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THE CHANGES OF TRAFFIC FLOW ON FIRST BUS RAPID TRANSIT ROUTE IN HANOI, VIETNAM

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ABSTRACT

The first Bus Rapid Transit system finally opened on December 31, 2016, ten years after the planning started. With funding and consultant of the World Bank, Bus Rapid Transit was expected to be a solution to solve traffic jams in Hanoi. However, its services operate inefficiently in Hanoi. It has failed to fulfill 50% of its designed capacity two years after its debut. Although Bus Rapid Transit was assessed to be a failure, it still has some influence on Hanoi traffic. This paper will compare the changes in traffic flow before and after operating on Bus Rapid Transit in Hanoi through two surveys was done in front of two Bus Rapid Transit stations.

KEYWORDS: *Bus Rapid Transit, Traffic Jam, Public Transportation*

Article History

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INTRODUCTION

As in other developing cities, now Hanoi must deal with many problems such as disorderly urbanized city, traffic jam, popular 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. Hanoi will have 6.1 million motorbikes 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.

The Hanoi Bus Rapid Transit (Hanoi BRT) 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. Currently,

Hanoi BRT operates inefficiently in Hanoi. It has failed to fulfill 50% of its designed capacity two years after its debut. In 2018 to September, the Hanoi 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.

The city had designated specific lanes for Hanoi BRT buses, but their speeds failed to meet standards and often caused traffic congestion during peak hours (Figure1). The BRT project will likely incur continual losses if it maintains the current pace of operation.

Figure 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)

Although Bus Rapid Transit was assessed to be a failure, it still has some influence on Hanoi traffic. This paper will compare the changes in traffic flow before and after operating on Bus Rapid Transit in Hanoi through two surveys was done in front of two Bus Rapid Transit stations.

METHOD

Data Collection

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

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 case.

Table 1: Overview of Survey

	Contents
Time	September 2016 and February 2017 Survey time period: morning, afternoon, evening
Location	No. 17 station (separated traffic) No. 21 station (mixed traffic) 2016: before operating Hanoi BRT 2017: after operating Hanoi BRT

Survey Location

Two locations were chosen to record videos (Figure 2). These are high traffic density locations on the BRT route - a major route linking the Western area to the old center of Hanoi:

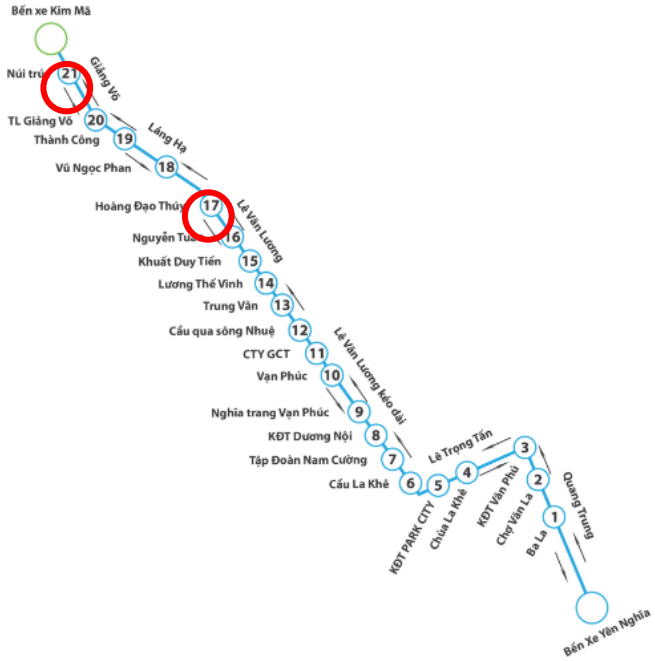

Figure 2: Survey Locations on Hanoi BRT Route (Source: Http://Www.Hanoibrt.Vn)

Location 1: 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 Hanoi BRT design in this street is separated from other vehicles (Figure 3).

Figure 3: In Front of No. 17 Station on Le Van Luong Street

Location 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).

Figure 4: In Front of No. 21 Station on Giang Vo Street

Survey Time Periods

The videos were created at three different periods: morning, afternoon, evening on September 2016 and February 2017. September 2016 was three months before HanoiBRT came into operation, February 2017 is two months after HanoiBRT came into operation.

In the morning: Almost schools and companies are begun at 8 a.m. Therefore, the morning is the peak hours period. It takes place from 6:30 a.m. to 8:30 a.m. The videos were recorded from 7:00 a.m. to 7:30 a.m.

In the afternoon: This is not peak hours; traffic volume is low. All the traffic vehicles can run with free speed. The videos were recorded from 0:00 p.m. to 0:30 p.m.

In the evening: The activities of companies and schools finish at about 4:30 p.m. Therefore, this is also the peak hours period. Peak hours period takes place from 5:00 p.m. to 7:00 p.m. The videos were recorded from 5:00 p.m. to 5:30 p.m.

Data Collection

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

Collecting data from analyzing each frame

A 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 (ti) (Figure 5). Average speed by the time is calculated by the formula:

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

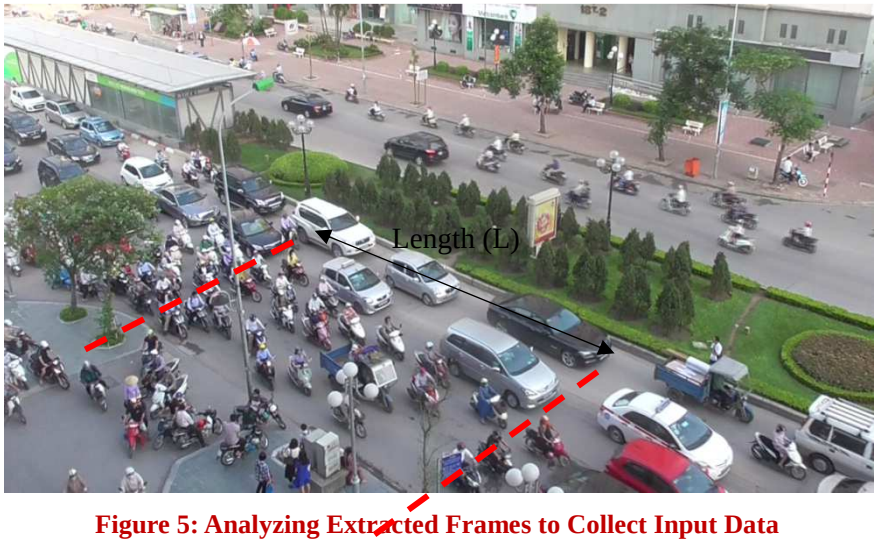

Figure 5: Analyzing Extracted Frames to Collect Input Data

Data Analysis

After having the input data, some functions are used to analysis comparison traffic situation in each case.The probability density function is used to show the speed of motorcycles and cars.In probability theory, a probability density function, or density of a continuous random variable, is a function whose value at any given sample (or point) in the sample space (the set of possible values taken by the random variable) can be interpreted as providing a relative likelihood that the value of the random variable would equal that sample. The probability density function is used to specify the probability of the random variable falling within a particular-range of values. This probability is given by the integral of this variable's PDF over that range.

Maxwell–Boltzmann distribution is used to show a relationship between density and speed of motorcycles. Maxwell–Boltzmann distribution was first defined and used for describing particle speeds in idealized gases, where the particles move freely inside a stationary container without interacting with one another, except for very brief collisions in which they exchange energy and momentum with each other or with their thermal environment.

In Figure 6, when a temperature is low (a = 1), the mean of particle speeds is low, and their variance is small. As temperature progressively increases (a = 2, a = 5), a salient transition is that both the mean and the variance of particle speeds increase accordingly. This is the relationship between temperature and speed of a particle in gases that is captured by Maxwell–Boltzmann distribution.

Similarly, if considered a means of transport is a particle, we can see idealized gases and vehicle traffic have the feature in common. When a temperature/density variable evolves, the distribution of the particle speed/vehicle speed variable changes accordingly. However, the changes in a traffic vehicle are opposite to a particle. When density (k) is low, a speed of a vehicle (v) will be fast. And when density is higher, speed will become slower.

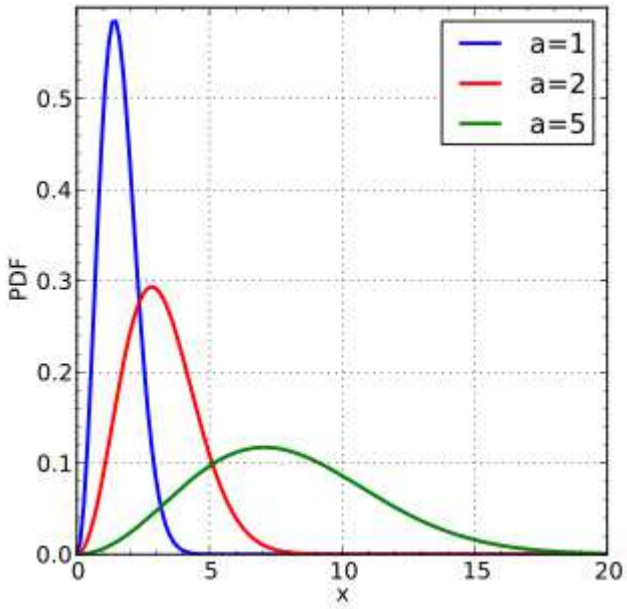

Figure 6: Maxwell–Boltzmann Distribution (Source: Https://En.Wikipedia.Org)

RESULTS

Location 1: In front of No. 17 station (separated traffic)

The collected data about traffic volume of each vehicle in location 1 was shown in table 2:

Table 2: The Traffic Volume of Each Vehicle before and After Operating Hanoi BRT in Location 1(Units/30 Minute)

Vehicle classification		Bicycle	Motorcycle	Car	Regular bus	BRT	Total
Morning	Before	32	7,935	1,560	10	-	9,537
	After	42	4,753	465	9	8	5,277
Afternoon	Before	12	1,980	630	14	-	2,636
	After	82	2,381	677	6	6	3,152
Evening	Before	85	3,540	570	18	-	4,213
	After	190	4,284	480	8	6	4,968

Before operating Hanoi BRT, motorcycles are the 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), and 5 times the number of cars (1,560 units). In the afternoon and evening, the number of motorcycles decreases 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 - check out time, the number of motorcycles occupies 84.03% (3,540 units), 41.6 times than the number of bicycles, 6.2 times than the number of cars (Table 2).

After operating Hanoi BRT, the composition of traffic flow changes clearly. In the morning, although motorcycles still dominate in traffic flow 90% (4,753 units), 113 times than the number of bicycles (42 units), 10.22 times than the number of cars (465 units). But the number of motorcycles is 0.6 times than before operating Hanoi 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) (Figure 7, 8 & 9).

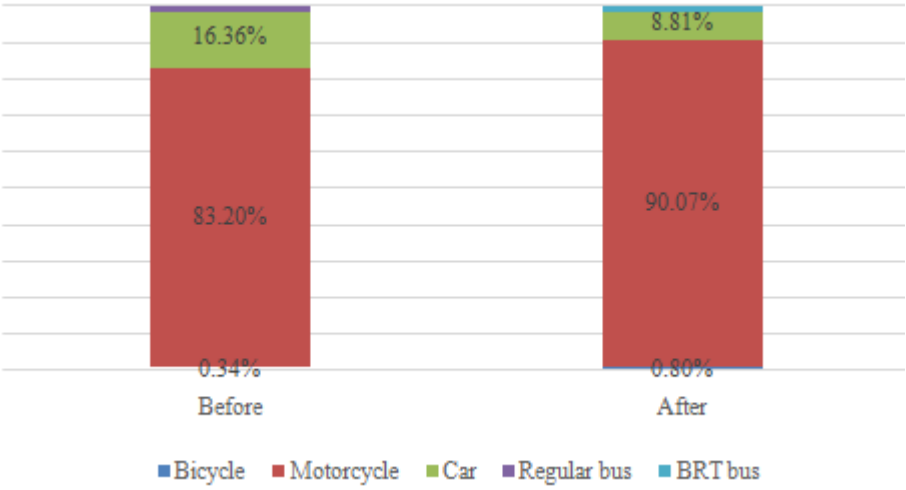

Figure 7: The Vehicle Composition Before and After Operating BRT in the Morning (Location 1)

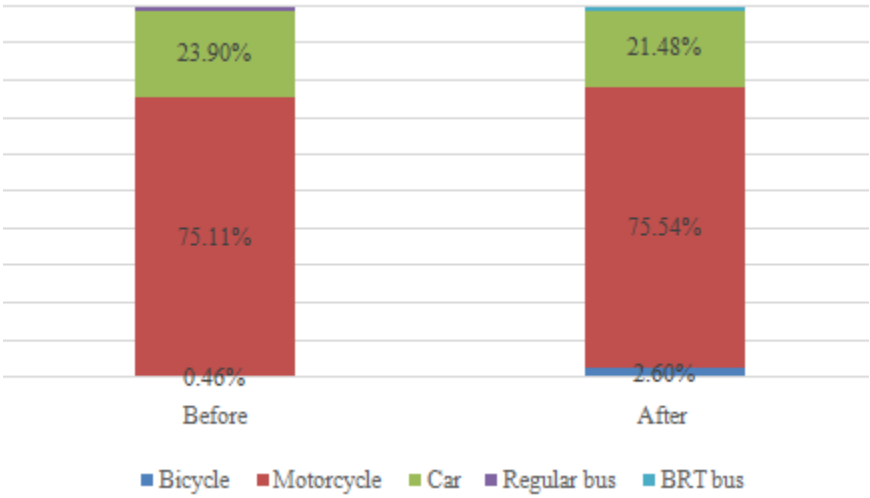

Figure 8: The Vehicle Composition Before and After Operating BRT in Afternoon (Location 1)

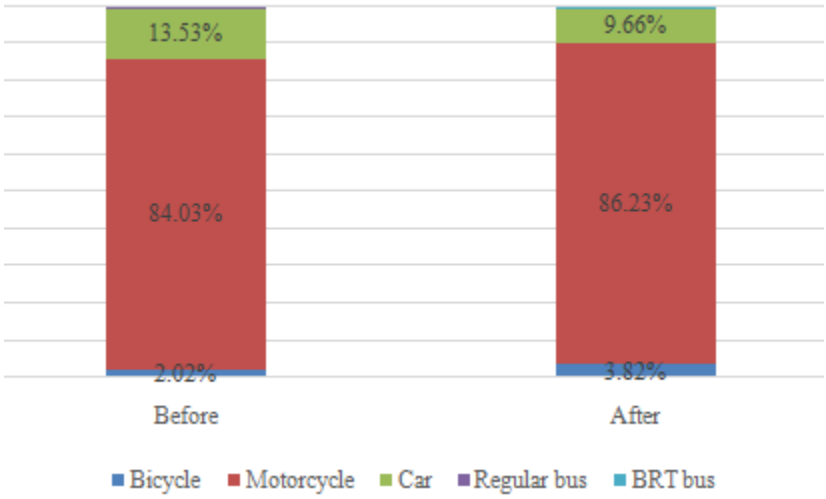

Figure 9: The Vehicle Composition Before and After Operating BRT in Evening (Location 1)

Base on Figure7, 8 & 9, we can see that after operating Hanoi 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. This is due to the change in the type of cars allowed to participate in traffic during peak hours.The traffic organization was adjusted towards priority for theHanoi BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, which caused severe traffic congestion. Taxis were also prevented from going throughHanoi BRT route from 6 am to 9 am and from 4:30 pm to 7 pm every day.

Table 3: The Composition of Cars in Traffic Flow in Location 1

		Before	After
Morning	Total	1,560	465
	Private car	1,431	465
	Taxi	129	0
Afternoon	Total	930	677
	Private car	414	513
	Taxi	216	164
Evening	Total	570	480
	Private car	378	480
	Taxi	192	0

Before operating Hanoi 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 HanoiBRT, 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 3).

Through the image processing technique, the speed of each vehicle is obtained from the calculated coordinates of the vehicles (Table 4).

Table 4: The Average of Each Vehicle before and After Operating Hanoi BRT in Location 1(Km/H)

Vehicle Classification		Bicycle	Motorcycle	Car	Regular Bus	BRT
Morning	Before	5.32	5.44	4.77	3.97	-
	After	13.56	20.08	14.41	14.23	16.80
Afternoon	Before	14.78	31.74	30.48	25.62	-
	After	14.68	30.47	32.15	28.31	27.36
Evening	Before	14.45	30.31	33.71	22.52	-
	After	15.74	25.07	17.33	17.56	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 operatingHanoi 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. Because the afternoon is not peak hours, the average speed of all vehicles is not much change compared with before operatingHanoi BRT.

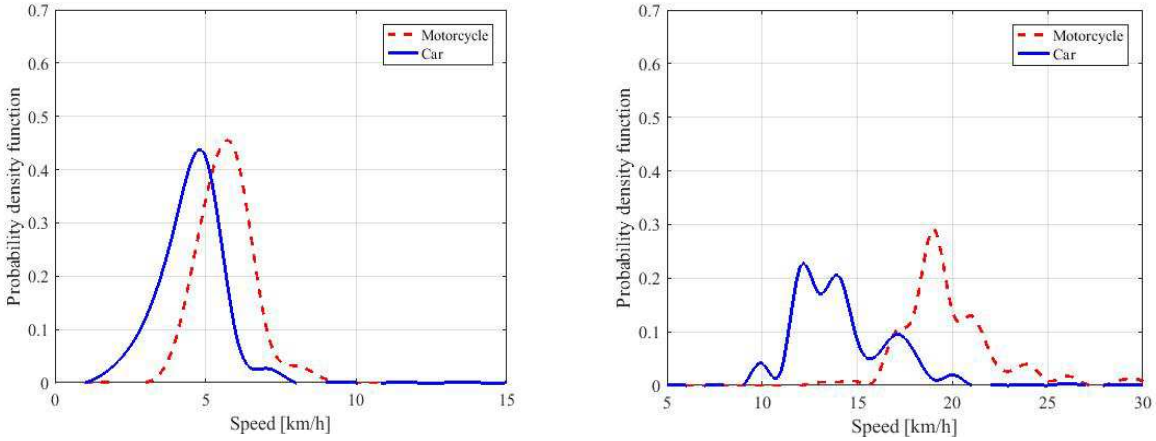

Figure 10: Calculated Density of Speed of Motorcycles and Cars in the Morning before and After Operating Hanoi BRT (Location 1)

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 in the flow of other vehicles. They are expressed as probability density in Figure10.Figure 11 shows the probability density of motorcycle speed at corresponding density k.

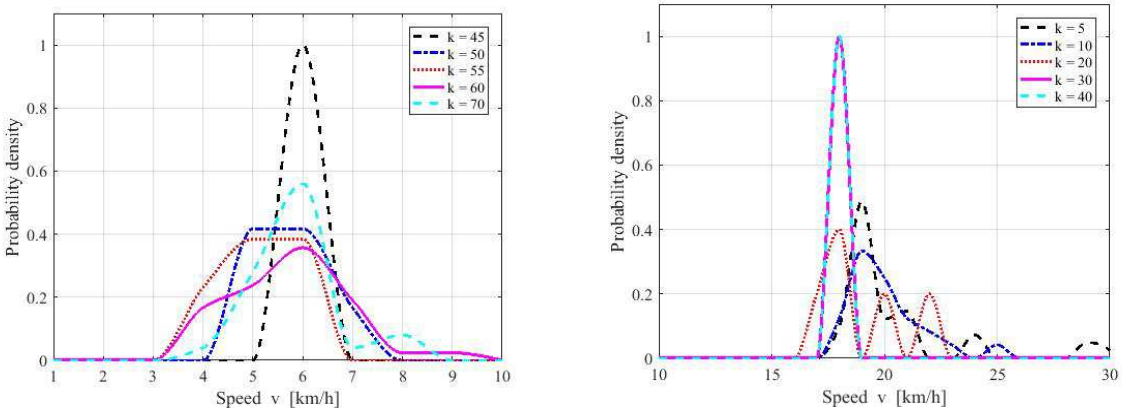

Figure 11: Probability Density of Motorcycle's Speed at Different Densities K in the Morning before After Operating Hanoi BRT (Location 1)

Location 2: In front of No. 21 station (mixed traffic)

The collected data about traffic volume of each vehicle in location 2 was shown in table5:

Table 5: The Traffic Volume of Each Vehicle before and After Operating Hanoi Brt in Location2 (Units/30 Minute)

Vehicle Classification		Bicycle	Motorcycle	Car	Regular Bus	BRT	Total
Morning	Before	57	5,824	799	21	-	6,701
	After	63	2,543	388	15	7	3,016
Afternoon	Before	55	2,890	685	17	-	3,647
	After	188	1,695	344	5	6	2,238
Evening	Before	61	5,003	605	14	-	5,683
	After	130	2,943	283	13	5	3,374

Before operating Hanoi BRT, this location has also congestion the same as location 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 5).

After operating Hanoi BRT, in the morning peak hours, the number of motorcycles decreases more than half of before operating Hanoi 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 HanoiBRT). 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), 10.4 times than the number of cars (283 units) (Figure 12, 13 & 14).

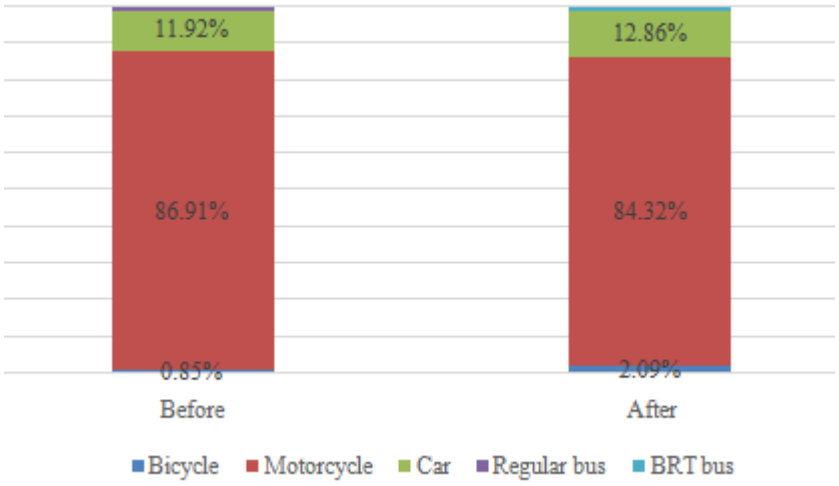

Figure 12: The Vehicle Composition Before and After Operating BRT in the Morning (Location 2)

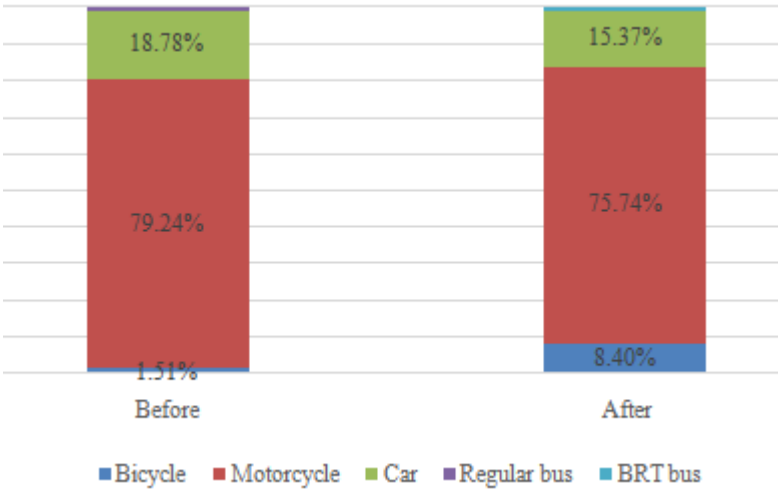

Figure 13: The Vehicle Composition Before and After Operating BRT in the Afternoon (Location 2)

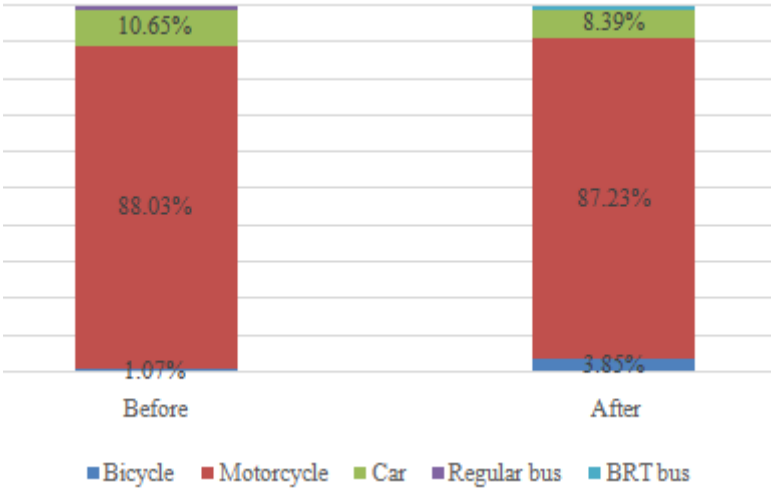

Figure 14: The Vehicle Composition Before and After Operating BRT in the Evening (Location 2)

Same as location 1, the traffic organization in location 2 was adjusted towards priority for the Hanoi BRT, restriction of other vehicles to turn left and banning them from traveling on overpasses during the rush hour, which caused severe traffic congestion. Taxis were also prevented from going through Hanoi BRT route from 6 am to 9 am and from 4:30 pm to 7 pm every day.

Table 6: The Composition of Cars in Traffic Flow in Location 2

		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 Hanoi 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 Hanoi 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 6).Through the image processing technique, the speed of each vehicle is obtained from the calculated coordinates of the vehicles (Table 7).

Table 7: The Average of Each Vehicle before and After Operating Hanoi BRT in Location2 (Km/H)

Vehicle Classification		Bicycle	Motorcycle	Car	Regular Bus	BRT
Morning	Before	14.85	17.77	27.11	22.70	-
	After	12.34	15.41	25.96	22.35	15.36
Afternoon	Before	16.27	27.83	35.12	32.48	-
	After	13.74	27.38	33.26	29.47	20.52
Evening	Before	15.27	25.01	33.66	31.75	-
	After	13.07	22.71	32.31	31.47	14.78

Table 7 shows that before operating HanoiBRT, 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).After operating Hanoi BRT, the changes, in this location, is the opposite of the changes in location 1. While the average speed of all vehicles in case 1 increase, in this case, the average speed of all vehicles decreases than before operating Hanoi 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 Hanoi BRT.

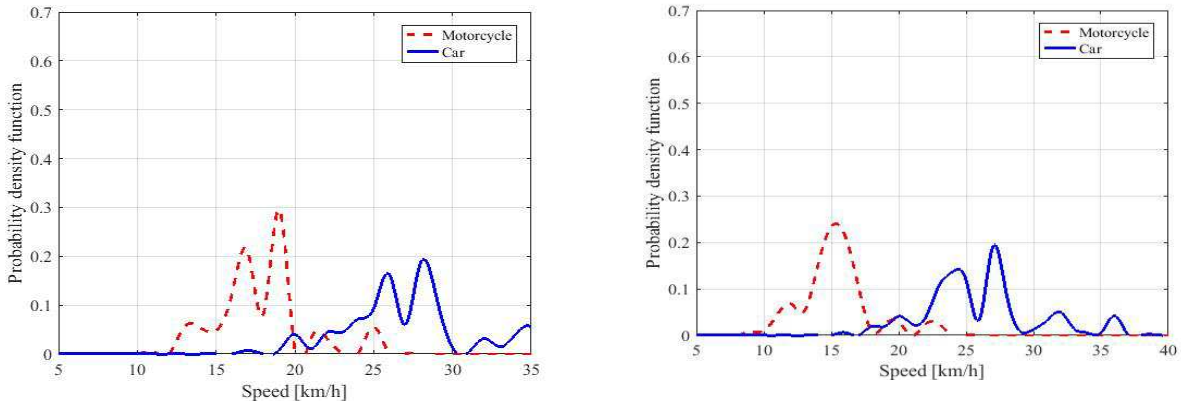

Figure 15: Calculated Density of Speed of Motorcycles and Cars in the Morning before and After Operating Hanoi BRT (Location 2)

In the morning after operating Hanoi BRT, motorcycles still have a lower speed compared with cars. The average speed for all types of vehicles is lower than before operating Hanoi BRT. They are expressed as probability density in Figure 15.Figure 16 shows the probability density of motorcycle speed at corresponding density k

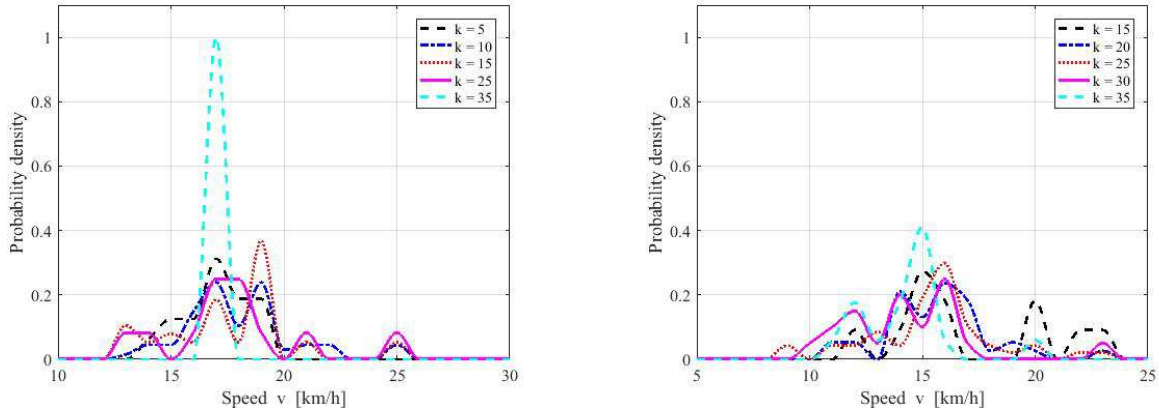

Figure 16: Probability Density of Motorcycle's Speed at Different Densities K in the Morning before After Operating Hanoi BRT (Location 2)

CONCLUSION

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 travelling on overpasses during the rush hour, which caused severe traffic congestion.

Only a single BRT route cannot solve traffic congestion in the urban area. However, 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.

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. BRT gradually attracts more passengers to use this public vehicle.

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