# GIS as modelling and decision support tool for air quality management: a conceptual framework

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**ABSTRACT**

High air pollution load in Indian metropolitan cities like Delhi, Mumbai, Kolkata, *etc.* has been a major contributing factor towards degrading the ambient air quality day by day. The degradation of air quality is a major environmental problem that affects many urban and industrial sites and the surrounding regions. A database consisting of information regarding the sources of emission, local meteorology and air quality may be created to assess the status of air quality. Air Quality Management System (AQMS) is a strategy to overcome the problems of air pollution and is most effective towards continuous improvements of air quality. It includes the evaluation of various sets of emission control schedules to determine consequences to air quality and the formulation of alternative emission control schedules to meet air quality goals. This research paper discusses the role of Geographical Information System (GIS) for the continuous improvement of air quality status as well as to make the AQMS more efficacious and cost effective. Various capabilities of GIS can be used to develop geospatial air quality models. A GIS based Decision Support System (DSS) for air quality management may be conceptualized with five modules, namely, data-entry module, assessment module, development module, control module and user-interface. It is expected that the development of DSS under GIS environment will make AQMS more efficient to provide an advanced modelling and analysis system for environmentalists, planners and decision makers.

**KEYWORDS:** Air, Modelling, DSS, Pollution, AQMS, Management, GIS

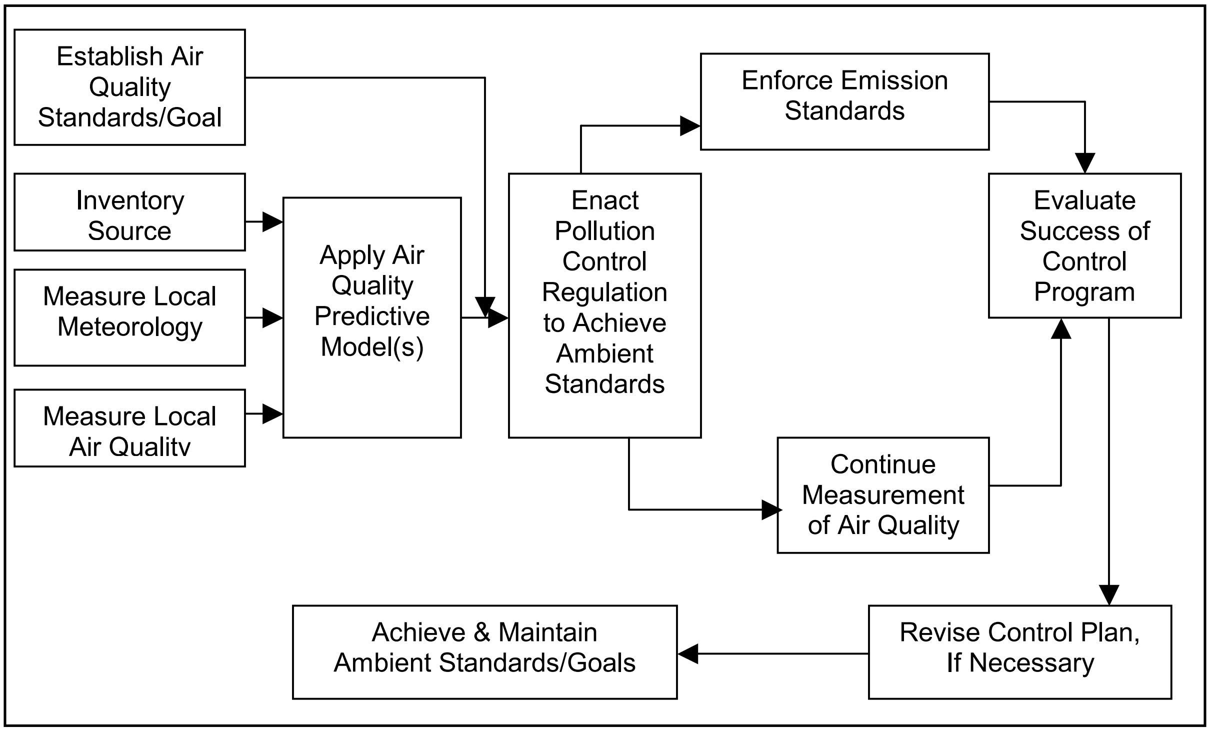
## 1.0 INTRODUCTION

Indian metropolitan cities like Delhi, Mumbai, Kolkata, *etc.* have high emission of air pollutants, which is degrading the ambient air quality day by day. The degradation of air quality is a major environmental problem that affects many urban and industrial sites and the surrounding regions worldwide. Air pollution can reach levels, where it significantly influences human health, diminishes crop yield, and destroys infrastructure and patrimony. The phenomena involved in air pollution are complex. Once emitted into the atmosphere, primary pollutants are transported by wind, turbulence and diffusion, which can undergo chemical reaction, change phase and finally are removed from the atmosphere by dry and wet deposition. Health and environmental impact of secondary pollutants, *i.e.*, those formed in the atmosphere can be more severe than their emitted precursor.

The inventorying of sources of emission, local meteorology and air quality gives the status of air quality. A predictive model may then be prepared to enact the pollution control regulation to achieve ambient standards/ goals. However, a better, efficient and cost effective approach for monitoring the ambient air quality is to develop an air quality management system.

## 2.0 AIR QUALITY MANAGEMENT SYSTEM (AQMS)

AQMS can be defined as the regulation of the amount, location and time of pollutant emissions to achieve some clearly defined set of ambient air quality standards or goals. It includes the evaluation of various set of emission control schedule to determine consequences to air quality. It also includes the formulation of alternative emission control schedules to meet air quality goals subject to some other constraint, *e.g.*, technological feasibility or minimum cost. AQMS is basically a strategy to overcome the problems of air pollution and is most effective towards continuous improvements of air quality, particularly when targeting regional problems. Figure 1 shows various components of an AQMS which may be implemented for achieving and maintaining high ambient air quality standards (Nevers, *et al.*, 1977).




Various techniques recommended by the Central Pollution Control Board (CPCB) for air monitoring of almost all criteria pollutants are point monitoring. This may involve integrative sampling, grab sampling and passive sampling techniques. The integrative sampling involves drawing a known volume of air through a medium (filter or adsorbent) for a typical period (*e.g.*, 24 hrs) followed by its subsequent analysis in laboratory. Grab sampling involves collecting a sample in a container (*e.g.*, Tedlar bag or stainless steel canister). Then, the air sample is analyzed with appropriate instrumentation (*e.g.*, chromatograph) with an appropriate detector for determination of airborne organic compounds. Passive sampling functions like integrative active sampling, except that a concentration gradient between the ambient air and a sorbent provide the driving forces for collection of the airborne contaminant rather than a pump driven sampler. Exposure times can vary from short periods (8 hrs) up to one month (*e.g.*, sulphation plates, passive diffusion samplers).

**4.0 AIR POLLUTION MODELLING**

Modelling of air pollution is generally based on various models, namely, Gaussian models, box models, narrow plume hypothesis, gradient transport models and trajectory models. Gaussian models are based on a set of empirical equations. A three-dimensional axis system with an origin on the ground is set up within the downwind, crosswind, and vertical directions. Pollutant concentrations crosswind and vertically are described by Gaussian distributions. Box models assume uniform mixing throughout the volume of a three-dimensional box. This formulation is usually applied to urban photochemical models.

Narrow plume hypothesis based models assume that the main contributors are located upwind. The pollutant's concentrations are calculated using a vertical growth rate instead of uniform vertical mixing. Gradient transport models are applied when the turbulence is limited to scales that are small compared with the volume of pollutant emitted. They are more appropriate to line and area sources rather than point sources. Trajectory models are based on a vertical column that is moved downwind at the mean wind speed, with pollutants added as they are emitted at every location.

A numbers of air pollution modelling software are available for ambient air modelling and transport related air pollution modelling. These include ***ISCST 3*** (Industrial Source Complex Short Term, version 3) which is widely used model for estimating near field concentrations of non-reactive pollutant. ***AERMOD*** is an American Meteorological Society/US Environmental Protection Agency Regulatory Model used for regulatory purposes. ***SCREEN 3*** is a model for environmental professionals to conduct a preliminary screening analysis using conservative techniques for the determination of whether more refined analysis is required or not. ***CALINE- 4*** model has been developed by California Department of Transportation (CALTRANS) and is the leader in the development of dispersion models for highways. ***HIGHWAY*** model is a short-term (one hour) line source dispersion model and was developed by EPA in 1975 in FORTAN. ***HIGHWAY-2*** is the upgraded version of the model and gives more realistic concentration estimates due to upgrade dispersion algorithm (Benson, 1988; Cohn *et. al.*, 1982; EPA, 2001).

## 5.0 AIR POLLUTION DATABASE FOR DELHI CITY

Delhi air monitoring is achieved by point monitoring approach, which involves various types of sampling techniques, like, integrative sampling, grab sampling, passive sampling, *etc*. Data obtained by monitoring is in the form of non- spatial form. Tata Energy Research Institute (TERI) has developed an interactive database system for air pollution data presentation. It includes compressive air pollution data generated at eighteen monitoring stations. Out of these, eleven are operated by TERI and seven by Central Pollution Control Board. These stations were spread all over Delhi and represent residential, commercial, and industrial areas. After conducting the monitoring over that location, TERI has proposed a user-interactive system for the presentation of pollutant level at different locations. TERI system is capable of providing output in the form of either as graph or as tables.

## 6.0 GIS: A TOOL FOR AIR QUALITY MANAGEMENT

Geographical Information System (GIS) is a computer based information system that enables capturing, modelling, manipulation, retrieval, analysis, and presentation of geographically referenced data. It is a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth. For efficient AQMS, there is a need to have a well-defined Decision Support System (DSS) so that the purpose of AQMS can be achieved and it is implemented in an efficacious manner. Various capabilities of GIS may be utilized for air modelling, which may include locating monitoring stations, developing air quality models and development of spatial decision support system. By doing air quality modelling under GIS environment, the output of the pollutant records can be obtained in the form of spatial records. GIS techniques are capable of supporting the development of geospatial air quality models.

For modelling under GIS environment, AQMS may be thought of comprising of four phases, namely, monitoring, modelling, development of DSS and execution. For implementation purpose and for the continuous improvement of air quality status, these four phases may be recombined depending upon the actual site conditions. It is expected that modelling under GIS environment will make AQMS more efficient and cost effective. However, the milestone capabilities of GIS for AQMS are: (a) to locate the monitoring stations, (b) to develop geospatial air quality models and (c) to develop spatial DSS.

### 6.1 Location of Air Monitoring Station

In AQMS, monitoring is the first operation and GIS makes this operation easy. The monitoring stations are major sources to assess the accurate air quality status for the desired area. These stations may be chosen by first developing an integrated geographic database and then applying suitable selection criteria under GIS environment.

### 6.2 Air Quality Modelling under GIS

Implementing air quality models under GIS environment is the strong features of GIS technology. GIS techniques are capable to provide geospatial air quality models, *i.e.*, at any time and any location any one can access the Air Quality Status (AQS) of that area (Jensen, 1999). The output of the pollutant records can be obtained in the form of spatial records. Most effective GIS software include Arc/Info and ArcView among others. For this purpose software's supporting script language may be used like Arc Macro language (AML) and Avenue of Arc/Info and ArcView respectively.

**6.3 Development of Decision Support System (DSS)**

The GIS based DSS provides an advanced modelling and analysis system for environmentalists so that they can reliably generate and simulate more information about environmental parameters. One of key components in spatial DSS is the data warehousing and analysis. For air quality monitoring, numerous records of meteorology, pollution and other related data for last several years are needed to be analyzed which may be done efficiently by developing DSS under GIS environment.

**7.0 PROPOSED GIS BASED DSS FOR AIR QUALITY MANAGEMENT**

GIS applications are developing rapidly. A well-defined DSS under GIS environment may be developed so that AQMS may work efficiently. This will help in taking the decisions to improve the present air quality status by means of making rules and regulations by the concerned authorities (Dalh, 1997). These decisions and regulations are being established by the spatial analysis from the GIS based air quality models. A GIS based DSS for AQMS has been proposed in the present paper. The proposed DSS consists of five modules. These modules are data-entry module, assessment module, development module, control module, and user-interface module. The proposed DSS under GIS environment is shown in Figure 2. A well defined spatial DSS will be beneficial for environmental scientists and policy makers.

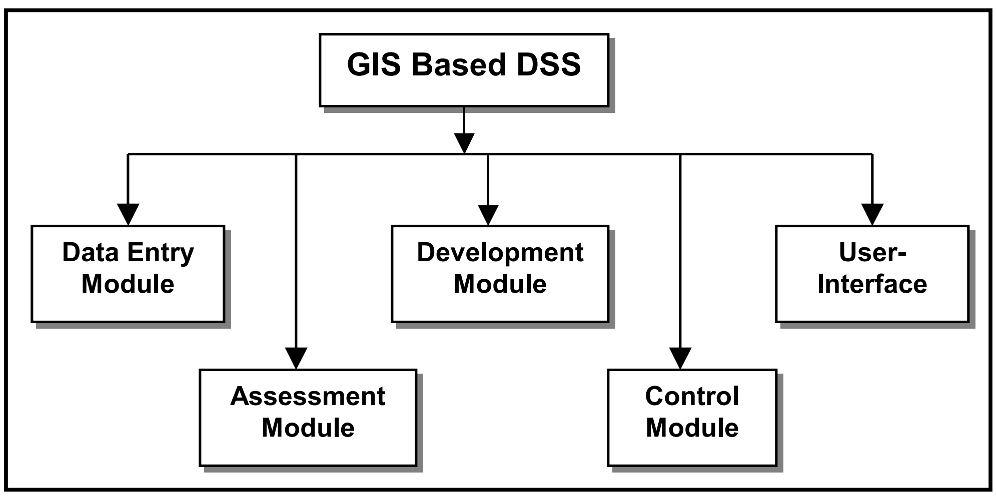



**Figure 2: The Structure of Proposed GIS-Based DSS**

**7.1 Data Entry Module**

This module is for entering basic geographic and attribute data. Data for control module is also entered using this module.

**7.2 Assessment Module**

The main objective of this module is to assess the variations of meteorological, air pollution and related data at each monitoring stations. This is used to develop various sub-modules which will be used to support the development module, *e.g.*, meteorological sub-module, pollution content sub-module, *etc.*

**7.3 Development Module**

This module is the used to develop the predictive models for any pollutant at any location. For each pollutant, a separate mathematical equation may be developed based on statistics of the pollutant records of previous years.

### 7.4 Control Module

This module is important to the decision-makers and it is used to control the pollution level of criteria pollutant. Various regulations and policies are a part of this module. This module helps the planners/ environmentalists to identify the required decisions which must be taken to achieve the goal.

### 7.5 User-Interface

It consists of menu-based interface to help various planners and decision makers in efficient usage of the developed DSS. All the modules should be well linked together within a GIS-based user interface and should provide graphics, dialog boxes, spatial analysis and other required functions.

## 8.0 CONCLUDING REMARKS

The air pollution problems originating from the various sources can be controlled by the development of air quality management system. This strategy of air pollution control can be achieved within four phases. First phase includes monitoring, second modelling, third development of DSS and last phase includes execution. GIS is a modern technological tool and may be used for the development of geospatial air quality models. Further, a GIS based DSS is expected to make air quality management system more efficacious and may be adopted as an efficient and cost effective approach for continuous improvement of air quality status. The advanced modelling capabilities of GIS are expected to be beneficial for environmentalists, planners and decision makers so that they can reliably generate, simulate and analyse more information about environmental parameters.

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