Analysis of Vehicle Emission Inventory and Emission Mitigation Strategy

Tu Anh TRINH[a], Thi Phuong Linh LE[b]

[a]*Ton Duc Thang University, Nguyen Huu Tho Street, Tan Phong Ward, District 7, Ho Chi Minh City – 760000, Vietnam; Email: trinhtuanh@tdt.edu.vn*
[b]*Vietnamese German University, Le Lai Street, Binh Duong New City, Binh Duong – 820000, Vietnam; Email: linh.phuongtl@gmail.com*

Abstract
Road transport have contributed a substantial emission of air pollutants that have damaged to people life quality. The aim of the study was to estimate the emission inventory from road transport using EMISENS. The study conducted a survey of traffic and vehicle characteristics using video camera and questionnaires. The data were gathered for 3 typical road types in 3 zones of Hochiminh city and for five typical vehicles. Other information (i.e. temperature, vehicle speed, emission factor) were also collected for emission inventory calculation. The analysis revealed that vehicle feet released a large amounts of CH4, CO, NOX, SO2, and MNVOC (ktonnes yr^{-1}). Motorcycle was the major source of CO, NMVOC, SO2 emission while car contributed the highest share of NOx. The promising emission mitigation strategies were also examined. The outcomes shows that switching to public transport and using biofuels can help to improve air quality in the city.

Key words: Vehicle Emission, Emission Inventory, EMISENS

1. INTRODUCTION

Traffic emission has become a significant contributor of air pollution in many Asian developing cities. Along with the socioeconomic development and a rapid growth in vehicle fleet leading to high traffic density and congestion problem, Vietnam is known as one of the most polluted countries in the world. Concerns have been growing about air pollution associated health impacts in some polluted cities, such as HCMC where motor vehicle is the main mode of transport and have been used extensively. In the city, there was about 7,4 million motorcycles registered in 2016, which accounted for 80% of the total fleet. The rest is composed of car, buses and trucks. Most researches verifies that the city is experiencing some of the worst air pollution in the world and although urban pollution originates from a wide range of sources, the majority comes from transport emissions (ADB, 2006; Ho *et al.*, 2006; Trinh, 2007). Moreover, the vehicle fleet consists of a variety of year models and technologies. The shortage of regulation and adequate emission inspection facilitates the use of old and dirty vehicles.

Recent studies points out that air pollution generated by traffic has become a serious impediment to the quality of life and urban health. A range of gaseous pollutants such as volatile organic compounds (VOC), nitrogen oxide (NOx), carbon monoxide (CO), sulfur oxide (SOx) and methane (CH4) is released from the vehicle fleet (Gwilliam *et al*., 2004; Colvile *et al*., 2001; Kawashima *et al*., 2006; WHO, 2005; Transportation Research Board (TRB), 2002). These emissions increases the risk of neurodegenerative diseases (Lee *et al*. 2016) and contributes to tropospheric ozone concentrations and secondary organic aerosols, which results in respiratory and cardiovascular system effects (Laurent and Hauschild 2014). Moreover, sensitive groups such as children and the elderly are at risk to urban air pollution (Andersen *et al*. 2012; Schultz *et al*. 2012). In one recent study on the relation between air pollution and health, Le *et al.* (2008) found that more than 90% of children under 5 years old suffered different illnesses. Apart from the detrimental health effects, studies suggested that the average economic loss per person per day caused by air pollution could approach as much as 729 VND. This economic loss is considerable in terms of direct medical costs (i.e. hospital admissions and the cost of pharmaceuticals) and indirect medical costs (i.e. time lost from work and premature death). It is urgent to have a well-designed strategy for emission reduction.

In Vietnam, road transport contributes significantly to air pollution and jeopardizes public health in the cities but has not been adequately characterized. Also, the available data are also insufficient to identify the contributions from motorcycle as well as other types of vehicle to the air pollution in the city. To make improvements in the air quality and having better urban air quality management, information on traffic-related air pollutants that are based on an accurate emission inventory is required. This study was designed to characterize the emission inventory from road traffic sources in HCMC. More update information on emission inventory plays an important role because emission inventory can be more revealing about residents' routine exposure. Also, improved knowledge about the air pollution level in the city has become a priority research question because it is the foundation of control programs for selected pollutants (Shuhaili, Ihsan, and Faris, 2013). In the research, emission inventory was produced for the year 2016. Level of selected gaseous pollutants (NMVOCs, SO2, NOx, CH4) was calculated. Research areas in the study is shown in Figure.2.

2. METHODOLOGY

2.1 Traffic Emission Inventory

Given the growing environmental and health concerns, a substantial body of literature has been produced on emission inventory. To support agency regulatory objectives, an emission inventory which is an accounting of the amount of pollutants discharged into the atmosphere have been developed over the past several years. A comprehensive emission inventory is the first step to develop an emission control strategy for selected pollutants (Gulia *et al*., 2015). Along with the aforementioned studies of health impact, much of the work on vehicle emissions in the past decade has tended to focus on emission inventory in several urban agglomerations. Also, emission inventory models are available allowing users to vary the fleet structure, technology proportions, vehicle activity and proportions of driving conditions to estimate emissions and total fuel consumption (Boulter, McCrae, and Barlow, 2006).

A range of different emission models including MOVES, MOBILE-6 and NMIM has been developed by US EPA (2011b). Kota et al. (2014) conducted a research on emission inventory of CO and NOX from on-road vehicles using MOBILE 6.2 and MOVES in Southeast Texas, USA. The study found that MOBILE 6.2 provides quite accurate estimates of emissions from the mobile sources when compared to MOVES. Along with US EPA, other models are also developed for research purposes and regulatory objectives such as ASPA with Circul'Air model and Slordal *et al*. (2007) with AIRQUIS. COPERT has been commonly used in EU in support of emission load estimation from motorized vehicles (Ekström, Sjödin, and Andreasson,, 2004). In China, Zhou *et al*. (2010) relied on MOBILE5B-China based on US. EPA's MOBILE5B and PART5 for motor vehicle emission inventory estimation.

A review of the literature has shown that limited studies have been done to develop emission load models for heterogeneous traffic conditions in developing countries. Ho, Clappier, and François (2010) pointed out that existing models required a lot of input parameters that were only specific to certain types of fuel, vehicle technology, road configuration; and developing countries with different conditions was not likely to use the models. In addition, the rapid economic development and the composition of traffic in developing countries that is mixed with a variety of vehicles, motorized and non-motorized accentuate the need for developing approaches to collecting and reporting emission inventory data so that it is a reliable and credible source of information facilitating sound decision making. Based on the above-mentioned reasons, Ho *et al.* (2010) developed EMISENS model - a new approach for generating road traffic emissions to contribute to a better management of the urban air quality in developing countries. EMISENS model combines the top-down and bottom-up approach and using Copert IV methodology to generate vehicle emission inventories in developing countries with low quality traffic data. The model also computes the uncertainties due to input parameters in using Monte Carlo method. According to COPERT IV methodology, the model considers three emission types: Hot emission (E_{hot}) – emissions occurring under thermally stabilized engine and exhaust after treatment conditions (Ong, Mahlia, and Masjuki, 2011), Cold emission (E_{cold}) - emission generated when vehicles are driven with cold engine and Evaporative emission (E_{evap}) - emission estimated for NMVOCs emissions and for gasoline passenger cars, gasoline light trucks and motorcycles (Ho et al. 2010). Total emissions are calculated based on equation: $E = E_{hot} + E_{cold} + E_{evap}$. The input and output data of the model presents in Figure 1. EMISENS has been applied in the cities of both developed and developing countries, e.g. Ho Chi Minh (Vietnam), Strasbourg (France), Seoul (Korea), Bogotá (Colombia), and Bangalore (India) with promising results (Ho et al. 2010).

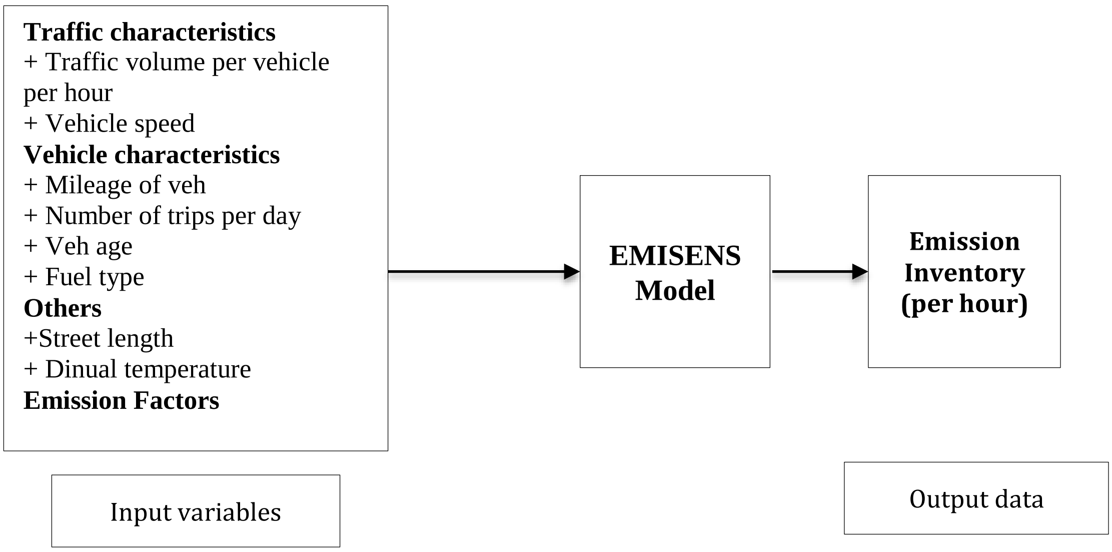

Figure 1. EMISENS model and its input variable and output data

2.2 Study Areas and Data Collection

2.2.1 Study areas

The availability of reliable local data plays an important role in calculating emission inventory (Nesamani, 2009). Data are not readily available in HCMC; therefore, it will be important for surveys to calculate emission inventory. Given time and financial constraints, it is infeasible to collect vehicle data in all areas, so the survey was only carried out in selected streets. EMISENS estimates vehicle emissions by using street categories and vehicle groups (Ho and Clappier, 2011). Regarding street categories, the streets were grouped into 5 categories based on the speed and function of the street (i) urban main street; (ii) urban secondary street; (iii) urban street in industrial zone; (iv) rural street and (v) highway street category. Via mobile devices, we manually collected traffic counts in (i) urban main street, (ii) urban secondary street and (iv) rural street, which represents central district, urban district, and suburb respectively. Central district includes the most busy and heavily congested roads, and more expensive motorcycles were observed in this zone while urban district have mainly narrow and busy streets. The majority of old motorcycles and light truck were observed there. Suburb are dominated by narrow streets, mostly old motorcycles and truck were observed in the area (Figure 2).

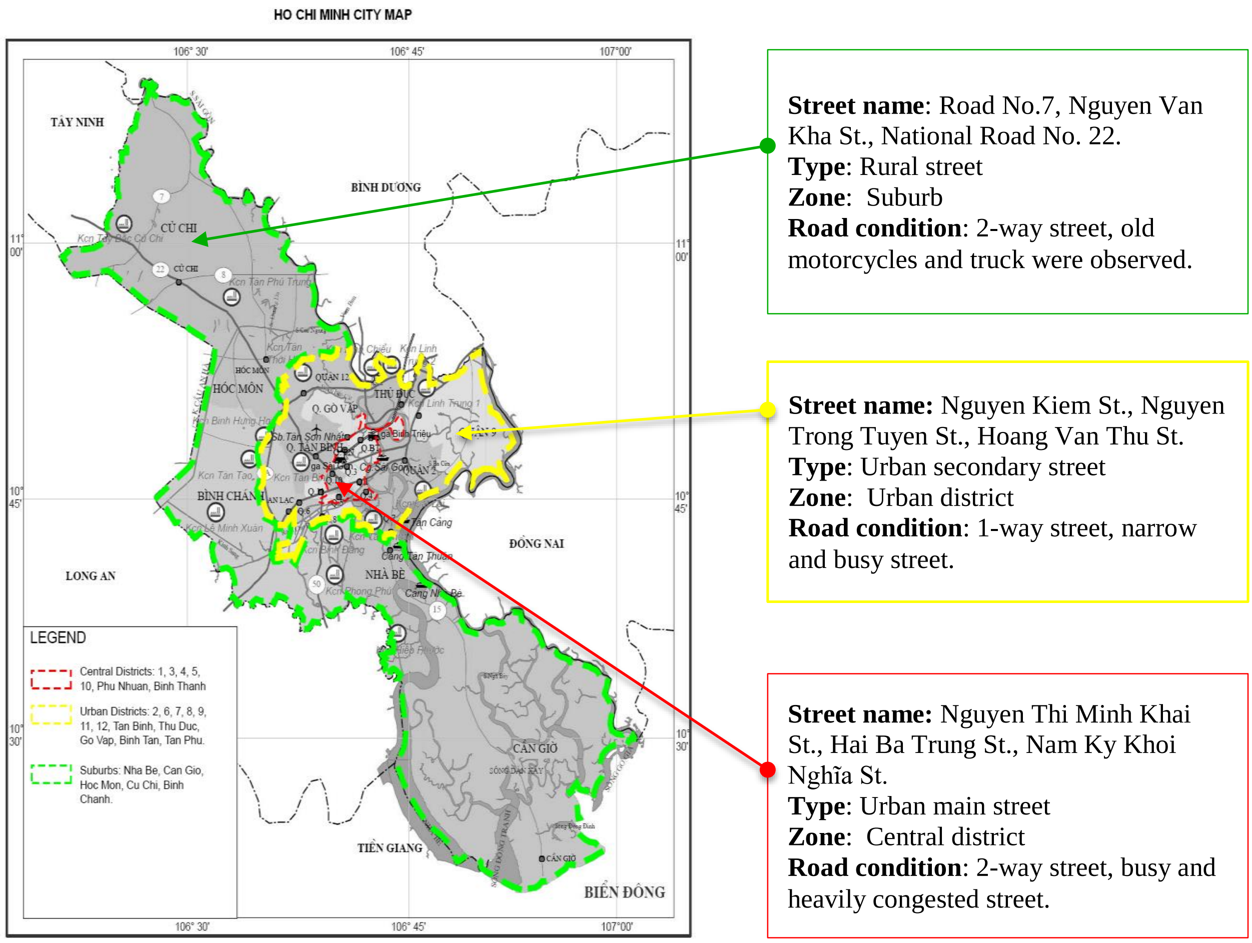

Figure 2. Study areas in 3 different zones

2.2.2 Data collection

Traffic characteristics

In terms of vehicle category, the vehicles were classified into 5 categories, namely, car (all the passenger car and private car), light truck (≤ 2.5 ton), bus (urban bus and coach) and motorcycle (2 strokes and 4 strokes) (Ho and Clappier 2011). Traffic count provides street-level traffic data for each street. The manual traffic count was recorded in 15-minute intervals on weekdays (Monday-Friday) and weekend (Sunday) during AM (from 7:00 to 9:00) and PM (from 16:00 to 18:00). For vehicle speed measurement, we used our motorcycle to follow vehicles running on the road and then found out the speed based on our motorcycle's odometer.

Emission factors

In the study, we use emission factors (EFs) suggested by Ho and Clappier (2011). The authors stated that they employed the EFs from the three different sources. Given the lack of EFs of SO2 and CH4, EF of SO2 from China was used and EF of CH4 was derived from Copert IV. The EFs calculated for HCMC (Belalcazar *et al*., 2009; Dzung and Thang, 2008).

Vehicle characteristics

A set of attributes including vehicle age, vehicle category, fuel type, mileage of vehicle, and number of trips per day was collected by online survey. The survey was conducted from 15/9/2016 to 30/9/2016. The data is drawn from an online survey of motorcyclist. Car, motorcycle, light truck, heavy truck and bus/coach were considered in the survey. Besides, information on the number of registered vehicle in 2015, temperature and street length were also gathered. A summary of data collection is given in Table 1.

Table 1. Data collection summary

Category	Method	Data types	Data quantity
Traffic characteristics	- Traffic count (Video camera) - Field measurement - Survey	- Traffic volume per vehicle per hour (7:00 – 9:00; 16:00 – 18:00) - Vehicle speed (km hr^{-1})	- 18 h record (6 record times x 0.5h per record time x 6 days)
Emission factor	Literature Review	Emission factor (g hr^{-1})	Emission factor per pollutants and vehicle category
Vehicle characteristics	Survey	- Type of fuel in-use per vehicle category - Vehicle age - Mileage of vehicle (km) - Number of trips per day	- 120 questionnaires to identify vehicle characteristics
Others	Internet, government agency	- Registered vehicle - Temperature - Street length	- Number of registered vehicle in the cities; - Diurnal temperature in Sep 2016 in the city; - The length of streets in central district, urban district, and suburbs

3. RESULT AND DISCUSSION

3.1. Traffic Volume and Vehicle Fleet Characteristic

Table 1 presents the hourly traffic voulme of five vehicle categories for the weekday (Monday – Friday) and during AM (from 7:00 to 9:00) and PM (from 16:00 to 18:00). A summary of their hourly traffic volume for the weekend is given in APPENDICE. The total traffic flow in central district was higher than those in urban district and suburb, reaching above 18,000 vehicles h^{-1} and 21,000 vehicles h^{-1} at off-peak time and peak-time respectively (Figure 3). There is no data available for light truck and heavy truck in central district and urban district, which reflects the fact that light truck is not allowed to enter the areas from 6:00AM to 8:00AM, and heavy truck is not allowed to enter from 6:00AM to 21:00PM.

Higher traffic volume was recorded during weekday (i.e. 14,000 – 21,000 vehicles h^{-1}) and lower was recorded at weekend (i.e. 9,000 – 16,000 vehicles h^{-1}) in three streets. During the period of 7:00–8:00AM and 17:00– 18:00PM and during weekdays in central and urban districts, more traffic congestions were observed, whereas there were no noticeable rush hours and traffic jams in suburbs.

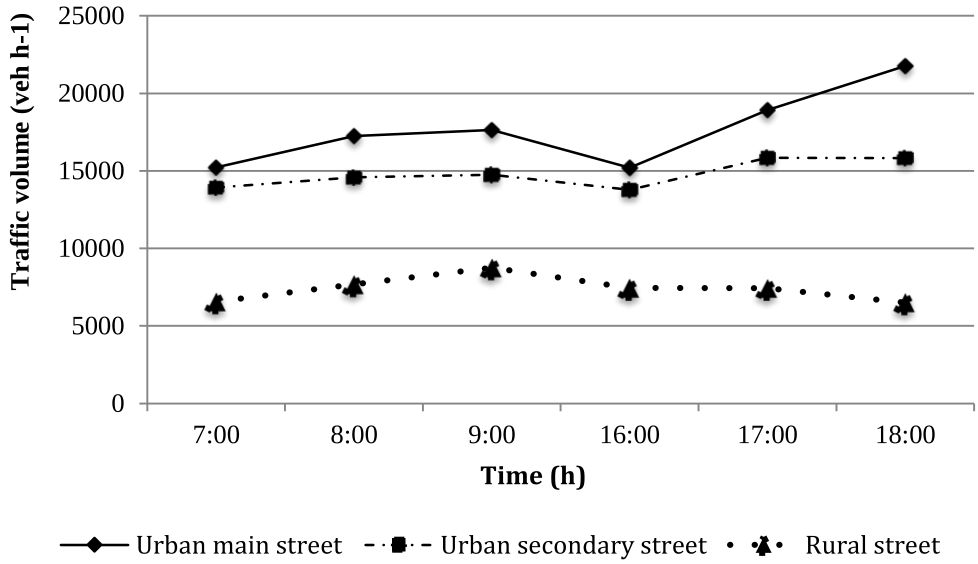

Figure 3. The hourly traffic volume in three kinds of street, vehicle h^{-1}

Apart from traffic volume, feet compositions also play an important role because it impacts on the emission inventory generated by different types of vehicle. In urban main street and urban secondary street, motorcycle was the most predominant vehicle type that had the largest share (>90%) of the fleet on weekdays and weekend. While Car accounted for ~5%, bus was of the smallest share, below 1% (Table 1). The fleet in suburb was dominated by motorcycle (47-66%), heavy truck (28-48%), car (1-3%), and light truck (1-2%) while bus only contributes a share of ~1%. Figure 4 shows the variation of the fleet composition (in %) at Road No.7 (Cu Chi Suburb).

3.2 Vehicle Fleet Characteristic

To investigate the vehicle fleet characteristic, a survey was conducted from 15/9/2016 to 30/9/2016 at residential areas, open markets, parkings, bus stations in central district, urban district and suburbs. A questionnaire was developed to interview vehicle drivers in HCMC. In total, 10 participants were involved in the interview (49 motorcycle riders (40,8%), 19 car drivers (15,8%), 12 bus drivers (10%), 27 light truck drivers (22,5%), and 13 heavy truck drivers (10,9%)). Characteristics, i.e. vehicle age, fuel type, engine type, mileage of vehicle were identified.

The results show that 98 % of the motorcycles was equipped with four-stroke engine. The average age was 3 years. More than 60% were of below 3 years old and the remains were produced less than 6. Although the majority have been manufactured in recent years, motorcycle has become a main source of pollution. The survey also revealed that 52% of motorcycles are vehicles non-compliant with EURO standards. Only 33% complied with EURO II and 15% with EURO III. Motorcycles (99%) and cars (70%) used gasoline while the main fuel used by heavy truck and light truck was diesel (72%). The majority of bus used dual fuel (diesel and CNG). More than 90% of the cars follow the EURO III and EURO IV. Most of the light trucks, buses, heavy trucks, which is of Vietnamese and Korean made with the model years ranged between 1994 – 1996 and 2000 – 2005, had no engine standards or complied with Euro I or Euro II. The total mileage of motorcycle and car was low, reaching below 20,000 km and 50,000 km respectively. Heavy trucks, light trucks and buses with odometer readings ranging from 100,000 – 300,000 km accounted for more than 50%.

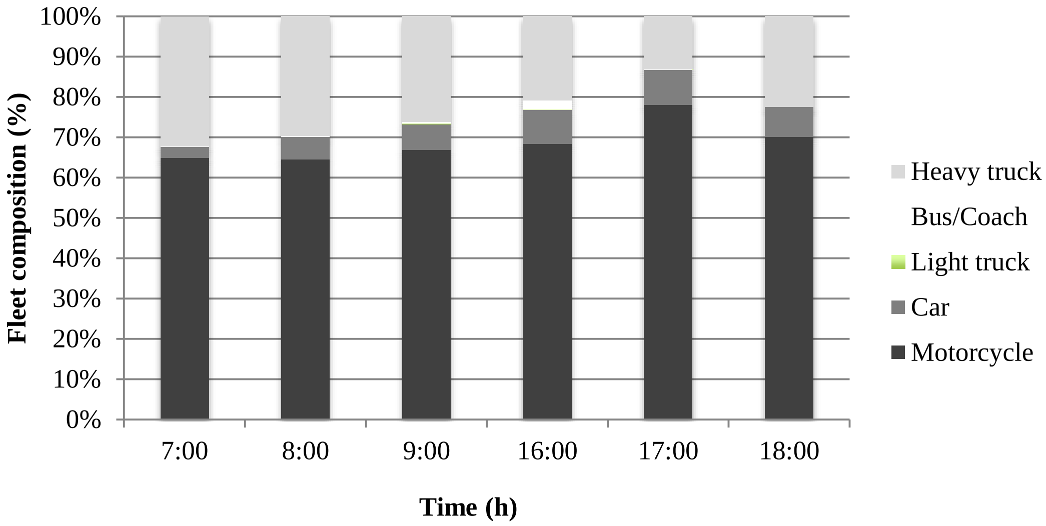

Figure 4. The fleet composition (in %) at Road No.7 (Cu Chi Suburb)

Table 1. Hourly traffic volume (vehicle/h) and Traffic fleet composition (%)

Weekdays (Monday – Friday)		7:00		8:00		9:00		16:00		17:00		18:00	
		Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%
Central district (urban main street)	MC	14424 ± 51	94.7	16362 ± 97	94.9	16519 ± 27	93.6	13020 ± 97	91.7	17815 ± 65	94.2	20597 ± 81	94.6
	Car	737 ± 43	4.8	776 ± 12	4.5	757 ± 10	4.3	974.00 ± 6	6.9	968 ± 6	5.1	1075 ± 18	4.9
	Bus	67 ± 3	0.5	108 ± 6	0.6	303 ± 10	1.7	208 ± 5	1.5	131 ± 4	0.7	96 ± 4	0.4
	Light truck					67 ± 5	0.4						
	Heavy truck												
	Total	*15228 ± 42*	*100*	*17246 ± 50*	*100*	*17646 ± 68*	*100*	*14202 ± 37*	*100*	*18914 ± 49*	*100*	*21768 ± 66*	*100*
Urban district (urban secondary street)	MC	13342 ± 53	95.8	13985 ± 56	95.9	14002 ± 62	95.0	13107 ± 23	95.1	15098 ± 44	95.3	15131 ± 27	95.7
	Car	538 ± 38	3.9	546 ± 21	3.7	551 ± 25	3.7	438 ± 20	3.2	507 ± 19	3.2	482 ± 28	3.0
	Bus	41 ± 2	0.3	53 ± 4	0.4	101 ± 5	0.7	132 ± 7	1.0	112 ± 2	0.7	103 ± 6	0.7
	Light truck					88 ± 4	0.6						
	Heavy truck												
	Total	*13921 ± 45*	*100*	*14584 ± 53*	*100*	*14742 ± 61*	*100*	*13779 ± 37*	*100*	*15842 ± 32*	*100*	*15813 ± 45*	*100*
Suburb (Rural street)	MC	4047 ± 22	61.7	4211 ± 17	54.5	5763 ± 20	65.9	4277 ± 13	57.5	4431 ± 12	59.7	3100 ± 25	47.6
	Car	121 ± 14	1.8	159 ± 4	2.1	161 ± 6	1.8	113 ± 4	1.5	101 ± 2	1.4	82 ± 3	1.3
	Bus	8 ± 1	0.1	7 ± 1	0.4	78 ± 2	0.9	65 ± 2	0.9	33 ± 1	0.4	22 ± 1	0.3
	Light truck	93 ± 2	1.4	90 ± 1	1.5	232 ± 11	2.7	194 ± 7	2.6	211 ± 5	2.8	190 ± 4	2.9
	Heavy truck	2287 ± 10	34.9	3208 ± 14	41.5	2510 ± 23	28.7	2795 ± 10	37.5	2650 ± 8	35.7	3117 ± 17	47.9
	Total	*6556 ± 31*	*100*	*7675 ± 37*	*100*	*8744 ± 36*	*100*	*7444 ± 29*	*100*	*7426 ± 31*	*100*	*6511 ± 27*	*100*

3.3 Emission Inventory

The results of traffic-related emission inventory for the year 2016 calculated by EMISSEN are given in Table 2. The analysis revealed that vehicle feet in HCMC released 14.91 ktonnes of CH_4, 1763.71 ktonnes of CO, 547.52 ktonnes of NO_X, 4.19 ktonnes of SO_2, and 193.62 ktonnes of MNVOC. Motorcycle and car were the main contribution of CH_4 which occupied 55.20% and 33.80% of the total emissions respectively (Figure 5). Motorcycle was the major source of CO and SO_2 emission with a record 54.37% and 50.36% of the total CO and SO_2 respectively. Car contributed the highest share of NO_x, above 34%, followed by heavy truck, above 22%, light truck (18.48%) and motorcycle (17.96%). Motorcycle generated around 101 ktonnes of NMVOC and was the main cause of NMVOC (52.18%).

Overall, CH_4, CO, NMVOC and SO_2 produced by motorcycles were more than 50% of total road transport emissions. This was in line with previous finding that motorcycle was the major cause of pollution in HCMC (Ho and Clappier, 2011). In 2011, motorcycle was around 86% of the total vehicles in HCMC and a large number of motorcycles had low quality engine with low proper maintenance (Ho and Clappier, 2011). In 2016, motorcycle still remained the largest share (>90%) of total vehicle fleet. From 2011 to 2016, the number of motorcycle in the city increased at a rate of 8.1% per year, reaching over 7.4 million in 2016. Besides, there was an increase in the number of car, from 493,000 in 2011 to 556,000 in 2015. This rapid growing of motorcycle and car contributes significantly to air pollution in the city. The results of emission inventory can be used as a foundation for designing emission control strategy facilitating emission reduction in HCMC. Three potential strategies will be given and discussion in the next section.

Table 2. Emission inventory from traffic sources for the year 2016 (ktonnes)

Emissions	**Car**	**Motorcycle**	**Light truck**	**Heavy truck**	**Bus**	**Total**	**Total Uncertainty (%)**
CH4	5.04	8.23	0.72	0.81	0.11	14.91	58.00
CO	757.8	959.01	17.07	21.11	8.72	1763.71	42.40
NOX	189.8	98.35	101.18	122.03	36.16	547.52	32.76
SO2	0.5	2.11	0.4	0.83	0.35	4.19	34.07
NMVOX	86.26	101.03	2.01	3.11	1.21	193.62	47.37

Note: The uncertainty reflects the variation of input parameters (i.e. different vehicle category, speed, temperature, street length, hourly street mileage)

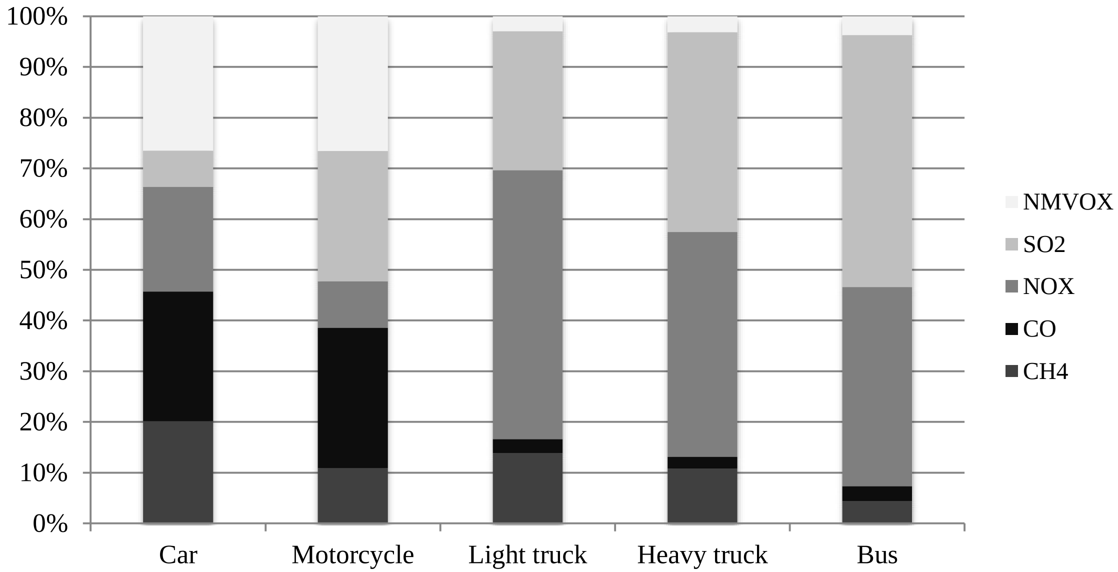

Figure 5. The distribution of road transport emissions

3.4 Emission Strategies for Air Pollution Reduction

Motorcycle and car have becoming the major cause of pollution in HCMC. Therefore, the strategies only focused on motorcycle and car. Three potential emission strategies were developed based on the assumption that 10% of motorcycles shift to public transport (Case 1), 10% of car shift to public transport (Case 2) and 10% of car shift to vehicles using biofuels (Case 3) while retaining the same other input parameters (i.e speed, street category, emission factors). The results are given in Table 3. Compared to the base case, emission reduction strategies for different pollutants ranged from 2.63% to 14.39% (Case 1), 1% - 20.12% (Case 2), and 8.20% - 19.7% (Case 3). It is clear that the decline in the number of motorcycle and car can significantly mitigate road transport emission in HCMC.

Table 3. Annual emission (kt yr^{-1}) under base case 2016 and emission strategies scenarios

Emissions	Base case	Emission (kt yr^{-1})			Reduction (%)		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
CH4	14.91	12.8	11.91	13.68	14.15	20.12	8.20
CO	1763.71	1688.3	1714.01	1556.21	4.28	2.82	11.80
NOX	547.52	468.74	542.5	459.62	14.39	0.92	16.10
SO2	4.19	4.08	4.09	3.79	2.63	2.39	10.00
NMVOX	193.62	185.5	173.47	155.47	4.19	10.41	19.70

The majority of motorcycle in HCMC are equipped with 2-stroke engine which is less fuel efficient than other types of engines and produces high pollution levels. Therefore, reducing the number of motorcycle can mitigate exhaust emission. In the Case 1, it is clear that there was a significant reduction of CH4 (14.15%) and NOX (14.39%) compared with the base year while SO2 emission was reduced in the small amount (4.08 ktonnes). With regard to CO, the figure dropped from around 1763 ktonnes in the base reference to around 1688 ktonnes in 2010. Similarly, the amount of NMVOC fell by approximately 8 ktonnes by shifting 10% of motorcycles to public transport. Looking at the Case 2, NMVOC is generated by gasoline vehicles; therefore 10% shift of cars led to a significant reduction of CH4 (20.12%) and NMVOC (10.41%). The total CO and SO2 emissions decreased to 2.82% and 2.39% respectively from the base year, but there is no significant change in NOX emissions. Because light truck and heavy truck contributed a relatively large amount of NOX (Table 3), the shift of cars did not have considerable impact on NOX emission. Public transport occupies less road space and causes less pollution per passenger-km than other modes (Ong *et al.*, 2011). It is also regarded as a key target for reducing road transport related emissions (Gregory *et al.*, 2016). HCMC is now characterized by a very limited supply of public transport services and a very low reliance on public transport for mobility. In fact, bus system is the only public transport mode available in the city which accounts for a paltry 1.4% of all daily passenger trips, lower than almost any other similarly sized city (WB, 2015). To achieve the goal of emission reduction, long term and short term investment to improve capacity and service quality of public transportation is significantly important.

Biofuels is known as a promising alternative fuel for road transport sector (Liaquat *et al.*, 2010). Many countries have taken some initiatives to produce biofuels and enacted the law or declared biofuel policy to authorize the use of biofuels as major transport fuel in domestic market. With regard to Case 3, it is clear that there was a major reduction in the amounts of NMVOC, NOX, CO and SO2 emissions to 19.7%, 16.10%, 11.80% and 10.00%, respectively from the base year. There was a slight fall in the amounts of CH4 between the base year and the Case 3. The emissions decreased from 14.9 ktonnes (base year) to around 13.68 ktonnes (Case 3). In fact, the use of biofuels as a mean of increasing sustainability and a major alternative of petroleum based transport fuels has high prospect in Vietnam as Vietnam has strong agricultural sector to support biofuels production from energy crops. Not only do biofuel help the country step-by-step mitigate severely environmental pollution, but it also reduces the petroleum dependency.

3. CONCLUSION

Motor vehicle has been identified as one of the largest emission sources in HCMC with subsequent adverse effects on urban health. The study estimated the emission inventory of road transport in the city by using EMISENS. Besides, emission reduction strategies were also identified by making comparision between emission levels of the base year 2016 and emissions generated in 3 different scenarios. Overall, vehicle feet in HCMC released a relatively large amount of CH4 (14.91 ktonnes yr^{-1}), CO (1763.71 ktonnes yr^{-1}), NOX (547.52 ktonnes yr^{-1}), SO2 (4.19 ktonnes yr^{-1}), and NMVOC (193.62 ktonnes yr^{-1}). The analysis also revealed that motorcycle and car are the major sources of air pollution; therefore, switching from motorcycle and car to public transport and using biofuels instead of petroleum based fuels promise the substantial improvement in air quality. In recent years, policy makers have become aware of the need to mitigate the negative impacts of transport on environment. The imperative to reduce vehicle emissions has been accepted and enshrined as an objective in the policies. The findings of the study are expected to provide readers with a better understanding of emission levels in the city and to provide useful background to decision making.

APPENDICE

Hourly traffic volume (vehicle/h) and Traffic fleet composition (%)

Weekend (Sunday)		7:00		8:00		9:00		16:00		17:00		18:00	
		Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%	Vehicle/h	%
Central district (Urban main street)	MC	9424	96.3	10003	96.2	13519	94.1	9020	90.6	13226	93.2	15738	94.4
	Car	337	3.4	354	3.4	554	3.9	786	7.9	843	5.9	821	4.9
	Bus	29	0.3	42	0.4	173	1.2	154	1.5	121	0.9	111	0.7
	Light truck					114	0.8						
	Heavy truck												
	Total	*9790*	*100*	*10399*	*100*	*14360*	*100*	*9960*	*100*	*14190*	*100*	*16670*	*100*
Urban district (Urban Secondary street)	MC	7287	95.8	8776	95.8	9003	92.8	9651	91.7	9987	94.0	11000	94.7
	Car	301	4.0	357	3.9	501	5.2	551	5.2	401	3.8	422	3.6
	Bus	20	0.3	27	0.3	97	1.0	165	1.6	111	1.0	101	0.9
	Light truck					102	1.1	162	1.5	127	1.2	89	0.8
	Heavy truck												
	Total	*7608*	*100*	*9160*	*100*	*9703*	*100*	*10529*	*100*	*10626*	*100.0*	*11612*	*100*
Suburb (Rural street)	MC	2002	41.0	2237	37.5	2400	35.0	2215	32.4	2100	31.9	989	18.6
	Car	62	1.3	121	2.0	179	2.6	133	1.9	122	1.9	97	1.8
	Bus	8	0.2	89	1.5	64	0.9	71	1.0	26	0.4	19	0.4
	Light truck	101	2.1	134	2.2	211	3.1	207	3.0	199	3.0	187	3.5
	Heavy truck	2711	55.5	3390	56.8	4001	58.4	4202	61.5	4133	62.8	4011	75.6
	Total	*4884*	*100*	*5971*	*100*	*6855*	*100*	*6828*	*100*	*6580*	*100*	*5303*	*100*

REFERENCES

Andersen, Z. J. et al. 2012. "Long-Term Exposure to Air Pollution and Asthma Hospitalisations in Older Adults: A Cohort Study." *Thorax* 67(1):6–11.

Belalcazar, Luis Carlos, Oliver Fuhrer, Minh Dung Ho, Erika Zarate, and Alain Clappier. 2009. "Estimation of Road Traffic Emission Factors from a Long Term Tracer Study." *Atmospheric Environment* 43(36):5830–37. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2009.07.059).

Boulter, Pg, Is McCrae, and Tj Barlow. 2006. "A Review of Instantaneous Emission Models for Road Vehicles." *TRL Unpublished Report UPR/IE/030/06. TRL Limited, Wokingham*.

Brook, Robert D. et al. 2010. "Particulate Matter Air Pollution and Cardiovascular Disease: An Update to the Scientific Statement from the American Heart Association." *Circulation* 121(21):2331–78.

Dzung, Ho Minh and Dinh Xuan Thang. 2008. "Estimation of Emission Factors of Air Pollutants from the Road Traffic in Ho Chi Minh City." *VNU Journal of Science, Earth Sciences* 24(2008):184–92.

Ekström, M., Å. Sjödin, and K. Andreasson. 2004. "Evaluation of the COPERT III Emission Model with on-Road Optical Remote Sensing Measurements." *Atmospheric Environment* 38(38):6631–41.

Gregory, David, Oscar Mclaughlin, Samantha Mullender, and Niruthavignesh Sundararajah. 2016. "London Forum for Science and Policy Briefing Paper New Solutions to Air Pollution Challenges in the UK." (April).

Gulia, Sunil, S. M.Shiva Nagendra, Mukesh Khare, and Isha Khanna. 2015. "Urban Air Quality Management-A Review." *Atmospheric Pollution Research* 6(2):286–304. Retrieved (http://www.sciencedirect.com/science/article/pii/S1309104215302373).

Ho, Bang Quoc and Alain Clappier. 2011. "Road Traffic Emission Inventory for Air Quality Modelling and to Evaluate the Abatement Strategies: A Case of Ho Chi Minh City, Vietnam." *Atmospheric Environment* 45(21):3584–93. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2011.03.073).

Ho, Bang Quoc, Alain Clappier, and Golay François. 2010. "Air Pollution Forecast for Ho Chi Minh City, Vietnam in 2015 and 2020." *Air Quality, Atmosphere & Health* 4(2):145–58. Retrieved (http://www.scopus.com/inward/record.url?eid=2-s2.0-84893674807&partnerID=tZOtx3y1).

Kota, Sri Harsha, Hongliang Zhang, Gang Chen, Gunnar W. Schade, and Qi Ying. 2014. "Evaluation of on-Road Vehicle CO and NOx National Emission Inventories Using an Urban-Scale Source-Oriented Air Quality Model." *Atmospheric Environment* 85(x):99–108. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2013.11.020).

Laurent, Alexis and Michael Z. Hauschild. 2014. "Impacts of NMVOC Emissions on Human Health in European Countries for 2000-2010: Use of Sector-Specific Substance Profiles." *Atmospheric Environment* 85:247–55. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2013.11.060).

Lee, Pei-Chen et al. 2016. "Traffic-Related Air Pollution Increased the Risk of Parkinson's Disease in Taiwan: A Nationwide Study." *Environment International* 96:75–81. Retrieved (http://linkinghub.elsevier.com/retrieve/pii/S0160412016303075).

Liaquat, A. M., M. A. Kalam, H. H. Masjuki, and M. H. Jayed. 2010. "Potential Emissions Reduction in Road Transport Sector Using Biofuel in Developing Countries." *Atmospheric Environment* 44(32):3869–77. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2010.07.003).

Nesamani, K. S. 2009. "Estimation of Automobile Emissions and Control Strategies in India Estimation of Automobile Emissions and Control Strategies in India Abstract :"

Ong, H. C., T. M. I. Mahlia, and H. H. Masjuki. 2011. "A Review on Emissions and Mitigation Strategies for Road Transport in Malaysia." *Renewable and Sustainable Energy Reviews* 15(8):3516–22. Retrieved (http://dx.doi.org/10.1016/j.rser.2011.05.006).

Schultz, Erica S. et al. 2012. "Traffic-Related Air Pollution and Lung Function in Children at 8 Years of Age: A Birth Cohort Study." *American Journal of Respiratory and Critical Care Medicine* 186(12):1286–91.

Shuhaili, Ahmad Fadzil Ahmad, Sany Izan Ihsan, and Waleed Fekry Faris. 2013. "Air Pollution Study of Vehicles Emission in High Volume Traffic: Selangor, Malaysia as a Case Study." *WSEAS Transactions on Systems* 12(2):67–84.

Zhou, Yu et al. 2010. "The Impact of Transportation Control Measures on Emission Reductions during the 2008 Olympic Games in Beijing, China." *Atmospheric Environment* 44(3):285–93. Retrieved (http://dx.doi.org/10.1016/j.atmosenv.2009.10.040).