AIR POLLUTION ASSESSMENT APPLYING GIS INTEGRATED SYSTEM

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Abstract: Despite decades of progress in reducing air pollution, almost all metropolitan areas in developing mega-cities are suffering from serious air pollution. In this study, the authors try to establish an "Air Pollution Assessment Applying GIS Integrated System" for providing more accurate information about air pollution. This system can be used to determine the concentration level and the number of people exposed at every pollution level with geographical distribution.

In establishing the simulation model and the testing validity of the model, data related with positional information is needed. In this regard, GIS can provide an invaluable tool for air pollution assessment.

As a preliminary stage in developing the GIS integrated system for developing mega-cities, the city of Nagoya was used to be as a pilot study to test the system.

1. INTRODUCTION

1.1 Background

Throughout the world, urban areas are developing at rapid pace. Increasing urban populations and growing levels of motorization have inevitably led to air pollution related problems. The mega-cities in the world will increase their air pollution concentration to levels as high as 75-100 per cent over the next decade(WHO/UNEP, 1992).

To cope with this situation, the collection of accurate and reliable data necessary for the evaluation of urban air quality is very important.

On such backgrounds, more convenient tools are needed for air pollution evaluation and monitoring. In this study, by using GIS, the authors try to establish system to provide a useful tool for assessing air pollution problem. With geographic information system (GIS), the area and the level affected by air pollution can be displayed more precisely and objectively. By using these study findings, the proposed system will create a reasonable background for decision-making and problem solving with regards to the air pollution problem.

1.2 Objectives

Given the explanation above, the main objectives in this study are as follows:

(1) By developing an GIS integrated air pollution assessment system, the authors provide a flexible and convenient tool for supporting assessment and easily explaining study findings .

(2) By applying the proposed system to the study area, Nagoya, the authors verify the potential of the proposed system for practical application.

2. THE STRUCTURE OF THE PROPOSED SYSTEM

2.1 The overview of the proposed system

GIS is the geo-referencing information system, therefore, the data and the results are displayed in real locations on maps. All planning data are intimately related to geography or spatial location. Statistical analysis can be performed effectively within GIS environment. In this way, GIS offers the possibility of supporting sophisticated decision making model.

The system consists of three essential parts: GIS, a simulation model for traffic air pollution, and counter measures for solving air pollution. The DBMS (data base management system) in GIS manages the spatial information and integrates with simulation model by transferring data and results. In the simulation model, the air pollution condition in the study area is simulated and analyzed via updating, storing, and retrieving of attribute data within GIS

By using the counter-measure system that will be developed in the next stage, some counter-measures can be chosen as an option. After choosing option, the effect of the counter-measure is simulated and analyzed. The outputs with geographical distribution are also reported, displayed and plotted through GIS. The ease of accessibility to this information using GIS, enables experts or decision-makers to evaluate the environmental processes affecting the dispersion of pollution from sources and to ascertain the risks associated with this pollution level.

The GIS Integrated System that was being developed in this study was designed as shown in Fig. 1.

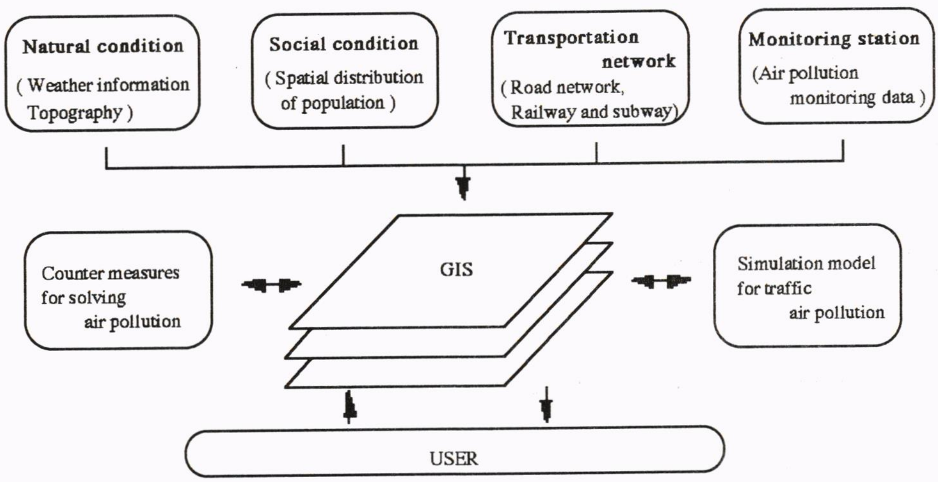

Fig. 1 Outline of the proposed system

2.2 Information in GIS

Information for air pollution may come from many sources. Measurements of environmental parameters taken in the study area may be incorporated. Historical and current information that is provided for the GIS schemes can be interfaced with the air pollution simulation model to aid in the formation of sound decisions regarding environmental patterns and process.

Three levels of information can be established for the air pollution assessment; thematic maps related to traffic air pollution, monitoring data and outputs from the simulation models.

2.2.1 Thematic maps with attributes

A database including a wide range of information characterizing study area must be generated. Features of the natural environment, such as topography and weather information are required. In addition, the transportation related information must comply in order to establish the simulation model. The distribution data of population are needed to evaluate the effect of the air pollution. Such information may be stored in GIS in either qualitative or quantitative terms.

2.2.2 Air pollution monitoring data

Effective analysis with GIS system requires that the database be maintained current with the environment which it represents. Monitoring inputs are needed to provide verification of the simulation model. In addition to verification, monitoring data can explain the current state of air pollution.

2.3 Air pollution simulation model

Air pollution caused by road traffic is mainly discussed in this study. A simulation model for traffic air pollution can estimate the present situation, as well as forecast the future situation in the study area. This section provide a brief overview of the general structure of the simulation model.

2.3.1 The structure of simulation model for traffic air pollution

The simulation model is composed of three major components: a transportation submodel, an emission submodel, and air dispersion submodel. These components are briefly described below in Fig. 2, which shows a simple flow chart of the model.

1) The transportation submodel

The transportation submodel is used to forecast the spatial distribution of transportation activity. This submodel is an adaptation of the conventional 4-step demand forecasting model that is widely used by transportation planners.

The output of the model are traffic related data such as volumes by type of vehicle and speed by road section. These are used as input by the emission model.

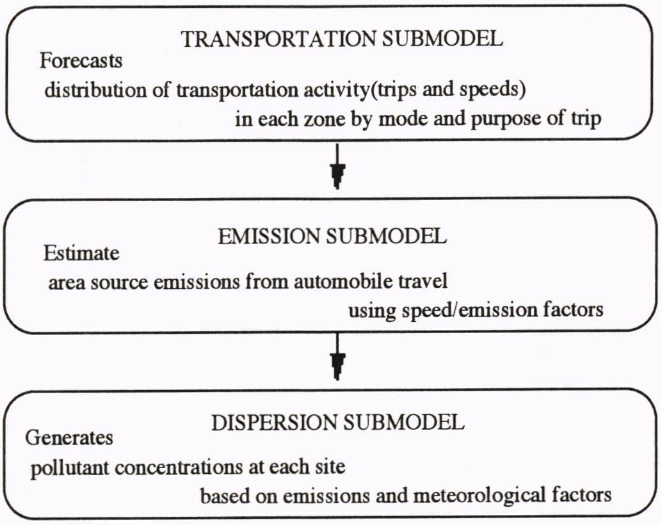

Fig. 2 Major Components of the Simulation Model for Traffic Air Pollution

2) The emission submodel

After the trip assignment portion produces the total number of vehicle trips on each network link, mobile source emissions can be calculated. The appropriate inputs to this emission model are the number of vehicles on each link, the average speed of the vehicles traveling on the link, and the average characteristics of the vehicles in the study area. The relationship between vehicle speed and emissions per kilometer in this study is based on the functions compiled by the manual for total control of an oxidized-nitrogen (Air Pollution Study and Control Centre, 1995). With the function given, the average emission rate is estimated by each type of vehicle for any average speed on a link. Thus, combining the emission rate of each vehicle type with the number of each vehicle type, the volume of emitted pollutants of each link can be estimated. The volume of emitted pollutants of each link are then used to determine the distribution of air pollution concentrations in the dispersion model.

3) Dispersion submodel

The principles of the dispersion model used in this study parallel those of the manual for total control of an oxidized-nitrogen(Air Pollution Study and Control Centre, 1995) where the dispersion parameters of the model for the road situation are described. More

details about dispersion model and their restriction of use can be found in this manual.
As a case study in Nagoya, the puff model is used as dispersion model under the assumption of weak wind. After estimating the concentration of NOx using the puff model, by the transform function suggested by the Bureau of pollution control in Nagoya(Bureau of Nagoya city for pollution control, 1990), the concentration of NO2 is calculated. The height for estimation is assumed to be at 1.5 meters corresponding to the height of human's head.
The average concentration at each site is then obtained by summing up all concentrations from each link of the road network. The results are displayed as map form in GIS.

2.4 Advantages of GIS integrated system

The need for estimating air pollution in real geographic location is one of the important issues in pollution estimation. By preparing more accurate estimation on the real sites affected by pollution, we can provide some reasonable basis for solving pollution problems and check for more effective counter measures. The spatial distribution of pollution is displayed and plotted on a map. It is very convenient to simulate and evaluate any counter measures before establishing a final scheme.
Using an overlay function, air pollution data and population distribution data can be evaluated at the same time. The output of this analysis can help to decide risk characterization associated with air pollution in the study area.

These advantages are useful in statistical analysis and help planners to perform traditional tasks both faster and better.

3. APPLICATION OF THE PROPOSED SYSTEM

3.1 The case study area

As a preliminary stage in developing GIS integrated model for metropolitan areas in developing mega-cities suffering from a serious air pollution, Nagoya, Japan is used as a case study. The metropolitan area of Nagoya is one of the three metropolitan areas in Japan.

3.2 Application into the case study area

3.2.1 Thematic map data

As thematic map data, transportation network data and population data are used in this study. With transportation network data, each road link contains with attribute data required by the air pollution simulation model. The attribute consists of the traffic volume of each vehicle type, speed, the number of lanes, etc. These were obtained from road transportation census(Bureau of roads in the ministry of construction, 1994).
Fig. 3 shows the map of the transportation network data.

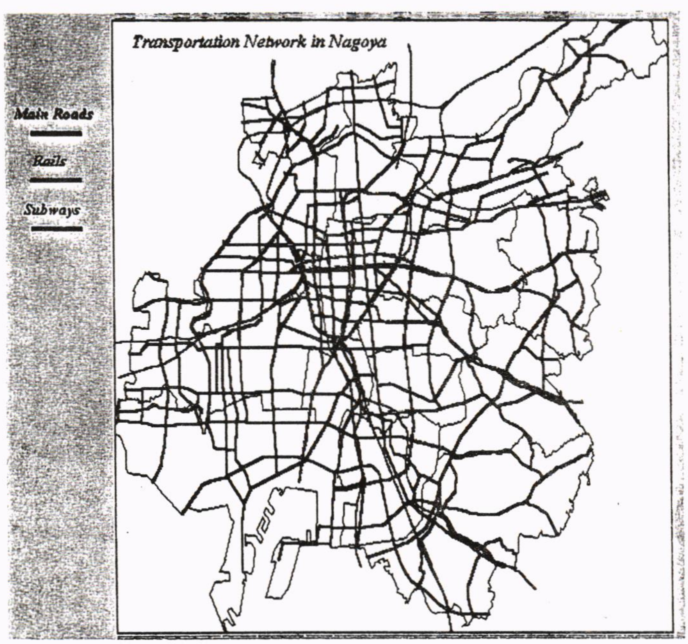

Fig. 3 Transportation Network in Nagoya

The map for spatial distribution of population data are needed to evaluate the affected population at each air pollution level. The map for population data has the attributes of population and area. The source of population data is stored by 500m mesh unit. Fig. 4 is the map showing the population distribution pattern.

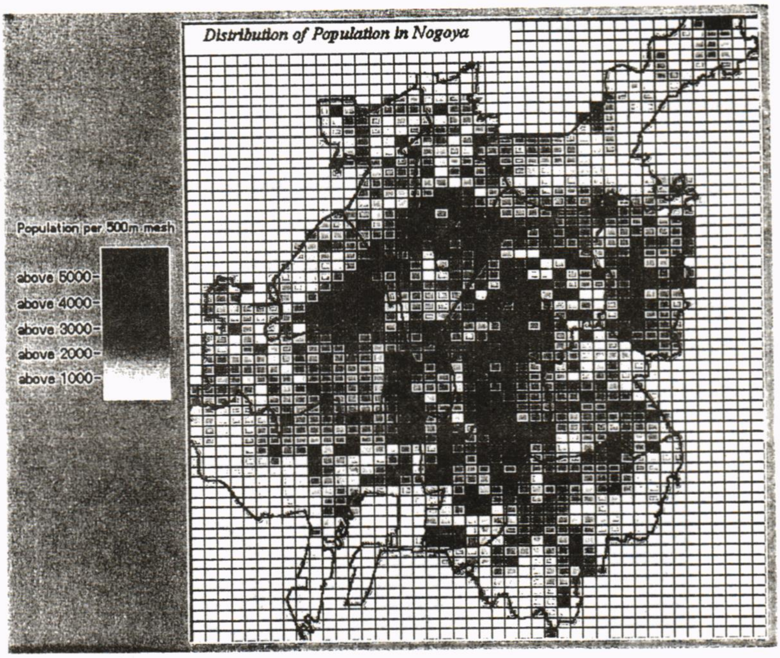

Fig. 4 Distribution of Population

Fig. 5 Air Pollution Monitoring Stations

3.2.2 Air pollution monitoring data

Monitoring data inputs are needed to estimate the current situation and provide verification of the simulation model. The monitoring data can be obtained from the air pollution stations in Japan(Gyousei, 1996). Fig. 5 shows the locations of the air pollution monitoring stations in Nagoya.

3.3 Spatial distribution of air pollution concentration

The simulation model provided spatial distribution of air pollution concentration. In this pilot study, we simulated only NO2. The results are shown in Fig. 6.

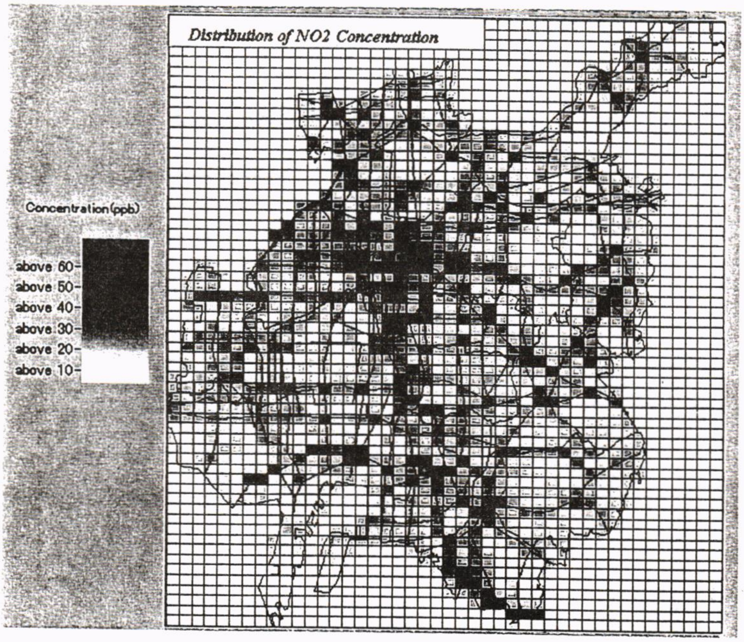

Fig. 6 Distribution of NO2 Concentration

Table 1 Correlation between simulated and monitored values of annual average

Air pollutant	Number of samples	Regression form	Correlation coefficient
NO2	26	Monitored values = 5.36 + 1.13* Simulated values	0.71

A comparison of NO2 concentration between simulated values and the monitored values which are obtained from the monitoring stations for air pollution in Nagoya is shown in Table 1. Judging from the result, the performance of the simulation model is considered to be sufficient for applying this study as prototype system. Using the proposed system, air pollution condition was assessed for annual average concentration in study area, Nagoya . The results are shown in Table 2. It shows that the concentration of NO2 weighted by the population is higher than by area. This resulted from the fact the amount of the population density in the surrounding areas of main roads is higher than in the distant areas from main road. It is a logical result. These findings can help when deciding on countermeasures.

Table 2 Outputs of Air Pollution Assessment

<table>
<tr><th>Concentration (ppb)</th><th>Area (km^2)</th><th>Annual average concentration (area weighted)</th><th>Population (person)</th><th>Annual average concentration (pop. weighted)</th></tr>
<tr><td>below 20</td><td>246.88 (75.65%)</td><td rowspan="5">13.4 (ppb)</td><td>1563088 (72.54%)</td><td rowspan="5">15.7 (ppb)</td></tr>
<tr><td>20 - 40</td><td>58.00 (17.77.%)</td><td>428373 (19.88%)</td></tr>
<tr><td>40 - 60</td><td>16.49 (5.05%)</td><td>128857 (5.98%)</td></tr>
<tr><td>above 60</td><td>5.00 (1.53%)</td><td>34476 (1.60%)</td></tr>
<tr><td>Total</td><td>326.37</td><td>2154794</td></tr>
</table>

4. CONCLUSION

By integrating simulation routines into GIS, the proposed system provides a flexible and useful tool for air pollution assessment. By using an integrated system, air pollution concentration was estimated at real locations. By overlaying population data with the air pollution concentration layer, we can easily find the number of people exposured at each level of air pollution can be easily found. The study findings are displayed as map making it more convenient for interpretation. These findings can help decide some political decision for reducing human exposure to pollutants decreasing risks to health and environment.

Although these outputs are based on a pilot study, they clearly reveal the potential of the proposed system for practical application. There are, however, many aspects that need to be updated and modified. In this pilot study, we simulated only NO2. There are many kinds of air pollutants(e.g., SOx, Pb, SPM, etc.) in addition to NO2. For comprehensive assessment of air pollution of each metropolitan area, the proposed system must be extended to other pollutants.

The part of counter-measure system has not completed yet. When completed, the proposed system will be applied to metropolitan areas in developing countries with the scenario of the counter-measures. It will be useful for finding the optimal scenario of counter-measures in each metropolitan area.

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