Urban Transport Environment Interaction – Defining a National level Action Plan

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ABSTRACT: Transportation system has contributed significantly to the development of human civilization; on the other hand it has a great impact on the environment in several ways. The most important environmental impact due to transport operation is air and noise pollution. It is a need to understand air and noise pollution, methods to quantify and measures to mitigate them. In this paper, a step-by-step methodology has been presented to study transport related air and noise pollution for five major cities in India i.e. Delhi, Jaipur, Lucknow, Chandigarh and Allahabad under a Nationally Coordinated Project "Urban Transport Environment Interaction" (UTEI). A detailed analysis of the collected data is taken up to develop a prediction model for air and noise pollution for Indian conditions and to recommend measures for reduction of pollution. It is also intended to present a futuristic scenario regarding transport related pollution for India and also to define a National Level Action Plan.

RÉSUMÉ : Le système de transport a contribué de manière significative au développement de la civilisation humaine ; par ailleurs, il a un impact important sur l'environnement de plusieurs manières. L'impact environnemental le plus important dû à l'exploitation du transport est la pollution de l'air et les nuisances sonores. Il est nécessaire de comprendre la pollution de l'air et les nuisances sonores, les méthodes pour les évaluer quantitativement et les mesures pour les atténuer. Dans la communication, une méthodologie a été présentée point par point pour étudier la pollution de l'air et les nuisances sonores liées au transport dans cinq villes principales en Inde, à savoir : Delhi, Jaipur, Lucknow, Chandigarh et Allahabad, dans un Projet Coordonné au niveau national, "Interaction sur l'Environnement du Transport Urbain" (IETU). On a adopté une analyse détaillée des données rassemblées pour développer un modèle de prédiction pour la pollution de l'air et les nuisances sonores dans des conditions indiennes et recommander des mesures pour la réduction de la pollution. Il est aussi prévu de présenter un scénario futuriste quant à la pollution liée au transport pour l'Inde et aussi de définir un Plan d'Action au Niveau National.

1 INTRODUCTION

1.1 Need of study

Relationships between land use and transport are of considerable significance for the environment. The obvious national concern on the deteriorating situation of environmental features is to be indexed and watched at all levels. There is a need for generating a database as well as the rational analytical approach to predict the behavior of the deterioration due to vehicular traffic on urban arterials and its interaction with environment.

1.2 Urban transport environment scenario in India

The largest share of transport activity is by road. Road transport is responsible for over 80% of final energy consumption. Over the last forty years, there has been a ten-fold increase in the number of motorized vehicles. For the forthcoming decades, it is expected that the number of vehicles will increase substantially. In India, the number of vehicles is growing at an annual rate of more than 7% per year. This has resulted in overcrowding of roads and increased pollution.

1.3 Air and noise pollution levels

In Delhi, vehicular populations have grown from 5 lakh in 1980 to 40 lakh in 2001[www.teriin.org]. Continued growth of metropolitan highway system combined with an increase in public awareness of environmental issues has focused on a need to evaluate the impact of traffic noise and air associated with highway systems on neighboring communities. The ambient noise and air standards specified by Central Pollution Control Board (CPCB), New Delhi are given in Table 1 and 2 respectively.

Table 1. Ambient Noise Levels in India

Area	Noise Level L_{eq} (dB(A))	
	Day Time	Night Time
Residential	55	45
Commercial	65	55
Sensitive	50	40
Industrial	75	70

* Ambient noise standards prescribed by Central Pollution Control Board.

Table 2. Ambient Air Quality Standards in India

Area	Pollutants ($\mu g/m^3$)			
	CO 8 hr	NOx 8 hr	SO_2 8 hr	SPM 8 hr
Industrial	5000	120	120	500
General	2000	80	80	200
Sensitive	1000	30	30	100

* Ambient Air standards prescribed by Central Pollution Control Board.

2 UTEI – A NATIONALLY COORDINATED APPROACH

2.1 Objectives

The objectives of this study are outlined below:

a) To create a database related with Traffic, Noise & Air Pollution for the above cities.
b) Development of a standard prediction model for air and noise pollution for India.
c) National and International interaction through research dissemination and exchange of ideas.
d) Development of measures for reduction of pollution from motor vehicles.
e) Evolving societal and legal framework for the benefit of users and nation.
f) Evolving national policies and regulatory laws for enactment.

2.2 Outcome

The five identified Institutions have worked in a coordinated framework to produce the output as desired.

a) Database has been developed on urban air quality and noise levels to associate them to urban traffic levels.
b) Models have been developed to relate the scale of urban transport and level of environmental quality. This will facilitate prediction of urban environment using the projected traffic flows.
c) Policy measures have been evolved for control of growth in private vehicle ownership and their usage.
d) Suitable educational programmes will be developed for mass awareness on urban environment and transport.

3 NOISE / AIR POLLUTION DATABASE

To generate a database on noise and air pollution in all the identified five cities and keeping in view the objective of the study, the sites were so selected as to represent the whole urban area in different land use zones like Residential, Commercial, Silence and Heavy Traffic areas. Total 20 locations have been identified for study in Delhi, 4 locations in Jaipur, 10 locations in Chandigarh, 8 locations in Allahabad and 5 locations in Lucknow, in all the above mentioned land use zones.

In order to predict traffic noise, a field data collection programme is designed to collect data regarding parameters like classified traffic volume, speed and ambient noise levels

The polluting factors for air include oxides of nitrogen (Nox), carbon monoxide (CO), sulphur dioxide (SO_2) and suspended particulate matter (SPM). In this study all these parameters are studied and so air samples for carbon monoxide, solution samples for SO_2 and Nox and dust samples for SPM are collected.

Apart from these specific parameters, certain general data has also been collected to generate the database like;

i. Geometric parameters like road width, number of lanes, lane width, shoulder width, presence of median and its width, presence of pedestrian sidewalk and its width and details of roadside developments.
ii. Longitudinal section parameters like the distance of receptor point from the intersection.

iii. Miscellaneous information regarding type and condition of roadway etc.

Classified traffic volume, speed and ambient noise levels have been collected for duration of 24 hours. The air samples for CO, Nox, SO_2 and SPM collected for duration of 8 hours during day and night.

4 MODELLING FRAMEWORK

4.1 Noise prediction

Prediction procedure involves consideration of the nature and noise level of the sources, propagation along the paths between sources and receivers and the location of the receivers. The noise prediction model, (Haris, 1991), predicts the 1-hour average noise level for a flow of vehicles traveling along an infinitely long line. The algorithms are based on the concept of a series of adjustments to a sound level. This reference level is taken at a distance of 15.2 m for a single vehicle traveling along an infinitely long straight level roadway with no shielding of the source. Adjustments are then made for traffic flow, receptor distance from the road, the extent of the road segment, type of ground cover between receiver and source, any shielding of the source, and, if applicable, the gradient of the road. The value of L_{Aeq} is determined from the following equation:

$$L_{Aeq} = L_o + \sum L_i \quad (1)$$

Where, L_{Aeq} = continuous steady noise level on A-weighted scale; Lo = basic noise level for stream of vehicles and Li = adjustments for each vehicle category.

The total 1-hour average sound level for each vehicle type $[(L_{eq})_i]$ is computed by arithmetically summing the various adjustments.

The noise contribution from different classes of vehicles may be combined by addition of sound intensities, which is equivalent to the expression

$$L_{eqH(combined)} = 10\log\sum_{i=1}^{n} 10^{LeqH/10} \quad (2)$$

where, $L_{eqH(combined)}$ = hourly equivalent sound level due to all categories of vehicles plying on road and L_{eqH} = noise level contribution from each vehicle class. [Bhattacharya et al.(2001)]

4.2 Air pollution prediction

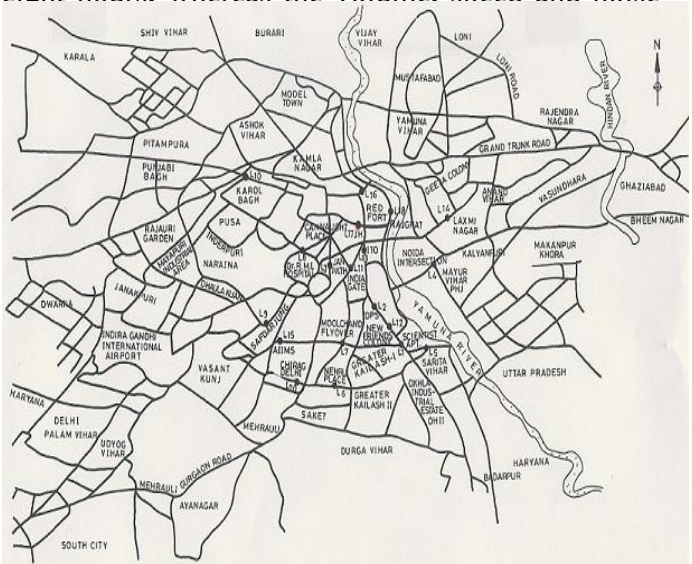
Vehicular pollution models can be defined as a mathematical technique or methodology based on physical principles for estimating pollutant concentrations. Numerous air pollution prediction models have been developed which are for finite line source as well as for infinite line source. Gaussian Plume model is a generic mathematical model developed and widely used to describe the dispersion phenomenon. Box model is the simplest form of a dispersion model, which is often used to estimate air pollution due to area sources. General Finite Line Source Model also works on the methodology of Gaussian Plume theory and gives satisfactory results. California Line Source Model developed by California Department of Transportation is based on Gaussain Infinite Line Source diffusion equation. [Jain et al.(2003)]

CALINE 4 is the latest version and the concentration of CO, Nox and aerosols can be predicted using this model. Software for this requires volume and meteorological data as the input parameters. It gives the hourly concentration of carbon monoxide in parts per million (ppm)[Nirjar et al. (2002)]

5 A CASE STUDY - DELHI

Out of the five identified cities for the Nationally Coordinated Project, Delhi represents the mega city. The sites were so selected in the city, as to represent the whole urban area in different land use zones like, Residential, Commercial, Silence and Heavy Traffic. Total 20 locations have been selected and categorized in different zones as shown in Figure1.

Delhi is one of the major metropolitan cities of India where transportation facilities are improving every year to meet the increasing demand due to excessive population growth. Hence, to generate the database for the city, data is collected for classified traffic volume, speed, ambient noise levels and air pollutants like Nox, SO_2, SPM and CO. The air pollutant sampling is done for duration of eight hours, whereas the volume, speed and noise



The processed noise data at the identified locations is subjected to regression analysis to find the correlation between the observed and the predicted noise levels for noise prediction. [Parida et al.(2003)].Chi-Square test is also conducted on the predicted and observed noise levels to test whether the deviations of the two processes are significant or not. The Chi-Square value calculated is compared with the tabulated Chi-Square values. If the calculated value is less than the tabulated value, it implies that the two sets of readings are good. Each set of observed and predicted values for the locations have been rated as good or poor. Good means that the observed and predicted noise levels does not vary considerably at 5% level of significance whereas, poor remark indicates that the observed and predicted noise levels vary considerably at 5% level of significance. Out of all the identified locations, following table 3 shows the calculated Chi-Square value for sample eight locations of Delhi.

From the regression analysis and the statistical test carried out, it has been concluded that FHWA model gives more consistent results for Indian conditions and hence the Noise Prediction model developed for Indian conditions is based on the concept of FHWA.

Table 3 Calculated Chi-Square Value for FHWA Model

S.No.	Location	Chi – Value	Remark
1	Safdarjung	17.66	Good
2	Karol Bagh	15.68	Good
3	India Gate	3.59	Good
4	N.F. Colony	26.16	Good
5	ITO	25.65	Good
6	Laxmi Nagar	16.58	Good
7	AIIMS	43.00	Good
8	Red Fort	23.77	Good

Similarly, the performance evaluation of CALINE 4 in terms of carbon monoxide emissions is carried out in the present study for Indian conditions by comparing the observed data with the predicted data. A significance test is also applied to check the consistency of the observed data with the predicted data to have confidence in prediction. Statistical analysis like t test has also been performed to determine the reliability of inter – relationship between predicted and observed values and is found to give acceptable results at 95% confidence level. Out of all the identified locations, following table 4 shows the summarised results of t test for sample eight locations of Delhi.

Table 4 Summarised Results of t Test for CALINE 4

	$\bar{d}$	Sd	N	DF	t_{calc}	α	t_{tab}
Safadrjung	77.1	276.6	16	15	1.11	0.05	2.1
Karol Bagh	276.5	319.1	16	15	1.98	0.05	2.1
India Gate	164.3	320.3	16	15	2.05	0.05	2.1
NFColony	360.1	315.1	16	15	4.57	0.05	2.1
ITO	110.2	239.0	16	15	1.84	0.05	2.1
Laxmi Nagar	183.1	359.6	16	15	2.03	0.05	2.1
AIIMS	254.5	768.3	16	15	1.32	0.05	2.1
Red Fort	166.5	329.2	16	15	2.02	0.05	2.1

From the regression analysis and the statistical test carried out, it has been concluded that CALINE 4 is well suited for Indian conditions for prediction of carbon monoxide emissions and hence Air Pollution Prediction model developed for Indian conditions is based on the concept of CALINE 4.

From the analysis of field data, it is found that both air and noise pollution levels are above the prescribed standards in the city and strategies to control this pollution should be adopted in order to maintain a healthy environment.

It is recommended that the most effective and efficient way to control noise is to provide noise barriers along the sensitive locations in urban areas. Noise barriers reduce the sound, which enters a community from a busy road by either absorbing it, transmitting it, reflecting it, back across the highway, or forcing it to take a longer path. Noise barriers are normally designed to provide to the tune of 15 dB(A) noise reduction at the receptor.

Similarly, to control air pollution, it is recommended to use unleaded petrol, catalytic converters, alternative fuels etc. Apart from this, proper maintenance of vehicle engines and aforestation also helps in reducing pollution caused by vehicular exhaust.

The focus of this Nationally Coordinated Project is thus to initiate a National Level Action Plan to reduce the environmental problems arising due to vehicular congestion on urban roads. The action plan will help in harmonizing policies and measures across various sectors and also in implementing the selected strategies.

6 DEVELOPMENT OF AIR AND NOISE PREDICTION MODELS FOR INDIAN CONDITIONS

In the present study, a standard noise prediction model is developed on the concept of FHWA model and a standard prediction model for carbon monoxide emission is developed on the concept of CALINE 4.

6.1 Noise prediction model

By observing the regression values for all the identified locations in all the identified cities, it was found that the values predicted by FHWA model

are more close and consistent with the observed values. Hence, a traffic noise prediction model has been developed for Indian conditions using FHWA model. All the predicted and observed noise level values are plotted and shown in figure 2. The developed equation is given as

$$Y = 53.416Ln(X) - 158.4 \quad (3)$$

Where, Y is predicted noise level in dBA and X is observed noise level in dBA.

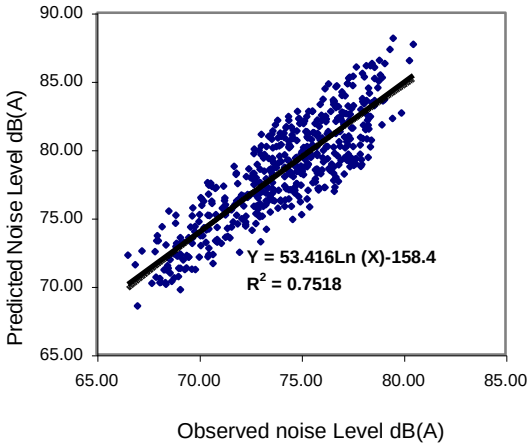


Figure2. Observed Vs. Predicted Noise Level

6.2 Air pollution prediction model

The standard air pollution prediction model is developed using CALINE 4. All the predicted and observed values are compared and a scatter plot is shown in figure 3. The developed equation is given as

$$Y = 0.479X + 564.01 \quad (4)$$

Where, Y is predicted CO concentration in $\mu g/m^3$ and X is observed CO concentration in $\mu g/m^3$

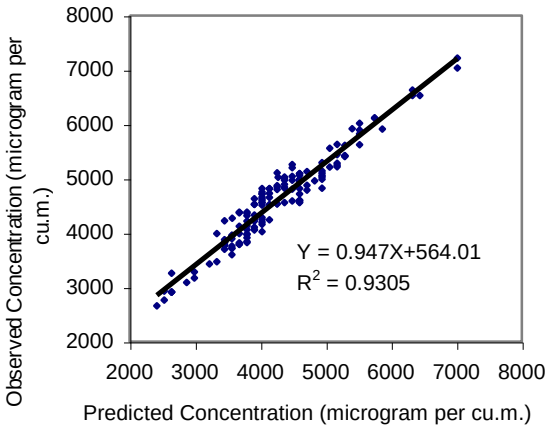


Figure 3. Observed Vs. predicted CO concentrations

7 NEED FOR NATIONAL LEVEL ACTION PLAN

Air and noise pollution are serious socio-economic environmental concerns in urban areas, especially in view of its adverse effects on human health. In developing countries around the world, an estimated 0.5 million – 1.0 million people die prematurely each year as a result of exposure to urban air pollution and millions of cases of respiratory illness are associated with air pollution in large cities.

Rapid increase in motorization in developing countries, contribute significantly to air and noise pollution. Tackling these pollution problems arising from the use of vehicles in turn calls for coordinating urban transport, environment and energy policies.

Unless properly checked and controlled, the consequent growth in congestion and pollution will adversely affect the health and quality of life of inhabitants. A national level action plan is therefore needed to deal with this rapidly growing problem. It has already been seen from the present study, that the pollution loads are far above the acceptable levels. Hence, the study can be well concluded by defining a national level action plan, which will offer a clear direction and a framework for future.

7.1 Pressure on Indian roads

Between 1970 and 1990, the number of vehicles has grown 11.5 times, from about 1.9 million to more than 21 million. At the same time, the figure per 1000 population has increased from 3.4 to 25.31 and is expected to increase further. The bulk of this vehicular population is found in urban centers. Of the total 25 million vehicles registered in 1993, 82 percent are personal modes of transport, with the share of two – wheelers and cars at 70 percent and 12 percent respectively.

The total length of Indian roads has increased from 917,000 kilometers in 1970/71 to 2,103,000 Kilometers in 1990/91. However, this increase in road capacity is inadequate in comparison to the number of vehicles.

Trend analysis and projections show that there will be a considerable rise in pollutant emissions over the next two decades. This signifies that more comprehensive measures to tackle pollution must be adopted in the immediate future and implemented stringently to protect the environment.

7.2 Projected transport pollution scenario in urban areas

From the present study, a macro level projection has been made for the transport pollution scenario in urban areas. Taking into consideration the data

of base year ie. 2001, a projection for noise and CO concentration for another 50 years is carried out.
The noise level in the base year is 78.61 dBA while it is projected as 90.80 dBA in the year 2051. This shows an increase of 11.99 dBA ie an increase of 15.3 percent.

Similarly, assuming the same traffic growth factor as 5% per year and emission factors for different vehicle categories as observed in base year carries out projection of CO concentration. The concentration of CO in base year is 3.7 ppm while it is projected as 14.9 ppm in the year 2051.
The projected pollution levels are shown in table 5.

Table 5. Projected Traffic and Pollution Levels

Year	Noise dBA	CO Concentration ppm
2001	78.61	3.7
2011	82.62	4.5
2021	84.81	5.8
2031	86.57	7.7
2041	88.33	10.6
2051	90.09	14.9

In the light of this gloomy scenario one finds silver lining in the work of Phil Goodwin where he concludes that "Environmental imperatives need not force us into lower standards of living or transport efficiency: rather they can trigger policies that create higher levels of welfare and efficiency, but that have in the past been inhibited by market imperfectness, unrealistic policy aspirations and inappropriate understandings and methods of analysis". This Nationally Coordinated Project has helped us to believe that it is possible to intervene in the process of urban transport environment interaction. Delay in the implementation of public transport system in Delhi has fuelled the growth of personalized transport and we have missed an opportunity to create a public transport culture. Still it is not too late and with a clarity in the perception of this issue a systematic action plan can be drawn out at National Level that can be implemented for combating transport related pollution for metropolitan cities.

7.3 Action plan

In a developing country like India deteriorating situation of urban environment in terms of noise and air pollution is a serious concern which requires due attention. Poor environmental quality in urban areas not only adversely affects human health but also is responsible for causing other forms of damages. Vehicular emissions are considered to be the main contributors to pollution in urban areas; hence it's essential to evolve measures to mitigate transport emissions so as to maintain a healthy environment. A systematic approach is required to formulate a strategy for improving the environmental quality in urban areas and hence an action plan is proposed for the same. The proposed action plan aims at reducing air and noise pollution in cities through improvement in transportation system. Close relationship between traffic operation and pollution level indicate that promoting public transport system, adopting demand management measure and traffic management techniques shall result in lowering down various pollution parameters.

i. The conditions for effectively controlling emissions through standards are reliable vehicle registration, emission standards that differentiate vehicles by type and age and methods for enforcing the standards.
ii. Improvements in fuel quality can contribute to better air quality if they are closely coordinated with improvements in vehicle technology.
iii. Through the provision of public transport, promotion of non-motorized transport, application of fuel taxes and other fiscal measures, area wide licensing, electronic road pricing in urban areas. Existing public transport should be rehabilitated; environment scenario can be improved, upgraded and restructured as required. Development outside urban areas should be based on existing accessibility by public transport networks; and connections should be considered before, not after development occurs.
iv. Vehicle use and maintenance practices such as using the correct type and amount of lubricant in two-stroke engine vehicles, avoiding over fueling diesel engines.
v. By coordinating traffic lights so as to decrease congestion and improve mobility. It will also confer environmental benefits because it will lower emission intensity of traffic.
vi. Educational institutes can contribute significantly towards training manpower for evolving eco-friendly transport system developments. Environmental Impact Assessment of Highway project is a relatively new subject and many institutes do not cover the same as part of curriculum. Sustainable transport strategies can be backed by objective analysis and presentation of future environmental scenario under different traffic conditions. Teaching and Research in this area will be useful in creating significant Human Resource capability for combating this menace.

8 CONCLUSIONS

Air and noise pollution levels in all the identified five cities are above the prescribed limits and traffic growth cannot be allowed to continue on its projected path. In the present study, the futuristic scenario of environmental pollution in terms of noise and air has been predicted. From the statistical test and regression analysis; it has been found that FHWA model gives more consistent result for Indian conditions. The Chi square test carried out for all the identified locations also shows the satisfactory performance of the model and hence the model for noise prediction for Indian conditions is developed on the concept of FHWA. Similarly the performance of CALINE 4 is evaluated for Indian Conditions in terms of statistical test and index of agreement. Index of agreement gives the degree to which model predictions are error free. The variation of index of agreement lies between 0.98 to 0.51, which is satisfactory, and hence the predictions are done using CALINE 4 and also a model is developed for Indian conditions using it.

The congesting and polluting transport activities will be more expensive and restrictive. But, this in turn provides the opportunity to trigger policies that create higher levels of welfare and efficiency, which are more convenient and attractive. From the present study, it has been concluded that noise levels are above the prescribed standard.

The study indicates, that to maintain a balance between growing transport scenario and environment, its essential to develop an effective technology to facilitate traffic flow and reduce congestion and also to develop an effective framework for transport planning at all levels. But, to meet all these challenges a strong commitment is required in the form of national level action plan. This action plan demands all round participation by all the players critical in the process of urban transport interaction. While government can provide an organizational mechanism, industry shall implement the technology and public need to keep the issue active demanding sustainable solutions.

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