ESTIMATION OF VEHICLE EMISSIONS DUE TO VEHICLE AGE IN SRI LANKA-A CASE STUDY FOR TOYOTA AND NISSAN CARS

A.C. Edirisooriya, E.M.A.C. Ekanayake and Terrance M. Rengarasu

ABSTRACT

This abstract presents the results of a 2015 study which aimed to model the effect of vehicle age on vehicle emissions, using 0.2 million vehicle emission testing reports from 2011 to 2013. This research is focused on Toyota and Nissan petrol motor cars which makes a major portion of motor cars in Sri Lanka. Variations of Carbon Dioxide (CO₂), Hydrocarbon (HC) and Carbon Monoxide (CO) with the vehicle age and vehicle make are analyzed. Using the results of analyse FORecast of Emissions from Motor Vehicles (FOREMOVE) model was modified to estimate total emission. According to the Sri Lankan vehicle registration data, failure steepness is 1.21 and characteristic service life is 15.21 years. In year 2013 number of Toyota and Nissan cars scrapped is 7429 and 3465. Using the vehicle emission testing data emission factors were estimated using polynomial method.

1. INTRODUCTION

Vehicle emissions all over the World are in rise mainly due to increased number of vehicles on the roads. In the 34 year period from 1970 to 2004, the second highest growth rate for greenhouse gas emissions achieved by the transportation sector. The growth in direct emission from transport sector in this 34 year period is 120% (Raupach et al. 2007). In 2012, more than 5 million vehicles are used in road systems worldwide. Vehicle emission is the topic for many past studies. Sri Lankan government has implemented acts to control and monitor vehicle emissions. However, what is needed is a vehicle emission model for Sri Lanka. This study aims to modify the Europe based model called ‘FORecast of Emissions from Motor VEHicles’ (FOREMOVE) to predict the total emissions (CO₂, HC, CO) from motor cars in Sri Lanka.

2. METHODOLOGY

200,000 vehicle emission testing (VET) reports from 2011 to 2013 were collected from Laugfs eco Sri (PVT) LTD, one of two companies carrying out VET in Sri Lanka. Vehicle registration data from 2005 to 2013 were collected from Department of Motor Traffic and fuel consumption data were extracted from used vehicles selling website.

2.1 Analysis of vehicle emission data

This study was focused on Toyota and Nissan petrol cars having a service life of less than 30 years. Variations of CO₂, HC, and CO with the vehicle age and vehicle make were analyzed. According to the analysis CO and the HC emission is increased with the vehicle age while CO₂ emission is decreasing. Figure 1 shows the emission variation of CO₂ for Toyota cars in 2012. There was an observable variation of CO and HC emission with the vehicle make. But there was no considerable variations of CO₂ emission with the vehicle make.

2.2 Modifying FORMOVE model

In this study (FOREMOVE) was selected and it was modified according to the Sri Lankan context to estimate total emission of per particular year. FORMOVE models first three equations are given in Equation 1 to 3.

1) To find the presence probability of certain type of vehicle.

\[ \varphi_i(k) = e^{-\left[(\frac{k+b_i}{c_i})^{k_i}\right]} \quad \text{and} \quad \varphi_i(0) = 1 \]  

(1)

2) Number of scrapped vehicles for particular year and

\[ C_{si}(t) = \sum_{k=1}^{n} \left[ C_i(t-1,k-1) \left( 1 - \frac{\varphi_i(k)}{\varphi_i(k-1)} \right) \right] \]  

(2)

3) Amount of carbon dioxide, carbon monoxide and hydrocarbon emission for a particular year.

\[ E_{pi}(t) = \sum_{i=1}^{m} \left[ VKM_i(t) EF_{ip} \right] \]  

(3)

Where, \( k \) is the age of vehicles, expressed in years. \( \varphi_i(k) \) is the presence probability of vehicles of type \( i \) having age \( k \). \( b_i \) is the failure steepness for vehicles of type \( i \). \( T_i \) is the characteristic service life for vehicles of type \( i \). \( C_a \) is the number of vehicles type \( i \) that were scrapped during year \( t \). \( CC_i(t-1,k-1) \) is the number of vehicles of type \( I \) and age \( k-1 \) that existed in the previous year. \( E_{pi} \) is the total amount of road traffic emissions in year \( t \). \( VKM_i(t) \) is the total vehicle kilometers travelled by vehicles of type \( i \) in year \( t \). \( EF_{ip} \) is the emission factor of vehicles of types \( i \) for pollutant \( p \).
3. RESULTS AND DISCUSSION

Nine years data obtained from the motor vehicle department on vehicle registration was used to estimate ‘failure steepness’ and the ‘characteristic service life’ of the Sri Lankan vehicle fleet which are the two parameters in the first equation of FOREMOVE. According to the Sri Lankan vehicle registration data failure steepness is 1.21 and characteristic service life is 15.21 years. Modified first equation of FOREMOVE is used in the second equation along with emission test data to estimate the number of scrapped vehicle for a particular year for Toyota and Nissan petrol cars separately. Results indicate that in 5,210 Toyota cars and 1,429 Nissan cars were scrapped in year 2012 while this number is 7,431 and 2,918 respectively for year 2013. Third equation of FOREMOVE needs emission factors and vehicle kilometers travelled. Using the vehicle emission testing data emission factors were estimated for CO\textsubscript{2}, CO and HC separately as a function of service life and make of the vehicle. Vehicle kilometers travelled too were estimated from the ODO meter readings available in the vehicle emission testing data. For example new Toyota car (0 age) having a emission factors of 0.2 g/km while 20 year old Toyota car will have 15.8g/km for CO. Overall results indicate that emission of CO\textsubscript{2} decrease with age while CO and HC emission factors increase.

4. CONCLUSIONS

The results reveal that there is a significant emission variation for Toyota and Nissan cars with the vehicle age and also with vehicle make. According to the results, HC and CO emission increase with vehicle age. The rate of increase of HC emission for Toyota cars in first ten years is 0.0485 g/l/year while that value increases to 0.172 g/l/year after ten years. Emission of CO\textsubscript{2} is decreased with vehicle age. For the first 10 years for Toyota cars CO\textsubscript{2} emission decrease at rate of 0.0084 kg/l/year while that value is 0.0487 kg/l/year after 10 years. Figure 2 shows HC, CO and CO\textsubscript{2} emission factor variation with vehicle age for Toyota cars. A 3\textsuperscript{rd} degree polynomial model was developed to predict the emission factors with vehicle age k. As an example the model for CO\textsubscript{2} HC and CO emission factors of Toyota cars are given in Equation 4, 5, and 6 respectively. Equation 7, 8 and 9 gives the CO\textsubscript{2}, HC and CO emission factors for Nissan cars respectively.

\[
\begin{align*}
EF_{CO_2}^T &= 2.406 + 0.028k - 0.004k^2 + 7.46 \times 10^{-5}k^3 \quad (4) \\
EF_{HC}^T &= 0.512 - 0.094k - 0.019k^2 + 3.86 \times 10^{-4}k^3 \quad (5) \\
EF_{CO}^T &= 0.025 - 0.012k - 0.002k^2 - 3.80 \times 10^{-5}k^3 \quad (6) \\
EF_{CO_2}^N &= 2.290 - 0.041k - 0.005k^2 + 8.2 \times 10^{-5}k^3 \quad (7) \\
EF_{HC}^N &= 0.696 - 0.017k + 0.006k^2 - 4.9 \times 10^{-5}k^3 \quad (8) \\
EF_{CO}^N &= 0.098 - 0.014k + 0.002k^2 - 3.4 \times 10^{-5}k^3 \quad (9)
\end{align*}
\]

REFERENCES


