Vehicle emission simulation model for a sustainable 'greener' transport system

Bhuvanachithra Chidambaram*,

ABSTRACT

The paper focuses on transport as one of the most valuable urban commons in the emerging Megacity of Hyderabad in India. The author reflects on the preliminary concepts for the ongoing research project 'Sustainable Traffic Solutions on the basis of Vehicle Emission Simulation Model for Hyderabad'. A key objective of the research is to create a vehicle emission simulation model to quantify the air-pollution related with different transport policies or strategies (e.g. promotion of public transport, coordination of traffic signals, effective land use and traffic planning regulations). Hence the model would serve as a major tool to evaluate the impacts and the mitigation potential of different transport strategies on pollution related issues such as air quality, health, global warming and to identify the least polluting/most environmental friendly solution. Though the technical approaches and strategies are a prerequisite to ease the Hyderabad traffic problems in Hyderabad, they are not self-sufficient. To effectively implement the identified – most suitable - mitigation strategy an Institutional Analysis through Institutions of Sustainability (IoS) framework is also essential. The framework-based methodology begins with the identification and definition of the potential transactions at regional (Hyderabad) level through the analysis of existing travel demand model. A transaction here is defined as the dynamics of the traffic flow that occurs due to the interaction between social entities (pedestrians, drivers etc.) and physical entities (vehicle, transport and road infrastructures etc.). A vehicle emission model is required and needs to be developed, primarily to relate the impacts of these transactions for the cause of pollution. Such a resulting model would be helpful not only to understand the existing transactions, their properties, but also, to relate, analyze and provide suggestions for remedial measures based on the existing Institutional setup, their rules and policies for implementation of emission based reduction strategies. The value of analyzing and developing this model based on the IoS framework is to make it dynamic and reflective to the changes and hence to provide a truly 'Greener' option to sustainably manage transport as urban common in the megacity of Hyderabad.

Keywords: sustainability; institutions; governance structures; vehicle emission; socio – economic factors; modeling and simulation

**** PhD Research Scholar, Division of Resource Economics, Humboldt Universität, Berlin***

1. INTRODUCTION

In the present scenario, the vehicle exhaust emissions have become an intangible and veritable threat to the citizens of Hyderabad. The city has nearly seven million population with density of 19,000 persons per sq.km. The increase in economic growth further increases the number of vehicle trips generated. Today, the city has 600-700 vehicle registrations carried out per day with the average vehicle density of 720 vehicles / km road [1]. So this ultimately result in heavy traffic congestion, enormous delay at road intersections, indiscriminate parking, increasing volumes of two-wheeler and cars, varying carriageway widths are some of the existing traffic problems in transport sector contributing to this exhaust emission [2]. So there is a need to develop strategies to control vehicular emissions through technological and institutional measures (improvement in mobility, congestion pricing, etc.). Though there has been significant works, that are being carried out for developing vehicle emission models, through various technical solutions, their effectiveness and efficiency have always been hindered due to Institutional factors. On the other hand, research activities that focus on policies do not always provide a comprehensive methodology to integrate the technical solutions and institutional measures into their decision making. Also, there is a strong need that the implementation feasibility of such technical solutions to their policies and more so, their sustainability to their subsequent changes have to be taken in to consideration.

2. RESEARCH OBJECTIVE

Based on the above background, the main objective of this research is to develop an integrated vehicle emission tool on the basis of a suitable framework that would facilitate in proposing sustainable traffic solutions through institutional analysis.

The preliminary task of this research is to create a comprehensive vehicle emission model for the Hyderabad city. This involves field data collection and vehicle emission estimation. Finally, with the results from vehicle emission estimation, an impact-scenario analysis would be done to recommend suitable and sustainable emission reduction strategies.

3. STATE-OF-ART

An extensive analysis has been carried out on various existing vehicle emission models. Most of the common models for the vehicle emission estimation are discussed here. The models are classified based on the two following procedures namely 1) Federal Test Procedure (FTP) and 2) European Test Procedure (ETP).

The models that follow FTP are IVE and MOBILE. The International Vehicle Emissions (IVE) model [3] is a computer- based model, developed and funded by US Environmental Protection Agency (EPA). It is designed in such a way, that its features are made flexible for its applicability to the developing nations. This model addresses the mobile source air emissions. This model considers three main components that help

in developing emissions inventories namely vehicle emission rates; vehicle activity and vehicle fleet distribution. The model uses vehicle specific power binning approach to calculate vehicle emission quantity. The model finally predicts local air pollutants, greenhouse gas emissions, and toxic pollutants. Another development of EPA for estimating pollution from highway vehicles is MOBILE [4]. This model was first developed in 1978 and is constantly updated. It is used for estimating hot running and cold start emissions from light-duty vehicles and motorcycles. It calculates emissions of carbon dioxide (CO2), hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO) and other toxic pollutants namely Benzene, Methyl Tertiary Butyl Ether, 1,3-Butadiene, Formaldehyde, Acetaldehyde, and Acrolein from passenger cars, motorcycles, light- and heavy duty trucks. In parallel to MOBILE6, a new generation mobile source emission model called the Motor Vehicle Emission Simulator (MOVES) [5] model was developed by US EPA , which estimate emission from both on-road and non-road emission sources. This model addresses all air quality pollutants as in the MOBILE model and has inbuilt emission inventory calculation. This differentiates this model from MOBILE.

The models that follow ETP are COPERT and HBEFA.The COPERT (Computer Program to calculate Emissions from Road Traffic) model financed by the European Environment Agency [6], was primarily developed to estimate emissions from road transport for annual national inventories. It estimates emissions of air pollutants namely CH4, N2O, NH3, SO2, heavy metals, polycyclic aromatic hydrocarbons (PAHs) and persistent organic pollutants (POPs). The total emissions are calculated as a product of activity data provided by the user and speed-dependent emission factors calculated by the model. The model accounts for different driving conditions variation in urban, rural and highway driving. This model uses the complete driving cycle and average speed to calculate emission. Another model developed by Environmental Protection Agencies of Germany, Switzerland and Austria is HBEFA (Handbook Emission Factors for Road Transport) [7]. This model provides emission factors, i.e. the specific emission in g/km for all current vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles, buses, coaches and motorcycles), each divided into different categories, for a wide variety of traffic situations. This model estimates hot emissions, cold start excess emissions and evaporative emissions. Different pollutants namely CO, HC, NOx, PM, several components of HC (CH4, NMHC, benzene, toluene, and xylene), fuel consumption (gasoline, diesel), CO2, NH3 and N2O, NO2, PN (Particle Number) and PM (Particulate Matter) for petrol vehicles are estimated in this model.

For the developing countries like India, only IVE model has made an attempt to estimate the vehicle emission by calibrating the software under local conditions of the City as carried out in Pune. The transport solutions are then be proposed for the city, using these models. However these models do not integrate an institutional approach to propose traffic solutions. Hence most of the traffic solutions are not sustainable in India. Here, an institutional approach may be defined as the analysis of social behavior, policies in transport infrastructure and vehicle activity in it. Some of the factors that influence the social behavior may be willingness to pay, affordability, time, comfort and convenience of people. An integrated tool is required for providing sustainable traffic

solutions. The workflow is supported by the conceptual framework 'Institution of Sustainability' (IoS) [8].

4. CONCEPTUAL FRAMEWORK

A conceptual framework (Fig 1) of the research was developed during the preliminary phase of the research. This framework provide as a basis to understand the integration of technical approach (vehicle emission model) with institutional approach (institutional parameters of actors involved). It starts with the identification of study stretches in Hyderabad to estimate vehicle emission quantity. Then the number of vehicle trips generated between the study stretches would be analyzed. This would be assumed as a transaction in IoS framework. In detail, a transaction is defined as the physical interaction between two groups of actors, namely, social entities (pedestrians, drivers etc.) and physical entities (vehicle, transport and road infrastructures etc.). This physical transaction may result in both positive and negative impacts to the actors involved in it. Some of the positive impacts are an increase in economic activity, more employment, and high income, thereby a rise in living standards of people. The negative impacts could be increase in traffic problems like congestion, accidents and vehicle emissions. In short, people and vehicle (actors) who create physical transaction by means of vehicle trips get affected themselves by the negative impacts of the transaction (vehicle emission). Then, to quantify this negative impact, a vehicle emission model would be used. Normally, a technical analysis would be done for the above result of vehicle emission model and suitable solutions are proposed to the stretches that are more polluted.

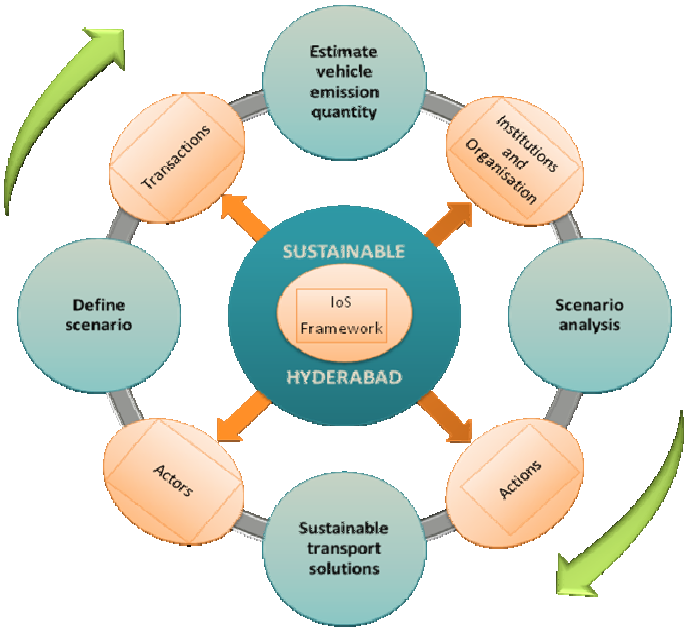

Fig 1. Conceptual Framework based on IoS

This research concept differs from a normal technical analysis, as it considers scenario analysis of a set of defined institutional parameters before proposing transport solutions. The scenario includes all the possible traffic strategies for the polluted stretches. Then institutional parameters of the actors, who create transactions, would be defined and analyzed to create an inventory under each scenario. This inventory would also made compatible with vehicle emission and travel demand software. Some of the institutional parameters defined are shown in Table1.

Table1. Actors and their corresponding institutional parameters

Actors	**Institutional parameters**
Driver	aggressive or normal or good
Police	discipline or indiscipline, sincere or insincere, punctual or unpunctual
Transport planner	efficient or inefficient, social minded or not
Transport Infrastructure	improper or proper, inadequate or adequate, time saving or consuming, comfort or discomfort, affordable or expensive
Road characteristics	deteriorated (crack, potholes, rutting) or normal or good
Policies and rules	enforced or followed or violated, strict or lenient, people friendly or unfriendly
Pedestrian	obedient or disobedient, discipline or indiscipline, aggressive or good

The vehicle emission and travel demand software would be validated using the processed institutional parameters to derive the best suitable emission reduction strategies for the selected polluted stretch. This phase is in accordance with institutional analysis phase of IoS framework. Hence, through the institutional analysis of each scenario, the sustainable emission reduction strategies could be made and recommended for transport policy decision makers which would be the last phase of IoS Framework (Action arena).

The above concept could be best explained by the following workflow (Fig 2):

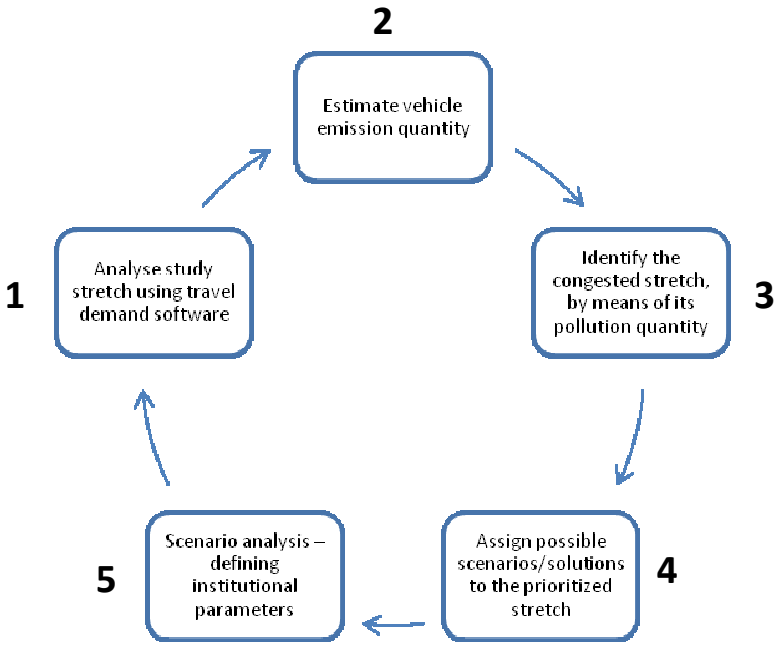

Fig 2. Concept workflow

The study stretches would be identified and analyzed using travel demand software. Then the vehicle emission model would estimate the pollutant quantity of each stretches. The stretches would be prioritized based on their pollutant quantity, i.e. higher the pollutant, more it is prioritized. For a sample case, one stretch that is more polluted on the basis of vehicle emission model is considered. The reason for the higher quantity of pollution in this stretch could possibly be congestion. The travel demand software enables to identify this cause and possible solutions (scenarios) could be assigned to this stretch. There are many transport solutions derived from simulation models to reduce traffic congestion, but this again depends on few quantized parameters like area, cost, number of road users etc. For this sample case, three common possible solutions (scenarios) could be considered, namely, road widening, construction of flyover or enforcement of lane following drive. The Institutional analysis will analyze separately these three scenarios using above listed institutional parameters and finally recommend the best scenario for the transport policy decision makers. Thus non quantized parameters like public behavior could be successfully integrated in the

simulation. This integration of top-down and bottom up approach hence would make the solution strategy truly sustainable.

5. CONCLUSIONS

The expected result and conclusion of the work would be the recommendation of the derived emission reduction strategies to transport policy decision makers for the betterment of existing policies. This would enable to evaluate the impacts and the mitigation potential of different transport strategies on pollution related issues, to identify environment friendly solution and provide stake-holders with valuable information on policy-based strategies of the transport system that influence the urban air-quality. Finally, it also facilitates the development of an integrated flexible tool and a framework, which quantifies vehicle emission and its integration with institutional analysis for proposing sustainable traffic solutions.

ACKNOWLEDGEMENT

This research is currently being carried out under the German funded BMBF Project "Sustainable Hyderabad" at the Humboldt University, Berlin together with the cooperation of PTV AG, Karlsruhe.

REFERENCES

[1] Madhusudana K, Present Status of Action Plan for Lowering of Air Pollution in the City of Hyderabad, Andhra Pradesh Pollution Control Board ,2010
[2] Walter C., and Schaefer T., Transport model for a Sustainable Hyderabad,PTV Planung Transport Verkehr AG, pp.7,2007
[3] Davis N, Lents J, Osses M, Nikkila N and Barth M., Development and Application of an International Vehicle Emissions Model, TRB Paper No. 05-1844, pp.4, 2005
[4] U.S. Environmental Protection Agency, Mobile Source Emission Factor Model (MOBILE), User Guide, pp.9, 2003
[5] U.S. Environmental Protection Agency,Motor Vehicle Emission Simulator (MOVES),User Guide, pp.17,2010
[6] European Environment Agency, COPERT4, Computer Programme to calculate emissions from road transport (COPERT), UserGuide, pp.19, 2007
[7] The Handbook Emission Factors for Road Transport (HBEFA), The Emission Functions for Heavy Duty Vehicles in the Handbook Emission Factors for Road Traffic, http://www.hbefa.net/e/index.html, 2010

[8] Hagedorn K., Particular Requirements for Institutional Analysis in Nature-Related Sectors, European Review of Agricultural Economics, Vol. 35, No. 3,pp.357-384,2008