

Impact of vehicle classification system to emission inventory development in China

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ABSTRACT

Accurate input data for emission factor models is very important to develop exact emission inventory. The method of matching the local vehicle classification data with the requirements of emission factor models impacts the results. First, this study finds that the vehicle weight distribution is a key factor that influences vehicle classification to match the classification of emission factors models. Because vehicle categories between statistical data from China and the international emission factor model are hard to match perfectly, the emission factors calculated by these emission factor models do not stand for the actual emission level. Secondly the selection of emission factor model is another factor which influences the vehicular emissions. After matching the classification of IVE by the vehicle weight distribution the CO, HC, NO_x and PM of vehicle emissions are calculated 5.29%, -1.10%, 10.84% and -1.22% respectively higher than non-matched. And the HC, CO and NO_x of vehicle emissions from MOBILE5a are 13.89%, 3.51%, 4.45% respectively higher than non-matched data. The accurate weight distribution of vehicle for any country which does not have its own emission factor model will improve accuracy of vehicle emission inventory.

1. Introduction

Since the 1990s, many large Chinese cities have experienced serious air pollution problems due to the rapid growth of automobile ownership. By the end of 2008, on-road vehicles (except motor vehicle) increased to 49,247,881 in China¹ and motor vehicle emissions have become a major source of air pollution. Because of the absence of a database in China, the vehicle emission inventory is difficult to establish with high temporal or spatial resolution.

The vehicle emission inventory of a city or the whole country has been reported in many papers²³⁴. Usually the vehicular emissions are calculated by emission factor models such as International Vehicle Emission (IVE) and the U.S. EPA MOBILE model, which are used widely in China to estimate vehicular emissions in the cities⁵⁶⁷⁸⁹. However, many factors impact results calculated by emission factor model. It is hard to develop an accurate vehicle emission inventory for the whole country even a large city.

While this approach provides a baseline estimate of on-road emissions, there are many disadvantages associated with modifying these highly region-specific models and data to accommodate other regions. However, these emission factor models are not designed for Chinese situation, which is not matched with input data of the emission factor models. For example, the vehicle classification in the emission factor models is not suitable for China. There is no matched perfectly classification data as the input data for emission factor models in China. Therefore if no one carefully treats the vehicle classification, it may bring the uncertainty to the emission inventory.

However, little research has been done on application of vehicular emission models and their

adaptability in China. We aim to improve the method of developing the vehicular emission inventory in China to make the data from China match the requirement of the emission factor models which are used to calculate the vehicle emission inventory. It is hoped that the question will be resolved with our proposed method.

2. Method and data

2.1 Method

Every emission factor model has its own vehicle classification. MOBILE5a calculates emission factors for gasoline-fueled light-duty vehicles (LDGVs), light-duty trucks (LDGTs), heavy-duty vehicles (HDGVs), and motorcycles, and for diesel light-duty vehicles (LDDVs), light-duty trucks (LDDTs), and heavy-duty vehicles (HDDVs). The LDGT comprises LDGT1 (0-2.7 tons) and LDGT2 (2.7-3.9 tons). The vehicle categories of IVE by weight comprise two major categories: auto or small truck (0-4.082 tons) and bus or truck (over 4.082 tons). And each major category consists of three categories: light, medium and heavy. Mini truck, light duty truck, medium duty truck and heavy duty truck constitute the truck classification complying with China National Standards GB/T 3730.1-1988 in China Automotive Industry Yearbook. Figure 1 illustrates that if the correspondence of classification between Chinese and the emission factor model is not determinate, the result by emission factor model is not accurate. Therefore it brings the uncertainty to vehicular emission inventory.

Figure 1 The classification of truck by China Automotive Industry Yearbook, IVE and MOBILE5a

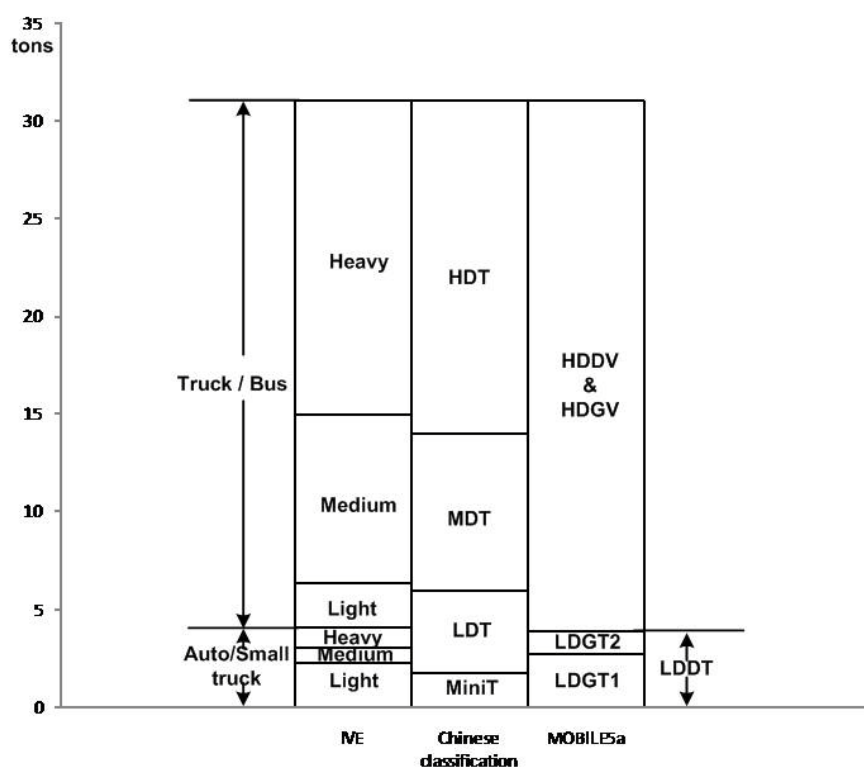
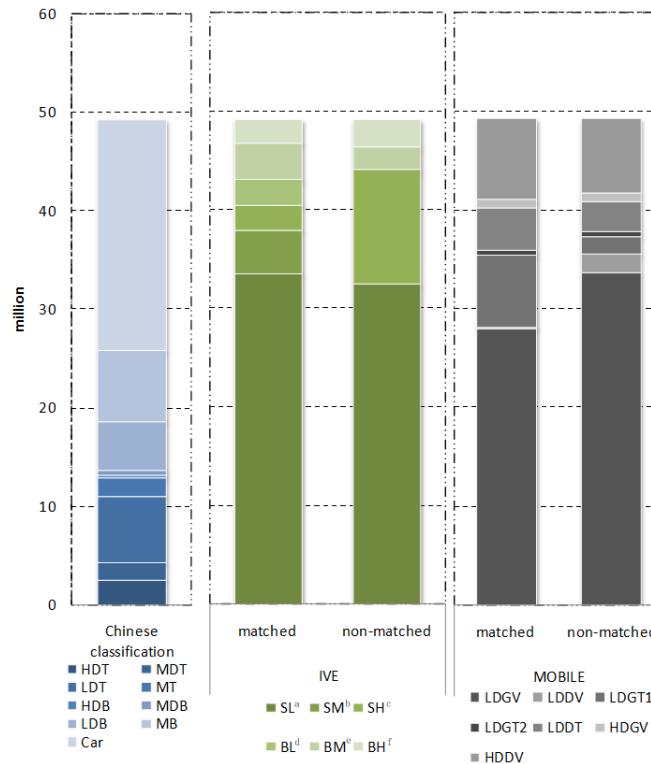


Figure 2 The vehicle population in each classification system



d BL means light vehicle of bus or truck

e BM means medium vehicle of bus or truck

f BH means heavy vehicle of bus or truck

2.2 Vehicle classification system and vehicle weight distribution in China

The raw data on the national vehicle population and the new sale of vehicle for each year were obtained from official statistical yearbooks. Since 1990, the original data have included population of each vehicle category classified by maximum total weight (GVWR). However, the vehicle population is classified by the China National Standards GB/T 3730.1-1988 that is different from the IVE model classification and the MOBILE5a model classification. So the vehicle population data classified by the China National Standards must be interpreted to what are suited for the IVE model and MOBILE5a model. But there is no study which is about how to interpret the data to match the vehicle classification requirements of emission factor models.

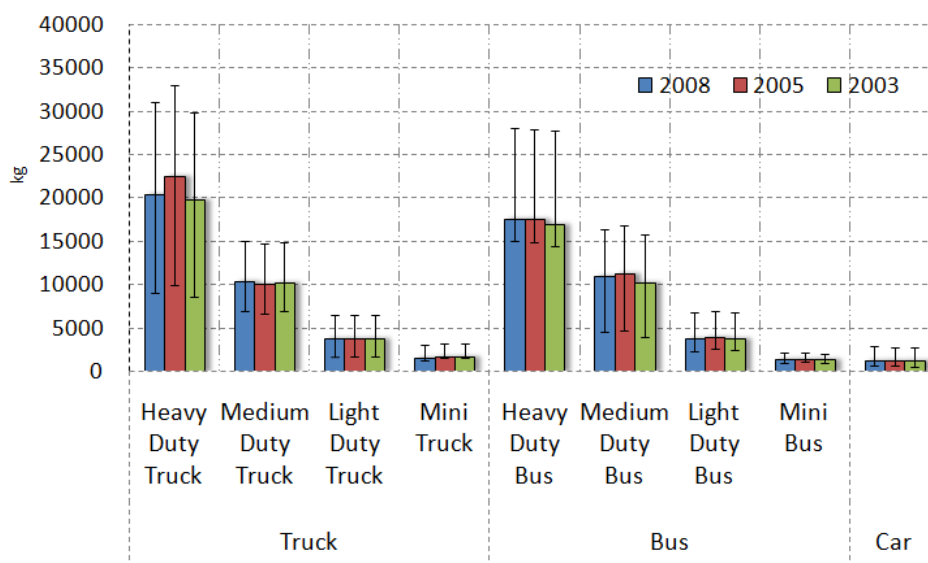
In our study the hypothesis is that the weight of vehicle distribution in new vehicle sale population in 2008 is considered to stand for the weight of vehicle distribution of vehicle population in 2008. The weight distribution of new vehicle in 2008 is developed basing on the investigating weight and sales volume of each category of new vehicle. The weight of vehicle distributions in new vehicle sale population in 2003 and 2005 are also determinate, which are similar to what in 2008. In the Figure 2 taking the light duty truck as an example, the average weight in 2003, 2005 and 2008 are 3789kg, 3766kg, 3735kg respectively and the standard deviation are 1499kg, 1570kg, 1511kg respectively. Consequently the weight distribution of new vehicles changes gradually. The mainly vehicle population consist of the about recent 7 years (the periods are not the same in different categories), so the hypothesis is workable.

Though the GB/T 3730.1-1988 sets the weight range in different categories, the real weight

distributions of vehicle in different categories are not like that. The Figure 2 shows the range of weight of vehicle in different categories. There are lots of medium duty vehicles whose weight reach the range of heavy duty vehicles. As a result the overweight medium vehicles' emission factors are the same as the heavy duty vehicles, and in the past basing on national standard they usually were still considered to the medium duty vehicles but ignoring the weight of vehicle.

Because the classification of vehicle from China Automotive Industry Yearbook is not matched with the vehicle classification requirements of emission factor models, there is a big uncertainty in the total vehicle emissions. All the emission factor models are according to GVWR to classify the emission factors as the basic emission rate. In another word the GVWR plays an important role in calculating the emission factors, which are similar if the GVWR is close by using the same fuel.

Figure 3 Weight distribution of new vehicle in 2008



2.3 IVE and MOBILE5a model

2.3.1 IVE model

The International Vehicle Emissions (IVE) model is a computer model designed to estimate missions from motor vehicles. Its prime purpose is for use in developing countries. The model predicts local air pollutants, greenhouse gas emissions, and toxic pollutants. It needs the vehicle fleet and the location information of the region which you want to calculate. You could design the vehicle fleet from over 700 kinds of technology which are including the fuel type, the size of the engine, the weight of the vehicle and so on. The location information contains fuel characteristics, the air conditioning use and driving characteristics.

The IVE model is based on the second by second driving pattern data which is similar to the MOVEs model¹⁰. Vehicle Specific Power (VSP) is a key parameter to connect the emission with the driving cycle. The IVE model will give you the vehicle emission which contains the cold start and the hot emissions. And for the volatile organic compounds emission the vapor emission is also calculated.

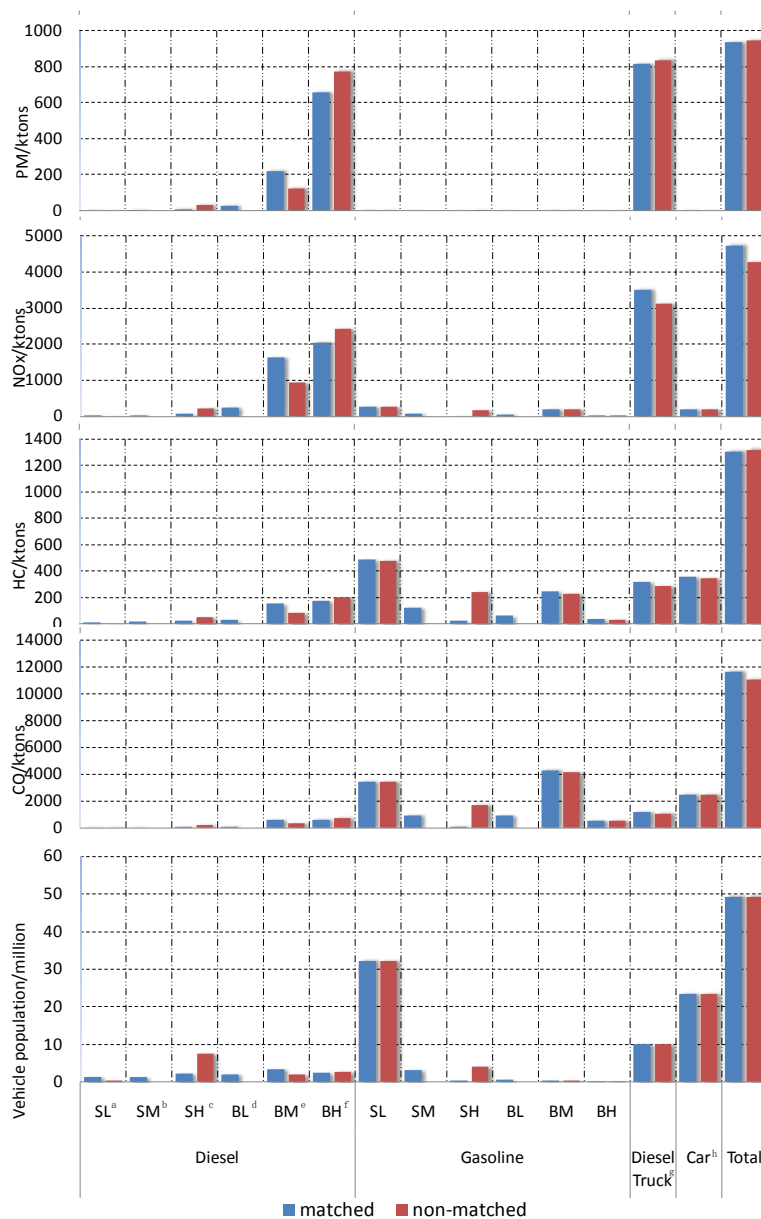
2.3.2 MOBILE5a model

MOBILE5 calculates emission factors for eight individual vehicle types in two regions (low and high altitude) of the country. MOBILE5 emission factor estimates depend on various conditions such as ambient temperatures, average travel speed, operating modes, fuel volatility, and mileage accrual rates. Many of the variables affecting vehicle emissions can be specified by the user. MOBILE5 will estimate emission factors for any calendar year between 1960 and 2020, inclusive. The 25 most recent model years are considered to be in operation in each calendar year.

3. Results

In order to estimate the accuracy of the vehicle emission inventory calculated by the emission factor model, the weight distribution of vehicles was determined by collecting the weight data of each new vehicle in 2008.

Figure 4 The vehicular emissions and population distribution of each category by IVE



a SL means light vehicle of auto or small truck

b SM means medium vehicle of auto or small truck

c SH means heavy vehicle of auto or small truck

d BL means light vehicle of bus or truck

e BM means medium vehicle of bus or truck

f BH means heavy vehicle of bus or truck

g all of the diesel truck in Chinese classification

h all of the car in Chinese classification

According to the original classification the CO, HC, NO_x and PM of vehicle emissions are calculated to be 11669.1, 1303.0, 4745.2 and 936.6 ktons respectively by IVE. Depending on the matched data the CO, HC, NO_x and PM of vehicle emissions are 5.29%, -1.10%, 10.84% and -1.22% higher than non-matched data, respectively. The Figure 4 presents that there is no vehicle in medium vehicle of auto and small truck and light vehicle of bus and truck in original classification. Due to average weight of the light duty truck in Chinese classification is 3735kg, all of light duty vehicles are put into the heavy vehicle of auto or small truck. Actually the weight distribution of light duty vehicle is wide and the range of weight is from 1700kg to 6495kg. So there are many vehicles whose weights are over 4082kg (the max weight of heavy vehicle of auto and small truck in IVE). Moreover the weight distributions of other categories are wider than what are described in China National Standard. This is the obvious difference between matched and non-matched data. The population of heavy vehicle of auto and small truck is overrated in the original classification. That is why the population of light and medium of bus or truck in matched data are more than in original classification.

The total emission of HC and PM are almost the same between matched and non-matched data, but the contribution to the total emission of each category of vehicle has been changed. The positive increasing emission almost equals the negative in all of the categories of vehicles in IVE. The Figure 5 illustrates that the classification system impacts the emission inventory of diesel vehicle in Chinese classification to car.

Figure 5 The vehicular emissions and population distribution of each category by MOBILE5a

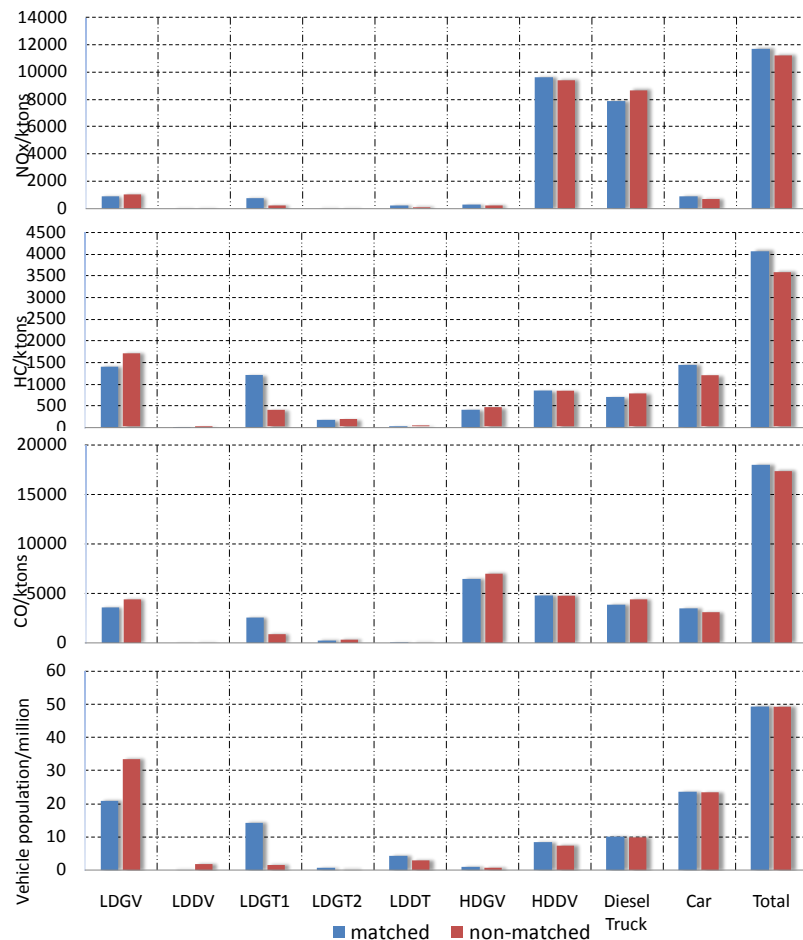


Figure 5 shows that the matched data method generally results in higher emissions than the

non-matched method and the percent difference of these missions between these two methods are respectively 13.89%, 3.51% and 4.45% for HC, CO and NO_x. Because it is the main difference between matched data and non-matched data in MOBILE5a that the population of LDGT1 in matched data is more than that in non-matched data. The GVWR of most of Multi-Purpose Vehicle (MPV) and Sport Utility Vehicle (SUV) is more than the average GVWR of cars, and the emissions from MPV and SUV are more than the cars, so they should be considered as the LDGT1 (shows in Figure 5). As a result the HC emission is the most different from the result of non-matched data.⁹

The seven vehicular categories in MOBILE are less than in IVE, and the ranges of vehicle weight in MOBILE classification are wider, especially the range of the weight of HDGV and HDDV is over 3.9 tons. According to weight distribution of vehicle the classification is adjusted to match the requirement of emission factor model. As a result, it has more significant influence on the results from IVE than from MOBILE.

4. Conclusion

In our study we find that the vehicle weight distribution is a key factor that helps vehicle classification to match the classification of emission factors models especially for the emission factor models which are not designed for China. Because vehicle classifications of statistical data from China Automotive Industry Yearbook and the international emission factor models are hard to match perfectly, the emission factors calculated by these emission factor models do not stand for the actual emission level. The GVWR (gross vehicle weight rating) distribution in different categories of vehicle in model year will be presented in this paper. And the paper presents the results from the different weight distribution of all kinds of vehicles by the IVE model and the MOBILE5a in the model year of 2008. In this study, the focused vehicles do not contain the motor vehicle.

The MOBILE5a model is more suited for macro scale to calculate the level of vehicular emissions, which do not need more information such as the driving cycle and the number of vehicle start. But the vehicular emission of a city is the focus, the IVE model may be the better choice. The driving cycle and the number of vehicle start are easy to get by investigation. The emission factor in IVE model is related with the VSP, so the emission factors calculated by the IVE model were more consistent with the on-road measurement than the MOBILE model⁴.

In order to estimate the accuracy of the vehicle emission inventory calculated by the emission factor models, it is necessary to determinate the weight distribution of vehicles by collecting the data.

Since emission factors have great influence on the emission inventory, it is important that whether the vehicle categories are matched with the vehicle classification of emission factor models. After matching with the classification of IVE by the vehicle weight data the CO, HC, NO_x and PM of vehicle emissions are calculated 5.29%, -1.10%, 10.84% and -1.22% respectively higher than non-matched. There is a big difference among the NO_x emission factors of bus or truck in IVE. So it is necessary for getting the accurate NO_x emission inventory to estimate exactly the population in different categories. The HC, CO and NO_x of vehicle emissions from MOBILE5a are 13.89%, 3.51%, 4.45% higher respectively than non-matched data. The accurate weight distribution of vehicle for any country which does not have its own emission factor model will help match the vehicle classification in emission factor models to improve accuracy of vehicle emission inventory.

REFERENCES

- ¹ China Automotive Industry Yearbook, 2008.
- ² Hao Cai, Shadong Xie “Estimation of vehicular emission inventories in China from 1980 to 2005”, Atmospheric Environment. 2007, 41, 8963–8979.
- ³ Haikun Wang, Lixin Fu, Yu Zhou, Xuan Du, Weihua Ge “Trends in vehicular emissions in China's mega cities from 1995 to 2005”, Environmental Pollution, 2010, 158, 394-400.
- ⁴ Haikun Wang, Changhong Chen, Cheng Huang, Lixin Fu “On-road vehicle emission inventory and its uncertainty analysis for Shanghai, China”, Science of Total Environment, 2008, 398, 60-67.
- ⁵ Fu L, He K, He D, Tang Z, Hao J. “A study on models of MOBILE source emission factors”, Acta Sci Circumstantiae, 1997, 17(4), 474-9.
- ⁶ Zhu C. “Coefficient of vehicular emission discharge and trend of pollution in Guangzhou City”, China Environ Sci, 1997, 17(3), 216-9 (in Chinese).
- ⁷ He D, Hao J, He K, Fu L. “Vehicle emission factors determination using model calculation”, Environ Sci, 1998, 19(3), 7-10 (in Chinese).
- ⁸ Fu L, Hao J, He D, He K. “The emission characteristics of pollutants from motor vehicles in Beijing”, Environ Sci, 2000, 21(3), 68-70 (in Chinese).
- ⁹ Yao Zhi-liang, He Ke-bin, Wang Qi-dong, Huo Hong, Liu Huan, He Chun-yu, James Lents “Application Study of IVE Vehicle Emission Model”, Huan Jing Ke Xue, 2006, 27(10), 1928-1933.
- ¹⁰ Koupal J, Michaels H, Gumberworth M, Bailey C, Brzezinski D. “EPA's plan for MOVES: a comprehensive mobile source emissions workshop”, Proceedings of the 12th CRC on-road vehicle emission workshop,; U. S. Environmental Protection Agency: San Diego, CA; 2002.

KEY WORDS

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vehicle classification system
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