EXECUTIVE SUMMARY

Transport affects the local and global environment in many ways and for a number of pollutants the road transport sector is one of the most significant contributors to environment externalities. The transportation activities particularly related to motor vehicle have been closely identified with increasing air pollution levels in various urban centres of the world.

Urban development is primarily linked with high vehicular density in urban areas which ultimately impacts air pollution. As most of the motor vehicles are found in urban cities and the trends is towards increasing urbanization specially in developing countries like India, it is expected that the vehicular air pollution related problems will further increase in future in these urban cities.

Vehicular Air Pollution

Transport sector contributes around 14% towards the global emissions of greenhouse gases. CO$_2$ represents the largest proportion of basket of greenhouse gas emissions. With rapid urbanization, road transport related CO$_2$ emissions from urban areas are likely to increase further in coming years mainly due to inadequate public transport system, high vehicle density in urban areas and increasing share of private vehicles vis-a-vis public transport vehicles in developing countries.

The problem of air pollution has assumed serious proportions in some of the major metropolitan cities of India due to concentration of large number of vehicles. In India, the number of motor vehicles has grown from 0.3 million in 1951 to 142 million in 2011, of which, two wheelers (mainly driven by two stroke engines) account for 70% of the total vehicular population. Two wheelers (2W) and car {four wheelers (4W), excluding taxis} which mainly constitute personal mode of transportation, account for approximately four-fifths of the total vehicular population. Vehicles in major metropolitan cities in India are estimated to account for 70% of CO, 30%-40% of NOx, 30% of SPM and 10% of SOx of the total pollution load of these cities.
Motivational Need and Overview
Gurgaon, an important satellite town in NCR has witnessed tremendous population growth and as a result motor vehicles increased immensely & threatening the urban-environmental conditions. In-spite of innovative approaches to develop Gurgaon in a systematic and coordinated manner, the seriousness of urban problems due to sudden population rise has been accelerating and threatening the urban-environmental conditions in Gurgaon. Transport facilities in Gurgaon are not adequate and have been deteriorating over the years. The development of public transport has not kept pace with traffic demand both in terms of quality and quantity. As a result, use of personalized vehicle and intermediate public transport is growing at a rapid rate. Public has encroached the parking space, footpaths and has further restricted the traffic flow. The levels of air quality due to vehicular pollution would be worthwhile to study.

Hence, an effort will be made through this study by considering the above factors and trying to establish a baseline traffic and transport scenario to understand its impact on Ambient Air Quality with seasonal variation, further to establish the relation between total vehicles and air pollutants and to establish relation between various air pollutants and meteorological attributes. CALINE 4 model has been used to predict the concentrations of CO and a sensitivity analysis has been performed with different combination of meteorological and traffic parameters to identify the most influential input variable among the various input variables. Based on the outcome of this study the remedial measure in form of Environmental Management Plan has been suggested to address the problem.

Review of Literature
To study the impact of vehicular pollution on ambient air quality, literature was reviewed extensively from different sources such as Ministry of Environment and Forests Library, Central Pollution Control Board, IIT, Delhi –Library, Indian Road Congress Publications, Ministry of Road Transport and Highways, Google Scholar etc. The literature gave reference of around 200
studies related to air pollution, and for the purpose of our study we have mentioned around 120 studies which are more closely related to impact of vehicular pollution on ambient air quality. The review of the literature was comprehensively summarized in the form of a table in literature review chapter, which provides a brief overview of the key published studies in the domain of ambient air quality and its relationship with different sources of pollution for identifying different sources explaining the phenomena.

**Gaps identified from previous literature**

In majority of the research papers the researches have tried to identify the various types of pollutants that are emitted by automobiles in city which becomes a cause for increasing air pollution problem. In some of the studies the researchers have tried to monitor and collect the data for various air pollutants in different part of the cities and have compared the collected primary data with National Ambient Air Quality Standards to identify the areas with high pollution levels.

Some researchers have tried to understand urban vehicular pollution problems vis-à-vis ambient air quality in megacity, while some researchers have tried to study the impact of air pollution on health, while some researchers have tried to study the relation between meteorological factors and air pollutants. Recently some of the researchers have studied the vehicular air pollution with regards to CO₂ emissions while some researchers have tried to evaluate various air dispersion models for urban highway corridor. There was no comprehensive study which could highlight various air pollution impacts due to vehicular pollution in a city. Hence, it was felt that a comprehensive study to assess impact of vehicular pollution on ambient air quality should be undertaken.

**Objectives of the present study**

The brief objectives of the present study was to establish a baseline traffic in terms of traffic volume and transport scenario in terms of traffic composition to understand its impact on ambient air quality with seasonal variation within the
urban limits of Gurgaon; to establish the relation between total vehicles and air pollutants at selected corridors and to study the relation between various air pollutants and meteorological attributes at selected corridors; to predict air concentrations of Carbon monoxide (CO) using CALINE 4 model for future 5 years; to carryout sensitivity analysis on predicted concentrations with different combination of meteorological and traffic parameters; and to suggest remedial measures by preparing Environmental Management Plan.

**Research Methodology**

The five road corridors representing different land-use pattern were selected for the study. National Highway- 8, Mehrauli- Gurgaon road and Gurgaon – Sohna road are important roads which account for major incoming and outgoing traffic movement in the city. All three road corridors which represent different land-use patterns (high traffic zone, major commercial area and a rural area) have been chosen for the present study. The other road corridors which have been selected represents other land-use pattern i.e. semi urban and residential areas.

The following field surveys were conducted for the research study:

i. **Traffic Volume Count Survey**

ii. **Ambient Air Quality Monitoring Survey**

iii. **Fuel Station Survey** (Fuel used in vehicle & Age of vehicle)

iv. **Road Geometry Survey** (carriageway width, median width)

Apart from above surveys meteorological data was collected from Indian Meteorological Department (IMD) for wind speed, wind direction, rainfall, stability class and ambient temperature. The mixing height data (for winter month) was also obtained from IMD and was used in the present study for modeling purpose.

Four hourly classified traffic volume count survey has been conducted at all the five road corridor for period of 16 hours from 6.00 am to 10.00 pm on normal working days covering both morning peak hours and evening peak hours. The traffic volume data has been collected on 4 hourly basis for the
time periods 06.00 to 10.00 hours; 10.00 to 14.00 hours; 14.00 to 18.00 hours and from 18.00 to 22.00 hours during two seasons - monsoon (in the month of August 2010) and pre-monsoon (in the month of March 2011). While hourly data for 24 hours was collected for the month of December, 2010 for modeling purpose. Ambient air quality monitoring survey was also conducted simultaneously at all the five road corridors for parameters – PM$_{10}$, PM$_{2.5}$, SO$_2$, NOx and CO. Fuel station survey was carried out the fuel being used in vehicle & its vintage. The road geometry surveys was carried out at all five road corridors to collect the information about road geometry. The details collected on road geometry included information pertaining to laning of the road; carriageway width and median width.

In the present study to predict air concentrations of Carbon monoxide CALINE4 model was used to predict the concentration of CO emitted from vehicle exhaust under standard meteorological conditions. The model was run for 24-hour period during post-monsoon season. Hourly weighted emission factors were calculated using the hourly traffic data recorded on study corridors. As the road corridor 1 (near IFFCO Chowk on NH-8) recorded the significantly higher traffic volumes in comparison to other road corridors, the modeling was performed only for the corridor 1. Further, as CO is the principal pollutant from the vehicular exhaust, the modeling was performed for CO only. Under standard meteorological condition, the CALINE4 model predicts the pollutant concentration in the prevailing wind direction; hence hourly concentration values at predetermined receptor locations were obtained. CO predictions have been done for year 2010 and for next five years thereafter i.e. for year 2015.

18 receptor points (9 points on each side of the road corridor) was selected at pre-identified receptor location with a specified distance from the edge of the mixing zone width (road width + 3 m on each side of the corridor) i.e. 1 m, 5m, 10m, 20m, 30m, 50m, 75m, 100m and 150m from the edge of the road on both the side.
The following results were obtained from CALINE4 model run for year 2010–

a) During the 24-hour period in which the model was run, two distinct peak concentration levels were observed during the morning and evening time; however the evening time peak concentration levels were significantly higher than the morning peak concentration level.

b) Morning Time Peak - The morning time peak was recorded between 9 am to 10 am. The total vehicle recorded vehicles were 22060 and emission load was 59725.95 gm/km

c) Evening Time Peak – The evening time peak was recorded between 7 pm to 8 pm. The total vehicle recorded vehicles were 23162 and emission load was 69319.25 gm/km.

The maximum predicted concentration at 1 m distance from the mixing zone was 3.41 mg/m$^3$ on Left side of the road. The pollutant concentration decreases drastically to 1/3rd within 50m distance from the mixing zone. After 50m distance, the pollutant concentration decreases gradually to baseline concentration levels.

In order to predict CO concentration for year 2015, all the meteorological parameters were kept constant and only projected traffic volume was calculated with an annual rise of 8% for first 3 years and 7% for 4$^{th}$ and 5$^{th}$ year. The maximum predicted CO concentration at receptor point on Left side of the road at 1 m distance from the mixing zone was found to be 4.44 mg/m$^3$. If we compare the predicted CO Concentrations of year 2010 and year 2015, it is observed that the CO Concentration will increased by 1.03 mg/m$^3$ in 5 next years’ time. It is also observed that the predicted CO Concentration levels in year 2015 will exceed the limits of NAAQS of 4.0 mg/m$^3$. The projected maximum hourly total traffic volume and total traffic load for year 2015 was 33353 and 99819.72 gm/km respectively.

**Conclusions and Findings**

The baseline traffic and transport scenario was established to understand the impact on ambient air quality at selected 5 road corridors within Gurgaon city.
The corridor 1 is 6-lane road and has a capacity of handling about 1.2 lakhs passenger car units (PCU) per day, while at present the corridor is handling over 2.5 lakhs PCUs. Similarly corridor 2 is 4-lane road and has a capacity of handling about 0.4 lakhs PCUs, while at present the corridor is handling over 1.0 lakhs PCUs. Simultaneously it was also observed that pollutants PM$_{10}$, PM$_{2.5}$ and CO concentrations when compared with National Ambient Air Quality Standards of CPCB were also found to be above permissible limits both in corridor 1 & corridor 2. The percentage proportion of buses is very less (less than 3%) in all the 5 road corridors which shows inadequate public transport facility in the city. On the other hand, the percentage proportion of car/jeeps and 2 wheelers is very high (over 70%) which, shows more use of personalized vehicle in absence of adequate public transport system. According to the results of seasonal variation in ambient air quality, high concentration of air pollutant was recorded in the winter seasons due to low temperature and low wind speed. This may be due to the stable atmospheric conditions leading to accumulation of pollutants in the area.

To establish the relation between air pollutants and total vehicles a correlation and regression analysis was undertaken between various air pollutants and total vehicles for all 5 road corridors. Linear regression models developed in the study have been scrutinized using $R^2$ values. The $R^2$ values were found supporting the hypothesis that there is a significant relationship between total traffic volume and level of air pollutants. The $R^2$ values reported moderately high to very high values ranging from 0.6 to 0.99 for various pollutants.

To establish the relationship between meteorological parameters and air pollutant concentration the data collected for PM, SO$_X$, NO$_X$ and CO was statistically compared with meteorological variables such as relative humidity, temperature and wind speed. The correlation analysis established a moderately high relationship between air pollutant concentration and wind speed, a moderate relationship between relative humidity and a weak relationship is seen between air pollutant and temperature.
The concentration of CO was predicted for corridor 1 where two distinct peak concentration levels were observed during the morning and evening time. The morning time peak was recorded between 9 am to 10 am. The evening time peak was recorded between 7 pm to 8 pm. The maximum predicted concentration of CO for year 2015 at 1 m distance from the mixing zone was 4.44 mg/m$^3$ on Left side of the road. When we compared the CO Concentrations of year 2010 and year 2015 it was observed that the predicted CO Concentration increased by 1.03 mg/m$^3$ in next 5 years. The predicted CO concentration when compared with NAAQS was also found to be exceeding the permissible limits.

The sensitivity analysis on predicted concentrations of CO was carried out with different combination of meteorological parameters (wind speed & wind angle) and traffic parameters (road width & median width). The results of sensitivity analysis revealed that wind angle, wind speed and road width are significant input variables while median width was less significant input variable.

The increasing air pollution from motorized vehicles is the leading cause of deterioration of air quality in Gurgaon. Concentration of PM$_{10}$, PM$_{2.5}$ & CO at road corridors 1, 2 and 3 are exceeding the National Ambient Air Quality Standards. Also calculated AQI levels at these three road corridors show an unhealthy air quality. Hence an Environmental Management Plan with site specific remedial measures has been suggested for these road corridors. In addition to this a general remedial measures are also suggested which can be implemented on all the 5 road corridors and on other urban roads of Gurgaon.

As a remedial measure an environmental management plan has been suggested which emphasis on strengthening of Public Transport in Gurgaon. Mass Transport system in Gurgaon is inadequate. Intra-urban mass transport system is almost negligible. The result is that personalized mode of transport is used heavily which is creating congested conditions on roads. The share of mass transport needs to be increased substantially by way of augmenting mass
transport infrastructure, not only for intra-urban but also with Delhi and other urban areas.

The other suggestions pertains to proper traffic management, traffic segregation, providing adequate traffic control system, proper land use planning, regulating pedestrian/vehicle restricted areas and by introducing cleaner fuels. The road side plantation acts as a carbon sink. The road side plantation along M.G. Road and Sohna road is almost absent. Also at various locations along NH 8 the tree planation cover is missing. Suggestion to plant more trees along these roads so that maximum pollutants can either be filtered or absorbed near the source has been proposed. A preview of further research which may be needed in this area has also been suggested.