東海大学大学院令和元年度博士論文

Analyzing Mixed Traffic Flow and Evaluating the Introduction of BRT Systems by Simulating Traffic Flow

（多種モードを考慮した混合交通流の解析とそれらに基づく交通流シミュレーションを用いたBRT システム導入の評価に関する研究）

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CHAPTER I: INTRODUCTION

1.1. Background

Asia is the largest and most populous of earths continents and its located in both the northern and eastern hemispheres. Asia comprises a full 30% of the worlds land area with 60% of the worlds current population. It also has the highest growth rate today, and its population almost quadrupled during the 20th century. The estimated population for Asia in 2018 is over 4.5 billion (Fig 1.1). The population density in Asia is 148 per km^2 and 50.2 % of the population is urban (2,302,156,571 people in 2019).

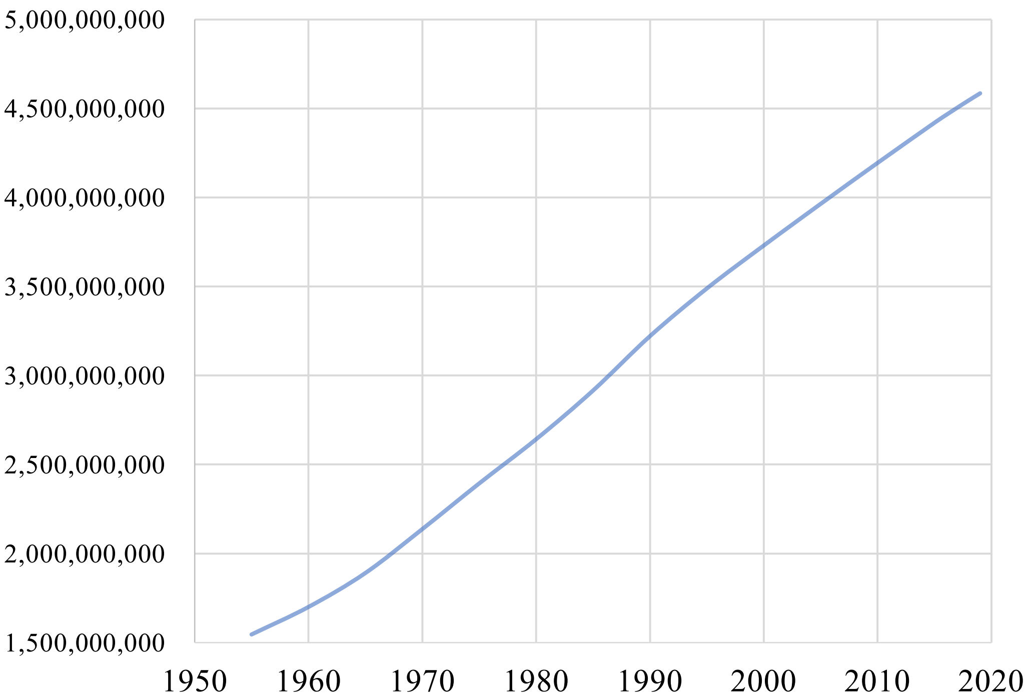

Figure 1.1: Asia population from 1955 to 2019

With rapid economic growth, the traffic environment is also changing quickly. The advance of motorization in many large cities in the developing countries of Asia is creating traffic congestion and air pollution that are growing more serious year-by-year. The problems are so bad that they are affecting economic and social functions, and the people face an urgent need to improve their urban transportation systems.

Hanoi - the capital city of the Socialist Republic of Viet Nam, is the countrys political, cultural, scientific and technological center, and plays an important role in the economy and international trade. After expanding administrative boundaries in 2008, Hanoi now covers an area of 3,358.9 square kilometers and has a population of over 7 million (Figure 1.2).

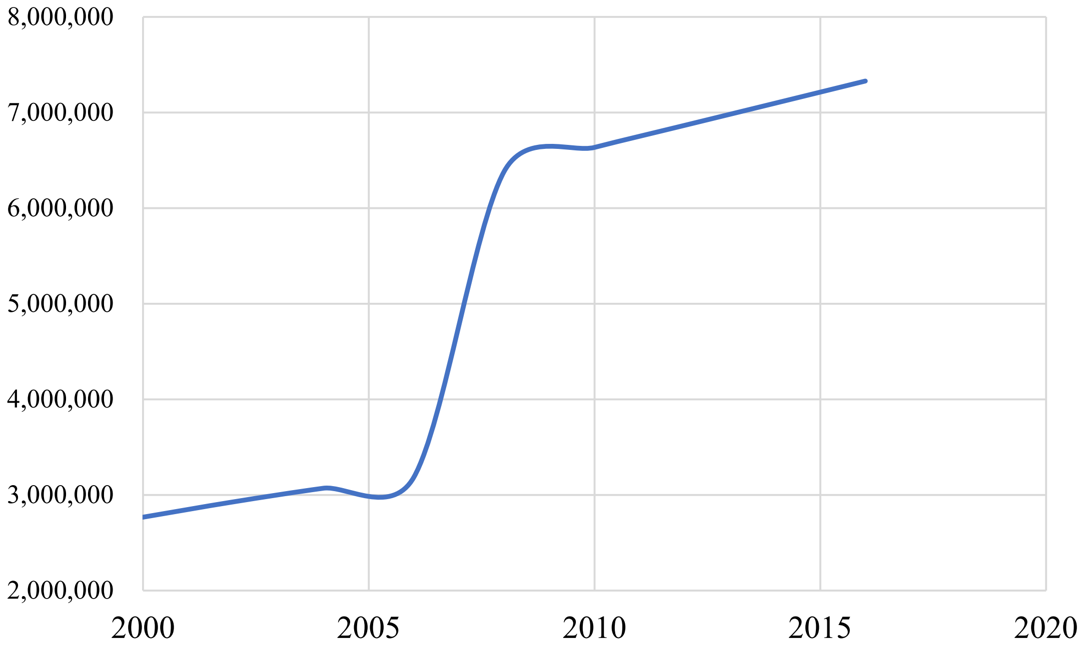

Figure 1.2: Hanoi population from 2000 to 2016

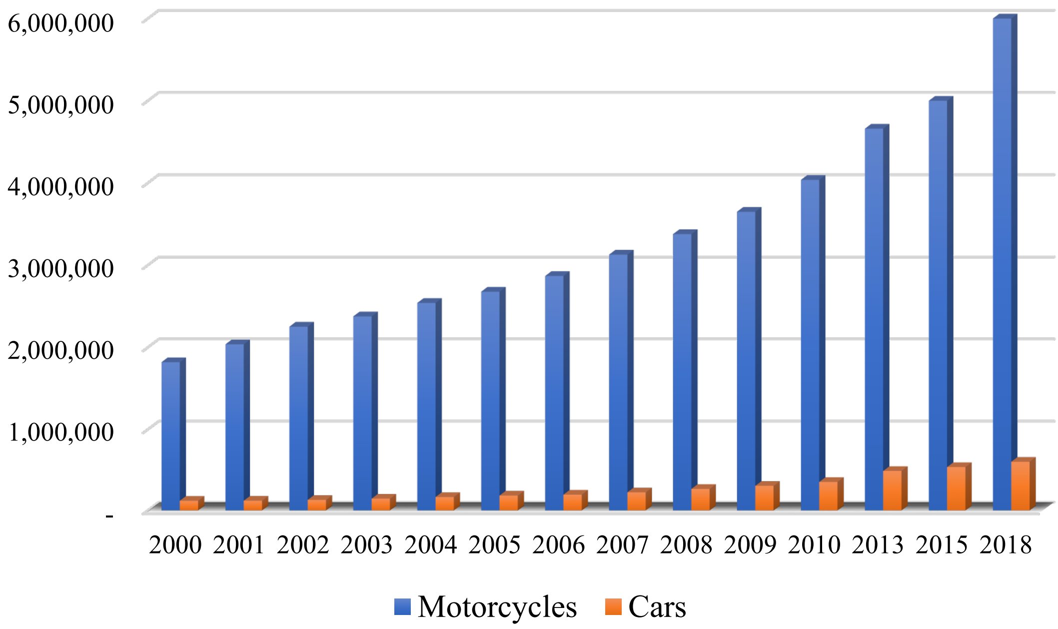

Figure 1.3: The increasing of motorcycles and cars in Hanoi

As in other developing cities, now Hanoi must deal with many problems such as disorderly urbanized city, traffic jam, population explosion, etc.… In recent years, Hanoi has undergone periods of rapid development and growth driven by restructuring of the economy in which transport is not exceptional. The number of vehicles has been increasing in accordance with travel demand, causing chaotic, mixed traffic in Hanoi that creates traffic congestion, accidents, air, and noise pollution looming large. The number of motorcycles has been increasing rapidly, from 1 million in the late 1990s to over 5.2 million today (Figure 1.3). Hanoi will have 6.1 million motorcycles by 2020, 7 million by 2025 and 7.5 million by 2030. Motorbikes are the most popular means of transport for locals. As the city's population soars, the number of private vehicles in operation has continued to rise rapidly. However, as the number of motorbikes has been increasing more rapidly, it has become one of the major reasons for traffic jams and pollution.

To solve this problem, Vietnam's Government decided the Bus Rapid Transit system is a solution. With low-cost investments in infrastructure, high capacity, friendly in the environment. Bus Rapid Transit is expected to be an effective transport solution to reduce construction for big urban areas in Vietnam nowadays. In 2030-2050 master plan and vision, Hanoi will have 8 Bus Rapid Transit routes.

1.2. Research purposes

Road traffic jams are a serious problem in Vietnam, especially in developing cities as Hanoi. Vietnam's Government decided the Bus Rapid Transit system is a solution to solve this problem. However, large cities in Asia have their own unique transport problems. And the Bus Rapid Transit system is not always successful. Although these initial experiences from Curitiba were highly successful, it was not replicated elsewhere as planners assumed that these systems were unique for conditions of Brazilian cities. And from experience in Asia developing cities, it shows that the Bus Rapid Transit system is not feasible due to a limitation in existing road space:

- Under the United Nations Development Programmes survey, the Trans -Jakarta system consumed fuel much more than the first estimation. Trans-Jakarta also lost passengers compared to the first term because of the over frequency, unsuitable time. In fact, the traffic of Trans-Jakarta shows that more than 2 holds buses which named Trans-Jakarta is effective especially in the rush hour because it has a private lane with a high barrier, other vehicles cant use that lane. In each head of a way or the tracks split still has a small way that other vehicle if doing on purpose, it tills can encroach.
- After a long time from construction to operation in 5/2010 till now, the number of people who use Bangkok BRT system nearly dont increase. In 6 years, the systems loss was 1.2 billion baht. It didnt get the target at first which is solving the traffic jam, t hen became big financial burden for the Government of Bangkok city.

Indonesia and Thailand are two countries in Southeast Asia like Vietnam with high traffic density and a high number of private transportations. These are two good examples of developing Bus Rapid Transit in developing countries and a lesson for Vietnam to develop Bus Rapid Transit. Bus Rapid Transit does not have a common standard that can be applied to every country or area. Two cities in a country do not mean Bus Rapid Transit in two cities will succeed. Therefore, if want to apply Bus Rapid Transit in a city, it is necessary to survey and analyze the traffic situation and social development in that city. This is also the main purpose of this study to improve the efficiency of seven Bus Rapid Transit routes to be built in Hanoi soon. The main purposes of this research are as follows:

- Summary of existing Bus Rapid Transit systems in Asia: history development, system overview, status and evaluating the effectiveness of these Bus Rapid Transit systems.
- Analyze status of traffic in Hanoi, Hanoi master planning to 2030 - a vision to 2050

and existing bus systems in Hanoi.

- Introduce the implementation of the first Bus Rapid Transit route in Hanoi. Analyze the changes in traffic status before and after operating Bus Rapid Transit.
- Quoting some issues should be considered for development Bus Rapid Transit in Hanoi through modeling the present condition by traffic simulation software.

1.3. Existing researches

Traffic congestion is a major problem in Vietnam. It greatly affects the economic growth and environment of big cities. Solving traffic problems is always a hot topic attracting many domestic and foreign researchers: *"Development of Motorcycle Unit (MCU) For Motorcycle-Dominated Traffic"*[1), *"Effect of adaptive cruise control systems on mixed traffic flow near an on-ramp"*[2), *"Modelling Mixed Traffic Flow at Signalized Intersection Using Social Force Model"*[3), *"Motorcycles in Developing Asian Cities: A Case Study of Hanoi"*[4), *"Simulation of Mixed Traffic Flow on Two-Lane Roads"*[5), *"The changes of group behavior in mixed traffic flow"*[6), *"A study on motorcycle-based motorization and traffic flow in Hanoi city: toward urban air quality management"*[7), *"Image processing analysis of motorcycle oriented mixed traffic flow in Vietnam"*[8)…

Motorcycles are the main reason for traffic congestion in developing countries. Therefore, these studies mainly focus on analyzing motorcycle-related issues and rarely mention other vehicle types. The major topics are often considered to be the impact of motorcycles on transport and the environment, methods to reduce the number of motorcycles in big cities, such as:

"The changes of group behavior in mixed traffic flow": This study analyses the change in motorcycle driver behaviors with the progress of urbanization and motorization, the observations are inside intersections between left-turn groups and straight-go groups. Firstly, it shows the changes of vehicle pattern inside intersection through the time and the effect factors to the vehicle patterns. Secondary, taking the conflict analyses for the mix traffic flow in consideration with the change of traffic volume, traffic components. Thirdly, showing the relations between conflict situation and the separation phenomenon. This study was conducted through analyzing the video data of traffic situation at same intersections in 2004, 2006, 2008, 2010.

"A study on motorcycle-based motorization and traffic flow in Hanoi city: toward urban air quality management": This paper presents the rapid motorcycle-based motorization due to the economic growth and its influence on the air in Hanoi. Firstly, discussing on the policies for mitigating air pollution by motorcycle source. Secondary, conducting an original household survey to discuss the effect of motorcycle taxation system as a penetration control measure on the motorcycle ownership. Thirdly, the effect of bus service improvement on modal shift from motorcycle to a bus is discussed by conducting an original questionnaire and person trip surveys. Fourthly, the effect of traffic signal system on the improvement of traffic flow is analyzed by conducting a field observation at signalized and unsignalized

intersection and comparing the characteristics of the traffic flow of both intersections.

"Image processing analysis of motorcycle oriented mixed traffic flow in Vietnam": This study assesses the traffic situation in Hochiminh city using image processing technique and traffic simulation. The original movie file was recorded on 2003/7/15, from 7:30 a.m. to 8:30 a.m. in Hochiminh city, Vietnam. This file is used to obtain the data for the simulation analyses through image processing technique. After modeling the present condition, several changes were made to comparing with initial model. However, in this study method of image processing method showed only motorcycles. And traffic composition in simulation includes only motorcycles, cars and buses.

And BRT is one of the solutions chosen to solve the traffic problem in big cities in developing countries. BRT has increasingly become an attractive urban transit alternative due to its cost-effective and flexible implementation. However, BRT is not always successful. Many researchers and organizations have always considered strategies to contribute to improving the effectiveness of BRT in developing countries, especially in Southeast Asia: *"The Issues and Realities of BRT Planning Initiatives in Developing Asian Cities"*[9], *"A Study on the Introduction of Bus Rapid Transit System in Asian developing cities, A Case Study on Bangkok Metropolitan Administration Project"*[10], *"Trans-Jakarta Bus Rapid Transit System Technical Review"*[11], *"Barriers to planning and implementing Bus Rapid Transit systems"*, *"Implementation of Bus Rapid Transit System in Nagpur City"*[12]…

"The Issues and Realities of BRT Planning Initiatives in Developing Asian Cities": This paper reviews the recent mass transit planning initiatives, especially BRT planning initiatives, in Asian cities and identifies the issues and realities of such initiatives in different regions of Asia. The countries were mentioned including China, India, Thailand, Malaysia, Bangladesh. The BRT systems in these countries were introduced and evaluating implementation, their effect on traffic situation.

"A Study on the Introduction of Bus Rapid Transit System in Asian developing cities, A Case Study on Bangkok Metropolitan Administration Project": This study introduces some strategies to support BRT implementation in Asian developing cities with case study on Bangkok, such as: providing good organizing feeder and parking facilities, decreasing number of local buses parallel/adjacent to BRT corridor, an advanced signal priority system, promoting BRT system to the public. These proposed strategies were evaluated by applying the demand forecasting model, the System for Traffic Demand Analysis (STRADA 3), and emission model, Japan Environmental Agency's model or JEA model.

“Trans-Jakarta Bus Rapid Transit System Technical Review”: This is a report was compiled by the Institute for Transportation and Development Policy (ITDP) - a global nonprofit at the forefront of innovation, providing technical expertise to accelerate the growth of sustainable transport and urban development around the world. The report is a summary of the technical issues surrounding the implementation of the Trans-Jakarta Bus Rapid Transit (BRT) System, opened in January 2004. It provided an independent source of information for the general public regarding the Trans-Jakarta BRT project and consolidated the expert advice provided by ITDP technical experts, such as: constructing a passing lane at each bus stop; having two adjacent bus stops at each bus stop location, rather than just one; consider procuring larger, articulated buses, and extend the existing stations to have two bus bays instead of just one.

As stated above, the BRT systems are not always successful and each country has different development and traffic conditions, especially in developing cites as Hanoi. If want to apply BRT in a city, it is necessary to survey and analyze the traffic situation and social development in that city. BRT is a new system for Vietnam in general and Hanoi in particular. It is simple to assess the effectiveness of a BRT system through observation such as: does it address or decrease traffic congestion or not? Do many passengers use it? Has the speed reached the design level? Although it has been evaluated as a failure there has not been any specific study on the impact of BRT into traffic, as well as the changes in traffic flow after operating BRT in Hanoi. Therefore, this research analyses the comparison traffic situation before and after operating BRT at two locations in three different time periods: morning, afternoon, evening. Two locations show two traffic organization types of BRT: exclusive lanes and mixed traffic. In this research, traffic composition was considered including bicycles, motorcycles, cars, buses and the changes in the number of taxis also was considered. The changes in traffic flow, density, the speed of each vehicle types will be presented.

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1.4. Research outline

This research is including 6 chapters:

Chapter I introduces the rapid population growth of Asia and Hanoi; problem definition, research purposes and scopes; existing research and outline of research.

Chapter II has two main topics:

- First, introduce worldwide history of Bus Rapid Transit development, especially focus on big cities in Asia. Status and evaluating the implementation of Bus Rapid Transit in those cities.
- Second, presenting about Hanoi BRT – the Bus Rapid Transit system was in planning since late 2004. Hanois 14.5km, 23 station BRT corridor finally opened a dozen years after the planning started, on 31 December 2016.

Chapter III introduces Hanoi focus on two topics master planning to 2030 - vision to 2050 and has two main topics:

- First, summary of Hanoi master planning to 2030 - vision to 2050
- Second, analyzing the surveys about the existing bus systems in Hanoi: history, success and problems are encountered.

Chapter IV analyses and compare traffic situation before and after operating BRT.

The videos of the actual traffic situation were recorded at the chosen locations in three different time periods (morning, afternoon, evening) before and after operating BRT. The video data will be extracted to frames, and from the analysis with each frame, the input data is collected. After having the input data, some functions are used to analysis comparison traffic situation in each location.

Chapter V is traffic simulation. Simulation software used in this chapter is Vissim 8.0. This chapters purpose is finding solutions to improve the effectiveness of existing Hanoi BRT system and in the future. The simulation technique is used to reproduce the existing traffic situation. Then, different plans are considered for analyses of changes in traffic flow. These plans include:

- Changes in traffic composition: Ban motorcycles, migration from motorcycles to private cars;

- Changes in management measures: Create exclusive lanes for each vehicle types, a route without signal.

Chapter VI is a synthesis of key points on the research, recommend solutions to solve the problems and new areas for future research.

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CHAPTER II: IMPLEMENTATION OF BUS RAPID TRANSIT SYSTEMS IN ASIA

2.1. Bus rapid transit system

2.1.1. Bus Rapid Transit definition

Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations.

Because BRT contains features like a light rail or metro system, it is much more reliable, convenient and faster than regular bus services. With the right features, BRT can avoid the causes of delay that typically slow regular bus services, like being stuck in traffic and queuing to pay on board.

There are three main reasons behind the increased interest in BRT systems:

- Higher Performance Services: A combination of high-frequency, high-capacity bus services, overpass lanes and station designs can lead BRTs to have a capacity of more than 40,000 Pax/hr/dir. This compares with Light Rail Transit (LRT) (15,000 Pax/hr/dir) or metro (80,000 Pax/hr/dir).
- Cheaper than alternative solutions: A BRT system entails a construction cost ranging from $1 to 12 million per kilometer. This is up to five times cheaper than LRT and 10 times cheaper than the metro. The cost varies with the specific characteristics of each system and the level of segregation and integration with other modes.
- Shorter Implementation Times: As with construction cost, the implementation time is driven by the complexity of the system, but in general a BRT project can be delivered in less than half the time of any of the alternative solutions (metro or LRT) (Table 2.1).

Table 2.1: Technical parameters of public transport options

	Metro	**LRT**	**Tramways**	**HCBRT**	**BRT**	**Bus Priority Lanes**	**City Bus**
Line Capacity (Pax/hr/dir)	40,000 - 75,000	15,000-45,000	5,000-15,000	20,000-35,000	7,500-15,000	5,000-7,500	Below 1,000
Cost per km (Infrastructure, vehicles, OCC, Maintenance	Very high	High	Medium/High	Medium/High	Medium	Low	Very Low, only bus stops and maintenance shop required
Alignment	Double-track railway	Double-track railway, elevated, a-grade or in tunnels	Double-track railway, at-grade	4 Bus Lanes (2 per direction)	2 to 3 Bus Lanes	2 Bus Lanes	Use public road
Segregation	100% segregated in tunnels, elevated or at-grade	High degree of segregation preferred, but sections with shared right of way possible	Uses public road, but may have reserved right of way on sections with higher demand	All Bus Lanes must be segregated to achieve high capacity	Bus lanes must be in general segregated, exceptions possible, reduce capacity and speed	Bus Priority Lanes must be exclusively for busses	None
Road space required	None	None in case of elevated and tunnel alignment, 2 lanes at-grade, additional space required for stations and terminals	2 Lanes, additional space may be required for stations and terminals, tracks can be shared with public roads or pedestrian roads	4 Lanes; more linear space for Interchanges and Terminals	2 Lanes, possibly 3 or 4 at Stations and Interchanges, space for major Interchanges and Terminals	2 to 3 Lanes (3 to 4 Lanes at Bus Stops)	Share with cars and pedestrian
Vehicles	High capacity EMU	Medium to high capacity EMUs (upgraded trams as an option)	Trams, articulated and or with wagons as an option	Special articulated bus with at-floor boarding and wide doors	Articulated buses; pre-paid boarding required	Standard City Bus, articulated as option	Standard City Bus
Passenger per Vehicle/Train	1,200-2,500	250-1,500	Depends on length	180-240	150-180	75-100	75
Traction	Electric	Electric	Electric	Diesel	Diesel (Electric as an option)	Diesel	Diesel
Feeder System	Necessary	Necessary	Not necessary	Necessary	Desired	Not necessary	Not necessary
Flexibility of route changes	Very low	Low	Low	Very low	Medium	Medium	Very high

2.1.2. History of Bus Rapid Transit

BRT's history resides in a variety of previous efforts to improve the transit experience for the customer. The first BRT system was in Curitiba, Brazil, which entered service in 1974. However, there were several smaller-scale efforts prior to Curitiba that helped to establish the idea.

Figure 2.1: Elevated Section of Runcorn Busway

(Source: http://transport-illustrated.blogspot.com/)

The origins of the BRT concept can be traced back to 1937 when the city of Chicago outlined plans for three inner city rail lines to be converted to express bus corridors. Likewise, BRT plans were developed for several other cities in the United States, including Washington, DC (1955-1959), St. Louis (1959), and Milwaukee (1970). Actual construction of a dedicated busway first occurred in 1971 in Runcorn

(England). Ground-breaking in its time, the Runcorn Busway was a very clever idea; a completely segregated bus system running on its own dedicated roads circulating 22km around a dense urban district with an elevated section into a shopping area at its intersection (Fig 2.1&2.2).

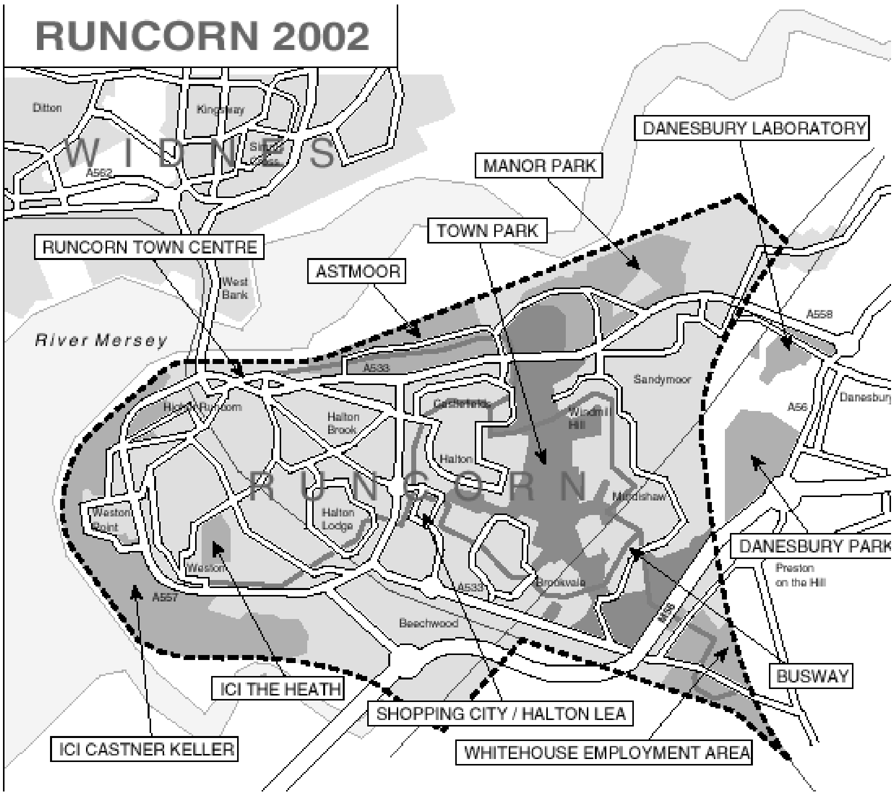

Figure 2.2: Runcorn Busway Location Plan

(Source: https://www.parliament.uk/)

BRT's full system was not realized, though, until the arrival of the "surface subway" system developed in Curitiba (Brazil) in 1974 (Fig 2.3). Ironically, the city initially aspired to construct a rail-based metro system. However, a lack of enough funding necessitated a more creative approach. Thus, under the leadership of Mayor Jaime Lerner, the city began a process of developing busway corridors emanating from the city center. The BRT system now has five radial corridors emanating from the city core. The system features 57 kilometers of exclusive busways and 340 kilometers of feeder services. The system annually attracts hundreds of city officials from other municipalities, all seeking to study the organizational and design features that have shaped Curitiba's success.

Figure 2.3: Tube-like station and BRT buses in Curitiba

(Source: http://81.47.175.201/livingrail/index.php)

Despite Curitiba's success and relative fame within the transport planning profession, the overall replication of the BRT concept was somewhat slow to gain momentum elsewhere. It was only in the late 1990s that BRT's profile became more widely known. To date, more than 170 cities have implemented some form of BRT system worldwide, carrying around 33 million passengers each weekday. At present, BRT systems worldwide comprised 280 corridors, 5,057 km of routes, 6,700 stations, and 30,000 buses. There is no precise definition of what constitutes a BRT system and what represents simply an improved transit system. Table 2.2 lists the cities with bus transit systems that possess some of the qualities of BRT.

Table 2.2: High quality bus system around the world

Region	Country	Number of Cities	Length (km)	First corridor commenced
Africa	Nigeria	1	22	2008
	South Africa	3	88	2009
	Tanzania	1	21	2016
Asia	China	20	672	1999
	India	7	174	2009
	Indonesia	1	207	2004
	Iran	3	165	2008
	Israel	1	40	2013
	Japan	2	29	2001
	Malaysia	1	5	2015
	Pakistan	2	50	2013
	Korea	1	115	
	Taiwan	3	107	1998
	Thailand	1	15	2010
	Vietnam	1	15	2016
Europe	Belgium	1	6	
	Finland	1	28	2003
	France	21	342	1975
	Germany	2	31	1980
	Netherlands	5	161	2000
	Spain	2	15	2009
	Sweden	3	96	1996
	Switzerland	1	11	2007
	Turkey	1	52	2007
	United Kingdom	7	135	1971
Latin America	Argentina	3	76	2011
	Brazil	21	765	1975
	Chile	2	105	2005
	Colombia	7	225	2000
	Ecuador	2	117	1995
	El Salvador	1	6	2015
	Guatemala	1	24	2007
	Mexico	11	394	2003
	Panama	1	5	2011
	Peru	1	26	1972
	Trinidad and Tobago	1	25	2011
	Uruguay	1	6	2012
	Venezuela	3	42	2007
Northern America	Canada	6	190	2005
	United States	13	353	1977
Oceania	Australia	3	90	1986
	New Zealand	1	6	2008
Total		**170**	**5,057**	

Figure 2.4: The distribution of Bus Rapid Transit in Asia

(Source: https://brtdata.org/)

BRT systems are not a recent development. It all started in the 1970s in several Brazilian cities – especially Curitiba which developed the first role model for BRT systems. Although these initial experiences were highly successful, it was not replicated elsewhere as planners assumed that these systems were unique for conditions of Brazilian cities. In Asia, prior to 2000, the experience of BRTs was very limited in number and scope. The Taipei (Taiwan) and Nagoya (Japan) systems perhaps stand out as the more complete systems in the Asian region, although not quite reaching the level of full BRT systems. However, twenty years later BRT gained momentum with planners in Bogota successfully replicating the system with several innovations. Bogota's success was contagious, and in 2000 the Trans-Jakarta (Indonesia) and Seoul (Korea) BRT systems started operating, thus leading Asian cities in transforming their public transport systems. Since then, BRT systems rapidly advanced. Currently, there are over

95 BRT systems in development in Asia.

Table 2.3: BRT systems in Asia

Country	Region	Income group	Number of Corridors	Length (km)	First corridor Commenced
India	South Asia	Lower middle income	9	174	2009
Indonesia	East Asia & Pacific	Lower middle income	12	207	2004
Pakistan	South Asia	Lower middle income	3	50	2013
Vietnam	East Asia & Pacific	Lower middle income	1	15	2016
China	East Asia & Pacific	Upper middle income	38	672	1999
Iran	Middle East	Upper middle income	10	165	2008
Malaysia	East Asia & Pacific	Upper middle income	1	5	2015
Thailand	East Asia & Pacific	Upper middle income	1	15	2010
Israel	Middle East	High income	3	40	2013
Japan	East Asia & Pacific	High income	2	29	2001
Korea	East Asia & Pacific	High income	12	115	
Taiwan	East Asia & Pacific	High income	3	107	1998
Total			**95**	**1,594**	

2.2. Implementation of Bus Rapid Transit systems in Asia

Economies are currently divided into four income groupings: low, lower-middle, upper-middle, and high. Income is measured using gross national income (GNI) per capita, in U.S. dollars, converted from local currency using the World Bank Atlas method. Estimates of GNI are obtained from economists in World Bank country units; and the size of the population is estimated by World Bank demographers from a variety of sources, including the UN's biennial World Population Prospects.

Table 2.4: The current classification by income

Country	Region	Income group
India	South Asia	Lower middle income
Indonesia	East Asia & Pacific	Lower middle income
Pakistan	South Asia	Lower middle income
Vietnam	East Asia & Pacific	Lower middle income
China	East Asia & Pacific	Upper middle income
Iran	Middle East	Upper middle income
Malaysia	East Asia & Pacific	Upper middle income
Thailand	East Asia & Pacific	Upper middle income
Israel	Middle East	High income
Japan	East Asia & Pacific	High income
Korea	East Asia & Pacific	High income
Taiwan	East Asia & Pacific	High income

2.2.1. Bus Rapid Transit in upper middle-income and high-income countries

1) Bus Rapid Transit in high-income countries

a) Japan

Nagoya – Yutorito Line

In order to increase the modal share of public transport and reduce traffic congestion, the Municipal Government of Nagoya developed a BRT system beginning in the early 1970s. They developed trunk bus systems, including "Guideway" buses, "Key Route" buses, and "Trunk" buses, along the major roads mot served by metro. The most well-developed BRT systems are "Guideway" bus (opened in 2001) and "Key Route" buses (opened in 1982 and 1985). Also, other general buses provide feeder services connecting these main routes. The total length of the existing 29 bus lanes is 90 km, most of which become exclusive buses lanes during peak hours, although they serve as mixed traffic lanes at other times.

Table 2.5: Summary of the first and most well-known BRT system in Japan

Summary of the System	
Segregated busways on trunk roads	Guideway Bus: exclusive guideways 6.8 km; busways on the roads 5.1 km Key Route Bus Line 1: 6.75 km Key Route Bus Line 2: 9.2 km
Headway	Guideway Bus: 3 - 5 minutes (peak period) Key Route Bus Line 1: 3 - 5 minutes (peak period) Key Route Bus Line 2: 1 - 2 minutes (peak period)
Number of Buses	Guideway Bus: 25 Key Route Bus Line 1: 29 Key Route Bus Line 2: 52
Bus vehicle capacity per unit	Guideway Bus: 64 passengers Key Route Bus Line 1: 77 passengers Key Route Bus Line 2: 73 passengers
Infrastructure cost	Guideway Bus: US$ 26 million/km Key Route Bus Line 1: US$ 0.6 million/km Key Route Bus Line 2: US$ 2.3 million/km

Kesennuma Line/ Ofunato Line

Bus Rapid Transit provides service as a temporary transport restoration project in areas heavily damaged by tsunami resulting from the Great East Japan Earthquake on 11 March 2011. Kesennuma and Ofunato lines are in Miyagi and Iwate Prefectures, in the Tohoku-region of Japan. Kesennuma Line is 55.3km in length and damaged from Yanaizu station to Kesennuma station. Temporary resumption of Kesennuma Line by BRT was realized on Dec. 2012, and Ofunato line on Mar. 2013.

Table 2.6: Overview of Bus Rapid Systems in Japan

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Kesennuma - Ofunato	Kesennuma Line	55.30	2012
2		Ofunato Line	43.70	2013
3	Nagoya	Yutorito Line	6.80	2001
Total			**105.80**	

b) Korea

Table 2.7: Overview of Bus Rapid Systems in Korea

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Seoul	Dobong Mia-ro	15.80	2004
2		Susaek Seongsan-ro	6.80	2004
3		Cheonho-daero	12.70	
4		Siheung Hangang-ro	17.70	
5		Mangu Wangsan-ro	10.40	
6		Gangnam-daero	5.90	2004
7		Songpa Jayang-ro	5.60	2007
8		Gyeongin Mapo-ro	12.10	
9		Yanghwa Sinchon-ro	5.20	
10		Dongjak Sinbanpo-ro	6.20	
11		Gonghang-ro	5.80	
12		Tongil Uiju-ro	11.10	
Total			**115.30**	

c) Taiwan

Table 2.8: Overview of Bus Rapid Systems in Taiwan

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Chiayi	Chiayi BRT	29.65	2008
2	Taichung	Blue Line	17.20	2014
Total			**46.85**	

d) Israel

Table 2.9: Overview of Bus Rapid Systems in Israel

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Haifa	Red Line	25.00	2013
2		Blue Line	18.00	2013
3		Green Line	16.00	2013
Total			**59.00**	

2) Bus Rapid Transit in upper middle-income countries

a) China

Table 2.10: Overview of Bus Rapid Systems in China

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Beijing	Beijing BRT Line 1	16.00	2004
2		Beijing BRT Line 2	15.00	2008
3		Beijing BRT Line 3	23.00	2008
4		Beijing BRT Line 4	25.00	2012
5	Changde	Changde BRT	18.90	2012
6	Changzhou	Changzhou BRT Line 1	29.60	2008
7		Changzhou BRT Line 2	20.30	2009
8	Chengdu	Chengdu BRT	28.80	2013
9	Chongqing	Chongqing BRT	11.50	2008
10	Dalian	Dalian BRT	13.70	2008
11	Guangzhou	Guangzhou BRT	22.90	2010
12	Hangzhou	Hangzhou BRT Line 1	27.10	2006
13		Hangzhou BRT Line 2	19.00	2008
14		Hangzhou BRT Line 3	9.30	2010
15	Hefei	Hefei BRT	7.70	2010
16	Jinan	Jinan BRT Line 1	8.40	2008
17		Jinan BRT Line 2	7.83	2008
18		Jinan BRT Line 3	7.63	2009
19		Jinan BRT Line 4	9.06	2009
20		Jinan BRT Line 6	13.54	2009
21		Jinan BRT Line 7	14.00	2014
22	Kunming	Kunming BRT	46.70	1999
23	Lanzhou	Lanzhou BRT	9.10	2013
24	Lianyungand	Lianyungand BRT	34.00	2012
25	Urumqi	Urumqi Line 1	14.87	2011
26		Urumqi Line 2	5.18	2011
27		Urumqi Line 3	17.15	2011
28		Urumqi Line 4	12.79	2015
29		Urumqi Line 6	19.17	2015
30		Urumqi Line 7	10.93	2014
31	Xiamen	Xiamen BRT Line 1	28.20	2008
32		Xiamen BRT Line 2	10.00	2010
33		Xiamen BRT Line 3	10.70	
34	Yancheng	Yancheng BRT	16.00	2010
35	Yichang	Yichang	13.00	2015
36	Yinchuan	Yichuan BRT	17.00	2012
37	Zaozhuang	Zaozhuang	33.00	2010
38	Zhengzhou	Zhengzhou	30.50	2009
Total			**676.55**	

b) Iran

Table 2.11: Overview of Bus Rapid Systems in Iran

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Isfahan	Isfahan BRT	17.00	2015
2	Tabriz	Tabriz BRT	18.00	2009
3	Tehran	Tehran BRT Line 1	18.70	2008
4		Tehran BRT Line 2	18.70	2009
5		Tehran BRT Line 3	14.30	2009
6		Tehran BRT Line 4	21.50	2011
7		Tehran BRT Line 5	22.00	2013
8		Tehran BRT Line 7	18.50	2011
9		Tehran BRT Line 8	6.20	2013
10		Tehran BRT Line 10	10.00	2011
Total			**165**	

c) Malaysia

Table 2.12: Overview of Bus Rapid Systems in Malaysia

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Petaling Jaya	BRT Sunway Line	5.40	2015

d) Thailand

Table 2.13: Overview of Bus Rapid Systems in Thailand

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Bangkok	Bangkok BRT	16.50	2010

2.2.2. Bus Rapid Transit in lower middle-income countries

a) India

Table 2.14: Overview of Bus Rapid Systems in India

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Ahmedabad	Ahmedabad BRTS	82.00	2009
2	Bhopal	Bhopal BRTS	24.00	2013
3	Indore	Indore BRTS	11.45	2013
4	Jaipur	Jaipur BRTS	7.10	2010
5	Pune-Primpi-Chinchwad	Sangvi Phata Kiwale Corridor	14.00	2015
6		Nashik Phata Wakad Corridor	8.00	2015
7		Sangamwadi Vishrantwadi	7.20	2015
8	Rajkot	Rajkot BRTS	10.70	2012
9	Surat	Udhna Darwaza to Sachin GIDC	10.20	2014
Total			**174.65**	

b) Pakistan

Table 2.15: Overview of Bus Rapid Systems in Pakistan

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Islamabad-Rawalpindi	Rawalpindi-Islamabad Metrobus	22.50	2015
2	Lahore	Lahore Metrobus	27.00	2013
Total			**49.50**	

c) Indonesia

Table 2.16: Overview of Bus Rapid Systems in Indonesia

Number	City	Corridor name	Length (km)	Year corridor commenced
1	Jakarta	Koridor 1	12.90	2004
2		Koridor 2	14.00	2006
3		Koridor 3	19.00	2006
4		Koridor 4	11.85	2007
5		Koridor 5	13.50	2007
6		Koridor 6	13.30	2007
7		Koridor 7	12.80	2007
8		Koridor 8	26.00	2009
9		Koridor 9	28.80	2011
10		Koridor 10	19.40	2011
11		Koridor 11	11.40	2012
12		Koridor 12	23.80	2013
Total			**206.75**	

2.3. The first Bus Rapid Transit system in Hanoi

2.3.1. Project description

The Hanoi Peoples Committee (HPC) proposes to seek a Credit from the International Development Association/World Bank (IDA/WB) to finance a program of measures aimed at improving transport in the City of Hanoi. The program, termed the Hanoi Urban Transport Development Project (HUTDP), is under development but could include, inter alia, investment in roads, busways and other bus priority and physical measures to assist bus operations together with bus reorganization, technical assistance studies and training to support the investment components. Hanoi Urban Transport Development Project which has been approved by the Hanoi Peoples Committee at Decision 1837/QĐ-UBND dated May 10, 2007. This World Bank funded ODA project is an important step in improving the citys urban transportation network and strengthening public transport capacity. The project has three components as summarized in Table 1. A brief description of the project components follows:

- The **Bus Rapid Transit Component (BRT)** [total US$99.88 million, IDA US$84.12 million, Government of Vietnam US$11.76 million, Global Environment Facility (GEF) US$4.0 million] will support the development of 37 km of segregated bus lanes and 9 km of bus priority along the Giang Vo- Lang Ha and Giai Phong - Dai Co Viet corridors (including a city center connection, with bus priority in mixed traffic), the construction of BRT stops, interchange stations, terminals and maintenance facilities, and the acquisition of 130 BRT vehicles. It will also support the establishment of a modern BRT management system, including bus ticketing and financial controls. Lastly, the component will finance the implementation of public consultation, communications and media strategy for disseminating information on the BRT system.

- The **Road Infrastructure and Sustainable Urban Planning** component [total US$194.33, IDA US$64.65 million, Government of Vietnam US$127.92 million, GEF US$1.75 million] includes the construction of a section of the Second Ring Road (RR2) between Nhat Tan Bridge and Cau Giay on the main western radial arterial and construction of a resettlement site to house persons displaced by the proposed road, together with support for sustainable urban land development and transportation planning in Hanoi.
- The **Institutional Development** component (ID) [total US$10.49 million, IDA US$6.44 million, Government of Vietnam US$0.32 million, GEF US$4.05 million] includes equipment procurement and technical assistance (TA) to (a) strengthen Air Quality Management; (b) support traffic safety; (c) support establishment and strengthening of a new Public Transport Authority and support transport planning and policy development; (d) finance replication activities that have been designed to address GEF's priority on replication; and (e) support project management for the GEF project and enhancement of project monitoring skills.

Table 2.17: Project Cost by Component

Component	Financed by GOV US$m	IDA US$m	GEF US$m	Total US$m
1. Development of the BRT System				
A. BRT System, civil works and equipment	11.76	84.12	1.40	97.28
B. Pedestrian and NMT access at BRT stations	0.00	0.00	1.30	1.30
C. BRT Consultation, Communications and Media Strategy	0.00	0.00	1.30	1.30
2. Road Infrastructure and Sustainable Urban Planning				
A. Second Ring Road between Cau Giay and Nhat Tan	124.28	46.47	0.00	170.75
B. Resettlement site CT1	3.64	18.18	0.00	21.83
C. Integrated Sustainable Urban Land Development & transport Planning	0.00	0.00	1.75	1.75
3. Institutional Development				
A. Air Quality Management	0.00	1.65	0.00	1.65
B. Traffic Safety	0.00	1.92	0.00	1.92
C. Public Transport Authority Strengthening & policy development	0.00	2.20	2.70	4.90
D. National and Regional Replication	0.00	0.00	0.90	0.90
E. Project Management and results management support	0.00	0.67	0.45	1.12
Total Cost (including taxes)	139.68	155.21	9.80	304.70

2.3.2. Modification of Bus Rapid Transit Component

There are three main modifications made to reflect the overlapping scope of other transport projects:

- First, an urban rail project is currently under construction along the same alignment as the original BRT plan (Khuat Duy Tien - Nguyen Trai - Ba La), resulting in competing for public transport modes rather than complimentary services. This component is therefore adjusted to realign the western section of the BRT corridor (along with Le Van Luong extension road - Le Trong Tan) in order to maximize the design capacity of the public transport systems. The route would also be extended to Yen Nghia Bus station as a new corridor.

- Second, In the original plan, there were to be 2 BRT lines in Hanoi, one line from Kim Ma to Yen Nghia and another line from Quang Lai to Van Dien to Bo Ho according to Decision No. 1837/QD-UBND dated May 10, 2007. However, because it took such a long time to implement the first line from Kim Ma to Yen Nghia, the World Bank decided to stop the second BRT line, and this was made official in Decision No. 1821/QD-UBND dated February 22, 2013.
- Third, the planned depot at Vinh Quynh will be relocated, with a new depot at Yen Nghia. The permanent depot will be financed by counterpart funds after site plans at Yen Nghia are finalized. In the meantime, a temporary depot will be set up at the existing Yen Nghia site for initial stages of the BRT operation. In addition, a BRT terminal will also be set up at the Yen Nghia site.

BRT realignment Project - section:(Figure 2.5) From Khuat Duy Tien - Nguyen Trai To Khuat Duy Tien and Le Van Luong interchange – Le Trong Tan (Ha Dong) – Yen Nghia Terminal - BRT component – Hanoi Urban Transport Development Project.

The BRT line from Kim Ma to Yen Nghia was selected based on detailed studies conducted by the French consultancy Egis. The 14.7 km BRT route goes from Kim Ma station in the central area of Hanoi and goes southwest along Giang Vo, Lang Ha, Le Van Luong, Le Van Luong keo dai, Le Trong Tan, Quang Trung to Yen Nghia station. The BRT realignment from Khuat Duy Tien - Nguyen Trai To Khuat Duy Tien and Le Van Luong interchange – Le Trong Tan (Ha Dong) – Yen Nghia Terminal have been designed in order to reduce conflicts of transport models and encroachments on the Khuat Duy Tien - Nguyen Trai intersection, which is suffered from heavy traffic congestion. The realignment project also aims to reduce the traffic volume on Nguyen

Trai Street (National highway 6). Besides, Le Van Luong extension has been constructed, therefore, the surface of street meets the technical requirement of BRT route, it is main that realignment project will have resulted in a reduction of the construction cost.

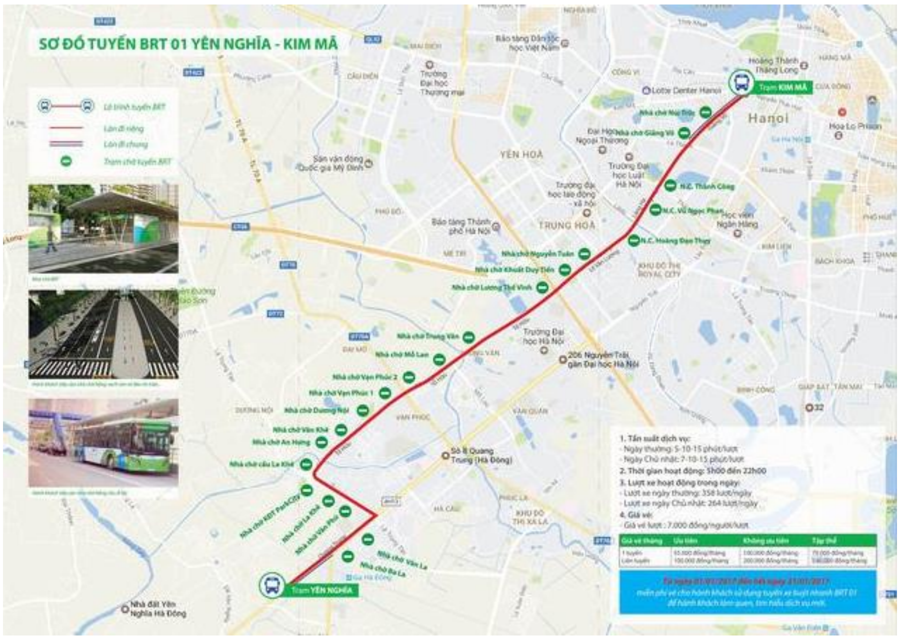

Figure 2.5: Realignment of the project

(Source: https://lotrinh.vn/)

2.3.3. Operation status

Finally, the BRT corridor opened a dozen years after the planning started, on 31st December 2016. This BRT route provides a critical connection from the central Hanoi to the southwest of the city with a total length of 14.7 kilometers and 23 stations including two terminals (Figure 2.6).

Figure 2.6: The first Bus Rapid Transit route in Hanoi
(Source: http://www.baogiaothong.vn/)

Table 2.18: Overview of the first Bus Rapid Transit system in Hanoi

Infrastructure	Number of corridors	1
	Number of BRT terminals	2
	Number of BRT stations	23
	Location of busway lanes	Centre of roadway
	Total length	14.7 km
	Station platform height	75 cm
	Average distance between stations	640 m
Vehicle	Bus type	Conventional bus
	Length	18 m
	Width	2.5 m
	Height	2.94 m
	Road clearance	40 – 60 cm
	Seats	40 – 70
	Designed capacity	90 passengers
	Loading door	1
	Alighting door	2
	Type of door	Double folding door
	Engines	Diesel – EURO II
Performance	Peak load (passengers/hour/direction)	520
	Peak frequency (buses/ hour/direction)	14
	Operating speed	19.6 km/h
	Daily demand (passengers/day)	8,000

Stations, Depot and Terminals

In addition to the two end terminals, there are 21 stations along the route with a distance between them varying between 500 and 700 meters (Table 2.19). BRT stations are closed with ticketing at the entrance. This provides fast and convenient boarding and relieves the driver from other tasks than driving. Convenient space for passengers waiting time has been designed. Since station platforms will have the same height as the bus floor, boarding will be fast and comfortable even for disabled persons (Figure 2.7, 2.8).

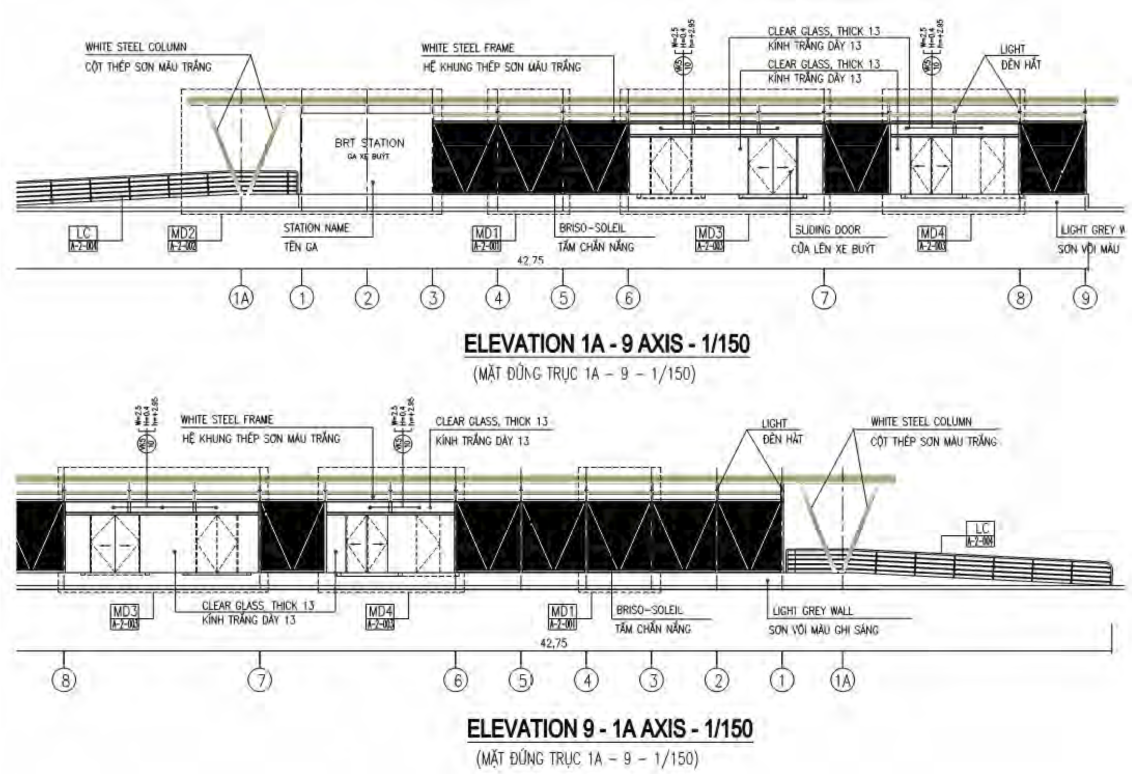

Figure 2.7: Cross-Section of BRT stop

(Source: http://sogtvt.hanoi.gov.vn/)

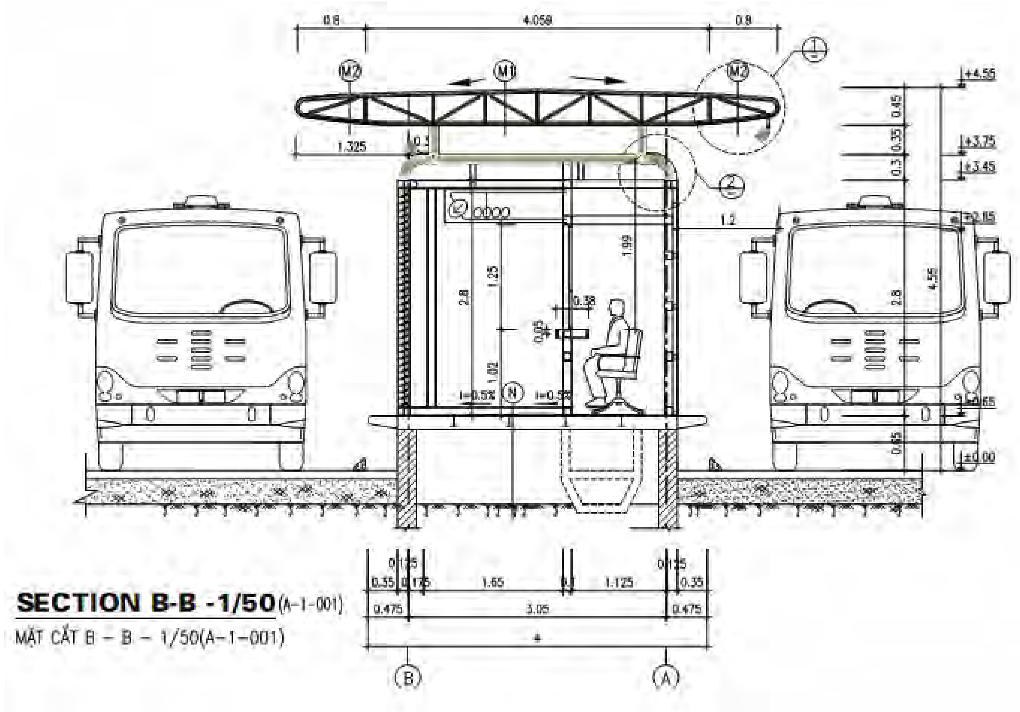

Figure 2.8: Cross-Section of BRT stop

(Source: http://sogtvt.hanoi.gov.vn/)

To a large extent, the dedicated BRT right-of-way and the stations have been modeled on successful BRT systems, notably the Transmilenio system in Bogota, Colombia.

A depot was constructed at Yen Nghia which serve as the service and maintenance center. It is provided with the necessary equipment for daily service and preventive maintenance as well as repairs. Fuel, lubrication, tires and a spare parts supply are provided there as well as washing facilities. The status of this facility (July 2013) is that a project has been defined (package BRT-CP4f) and the contract award is scheduled for March 2014 with an investment of slightly over one million USD.

Yen Nghia is also currently a major coach station and many passengers coming from Province might find very convenient to transfer with short walking distance to the

BRT line. Space for night parking for a small number of BRT buses are provided at Kim Ma end station.

Table 2.19: Bus stop location

No of Station	Station Name	Location
End Terminal	Kim Ma	Km13+960
S21	Nui Truc	Km13+220
S20	Trien Lam Giang Vo	Km12+410
S19	Thanh Cong	Km11+940
Addition	Indira Gandhi Park	Km11+610
S18	Vu Ngoc Phan	Km11
S17	Hoang Dao Thuy	Km9+800
S16	Nguyen Tuan	Km9+200
S15	Khuat Duy Tien	Km8+480
S14	Luong The Vinh	Km8+573
S13	Trung Van	Km7+757
S12	Song Nhue	Km7+300
S11	Cong Ty GTC	Km6+747
S10	Van Phuc	Km6+147
S9	Nghia Trang Van Phuc	Km5+693
Addition	Khu Do Thi Van Khe	Km5+257
S8	Khu Do Thi Duong Noi	Km5+29.05
S7	Tap Doan Nam Cuong	Km4+557.25
S6	Cau La Khe	Km4+57.25
S5	Khu Do Thi Park City	Km3+700
S4	Chua La Khe	Km3+192.75
S3	Khu Do Thi Van Phu	Km2+452.25
S2	Cho Van La	Km2
S1	Ba La	Km1+557.25
Start Terminal	Yen Nghia	Km0

BRT Buses:

The route will be operated by air-conditioned BRT buses, tentatively with a capacity of 90 passengers of which 38 are seated (including 5 seats for special need) (Figure 2.9). The buses are equipped with 630 - 650 mm floor height (depending on manufacturer). This will correspond with the design of the elevated station platforms and provide comfortable boarding for all categories of passengers. Doors for the BRT section are on the left side, but there are also extra doors and steps on the right side to make possible – if necessary and rational to extend the BRT line on regular routes.

Figure 2.9: Bus Technology

(Source: http://hanoi.vietnamplus.vn/)

With assumptions regarding commercial speed and desired frequency of service, the "base traffic" would be provided with some 27 buses (Figure 2.10) while peak hour service in the morning and afternoon would require 45 buses (Figure 2.11).

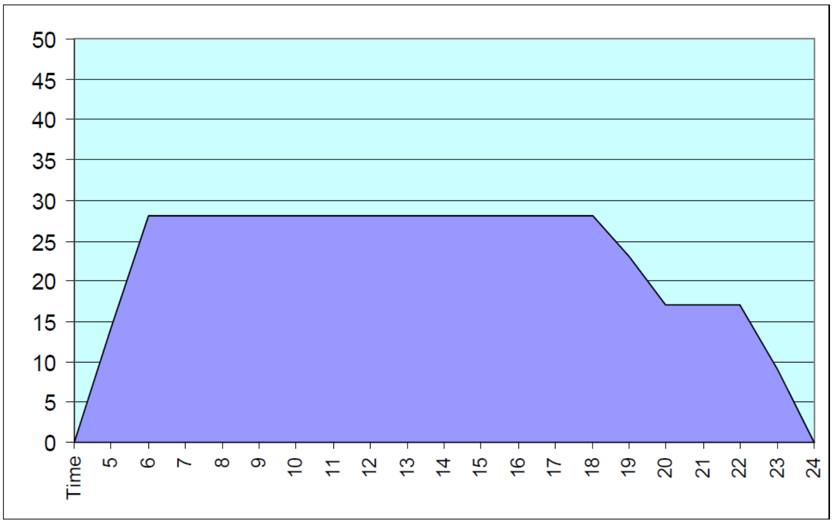

Figure 2.10: BRT buses frequency in weekend

(Source: http://sogtvt.hanoi.gov.vn/)

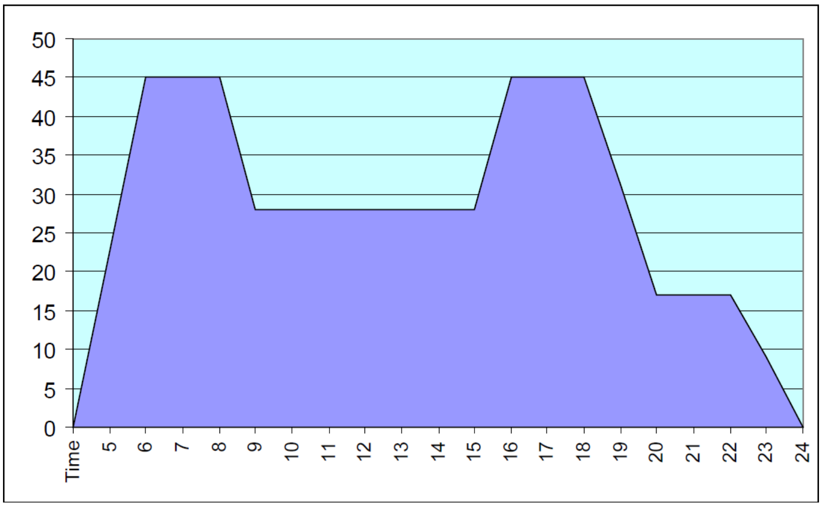

Figure 2.11: BRT buses frequency in weekday

(Source: http://sogtvt.hanoi.gov.vn/)

Fare collection:(Figure 2.12)

At the start of the BRT operation, there will be a combination of two systems. At the BRT stations, tickets for the BRT itself will be provided at the entrance and these could be in the form of smart card technology. Since it is important, however, to maintain integration between regular bus and BRT, transfer possibilities must be ensured. Since BRT is the newcomer and since BRT is in many ways a pilot project, it seems likely that such a smart card technology will not be introduced in the regular bus system. Thus, there would be a dual ticketing system with a combination of high technology in the BRT itself and with the actual manual technology in the rest of the system.

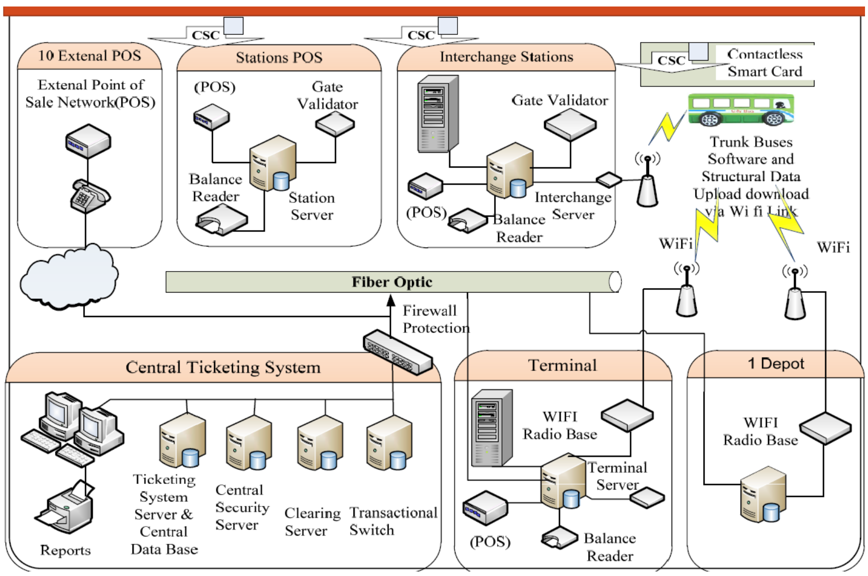

Figure 2.12: Ticketing system

(Source: http://sogtvt.hanoi.gov.vn/)

If a more advanced technology is introduced inside the BRT itself, then there are different options regarding who will handle it and care for its maintenance. Basically, there seem to be two options:

- The contractor that handles the BRT stations also handles the ticketing equipment and its maintenance;
- The supplier of the ticketing equipment undertakes the responsibility for the maintenance.

Information systems: (Figure 2.13)

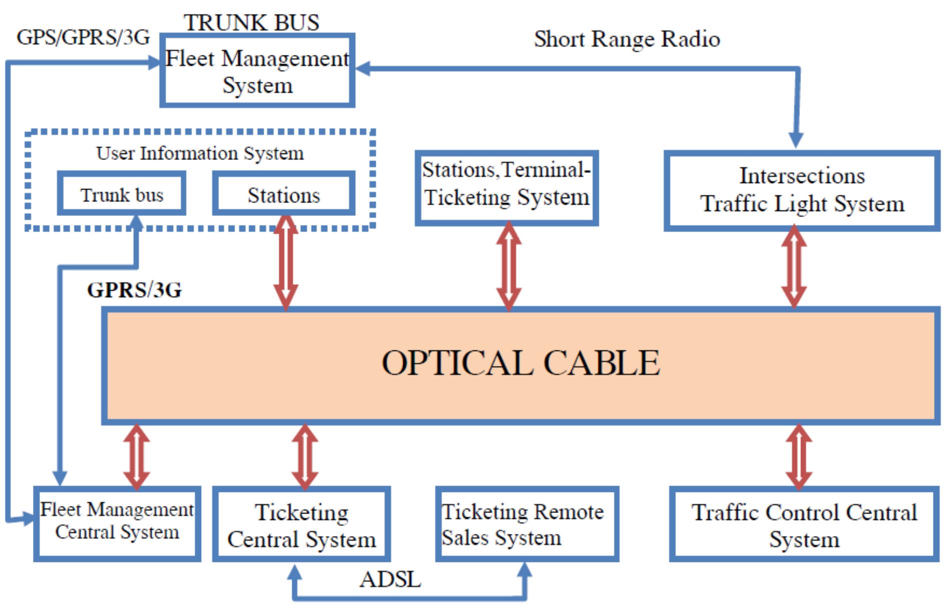

Figure 2.13: Physical architecture of the communication system

(Source: http://sogtvt.hanoi.gov.vn/)

Various kinds of intelligent information systems may be considered in the BRT operation. This could include for example AVL systems (Automatic Vehicle Location) based on GPS technique, information systems to passengers in the BRT buses and in the stations, operation control center functions, etc.…

The BRT communication and information systems consultant will support planning, design, and implementation through testing of a public transport ITS (Intelligent Transport Systems) including the following functional elements:

- Automatic Vehicle Location (AVL);
- All aspects of voice and data communications;
- Automated dispatching;
- Real-time operations supervision;
- Passenger information;
- Ticketing/fare collection;
- Passenger counting;
- Fleet management;
- Data archiving and analysis in support of planning and scheduling.

2.3.4. Evaluate Hanoi BRT base on the BRT Standard

The BRT Standards was compiled by The Institute for Transportation and Development Policy.

The Institute for Transportation and Development Policy (ITDP) works around the world to design and implement high quality transport systems and policy solutions that make cities more livable, equitable, and sustainable. ITDP is a global nonprofit at the forefront of innovation, providing technical expertise to accelerate the growth of sustainable transport and urban development around the world. Through our transport projects, policy advocacy, and research publications, we work to reduce carbon emissions, enhance social inclusion, and improve the quality of life for people in cities. ITDP has offices in Brazil, China, India, Indonesia, Kenya, Mexico, and the United States; employs more than 80 staff members; and supplements this team with leading architects, urban planners, transport experts, developers, and financiers.

The BRT Standard is the centerpiece of a global effort by leaders in bus transportation design to establish a common definition of bus rapid transit (BRT) and ensure that BRT systems more uniformly deliver world-class passenger experiences, significant economic benefits, and positive environmental impacts.

The BRT Standard scoring system was created as a way of protecting the BRT brand and offering recognition to high quality BRT systems around the world. Certifying a BRT corridor as gold, silver, bronze, or basic sets an internationally recognized standard for the current best practice for BRT.

Table 2.20: The score of Hanoi BRT base on the BRT Standard

BRT basic (Max Score: 38)	**Points**	**Hanoi BRT**
Type of Dedicated Right-of-Way		
Physically separated, dedicated lanes	8	**-**
Color-differentiated, dedicated lanes with no physical separation	6	**-**
Dedicated lanes separated by a painted line	4	**4**
No dedicated lanes	0	**-**
Corridor Configurations		**-**
Two-way median-aligned busway in the central verge of a two-way road	8	**8**
Bus-only corridor where there is a fully exclusive right-of-way and no parallel mixed traffic	8	**-**
Busway that runs adjacent to an edge condition like a waterfront or park where there are few intersections to cause conflicts	8	**-**
Busway that runs two-way on the side of a one-way street	6	**-**
Off-Board Fare Collection (During All Operating Hours)		
Barrier-controlled	8	**-**
Proof-of-payment	7	**7**
Onboard fare validation—all doors	4	**-**
Intersection Treatments		
Turns prohibited across the busway	7	**-**
Signal priority at intersections	2	**-**
Platform-Level Boarding		
Buses are platform level, having 4 centimeters or less of vertical gap	7	**-**
Stations in corridor have measures for reducing the horizontal gap	6	**-**
Total		**19**

According to BRT Standards, Hanoi BRT only reached 19 out of 38 points. This can be seen that the Hanoi BRT system does not meet the basic conditions of a BRT system.

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CHAPTER III: EXISTING PUBLIC TRANSPORT SYSTEM IN HANOI

3.1. Hanoi urban development trend

3.2. Evaluating the existing bus systems in Hanoi

3.2.1. Development of bus systems

3.2.2. Success of bus systems

3.2.3. Lesson learned from bus development activities in Hanoi

3.2.4. Opportunities and challenges for public transportation development in the future

3.3. Conclusion

References

3.1. Hanoi urban development trend

In Hanoi master planning to 2030 and vision to 2050, the population of Hanoi is forecast to grow to 7.44 million by 2020, around 9.2 million by 2030, and 10.8 million by 2050. The city was planned as a polycentric city which includes the main center (current Central Commercial District) connected with 5 satellite urban areas and the number of small towns within from 5 km to 30 km by ring roads and centripetal routes system (Figure 3.1).

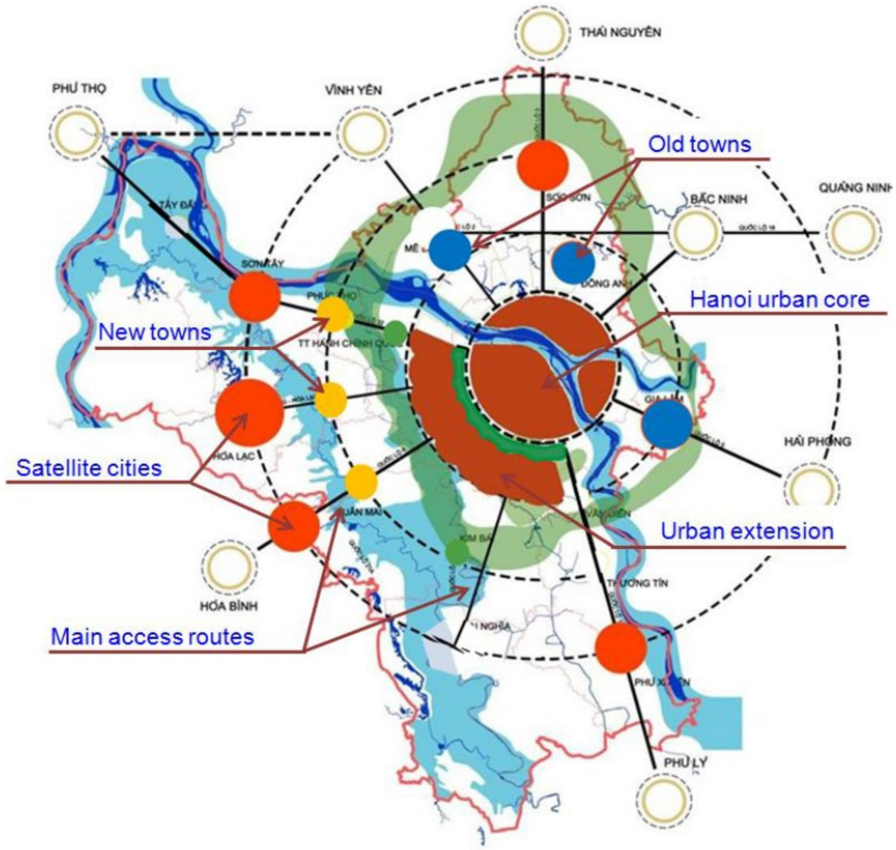

Figure 3.1: Hanoi master planning to 2030 and vision to 2050

Public transport is seen as a solution to traffic jams in the capital as it can address the large population and weak infrastructure. According to the planning, Hanoi aims to reduce up to 10 congestion hotspots and limit the duration of traffic jams to less than 30 minutes. Hanois Government shall build up several kinds of Urban Mass Rapid Transit (UMRT) including subway, light rail transit, monorail, and bus rapid transit system together with improving the level of service of the current bus system. The plan sets a target to increase the public transit share to over 30-35% by 2020, 50% by 2030, and 70% after 2030. With regards to public transport, the planning sets the criteria for public transport network density of 2-3km/km^2 in the central area and 2-2.5 km/km^2 in the satellite towns and aims at increasing the public transport modal share by the following:

- 2020 Public Transport Modal Share

  Central Area: 30-35%

  Satellite Towns: 15%

- 2030 Public Transport Modal Share

  Central Area: 65-70%

  Satellite Towns: 40% (50% after 2030)

Vietnam's Government also chose BRT to solve urban transportation problems in big cities as Hanoi, Da Nang, Ho Chi Minh city. With low-cost investments in infrastructure, high capacity, friendly in the environment. BRT is expected to be an effective transport solution to reduce construction for big urban areas in Vietnam nowadays. In 2030-2050 master plan and vision, Hanoi will have 8 BRT routes.

3.2. Evaluating the existing bus systems in Hanoi

3.2.1. Development of bus systems

Figure 3.2: Hanoi bus map

(Source: http://xe-buyt.com/)

Public passenger transport in Hanoi has a history of over 115 years. The company was founded in 1899 by the French-based Tonkin Territory, to build and operate the Tramway lines in the city. Tramway network of Hanoi has developed to 5 routes with a total length of 32 km and the tramway axis has become the axis of urban development of Hanoi. In 1988, the Tramway lines were dismantled, and replaced by the trial operation of Trolleybus on two lines: Sword Lakeside - Ha Dong; Sword Lakeside- Mo market, which stopped runny by the end of 1993. The development of buses in Hanoi can be divided into 5 stages as follows:

Hanoi buses before the renovation (before 1986): Bus routes of Hanoi were formed in the 1960s, reaching its zenith of development in 1980 with 28 lines downtown, 10 full-service bus lines with 500 buses which had carried 50 million passengers, satisfying 20% of the travel needs of people in that period. This was the stage when the bus operation was under the subsidy mechanism.

The crisis of Hanoi buses (from 1986 to 1992): The country removed the subsidized regime, bus businesses had to self - financed so they shifted from public bus transport to inter-provincial transport and service business. The lowest point of bus development was in 1992 when the number of bus routes reduced to 13 and the capacity of transportation was less than 3 million passengers. This was also the start of the booming period for motorbikes in Hanoi.

Bus Rebound (from1993 to 2001): Since 1993, the city began to re-subsidize, but bus ridership grew very slowly (from 4.8 million passengers in 1993 to 15.2 million in 2001). Under the circumstance, in June 2001, the city decided to establish Hanoi public transportation and service company (now Hanoi transport Corporation) for a comprehensive renovation and rapid development of public buses in Hanoi.

Comprehensive renewal period (from 2002 to 2010): With the attention of the city to make an initial change, Hanoi Transport Corporation (Transerco) focused on comprehensive renovation of bus operation according to "leading supply" principle: Streamlining the flow of routes and networking; issuing interconnected monthly tickets; renovating means of transport; applying centralized management and improving service quality with a criterion: "Travelling by bus is faster than by bicycle, cheaper than by motorbike". With the advent of both the political system and the support of the people, Hanoi succeeded, and the bus development model of Hanoi was replicated in many cities across the country.

Period of saturation and tendency of decreasing (from 2011 up to now): During this period, the number of routes and means has also been increasing but the amount of transport has almost been saturated. Particularly, in 2014, 2015 and the first 6 months of 2016, the number of bus users were on a downward trend (only attaining 90 to 92 percent of the number of users on main routes and conventional routes compared to the same period of previous years). By the end of 2015, Hanoi had 72 subsidized buses (1.1 times higher), with 1,208 vehicles (a rose by 1.15 times). However, the number of 2015 decreased comparing to that of 2014, and comparing to that of 2010 it increased only by 1.02 times; In the first 6 months of 2016, the number of passengers only reached 90% over the same period of the previous year.

Table 3.1: Bus development targets for the period of 2010 – 2015

No.	Target	Unit	2010	2011	2012	2013	2014	2015
1	Total number of routes	Route	80	82	86	89	91	91
2	Subsidized routes	Route	65	65	67	70	72	72
3	Number of subsidized buses	Bus	1,046	1,104	1,140	1,189	1,206	1,208
4	Total number of passengers carried by subsidized buses	Million passengers	421	440	453	458	463	431

The main causes of the above conditions:

- Unstable bus infrastructure: The construction of key projects, bus stops, waiting houses has continuously been adjusted, encroached. Private vehicles have increased too fast compared to the development of transport infrastructure, affecting the speed of bus operating along the mixed lanes.
- Service quality does not seem to be compatible with the requirements of passengers which are increasingly higher and more diversified. Buses are not as convenient as personal means in terms of travel for short and medium distances.
- Ticket price is no longer an attractive factor for short and medium trips (as it is being completed by private means, type of taxis like Uber, etc....)
- Decrease the possibility of access: Because urban space planning is not compatible with public passenger transport planning, new urban areas lack land areas and access to public transportation.

3.2.2. Success of bus systems

The bus area was expanded and initially attracted passengers: After 16 years (2001 - 2016), Hanoi bus has "bought the habit" of the people. The number of routes has increased 2.4 times, the quantity of buses has risen by 3.6 times, and over 28 times increase is witnessed in the quantity of bus ridership: from 15 million passengers in 2001 to over 431 million in 2015. Currently, Ha Noi has 96 bus routes (75 of which are subsidized, 12 are non-subsidized and 9 are nearby bus routes). The route network covers all downtown districts and 26/40 town areas, townships and administrative centers of suburban districts. Buses have made positive contributions to reducing congestion: The area of occupancy dynamically for a bus ridership is 1.5 – 2 m^2, while that for a person riding motorbikes is 8 – 12 m^2 and for a car is 24 - 26m^2. The survey results show that the rate of road occupancy for a bus in certain main streets is below 10% but the bus can cover over 15% of travel demand such as in Cau Giay axis; Kim Ma; Nguyen Van Cu, etc....

A high efficiency of exploitation: In 2001, the average of one bus was only 119 passengers per day, yet by 2010, this number rose by 1,152 passengers, reaching the maximum level. However, by 2015, an average bus could only carry 867 passengers per day.

The quality of bus services is basically consistent with the feature of passengers: According to the survey results, in the period from 2001 to 2010, the cheap price of bus ticket was the major factor for attracting passengers; 26% of the respondents rated the service quality as good; 65% rated it as normal, 8% rated it as poor and 1% rated it as very poor. However, by 2016, the evaluation of bus service quality has changed due to the demand of passengers increasing and becoming more diversified.

3.2.3. Lesson learned from bus development activities in Hanoi

Firstly, the advent of both the political system and the determination of the Citys leaders along with the selection of the development model, the appropriate steps were decisive factors in the success of the Hanoi bus in those years. City investment was just to make an initial push, then the step by step socialized but still played a leading role in the state economy.

Second, to develop public passenger transport, apart from investment in facilities, infrastructure, logistics facilities, as well as advanced system of management and administration equipment, the development of infrastructure for bus operation (such as priority lane, peculiar lane for bus, initial stop, final stop, transit position) should also be taken in to account.

Thirdly, people in big cities of Vietnam do not lack means of transportation. Therefore, comprehensive renovation and improvement of service quality according to the "leading supply" principle are a decisive factor to limit their personal means of transportation and increase the use of public buses.

Fourthly, the city had a mechanism of policy to develop in accordance with each stage, policies on public transport infrastructure in general and buses. Long-term subsidy policy was a factor that ensures the sustainable development of public bus.

3.2.4. Opportunities and challenges for public transportation development in the future

1) Features of passengers and the requirement to improve service quality

Table 3.2: Features of bus ridership

No.	Features of bus ridership	Survey in 2010	Survey in 2016
1	Area of serving passengers	Mainly focus on downtown area of Hanoi (78%)	Cover almost suburban districts of Hanoi
2	Passenger using bus	Mostly high school or college/ university students (65%), business sector (15%)	Diversified type of passengers, namely high school, college/ university students (37%); retired people, housewife (14%); worker (11%); office worker (12%)
3	Income of passenger	The majority were low-income people (51% of the passengers having income of less than 1 million VND; 32% get income ranging from 1 to 2 million VND)	Average income of bus passengers was below 6 million VND, accounting for 81%; 35% of the passenger had income of 2 to 4 million VND, 23% have income of 4 to 6 million VND; high income people (over 10 million VND, accounting for 5% of the passenger rate) started to use buses.
4	Purpose of travelling by bus	Most passengers (60%) use bus for going to school or to work.	Going to school or to work accounted for quite a high rate of 52%.
5	Average distance that passengers travel	6km for downtown travelling; 10km on for suburban travelling	Mainly selected buses with distance trip of over 10km (63%); 27% of the passenger selected bus for distance less than 10km.

From the results of the surveys in 2010 and 2016, the change in the features of passengers using buses is as follows:

- Type of passengers: In the 2001-2010 period, bus passengers were mainly students (65%) but up to now the type of passengers has become more diversified (with students making up of 37%, other groups such as retired people, housewife accounting for 14%, employee 23%).
- Passenger income: In the 2001-2010 period, the majority of bus passengers had low income (less than 1 million accounting for 51%, from 1 to 2 million accounting for 32%) but up to now average income of passengers has been higher (from 2 to 4 million, accounting for 35%, 4 - 6 million accounting for 23%) and high-income people (over 10 million) has started to use the bus.
- Purpose of the trip: Using bus has been mainly for regular trips such as going to school and going to work.
- The average travel distance of passengers: In the 2001-2010 period, the distance of traveling was mainly 6 km in the downtown area of the city (which accounted for 78%) and 10 km in the suburban area. At present, the travel distance of over 10km makes up of 63% and less than 10km travel distance only accounts for 23%.
- Passengers requiring higher access: In 2010, 40% of passengers accepted going further than 500m to the bus stop. However, up to now, 76% of passengers accept to walk to the destination and 58% accept to go to a bus stop with less than 500m.
- Reasons for choosing bus: In 2010, the rate of selecting the bus because of the low cost was 50%, followed by safety which made up of 20%. However, up to now, low cost only accounts for 18% of the reasons, passengers require higher about safety, security (30%) and quality of service. Cheap tickets are no longer the biggest advantage for choosing buses as means of travel today.

- Reasons for not using buses: In the period before 2010, the reason for not traveling by bus was mainly due to a long time of waiting (65%) but now there are many reasons of not choosing bus such as low quality of infrastructure, service, facilities, staff attitude, etc.… General assessment of service quality: In the period before 2010, passengers assessed the quality of bus services to be relatively high (91% rated bus quality from average or above, but up to now this is only 65% and there are even 28% of the passengers evaluating the service as not satisfactory).

These changes are not only opportunities but also challenges for the development of public passenger transport generally and buses particularly in Hanoi in the coming period. Changes to passenger service quality:

Table 3.3: Passenger requirements of bus service quality

No.	Service quality	Survey in 2010	Survey in 2016
1	Assessment of the accessibility to bus	40% of the passengers must walk farther than 500m to the bus stop	The distance for walking was mainly less than 500m (accounting for 58%); distance to the destination was less than 500m (accounting for 76%)
2	Reason for choosing to travel by bus	Low cost of ticket (50%); safety (20%)	Low cost of ticket (18%), safety, and security (30%); nowadays low cost of ticket is no longer the biggest advantage of travelling by bus.
3	Reason for dislike using bus	65% due to long time of waiting (65%); 16% on account of bad quality of service and 10% because of long distance to walk	Long time of waiting for bus accounted for 12%; inappropriate route accounted for 11%; 11% due to long time of the trip and 10% due to long distance to walk
4	Quality of service on the bus	Average and good assessment accounted for 91%	65% assessed as acceptable; 28% were not satisfactory
5	Overall assessment of service quality	Relatively appropriate for passengers	Not satisfied when the income and type of passengers were variable with higher demand for a better quality

2) The introduction of new public passenger transport modes in the coming time

Along with the development of public passenger transport buses, the city has been developing fast and mass modes of passenger transport. It is expected that by the end of 2016, the BRT route: Kim Ma - Yen Nghia has come into operation; By the end of 2018, the 2A railway Cat Linh – Ha Dong will be operated; and by 2020, the third railway line will be operated between Nhon and Hanoi Railway Station. When these modes go into operation, the bus will play the role of connecting, gathering and releasing passengers to ensure the best quality of passenger service. The task required is to have a state management agency on public passenger transport, modern electronic ticket system, transit system, conveniently connective terminals, etc....

3) Urbanization and development of urban space in Hanoi according to approved planning

Before merging period (before 2008), Hanois urban space was mainly concentrated in the downtown area of Hanoi, thus public passenger transportation system only developed in the original downtown districts. Following the emergence, in Ha Noi there was the rapid development of satellite urban areas (Xuan Mai, Son Tay, Hoa Lac, Phu Xuyen, Dong Anh, Soc Son ...) following “multi-center direction”; therefore, inter-regional public transport and the regional connection will play an important role in the next phase. This was the opportunity for the bus to expand the service area, meeting the need of people in the suburbs, connecting the satellite towns with the center of Hanoi.

4) The shortcomings need to be overcome for the Hanoi bus to develop sustainably and efficiently

About route network and bus infrastructure: According to interviews, 93% of passengers assessed the suitability of the routes as low and medium, and 59.6% of passengers use monthly tickets but do not transit, which shows the network of routes does not seem to meet the demand of passengers.

Infrastructure for buses is not only insufficient but also weak. In many areas, it is difficult to get access to the bus. The development of standard infrastructures such as the terminal, transit point, and dedicated lane encounters plenty of difficulties. In a total of 1,974km bus lines, there is only 1.3km for the dedicated road. In a total of 78 terminals, 55 are located on the curb, unstable and unplanned areas, which accounts for 70%; The entire bus network has only 5 transit points.

Road network is overload, personal vehicle increase, travel time gets lengthened, service quality is affected especially during rush hours. According to statistics of Hanoi Police, in the 2011-2015 period, the motorcycles growth rate was 7.66% per year; automobiles increased by 12.9% per year (in which cars increased by 16.15%). Currently, Hanoi has over 5 million motorbikes and nearly 550 thousand cars; over 1 million bicycles and electric bicycles, while the growth rate of the citys transport infrastructure is only 3.9% per year. Infrastructure limitation and the rapid growth of personal vehicles lead to the extension of bus travel time up to 40 percent comparing to that of 2015. On major corridor axes, buses frequently arrive from 10 to 15 minutes later than scheduled due to traffic jams.

Regarding the mechanism and policy: There is a lack of planning for development of a modern multi-modal public passenger transport system. There has been a resolution on priority for development of public passenger transport but has not been implemented due to the lack of specific guidelines for implementation.

3.3. Conclusion

Compared with mass transportation means such as subway, BRT, conventional buses are somewhat less transportable. However, with narrow traffic environment and space in many areas of Hanoi, buses are seemingly more suitable. Along with the implementation of measures to limit private vehicles, regulating traffic demand; building and promoting the development of public transport is also one of the basic solutions to reduce environmental pollution, air pollution due to traffic jams. In addition, some solutions are set up for specific research, such as the congestion charge, the system consists of tolls at access points around the central city which charge varying fees to incentivize public transport – or at least not car use – during peak hours; set up a scheme on collection of environmental pollution charges for various types of land-road traffic means according to the levels of waste gas on circulation; to raise parking charges per hour or per area from suburban areas to the center of the city to limit parking in inner city. At the same time, scrutinize, closely inspect, resolutely handle and recover used vehicles in contravention of regulations; Review regulations on restrictions and licensing of transport vehicles in the inner city.

The Hanoi Peoples Committ ee has approved the project "Strengthening the management of land-road traffic means in order to reduce traffic congestion and environmental pollution in Hanoi, 2017-2020, vision till 2030". However, the current problem is the construction of overhead trains or subway is very expensive and complex. Moreover, not in every area nor any route can these types be built. BRT requires very strict operating conditions such as private lane, priority signaling system, etc... Meanwhile, conventional buses have the advantage of reaching most residential areas, operating condition required is only on an average level. On the other hand, for great modes of transportation, each trip can accommodate thousands, millions of visitors and transport them to the station or transit points. The conventional bus becomes the force to release quite many passengers. Thus, whether there is an addition of subway, BRT or any other means, conventional buses will still be the main public passenger transport force of Hanoi. In order to meet the forthcoming requirements, Hanois conventional bus needs detailed, scientific planning; this should be accompanied by practical measures to improve service quality with the support of advanced technology to develop buses into smart, accessible and environmentally friendly modes of transportation. This is the solution to create a new look for urban of Vietnam, the urban that worth living in with transport system properly planned and sustainably developed.

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CHAPTER IV: TRAFFIC SITUATION BEFORE AND AFTER OPERATING BUS RAPID SYSTEM IN HANOI

4.1. Introduction

The Hanoi Bus Rapid Transit project is one of the components of the Hanoi Urban Transport Development Project (HUTDP) that was approved by the Hanoi People's Committee in Decision 1837/QĐ-UBND dated May 10, 2007 and funded by the World Bank. The HUTDP was originally approved by the World Bank board on July 3, 2007, with the original closing date of December 31, 2013. Hanoi BRT has been opened to traffic on December 31, 2016, more than 12 years since it was planned by domestic and foreign experts, especially those from the World Bank. Because it took such a long time to implement the first line from Kim Ma to Yen Nghia, the World Bank decided to stop the second BRT line, and this was made official in Decision No. 1821/QD-UBND dated February 22, 2013. The BRT line from Kim Ma to Yen Nghia was selected based on detailed studies conducted by the French consultancy Egis. The 14.7 km BRT route goes from Kim Ma station in the central area of Hanoi and goes southwest.

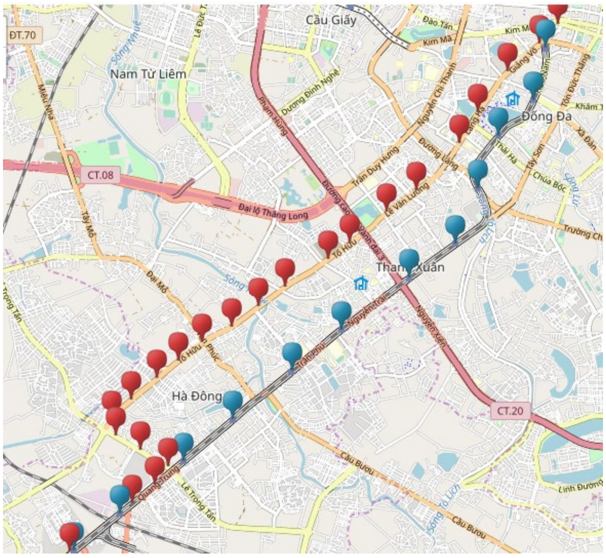

Figure 4.1: The Hanoi BRT corridor (red line) and the Metro corridor (blue line)

(Source: https://www.openstreetmap.org)

Figure 4.2: The Hanoi BRT station underneath an elevated metro line

(Source: https://www.fareast.mobi/)

Firstly, the operations of the BRT are ineffective due to low passenger demand and the overlapping with the metro line which is parallel with the route. The BRT corridor, which is south of the metro line, passes by large expanses of farmland, low-density housing and even a large cemetery, whereas the metro corridor, only 1.3km away, passes through a very dense urban corridor with high local demand (Figure 4.1 & 4.2). After the metro opens in a year or two, it is hard to see officials persisting with segregation of the BRT lanes with what is sure to be very low passenger demand.

Secondly, the BRT design capacity is so low, and the system is so unattractive, that only a very small proportion of any future demand will be accommodated by the BRT. In addition, the failure of the route results from low capacity station design. Some of the Hanoi BRT stations have street level access, but many of these impose long additional walking distances on passengers by forcing them to walk to an adjacent intersection. (Figure 4.3). The poor station access will greatly reduce the appeal and ridership of the system. With long detours imposed on passengers wishing to access many stations, including steep and unpleasant stairs to access 7 of the 23 stations, and questionable speed benefits due to mixed traffic intrusion into the BRT lanes in congested locations. The seven stations featuring pedestrian bridges have steep stairs and only one access ramp at each foot of the stairs, instead of two. This results in long detours for pedestrians to enter the BRT stations. BRT passengers would probably have been better off at the regular kerbside bus stops which at least did not impose onerous additional walking distances and stairs. At Khuat Duy Tien station, passengers need to walk 200m to access a boarding area that is only 20m away and go up and down two sets of stairs (Figure 4.3).

Figure 4.3: The Hanoi BRT station access at Khuat Duy Tien station.

(Source: https://www.fareast.mobi/)

The World Bank's Hanoi BRT project does not really have an operational design. It is essentially a trunk-only BRT line with a single bus route running up and down the corridor (Figure 4.4). Begin route: Kim Ma station – Giang Vo- Lang Ha- Le Van Luong – National Road 6 – Yen Nghia station. Return route: Yen Nghia station – National Road 6 – Le Trong Tan – Le Van Luong – Lang Ha- Giang Vo – Giang Van Minh – Kim Ma – Kim Ma station.

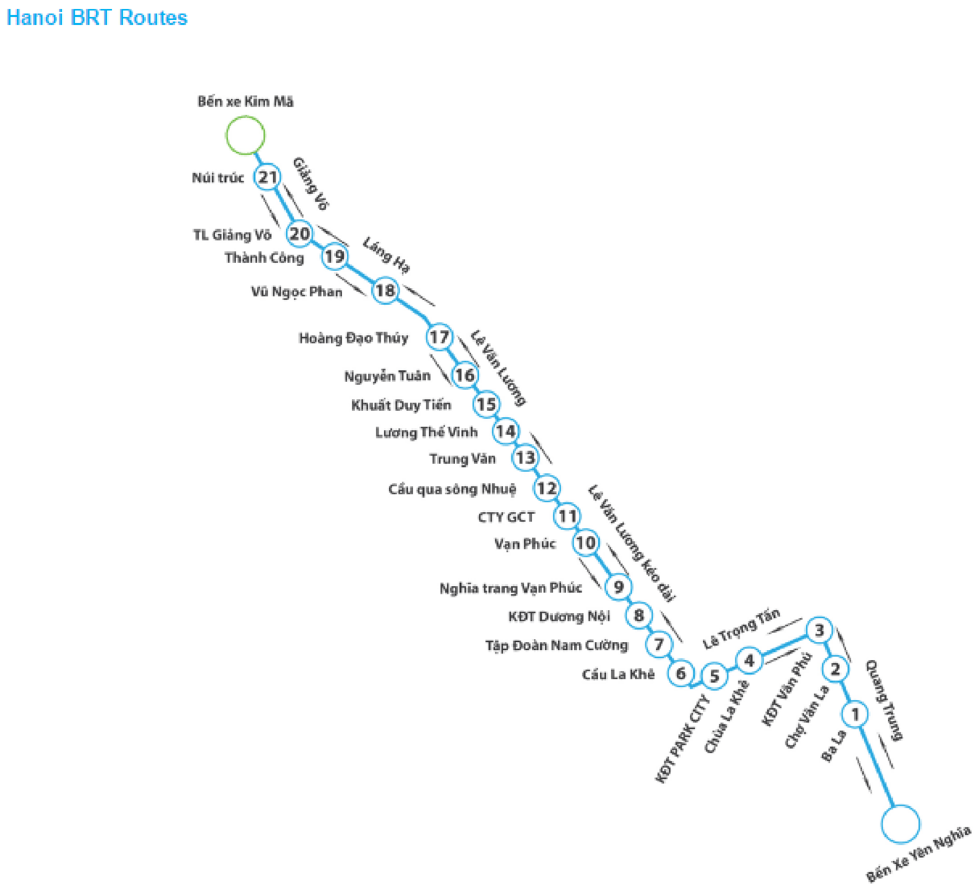

Figure 4.4: The Hanoi BRT operational design

(Source: http://hanoibrt.vn/)

4.2. Purposes

The development of BRT system in Hanoi was expected to contribute to solving multi-dimensional transport related problems, such as traffic congestions, road accidents, pollution and noise, and air, global warming and climate change, as well as to alleviate the problems of social inequality, in a concrete and sustainable manner. However, Hanoi still has several problems in operation and the most common problem is the lack of the BRT system capacity. Therefore, further feasibility studies are required before actual BRT implementation can occur.

The purposes of this chapter are to analyze the traffic situation in Hanoi before and after implementing Hanoi BRT system. After the general analysis of the situation, the study presents some issues should be considered for development BRT in Hanoi.

The main purposes of this chapter are as follows:

- Analyzing the traffic situation on the first Hanoi BRT system route (before and after implementing);
- Comparing the traffic situation between before and after implementing the system;
- Evaluating the effectiveness of Hanoi BRT system.

4.3. Methodology

Step 1: Data collection

The videos of the actual traffic situation were recorded at the chosen locations in three different time periods before and after operating BRT.

Step 2: Analysis

The video data will be extracted to frames, and from the analysis with each frame, the input data is collected.

After having the input data, some functions are used to analysis comparison traffic situation in each location.

Table 4.1: Overview of survey

Location	Date	Period
Case 1: No. 17 station (separated traffic)	14/09/2015 28/02/2017	7:00 – 7:30
		12:00 – 12:30
		17:00 – 17:30
Case 2: No. 21 station (mixed traffic)	07/09/2015 21/02/2017	7:00 – 7:30
		12:00 – 12:30
		17:00 – 17:30

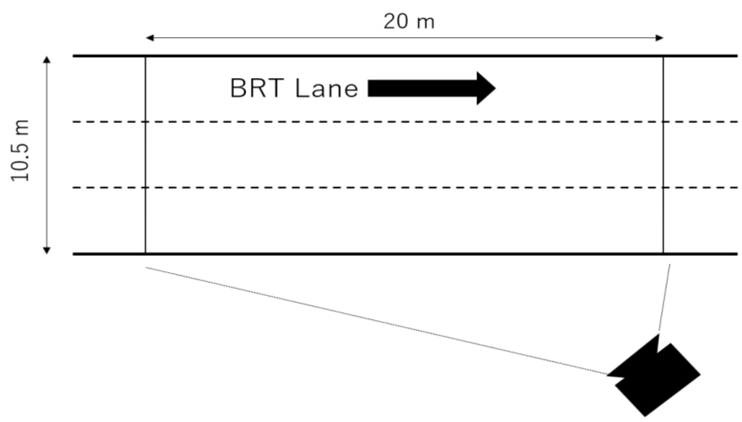

Figure 4.5: Video survey method

4.3.1. Survey location

Two locations were chosen to record videos (Figure 4.5). These are high traffic density locations on the BRT route - a major route linking the Western area to the old center of Hanoi:

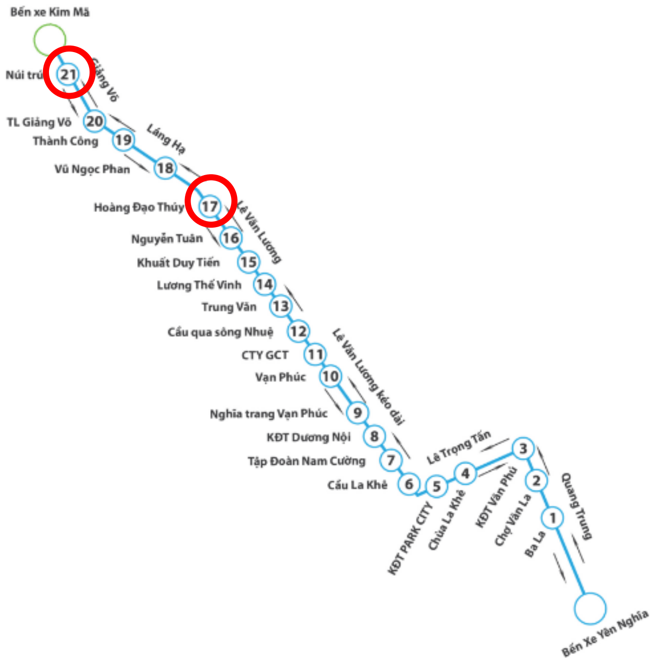

Figure 4.6: Survey locations on Hanoi BRT route

<u>Case 1</u>: In front of No. 17 station (Hoang Dao Thuy station) on Le Van Luong Street.

Le Van Luong Street is 1.52km long. This is a new street, a “Golden” spot of Hanoi, under the new-innovation of infrastructure, close to lots of new urban areas Modern systems of services, schools, hospitals. Le Van Luong Street is three lanes road. The operational BRT design in this street is separated from other vehicles (Figure 4.7).

Figure 4.7: In front of No. 17 station on Le Van Luong Street

Case 2: In front of No. 21 station (Nui Truc station) on Giang Vo Street.

Giang Vo Street is 1.5 km long. Many schools, companies, and stores are gathered in this area. Giang Vo Street is three lanes road. The operational BRT design in this street is mixed traffic with other vehicles (Figure 4.8).

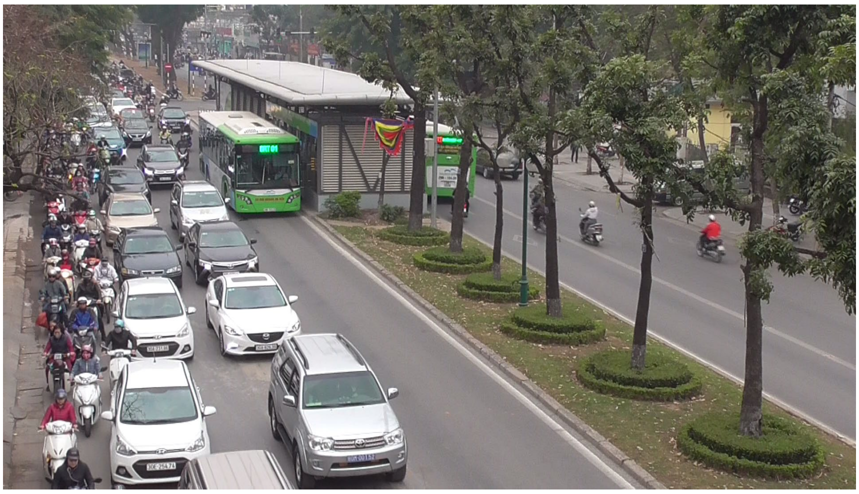

Figure 4.8: In front of No. 21 station on Giang Vo Street

4.3.2. Survey time period

Traffic surveys aim to capture data that accurately reflects the real-world traffic situation in the area. In the past, this has involved having people standing by the side of roads and recording their observations on paper pads. In recent years, this approach has been largely replaced by recording traffic using video cameras and then analyzing the video footage later in the office. This method is often used to analyze the traffic situation in developing countries. "Analysis of Motorcycle Effects to Saturation Flow Rate at Signalized in Intersection in Developing Countries"[1)]: The purposes of this research is to investigate and to analyze the effects of motorcycles at signalized intersections in Hanoi and Bangkok by analyzing video surveys: 11:00 - 13:00 and 16:00 - 18:00 in September and October 2002 in Bangkok; 7:00 - 9:00 and 16:00 - 18:00 in December 2002 in Hanoi. "Image processing analysis of motorcycle oriented mixed traffic flow in Vietnam"[2)]: The original movie file was recorded on July 2003, from 7:30 a.m. to 8:30 a.m. in Hochiminh city, Vietnam. This recording set is used to analyze the traffic situation in Hochiminh City before the implementation of transport policy and modifications in the public transport system. "Motorcycles in Developing Asian Cities: A Case Study of Hanoi"[3)]: This study provides a better understanding of the factors that influence the purchase of motorcycles and use of the various modes of transport that will be available to the community in Hanoi, through observation surveys and questionnaire surveys were deployed between April and June 2014…

Unlike developed countries with advanced public transport systems, the number of passengers using public transport increases in the winter. In developing countries, public transport systems are limited, Personal vehicles are still the main means of transportation. It occupies mainly in the transport composition at any time of year.

The videos were created at three different periods: morning, afternoon, evening in September 2015 and February 2017. September 2015 is before BRT came into operation. February 2017 is after BRT came into operation. September and February are the beginning of two semesters (Table 2) and the dates selected for the survey do not match the holiday (Table 3), so there will be no big changes in traffic flow.

- In the morning: Almost schools and companies are begun at 8:00. Therefore, the morning is the peak hours period. It takes place from 6:30 to 8:30. The videos were recorded from 7:00 to 7:30.
- In the afternoon: This is not the peak hours; traffic volume is low. All the traffic vehicles can run with free speed. The videos were recorded from 12:00 to 12:30.
- In the evening: The activities of companies and schools finish at about 16:30. Therefore, this is also the peak hours period. Peak hours period takes place from 17:00 to 19:00. The videos were recorded from 17:00 to 17:30.

Table 4.2: Schedule of schools in Hanoi

	Semester 1	**Semester 2**
Nursery school	06/09 - 06/01	10/01 - 19/05
Primary school	06/09 - 06/01	10/01 - 19/05
Junior high school, High school	15/08 - 247/12	27/12 - 15/05
University, College	29/08 - 24/12	27/12 - 15/05

Table 4.3: Public Holiday schedule in Vietnam

	2015	**2017**
New Year	01/01 - 04/01	01, 02/01
Vietnamese New Year	15/02 - 23/02	26/01 - 01/02
Hung Kings Commemorations	28/04	06/04
Liberation Day	29, 30/04	29, 30/04
International Workers' Day	01/05 - 03/05	01, 02/05
National Day	02/09	02/09 - 04/09

4.4.3. Data collection

The video data will be extracted to frames in 60 frames per minute.

Collecting data from analyzing each frame.

Camera records a line segment of length (L), in a period (t), the number of vehicles traveling in that line segment in one direction is (n), the time each vehicle goes through that line segment is (t_i) (Figure 4.9). Average speed by the time is calculated by the formula:

$$v_t = \sum \frac{v_i}{n} = \frac{\sum \frac{L_i}{t_i}}{n} = \frac{L}{n}\left(\sum \frac{1}{t_i}\right) \qquad (4.1)$$

This method is quite accurate: Repeat counting many times on the same video will ensure the error for the total number of vehicles is less than 1%. To evaluate the accuracy of this method, we compared a specific number of vehicles in the field with the number of vehicles recorded on the video.

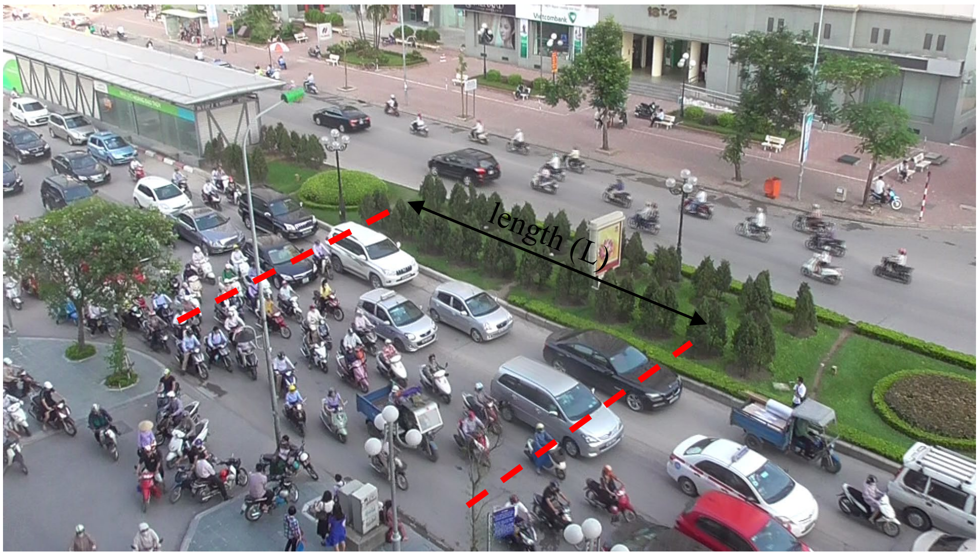

Figure 4.9: Analyzing extracted frames to collect input data

4.3. Results

4.3.1. Case 1: Le Van Luong street – exclusive BRT lane

Le Van Luong Street, Trung Hoa ward, Cau Giay district and Nhan Chinh Ward, Thanh Xuan district, Hanoi, Vietnam. It's 1.52km long, from Hoa Muc bridge, linking Lang Ha and Khuat Duy Tien road. This is new street named in August 2005. This is a "Golden" spot of Hanoi, under the innovation of infrastructure, close to lots of new urban areas such as Trung Hoa- Nhan Chinh, The Manor, Trung Yen, Mandarin… Modern systems of services, schools, hospitals. The operational BRT design in this street is separated from other vehicles (Figure 4.10).

Figure 4.10: The operational BRT design in Le Van Luong Street

1) Traffic volume

The data obtained in front of No. 17 station on Le Van Luong Street are shown in Table 4.4 and Table 4.5.

Table 4.4: The traffic volume of each vehicles before operating BRT in case 1 – Le Van Luong Street (units/30 minutes)

Vehicle class	Morning	Afternoon	Evening
Bicycle	32	12	85
Motorcycle	7,935	1,980	3,540
Car	1,560	630	570
Regular bus	10	14	18
Total	9,537	2,636	4,213

Before operating BRT, motorcycles are main traffic vehicle in traffic flow. In the morning, motorcycles occupy 83.2% of the total number of vehicles (7,935 units), 48 times than the number of bicycles (32 units), 5 times than the number of cars (1,560 units). In the afternoon and evening, the number of motorcycles decrease clearly than the morning, but motorcycles still dominate in traffic flow. In the afternoon, the number of motorcycles still occupy 75.11% of the total number of vehicles (1,980 units), 165 times than the number of bicycles (12 units), and 3.14 times than the number of cars (3,540 units). In the evening - checking out time, the number of motorcycles occupy 84.03% (3,540 units), 41.6 times than the number of bicycles, 6.2 times than the number of cars (Table 4.4).

Morning is the period that has high traffic volume in a day. Total is 9,537 vehicles before operating Hanoi BRT and reduced to 5,277 vehicles after operating. Before and after operating Hanoi BRT, motorcycles are always the main traffic vehicle in traffic flow. After operating BRT, composition of traffic flow changes clearly. In the morning, motorcycles still dominate in traffic flow 90% (4,753 units), 113 times than the number of bicycles (42 units), and 10.22 times than the number of cars (465 units). But the number of motorcycles is 0.6 times than before operating BRT (4,753 units). In the afternoon, motorcycles occupy 75.5% of the total number vehicles (2,381 units), 29 times than the number of bicycles (82 units) and 3.5 times than the number of cars (677 units). In the evening, motorcycles occupy 86% (4,284 units), 22.5 times than the number of bicycles (190 units), 8.9 times than the number of cars (480 units) (Table 4.5).

Table 4.5: The traffic volume of each vehicles after operating BRT in case 1 – Le Van Luong Street (units/30 minutes)

Vehicle class	Morning	Afternoon	Evening
Bicycle	42	82	190
Motorcycle	4,753	2,381	4,284
Car	465	677	480
Regular bus	9	6	8
BRT	8	6	6
Total	5,277	3,152	4,968

Base on Table 4.4 and 4.5, they show that after operating BRT the change of cars opposite the change of motorcycles. While the number of cars decreases in peak hours (morning and evening), in the afternoon the number of cars should more than the peak hours.

After operating BRT, the number of motorcycles has decreased by 40.1%, the number of cars by 70.19%, the number of regular buses by 10%, the total of all vehicles by 44.67% (Table 4.6). The reason for this change is due to the traffic organization was adjusted towards priority for the BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, banning taxis from

Hanoi BRT route during peak hour, reducing the frequency of regular buses.

Table 4.6: The difference of traffic volume in case 1 after operating Hanoi BRT

Classification	**Morning**	**Afternoon**	**Evening**
Bicycle	31.25%	583.33%	123.53%
Motorcycle	-40.1%	20.25%	21.02%
Car	-70.19%	7.46%	-15.79%
Regular bus	-10%	-57.14%	-55.56%
BRT	-	-	-
Total	-44.67%	19.58%	17.92%

Table 4.7: The composition of cars in traffic flow in case 1 – Le Van Luong Street (units/30 minutes)

		Before	**After**
Morning	**Total**	**1,560**	**465**
	Private car	1,431	465
	Taxi	129	0
Afternoon	**Total**	**630**	**677**
	Private car	414	513
	Taxi	216	164
Evening	**Total**	**570**	**480**
	Private car	378	480
	Taxi	192	0

Before operating BRT, in the morning: the number of cars include 1,431 units of private car and 129 units of taxi (total 1,560 units); in the afternoon: the number of cars include 414 units of private car and 216 units of taxi (total 630 units); in the evening: the number of cars includes 378 units of private car and 192 units of taxi (total 570 units). After operating BRT, in the morning: the number of cars include 465 units of private car and 0 units of taxi (total 465 units); in the afternoon: the number of cars include 513 units of private car and 164 units of taxi (total 677 units); in the evening: the number of cars includes 480 units of private car and 0 units of taxi (total 480 units) (Table 4.7).

2) Average speed

The average speed of each vehicle type before and after operating BRT is shown in Table 4.8 and Table 4.9.

Table 4.8: The average speed of each vehicle before operating BRT in case 1 – Le Van Luong Street (km/h)

Vehicle class	Morning	Afternoon	Evening
Bicycle	5.32	14.78	14.45
Motorcycle	5.44	31.74	30.31
Car	4.77	30.48	33.71
Regular bus	3.97	25.62	22.52

Based on Table 4.8 analyzing the average speed of each vehicle, they show that the average speed of all vehicles class is very slow. The average of bicycles is 5.32 km/h, of motorcycles is 5.44 km/h, of cars is 4.77 km/h, of regular buses, and is 3.97 km/h. This speed is equivalent to the pedestrians speed (5 km/h). The average speed of motorcycles and cars collected in the afternoon and evening are significantly improved than the peak hours in the morning. In the afternoon, the average speed of motorcycles is 31.74 km/h, 5.8 times than in the morning; the average speed of cars is 30.48 km/h, 6.4 times than in the morning; the average speed of bicycles and regular buses are 14.78 km/h, 25.62 km/h, increased several times than in the morning. In the evening, the average speed of all vehicles class is the same as in the afternoon: 30.31 km/h with motorcycles, 5.6

times than in the morning; 33.71 km/h with cars, 7.1 times than in the morning; 14.45 km/h with bicycles, 2.7 times than in the morning; 22.52 km/h with car, 5.7 times than in the morning. In the morning, cars have a lower speed comparing with motorcycles. The average speed for all types of vehicles is very low, probably because of the large volume of motorcycles, which interfere with the flow of other vehicles.

Table 4.9: The average speed of each vehicle after operating BRT in case 1 – Le Van Luong Street (km/h)

Vehicle class	Morning	Afternoon	Evening
Bicycle	13.56	14.68	15.74
Motorcycle	20.08	30.47	25.07
Car	14.41	32.15	17.33
Regular bus	14.23	28.31	17.56
BRT	16.80	27.36	16.03

After operating Hanoi BRT, the average speed of all vehicles class increases significantly in the peak hours. In the morning, the average speed of bicycles increases to 13.56 km/h, 20.08 km/h with motorcycles, 14.41 km/h with cars and 14.23 km/h with regular buses. Compared to before operating Hanoi BRT, the average speed of motorcycles increases 3.7 times, the average speed of cars increases 3 times, the average speed of bicycles increases 2.5 times, the average speed of regular buses increases 3.6 times. In the evening, the average speed of cars and regular buses are slower than before operating Hanoi BRT. The average speed of motorcycles is 25.07 km/h, the average speed of cars is 17.33 km/h, the average speed of bicycles is 15.74 km/h, the average speed of regular buses is 17.56 km/h (Table 4.9). Because the afternoon is not peak hours, the average speed of all vehicles is not much change compared with before operating Hanoi BRT.

3) Relationship between vehicle types

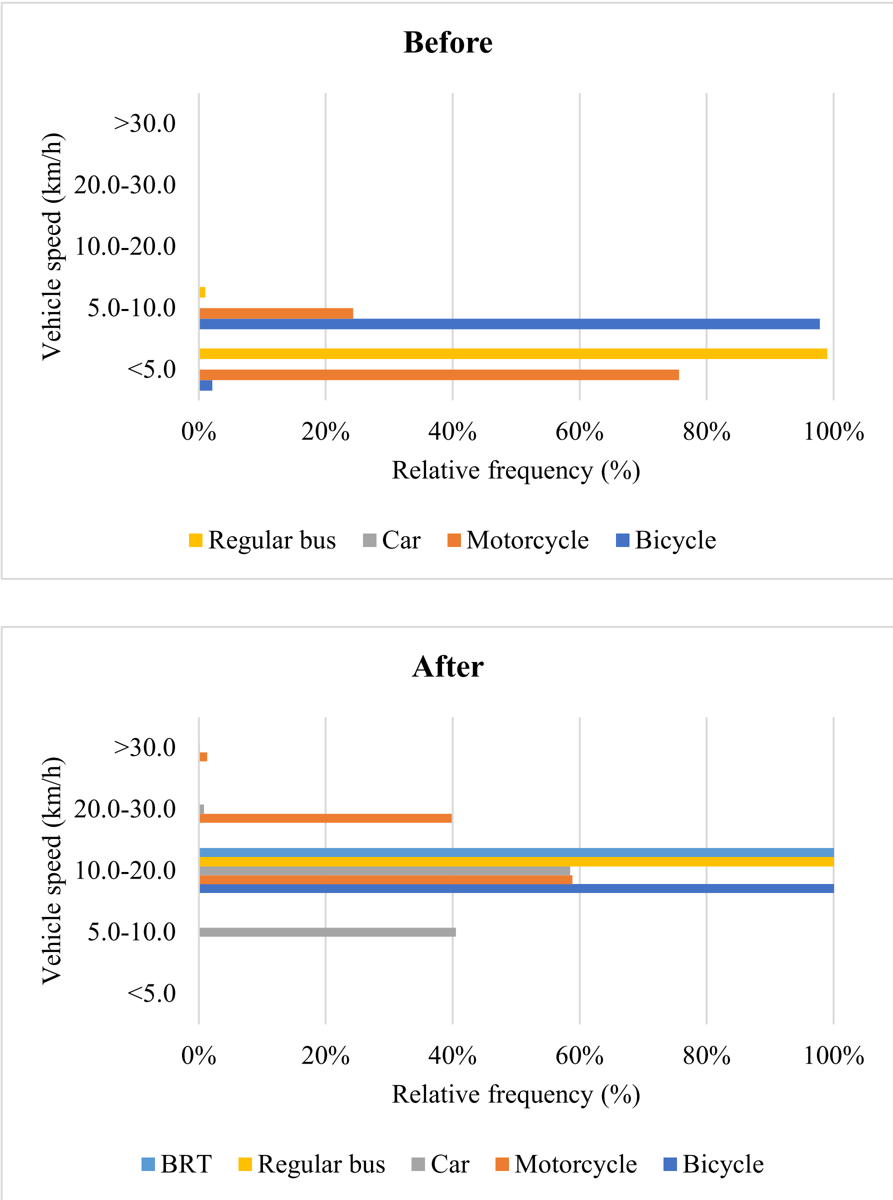

Figure 4.11: Relative frequency of speed of vehicle types in case 1

In this case, the average speed of all vehicles is low, mostly below 5 km/h. However, contrary to case 1, in this case after operating BRT, the average speed of vehicles has increased significantly, ranging from 10 to 20 km/h (Figure 4.11).

The reason is the reduction of large numbers of cars circulating during rush hour. As in case 1, the number of cars has been increasing rapidly also greatly affects other vehicles (Figure 4.12).

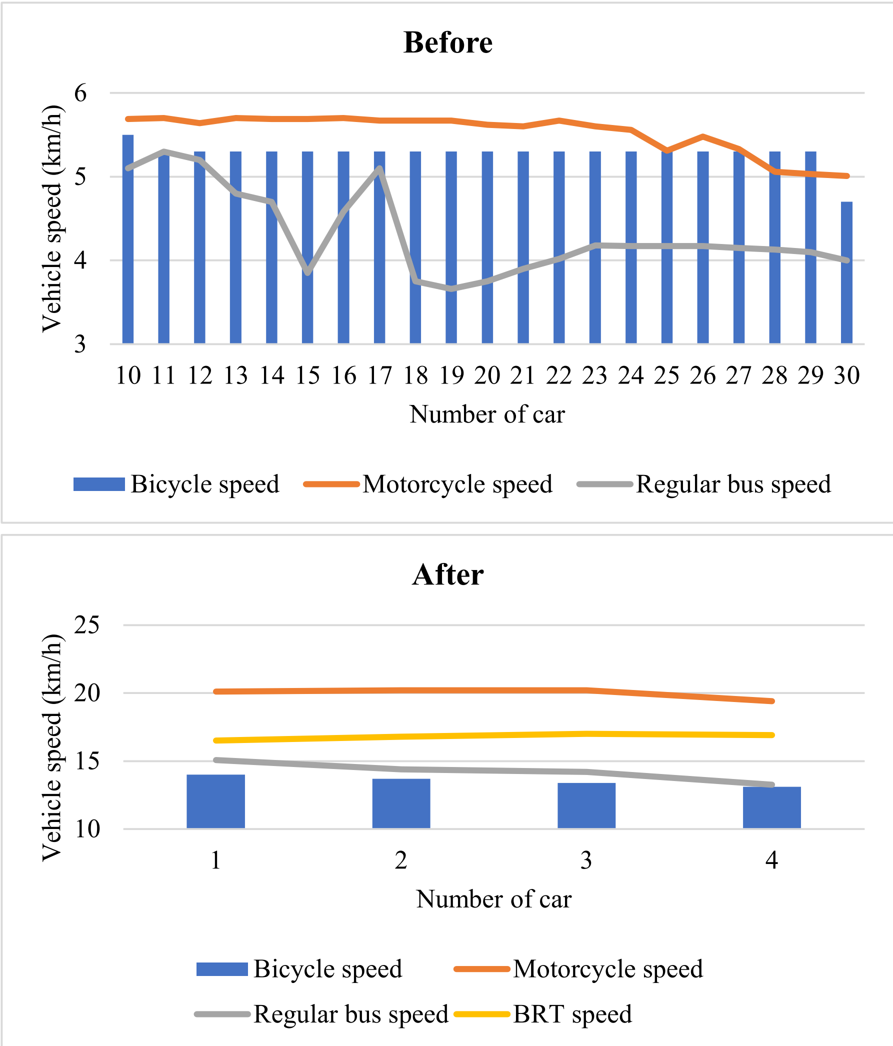

Figure 4.12: Relationship between the number of car and speed of other vehicles types in case 1

4.3.2. Case 2: Giang Vo street – mixed lane

Giang Vo street, Cat Linh Ward, Dong Da district – Giang Vo, Kim Ma ward, Ba Dinh district, Hanoi, Vietnam. It's 1,5 km long, from Nguyen Thai Hoc street, crossing the intersection Giang Van Minh – Cat Linh, passing Giang Vo Exhibition & Fair Center, until the junction of Lang Ha – La Thanh. The operational BRT design in this street is mixed traffic with other vehicles (Figure 4.13).

Figure 4.13: The operational BRT design in Giang Vo Street

1) Traffic volume

The data obtained in front of No. 21 station on Giang Vo Street are shown in Tables 4.10 and Table 4.11.

Table 4.10: The traffic volume of each vehicles before operating BRT in case 2 – Giang Vo Street (units/30 minutes)

Vehicle class	Morning	Afternoon	Evening
Bicycle	57	55	61
Motorcycle	5,824	2,890	5,003
Car	799	685	605
Regular bus	21	17	14
Total	6,701	3,647	5,683

Before operating BRT, this case has also congestion the same as case 1. The number of vehicles changes clearly in 3 periods: morning, afternoon and evening. The morning congestion is anticipated due to the large number of people from the suburbs who are concentrated in the city center for work. In this time, the number of motorcycles is 5,824 units, about 2 times that afternoon (2,890 units). Meanwhile, the phenomenon of afternoon congestion will appear in the opposite direction. In the checkout time, people from the company, the work center in the center will go home in the direction of going to the suburbs. In the evening, the number of motorcycles is 5,003 units, while the number of motorcycles in the evening is only 2,890 units. However, the number of cars did not change significantly between morning, afternoon and evening: 799 units in the morning, 685 units in the afternoon, 605 units in the evening (Table 4.10).

In the morning, motorcycles are the main traffic vehicle in traffic flow. The number of motorcycles occupies 87% (5,824 units), 102 times than the number of bicycles (57 units), 7.2 times than the number of cars (799 units). Although the number of motorcycles in the afternoon and evening has some changes compared with the morning, motorcycles are still the main traffic vehicle in traffic flow. In the afternoon, the number of bicycles is 2,890 units, occupy 79% of the number of total vehicles, 52.5 times than the number of bicycles (55 units) and 4.2 times than the number of cars (685 units). In the evening, motorcycles occupy 88% of the number of total vehicles (5,003 units), 82 times than the number of bicycles (61 units), and 8.2 times than the number of cars (605 units) (Table 4.10).

Table 4.11: The traffic volume of each vehicles after operating BRT in case 2 – Giang Vo Street (units/30 minutes)

Vehicle class	Morning	Afternoon	Evening
Bicycle	63	188	130
Motorcycle	2,543	1,695	2,943
Car	388	344	283
Regular bus	15	5	13
BRT	7	6	5
Total	3,016	2,238	3,374

After operating BRT, in the morning peak hours, the number of motorcycles decreases more than half of before operating BRT (5,824 units decrease to 2,543 units). However, motorcycles are still main traffic vehicle in traffic flow: occupy 84% of the total number vehicles, 43 times than the number of bicycles (63 units), 6.5 times than the number of cars. The number of cars also decrease, only 388 unit (decrease about 49% than before operating BRT). In the afternoon, the number of motorcycles occupies 75.7% of the total number vehicles (1,695 units), 9 times than the number of bicycles (188 units), 4.9 times than the number of cars (344 units). In the evening, the number of motorcycles occupies 87% of the total number vehicles (2,943 units), 22.6 times than the number of bicycles (130 units), and 10.4 times than the number of cars (283 units)

(Table 4.11).

The number of motorcycles has decreased by 56.34%, the number of cars by 51.44%, the total of all vehicles by 54.99% (Table 4.12). The reason for this change is due to the traffic organization was adjusted towards priority for the BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, banning taxis from Hanoi BRT route during peak hour, reducing the frequency of regular buses.

Table 4.12: The difference of traffic volume in case 2 after operating Hanoi BRT

Classification	Morning	Afternoon	Evening
Bicycle	10.53%	241.82%	113.11%
Motorcycle	-56.34%	-41.35%	-41.18%
Car	-51.44%	-49.78%	-53.22%
Regular bus	28.57%	-70.59%	-7.14%
BRT	-	-	-
Total	-54.99%	-38.63%	-40.63%

Table 4.13: The composition of cars in traffic flow in case 2 – Giang Vo Street (units/30 minutes)

		Before	After
Morning	**Total**	**799**	**388**
	Private car	659	388
	Taxi	140	0
Afternoon	**Total**	**685**	**344**
	Private car	503	225
	Taxi	182	119
Evening	**Total**	**605**	**283**
	Private car	495	283
	Taxi	110	0

Before operating BRT, in the morning: the number of cars include 659 units of private car and 140 units of taxi (total 799 units); in the afternoon: the number of cars include 503 units of private car and 182 units of taxi (total 685 units); in the evening: the number of cars includes 495 units of private car and 110 units of taxi (total 605 units). After operating BRT, in the morning: the number of cars include 388 units of private car and 0 units of taxi (total 388 units); in the afternoon: the number of cars include 225 units of private car and 119 units of taxi (total 344 units); in the evening: the number of cars includes 283 units of private car and 0 units of taxi (total 283 units) (Table 4.13).

2) Average speed

The average speed of each vehicle type before and after operating Hanoi BRT is shown in Tables 4.14 and Table 4.15.

Table 4.14: The average speed of each vehicle before operating BRT in case 2 – Giang Vo Street (km/h)

Vehicle class	Morning	Afternoon	Evening
Bicycle	14.85	16.27	15.27
Motorcycle	17.77	27.83	25.01
Car	27.11	35.12	33.66
Regular bus	22.70	32.48	31.75

Table 4.14 shows that before operating BRT, the first main vehicles in the traffic flow - motorcycles have an average speed of about 17.77 km/h. Cars are the second vehicles in the traffic flow that have an average speed of about 27.11 km/h. The average speed of bicycles is 14.85 km/h, and of regular buses is 22.7 km/h. The average speed of

motorcycles and cars in the afternoon and evening are improved than the morning. In the afternoon, the average speed of motorcycles is 27.83 km/h (increase 10.06 km/h), the average speed of cars is 35.12 km/h (increase 8.01 km/h), the average speed of regular buses is 32.48 km/h (increase 9.78 km/h). In the evening, the average speed of motorcycles is 25.01 km/h (increase 7.24 km/h), the average speed of cars is 33.66 km/h (increase 6.55 km/h), the average speed of regular buses is 31.75 km/h (increase 9.05 km/h). The average speed of bicycles does not change significantly between morning, afternoon and evening (14.85 km/h in the morning, 16.27 km/h in the afternoon, 15.27 km/h in the evening).

Table 4.15: The average speed of each vehicle after operating BRT in case 2 – Giang Vo Street (km/h)

Vehicle class	Morning	Afternoon	Evening
Bicycle	12.34	13.74	13.07
Motorcycle	15.41	27.38	22.71
Car	25.96	33.26	32.31
Regular bus	22.35	29.47	31.47
BRT	15.36	20.52	14.78

After operating BRT, the changes in this case are the opposite of the changes in case 1. While the average speed of all vehicles in location 1 increase, in this case the average speed of all vehicles decreases than before operating BRT. In the morning, the average speed of motorcycles is 14.41 km/h (decrease 2.36 km/h than before), the average speed of cars is 25.96 km/h (decrease 1.15 km/h than before). The average speed of all vehicles in the afternoon and evening also decrease 2-3 km/h than before operating BRT (Table 4.13).

3) Relationship between vehicle types

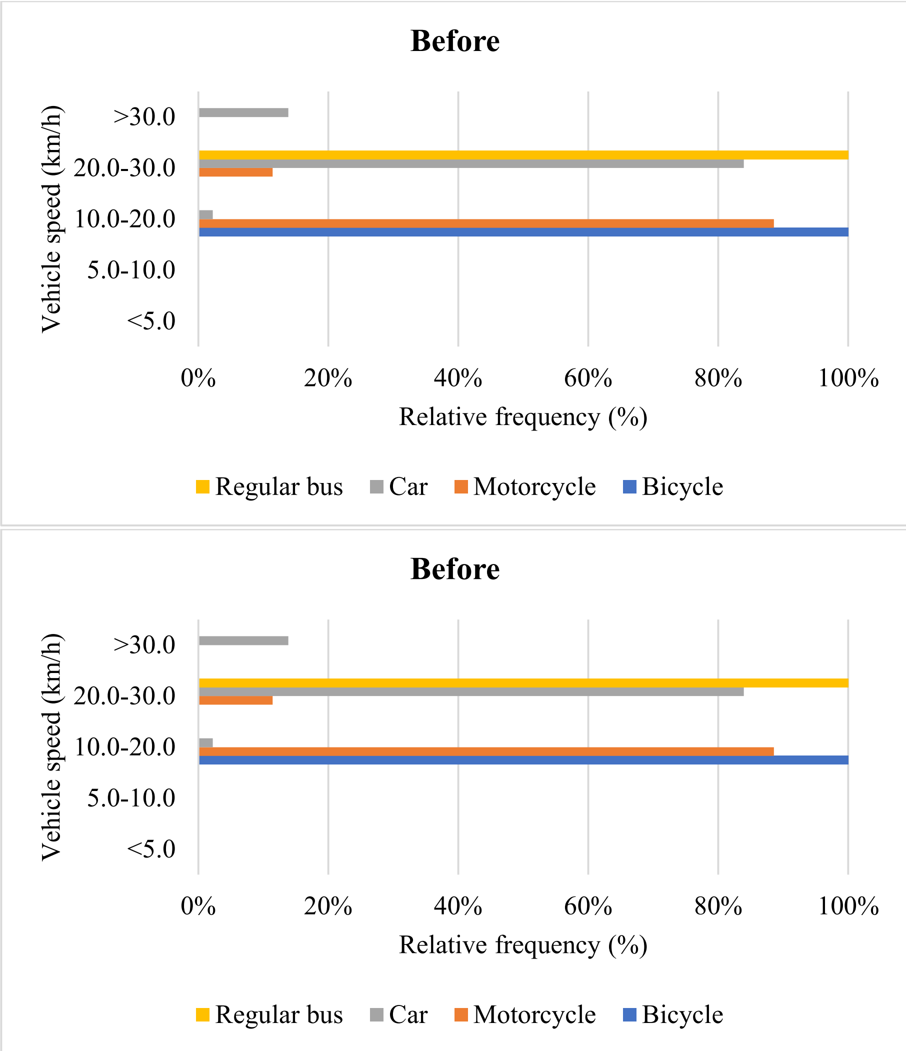

Figure 4.14: Relative frequency of speed of vehicle types in case 2

Both before and after operating BRT, the average speed of bicycles and motorcycles is always in the range of 10-20 km/h, the average speed of cars and buses ranges from 20-30 km/h (Figure 4.14). However, after operating BRT, the speed of both cars and motorcycles decreased. The reason is that the operation of the rapid buses means a reduction in available traffic area for other vehicles. Besides, the number of cars has been increasing rapidly also affected other vehicles. This relationship is shown in Figure 4.15.

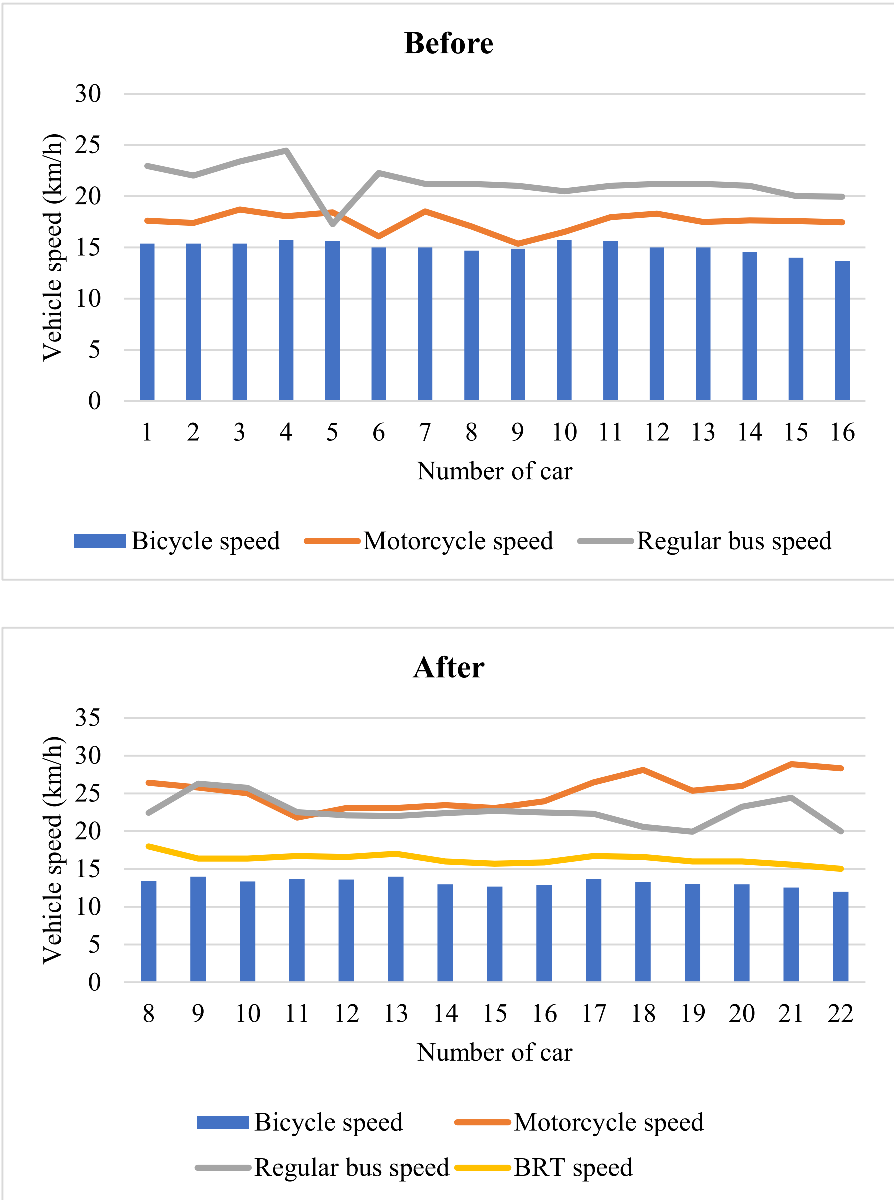

Figure 4.15: Relationship between the number of car and speed of other vehicles types in case 2

4.4. Conclusion

With the aim of giving priority to public transport, Hanoi has made efforts to create favorable conditions for rapid buses to effectively operate, contributing to less traffic congestion.

It was considered a breakthrough to develop the public transport system as well as raise public awareness of participating in the traffic. Creating favorable conditions for the new status of the vehicle to operate, as well as effectively connecting them with other vehicles, will encourage people to reduce personal vehicle usage. BRT gradually attracts more passengers to use this public vehicle.

However, many people using other means of transport have had mixed opinions regarding the rapid buses. The 14.7 km route starts at Kim Ma bus station and runs through Giang Vo, Lang Ha, Le Van Luong, To Huu, Le Trong Tan, Tran Phu, and Ba La streets, to Yen Nghia station. The streets have high vehicle density, so traffic jams have occurred frequently during rush hour; therefore, the operation of the rapid buses means a reduction in available traffic area for other vehicles. In addition, the traffic organization was adjusted towards priority for the BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, which caused severe traffic congestion.

Only a single BRT route cannot solve traffic congestion in the urban area, appropriate strategies to support BRT system development are necessary.

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CHAPTER V: STRATEGIC PLANS TO IMPROVE EFFECTIVENESS OF HANOI BRT

5.1. Introduction

Currently, Hanoi BRT operates inefficiently in Hanoi. The city had designated specific lanes for BRT buses, but their speeds failed to meet standards and often caused traffic congestion during peak hours (Figure 5.1). In 2018 to September, the BRT project had seen nearly 93,000 trips made with more than 3.7 million commuters. That means it served an average of 40 passengers per trip, while the standard capacity is 90 passengers per trip. An efficient BRT project should serve some 30,000-40,000 commuters per day, with a BRT bus departing every 3 - 5 minutes. The BRT project will likely incur continual losses if it maintains the current pace of operation. The reasons for failures included: institutional and legislative context; political leadership and commitment; management of competing modes; public participation; funding and coordination; physical design; image promotion, …

Figure 5.1: Hanoi BRT buses are unable to move fast during peak hours

(Source: http://english.vietnamnet.vn/fms/society/170657/hanoi-brt-bus-collides-with-car.html)

5.2. Purposes

This chapters purpose is finding solutions to improve the effectiveness of existing Hanoi BRT system and in the future. The simulation technique is used to reproduce the existing traffic situation. Then, different plans are considered for analyses of changes in traffic flow. These plans include:

- Changes in traffic composition: Ban motorcycles, migration from motorcycles to private cars;
- Changes in management measures: Create exclusive lanes for each vehicle types, route without signal.
- Increasing passengers using BRT: encourage motorcycle users to switch to using BRT

5.3. Methodology

5.3.1. Commonly used simulation models

1) AIMSUN

The car-following model used in AIMSUN is a safety distance model based on the model developed by Gipps (1981).

In Gipps car-following model, vehicles are classified as free or constrained by the vehicle in front. When constrained by the vehicle in front, the follower tries to adjust its speed in order to obtain safe space headway to its leader. A specific headway is considered safe if it is possible for the follower to respond to any reasonable leader action without colliding with the leader. When free, the vehicle's speed is constrained by its desired speed and its maximum acceleration. The maximum speed depends on acceleration as expressed in (5.1).

$$V_a(n,t+T) = V(n,t) + 2.5a(n)T \times \left(1 - \frac{V(n,t)}{V^*(n)}\right)\sqrt{0.025 + \frac{V(n,t)}{V^*(n)}} \quad (5.1)$$

where

$V(n,t)$ is the speed of vehicle *n* at time *t*;

$V^*(n)$ is the desired speed of vehicle n for the current section;

$a(n)$ is the maximum acceleration for vehicle n;

T is the reaction time (this is equal to simulation step).

The speed is also influenced by vehicle characteristics and the limitation imposed by the leader vehicle, as shown in (5.2).

$$V_b(n,t+T) = d(n)T + \sqrt{d(n)^2T^2 - d(n)\left(2\{x(n-1,t) - s(n-1) - x(n,t)\} - V(n,t)T - \frac{V(n-1,t)^2}{d'(n-1)}\right)} \quad (5.2)$$

where

$d(n)$	is the maximum deceleration desired by vehicle n;
$x(n,t)$	is the position of vehicle n at time t;
$x(n-1,t)$	is the position of preceding vehicle ($n-1$) at time t;
$s(n-1)$	is the effective length of vehicle ($n-1$);
$d'(n-1)$	is an estimate of the desired deceleration of vehicle ($n-1$).

2) PARAMICS

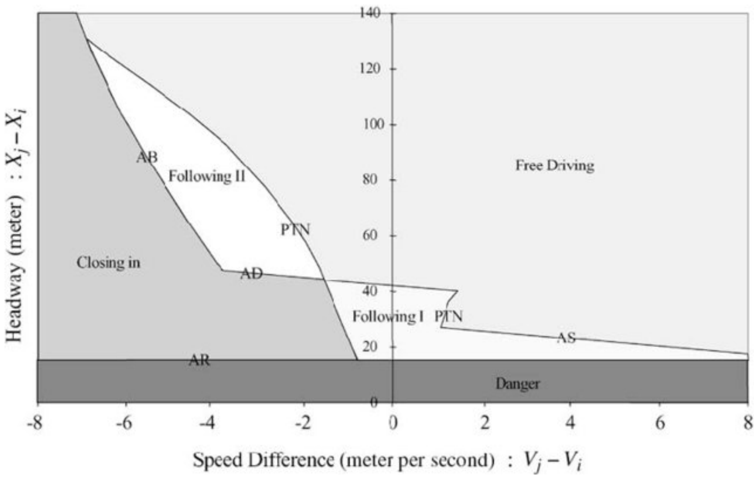

Figure 5.2: Car-following phase-space diagram[1)]

The acceleration model used in Paramics is based on the psycho-physical model developed by Fritzsche (1994). The basic concept is that the car-following plane is divided into five phases (or regions) representing different modes of car following as shown in Figure 5.2. This figure depicts a two-vehicle car-following case where the lead vehicle is traveling at 20 m/s. The five phases are denoted as: Following I, Following II, Danger, Closing In, and Driving Freely. These phases are determined using the following thresholds.

1) Perception-Threshold Negative (PTN) is defined as the negative relative speed of a pair of vehicles

$$PTN = -k_{PTN}(\Delta x - s_{n-1})^2 - f_x$$

$$PTN = -k_{PTN}(\Delta x - s_{n-1})^2 - f_x \tag{5.3}$$

where

k_{PTN} *and* f_x are model parameters

2) Perception-Threshold Positive (PTP) is defined as the positive relative speed of a pair vehicles.

$$PTP = k_{PTP}(\Delta x - s_{n-1})^2 + f_x \tag{5.4}$$

where

k_{PTP} *and* f_x are model parameters

3) Desired-Distance (AD) threshold represents a comfortable distance headway of the vehicles, which is related to speed of the follower vehicle.

$$AD = s_{n-1} + T_D . v_n$$

$$AD = s_{n-1} + T_D . v_n \tag{5.5}$$

where

T_D is a parameter representing the desired time gap

4) Risky-Distance (AR) threshold represents conditions when the distance headway is too close for comfortable driving.

$$AR = s_{n-1} + T_r . v_{n-1} \tag{5.6}$$

where

T_r is the risky time gap

5) Safe-Distance (AS) threshold represents conditions when a driver cannot decelerate quickly enough to avoid a risky situation, as defined by the risky distance threshold (AR).

$$AS = s_{n-1} + T_s . v_n \tag{5.7}$$

where

T_s is a model parameter

6) Braking-Distance (AB) threshold is an additional threshold used to avoid collisions that may occur because of higher speeds or late deceleration.

$$AB = AR + \frac{\Delta v^2}{\Delta b_m} \quad (5.8)$$

$$\Delta b_m = |b_{min}| + a_{n-1}^{-} \quad (5.9)$$

where

b_{min} and a_{n-1}^{-} are model parameters controlling maximum deceleration

Table 5.1 summarizes the conditions that govern the determination of the five regions of the car-following model.

Table 5.1: The conditions that govern the determination of the five regions

Phase	Response from Follower Vehicle (*i*)
Danger	$\Delta v \leq AR$ Action: Deceleration necessary
Closing in	$AR < \Delta x \leq AR$, and $\Delta x \leq \Delta v_{PTN}$ Action: Deceleration necessary
Following II	$\Delta x \leq \Delta v_{PTN}$, and $AD < \Delta x$ Action: None
Free Driving	$[\Delta v > \Delta v_{PTN}$, and $AD < \Delta x]$ or $[\Delta v > \Delta v_{PTN}$, and $AS < \Delta x]$ Action: Uninfluenced by leader vehicle
Following I	$[\Delta v_{PTN} < \Delta v < \Delta v_{PTP}$, and $AR < \Delta x < AD]$ or $[\Delta v \geq \Delta v_{PTN}$, and $\Delta x < AS]$ Action: None

3) VISSIM

VISSIM incorporate a car-following model based on the psycho-physical model suggested by Wiedemann. (PTV) The model was first presented in 1974 (Wiedemann, 1974) and has been continuously enhanced since then. The basic assumption in these models is that a driver can be in one of four driving states.

1) Free-driving state, where no influence is exerted from leading vehicles. In this state, the driver attempts to reach and maintain a desired speed.
2) Approaching state, when the driver of the follower vehicle consciously observes that she is approaching a slower vehicle in front.
3) Following state, where the headway for a pair of vehicles is between the maximum following headway and the safe headway. In this state, the follower vehicle can accelerate or decelerate in accordance with the vehicle in front.
4) Braking state, when the headway between vehicles drops below a desired safety distance.

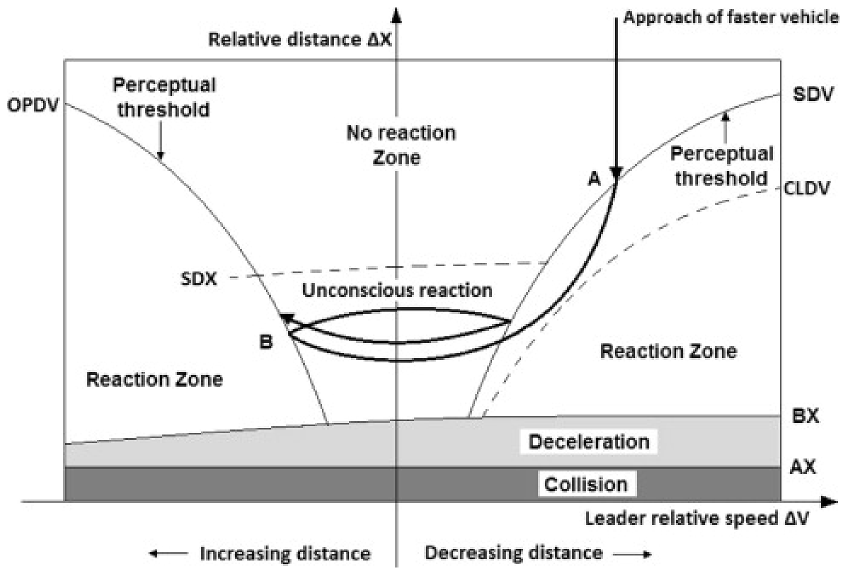

Figure 5.3: Car-following model by Wiedemann[2)]

The VISSIM traffic model comprises a psychophysical car-following model for longitudinal vehicle movement and a rule-based algorithm for lateral movements (lane changing). The car-following behavior switches from one mode to another according to predetermined perceptual threshold levels that form the basis of the psychophysical models. These thresholds are defined as a combination of speed and headway differences. In VISSIM, each river–vehicle unit is described as a driver–vehicle element (DVE). Figure 5.3 shows the interaction between two vehicles where DVE*j* is moving faster than and approaching a slower vehicle DVEi. Driver *j* begins to decelerate until an individual threshold, which is a function of acceptable speed difference and spacing, is reached. Driver j then maintains a speed at or below the current speed of DVEi, until other thresholds are reached, and the driver then accelerates again.

One of the challenges of a psychophysical model rests with the distributions of thresholds. Continuous measurements of different traffic conditions are required to calibrate the model in a realistic manner. The thresholds in Figure 5.3 are defined below. Driver-specific perception abilities and individual risk behavior is modeled by adding random values to each of the parameters.

AX	Desired distance between the front sides of two successive vehicles in a standing queue.
ABX	Desired minimum following distance, which is a function of *AX*, a safety distance, and speed.
SDV	Action point when a driver consciously observes approaching a slower vehicle. SDV increases with increasing speed differences. In the original work of Wiedemann, an additional threshold is applied to model additional deceleration by usage of brakes.
OPDV	Action point when drivers of follower vehicles notice that they are traveling slower than the leading vehicles and start to accelerate again.
SDX	Perception threshold to model the maximum following distance, which is about 1.5–2.5 times *ABX*.

The desired distance between stationary vehicles, *AX*. This threshold consists of the length of the front vehicle and the desired front to rear distance and is defined as:

$$AX = L_{n-1} + AXadd + RND1_n.AXmult \tag{5.10}$$

where *AXadd* and *AXmult* are calibration parameters. $RND1_n$ is a normally distributed driver dependent parameter.

The desired minimum following distance at low-speed differences, *ABX*. This threshold is calculated as

$$ABX = AX + BX\pi \tag{5.11}$$

$$BX = (BXadd + BXmult.RND1_n).\sqrt{v} \tag{5.12}$$

where *BXadd* and *BXmult* are calibration parameters. The speed *v* is defined as

$$v = \begin{cases} v_{n-1} \text{ for } v_n > v_{n-1} \\ v_n \text{ for } v_n \leq v_{n-1} \end{cases} \tag{5.13}$$

The approaching point, *SDV*. This threshold is used to describe the point where the driver notices that he or she approaches a slower vehicle. SDV is defined as

$$SDV = \left(\frac{\Delta x - L_{n-1} - AX}{CX}\right)^2 \tag{5.14}$$

$$CX = CXconst.\left(CXadd + CXmult.(RND1_n + RND2_n)\right) \tag{5.15}$$

where *CXconst, CXadd* and *CXmult* are calibration parameters.

The increasing speed difference, *OPDV*. This threshold describes the point where the driver observes that he or she is traveling at a lower speed than the leader. This threshold is defined as

$$OPDV = CLDV.(-OPDVadd - OPDVmult.NRND) \tag{5.16}$$

where *OPDVadd* and *OPDVmult* are calibration parameters. *NRND* is a normally distributed random number.

The maximum following distance, *SDX*. This distance varies between 1.5 and 2.5 times the minimum following distance, *ABX*. *SDX* is defined as

$$SDX = AX + EX.BX \tag{5.17}$$

$$EX = EXadd + EXmult.(NRND - RND2_n) \tag{5.18}$$

where *EXadd* and *EXmult* are calibration parameters. *NRND* is a normally distributed random number and $RND2_n$ is a normally distributed driver dependent parameter.

Free-driving state:

The vehicle is located above all thresholds in the state diagram, Figure 5.3, and travels uninfluenced of the surrounding traffic. The vehicle uses its maximum acceleration to reach its desired speed. When the desired speed is reached, inexact handling of the throttle is modeled by assigning an acceleration of – b_{null} or b_{null} to the vehicle. The maximum acceleration, $b_{\max}$, for passenger cars is defined as

$$b_{max} = BMAXmult.(v_{max} - v.FaktorV) \tag{5.19}$$

$$\text{FaktorV} = \frac{v_{max}}{v_{des} + FAKTORVmult.(v_{max} - v_{des})} \tag{5.20}$$

where

BMAXmult	is a calibration parameter
v_{max}	is the vehicles maximum speed
FAKTORVmult	is a calibration parameter

Approaching state:

When passing the *SDV* threshold, the driver notices that he or she is approaching a slower vehicle. The driver decelerates in order to avoid collisions. The following deceleration rate is used:

$$b_n = \frac{1}{2}.\frac{(\Delta v)^2}{ABX - (\Delta x - L_{n-1})} + b_{n-1} \tag{5.21}$$

where

b_{n-1} is the deceleration of the leader

Following state:

The thresholds *SDV*, *SDX*, *OPDV* and *ABX* constitute the following regime. In order to account for inexact handling of the throttle, vehicles acceleration rate is always assumed to always be separated from zero. When a vehicle passes into the following regime, passing either the *SDV* or the *ABX* threshold it is assigned the acceleration rate – b_{null} and when passing the thresholds *OPDV* or *SDX* it is assigned the acceleration b_{null}.

The acceleration or deceleration rate, b_{null}, is defined as

$$b_{null} = BNULLmult.(RND4_N + NRND) \tag{5.22}$$

where

BNULLmult is a calibration parameter

$RND4_n$ is a normally distributed driver parameter

NRND is a normally distributed random number

Braking state:

When the front to rear distance is smaller than *ABX* the follower adopts, if necessary, the following deceleration to avoid collision with the vehicle in front:

$$b_n = \frac{1}{2}.\frac{(\Delta v)^2}{ABX - (\Delta x - L_{n-1})} + b_{n-1} + b_{min}.\frac{ABX - (\Delta x - L_{n-1})}{BX} \tag{5.23}$$

The vehicle's maximum deceleration rate, b_{min}, is calculated as

$$b_{min} = -BMINadd - BMINmult.RND3_n + BMINmult.v_n \tag{5.24}$$

where

BMINadd is a calibration parameter

BMINmult is a calibration parameter

$RND3_n$ is a normally distributed driver parameter

5.3.2. Evaluation of the commonly used simulation models

The evaluation of car-following behavior reported in: *"Comparative Evaluation of Microscopic Car-Following Behavior"* [1], *"Comparison of Car-Following models"*[2].

The paper *"Comparative Evaluation of Microscopic Car-Following Behavior"* [1] used an error metric (EM)on distance as a key performance measure. The distance to the leader vehicle observed in the field (d_f) was compared to the values obtained from each traffic simulator (d_s). To avoid overrating on discrepancies for large distance, the EM was weighted by logarithm and squared, as shown below:

$$EM = \sqrt{\sum \left(\log \frac{d_s}{d_f} \right)^2} \tag{5.25}$$

where

d_s is the simulated car-following distance to the leader vehicle at simulation time t

d_f is the field car-following distance to the leader vehicle at time t

In paper *"Comparison of Car-Following models"*[2)], three models have been implemented in MATLAB. Each model's follower equation has then been allowed to act on the same driving course of events of an artificial leader. The outcome of the experiment is then for all four models the follower's driving course of events when constrained by the same leader. The following driving course of events of the leader – follower pair was implemented: The leader started to drive with constant speed, 20 m/s, the follower was given a front to rear distance of 28 m to the leader and the same initial speed as the leader. After 40s, the leader started to decelerate with a rate of 2 m/s^2. The deceleration lasted for 2s. After an additional time of 18s, the leader started to accelerate with a rate of 2 m/s^2. In similar fashion as the previous deceleration; the acceleration lasted for 2s. Both the deceleration and acceleration of the leader was implemented as simple steps, that is, in the time step before the action the leader's acceleration rate was zero and in the next time step the acceleration rate was immediately changed to 2 m/s^2.

The EM on distance was used as the key performance indicator. The results showed similar EM values for the psychophysical spacing models used in Vissim and Paramics with better values reported for the Gipps-based models implemented in Aimsun. Vissim and Paramics model inexact throttle control by applying a small acceleration or deceleration rate to the follower at every time step in the following regime. This has one side effect; the follower switches regimes even if the leader drives at constant speed, ... the follower changes its behavior without any action from the leader. Vissim’s and Paramics’s approach might make the resulting microscopic driving course of events closer to those observed in real traffic.

Table 5.2: Comparison of some commonly used simulation models

	VISSIM	PARAMICS	AIMSUN	CORSIM	SIMTRAFFIC	HUTSIM	TEXAS	WATSIM	INTEGRATIO N
Characteristic									
BEHAVIOR MODELING									
Parameterized gap-acceptance model	yes	yes	yes	yes	yes	yes	yes	yes	yes
Parameterized lane-changing model	yes	yes	yes	yes	yes	yes	yes	yes	yes
Parameterized car-following model	yes	yes	yes	yes	yes	yes	yes	yes	yes
Parameterized turn speed	yes	no	no	no	yes	no	yes	no	no
Reaction to yellow	by drive, by vehicle	by drive	yes	by type	by type		by drive, by vehicle	by type	
Variable driver reaction time	no	yes	yes	no	no	planned	yes	no	no
Intersection box movements	yes	yes	yes	yes	yes		yes	yes	no
Variable acceleration /deceleration rate	yes	yes	yes	yes	yes	yes	yes	yes	yes
sight distance limits	yes	no	no	yes		yes	yes		no
Rolling yield	yes	yes	yes	yes	yes		yes	yes	
Vehicles interact with pedestrians	yes	yes	yes	implicit	yes	yes	no	implicit	no
Friendly merging	yes	ramps only	ramps only	yes	no		no	no	no
Multi-lane merging	yes	yes	no	no	no		no	no	
Intersection right-of-way	yes	yes	yes	yes	yes	yes	yes	yes	
Maneuver failure recording	possible	possible	possible	possible	possible	possible	yes	possible	no
Parking maneuvers	yes	yes	no	yes	no		no	no	no
Turn signal modeling	no	no	no	no			no	no	no
U-turns	yes	yes	yes	no	yes		yes		
Driveways at the intersection corners	yes	yes	no	no	no	no	no	no	no

5.3.3. PTV Vissim – input parameter values

1) PTV Vissim

PTV Vissim 8.0 was used to perform the simulations in this research. This is software developed by PTV AG (Germany) for traffic analyses. It consistently models all road users and their interactions and has become a recognized standard in the field of transport planning. PTV Vissim is used to model transport networks and travel demand, to analyze expected traffic flows, to plan public transport services and to develop advanced transport strategies and solutions. The software offers flexibility in several respects: the concept of links and connectors allows users to model geometries with any level of complexity. Attributes for driver and vehicle characteristics enable individual parameterization.

Vehicles are moving in the network using a traffic flow model. The quality of the traffic flow model is essential for the quality of the simulation. In contrasts to simpler models in which a largely constant speed and a deterministic car following logic are provided, Vissim uses the psycho-physical perception model developed by Wiedemann (1974). The basic concept of this model is that the driver of a faster moving vehicle starts to decelerate as he reaches his individual perception threshold to a slower moving vehicle. Since he cannot exactly determine the speed of that vehicle, his speed will fall below that vehicle's speed until he starts to slightly accelerate again after reaching another perception threshold. There is a slight and steady acceleration and deceleration. The different driver behavior is taken into consideration with distribution functions of the speed and distance behavior.

PTV Vissim is not just a basic traffic simulation software; it is an advanced software package that is based on decades of intensive research, continuous development and close networking with customers. You have access to a stable simulation tool that always incorporates the latest findings from research and practice and that sets new standards.

- Allows simulation of movement in many different applications and use cases
- Inbuilt scenario functionality to manage projects with multiple design options, future forecasts or vehicle characteristics
- In-built pedestrian, cyclists, and vehicles simulation in a single software platform.
- Detailed representation of geometry and individual vehicle behavior models to allow realistic localized conditions to be replicated
- Flexible API's to allow customization and interfaces to external software packages for advanced applications.

PTV Vissim is already deployed in over 2,500 cities worldwide and has already become the standard for traffic simulation in many countries.

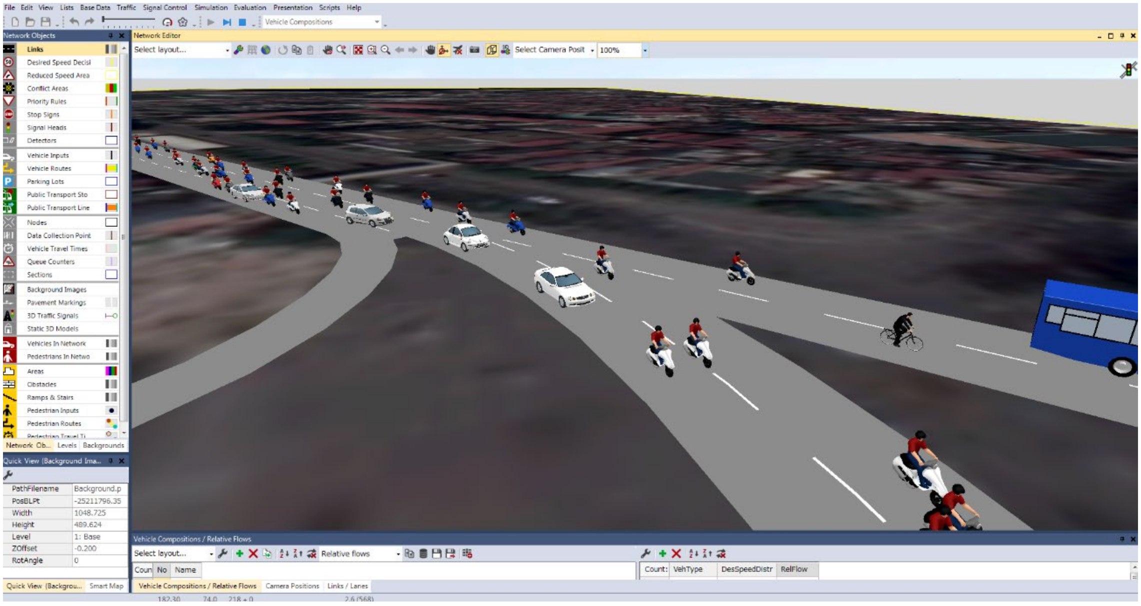

Figure 5.3: An excerpt image of simulation

PTV Vissim is widely used software in many studies of public transport systems such as BRT. "Calibration of Vissim for Bus Rapid Transit Systems in Beijing Using GPS Data"[1)]: This paper presents an approach for calibrating the microscopic traffic simulation model VISSIM using GPS data for application to Beijing BRT.

"Capacity Analysis of Bhopal BRTS using Empirical and Simulation Model"[2)]: The main objective of this study is to estimate the BRT bus lane capacity. The estimation of bus lane capacity was carried out by considering the empirical and micro simulation model. In micro simulation, a model of Bhopal BRT transitway was developed in VISSIM simulation software. "Modelling and Simulation of Cooperative Control for Bus Rapid Transit Vehicle Platoon in a Connected Vehicle Environment"[3)]: The aim of this paper is to develop a cooperative control model for improving the operational efficiency of Bus Rapid Transit (BRT) vehicles. An actual signalized intersection along the Guangzhou BRT corridor is employed to verify and assess the cooperative control model in various traffic conditions. And the microscopic traffic simulation software VISSIM5.2 is used as the traffic simulation environment…

2) Input parameter values

The parameters used in the simulation are expressed below:

- Network parameter

  Number of lanes: 3

  Lane width: 3.5 m

- Traffic parameter

  Traffic volume: 6,032 units/hour

  Traffic composition: bicycles 2.09%, motorcycles 84.32%, cars 12.86%, regular buses 0.5%, BRT buses 0.23%

- Vehicle parameter

  Desire speed (min - max): bicycles (10 – 20 km/h), motorcycles (15 – 40 km/h), cars (25 – 65 km/h), regular buses (20 – 60 km/h), BRT bus (15 – 50 km/h)

- Driving behavior parameter

  Lane change: Free Lane Selection

  Min. headway: 0.5 m

  Look ahead distance: minimum 0.0 m, maximum 100.0 m

  Overtake on same lane: bicycles, motorcycles, cars, regular buses

  Vehicles can overtake on a lane to the right and left

- Signal controller parameter

  Red light: 45s, Green light: 60s, Amber light: 3s, Turn right on red

5.4. Analysis of traffic situation using micro simulation

Table 5.3 shows average simulated speed of all vehicles was collected through modeling

Table 5.3: Average speed of each vehicle in simulation and real data (km/h)

Classification	Simulated data	Real data
Bicycle	14.00	12.34
Motorcycle	15.89	15.41
Car	17.61	25.96
Regular bus	22.13	22.35
BRT	14.67	15.36

Cars and buses show a simulated speed faster than the simulated speeds of the motorcycles, just as in the collected data through recording.

5.4.1. Plan 1: Migration from motorcycles to private cars plan

Hanoi - a city of over 5 million motorcycles - is planning on banning the popular two-wheeled transport by 2030. The city council voted for the ban almost unanimously, hoping to unclog roads and reduce soaring levels of pollution. The council has also promised to increase public transport so that half the population are using it by 2030, instead of the current 12%. The limitation on motorcycles is aimed at reducing traffic congestion, economic damage, travel times and costs for residents, and minimizing environmental pollution. The move is expected to reduce the number of traffic accidents, contribute to the city’s sustainable development and improve residents’ quality of life.

Under the proposal, before terminating motorbike traffic altogether, the capital’s authorities will restrict the areas they can enter. Permitted areas will be required to have appropriate infrastructure and meet standards for public transportation services. The Transport Development and Strategy Institute under the Ministry of Transport also said that due to differences in the capabilities of the public transit system in various districts, the ministry will initially select areas to restrict and move towards an outright motorbike ban in Hanoi by 2030.

In this plan, different cases are considered for analyses. These cases include the influence of future changes in vehicle composition and changes in motorcycle volume. This plan considers simply the change in traffic composition, keeping the total traffic volume constant (Table 5.3).

Table 5.4: Changes in vehicle composition

Classification	Existing situation	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Bicycle	2.09%	2.09%	2.09%	2.09%	2.09%	2.09%	2.09%
Motorcycle	84.32%	0%	10%	20%	30%	40%	50%
Car	12.86%	97.4%	87.4%	77.4%	67.4%	57.4%	47.4%
Regular bus	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
BRT	0.23%	0.23%	0.23%	0.23%	0.23%	0.23%	0.23%

The results of each cases are expressed in Table 5.3

Table 5.5: Average speed of each cases (km/h)

Classification	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Existing situation
Bicycle	15.21	14.34	15.78	15.11	13.8	13.91	14
Motorcycle		18.8	17.42	17.43	17.19	15.9	15.89
Car	25.35	24.18	21.43	20.9	19.86	18.01	17.61
Regular bus	15.21	22.75	13.19	13.67	14.57	20.29	22.13
BRT	16.54	16.48	15.57	21.47	17.78	19.09	14.67
All vehicles	25.08	23.51	20.34	19.58	18.57	16.87	16.32

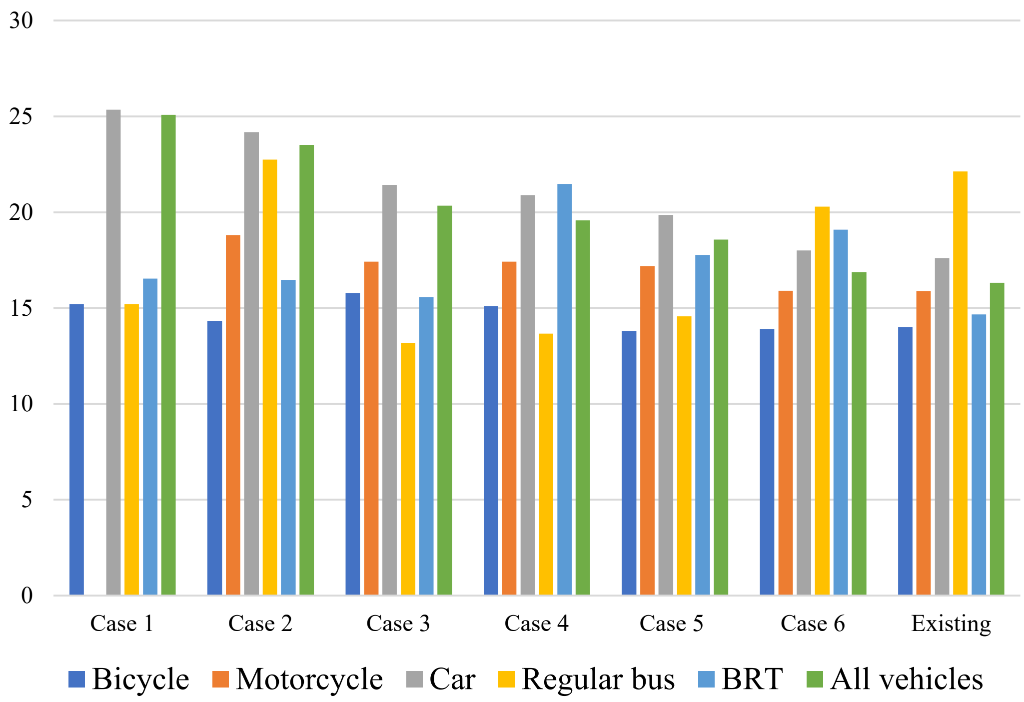

Figure 5.4: Comparing all of vehicle's average speed in each case

The comparing analyses of the average speed among the existing situation and the other cases show that the decrease in the motorcycle volume in will generate an increasing in the average speed for all types of vehicles (Figure 5.4). These changes are explained in

Table 5.6: The speed difference from existing situation

Classification	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Bicycle	8.64%	2.42%	12.71%	7.92%	-1.42%	-0.64%
Motorcycle		18.31%	9.62%	9.69%	8.18%	0.06%
Car	32.59%	37.30%	21.69%	18.68%	12.77%	2.27%
Regular bus	-31.26%	2.80%	-40.39%	-38.22%	-34.16%	-8.30%
BRT	12.74%	12.33%	6.13%	46.35%	21.19%	30.12%
All vehicles	53.67%	44.05%	24.63%	19.97%	13.78%	3.37%

5.4.2. Plan 2: No traffic light route

A traffic light is just a tool for drivers on one road to communicate with drivers on another, poorly and coarsely. Red equals don't go now, we are coming through the intersection.

Stuck at an intersection, you always watch unfold the fundamental problem of traffic. On green signal, the first car accelerates, and then the next, and then the next, and then the next, and then you, only to catch the red. Had the cars accelerated simultaneously you would have made it through. Until signal turn red, the driver who sees it brakes a little, the driver behind him doesn't notice immediately and brakes a little harder than necessary, the driver behind him does the same until someone comes to a complete stop and cars approaching at high way speeds must now stop as well.

After all, just as with the highway, the best intersection is no intersection.

This plan considers the change in management measures and changes in traffic composition. The changes in traffic composition are same as plan 1: 6 cases with motorcycle volume reduce from 50% to 0%.

The results are calculated and expressed in Table 5.7

Table 5.7: Average speed of each cases without traffic light (km/h)

Classification	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Existing situation
Bicycle	14.63	15.76	13.66	14.61	15.47	14.21	15.18
Motorcycle		18.1	16.89	16.97	16.73	16.18	17.25
Car	26.13	22.48	20.09	19.29	18.97	18.35	18.86
Regular bus	27.14	24.43	20.09	17.02	22.98	14.62	17.67
BRT	20.91	16.49	21.08	21.22	20.85	18.65	19.54
All vehicles	25.85	22.06	19.28	18.29	18.08	17.15	17.53

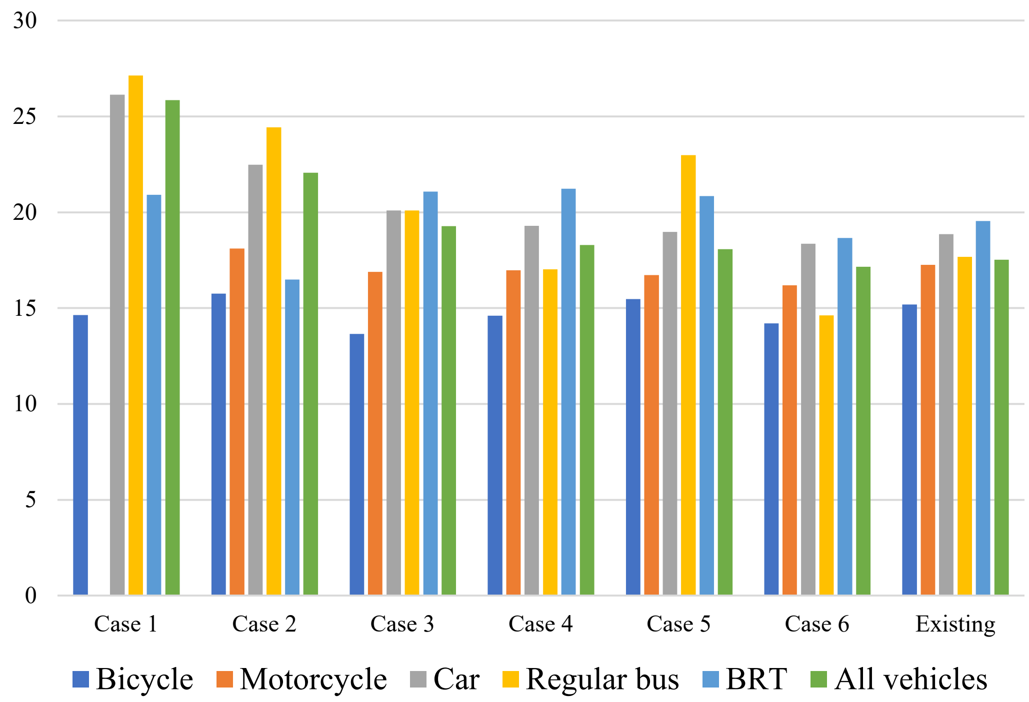

Figure 5.5: Comparing all of vehicle's average speed in no traffic light plan

As it can be seen in Figure 5.5, the average speed decreases when the motorcycles volume increases while cars volume decreases. Thus, if present trend continues, it is likely that traffic problems, mainly congestion, will increase.

The speed difference between plans in plan 1 and plan 2 are showed below.

Table 5.8: Summary of speed difference between plan 1 and plan 2

Classification	Case 1		Case 2		Case 3		Case 4		Case 5		Case 6		Existing situation	
	Plan 1	**Plan 2**	**Plan 1**	**Plan 2**	**Plan 1**	**Plan 2**	**Plan 1**	**Plan 2**	**Plan 1**	**Plan 2**	**Plan 1**	**Plan 2**	**Plan 1**	**Plan 2**
Bicycle	15.21	14.63	14.34	15.76	15.78	13.66	15.11	14.61	13.8	15.47	13.91	14.21	14	15.18
Motorcycle			18.8	18.1	17.42	16.89	17.43	16.97	17.19	16.73	15.9	16.18	15.89	17.25
Car	25.35	26.13	24.18	22.48	21.43	20.09	20.9	19.29	19.86	18.97	18.01	18.35	17.61	18.86
Regular bus	15.21	27.14	22.75	24.43	13.19	20.09	13.67	17.02	14.57	22.98	20.29	14.62	22.13	17.67
BRT	16.54	20.91	16.48	16.49	15.57	21.08	21.47	21.22	17.78	20.85	19.09	18.65	14.67	19.54
All vehicles	25.08	25.85	23.51	22.06	20.34	19.28	19.58	18.29	18.57	18.08	16.87	17.15	16.32	17.53

5.4.3. Plan 3: Increasing passengers using BRT

The first BRT project in the capital city of Hanoi has failed to fulfill 50% of its designed capacity two years after its debut. So how will the traffic situation change when the number of passengers using BRT increases?

This section will study and show the change in speed of each vehicle types when motorcycles users switch to use BRT. BRT capacity will be increased from 50% to 100% (Table 5.9)

Table 5.9: Change in BRT passengers and vehicle composition

BRT capacity	**Existing (50%)**	**Case 1 (60%)**	**Case 2 (70%)**	**Case 3 (80%)**	**Case 4 (90%)**	**Case 5 (100%)**
Bicycle	2.09%	2.14%	2.19%	2.23%	2.29%	2.34%
Motorcycle	84.32%	84.18%	83.84%	83.48%	83.10%	82.70%
Car	12.86%	13.17%	13.46%	13.76%	14.07%	14.40%
Regular bus	0.50%	0.51%	0.52%	0.53%	0.54%	0.56%
BRT	0.23%	0.24%	0.24%	0.25%	0.25%	0.26%

The results are calculated and expressed in Table 5.10

Table 5.10: Average speed of each cases (km/h)

BRT capacity	**Existing (50%)**	**Case 1 (60%)**	**Case 2 (70%)**	**Case 3 (80%)**	**Case 4 (90%)**	**Case 5 (100%)**
Bicycle	14	11.75	13.95	14.8	11.68	14.95
Motorcycle	15.89	15.74	15.77	15.6	15.85	15.19
Car	17.61	17.76	19.09	18.4	12.31	16.12
Regular bus	22.13	19.06	13.5	13	12.31	16.12
BRT	14.67	16.91	18.43	17.7	18.91	18.13
All vehicles	16.32	16.08	16.29	16	16.1	15.67

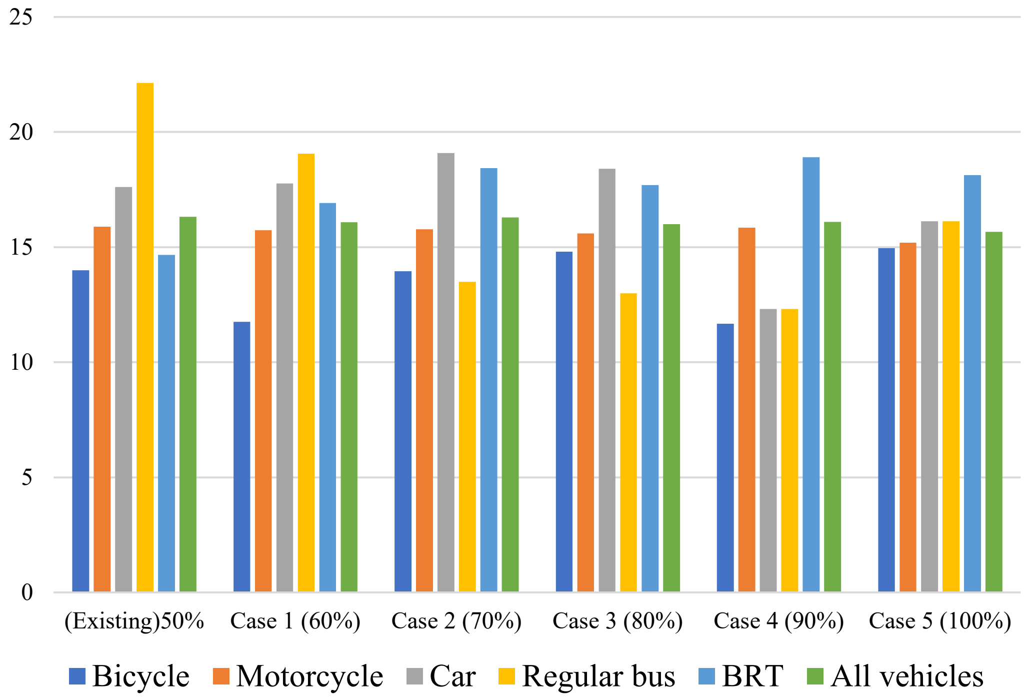

Figure 5.6: Comparing all of vehicle's average speed when increasing BRT capacity

Through Table 5.9 and Figure 5.6, there is not much change in the speed of each vehicle. Only speed of car and BRT is increased, while other vehicles are almost unchanged or reduced.

With the current large traffic volume even if BRT runs at full capacity, it has not been able to reduce traffic congestion in Hanoi.

5.5. Conclusion

Mixed traffic flow is the important problem now, not only in Vietnam, but also in almost developing countries. With the mix traffic flow, we must consider many problems in traffic control and traffic safety, especially in the cases of some countries that private vehicle ownership increases very quickly.

Through micro simulation technique, it showed that the presence of high number of motorcycles in the network interferes the flow of other vehicles, reducing their average speed drastically. Besides that, the traffic behavior depends on the traffic state. In fact, in uncrowded traffic, vehicles run independently and do not affect each other. But in crowded traffic, vehicles in each flow do not follow the lane and they influence the flow of other vehicles.

Hanoi is one of the motorcycle cities with the high rate in traffic flow is motorcycle. Therefore, the traffic behavior in here also has many special features that we need to understand more. With the expansion of the city, there are many changes in the traffic flow from suburb to the center; therefore, the changes are not only in the traffic volume but also in the traffic components, from that, the behavior and interactions between vehicles in the flow also changes. If the number of buses increases, the traffic problems, like congestion and low speed, will increase. Especially in the morning when traffic vehicle from suburb goes into the city center.

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CHAPTER VI: CONCLUSION

6.1. Existing public transport system in Hanoi

6.2. Impacts of Hanoi BRT to traffic situation

6.3. Some suggestions to improve Hanoi BRT

The BRT systems in the case study cities were curtailed due to a combination of reasons. The institutional setup was too complex to coordinate and implement this type of project. Local transportation agencies were cast in past roles and purposes which they were unable and/or unwilling to change. In some cases, the selection of the first corridor was ineffective. While most projects had the support and commitment of a high-level politician or party (at least part of the way), they did not amass the necessary political pull and popular goodwill to push the project forward within a short time before the novelty effect wore off. Partly this owes to feeble promotional and communication efforts targeting potential users and stakeholders, but also to opposition based on political affiliation rather than concern for the city. However, the key barriers to BRT are not the same in all cases. Because the BRT concept is multifaceted, the balance of issues varies from place to place depending on context. In a qualitative review such as this, it is impossible to quantify the weight of each factor for comparison purposes.

6.1. Existing public transport system in Hanoi

Compared with mass transportation means such as subway, BRT, conventional buses are somewhat less transportable. However, with narrow traffic environment and space in many areas of Hanoi, buses are seemingly more suitable. Along with the implementation of measures to limit private vehicles, regulating traffic demand; building and promoting the development of public transport is also one of the basic solutions to reduce environmental pollution, air pollution due to traffic jams. In addition, some solutions are set up for specific research, such as the congestion charge, the system consists of tolls at access points around the central city which charge varying fees to incentivize public transport – or at least not car use – during peak hours; set up a scheme on collection of environmental pollution charges for various types of land-road traffic means according to the levels of waste gas on circulation; to raise parking charges per hour or per area from suburban areas to the center of the city to limit parking in inner city. At the same time, scrutinize, closely inspect, resolutely handle and recover used vehicles in contravention of regulations; Review regulations on restrictions and licensing of transport vehicles in the inner city.

The Hanoi Peoples Committee has approved the project "Strengthening the management of land-road traffic means in order to reduce traffic congestion and environmental pollution in Hanoi, 2017-2020, vision till 2030". However, the current problem is the construction of overhead trains or subway is very expensive and complex. Moreover, not in every area nor any route can these types be built. BRT requires very strict operating conditions such as private lane, priority signaling system, etc... Meanwhile, conventional buses have the advantage of reaching most residential areas, operating condition required is only on an average level. On the other hand, for great modes of transportation, each trip can accommodate thousands, millions of visitors and transport them to the station or transit points. The conventional bus becomes the force to release quite many passengers. Thus, whether there is an addition of subway, BRT or any other means, conventional buses will still be the main public passenger transport force of Hanoi. In order to meet the forthcoming requirements, Hanois conventional bus needs detailed, scientific planning; this should be accompanied by practical measures to improve service quality with the support of advanced technology to develop buses into smart, accessible and environmentally friendly modes of transportation. This is the solution to create a new look for urban of Vietnam, the urban that worth living in with transport system properly planned and sustainably developed.

6.2. Impacts of Hanoi BRT to traffic situation

With the aim of giving priority to public transport, Hanoi has made efforts to create favorable conditions for rapid buses to effectively operate, contributing to less traffic congestion.

It was considered a breakthrough to develop the public transport system as well as raise public awareness of participating in the traffic. Creating favorable conditions for the new status of the vehicle to operate, as well as effectively connecting them with other vehicles, will encourage people to reduce personal vehicle usage. BRT gradually attracts more passengers to use this public vehicle.

However, many people using other means of transport have had mixed opinions regarding the rapid buses. The 14.7 km route starts at Kim Ma bus station and runs through Giang Vo, Lang Ha, Le Van Luong, To Huu, Le Trong Tan, Tran Phu, and Ba La streets, to Yen Nghia station. The streets have high vehicle density, so traffic jams have occurred frequently during rush hour; therefore, the operation of the rapid buses means a reduction in available traffic area for other vehicles. In addition, the traffic organization was adjusted towards priority for the BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, which caused severe traffic congestion.

Only a single BRT route cannot solve traffic congestion in the urban area, appropriate strategies to support BRT system development are necessary.

6.3. Some suggestions to improve Hanoi BRT

Mixed traffic flow is the important problem now, not only in Vietnam but also in almost developing countries. With the mix traffic flow, we must consider many problems in traffic control and traffic safety, especially in the cases of some countries that private vehicle ownership increases very quickly.

Through the microsimulation technique, it showed that the presence of the high number of motorcycles in the network interferes the flow of other vehicles, reducing their average speed drastically. Besides that, the traffic behavior depends on the traffic state. In fact, in uncrowded traffic, vehicles run independently and do not affect each other. But in crowded traffic, vehicles in each flow do not follow the lane and they influence the flow of other vehicles.

Hanoi is one of the motorcycle cities with a high rate in traffic flow is a motorcycle. Therefore, the traffic behavior in here also has many special features that we need to understand more. With the expansion of the city, there are many changes in the traffic flow from suburb to the center; therefore, the changes are not only in the traffic volume but also in the traffic components, from that, the behavior and interactions between vehicles in the flow also changes.

Therefore, to increase the effectiveness of the BRT system, should consider the BRT support measures. The two options outlined in this study are:

- Limit the number of motorcycles accessing BRT routes during peak hours;
- Limit traffic signals at the intersection, giving priority to traffic flow on the BRT route.

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