Review On Vehicular Emission Models (Hdm4)

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ABSTRACT

Higher economic growth, inadequate conveyance facilities, wishes to have a private automotive have resulted in increase in variety of vehicles. This increase in variety of vehicles is inflicting several issues like transport pollution, congestion, road accidents, traffic noise etc. Through pipe, vehicles emit numerous harmful chemical compounds as an immediate results of combustion method. Since vehicle emissions ar ground level sources, they need direct impact on health of human beings, excluding increase in variety of vehicles, roads that accommodate these vehicles have vital impact on transport emissions. transport emissions ar extremely associated with fuel consumption by vehicles. Traffic jams, long queues on red lights and poor road conditions have an effect on the steady pattern of flow and this result into higher fuel consumption and consequently high transport emissions ar determined. road Development and Management i.e. HDM-4 may be a software tool that has been used worldwide as a designing and programming tool for road investment and maintenance activities. Emission models ar introduced in HDM-4 to predict the environmental impacts of any projected infrastructure investment. Seven parts of car exhaust emissions particularly greenhouse emission, CO, hydrocarbons, inhalation anaesthetic, dioxide, particulates and lead ar modelled in HDM-4. This paper describes the HDM-4 emission models intimately. As these emission models ar based mostly upon fuel consumption approach, fuel consumption in respect to road attributes is additionally mentioned.

1. INTRODUCTION

Almost each urban centre, not solely in Bharat, however throughout the planet is facing the matter of poor air quality. pollution thanks to vehicle exhaust may be a vital contributor to overall pollution. road Development and Management i.e. HDM-4 tool is that the outcome of the International Study of road Development and Management (ISOHDM) and may be a package tool that has been used worldwide for coming up with and programming of road investment and maintenance activities. The HDM-4 analytical framework predicts road deterioration, road works effects, road user result and environmental effects. The environmental effects embrace vehicle emissions, traffic noise and energy balance analysis. In HDM-4, seven parts of auto exhaust emissions specifically dioxide, carbon monoxide gas, hydrocarbons, inhalation anaesthetic, sulfur dioxide, particulates and lead are modeled. These parts are calculable to make the bulk of conveyance emissions and ar the foremost damaging to the natural surroundings additionally on the human health. With the HDM-4 emission models, it's attainable to research the changes within the conveyance emissions as a results of implementing totally different road maintenance and improvement choices, or once there ar major changes to the fleet victimisation the road network (for example, thanks to improved vehicle technology). Environmental effects analysis through HDM-4 can facilitate in creating decisions relating to pavement maintenance activity. This paper first of all reviews totally different conveyance emissions modelling approaches and so presents HDM-4 emission models thoroughly. As Emissions models in HDM-4 are extremely associated with fuel consumption thus details of fuel consumption also are mentioned.

2. EMISSIONS MODELLING APPROACHES

For the modelling of vehicle emissions, several approaches have been developed. Each of the following approaches has advantages as well as disadvantages and is used for specific types of applications:

a) Average speed
b) Single emission factors
c) Fuel consumption
d) Detailed traffic flow/ engine power calculations

Average speed
This approach utilizes the empirical relationship between emissions level (in gram/veh-km) and average speed for the particular emission component and vehicle type. Total level of emissions is then obtained by multiplying total veh-kms travelled at that speed. Advantage of this approach is that the only independent variable average speed is used to calculate emission levels. Moreover average speed represents a combination of driving pattern, so partially effect of acceleration and deceleration is taken into account.

**Single emission factors**

This approach applies a separate emission factor for each combination of vehicle type and pollutant. In this approach, driving activity i.e. driving conditions have no effect over the level of emissions. Total number of kilometers travelled by each vehicle type is the only factor to calculate total emissions. Its advantage is that it is simple to calculate emissions and disadvantage is that altering road conditions has no direct impact on emission levels.

**Fuel consumption**

This approach links emissions with fuel consumption. This is the approach which has been applied for modelling of current HDM-4 emission models. Its main advantage is that where fuel consumption is calculated in a detailed way, for example modelling the effect of road condition, gradient, engine function and so on, changes in fuel consumption are related directly to changes in road condition. Levels of pollutant emissions can therefore also be related directly to changes in road condition, as well as traffic and vehicle technology.

**Detailed traffic flow/ engine power calculations**

In this approach, information on real driving cycles is used to simulate vehicle engine condition over time. This approach is supposed to be accurate but most data intensive also. The lack of relevant data makes this approach difficult to apply.

### 3. HDM-4 EMISSIONS MODEL FORM

The engine out emissions are predicted based on fuel consumptions rates and then these emissions are acted upon by catalytic converter (a vehicle emission control device), if present, to yield tailpipe emissions observed by the environment.

\[
\text{TPE} = \text{EOE} \times \text{CPF}
\]

TPE is tailpipe emissions which are actually observed by the environment.

EOE is engine out emissions which are actually produced during combustion process and then they are treated by catalytic converter.

CPF stands for catalyst pass fraction, which is effectiveness of catalytic converters in reducing emissions.

#### 3.1 Engine out Emission Models

These models give engine out emissions by component for standard motorised vehicle types. There are 16 standard vehicle types in HDM-4. The following components of vehicle exhaust emissions are modelled in HDM-4:

1. Carbon monoxide
2. Sulphur dioxide
3. Nitrous oxide
4. Hydrocarbons
5. Particulates
6. Lead
7. Carbon dioxide
Carbon monoxide

A direct relationship exists between engine out emissions and fuel consumption which is evident from the model also.

\[ \text{EOE}_{\text{CO}} = a_{\text{CO}} \times \text{FC} \]

EOE\(_{\text{CO}}\) is the engine out CO emissions in gram/km \(a_{\text{CO}}\) is a model coefficient, defined as grams of CO emitted per gram of fuel consumed (gramco/gramfuel).

FC is the Fuel Consumption in gram/km.

Sulphur dioxide

The amount of SO\(_2\) emitted is related directly to the quantity of sulphur present in the fuel. Model coefficient is estimated by assuming all the sulphur present in the fuel is converted to SO\(_2\). The following relationship is used to predict engine out emissions:

\[ \text{EOE}_{\text{SO}_2} = 2a_{\text{SO}_2} \times \text{FC} \]

EOE\(_{\text{SO}_2}\) is the engine out SO\(_2\) emissions in gram/km

\(a_{\text{SO}_2}\) is defined as grams of SO\(_2\) emitted per gram of fuel consumed (gso2/gfuel)

Nitrous oxide

This component of exhaust emissions is least related directly to fuel consumption. That is why the model presented below is bit complex.

\[ EOE_{\text{NOx}} = \max \left[ a_{\text{NOx}} \left( FC - \frac{FR_{\text{NOx}}}{V} \right) \times 1000, 0 \right] \]

EOE\(_{\text{NOx}}\) is the engine out NO\(_x\) emissions in gram/km

\(a_{\text{NOx}}\) is defined as grams of NO\(_x\) emitted per gram of fuel consumed (gNOx/gfuel) \(FR_{\text{NOx}}\) is a fuel threshold parameter below which NO\(_x\) emissions are very low in g/s

Hydrocarbons

It is believed that hydrocarbons are generated from two sources within a combustion engine. First source is burning of fuel and second is from incomplete combustion. So, the model which predicts engine out emissions takes the following form:

\[ EOE_{\text{HC}} = a_{\text{HC}} \times FC + \frac{r_{\text{HC}}}{V} \times 1000 \]

EOE\(_{\text{HC}}\) is the engine out HC emissions in gram/km

\(a_{\text{HC}}\) is defined as grams of HC emitted per gram of fuel consumed(gHC/gfuel) \(r_{\text{HC}}\) is a constant to account for incomplete combustion in gram/sec

Particulates

These emissions are modelled in a same way as hydrocarbons. So, the model form is as follows:

\[ EOE_{\text{PM}} = a_{\text{PM}} \times FC + \frac{r_{\text{PM}}}{V} \times 1000 \]
EOEPM is the engine out PM emissions in gram/km

aPM is defined as grams of PM emitted per gram of fuel consumed (gPM/gfuel) rPM is a constant to account for incomplete combustion in gram/sec

Lead

The amount of lead emitted is related directly to the quantity of lead present in the fuel. Model coefficient is estimated by assuming a proportion of the lead present in the fuel is converted to lead emissions. The following relationship is used to predict engine out emission

$$\text{EOEPb} = \text{Prop}_\text{Pb} \times \text{aPb} \times \text{FC}$$

EOEPb is the engine out Pb emissions in gram/km Prop_Pb is the proportion of lead emitted

aPb defined as grams of Pb emitted per gram of fuel consumed (gPb/gfuel)

Carbon dioxide

For understanding of carbon dioxide emission model, first we need to understand about functioning of Catalytic Converters.

3.2 Catalytic Converters (CC)

Catalytic converters convert certain harmful emissions to less harmful chemical compounds. They convert, if present, any carbon in carbon monoxide, hydrocarbon, and particulate matter into carbon dioxide. The effectiveness of catalytic converters in reducing emissions is modelled through the term Catalyst Pass Fraction (CPF).

Carbon dioxide

The prediction of CO2 is modelled through carbon balance equation. This model directly gives tailpipe emissions, as the catalytic converter increases the output of CO2 by converting CO and HC and PM into CO2. The model takes the following form:

$$\text{TPE}_{CO2} = 44.011 \left[\frac{\text{FC}}{12.011 + 1.008 \times \text{aCO2}} - \text{TPE}_{CO} - \text{TPE}_{HC} - \text{TPE}_{PM}\right]$$

TPECO2 is tailpipe CO2 emissions in gram/km

aCO2 is a fuel dependent model parameter representing the ratio of hydrogen to carbon atoms in the fuel

TPEx is the tail pipe emissions for component x. Here x is CO, HC and PM.

4. FUEL CONSUMPTION

Fuel consumption is a significant component of vehicle operating cost. It is affected by road condition and alignment, vehicle characteristics, traffic congestion and driving activity. Therefore fuel consumption is sensitive parameter to any investment decisions made for the road network. When vehicle moves along a road, it encounters various forces which oppose the motion

5. STEPS FOR CALIBRATION OF HDM-4

It is important that prior of using HDM-4 for the first time in any country, the system should be configured and calibrated for local use. Since HDM-4 has designed to be used in a wide range of environments, calibration of HDM-4 provides the facility to customize system operation to reflect the norms that are customary in the environment under study (Bennett et al). Calibration of the HDM model focuses on the two primary components which determine the physical quantities, costs and benefits predicted for the analysis, namely:

• Road User Effects (RUE) ; and
• Road Deterioration and Maintenance Effects (RDME)
The degree of local calibration appropriate for HDM is a choice that depends very much on the type of application and on the resources available to the user. For example, in planning applications the absolute magnitude of the RUE and road construction costs need to match local costs closely because alternative capital projects with different traffic capacities or route lengths are evaluated on the comparison of the total road transport costs. In road maintenance programming, on the other hand, the sensitivity of RUE to road conditions, particularly roughness, and all the road deterioration and maintenance predictions are the most important aspects [2].

6. LEVELS OF CALIBRATION

There are three levels of calibration for HDM, which involve low, moderate and major levels of effort and resources, as follows:

Level 1 - Basic Application: This level determines the values of required basic input parameters, adopts many default values, and calibrates the most sensitive parameters with best estimates, desk studies or minimal field surveys.

Level 2 – Calibration: This level requires measurement of additional input parameters and moderate field surveys to calibrate key predictive relationships to local conditions. This level may entail slight modification of the model source code.

Level 3 – Adaptation: This level undertakes major field surveys and controlled experiments to enhance the existing predictive relationships or to develop new and locally specific relationships for substitution in the source code of the model.

The various resistances when the vehicle moves are aerodynamic resistance, gradient resistance, rolling resistance, curvature resistance, inertial resistance. Any change in road attributes that affect the forces opposing motion, will impact fuel consumption and consequently vehicle emissions. The important attributes relating to the road are:

- Roughness
- Texture
- Gradient and Curvature

The HDM-4 fuel consumption model is a mechanistic model which relates fuel consumption to the total power requirements of the engine.

7. Need of Calibration for Indian Conditions

The HDM-4 emission models have been developed through the field experiments conducted in wide range of conditions having different environments, technology and climate conditions. These models need to be calibrated so that the predictions made by calibrated HDM-4 models represent the specific local ground conditions. To account for local conditions, several calibration factors are incorporated with these emission models. These calibration factors can be edited to match the conditions that are collected locally. With the calibrated HDM-4 emission models, it is possible to analyze the changes in the vehicular emissions as a result of implementing different road maintenance and improvement options, or when there are major changes to the fleet using the road network (for example, due to improved vehicle technology). Such a calibrated HDM-4 emission model will help in making choices regarding pavement maintenance activity for Indian conditions.

Chandrama prasad et al. [7] in their work calibrated the HDM-4 emission models for Indian conditions. Their calibration work consisted of three stages; these are a) Sensitivity analysis b) Calibration models c) validation. They calibrated the emission models by comparing the emission outputs from uncalibrated HDM-4 with VAPIS emission predicting tool (VAPIS is other emission predicting tool). After the validation process, they compared the HDM-4 predicted emissions and observed values of emissions. Variability range of observed and predicted emissions by calibrated under their study is from 21.39% to 33.87%.

CONCLUSIONS

Air pollution is acknowledging National level drawback and evaluating every and each parameter that affects pollution is very vital. Road characteristics for instance roughness have vital impact on transport emissions. HDM-4
assesses the changes in emissions as a result of changes in road characteristics, tie up, and vehicle technology. Therefore, HDM-4 models are additional directed towards the road characteristics instead of individual vehicle emissions whereas MOBLE and MOVES (Emission models of U.S Environmental Protection Agency) are dedicated towards individual vehicle emissions instead of road characteristics. This means the individuality of HDM models with reference to different models within the space of route engineering. When the analysis in HDM-4, variety of output reports are generated that are: Emissions by Vehicle sort, Emissions internet Annual modification and Emissions outline. To any route engineer/transport analyst, Emissions internet Annual modification report is extremely vital as during this report, changes in emissions are discovered in response to maintenance/improvement applied to the road. It's conjointly helpful for policy manufacturers and transport planners. It's been so finished that the applying space of HDM-4 emission models is kind of totally different from different models.

REFERENCES

[7]. HDM-4 Manual Modelling Road User and Environmental Effects in HDM-4; Volume-7, Section B4, Fuel Consumption