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Emission Inventory and Predict from Road Traffic Sources for Hanoi

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Abstract

Traffic emission inventory by age-cohort vehicles is an effective tool for manager to identify exactly the main vehicles polluted the air in urban area. Hanoi is one of the largest cities in Vietnam, now is facing with the serious air pollution problems which is mainly contributed by transport vehicles. In this paper, we used the dynamics model to build an age-cohorts model to estimate and predict the emissions from vehicle fleet of Hanoi by the year 2040 as well as assess the effectiveness of the management measures. The results shows that motorcycles is the main traffic air pollution source of Hanoi, accounting for 98% CO emissions, 75% NO_x emissions, 81% PM emissions and 98% HC emissions. Among that, the motorcycles at the age from 3 to 9 years is the largest contributors with 57,72% CO emission, 58,5% HC emission, 62,53% NO_x emission, and 54,29% PM emission. It's estimated that, up to the year 2040, motorcycles still is the majority emission source, with a proportion of about 89% CO, 63% NO_x, and 69% PM emissions.

Keyword: Emission inventory, dynamics model, Hanoi traffic.

1. Introduction

Emission inventory is a powerful tool for environmental government agencies to observe, manage emission sources (CEMNA, 2008). However, the current methods using for road traffic emission inventory almost focused on classified by type, weight, or engine power of vehicle, but has not assessed the impact of age-cohorts vehicle. Therefore, they could not indicate the contribution to air pollution of vehicle fleet in different ages, as well as which age-cohorts contribute most to the traffic emission. Moreover, the age-cohorts model also helps managers to evaluate the discharge changes of the vehicle population over time and estimate emission from traffic.

Hanoi is currently facing problems of air pollution which traffic is one of the main sources of contribution, with about 4 million motorcycles and 280 thousand automobiles (Vietnam Registration, 1/2011). However, the emission inventory of road traffic sources is not conducted frequently; results are still limited due to lack of a united methodology and procedure (Ho et al., 2010). To improve the efficiency of the air environment quality management requires a uniform program to inventory emissions from road traffic source for Hanoi.

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Dynamics models are simple software that allow us to model the road traffic sources, monitor the variation of the vehicle population by using age-cohorts, not only to predict the pollution from vehicle fleet, but also to evaluate the role of each age-cohort vehicle to overall emissions, and assess the effectiveness of policies and technology measures to the elimination of air pollutants. In this study, we used Stella to conduct research “Emission Inventory and Predict from road traffic sources for Hanoi”.

2. Materials and Methods

2.1 Method of calculating emission amount

Emission of a certain traffic group can be calculated by the equation:

$$E_i = \sum_j \sum_k V_{jk}.VKT_{jk}.EF_{ijk} \qquad (1)$$

in which:

E_i: total emission per year of pollutant i (g/year)

V_{jk}: total vehicle j at the age of k

VKT_{jk}: Vehicle Kilometres Travelled of vehicle j, age k per year (km/vehicle/year)

EF_{ijk}: Emission factor of vehicle j at the age of k (g/km)

2.1.1 Emission factor

The research by US EPA has shown that there is a relation between emission of pollutants with the age of traffic vehicles. More specifically, the longer the using time of a vehicle (or the run distance), the more pollutants it emits. This also means that emission factor will increase together with the using age of traffic vehicles.

In order to predict the influence of new technology on emission of traffic vehicles, EPA has conducted specific researches on the impacts. The diagram in Figure 1 shows that the bigger the rate of vehicles changing from normal emitters to high emitter is, the higher emission factor is (Philip, 2001). These emission lines of HC have shown that emission factor of new vehicles (0% change) will reduce from the past (1975) to the future (2020) and the differential degree of emission among rates in the same line also tends to reduce. This means that vehicles in future will have emission degree depend on using age (or run kilometres) with fewer differentials.

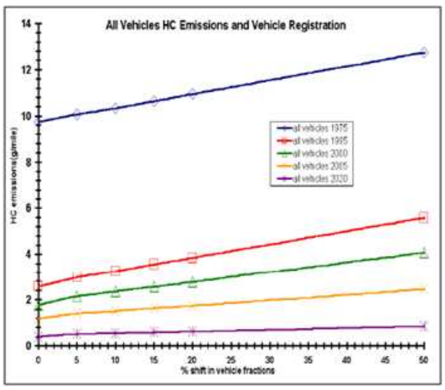

Figure 1. All Vehicles HC Emissions and Vehicle Registration (Giannelli R.A.et al., 2002)

At present, Hanoi does not have emission factors for automobile vehicle. The research proposes to use emission factors of Department of Transport, United Kingdom. These emission factors were taken in the report “Emissions Factor 2009: Final Summary Report” which announced on June 29th 2009. This is a detailed report which carried out on large scale, establishing new emission factors set to reflect precisely real traffic source of Britain which has not been updated for a long time. The research has established a set of emission coefficient for vehicles before the standard Euro I (before 1993), standard Euro I (since 1993-1996), standard II (since 1996-2000), standard III (2000-2005), standard IV (2005-2009), standard V (2009-2014) and standard VI (>2014) (standards V and VI are applied in future). Therefore, this is a very new coefficient set classified upon vehicle age which is suitable for current inventory.

2.1.2 Vehicle Fleet

2.1.2.1 Classification

Means of transportation of Vietnam in general, and of Hanoi in particularly is very diversified and complicated. Emission inventory and traffic data for air pollution models require detailed classification of transportation means in order to reflect diversification in air emission of traffic sources. In most researches, traffic source is classified into 3 main groups: 2- wheel vehicles, light duty vehicles (LDVs) and heavy duty vehicles (HDVs) (Boulter P.G. et al., 2009).

In order to meet requirements of emission inventory, the research proposes to classify the transport means in Hanoi city into 3 main groups: motorcycle, light duty auto vehicles and heavy duty auto vehicles. In each above mentioned groups, transport means are classified into smaller groups according to their using age. Due to shortage of detailed data, the research cannot establish the structure to classify auto vehicle types based on their weight (N1, N2, N3, M1, M2, M3) stipulated the standard of Vietnam 05:2009/BGTVT. The research only refers to light duty auto vehicle (<= 3.5 tones) and heavy duty auto vehicle (>3.5 tones). The structure of vehicle classification in this research is shown in the Figure 2.

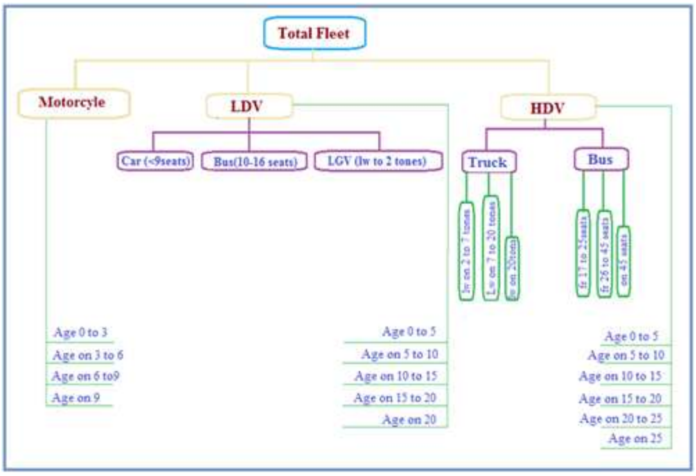

Figure 2. The Structure of the road vehicle fleet

2.1.2.1 Data collection and processing

Data source of traffic vehicle in Hanoi city, which is provided by Vietnam Register, is shown in the table 1 and table 2 hereinafter. According these data, auto vehicle population of Hanoi city has had an increase of 32,258 ones up to January 2011, equal to annual average increase of 15.52%, of which increase in car accounts for 20%, coach accounts for 3 % and truck accounts for 7%.

Table 1.Vehicles in traffic data by 30 - Apr - 2010 (Vietnam Register, 4/2010)

Location	Total	Car	Passenger car and Bus	Truck
Nationwide	1,198,268	514,945	104,357	527,855
Hanoi	248,846	159,560	16,085	67,914

Table 2. Vehicles in traffic data by 31-Jan-1-2011(Vietnam Register, 1/2011)

Location	Total	Car	Passenger car and Bus	Truck
Nationwide	1,278,722	556,945	97,468	552,244
Hanoi	280,724	186,933	16,445	71,771

The data of Vietnam Register also show the proportion of trucks, buses nationwide, shown in detail in table 3, 4.

Table 3. Proportion of Bus types nationwide in 2010 (Vietnam Register, 1/2011)

Type	Number of vehicles	Proportion
From 10 to16 seats	56472	58%
From 17 to25 seats	5694	6%
From26 to 45 seats	23629	24%
On 45 seats	11610	12%
Total	97468	100%

Table 4. Proportion of Truck types nationwide in 2010 (Vietnam Register, 1/2011)

Weight	Number of vehicles	Proportion
To 2 tones	269,011	49%
On 2 tones to 7 tones	171,742	31%
On 7 tones to 20 tones	108,192	20%
On 20 tones	3,299	1%
Total	552,244	100%

Supposing that types of bus and truck in Hanoi city has the same proportion as the one of the whole country. In this case we can separate two groups of 10- 16 seats coach and truck with weight up to 2 tones into light duty auto vehicle group (including car). The groups of remain coach and truck belong to the heavy duty vehicle group. The result is shown in the table 5.

Table 5. Vehicle kilometer travelled (VKT) modified in Hanoi

	LDVs	HDVs
VKT (km/year)	6,440	6,924

The amount of under 10 years old vehicles of Vietnam has taken up for 73% of total vehicle nationwide, the amount of over 10 to 15 year old vehicles has accounted for 11% and the amount for over 20 year old vehicle has made up for 6% by the end of the year 2010. The data comes from Vietnam Register. If groups of vehicle, which is classified by using ages, of Hanoi city have the same proportion, we can have data source of automobile vehicle types shown in table 6.

2.1.3 Vehicle Kilometres Travelled

Annual kilometer travelled of vehicles in Hanoi was established based on the result of research "Emission Inventory of Air Pollutants from Road Traffic Sources in Hanoi City for Environmental Planning" conducted by CEMM in 2010 (Ho et.al, 2010). However, the auto classification of that research does not match with classification method of this research. Therefore, the data is adjusted to match with average weight method.

2.2 Establishing dynamics model by Stella

The "group model" is used to model the vehicle populations in which the activities of certain groups in the population needed to be monitored and the group's relative size may change by the dynamic. The group model will split a population (people, animals, cars...) into sub-populations (or groups) based on age. The value of a group at a time is the amount of inflow from the previous group minus the flow out and goes into the next one. If each group has a scrap component, we take it as a supplemental out flow to the model.

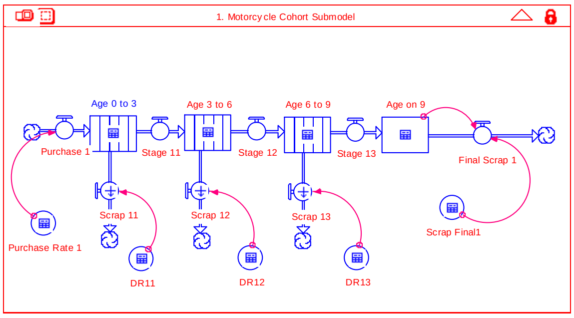

Figure 3. Motorcycle by Using Age-Cohorts Sub model

This Stella model concludes three vehicle sub models, followed three main transports in Hanoi. Each ones simulates a system of automobiles divided into some cohorts based on age of vehicle. Each cohort in the Vehicle Cohort Submodel contributes to emissions calculated in the Emissions Submodel. Each type of vehicle has different age so vehicles are classified into different age-cohorts. Motorcycles have shorter using time than automobiles (only about 10 years). Therefore, groups of motorcycles also have shorter age with differential of 3 years old among cohorts. Automobile types are divided into cohorts with age differential of 5 years old among groups. However, type of heavy duty automobiles have longer using time (about 30 years) so they are divided into 6 cohorts. Light duty auto vehicle (25 years) are only classified into 5 groups.

Initial input flow of these vehicle groups is the number of vehicle which is bought at that time. As it was shown in the model, the number of annually newly- bought vehicle is identified by composition of growth rate and the total number of this vehicle type. The final output flow is the number of vehicles finally to be getting rid of after long using time. At each age-cohorts, we also add a scrap flow representing vehicles omitted by accidents or malfunction.

After already establishing vehicle complex models, in order to examine emission inventory, we need more sub models to calculate emission for each vehicle cohort at different ages. The variables include emission factor for each age-cohorts, annually vehicle kilometre travelled (VKT) for each group.

3. Result and discussion

3.1 Emission inventory of traffic sources at highways of Hanoi

The estimated emission from traffic sources of Hanoi in 2010 is described in table 6.

The result shows that motorcycles are still the main emission source causing pollution in Hanoi city with emission rate accounting for 76% (minimum) and 98% (maximum). Despite the smallest proportion among examined traffic vehicles, heavy duty vehicle group has high emission rate of NO_X and PM (22 % and 18% respectively). Light duty autos take up a considerable emission amount as compared to heavy duty ones. However, its emission amount takes up inconsiderable rate among all calculated gas pollutants (from 1-3%).

Table 6. Estimation of air pollution emissions from vehicle fleet in 2010

	Motorcycles		HDVs		LDVs		Total Emission (tones)
	Emissions (tones)	Proportion (%)	Emissions (tones)	Proportion (%)	Emissions (tones)	Proportion (%)	
CO	160,377.87	98	417.79	0.26	2680.1	1.64	163,475.76
HC	12,494.96	98	100.06	1	155.23	1	12,750.25
NOx	7,274.85	75	2,086.67	22	296.94	3	9,658.46
PM	227.40	81	50.61	18	3.3	1	281.30
CO_2	1,603,407.62	76	232,720.14	11	281,812.00	13	2,117,939.76

In general, these results are lower than estimations in the report “Emission Inventory of Air Pollutants from Road Traffic Sources in Hanoi City for Environmental Planning” carried out by CEMM in 2010 (Ho et.al, 2010). The report has shown that CO emission amount is lower than 55.3% and NO_X is 15.21 %. This remarkable differentl is due to the following reasons:

- Firstly, CEMM used emission factors of WHO. This research used coefficient set of British Transport Bureau which was established in 2009. Therefore, emission coefficient value of these pollutants is also lower than of WHO.
- Secondly, more than 70% of the vehicles in Vietnam is under 10 years old while the emission coefficients of WHO are high, equal to emission factors of over 10 years old vehicles in the emission coefficient set by British Transport Ministry. Therefore, the emission coefficient of WHO cannot represent for the auto population of Vietnam in general and Hanoi in particular.

3.2 Predicting emission amount of road traffic in Hanoi city from 2010 to 2040

In addition to emission inventory of road traffic sources in Hanoi city, the research also predicted tendencies of emission from now to 2040. In 2040, motorcycles are still the biggest emission source although the proportion can be reduced, of which CO emission amount accounts for 89%, NO_X and PM occupy 63% and 69% respectively.

Emission of vehicles in Hanoi to 2040 are described in Figure 4, 5, 6, 7 hereinafter.

The findings have shown that pollutants tend to increase fast from now to 2020, and then it will reduce in a cycle of about 2 years. After that, emission amount of pollutants will fall in a rather stable state. It can be a slight increase (to CO, NO_X, and PM) or decrease (to HC). To 2034, emission amounts of substances such as CO, NO_X, and PM will tend to increase with faster speed until 2040. Fast growth then reduction happens in the period from 2010 to 2020 can be explained by the fact that 70% the number of means of transportation in Hanoi are under 10 years old. Therefore, there are a great number of means of transportation becoming older and changing into group with higher emission factor in the period of 2010-2020.

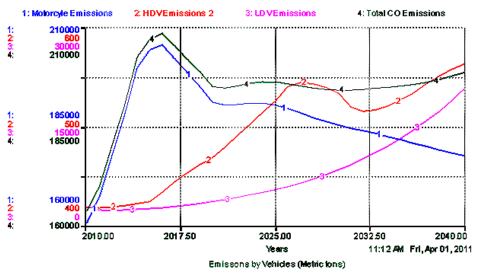

Figure 4. Estimate and Predict CO Emissions from Vehicles to 2040.

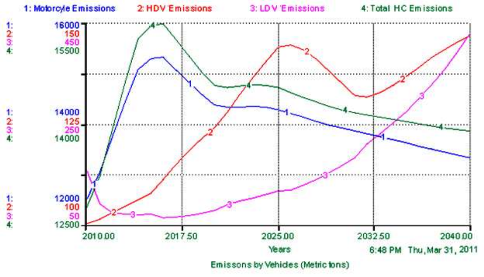

Figure 5. Estimate and Predict HC Emissions from Vehicles to 2040.

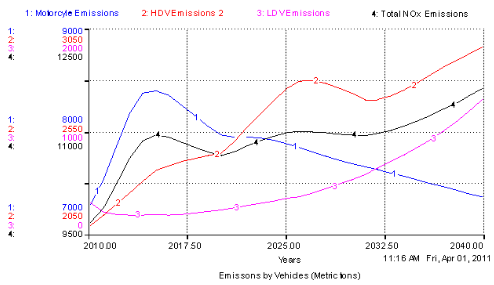

Figure 6. Estimate and Predict NO_X Emissions from Vehicles to 2040.

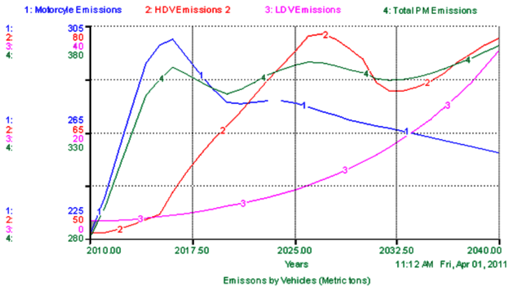

Figure 7. Estimate and Predict PM Emissions from Vehicles to 2040.

3.3 Assessing effectiveness of applying new gas exhaust standards

The assessment is based on 2 assumptions:

- Scenario 1: Apply Euro 3 standard for motorcycles and Euro 4 standard for auto in 2012; apply Euro 5 standard for auto in 2015.

Contents of predicting emission of CO and NO_X of traffic means in Hanoi to 2040 according to the Scenario 1 are described by Figure 8 and 9 hereinafter.

- Scenario2: Apply Euro 3 standard for motorcycles and Euro 4 standard for auto in 2014; apply Euro 5 standard for auto in 2017.

Contents of predicting emission of CO and NO_X of traffic means in Hanoi to 2040 according to the Scenario 2 are described by Figure 10 and 11 hereinafter.

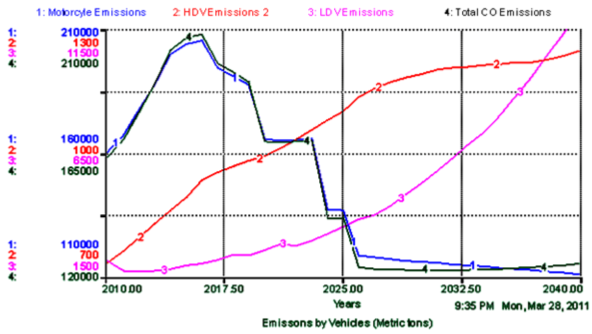

Figure 8. CO Emission Scenario 1

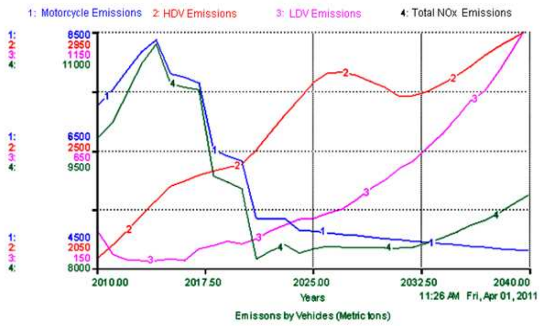

Figure 9. NO_X Emission Scenario 1

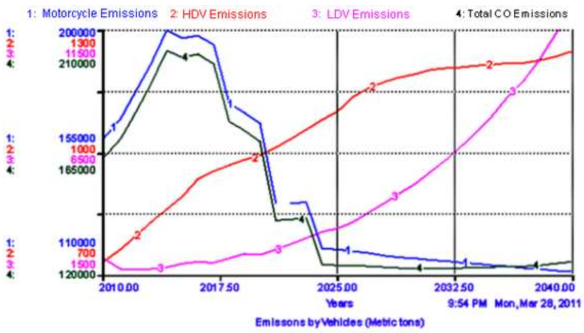

Figure 10. CO Emission Scenario 2

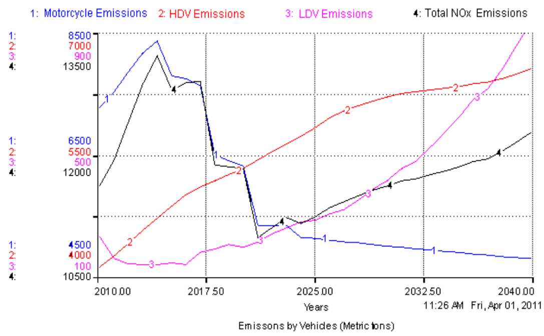

Figure 11. NO_X Emission Scenario 2

From the above results, we can come to the following remarks:

- Application of higher gas exhaust standards can bring back effectiveness in gas exhaust reduction. In details, if we apply new gas exhaust emission standard in 2020 it will reduces emission, of which CO will decrease by 13.25-13.41%, NO_X will decrease by 15.11-15.41 %. To 2040, the number will be 36.17-36.18% to CO and 22.31-23.51% to NO_X respectively.
- Therefore, application of new standards earlier (2012) or later (2014) will bring be effective in the period of 2010-2020, with gas exhaust amount will reduce 2 years earlier. Since 2020-2040, the difference of CO and NO_X emission between the two assumptions is not considerable (0.01-0.43%). These above images also show the difference of line representing total CO emission (green line) according to the scenario 2 having similar shape in the period of 2025 to 2040 while the line representing total NO_X emission amount to 2040 of the scenario 1 is lower than that of the scenario 2.
- Figure 8, 10 shows that motorcycle is still the main CO emission source to 2040. The total emission line (green) look similar to the emission line of motorcycle source (navy blue). While, sources of autos influence more clearly to NO_X emission in future as shown in image 9 and 11. Therefore, in the near future, motorcycles are still the main object in policies of controlling emission from traffic sources of Hanoi city.

4. Conclusion

Running the model for means of transportation by age-cohorts has shown us the results of emission inventory for each vehicle groups according to their age. It gives predictions on emission of these means in future, assessing impact level of method fastening emission standard to acceptable level of traffic means in Hanoi city which submitted to the Prime Minister for approval by the Ministry of Transport. By the year 2040, motorcycle is still the main emission source among traffic sources in Hanoi. However, amount of pollutant emission from vehicle source tends to reduce gradually from now to 2040 while emission from auto source will increase.

Emission inventory from traffic source in 2010 according to the method conducted in this research has shown lower result as compared to the results found in “inventory of emission from road traffic source in Hanoi city for environment planning” (Ho et al., 2010). The main cause is to use different emission factor sets. Database serving for inventorying emission from traffic in Hanoi in particular and in Viet Nam in general is still limited- we have not established an automobile emission factors set up to now, this influences to the accuracy of output results and does not reflect the true emission of pollution sources. Therefore, it’s needed to have further research in order to accomplish inventory data of emission and improve effectiveness of emission inventory tool.

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