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PREDICTING SHORT TERM VEHICULAR RELATED AIR POLLUTION FOR CORRIDORS: A CASE STUDY IN ISTANBUL, TURKEY

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ABSTRACT

This paper suggests a method by which a governmental agency can use short term traffic forecasting and air pollution modeling techniques to predict air pollution (i.e., CO, NOx, particulate matter) for major corridors for one or two days in advance to provide a simple advisory system for decision-makers and the public. The authors propose the use of a Geographic Information System (GIS) integrated with a travel demand and an air pollution dispersal model. This system will first be tested on a corridor in Istanbul, Turkey. After the model has been tested for this corridor, the authors would discern how it could apply it for the major corridors in Istanbul. It is thought that this system will be a very useful device for decision-makers to warn the public about possible health hazards, but also to view alternatives to mitigate the effect of traffic pollution. The public, in turn, could lessen the situation by choosing alternative routes in predicted areas of high pollution or using public transportation.

Key Words: GIS, travel demand modeling, CO, NOx, Air Pollution Dispersal Modeling.

1. INTRODUCTION

Air pollution related to vehicular traffic in corridors has been proven to have serious short and long term health consequences to the residents living near them (Krzyzanowski, 2005; Minnesota Center for Environmental Advocacy, 2003). Young children and the elderly are particularly vulnerable to this type of pollution. Educational institutions, social service agencies, and governmental buildings in densely urbanized areas are often placed immediately adjacent to congested arterials. The primary concern of governmental agencies has been the overall pollution of an urbanized area. For the most part, the consequences of traffic related air pollution in small areas where people may be at the greatest risk are ignored. It is estimated that more people die of traffic related air pollution than traffic accidents.

The key to being able to mitigate the effects of traffic related air pollution is adequate modeling tied to decision-making. If public officials can alert the public about severe traffic related pollution along certain corridors, then segments of the population such as the young or the elderly can stay indoors or refrain from serious physical exercise. In the long term, being able to model traffic related pollution would enable local decision-makers to evaluate the effectiveness of mitigation strategies and better plan new urban development.

There is well developed body of research in air dispersal models related to vehicular traffic (Angelino et al., 1999; Dommen et al., 2003; Gulliver and Briggs, 2005; Jensen et al., 2001; Lin, and Lin, 2002; Masud, 1999; Maurizio et al. 1998; Reynolds and Broderick, 2000; Xia and Shao, 2005). This topic is complex because of the numerous variables such as the types of pollutants (i.e., CO, NOx, particulate matter); the time of day; photo-chemical reactions; meteorological conditions; amount and composition of traffic flow; topography and heights of buildings and concentration (i.e. “the urban canyon effect”); and scale/resolution. Because of these numerous factors, the models developed for traffic related air pollution are data intensive and necessitate complex formulae. Nevertheless, the application of such models is limited in application. In addition, the effects of traffic related air pollution in urbanized areas in developing countries with high density, limited regulations and strained transportation infrastructure is very sparse.

The use of Geographic Information Systems (GIS) has proven to be effective in modeling and the monitoring of traffic related air pollution. GIS modeling is directly related to the linear aspects of traffic related air pollution. The use of raster models have also been use to model traffic related air pollution. The use of a GIS linked to the Internet to provide real time information about air pollution in several cities. The linking modeling and real time information for air pollution related to traffic is not an unrealistic extrapolation of the use of GIS and the Internet.

2. CASE STUDY AREA

The area selected for the testing the model is Istanbul, Turkey (see figure 1.) Istanbul has developed extremely rapidly over the last twenty years to become one of the largest cities in Europe (Ocakci, 2000). The population is estimated to be approximately fifteen million. Istanbul, like other high developing countries is the “primate city” for Turkey and has received the majority of growth. The growth has been haphazard with little or no planning. In the suburban areas, high rise developments are common contrasting with the relatively low rise development in the older center. With the rapid development, urban infrastructure such as roads and public transport systems are lagging behind the demand. Congestion is often severe along the major corridors

Istanbul growth has been fueled by the development of highways running east to west.

The linking of the European and the Asian side by two bridges has also been a major component in the growth of Istanbul. The growth has been high density along these corridors. There has few major arterials traversing Istanbul from north to south.

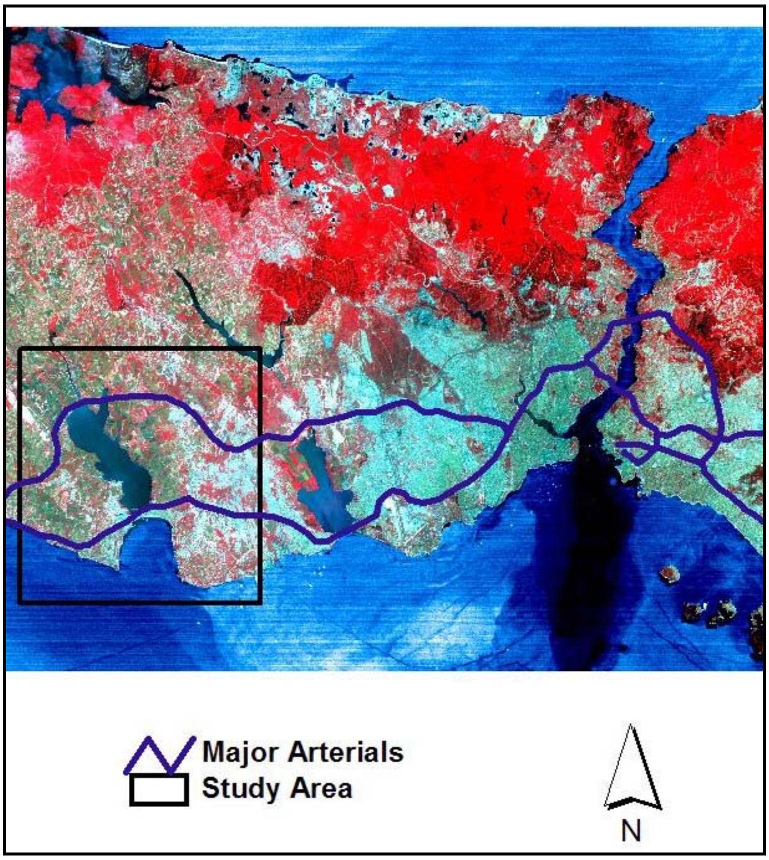

Figure 1. Istanbul urbanized area with Study Area

Istanbul has a different vehicle composition in the traffic flow than is found in developed countries such as Germany, the UK or the United States. There are a great many older vehicles that pollute more. Due to the lower automobile ownership, there is a large amount of buses (Ocakci, 2000). In addition, there is a large amount of trucks.

Because of the unbridled development, one often finds intense development directly adjacent to major corridors. This includes residential, commercial, and institutional land uses (i.e., schools, hospitals, governmental buildings etc.). It is obvious that residents and workers in these highly congested corridors are being exposed to significant traffic related air pollution. However, to the authors knowledge, local government is unaware of this problem and therefore do not have the necessary information to develop appropriate mitigation measures.

A corridor in Istanbul was selected to develop a short-term advisory system related to the levels of traffic related air pollution, specifically CO, NOx and particulate matter (See Figure 2).

The corridor is located within the Büyükçekmece Municipality of the Greater Metropolitan Istanbul Area (Istanbul Büyüksehir Belediyesi.) It is a moderately dense area and has a variety of land uses including institutional, commercial and residential.

At a later time, specific information such as land use using high resolution remote sensing images will be included in the GIS database. This could be used to identify which particular building would be affected by the air pollution

3. DESCRIPTION OF MODEL

The proposed pollution dispersion model (see figure 2) would integrate travel demand and meteorological models within a GIS to predict the effect of pollutants for a short time period—one or two days in advance. The travel demand model would be a key element in this system. It would include existing traffic counts, capacities, composition of the traffic (i.e., automobiles, trucks, buses etc.), and key traffic generators along the corridor.

Using the predicted volumes and vehicle composition, traffic related air pollutants would be estimated for the corridor using pollution factors suitable for Istanbul. It is estimated that the pollution would follow a Gaussian distribution along the corridor.

Concentrations would be estimated for a buffer area in the corridor for about two hundred (200) meters. The intervals would be spaced at twenty (20) meters. It would be estimated that the amounts of the pollution would be most concentrated along the immediate corridor with variations based on the predicted weather conditions. These estimates would be put in categories according to standards.

These levels would be displayed in a GIS according to their severity. This GIS display could be integrated with the Internet for informing decision-makers and the public about the risk of pollution for their particular area.

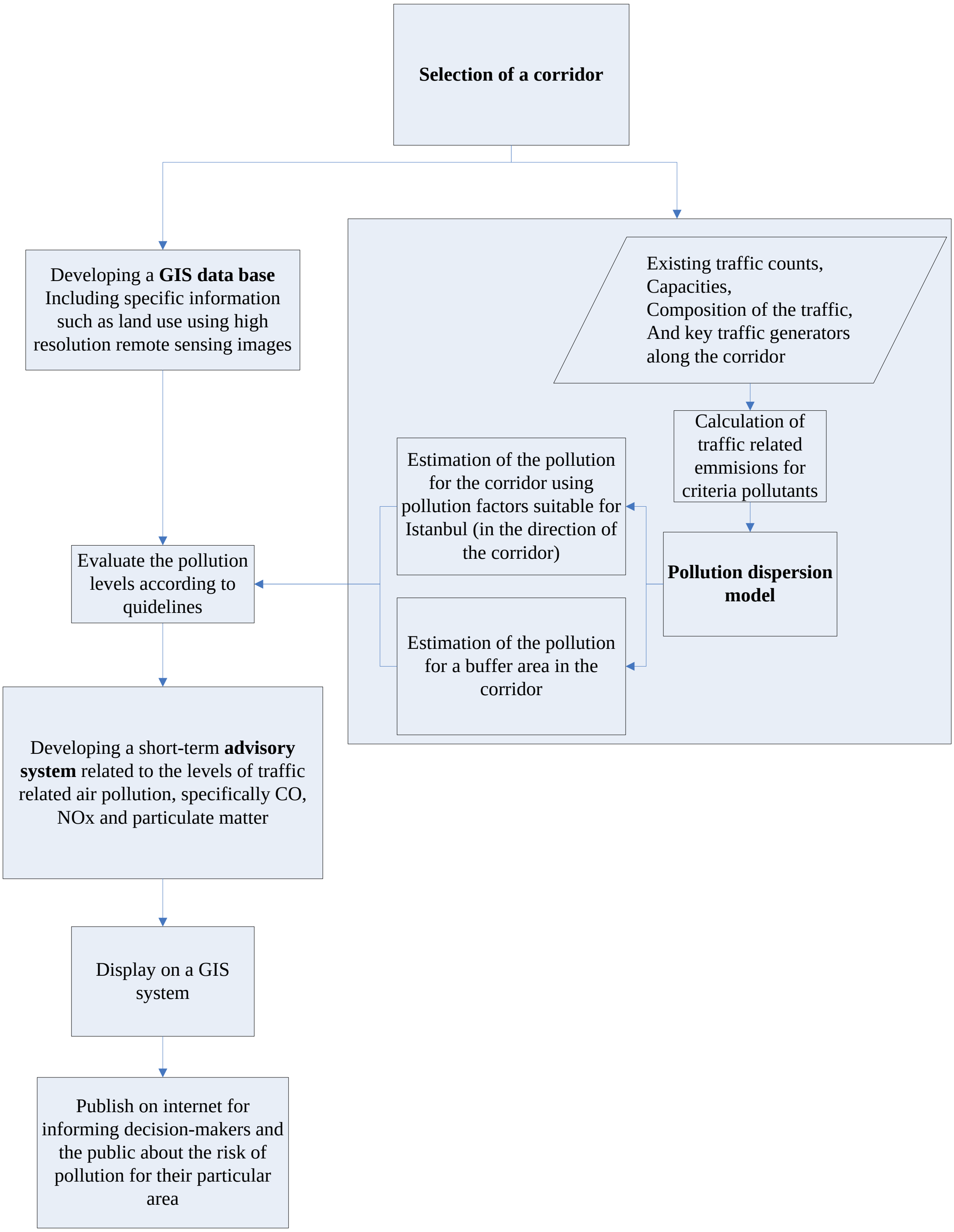

Figure 2. Description of proposed GIS based pollution dispersion model for corridors

4. RESULTS AND DISCUSSIONS

One of the most important tasks of these kinds of studies is the calculation of traffic related emission ratios and distributions of pollutants. As an application of this method, CO_2 was selected as parameter for this case study. CO_2 was selected for the test pollutant because it can be directly related to vehicle emissions. For evaluation of CO_2 over the selected corridor, a traditional Gaussian distribution model was used.

To simplify the results, it was assumed that meteorological conditions are stagnant (no wind direction and no air turbulence). The results are displayed by using a GIS system in the figures 3 and 4.

The hourly traffic data of selected area was estimated using existing traffic count data and visual observations at various places along the corridor. The volume of the traffic on the corridor changes from 50 car equivalents per/min to 300 car equivalents cars per/min. For the transformation of vehicles to car equivalents, we used the method suggested by Xia and Shao (2005).

The results of the model could be viewed in two different formats according to purpose: One format would be the specific aspects of the pollution distribution at high resolution, as seen in Figure 3. The other is the advisory system as illustrated in Figure 4. Figure 3 is the close up of the pollution buffers of the corridor, controlling for meteorological conditions.

The heaviest concentration would be in the buffers immediately adjacent to the arterial with lesser amounts in the outlying buffers. This concentration distribution would change depending on the particular day of the year. The resolution of such a buffer is important to determine particular land uses (such as schools, hospitals etc.) that may be adversely affected by the pollution.

The advisory map is a summary for decision-makers and the public (see Figure 4). There are some locations because of either steep slope, buildings or congestion caused by entering vehicles, which would be areas of high pollution. For example, Sector 5 is an area where are many buses stopping and causing congestion.

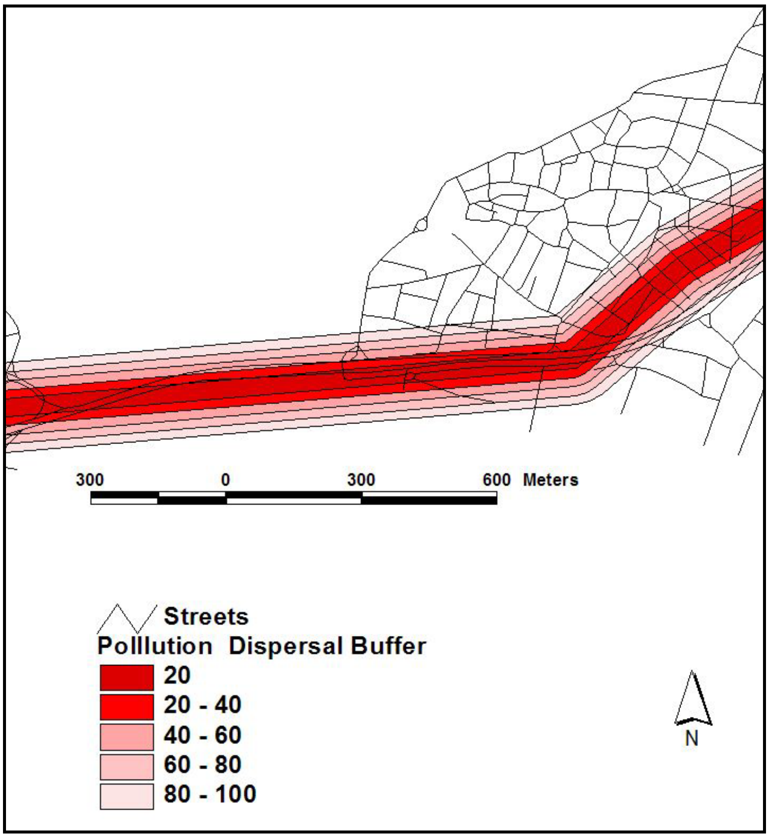

Figure 3. Close-up of CO_2 pollution dispersal buffer for the corridor under stagnant meteorological conditions (no wind direction and wind speed)

5. CONCLUSIONS

The paper suggests a method by which a governmental agency can use short term traffic forecasting and simplified air dispersal modeling techniques with weather forecasting for particular micro-climates for predicting air pollution measurement for a particular corridor for one or two days in advance.

The model is fairly complex due to the aspects of modeling correctly the amount of pollutants and the dispersal based on micro-climatic conditions. The authors will be developing the actual model so that the usefulness of such a system can be discerned.

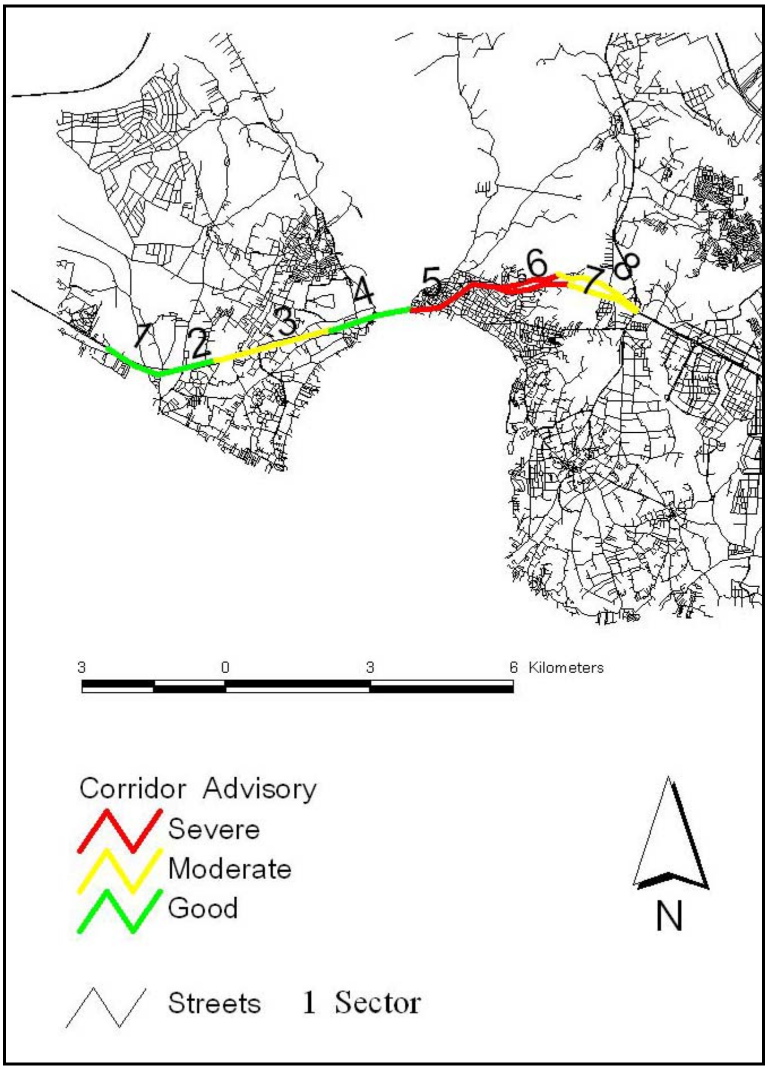

Figure 4. Sample Corridor Advisory System

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