

Developing a Toolbox for Calculating Motorcycle Emission and the Difference of CO₂ from Motorcycle for Each Type of Road in Hanoi

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Abstract—Number of motorcycle in Hanoi increase year by year, it lead to various problems especially pollution. How to calculated motorcycle emission which can be reflex road condition and individual behavior become very necessary. With major aim to develop toolbox can calculate motorcycle emission which can be reflex current situation in Hanoi, The relationship of motorcycle emission and power will be applied. By using global position system (GPS) data to calculate power, toolbox can be automatic clean error, cut trips and calculated motorcycle emission by each trip. On the other hand, by dividing trips for each type of road in Hanoi, this research also has comparisons the difference of motorcycle speed, CO₂ emission and also the impact of peak hour on each type of road. This studies tents to make some analysis for people deeply understanding the current situation of motorcycle emission in Hanoi.

Index Terms—GPS, motorcycle emission, Hanoi, toolbox.

I. INTRODUCTION

Hanoi, the capital city of Vietnam, located in the right bank of the Red River. It comprises one town, 10 urban districts and 18 rural districts with an area of 3,344,7 square kilometers (km²) and a total population of 6,913,161 peoples (Vietnam statistics 2010). According to Vietnam register organization, number of motorcycle in Hanoi until the end of 2009 is 3.6 million units with average 15% [1] annual increasing and private transport mode accounts for over 90% of daily passenger trip [2]. With such growth rates, the total number of cars and motorbikes taken together in Hanoi is expected to reach 2,939,800 units by 2010 and 7,107,720 in 2020, not talking into account the number of car and motorbikes used in Hanoi, but registered in other provinces (Institute of Meteorology and Environment Science, 2007). Both now and in the coming years, motorbikes will be the primary means of transport for the in habitants of Hanoi. Motorbikes constitute a major emission source of CO. As a result, in the future, this means of transportation will produce a serious pressure on Hanoi's air quality.

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According Hanoi Traffic Police Bureau 2010, the number of transportation vehicle especially motorcycle increased rapidly and concentrated in big city such as Ho Chi Minh and Hanoi. For example, in 2000, the total number of motorcycle is nearly 800 000 but in 2009, amount of motorcycle increase more than 4 times (nearly 3.6000.000).

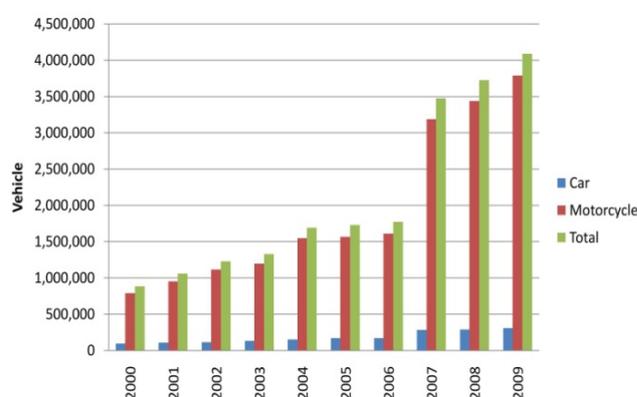


Fig. 1. Vehicle in Hanoi 2000-2009

Sources: Hanoi Traffic Police Bureau (2010)

Nowadays, global position system (GPS) is very popular in Vietnam especially in Hanoi. Motorcycle usage also tent to use GPS for tracking location and safety increase day by day. Therefore, if data could be used to calculate motorcycle emission, the government would be able to control emission from motorcycle by each individual. On the other hand, individuals who own motorcycle equipped GPS device, would utilize data recorded to know emission, distance, time of their trips and optimize their route choice.



Fig. 2. Setup GPS for motorcycle

To exploit effectively of GSP capability, this study attempts to make a GPS toolbox that can easily calculate motorcycle emission based on an improved method and also can extract all information about trips by using MATLAB (Graphical user interface). This method can reflect traffic condition by using data recorded second by second. After that, new software will be created base on MALAB Compiler

with the aim of assisting all residents in easily using and getting information about their trips by themselves.

On the other hand, all trips collected will be divided by route and calculate the average speed and carbon dioxide of motorcycle user in Hanoi.

II. LITERATURE REVIEW

To date, several studies on motorcycle emission inventory in Hanoi have been conducted. For example, in 2005, Swiss-Vietnamese Clean Air Program (SVCAP) suggested a specific project for the generation of emission factor using SIM-air (Simple Interactive Model for Better Air Quality) [2]. However, the emission levels were derived based on the information collected from other Asian countries and the US since there was no related information available in Hanoi. In 2008, Kim Oanh and Thuy conducted a study focusing on the derivation of motorcycle emission inventories for Hanoi [1]. Nevertheless, the emission factors and speed adjustment factors used in the International Vehicle Emission (IVE) model were based on the “Los Angeles Route Four” (LA4) driving cycle. In 2010, Tung et al. developed the emission factor and emission inventories using “Centre for Environmental Monitoring Motorcycle Driving Cycle” (CEMDC) which resulted from 10 routes of motorcycles running in the urban areas of Hanoi [3]. Limitation of this study is that it does not reflect the influence of traffic congestion and cover rural areas and so on in Hanoi.

Currently, GPS software is very popular in the world. There is a lot of software which can identify and view trips in Google map. For example TRAVTIME, it can analyze GPS data collected from probe vehicles carrying a GPS logging device. However, in the situation of Hanoi which has various problems in traffic, behavior of road users is quite different from other cities. Therefore, it is difficult to identify trips accurately. On the other hand, until now, there has been no software which can deal with automatically identifying trips, cutting trips and calculating emission for motorcycles.

III. METHODOLOGY

Methodology of this research shows in Fig. 3:

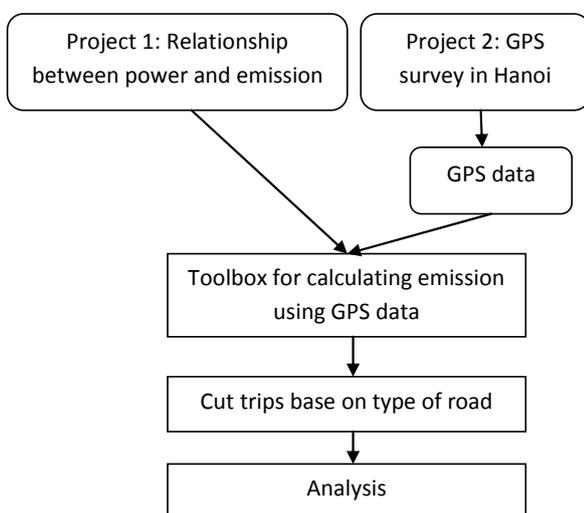


Fig. 3. Methodology

The first, toolbox for calculating motorcycle emission will be created by using relationship between power and emission with two functions: automatic calculate and cut trips by manual by identify start and stop point using “Time machine X” software.

A. Survey

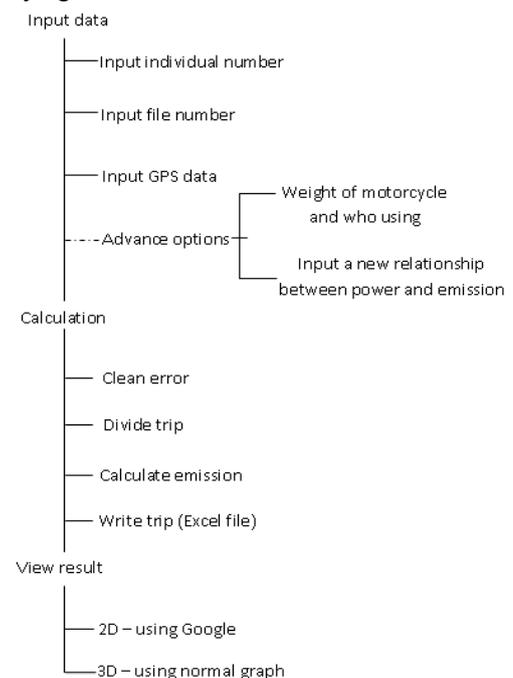
The major aim of the project was to provide a basic tool that allows novices to control basic hardware used for calculation motorcycle emission in Hanoi without limiting the power and flexibility of the underlying programming language. Therefore, we used MATLAB GUI (graphical User Interface) to make a program.

With the aim of using GPS data to calculate emission from motorcycle, the second project was conducted in Hanoi in 2011 by recruiting 65 people who only used motorcycles. In the project, these 65 persons were asked to bring GPS devices all the times outside of their homes over a week. Based on the collected all data, we make a toolbox for GPS data which can identify motorcycle trips, cut trips and calculate emissions.

Data collected in a household trip diary survey in Hanoi will be used. In that survey, information related to socio-economic of household and each respondent (> 15 year olds), vehicle information were collected. Each respondent was asked to fill in a trip diary which records all trips they make during one week in detail and to bring a GPS device in all their activities. All respondents who use motorcycles as main mode will be filtered out for examining motorcycle emission.

B. Toolbox for Calculating Motorcycle Emission

Four core functions are developed in the MATLAB toolbox: data cleaning, dividing trips, emission calculation and displaying results



1) Data cleaning

GPS data will be cleaned in two steps: the first step, by

cont the total time lost of signal, if GPS lost signal in less than one minute, we assume this point like previous point. On the other hand, if GPS lost signal more than one we separated into 2 data.

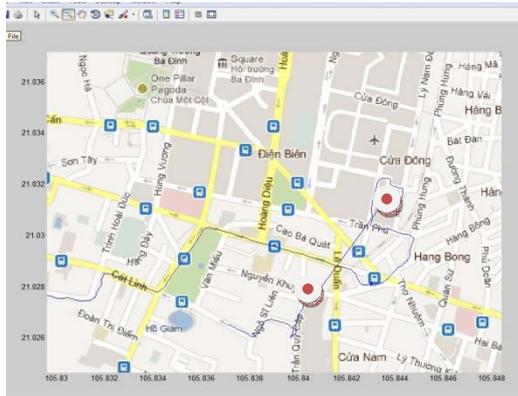


Fig. 4. GPS lost signal

In the second step, sometime GPS have a low signal and the number recorded is not correct (base on maximum of motorcycle acceleration). In this case we assume this point is the same with previous point.

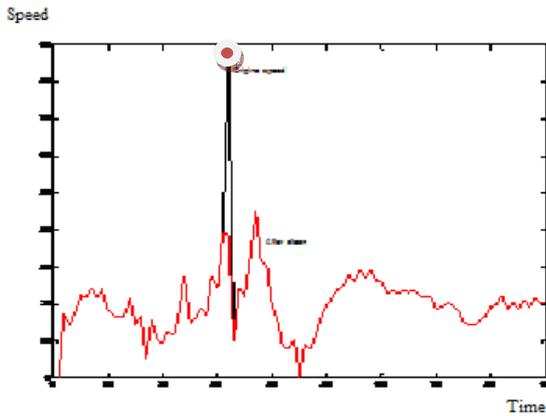


Fig. 5. Random error

2) Dividing trip

This process shows in figure 5 by using speed base [4] to identify start point and end point:

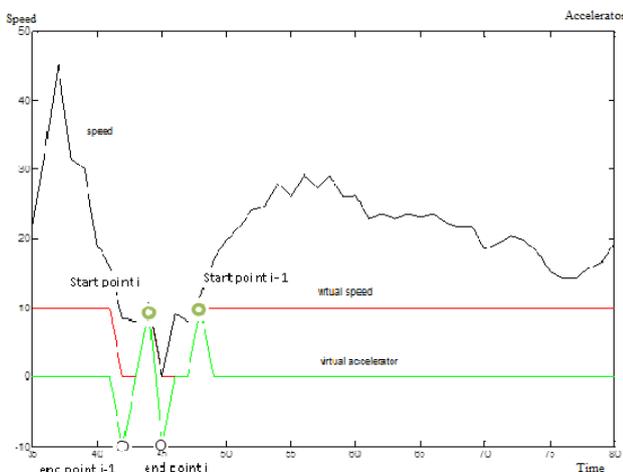


Fig. 6. Detected start point and end point

Detect all start and end points: Virtual speed is assumed, if speed > 10 km/h [5] then virtual speed equals 10, otherwise, it equals 0). Differential of virtual speed (virtual acceleration)

is used to find out all points when the virtual speed changes from 0 to 10 (start point) and from 10 to 0 (end point).

Sort start and end points: If virtual speed equal to 0 less than 300 second, congestion and traffic control would be considered. Inversely, vehicle finished trip.

3) Emission calculation

The power used for vehicle operation can be calculated based on the following equation [6]:

$$P \text{ (kW)} = m \times [V \times [1.1 \times A + 9.81 \times (\tan(\sin(G)))] + 0.132] + 0.000302 \times V^3 + A_c$$

where: m: weight (ton) V: velocity
 A: acceleration G: angle of road (radian)
 A_c: power share for air conditioner

In case of Motorcycle in Hanoi:

$$G=0 \text{ and } A_c=0$$

After calculate power of motorcycle, by using the equation find out in project 1 [7] (you can see in Fig. 7 and equation below)

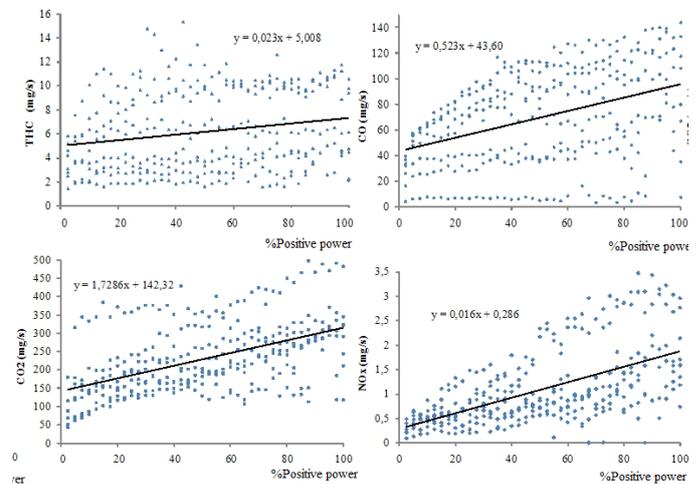


Fig. 7. Power and emission

With negative power:

$$P_{max-} \text{ \& } THC: Y = 0.002x + 3.386$$

$$P_{max-} \text{ \& } CO: Y = -0.117x + 40.26$$

$$P_{max-} \text{ \& } CO_2: Y = 0.182x + 246.9$$

$$P_{max-} \text{ \& } NO_x: Y = -0.002x + 0.322$$

4) Displaying results:

This result will be displayed for each trip, in the format of 2D or 3D. In case of 2D, the map of world [8] is used to show in figure with longitude and latitude, as well as all results of one trip in next figures including speed, power, total Hydrocarbon, CO₂, CO, and NO_x. In case 3D, longitude, latitude and time will be showed in one figure.

C. Analysis

In addition, this toolbox not only can automatic cut and calculate emission but also can cut and calculate trips by manual input start point and end point. In this case, by using "Time machine X" software identifies start point and end point base on speed and location. In case of Hanoi, there are three types of road in Hanoi: highway, arterial and residential street [1].

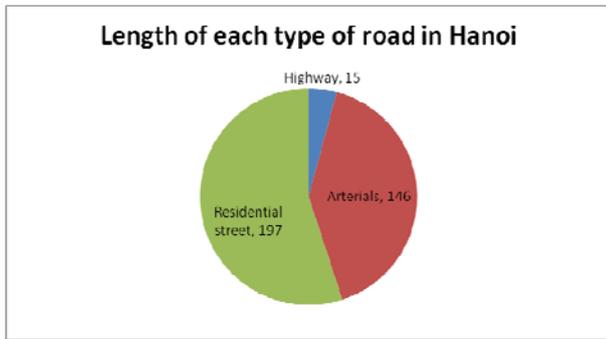


Fig. 8. Length of each type of road in Hanoi

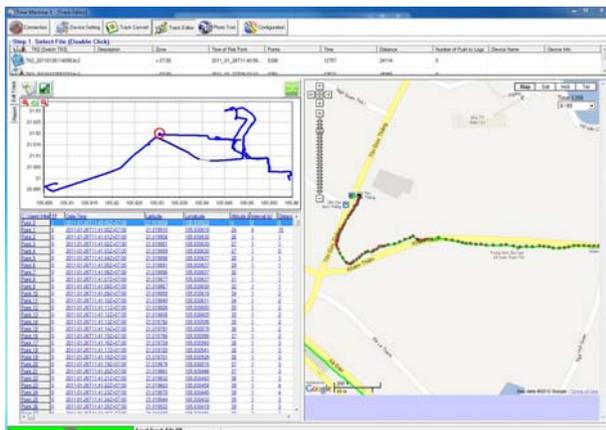


Fig. 9. Identify start and end point using time machine X

After detect start point and end point, all trips will be divided into 3 groups base on type of road and put in toolbox to calculated emission for each trips.

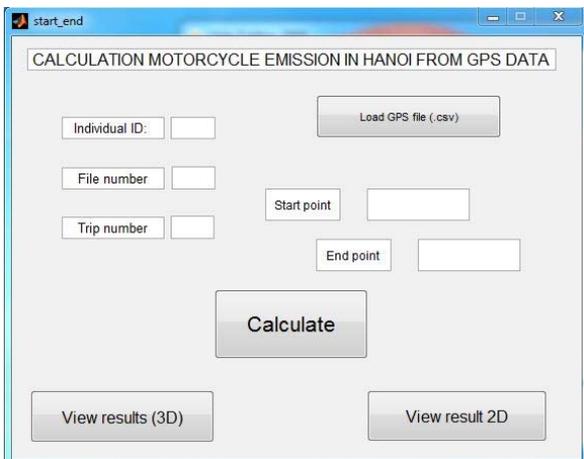


Fig. 10. Interface of toolbox

95 trips include three types of road in peak hour and non peak hour will be examined.

IV. RESULTS AND DISCUSSIONS

A. Toolbox for Calculating Motorcycle Emission

By using t-statistics, the results of this toolbox will be examined with the results from field measurement. 18 measurements were recorded with detailed information regarding the speed and emission. By using the speed information, the calculated CO₂ emissions from this toolbox was compared with the measured data. The results from the calculated and measured data were checked by using the

t-test (two-sample assuming equal variances).

TABLE I: COMPARISON BETWEEN CALCULATING AND MEASUREMENT t-test (two-sample assuming equal variances)

	Calculating	Measurement
Mean	36.34	35.07
Variance	8.01	5.97
Hypothesized	0	
t Stat	1.42 (<1.96)	

As you can see in the Table 1, with level of significance is 0.05, the value of test statistic $t=1.433989$ (the rejection rule for this test is $t < -2.110$ or $t > 2.110$ from the t distribution table where the t value is based on a t distribution with n-1 degrees of freedom and where the area of the upper one tail is 0.025). In this case, $-2.110 < t < 2.110$ the null hypothesis could not be rejected so in other words, the means for the calculated and measured results are equal.

B. The Difference in CO₂ Emission between Urban and Rural areas

By applying the toolbox, the CO₂ emissions from a total of 995 trips was calculated with 378 of these trips coming from rural areas, 498 trips coming from urban areas and 119 trips coming from travel between urban and rural areas. The t-test with two samples assuming unequal variances will be applied to compare the differences in CO₂ emissions between the rural and urban areas. The result is shown in Table II.

TABLE II: COMPARISON OF CO₂ EMISSION FOR MOTORCYCLE t-test (two-sample assuming equal variances)

	Urban	Rural
Mean	35.52	30.85
Variance	128.60	67.59
Hypothesized	0	
t Stat	7.37 (>1.96)	

In this test, by using the null hypothesized mean difference, the result shows that t statistics equal 7.3720 which is bigger than 1.96 (t-table) and it shows a p-value = 1.82655E-13 lower than $\alpha=0.05$ so we are able to reject the null hypothesis. Based on sample results, CO₂ emission in rural areas is different with urban areas.

By comparing the means of both areas, in the rural area, CO₂ emissions from motorcycles is lower than urban areas and the variance is also lower. The reason is that in the urban area, normally traffic jams occur every day, so that there is a large influence on CO₂ emissions from traffic jams.

C. Route Analysis

The results when this toolbox was applied for calculating the CO₂ emissions for each road type are shown in Fig. 11, 12.

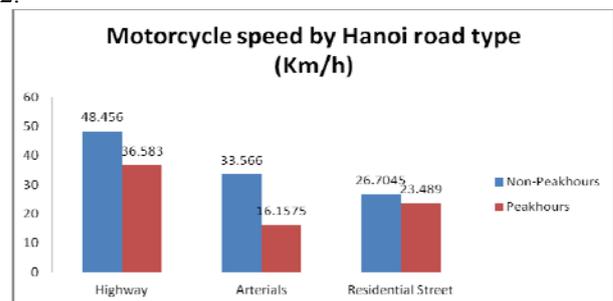


Fig. 11. Motorcycle speed in Hanoi by road type

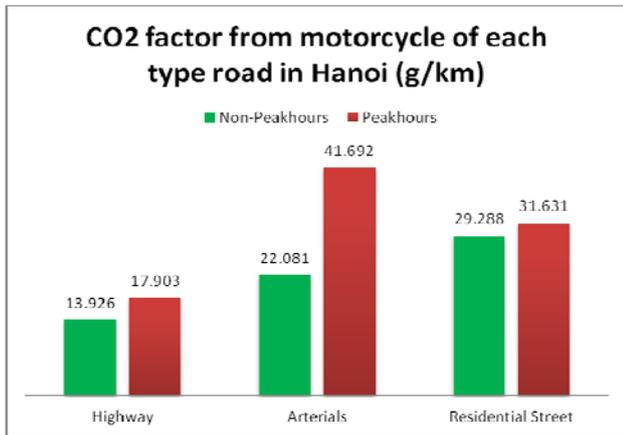


Fig. 12. CO₂ factor from motorcycles for each type of road in Hanoi

As you can see from Figure 5-2 and Figure 5-3, in peak hours, the speed of motorcycles of all types of roads in Hanoi was reduced. Inversely, the CO₂ emissions from motorcycles increased. For highway, the speed was reduced from 48.456 to 36.583 km/h and the CO₂ emissions increased from 13.926 to 17.903 g/km. In case of residential streets, the gap between peak hours and non peak hours is the smallest; the speed slows down from 26.7045 to 23.498 km/h and CO₂ emissions rose from 29.288 to 31.631 g/km. Peak hours has a strong effect on arterials. The speed of motorcycles sharply decreases from 33.566 to 16.1575 km/h and big gap in CO₂ emissions from non peak hour and peak hour is shown (22.081 in non peak hour and 41.692 g/km for peak hour). So the best solution for motorcycle drivers inside the CBD who want to reduce their CO₂ emissions is to choose arterials during the non peak hours and to choose residential streets during the peak hours.

V. CONCLUSION

The motorcycle will still play an important role in the transportation system in Hanoi for at least the next 15 years. Therefore research related to motorcycles in Hanoi and also for developing and developed countries has been expanded to a wide range of topics in the last several decades and continuous work is being done on topics which include traffic safety, route choice analysis, activity – base analysis, environment, and so on. This dissertation deals with the issue of environmental problems with a focus on how to calculate and reduce the motorcycle emissions based on GPS information.

To simplify all of the processes in calculating the emissions from motorcycles, a toolbox with calculating program was designed. This toolbox uses GPS data which was collected from motorcycle usage activities as input information into the program for calculating precisely the amount of emissions as well as each type of emissions such as CO, CO₂, HC, NO_x, etc. The calculation process contains three steps: cleaning the GPS data, automatically identifying

trip(s) and calculating emissions by using the MATLAB program. Moreover, all results could be represented not only as figures but also as Excel files (which may re-used as input for other programming processes).

The toolbox was used to examine motorcycles' emissions in different travelling conditions such as different types of roads (i.e., on residential (branches) roads, on main roads and on highways) and different types of areas (i.e., CBD (Central Business District), non-CBD and rural areas). The result shows that in urban area, the CO₂ emission factor from motorcycle has higher than rural area. It can explain that in urban area the congestion level is higher than rural area. In addition, the results suggest that those who live within the CBD and drive motorcycles in peak hours should chose residential roads to save their travel time as well as to reduce the motorcycle's emissions factor.

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