Research on Bus Rapid Transit (BRT) and its Real-Time Scheduling

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Abstract-**With the fast development of the economy, the urban traffic demands increases rapidly, Bus rapid transit (BRT) system, a new type and high efficient bus operator system and a comprehensive mass transit system between the metro and regular bus systems, can alleviate traffic congestion, reduce resident traffic cost effectively, and improve transportation quality and efficiency, with its advantages becomes an effective way to improve urban traffic status. In this article, the definition, major elements, advantages, functions and development of BRT are provided, and a new real-time scheduling is given which is going to be applied to the Zhongshan Avenue BRT system in Guangzhou China.**

***Keywords*-bus rapid transit (BRT); public transport systems; bus dispatch; scheduling scheme**

I. INTRODUCTION

Since the 1970s, as economic development and per capita income level improve, motor vehicle ownership in every country is increasing rapidly, which has caused serious traffic congestion, energy crisis, shortage of land resources, environment deterioration and air pollution[1]. It has little effect to alleviate the congestion by constructing new roads or widening the existing roads, even makes the traffic condition worse. Urban development needs the support of public transport systems. But, the railway system, because of the huge investment and the difficulty to cover a large area in limit time, has a limit capacity to transfer passengers; and regular bus systems have many functional limitations like low operational efficiency and poor level service, etc[2-4].

Nowadays many decision makers of city are looking for the better high-quality transit mode to improve the efficiency of road resources and to alleviate traffic congestions. Bus rapid transit (BRT), a new type and high efficient bus operator system and a comprehensive mass transit system between the metro and regular bus systems, whose transportation speed and capacity is close to the rail transportation and whose cost is close to the general bus, is becoming more popular and welcome in many cities[1,2]. BRT has been found one of public transport systems with the most economic and efficient advantages in the world, and it can quickly build public transport system and form a complete network, and can also provide fast and high-quality services.

II. BRIEF INTRODUCTION OF BRT

A. Definition of BRT

Bus Rapid Transit is a flexible, high performance, rapid transit mode that combines such elements as exclusive right-of-way, specifically designed stations, operation systems, customer service systems and Intelligent Transportation Systems (ITS), to offer a reliable, speedy, comfortable and low-cost service [1].

B. Major elements of BRT

BRT is a flexible, rubber-tired rapid-transit mode that combines vehicles, stations, running ways, fare, ITS and services elements into an integrated system with a strong positive identity that evokes a unique image [1-12].

1) BRT vehicles

The BRT buses are usually uniform with bright colors to be easily identified and to show the brand effect of system. Vehicles with low floors are very convenient for passenger alighting and boarding. The use of advanced articulated buses as long as 18-25m which could accommodate 200-250 persons is to increase the capacity and lower the average operate cost. BRT systems in many cities are preferred to the low-emission and low-noise buses which have little influence to the environment [5].

2) Stations and intermodal terminal

The design of stations takes into account the safety, comfort and closure. The stations are equipped with automatic ticketing and fare collection system outside the vehicles, Variable Message Signal (VMS) and operating information system. The stations platforms meet the vehicles floors to allow for convenient alighting and boarding. And the stations also have a quality image and unique identity or significant architectural features to make the difference of the usual stations to facilitate the identification of passengers [6].

3) BRT Corridors

BRT vehicles operate on dedicated bus corridors to make them to maintain vehicle speed from the impact of congestion. BRT corridors are the most critical element in determining the speed and reliability of BRT services. Operating speed is 20-35km/h, close to the speed of the rail. And in the intersection,

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BRT vehicles have priority right of traffic lights to Increase their operating speed [7].

4) Fare collection

BRT system includes an integrated fare collection system of a ticketless system, magnetic strip technology, and smart cards which are similar to the subway or light rail and other rail traffic systems. Pre-board fare collection is used to allow for simultaneous alighting and boarding. In the station, passengers can select the bus line freely. All these can reduce the time the time of passengers' buying tickets and getting on, passengers' waiting time and vehicles' dwelling time [1].

5) ITS application

Intelligent Transportation Systems (ITS) can greatly enhance the success of BRT systems. At relatively modest costs, ITS can improve operation management and vehicle control and can replace some of the functions provided by expensive and difficult to maintain physical infrastructure, or other types of rapid transit. They can be used to convey passenger information in a variety of venues, monitors, or control bus operations, provide priority at signalized intersections, enhance safety and security on board vehicles and at stations, and even provide guidance for BRT vehicles. ITS mainly aids operation management and vehicle control [8-11].

6) Service plan and operation organization

BRT system usually can provide all-day, high frequency service. Service lines and schedules can be adjusted according to the season, date and time to meet different needs of passengers [12, 13].

C. Advantages of BRT Systems

BRT has many advantages as follows (See also TABLE I and TABLE II):

1) Integrate regular bus lines and save vehicles;
2) Lower capital and operating costs;
3) Shorter construction period;
4) Alleviating traffic congestion;
5) Low investigation and quick effectiveness;
6) Massive capacity, higher speed and reliability;
7) Higher flexibility, better security, customer friendly;
8) Environment friendly and low energy consumption;
9) Transit-supportive land development;
10) Flexible layout;
11) Fully utilize the existing operation management;
12) Increasing the proportion of bus travel;
13) Sustainable development of urban passenger transport;
14) Advanced operation and operation system.

TABLE I. EMISSIONS AND ENERGY CONSUMPTION OF DIFFERENT PUBLIC TRANSPORT MODES (PER MILLION PER KILOMETER)

Pollutant	*Private car*	*Taxi*	*Regular bus*	*BRT*	*Rail*	*Motor*
CO_2 (ton)	140.2	116.9	19.8	4.7	7.5	62.0
NO_x (kg)	746.0	662.0	168.4	42.0	17.5	90.0
Oil consumption (ton)	49.2	41.0	6.9	1.6	2.6	21.8

TABLE II. COMPARISON OF CONSTRUCTION OF DIFFERENT PUBLIC TRANSPORT MODES

	Subway	*Light Rail*	*BRT*
investment cost (million $ /km)	30-120	10-30	3-12
passenger traffic (thousand persons/h/direction)	30-80	10-30	10-40
mean velocity (km/h)	25-60	20-40	20-30
Time (year)	8-10	4-6	1-2

D. Functions of BRT

BRT is not only advantageous for metropolitan areas, but also for less developed cities with different development stages. In metropolitan areas, BRT, is an important part of the transportation system and can be used as a complement, extension or substitute for rail. And BRT in a medium-sized city can be used as the framework of public transportation system. Furthermore, between the satellite town of a city and the downtown area, it can link these areas. The function of BRT includes:

1) The update form of conventional bus system;
2) The subject of the entire public transportation;
3) A way to improve public transport services;
4) The extension of the metro system;
5) The supplement of the metro system;
6) The connector of the metro system and bus system;
7) An avenue for consumer market development and land use orientation, i.e. Transit oriented development (TOD);
8) A support for urban spatial strategy.

E. Global overview of BRT development

Since the first BRT route in the world was established in Curitiba, Brazil, 1973, BRT has already become popular in the world quickly, and get much supports from large and international financial organizations such as UN-Habitat, International Energy Agency, Institute for Transportation and Development Policy, United Nations Development Program, World Bank, Asian Development Bank, Central America Development Bank, Global Environment Facility, and so on. Currently, BRT systems are being planned and implemented in many cities in the world [1, 2].

For instance, more than 20 cities in North America, including Los Angeles, New York, Chicago, Seattle, Pittsburgh, Miami, Honolulu, Hartford, Cleveland, Orlando, Eugene and Boston in United States, Ottawa and Vancouver in Canada, Mexican city in Mexico; more than 20 cities in Latin America, including Curitiba, Belo Horizonte, Campinas, Porto Alegre, Recife, Sao Paulo in Brazil and Bogota, Quito in other cities; more than 20 cities in Europe, including Paris, Nancy, Clermont-Ferrand, Rouans, Nantes, Rennes and Lyon in France, Leeds, Ipswich, Bradford, Leeds and Runcorn in U.K. and Eindhoven, Essen in Holland; Brisbane, Adelaide and Sydney in Australia, Oceania; and Nagoya, Nagoya in Japan, Seoul in Korea, Jakarta, Surabaya in Indonesia, Bangalore in India, Ankara, Istanbul in Turkey, Dacca in Bengal, Asia; Dar Es Salaam in Africa [1, 2, 14-17].

In recent years, BRT has garnered high regard in China with strong economies and high vehicle ownership. Many Chinese cities are interested in implementing BRT systems at present. The first demonstration line of BRT—Beijing BRT line 1 already completed at the end of 2005. And, Guangzhou, Jinan, Hangzhou, Kunming, Xi'an, Chengdu, Dalian, Shenyang, Chongqing have built. Moreover, Shenzhen, Tianjin, Fuzhou, and several other cities are making arrangements for the preliminary preparation of BRT project at present [3, 4, 18].

III. Real-Time Scheduling Scheme of BRT

For a public transportation system, the scheduling of its daily operations management is most important. Bus scheduling is the basic focus of bus carriers because it has many impacts on bus usage efficiency, timetable establishment, and crew scheduling. As a result, BRT' scheduling is essential to play BRT's operational effectiveness and ensure its competitive capability to regular bus, light railway and subway transportation or other mass public transits. Research in theory and application of BRT scheduling is very important [19].

At present, BRT is usually scheduled as regular bus, and, referring to non-deterministic polynomial problems, it is difficult for bus scheduling problems to search the global optimal solutions. Some parallel algorithms, such as multiobjective programming, genetic algorithm, tabu search, simulated annealing, and artificial immune algorithm are introduced to solve vehicle routing and scheduling problems in recent years [21-23]. And Artificial Transportation Systems may also be one of solutions for real-time scheduling scheme of BRT [24-27].

But practically, the scheduling of BRT is very complicated which is influenced by road conditions, station status, fleet size, economic interests of bus companies, weather, large-scale social activities, traffic accident, natural disasters, terrorist activities, traffic control, construction of urban construction, etc.

Because BRT scheduling, especially real-time scheduling, many data such as the wishes of the passengers, OD matrix, The number of stations on and off and Number of bus stop, etc, are needed, which are difficult to get. So, we provide a scheduling scheme which only need the density number of stations which can be easily gotten by camera video signal of the station. This scheme based on the origin running scheduling scheme, using "if-then" statements which can easily be added, deleted and modified, can give full play to BRT's fast and flexible characteristics.

The advantages of the method:

1) The previous methods usually can optimize one line, but our method can optimize all the lines running in the BRT Corridors.
2) The optimization of previous methods needs the number of the on and off of a bus line which is hard to get. So, it is done using investigative or statistical data, but theoretical analysis can be done only. Our methods can optimize the scheduling by the number of bus stop, which can be gotten easily.
3) The optimization of previous methods is not real-time. Our methods can optimize the real-time scheduling, because the number of bus stop can be got in real time.
4) The previous methods are such intelligent algorithms as multiobjective programming, tabu search, genetic algorithm and so on, which are meaningful to the actual scheduling optimization; our methods use "if-then" which is very simple, flexible and practical.

Density meter of waiting for the bus passengers is divided into five levels: less, general, much, more, most (quantitatively denoted by f1, f2, f3, f4, f5, respectively). And, the parameters according to their degree of importance may be considered, for example, $r1<1$ denotes unimportant; $r2=1$ usual; $r3>1$ very important.

For a BRT line with n stations, the average density F is

$$F = \frac{1}{n}\sum_{i=1}^{n} f_i r_i$$

For the stations S1, S2, S3, S4, S5,······, the density are s1,s2,s3,s4,s5······

1) IF $F<f1=1$, then the rank is less;
2) IF $1<=F<f2=2$, then the rank is general;
3) IF $2<=F<f3=3$, then the rank is much;
4) IF $3<=F<f4=4$, then the rank is more;
5) IF $F>=f4=4$, then the rank is most.

The scheduling scheme is as follows:

1) If the rank is less, then reducing the frequency to non-peak level, or lower;
2) If the rank is general, then taking the non-peak frequency;
3) If the rank is much, then taking evening peak frequency;
4) If the rank is more, then taking morning peak frequency;
5) If the rank is most, then taking morning peak frequency, and considering adding station express, shuttle bus, cutting empty bus or other schemes;
6) If the density of more than half of stations of a line are much more than f3, then adding the frequency;
7) If the density of more than half of stations of a line are less than f2, then reducing the frequency;

8) If the density of several stations from far away are more than f4 and the density of other stations are less than f3, then adding station express;

9) If the density of several stations nearby are more than f4, then adding shuttle bus or cutting empty bus;

………………………..

And so on.

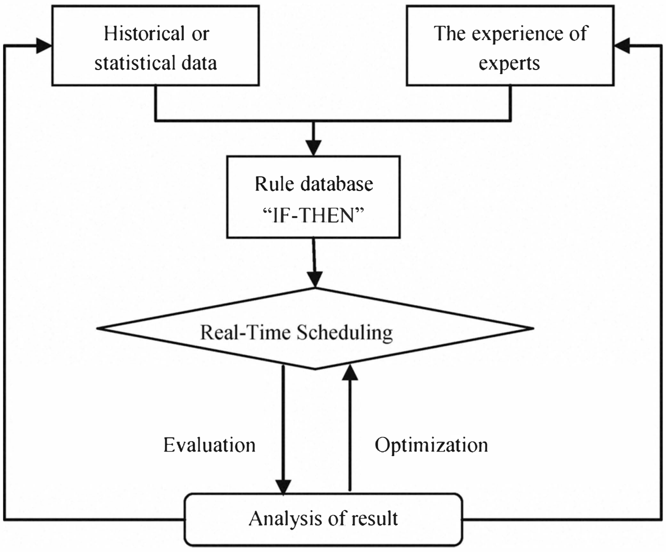

Figure 1. The schematic diagram of the real-time scheduling

On this basis, BRT's real-time scheduling scheme can be optimized by considering the video signal analysis from car camera, and the information of BRT vehicles by ITS.

Now, this BRT's real-time scheduling scheme is going to be applied to the Zhongshan Avenue BRT system in Guangzhou China.

IV. Conclusion

This article describes the situation of BRT: the definition, major elements, advantages, functions and its development. Then a new real-time scheduling scheme of BRT is provided which can be easily and flexibly achieved.

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