Smart Card Reader or Both)

Source: (Left) <http://www.公众传媒集团.com/view.asp?id=8752>; (Middle) http://gzdaily.dayoo.com/gb/content/2004-07/23/content_1644007.htm; (Right) <http://news.xkb.com.cn/guangzhou/2010/0501/60150.html>

Off Board Collections



1. Cash Box off board (In the station or On the platform)

Source: (Left) Guangzhou Institute of Transportation (GIT), 2010; (Right) http://midchina.xinhuanet.com/2010-07/29/content_20519907.htm

2. Magnetic Tokens and Electronic Entrance (Just like Metro) (Xiamen)



Source: (Left & Right) http://www.xm.gov.cn/zwgk/wmbss/wmbssxgbd/200810/120081008_280066.htm; (Middle) <http://www.dianping.com/photos/4105511>

3. Smart cards and Electronic Entrance (Just like Metro)



Source: (Left) <http://baike.baidu.com/view/1922054.htm>; (Middle) http://www.ca800.com/trader/traffic/news_detail.asp?id=79862; (Right) Guangzhou Institute of Transportation (GIT), 2010

Generally speaking, off-board fare collections are normally used in closed BRT system, in which there are specific entrances and exits of the BRT station before any platform just like a normal URT system. Since all the fare deal will be settled before platform waiting, this way could shorten the stop time of buses to receive or discharge passengers. For the busy stops of multiple lines or with high passenger flows, this is a very helpful method to support higher operation speed and efficiency. However, since the whole system is closed with certain entrances, the bus running will have less flexibility. Generally, the buses could only pick up and discharge passengers gathered on certain locations. Further, since the equipment installation fees and station construction costs are considerable, the station number in the area will generally get limited to lower level, which will make the route and stops less close to their passengers.

On-board fare collection ways, on the other hand, work in open system and will comparatively cost more time and supervision strength for receiving and discharging passengers, but they have higher flexibility and cost less in equipment installations and station constructions. Normally used in the normal bus service, those fare collection ways will trade off high operation speed for flexibility in community service.

BRT as a rapid transit should keep efficiency as a primary principle in operations, but as a bus transit originally, it should also take the flexibility factor into consideration at the same time. Therefore, how to balance the two features is hard question to answer.

A good attempt was from the famous BRT system in Guangzhou. The BRT system applies a mixed fare collection with both validated on-board and off-board fare collection measures:

When BRT buses travel in the dedicated busway sections in the high-density city area, the lines keeps in a closed system accepting off-board fares. There are Yang Cheng Tong smart card readers and cashbox at every station entrance. After passengers pay the fare, either by smart cards or in cash, they pass the turnstiles to reach the platforms and then choose the bus route they want to take. At these platforms, passengers can use both the front door and the rear door to board.⁷⁸

When the BRT buses travel in mixed-up lane sections, that is on conventional roads, the BRT buses will turn to the on-board fare collection ways. Passengers can only board at the front door and need to first insert certain-amount money to the cashbox or

⁷⁸ From: Guangzhou Bus Rapid Transit (GBRT),
[<http://hubdat.web.id/spesial-konten/dokumen-publikasi/umum/1066-giangzhou-bus-rapid-transit/download>]

swipe their Yang Cheng Tong smart card to pay the fare. Disembarking could only happen at the rear door of the vehicle at the same time.⁷⁹

Worth notices, for better integration between BRT and URT system, the off-board fare collection ways would be preferred in the BRT stations linked with metro or light rail stations. As a long term target, all the extra dual entrances and exits between them could be moved for seamless connections. Only one-time entrance is needed for getting into the integrated BRT&URT transport system and before the passenger get out from an exit, no payment will be needed on transfers.

4.3.3 Unified institutional system of management

As part of the integration between BRT and URT, the managements and operations should be combined. To ensure this, institutionally, there should be some management department or institution generally supervises and manages the works in both of the system. Nowadays, this goal hasn't been reached yet.

However, an integrated management structure in a multi-operator BRT system has been accomplished in Guangzhou and the success there can pass us some valuable experience for integrating managements between BRT and URT in the future.

The specific difficulty in integration of fare collection in Guangzhou is that: On the main street called *Zhong Shan Avenue* which is targeted to build up dedicated busway, there were 87 normal bus lines operated by 3 big group corporations with totally 7 branch bus operating companies. Even after filtering and combining some lines, there are finally 30 BRT lines settled in the same corridor, still operated by different companies. How to obtain a collectively unified management on all the lines operated by different operators and how to uniform the ticket price and fare collection were major problems facing by the transport planning board in Guangzhou. Especially, when the city decided to apply a flat-fare structure and off-board fare collection measures to easy the passenger transfers, it raised a challenge in management and fare distribution.

To solve the problems and to guarantee better and more uniform services in BRT system, the city finally decided to found a new corporation specifically in charge operation management on the BRT system, which is called *Guangzhou BRT Operation and Management Corporation*. A creative institution structure has been formed. (Figure 4.3-15)

⁷⁹ From: Guangzhou Bus Rapid Transit (GBRT),
[<http://hubdat.web.id/spesial-konten/dokumen-publikasi/umum/1066-giangzhou-bus-rapid-transit/download>]

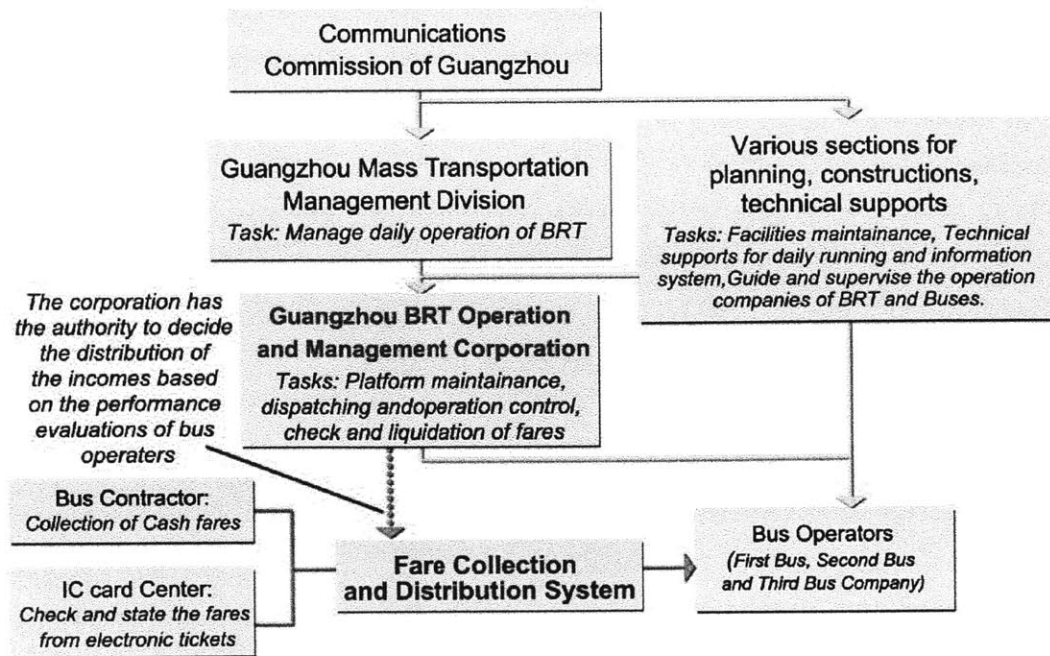


Figure 4.3-15: Operation Management system in Guangzhou BRT

Source: Guangzhou Institute of Transportation (GIT), 2010

Worth of notices, this corporation has also an especially important role in fare collection and distribution process, since it has the authority to evaluate the performance of the bus operators and could decide the detail distribution of the collected fares accordingly.

4.4. Integrating Land Development and Transits

Developments in transport system will have significant influence on the surrounding environment and urban growth. Especially for the high-class transfer center like a general transport hub, the new construction itself will attract huge daily passenger flows, which will bring new business chances. Also, the change in transport conditions is always an important location factor causing population migration and redistribution of resources in the city. Therefore, it is very significant for us to consider how to rationally utilize these opportunities in urban growth with the integration of BRT and URT systems.

4.4.1 Transit-Oriented Development

Transit-oriented development (TOD) is one of the most popular tools of the utilization. TOD is defined as a mixed-use residential or commercial area designed to maximize access to public transport, and often incorporates features to encourage transit ridership. A TOD neighborhood typically has a center with a transit station or stop (train station, metro station, tram stop, or bus stop), surrounded by relatively high-density development with progressively lower-density development spreading outward from the center. TODs generally are located within a radius of one-quarter to one-half mile (400 to 800 m) from a transit stop, as this is considered to be an appropriate scale for pedestrians.⁸⁰

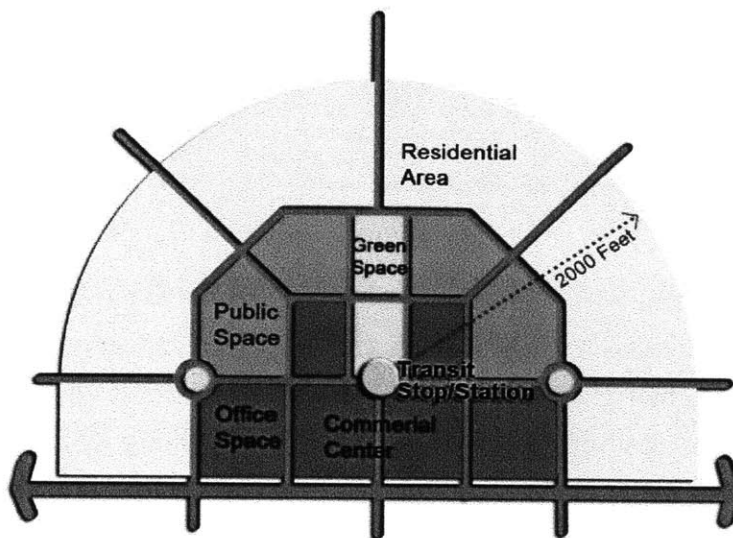


Figure 4.4-1: Land use mode in TOD

Source: Refer to DUSP, MIT, Sustainable Community Development, Shantou Planning Studio, 2010 spring, P178, Originally From: [http://trc.bjut.edu.cn/bbs/printpage.jsp?forumID=9&rootID=2134], 2009; [http://www.fwwwd.com/content/2008-12/02/content_3434518.htm], 2009

TOD pursues a combination of transit and walking & cycling environments. (Figure 4.4-2) Comparing to car environments, TOD could gain a better balance between speed, spatial reach and capacity of transportation, which could bring a greater efficiency and scale economy. The main goals of TOD include:

- (1) Activate economic development and commercial activities;
- (2) Promote the circulation in the area and strengthening the connections between clusters with different functions;
- (3) Cooperate with compact and mixed use development in land use;
- (4) Build up a pedestrian-and- environment friendly community;
- (5) Create a growth pole of the city.

⁸⁰ Refer to DUSP, MIT, Sustainable Community Development, Shantou Planning Studio, 2010 Spring, P178 Originally from: [http://en.wikipedia.org/wiki/Transit-oriented_development]

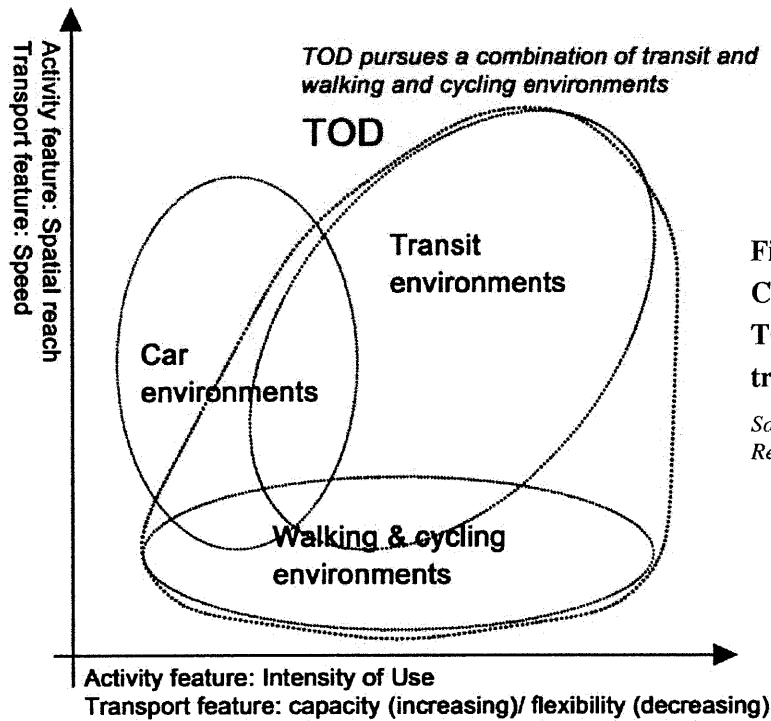


Figure 4.4-2:
Comparison between
TOD and other
transport environments

Source: Carey Curtis, John L. Renne, Luca Bertolini, 2009

There are a lot previous successful development cases by TOD mode. Hong Kong is one of the most famous cities getting huge benefits from TOD. The land resource in Hong Kong is very restricted, that is the reason for Hong Kong to invest a lot to develop public transit. Also, because of this urgent needs facing by Hong Kong, the researches on public transit, TOD modes and related financial modes are very advanced in Hong Kong. When developing metro lines, the government will cooperate with the real estate developers to develop the surrounding areas together. Financially, the metro infrastructure constructions could be partly funded by the revenues from paid transfers of the land use rights, which also turned the metro system in Hong Kong to be one of the rare cases of profitable public transports. Spatially, the mixed-use TOD communities with controlled urban density could be also built up. (Hailei Wei, Decun Dong, 2007) Based on the cooperation between developer, government and residents, the win-win balance between real estate development, transit construction and setting up of public facilities has been reached in Hong Kong. ⁸¹

To introduce the TOD model into urban growths in reality, there are five major principles in urban planning and design: (Hailei Wei, Decun Dong, 2007)

- 1) Surrounding the public transport stations, there should be a more intensive development density to inspire the use of public transports;

⁸¹ Refer to: DUSP, MIT, Sustainable Community Development, Shantou Planning Studio, 2010 Spring, P178

- 2) In planning and zoning, residential, retail and office clusters should be arranged close to the public transport stations and with high accessibility;
- 3) Mixed-use in land use pattern should be encouraged, and the key is to put the residential clusters in the walkable distance to other retail and office space.
- 4) New developments should adapt to and combine with the existing transport networks;
- 5) Guarantee the pedestrian characteristic in residential communities.

4.4.2 BRT and TOD

In previous experiences, TOD is more associated to URT systems, but along with the developments and popularity of BRTs in the world, the BRT-Oriented Developments are now easier to see and are becoming more significant.

A Successful case from Curitiba

Curitiba city is the capital of the Brazilian state of Paraná. It is Parana state's and southern Brazil's largest city and economy.⁸² As we introduced in Chapter one, (1.1.2 BRT in the world, page 9) the BRT system in Curitiba opened in 1974 was the first BRT system implemented in the world. Since the 1970s Curitiba's administrators have constantly innovated in upgrading the city's bus based transit system through performance and capacity improvements. The city introduced high capacity bi-articulated buses and the electronic fare ticketing systems. In 2009, with the introduction of the Green Line, its sixth BRT corridor which includes the operation of 100% bio-diesel articulated buses. In 2010 the city introduced capacity enhancements for one of the existing corridors, which improve its performance to levels that are typical of metro systems. System operation will be further enhanced with advanced traffic management and user information systems.⁸³ Nowadays, the BRT system in city actually is working in commons with URT systems in other cities around the world. It is also one of the most heavily used, yet low-cost, transit systems in the world.

Because of the success in building the complete BRT system, the TOD case from Curitiba is also different with the Metro-Oriented Developments usually seen in other countries. Based on its popular and successful BRT network, the city created a fresh but classic BRT-Oriented Development model in planning and implemented it in the whole city area (Figure 4.4-3).

⁸² From: <http://en.wikipedia.org/wiki/Curitiba>

⁸³ From: Luis Antonio Lindau, Dario Hidalgo, Daniela Facchini, Curitiba, 2010,

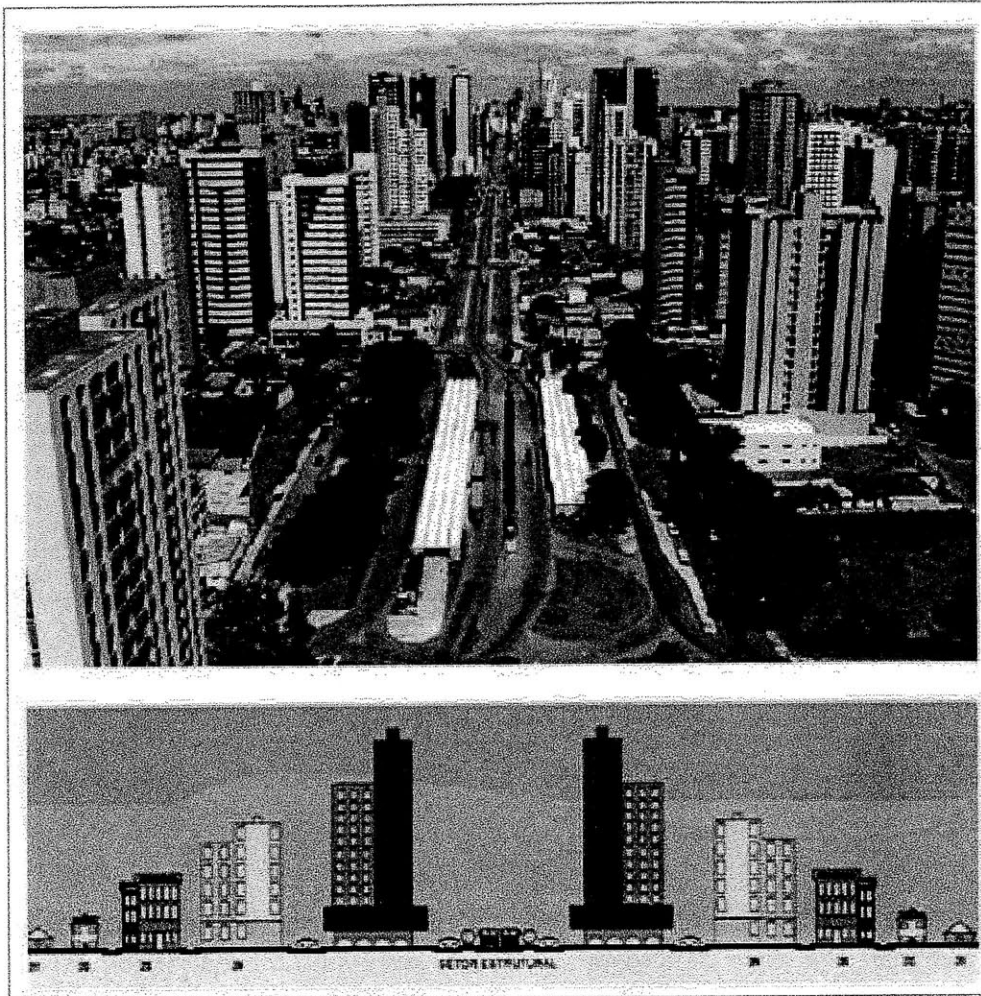


Figure 4.4-3: Conceptual Linear TOD plan that became reality in Curitiba

Source: Luis Antonio Lindau, Dario Hidalgo, Daniela Facchini, Curitiba, 2010.
Originally from Urban Development Authority of Curitiba (URBS), Curitiba

The principal ideas behind the planning are: With high-density demographic characteristics, the city area needs some high-capacity, high-speed and dedicated public transport corridors. At the same time, for the economical efficiency in operations of a huge public transport system, the demand scale of public transit services along the corridors should reach some high threshold, which only can be supported by surrounding dense communities.⁸⁴ Based on this logic conception of interactive dependency, Curitiba city decided to build up a broad framework of BRT network in the city and integrated developments in land use, road system and public transport by TOD model.

Called as “*Rede Integrada de Transporte (RIT)*” locally, *the Integrated Transportation Network* (cored by the BRT system) in the city is originally a municipal initiative that sought integration of transportation and land use; RIT was

⁸⁴ Hailei Wei, Decun Dong, 2007

conceived around structural axes that provide the backbone of TOD initiatives through relatively low cost and high impact interventions, but finally, this basis evolved into a comprehensive TOD model for economic developments with a flexible, efficient and low-cost BRT public transport. Today RIT covers 14 of the 26 cities of the metropolitan area.⁸⁵

A typical structural axis includes two side blocks and three roadways and is thus called a “trinary” system. Figure 4.4-3 displays the concept and the reality along one of the key arterial corridors. Figure 4.4-4 provides more detail explanation on the structure.

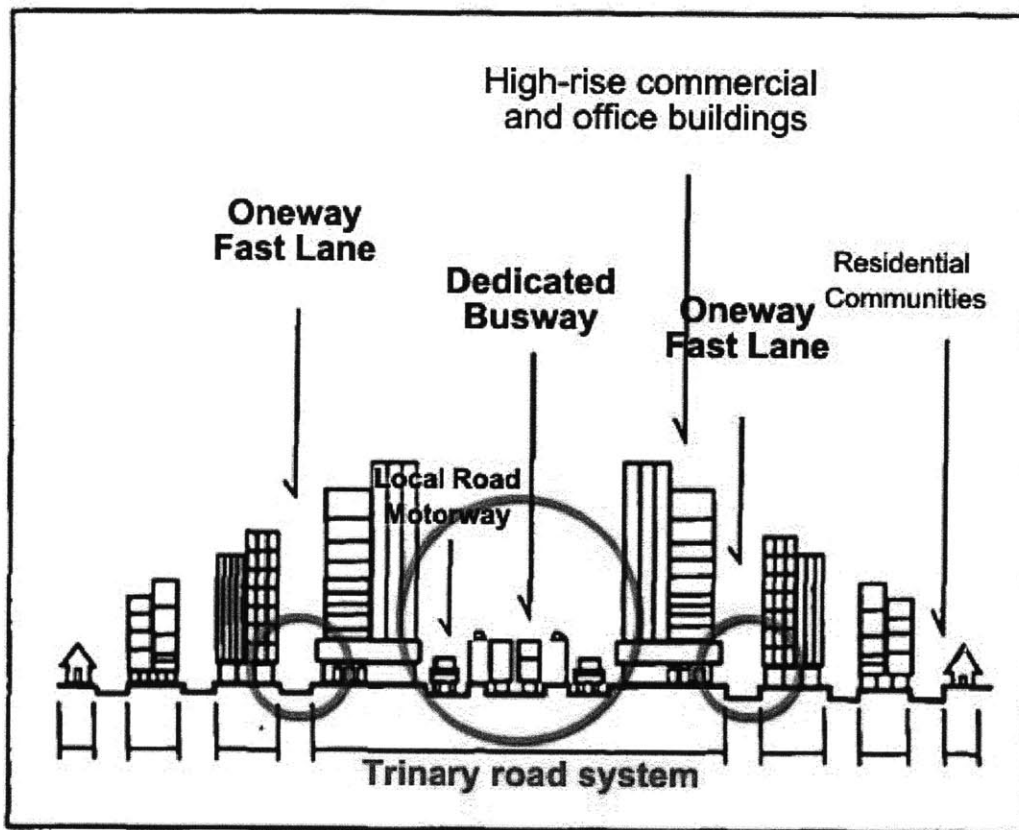


Figure 4.4-4: Skyline Analysis of the TOD pattern in Curitiba

Source: Hailei Wei, Decun Dong, 2007

In detail, the central avenue is dedicated to bus transit (median busway and tube stations) and local traffic that accesses buildings and parking. The parallel streets are dedicated to higher speed traffic (including direct buses), with each street providing traffic in one direction only (towards the city center and towards the suburbs). (Figure 4.4-5) The side blocks are zoned as mixed use, high density development. (Figure

⁸⁵ Refer to: Luis Antonio Lindau, Dario Hidalgo, Daniela Facchini, 2010; and Hailei Wei, Decun Dong, 2007

4.4-7) Blocks further away from the “trinary” system are zoned for lower density. (Figure 4.4-6) As result, urban development is linear along the structural axes. Over time the concept proved successful in achieving linear TOD.



Figure 4.4-5: Trinary road system in Curitiba

Source:
[<http://sustainablelosangeles.blogspot.com/2009/02/lost-angeles-how-la-can-take-lesson.html>]

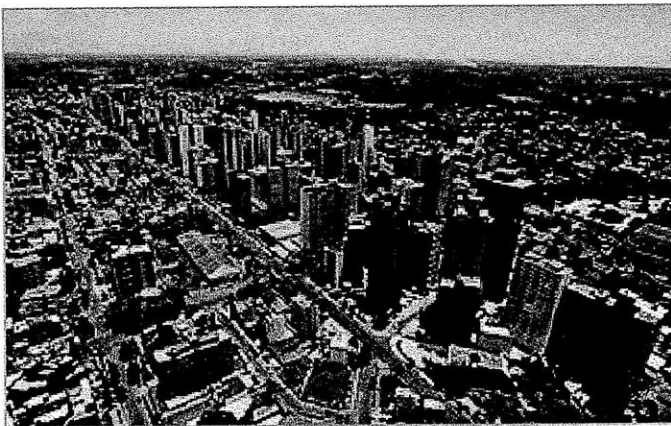


Figure 4.4-6: The change in density in the city area

Source:
[<http://sustainablelosangeles.blogspot.com/2009/02/lost-angeles-how-la-can-take-lesson.html>]



Figure 4.4-7: High-density and mixed-use developments long with the central avenue

Source:
[<http://stlelsewhere.blogspot.com/2010/06/st-louis-brt-curitiba-brt.html>]

Until now, Curitiba is still the only city in Brazil that has directed its growth by integrating urban transportation, land use development and environmental preservation.

4.4.3 Applicability in China

According to the urbanization and metropolitanization progresses in China, there are two patterns of urban spatial structures will become majorly popular in the future. One is big metropolises and metropolitan areas with multi-centers and satellite towns, the other one is middle-scale cities with dispersed clusters. Both of these two patterns will get rid of the disadvantages of disordered urban sprawls and turn the city areas into a more intense and compact forms with polycentric frame. Responding to these trends, the transit demands in the city areas will alter into two main kinds, one is for the short-distance trips in one cluster, the other is for long-distance trips between clusters. Because the construction cost of URT lines are much higher, URT is more suitable for short-distance but high-density transit services, which means using URTs to link multi centers is not very economic. Therefore, the second-type transit demands, transits between clusters, are turning to the basic customer resources for BRTs.⁸⁶



Figure 4.4-8: Route of BRT line in Guangzhou, China

Source: Base map from: [<http://www.chinabrt.org/maps/maps-guangzhou.aspx>]; Graphing: by Author.

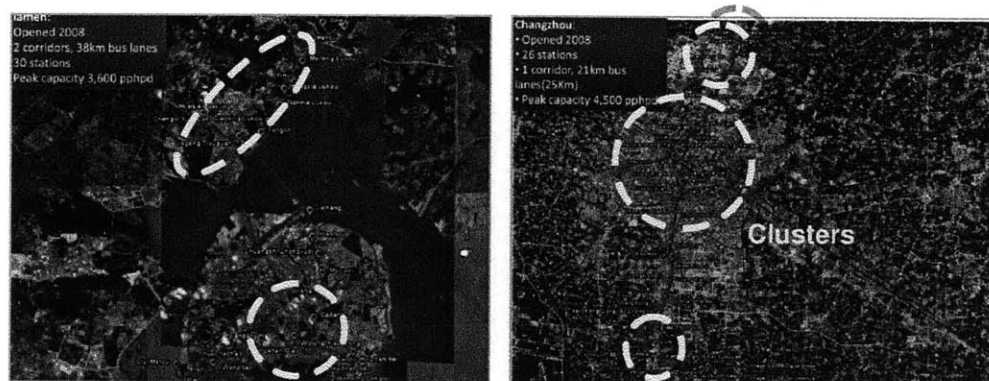


Figure 4.4-9: Routes of BRT lines in Xiamen and Changzhou, China

Source: <http://www.slideshare.net/EMBARQNetwork/brt-in-china-a-brief-review>

Especially, in most of the secondary cities of China, a metro system is too expensive and requires a certain threshold in economy, so it could hardly be built in short term.

⁸⁶ Hailei Wei, Decun Dong, 2007

Also as a rapid transit with sufficient capacity in service, BRT will start to undertake the leading role in public transports in these areas. Therefore, for these cities BRT-Oriented Developments are more practical.

Meanwhile, for the big metropolises and major cities have had or are having a URT system, BRT is still practical and functional in different areas. The integration age of BRT and URT is also coming. Not only for the corridors of URT and BRT, The connections between the two systems will create new and more influential chances for TOD, such as around some general transport hubs, interchange centers, or just the transfer station between BRT and URT. (Ex. ShiPaiQiao Station in Guangzhou)



Figure 4.4-10: 3D map of the area along BRT corridor in Guangzhou

Notice: Shi Pai Qiao Station is an interchange center between metro and BRT systems

Source: <http://gz.o.cn/>

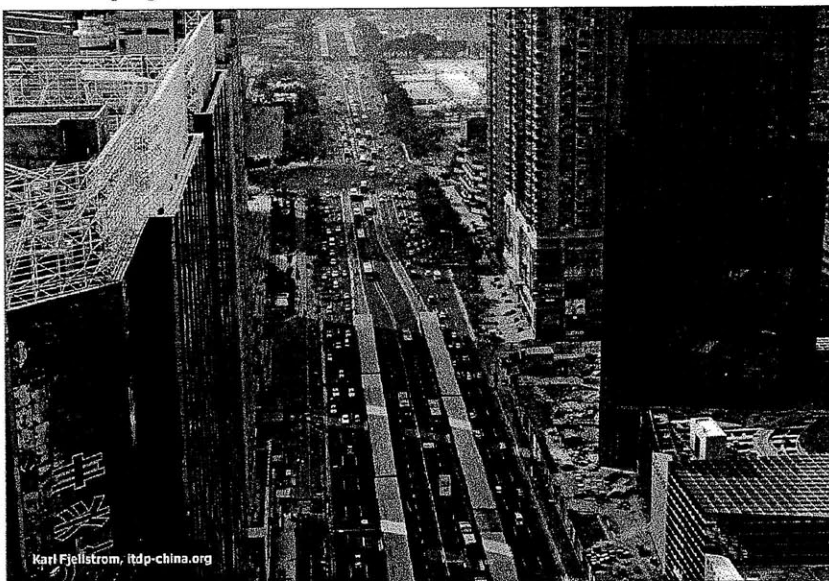


Figure 4.4-11: Guangzhou BRT Shipai Qiao Station

Source: IITDP, by Karl Fjellstrom, [<http://www.transportphoto.net/photo.aspx?id=9900&c=Guangzhou&l=cn>]

For Guangzhou city, since the BRT lanes was built very recently, most of the surroundings along the BRT corridor in the city central area have already been constructed before inserting the BRT lines, and the high density and busy life in the area are part of the reasons for locating the first experimental BRT corridor there. In another words, it is more like a development-oriented BRT location. Though the TOD model and conception of mixed land use will still be useful to guide the future developments there, but the adjustment room will be comparatively limited.

However, for the extension part to the city suburb, the stage of development is still early with much lower construction density and FAR. In this section, the development-orienting function of the BRT corridor could be better utilized. For the best uses, comprehensive and integrated planning of the areas with mixed-use and residential-friendly principles will be the first step.



Figure 4.4-12: Actual looking of the area along BRT corridor at out-of-central-zone section in Guangzhou

Source: Karl Fjellstrom, ITDP, 2010

As a conclusion, we should keep in mind that the integration of the URT and BRT systems will not only mean to the comprehensive networks, convenient connections in transfers, and unified managements. To some extent, it means to the TOD chances in economic developments and urbanizations as well. Therefore, our tasks also include rational urban planning and financial policies to support that happen, which will not be introduced in detail in this paper.

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