CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

The Ambient air composition of major cities has undergone several changes. Anthropogenic pollutants generated day by day is on the rise leading to higher concentration of pollutants in a particular region. Plants, animals as well as human beings are being affected by air quality. As the pollutant mixes with a large air mass, its concentration diminishes by dilution and is reduced to a threshold level. The level of a pollutant below which no significant ill effects are observed is called threshold level. The assumption that ‘nature will take care of pollutants’ do not hold good any longer. Higher concentrations of pollutants are emitted in cities like Coimbatore which is undergoing rapid urbanization and industrialization. Health impacts are driven by population growth, increased vehicular traffic, combustion of fossil fuels and city congestion. An extensive review of literature has been carried out for the present study and the relevant papers are narrated below.

Substantial evidence has accumulated that air pollution affects the health of human beings and animals, damages vegetation, affects soils and deteriorates materials, affects climate, reduces visibility and solar radiation, impairs production processes and contributes to safety hazards. Air pollutants affect atmospheric properties in the following ways: Visibility reduction, fog formation and precipitation, solar radiation reduction and temperature and wind distribution alteration.
These effects are primarily associated with the urban atmosphere. Pollutants which are known photo toxicants are sulphur dioxide, peroxy acetyl nitrate which is an oxidation product in photochemical smog and ethylene.

### 2.2 MITIGATION STRATEGIES

Air pollution cannot be completely controlled, therefore, mitigation strategies are important in order to reduce its impacts. Past researchers have reported a number of active and passive approaches to mitigate or suppress all the above air pollution impacts. Active approaches are stronger and more controllable in nature. They are based on air pollution monitoring that is used to derive abatement measures and policy measures to control air pollution. These approaches are called pro-active approaches. Passive approaches are more pre-active in nature and more informative as they provide guidelines for relevant authorities to minimize and prevent public exposure to polluted air. Table 2.1 presents these mitigation measures.

**Table 2.1 Air Pollution Mitigation Strategies**

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Measures</th>
<th>Examples</th>
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<tbody>
<tr>
<td>1. Active</td>
<td>Monitoring and management strategies</td>
<td>WHO, EU and country specific monitoring, and standards</td>
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<tr>
<td></td>
<td>Policy measures</td>
<td>Transport policy – mass transport, pedestrianisation, cycling, vehicle tax etc</td>
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<td></td>
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<td>Energy policy – use of petroleum, coal, LPG, renewable energy etc.</td>
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<td></td>
<td>Abatement measures</td>
<td>Setting up standards, assessment and enforcement – fuel/engine standards (Euro I,II etc), road pricing etc</td>
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<td>2. Passive</td>
<td>Public information and warning</td>
<td>Alarming for air pollution exposure and health risk</td>
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<td></td>
<td>Guidelines and regulations to practice</td>
<td>Land-use planning, zoning, sensitive activity planning considerations</td>
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<td>Transport net work/street planning, building planning/design codes and regulations etc.</td>
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The above-mentioned approaches in Table 2.1 aim to mitigate air pollution in the following three different ways: Reduce air pollution from the source itself (less combustion), reduce the high concentration (strength) of air pollutants (e.g. purified fuel and proper ignition) and reduce concentration (dispersion and dilution and low exposure)

The first two strategies of active approaches are strong and controllable in nature and they reduce the rate of emission. The third strategy is a passive approach and is also more crucial to the effectiveness of the first two. However, integrated approaches are more effective than singular approaches in order to reduce emission levels while reducing their effects by reducing concentration and preventing peoples’ exposures to them.

2.3 URBAN STREET LEVEL AIR POLLUTION

Street level air pollution deals with many dimensions in urbanity: sources of urban air pollution, urban micro-meteorology/microclimate, physical setting/urban morphology; both natural and man made structures and its activities etc. Therefore, street level air pollution deals with complex variables other than sources of air pollution. To investigate this phenomenon, it is important to understand physics of urban air pollution and behaviour of air pollutants after they have been discharged from a source.

2.3.1 Physics of urban street level air pollution

Physics of urban air pollution describes the behaviour of air pollutants once they have been discharged to the atmosphere; what internal and external factors that determine air pollutant concentration of a place and how it happens. Once air pollutants are discharged to the atmosphere, they are subjected to either or a combination of the following: transformation, dilution, dispersion and deposition. All these processes depend on properties of air
pollutants, forces that act on these air pollutants and the surrounding physical environment. Therefore, physics of air pollution is determined by the processes which determine air quality or air pollution concentration of a place.

**Transformation:** In the transformation process, some primary air pollutants, particularly gaseous, may change their physical and chemical status when they are exposed to atmospheric conditions: solar radiation, sunlight, humidity, temperature, other gases etc. Under the above conditions, primary air pollutants such as NO, CO, SO\textsubscript{2} transform to secondary air pollutants such as NO\textsubscript{x}, O\textsubscript{3}, CO\textsubscript{2}, H\textsubscript{2}S, SO\textsubscript{4} when reacted with atmospheric agents such as water vapour (H\textsubscript{2}O), Oxygen (O\textsubscript{2}) etc. Both atmospheric conditions and physical space are essential for this action to take place.

**Dilution:** Dilution refers to the reduced strength and concentration of air pollutants agents when they are mixed with a large volume of atmospheric air. Some transformations are processes of dilution by chemical processes, e.g. atmospheric O\textsubscript{2} reacts with primary pollutants to transform into O\textsubscript{3}, NO\textsubscript{2}, CO\textsubscript{2}, SO\textsubscript{2} etc.

**Dispersion:** Dispersion is diffusion or movement of air parcel from its origin which could happen in either or both vertical and horizontal motions. Physical status of air pollutants is related to dispersion; lighter molecular mass of gases (CO = 28; NO = 30; NO\textsubscript{2} = 46; O\textsubscript{3} = 48) has a higher speed as per Maxwell’s gas distribution of speed. But this process also depends on meteorological condition and atmospheric stability as well (Mayer 1999, Manins et al 1998); wind condition in particular, temperature and other meteorological factors.
Deposition: Deposition happens when air pollutants fall to the ground and deposit on vegetation or manmade structures. Deposition causes damages to flora and fauna and other structures. Deposition is mainly influenced by physical size and atmospheric conditions. For example, heavy particulates cause sedimentation faster than lighter particulates. Air pollutants will also be washed away when there is a high atmospheric moisture level and precipitation.

All these phenomena indicate that, in addition to internal factors such as physical and chemical status of air pollutants, behaviour of air pollution is also highly influenced by external factors such as meteorological factors, atmospheric stability of an area and conditions of physical space that air circulates. Previous researchers indicate that besides meteorology and atmospheric stability of urban areas, physical profile within urban canopy layer also highly affects the physics of urban air pollution (Givoni 1998; Chan et al 2001). Mayer (1999) provided a schematic explanation of the above process as given in Figure 2.1.

2.3.2 Effects of urban morphology

Givoni (1998) indicated some of the important parameters that can modify the urban wind field such as overall density of the urban area; size and height of individual buildings; orientation of streets; and availability, size, and distribution of open spaces and green shutter belts. Urban morphological database developed by Cionco and Ellefsen (1997) was found to be applicable for analysis of urban climate related issues including air quality. Ratti et al (2000) derived a mathematical model for urban areas that could predict relationships between urban building types and air pollution at city/meso-level and above. This research was based on laboratory and field experiments on flow and transfer processes in urban areas. Another urban air quality study conducted by Kirby (1995) reported the correlations between air pollutant
concentration and two street configurations: Canyon Street and etc. Further Santamouris (2000) observed that “high building densities and particularly building layouts can significantly reduce rates of air pollutant dispersion near the ground”.

Figure 2.1 Physics of Air Pollution- Schematic Explanation (Mayer 1999)
2.3.3 Effects of other factors and their behaviour

Previous studies have reported several other factors that affect air pollutant concentration; Lam et al. (1999) indicated the effects of location on air pollution concentration. A study on three European cities reported that there is a relationship between proximity to the city center and air pollutant concentration (Givoni, 1998) and Golany (1995) suggested that population density, city size, topography, intensity of human activities, altitude, distance from sea are some other factors of pollution concentration at regional level or ‘level I factors’, as suggested by Hawkes et al (2002). Chan et al. (2001) suggested that besides the distance from the source of air pollution, factors such as traffic conditions, geographical characteristics, and land use characteristics affect air pollutant concentration. However, most of these factors indirectly affect pollution concentration by modifying micro-meteorology.

Hawkes et al (2002) summarized all the suggestions and indications to a typology of morphological effects into three different levels: Level 1 (local topography, altitude, proximity to water, location of uses); Level 2 (urban density, vegetation, overall arrangement of buildings such as compact, disperse etc. plot ratio, occupancy patterns); and Level 3 (built form orientation, built form surface to volume ratio, building spacing, and building heights). According to Figure 2.2, there are two scenarios that explain the relationship between urban morphology and pollutant concentration: one is the direct impact of urban morphology on air pollutant concentration; and the other is the indirect effect of urban morphology in changing micro-meteorology which in turn affects air pollutant concentration.
2.4 VEHICULAR POLLUTION

A few studies on the estimation of vehicular emission inventories were carried out internationally. Vehicular emission inventories in Spain were estimated by Buron et al (2005) using COPERT III. Bellasio et al (2006) estimated the road traffic emission inventory in Sardinia, Italy, using COPERT III. They calculated the emissions of several vehicular pollutants and evaluated the contribution of different vehicle categories to the emissions. Saija and Romano (2002) adopted the COPERT methodology to estimate road transport emissions in Italy, and developed a top-down approach when the required data for the local level estimation were unavailable. Schifter et al. (2004) estimated an emission inventory for the metropolitan area of Mexico City, based on the emission factors derived from remote-sensing measurements and the vehicular activity data obtained according to fuel consumption. Muncaster et al (1996), Ya-Wen and Chi-Hung (2005), also carried out related research, using the technology of remote-sensing measurements. They measured the emission factors of certain pollutants emitted by certain vehicle categories. In China, Li et al. (2003) calculated the emission factors based on MOBILE5 model and fuel consumption. Weng et al. (2006) estimated the vehicular emissions in Shanghai, using the international vehicle emission (IVE) model. Song and Xie (2006) established the Chinese inventories of vehicular emissions in 2002 based on COPERT III program.

**Figure 2.2** Relationships between Street Level Air Pollution and Urban Morphology
2.5 AIR QUALITY MONITORING

Air quality is a major environmental issue in many areas. When meteorological and emissions data are available for a region, its air quality levels can be modelled based on different scenarios, such as:

- the formation of photochemical smog;
- the impact of population growth; or
- increased motor vehicle use.

Most economic activities, involving the use and conversion of energy, and transportation prominently among them, are accompanied by emissions of air pollutants, thus degrading the environment, and in particular the urban environment. An emission is the compound or pollutant as it enters the atmosphere from an emission source, e.g., flue gas as it comes out of an exhaust or chimney. Often emissions are also called primary pollutants (Ravichandran et al 1998). Once emitted the pollutants are dispersed in the atmosphere, more or less quickly depending on the weather conditions. Numerous chemical reactions take place during this dispersion. This produces more stable compounds that can be detected and analyzed in measuring stations. These are the pollutants that we breathe or which are deposited on the ground.

Many different substances and compounds are considered air pollutants. They are generally of anthropogenic origin, and result, in their majority, from combustion processes of fossil fuels (Stern 1994). There are also natural pollutants such as gases and dust from volcanoes, forest fires, or dust entrained by storms. While these may be of considerable importance on a global scale, it is the anthropogenic pollutants we are most concerned with in the urban environmental context (Thad Ghosh 1985). All pollutants exhibit a
bimodal distribution pattern that is, decrease in concentration from morning towards midday with a subsequent buildup towards evening. Among them, concentration of oxides of nitrogen and carbon monoxide are moderately higher during midday hours (Rajendra Prasad et al 2003).

From the perspective of spatial analysis, we can discriminate between:

- fixed or mobile sources;
- point sources,
- line sources,
- diffuse or area sources.

The emission of any toxic element in the surrounding atmosphere leads to serious harmful effects at the place of origin and also at distant places. Hence, it is necessary to make the pollutants get dispersed and diluted as soon as possible to minimize its ill effects (Ashutosh Dubey 1992). Health impacts of air pollution are driven by population growth, industrialisation and increased vehicular traffic. Combustion of fossil fuels and their products is responsible for anthropogenic air pollution and this problem is particularly acute in urban areas (Shanker and Rao 2000). City dwellers are exposed regularly to pollution. Exposed people may be at risk and may face serious chronic health hazard problems since it has been well proven by researchers that there is direct correlation between environmental pollution and morbidity and mortality (Schwartz et al. 2001). Robert et al (1981) studied the application of the three stage methodology for the air quality monitoring network design problem which involves diffusion modeling, statistical modeling and finally solution to mathematical models. Shannigrahi et al (1998) described the method of monitoring the air pollutants like SPM, CO, SO₂ and trace elements. The analytical techniques for determining the
concentration of these pollutants were also discussed. The pollution data derived from a single monitoring site cannot be considered representative of more than a small surrounding area (David et al 1997). Singh et al (1990), predicted and measured concentrations of traffic carbon monoxide over Delhi using the GFLSM.

Spatial distributions of traffic-related pollutants in street canyons were investigated by Xiao-min et al (2009) using field measurements and Computational Fluid Dynamics (CFD). The concentration of vehicular pollutants, wind, turbulence and traffic volume were measured in three different typical street canyons in Guangzhou City by Qin and Kot (1993). A simple semi-empirical model for predicting the effect of changes in traffic flow patterns on carbon monoxide concentrations was presented by Kim et al (2003). The dispersion component of the model was based on a modified empirically optimized box model requiring only wind speed and direction information. Ruwim et al (1996) discussed the influence of local conditions on air pollution concentrations, regarding the dependency of pollution levels on street configuration and meteorological parameters. The examples used were based on measurements from locations in Copenhagen and on model calculations using the Danish Operational Street Pollution Model (OSPM).

Several research works focused on the assessment of the effects of traffic pollution. Karim (1999) monitored the ambient concentration of CO, NOx, lead, particulate matter and black smoke at street intersections of metropolitan Dhaka, and estimated all traffic pollutant concentrations at 82 street intersections using a Gaussian plume model to check for any violations of international compliance. Roorda et al. (1998) measured indoor and outdoor traffic related air pollutants in six city districts near motorways in the west Netherlands in order to study the exposure assessment.
Milind (2007) used spectral methods to analyze changes in air quality at a single monitoring site in Delhi. Power spectral density calculations of daily concentration data for particulate matter (PM10), carbon monoxide (CO), oxides of nitrogen (NOx) and oxides of sulfur (SOx) revealed the presence of trends and periodic oscillations for all the pollutants. Singular Spectrum Analysis (SSA) was used to decompose daily data into statistically significant non-linear trends, seasonal cycles and other oscillations. Indrani and Rakesh (2006) used a set of time series analysis methods viz. t-test adjusted for seasonality, Seasonal Kendall test and Intervention analysis to identify and estimate the trend in PM10 and total suspended particles (TSP) levels in India. Vulnerable analysis (VA) was carried out by Mrinal et al (2004) to evaluate the air pollution stress at different locations in Kolkatta.

Evaluation of traffic pollution in streets requires basically information on three main factors: traffic emissions, the meteorological conditions and the street surroundings. Examining the relationships between model predictions and measurements with respect to the meteorological conditions and inter-relationships between different pollution components allowed quantitative evaluation of the traffic emissions. This methodology was adopted by Berkowicz et al (2006) using the Danish Operational Street Pollution Model OSPM, and time series of traffic related pollutants. Street level concentrations of NOx and CO were calculated using OSPM as the dispersion model and emission data estimated by the widely used COPERT (European methodology). Meenakshi and Saseetharan (2003) analysed the seasonal variations of suspended particulate matter and oxides of nitrogen concentrations in five stations in Coimbatore city. Francesca et al (2006) assessed nitrogen oxides (NO2 and NOx), sulphur dioxide (SO2), and benzene, toluene, xylene (BTX) in ambient air by diffusive sampling technique, through three measurement campaigns at 100 locations in the Chinese city of Suzhou. Calori et al (2006) used SPRAY Lagrangian particle model, coupled
with the MINERVE diagnostic wind field code, to reconstruct the model, taking into account CO and NOx.

2.6 AIR POLLUTION METEOROLOGY

Photochemical pollution is a complex and highly non-linear process involving hydrocarbons (HC), nitrogen oxides (NOx) and sunlight and is influenced by the meteorological condition because: (a) user emission are weather sensitive (particularly to air temperature and humidity); (b) transport processes depend on mixing depth, wind speed and atmospheric stability; (c) chemical reactions are initiated by the ultraviolet radiation available (Derwent and Horvo 1994). The wind rose is a graphical representation of the frequencies of the different wind directions (Jensen 1999). According to Benvenuto et al 2000 the modeling of urban air quality prediction is a difficult task because the processes are controlled by complex chemical and physical mechanism. Kaminski et al (1998) addressed the problem of optimum data dimensionality reduction in radiation analysis of weather factor and their influence on the recorded air pollution concentration in urban areas. Sanjay et al (1995) conducted a systematic study of meteorological and ambient air quality assessment at the industrial city of Kota.

Vikas and Choudhury (1994) attempted to give a brief account of different aspects of meteorology in managing the environment effectively, using the meteorological and air quality data, with the need for standardizing the air quality models. Levy et al (2003) related the concentrations of PM$_{2.5}$, ultra-fine particles and polycyclic aromatic hydrocarbons to traffic volume, wind direction and distance from the road, using linear mixed effects regression models. Based on hourly measurement of NO$_x$, NO$_2$ and O$_3$ and meteorological data, an ordinary least square (OLS) model and a first order autocorrelation (AR) model were developed to analyse the regression and prediction of NOx and NO$_2$ in London by Ping shi and Roy (1997).
Chaloulakou et al (2003) used linear regression to relate PM$_{10}$ and PM$_{2.5}$ concentrations to predictor variables as temperature, wind speed, wind direction, time of year and day of week. Several authors used non-linear methods. Kukkonen et al. (2003) concluded that neural networks are superior to linear techniques in predicting PM$_{10}$, NO$_2$, NO$_x$ or Ozone concentrations from several meteorological variables. In addition, they compared neural networks to several other methods, including generalised additive models (Hastie and Tibshirani 1990). Data on the concentrations of seven environmental pollutants (CH$_4$, NMHC, CO, CO$_2$, NO, NO$_2$ and SO$_2$) and meteorological variables (wind speed and direction, air temperature, relative humidity and solar radiation) were employed to predict the concentration of Ozone in the atmosphere using both multiple linear and principal component regression methods by Sabah et al (2005).

### 2.7 AIR QUALITY MODELING

Air quality models are an important tool for managing air quality. They can be used to predict the impact of urban planning decisions, such as the placement of roads, and the location or expansion of residential and industrial areas. Models are usually formulated as mathematical models which describe the physical processes and features of a physical system in mathematical terms. One of the main benefits of models is that they can be used to predict particular occurrences or phenomena that we may not be able to identify through observations. For instance, a model may show that a threshold concentration of a particular pollutant can trigger an air pollution episode. Modelling of occurrences such as photochemical smog is a complex process. Concentrations of ozone (one of the major components of photochemical smog) and emissions of other pollutants are commonly used to model air quality situations. Meteorological data, such as wind speed and direction, and photochemical reactions between pollutants are combined with
data from a pollutant emissions inventory for a region to model the processes that occur in the atmosphere.

The findings of the model can be used to support strategies to manage the emissions from pollution sources if the causes of pollution are known and the consequences of exceeding the threshold concentration are detrimental. The factors that affect the transport, dilution, and dispersion of air pollutants can be grouped into:

- emission or source characteristics
- the nature of the pollutant material
- meteorological characteristics
- the effects of terrain and anthropogenic structures.

2.7.1 Dispersion modeling

Air quality models are used to predict ground level concentrations. The object of a model is to relate mathematically the effects of source emissions on ground level concentrations. Reactive models address complex multiple-species chemical mechanism common to atmospheric photochemistry and apply to pollutants such as NO, NO₂, and O₃. Models can be described as simple or advanced based on the assumptions used and the degree of sophistication with which the important variables are treated. Advanced models have been developed for such problems as photochemical pollution, dispersion in complex terrain, long-range transport, and point sources over flat terrain. The most widely used models for predicting the impact of relative unreactive gases, such as SO₂, released from smokestacks are based on Gaussian diffusion. It can also be classified as process oriented statistical models. In general term a distinction between process-oriented models and statistical models can be made. Process oriented models are based
on the description of physical/chemical processes: starting with emissions, atmospheric advection and dispersion, chemical transformation and deposition is calculated. This type of models is able to give a description of cause-effect relations. Statistical models are valuable tools in estimating present air quality by means of interpolation and extrapolation of measuring data. There are three types of dispersion models: Lagrangian, Eulerian and Gaussian dispersion models.

The description of a Lagrangian model is often taken to refer to a moving coordinate system and can take the form of a trajectory box model or a particle model. Such models are sometimes referred to as Random Walk models. In the case of a Lagrangian particle model atmospheric transport and diffusion are simulated by tracking the movement of large numbers of particles that represent quantities of an air pollutant according to average wind and turbulence parameters with random movement also considered. Both average wind conditions and specific prescribed flow-fields can be accommodated to control the movement of the particles. Lagrangian models can be quite computationally intensive, their accuracy depending on the number of particles released, and they can accommodate chemical sub-models.

As opposed to the moving Lagrangian framework, Eulerian models operate on a fixed coordinate system, where the emission, transformation and transport are parameterized in terms of the fluxes to and from a two or three-dimensional fixed coordinate system. Such a modelling system tends to be mathematically complex, is computationally intensive and not so well suited to the treatment of emissions on a plume-scale, which may need to be embedded as a sub-model.

The Gaussian formulation is one of the most commonly used frameworks for modelling local dispersion of a pollutant. It describes the
transport and diffusion of a gas (or particle) from a source to a receptor according to stability class and other parameterized characteristics of the atmosphere. It can be applied to plumes from point, line and area sources. In this research work models based on Gaussian dispersion model are used.

A dispersion model is a mathematical description of the meteorological transport and dispersion processes, using source and meteorological parameters, for a specific period in time. The model calculations result in estimates of pollutant concentration for specific locations and times (Ryan 1992). There are four main types of roadside air dispersion models: Gaussian plume dispersion model, atmospheric box model, source apportionment, and computational fluid dynamics (CFD). The Gaussian plume model is probably the most widely used because of its simplicity. It assumes a Gaussian distribution of pollutant dispersion and no chemical or removal processes take place during dispersion (Anjali et al 1999). Such models include the US Environmental Protection Agency’s (EPA) CALINE family of models (i.e., CALINE3, CAL3QHC, and CAL3QHCR) and California Air Resources Board’s CALINE4. Ujaini and Priya (1993) presented a review on the atmospheric dispersion models. They discussed the importance of dispersion modeling, qualities of good dispersion model and a detailed review on Gaussian dispersion models.

Mukerjee and Ray (1992) proposed a model for simulating an average daily distribution of values of some meteorological parameters required for dispersion modeling using data from Indian Meteorological Department for different stations in India. Sivacoumar and Thanasekaran (1998) discussed different methodologies available for estimation of pollution load for Indian vehicles, which can be used as input data for highway pollution simulation models. Tiwari and Kumar (1998) evaluated the air pollution impact due to a proposed cement factory at Kymore using Gaussian
plume dispersion model and superimposed the results on a baseline data. Agarwal et al (1998) discussed the Gaussian dispersion model configuration with model assumptions and the parameters affecting the air pollution prediction from an elevated point source. The CALMET meteorological model and its puff dispersion model CALPUFF were used by Tolga (2004) to predict dispersion of the sulfur dioxide emissions from industrial and domestic heating sources in Izmir, the third biggest province in Turkey.

The relative sensitivity of the Gaussian plume model with respect to the input parameters was checked analytically by Neumann and Halbritter (1980). Md Musud and Takashi (2000) used an air pollution dispersion model which simulated the spatial dynamics of the NOx pollutants. Mukherjee and Viswanathan (2001) used the Street canyon module and Gaussian line source module of a regional-scale dispersion model Indic Airviro to simulate ambient CO concentrations due to traffic flow at two roadside monitoring locations in Singapore. Magne and Ingrid (2005) presented a general model where the logarithm of hourly concentration of an air pollutant was modelled as a sum of non-linear functions of traffic volume and several meteorological variables. Seong et al (2004) calculated the dispersion characteristics of vehicle emission in an urban street canyon using the aspect ratio of a street canyon (i.e. the ratio of the width of a street and the average height of buildings) and the direction of external wind. An empirical method was developed by Sanchez et al (1986) to improve the calculated concentrations of particulate and gaseous fluorides with the aid of the Gaussian plume model.

Lin and Niemeier (2003) demonstrated that traffic variability can result in significant difference in total vehicle emissions. Studies have shown that concentrations and size distributions of aerosols have clear time dependency, correspondent to time-variant traffic patterns, vehicle speeds, and traffic intensity (Sturm et al 2003). Sivacoumar and Thanasekaran (1999)
used the Gaussian-based Finite Line Source Model to predict pollutant concentration due to automobiles from roadways in Chennai city, to predict carbon monoxide concentrations. Elizabeth et al (2007) used the range of CALINE4’s PM$_{2.5}$ modeling capabilities by comparing previously collected PM$_{2.5}$ data with CALINE4 predicted values. Sharad and Mukesh (2007) developed the statistical distribution model fitting to CO concentrations for the heterogeneous traffic pattern at the urban hotspots in Delhi, India.

Road transport has become by far the major source of environmental pollution and traffic congestion in urban areas. Though a lot of research has been done to investigate the functional relationship linking air quality and air pollution from transport, a further improvement in the knowing of this relationship is needed. Costabile and Allegrini (2008) analyzed this relationship and developed a more flexible framework to allow communication between transport emissions and air quality concentrations. A detailed airborne investigation of air pollution in the Hong Kong region was undertaken by Carras et al (2002). The system consisted of a numerical weather prediction module, a prognostic air–chemistry/transport model, an emissions inventory system and a Graphical User Interface (GUI) for display of results and preparation of simulations. Slini et al (2006) provided an operational air quality forecasting module for PM$_{10}$. Statistical methods were investigated and applied. Yong et al (2008) developed a Bayesian hierarchical model for urban air quality predications. Anjaneyulu et al (2006) monitored Carbon Monoxide (CO) concentration at 15 links in Calicut city and air quality performance was evaluated over each link. The CO pollutant concentration values were compared with the National Ambient Air Quality Standards (NAAQS), and the CO values were predicted by using CALINE4, IITLS and Linear regression models.
The prediction of tropospheric ozone concentrations is very important due to the negative impacts of ozone on human health, climate and vegetation. The development of models to predict ozone concentrations is thus very useful because it can provide early warnings to the population and also reduce the number of measuring sites. Sousa et al (2007) predicted the next day hourly ozone concentrations through a new methodology based on feed forward artificial neural networks using principal components as inputs. Five year data on CO, NO, NO$_2$, O$_3$, smoke and SO$_2$ concentrations recorded at one air-pollution monitoring station in the city of Athens was analyzed using principal component analysis (PCA) by Statheropoulous et al (1998). Holmes and Morawska (2006) provided a review of the application of atmospheric models for particle dispersion. The different types of dispersion models available, from simple box type models to complex fluid dynamics models were outlined and the suitability of the different approaches to dispersion modelling within different environments, in regards to scale, complexity of the environment and concentration parameters were assessed. A multiple source stationary Gaussian atmospheric dispersion model was tested in the Copenhagen area for 20 dispersion and decay parameter combinations, using different parameters for high and low sources by Lars and Maks (1977). Dietmar et al (2001) studied numerical simulations performed with a Gaussian finite line source dispersion model CAR-FMI and a Lagrangian dispersion model GRAL, and compared the model predictions with the field measurements.

Specific data analysis techniques that revealed the performance of air quality models in simulating the measured concentrations’ cumulative distribution were studied by Rao et al (1985). A line source model, developed in Indian Institute of Technology (IIT) Delhi, India, namely IIT line source (IITLS) model, was proposed by Goyal and Ramakrishna (1999) to describe the downwind dispersion of pollutants near roadways.
2.7.2 CALINE4 Dispersion Model

The CALINE-4 model is a fourth-generation line source air quality model that is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadway. Given source strength, meteorology, site geometry and site characteristics, the model predicts pollutant concentrations for receptors located within 150 meters of the roadway. The CALINE-4 model allows roadways to be broken into multiple links that can vary in traffic volume, emission rates, height, width, etc. Amit and Yaacov (2003) compared several transportation-related air quality models: two line-source models (CALINE4 and HIWAY2), two mobile-source models (Mobile5b and COPERT3), along with real-world emission factors to evaluate the models. A comparative evaluation of two Gaussian-based line source models namely, CALINE4 and the general finite line source model, was presented by Rajiv et al (2009). CALINE4 was used by Baijayanta et al (2009) to predict CO concentration in Kolkata. Albassam et al (2008) used CALINE4 to assess the CO concentrations based on the recorded traffic flow and emission inventory with the prevailing meteorological conditions that existed at the specified time.

Joseph et al (2005) evaluated two atmospheric dispersion models against the results of a measurement campaign that was conducted near a major road at Elima ki in southern Finland. Elizabeth et al (2007) explored the range of CALINE4’s PM$_{2.5}$ modeling capabilities by comparing previously collected PM$_{2.5}$ data with CALINE4 predicted values. Gtamotnev et al (2003) used CALINE4 for the analysis of aerosols of fine and ultra-fine particles, generated by vehicles on the road. They developed and justified a scaling procedure of the CALINE4 package. The CALINE4 air quality model, was applied to calculate the immediate roadway contribution of air particulate matter <10μm (PM$_{10}$) and carbon monoxide by Chumpol et al (2003). The
monitoring data from Beta-Ray absorption and for carbon monoxide from non-dispersive infrared absorption were used as reference. The CALINE4 roadway dispersion model has been applied to concentrations of NO\textsubscript{x} and NO\textsubscript{2} measured near by Kerstin et al (2007).

2.7.3 GIS Based Modelling

Geographical Information System (GIS) is a computerized geographic database management system for the capture, storage, retrieval, analysis and display of the map. Geographical information systems are widely used computer tools that allow geographically referenced data to be organized and manipulated.

In GIS, features on the earth’s surface are mapped on to a flat two-dimensional map as points, lines and areas. An x, y (Cartesian) coordinate system is used to refer map locations to ground locations. Each point is recorded as a single x, y location lines and areas are recorded as a series of ordered x, y coordinates. Areas are recorded as a series of x, y coordinates defining line segments that enclose an area. So, with x, y coordinates we can represent points, lines and polygons as a list of coordinates instead of as a picture or map. These coordinate lists represent how map features are stored in a computer as a set of x, y coordinates (digits) and hence the term ‘digitize’ is used to refer to map data automation. Thus, in GIS all the map features are stored in a series of files on the computer in a ‘digital map data base’. The digital map database in GIS mainly consists of two types of information for a given geographical map. They are (1) Spatial information and (2) Descriptive attribute information.

Spatial information refers to shape of geographical features and their spatial relationship to other features. These are represented by location features like points, lines and area. Point features may represent a discrete
location defining a map object whose boundary or shape is too small or be shown as a line or a area feature (e.g.) well, buildings etc; Line feature may represent a linear shape of a map object too narrow to be displayed as a area (e.g) roads, village boundaries etc; Area features represent a closed Figures whose boundary encloses a homogenous area (e.g) a desert, lake, country etc;

Attribute information contains descriptions, classifications and measurements of the geographical features. Each geographical feature may have attributes depending on the significance of it. The attribute data has descriptive, quantitative and qualitative information about each feature on the geographical map. eg. ID number of a road, link number of the road, road name, road type, road width, road length, x, y coordinates of the two end points of the road, traffic volume of the road, average speed of the vehicles, total quantity of the pollutants emitted on the road etc.

The power of GIS lies in linking the spatial information and attribute information and maintaining the spatial relationship between the map features and to carry out spatial operation. This data integration opens the way for powerful and varied variety of looking at and analyzing this data. An important feature of GIS is its ability to bridge the technical gap between analysts and decision-makers need for easy-to-understand information. The communication power of GIS (thematic maps, GUIs, 3D surface plots, etc) is also a feature that has made GIS one of the most used platforms for planning. In addition to the process of updating geographical objects, keeping the valid topological (either temporal or spatial) relationship are also operational. The data will be structured and stored in the temporal database.

Urban environmental management must integrate the spatial, structural features of a city, typically captured in GIS, and the dynamics of environmental quality indicators that can be obtained by monitoring. To provide decision-relevant information supporting planning and management,
these components are integrated in models for scenario analysis and optimization tasks. The development of GIS, which have gained wide appreciation during the last 20 years, offers the opportunity to predict pollutant concentrations on a fine spatial scale (Burrough and McDonnell 1998). The SAVIAH study (Briggs et al. 1997 and 2000) which applied this practicable technique to the estimation of NO₂ annual average concentrations has a pioneer role in its propagation.

Arystanbekova (2004) proposed an analytical Gaussian model for diagnosis and prognosis of atmospheric pollution level at damage emissions. This model read the input data from GIS files and produced the outputs in a format acceptable by GIS. Hatefi and Delavar (2007) developed a prediction model for air pollution in 2004 using the data of 2002 and 2003. Additionally by using the method of local contribution to concentration in canyon streets, the concentration of both CO and NO₂ at each month and for six highways of Tehran and for each vehicle was calculated. The prediction model was a GIS-based model that takes geometry of the streets and vehicle numbers. Meenambal et al. (2005) studied, the concentration of Carbon-Monoxide (CO) along and near the major roads at Coimbatore west zone due to vehicular emission using CALINE4 model.

Saksena et al. (2002) studied the spatial patterns of ambient air quality of Delhi in the absence of extensive datasets needed for space-time modeling. Weng and Yang (2006) investigated the relationship of local air pollution pattern with urban land use and with urban thermal landscape using a GIS approach. The spatial distribution of SO₂ concentration was studied by Sanchez et al. (1986) at nine locations in the urban area of Valladolid, using the principal component factor analysis. Pummakarnchana et al. (2005) used a portable device, comprising of solid state gas sensors integrated to a Personal Digital Assistant (PDA) linked through Bluetooth communication tools and
Global Positioning System (GPS), which provided information on pollution levels at multiple sites simultaneously. They published the air quality report thus generated using Internet GIS to provide a real-time information service, for increased public awareness and enhanced public participation. Ling et al (2005) described a new framework to link existing air quality tools and the implementation of this framework through the development of prototype software Integrated Modular Program for Air Quality Tools (IMPAQT).

Agrawal et al (2003) discussed the role of GIS for the continuous improvement of air quality status as well as to make the AQMS more efficacious and cost effective. A decision support system was developed to support local authorities in air quality management for big Turkish cities by Tolga Elbir (2003). The system is based on CALPUFF dispersion model, digital maps and related databases to estimate the emissions and spatial distribution of air pollutants. A model to determine the air quality in urban areas using a geographical information system was presented by Puliofito et al (2003). The system permitted the integration, handling, analysis and simulation of spatial and temporal data of the ambient concentration of the main pollutant. Taosheng (2005) reported a preliminary study of the forecast and evaluation of transport-related air pollution dispersion in urban areas by modifying the traditional Gauss dispersion models combined with a self-developed GIS platform, and a simulative system with graphical interfaces.

Schmidt and Schafer (1998) developed an integrated simulation system for traffic flow information, air pollution modeling and decision support in a distributed High Performance Computing Network to investigate the air quality in urban areas. Moragues and Alcaide (1996) used GIS to assess and locate traffic effects before and after a new traffic infrastructure enters services, and the results showed that GIS is an effective tool for carrying out environmental impact assessment. Gualtieri and Tartaglia (1998)
developed a comprehensive model for the evaluation of air pollution caused by road traffic in urban areas to help the decision making of local administrators. Jenson (1998) developed a model which combined GIS and the Danish Operational Street Pollution Model, for population exposure to traffic air pollution in order to improve assessment of health impacts and in support of risk management. Rebolj and Sturm (1999) integrated existing emission calculation software with a graphical user interface to estimate traffic air pollution.

The use of GIS in air quality or emission inventory related activities is at an advanced stage in India. Sikdar (2001) applied GIS for air pollution profiling for Delhi city, from monitored hourly data and demonstrated its usefulness in transportation management. Nansai et al (2004) proposed methodologies to systematize procedures of developing an emission inventory for Japan using a GIS platform. Charlot (2002) have used GIS tools for designing the mobile emissions estimation system for Chennai city in India and calculated the vehicular emissions in a gridded manner. Streets (2003) have used GIS for gridding emissions for several gases, including CO, over the Indian and East Asian region and provided some useful information on a broader scale.

The extensive literature survey made has helped to frame the objective for the study, to analyse the data and to arrive at effective conclusion.