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A DECISION SUPPORT SYSTEM FOR HEALTH EFFECTS DUE TO TRANSPORTATION POLLUTION

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ABSTRACT

Traffic congestion is part of daily life in India, vehicle-related air pollution is growing at an alarming rate, and traffic delays have tripled in the last three years. It is not only the health cost that is going to be enormous and burdensome on the national exchequer, but the loss of potential working ability of the people due to poor health conditions. In this paper, a Health Care Decision Support System (HCDSS) is designed and developed to study health effects due to congestion and pollution related to transportation system in India. The HCDSS comprises of five main components– Database Management Subsystem (DBMS), Knowledge Base Management Subsystem (KBMS), Central Decision Making Desk (CDMD), Central Vision Exhibit Board (CVEB), and Dialog Management Subsystem (DMS). The developed HDSS will help to identify the hazardous nature of transport-related air pollution, present the factors that may affect exposure and the attribution of the observed ad versed health effects to pollution from traffic sources and also help in understanding mortality risks The developed HDSS will help Health Care Professional and Transportation System Decision Members in decision making along with (re)consideration of their Ideologies, Socio-cultural Structures, etc which will improve the Quality of Life of Commuters.

Keywords: Transportation System, Air Pollution, Congestion, Decision Support System.

INTRODUCTION

Transport poses a dilemma in that it is necessary for economic and social development, yet it is associated with environmental degradation, especially with regard to atmospheric pollution. With the rapid urbanization and economic development in India, urban transportation has already become one of the prominent environmental issues that are contributing to both local and global environmental concerns.

The effects on health of transport-related air pollution are among the leading concerns about transport. It focuses on air pollution related to road transport and the risks it presents to human health. In the coming decades, road transport is likely to remain a significant contributor to air pollution in metropolitan cities in India. Research in recent decades consistently indicates the adverse effects of outdoor air pollution on human health, and the evidence points to air pollution stemming from transport as an important contributor to these effects. The transport-related air pollution increases the risk of developing an allergy, the risk of heart attack, changes in autonomic nervous system regulation and increased inflammatory responses, increased incidence of lung cancer and can exacerbate symptoms, particularly in susceptible subgroup.

Dziekan and Vermeulen [3] investigated the effects of real-time information, located at stops and stations, on the public transportation customer and also considered perceived wait time, feelings of security, and ease of use as sensitive indicators. Peytchey and

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Claramunt [9] described the design and development of a supervisory traffic decision support system with GIS support developed in conjunction with the real-time traffic control implemented in the city of Nottingham in the United Kingdom. Randall et al [10] developed a geographic information system (GIS) based tool to provide decision support for the development of neighbourhood traffic calming plans for all street types which was potentially useful because of the increased use of traffic calming measures and the growing public desire for safer streets. Arentze and Timmermans [1] described an operational system for integrated land-use and transportation planning called Location Planner. The system was integrated a wide variety of spatial models in a flexible and easy-to-use problem solving environment and allowed the users to address a wide range of problems. Marell and Westin [6] focused on drivers' attitudes towards risk, traffic safety and safety measures. A study of drivers' attitudes and acceptance of an electronic device for speed checking (which the drivers tested for nine months) indicated a high acceptance level. Wong and Woon [12] presented a refinement of the method for optimizing traffic timing plans which is based on iteratively re-estimating the Time Of-Day intervals. The aim of this study was to analyze the functional relationship linking air quality and air pollution from transport and to develop a more flexible framework to allow communication between transport emissions and air quality concentrations.

To manage and control the traffic pollution several decisions should be taken by decision makers. Decision Support Systems (DSS) are the systems designed to interactively support all phases of a user's decision making process. It is a computer program application that analyzes data and presents it so that users can make decisions more easily. The key to decision support systems is to collect data, analyze and shape the data that is collected and then try to make sound decisions or construct strategies from analysis.

Matzoros [7] presented an implementation study of a computerised decision support system for public transport management for the Athens Public Transport Authority (APTA) and analysed the current situation, specified user requirements, determined system functionality, designed the system architecture, organised the project and, finally, planned dissemination activities. Fusun et al [4] proposed a decision support system that guides transportation policy makers in their future strategic decisions and facilitates analysis of the possible consequences of a specific policy on changing the share of transportation modes for both passenger and freight transportation. Borne et al. [2] outlined the necessity of a decision support system that detects, analyzes, and resolves the unpredicted disturbances to deal with the real-time regulation of traffic within a disrupted transportation system. Ling et al. [5] described a framework to link existing air quality tools and discussed the implementation of this framework through the development of prototype software IMPAQT (Integrated Modular Program for Air Quality Tools) which was aimed to aid transport or environmental planners by increasing the efficiency of air quality assessments. Omero et al [8] described the problem of assessing the performance of a set of decision making units (DMUs), simultaneously considering different kinds of information and performance indexes deriving from various analyses.

In this paper, a Health Care Decision Support System (CDSS) is designed and developed to study health effects due to congestion and pollution related to transportation system in India. The developed HCDSS will help to identify the hazardous nature of transport-

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related air pollution, present the factors that may affect exposure and the attribution of the observed ad versed health effects to pollution from traffic sources and also help in understanding mortality risk (due to Cardiopulmonary causes), elevated risks of respiratory morbidity, and risk of lung cancer, etc.

ARCHITECTURE OF HCDSS

The Health Care Decision Support System is designed to identify the hazardous nature of transport-related air pollution on health which will allow decision-makers to combine personal judgment with computer output, in a user-machine interface, to produce meaningful information for support in a decision-making process. This system is capable of assisting in solution of all problems (structured, semi-structured, and unstructured) using all information available on request. The guiding principles for the designed System are verifiable knowledge, validated system utility and clinical efficacy and user-friendly interfaces for convenient access and knowledge updates. The HCDSS consists of five main components– Database Management Subsystem (DBMS), Knowledge Base Management Subsystem (KBMS), Central Decision Making Desk (CDMD), Central Vision Exhibit Board (CVEB), and Dialog Management Subsystem (DMS). A user utilizes and maintains data in the database through the Dialog Subsystem, and analyzes the performance by using the knowledge-base management subsystem. Prioritization in the model base can be made by using Quality Analysis Tool Shell comprising of Multi-Criteria Futuristic Decision Making Methodology. Figure 1 shows the architecture of the HCDSS with its components:

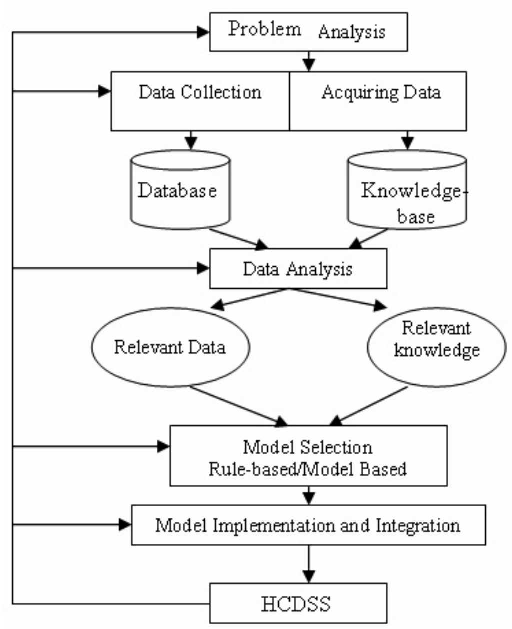

Figure1: Flow diagram for development of HCDSS

1. **Database Management Subsystem**
   The main task of the Database Management Subsystem is the simplification, preparation, and pre–processing of input data; and also control and verification of the bulk of data required by the Health Care Modules. The Subsystem consists of a central data depository that contains all the relevant historic and current data, and

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tools to automatically extract the necessary data for their primary sources of storage and re-store them in the warehouse.

2. Knowledge-Base Management Subsystem

The knowledge-base management subsystem is for knowledge rule management (e.g., retrieval, updating, deletion, etc.) and reasoning. It utilizes its internal knowledge for reasoning, and communicates with the Data Management Sub-System via an integration interface for knowledge updating. It also interacts with the user through the Dialog Management Subsystem to master more in the measuring performance.

In the rule base, the specialized domain knowledge is presented in the form of IF-THEN-ELSE statements and stored in the knowledge base. Users can modify, add or drop into the system their latest knowledge. Once the new knowledge has been added, the system is able to automatically diagnose all vital situations which a Transportation Decision Makers may face.

3. Central Decision Making Desk

The Central Decision Making Desk is collection of Programs used for decision making. It comprises of two components:

a) Quality Control Program

The Quality Control Program selects a suitable rule from the rule base and then gets the facts from the database to infer the conclusion. Upon receiving the known facts from the database, the Program infers and explains the situation and triggers actions or gives the suggestions for decision making.

b) **Quality Analysis Tool Shell**

The Multi-criteria and futurologistic approach of Quality Analysis Tool Shell comprising of Model Base Management Subsystem provides an effective dimension to deal with complex multi-criteria decision problems.

Model Base Management Subsystem

The Model Base Management Subsystem accepts the data from Database Management Subsystem, interacts with the related Health Care Informatics Modules, computes the values using MCFDM Methodology; and displays the results through Dialog Management Subsystem and Central Vision Exhibit Board for the user for decision making or provides results to the Knowledge Base.

MCFDM Methodology

Multi-criteria Futuristic Decision Making (MCFDM) Methodology (Singh et al, [11]) is a multi-person, multi-objective, multi-level, multi-period methodology. It implicates multi-criteria approach for futurologistic decision problems and consolidates information about tangible and intangible criteria and alternatives in futuristic decision making process. MCFDM Methodology is a non-linear framework for analyzing both deductive and inductive futuristic thinking that allows the consideration of several Multi Futuristic Decision Factors at a time, along with a feedback control mechanism and numerical trade-off without the use of the syllogism.

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4. **Central Vision Exhibit Board**
   The Central Decision Making Desk interacts through a Central Vision Exhibit Board. In this Board globally shared database, local knowledge base and specialized Decision making sources act upon a Central Black Board Problem Solving Architecture according to a strategy aiming at building a problem solution.

5. **Dialog Management Subsystem**
   The Dialog Management System is designed for the Decision Members with a variety of health care decision-making needs. The Dialog Management Subsystem comprises of two Interfaces: a) Decision Making Interface and b) Knowledge Update Interface. The Decision Making Interface allows the User to take decisions for preventing congestion and pollution. The Knowledge Update Interface enables the Experts to update the knowledge base. The Experts can add remove or modify an existing rule. The Dialog Management System captures the Decision Members preferences, degree of expertise, skills and then receives and interprets their input, and finally presents the output in the form of charts, text, graphs and tables along with suitable form and visual displays. The Decision Making Interface capabilities are broadly classified into two categories: Query Support Display Desk and Decision Support Display Desk due to variety of users with different decision making tasks. While Query Support Display Desk allows adhoc retrieval of health care Information, Decision Support Display Desk supports the decision-making tasks and allows the user to generate a number of displays from the data available in the system, into pre-defined format.

HEALTH CARE INFORMATICS MODULES

Air pollution contributes to mortality and morbidity. It has both acute and chronic effects on human health ranging from minor irritation of eyes and the upper respiratory system to chronic respiratory disease, heart disease, lung cancer, and death. Air pollution has been shown to cause acute respiratory infections in children and chronic bronchitis in adults. It has also been shown to worsen the condition of people with preexisting heart or lung disease. Among asthmatics, air pollution has been shown to aggravate the frequency and severity of attacks. Both short-term and long-term exposures have also been linked with premature mortality and reduced life expectancy. To improve the Quality of Life of the commuters and to self-service by commuters, HDSS comprises of following Modules:

A. Contribution of traffic to Air Pollution

Increasing traffic congestion and the growth of traffic volume in urban areas are fuelling non-attainment and undermining the benefits to urban air quality of the introduction of cleaner fuels, more stringent emission limits for new vehicles, and road management. Also, at urban and rural background locations, average ozone concentrations are expected to increase further, owing to a decrease in emissions of nitrogen oxides, which act as ozone sponges, and possibly owing to an increase in hemispheric background concentrations of ozone. Further, the relative contribution of road-traffic non-tailpipe emissions to PM_{10} is expected to increase in the coming years. Owing to continuing urbanization and expansion of urban areas, an increasing share of the population is likely to be exposed to elevated levels of traffic-related pollutants, in spite of the general decrease in overall air pollution levels. Also, exposure to traffic-related air pollutants is probably increasing, as a result of the increasing share of passenger vehicles in

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commuting and the increasing amount of time vehicles spend in congested traffic on high-volume roads.

Decreasing traffic emissions have resulted in improved air quality. Mobility in general and road transport in particular are expected to increase. Technological improvements, along with more stringent exhaust-emission legislation (for example, on exhaust after treatment and reformulated fuels) will, however, contribute to a further substantial reduction in emissions of air pollutants per vehicle-kilometer for passenger and freight vehicles. Additional measures are required to correct this situation through traffic management, greater use of transport means other than cars and lorries, physical planning that, among other things, reduces traffic in residential areas, optimizes travel distances and enables safe walking and cycling for everyday transport.

The User query, through the Diagnosis Interface, goes to the Central Decision Making Desk wherein the Quality Control Program checks the knowledge base and the database and displays the solution.

B. Human Exposure to Transport-Related Air Pollution

Assessing the population's exposure to transport-related air pollution requires the consideration of a range of factors. Levels of pollutants vary between cities and even over short distances; this has implications for the assessment of exposure. Where populations and individuals spend their time living and working is also important. The pollutants of concern to health include nitrogen dioxide, carbon monoxide, PM_{10}, $PM_{2.5}$, black smoke, benzene, PAHs and metals (such as lead). Some groups may receive much higher exposures than others, such as people who live and work near busy roads and those who travel or commute in heavy traffic. Also, the intake of pollutants by road users varies between drivers, bicyclists, and pedestrians. Further, exposure to transport-related air pollution is difficult to separate from exposure to total air pollution. Owing to trends in urban emissions, however, traffic may conceivably be responsible for exposing an increasing proportion of the population to air pollution, even though air pollution levels have decreased.

Since vehicle emissions by definition take place on roads, people who live close to busy roads might be expected to be exposed to higher concentrations of transport related air pollution and at greater risk of adverse effects on health.

People whose jobs require travel clearly spend the most time in traffic, and young and elderly people tend to spend the least. Women, who often have less access to a car and who are less likely to be commuters, also tend to have lower travel times. Poor people may be less likely to own or drive a car, but are more likely to use public transport, and thus spend longer periods in buses, trains or underground railways. When compared with the general population, people with outdoor occupations in urban areas are typically exposed to higher concentrations of transport-related air pollution or are in contact with it for longer periods, or both.

Real attention and future exposure assessments thus need to focus on some of groups at particular risk, and on the time–activity patterns that determine their exposures. These groups include:

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1. People (especially the elderly and very young) who live close to busy roads;
2. Children whose schools lie close to major roadways; and
3. People who spend much of their time travelling through or working in environments with heavy traffic, such as traffic wardens and traffic police, street traders and some commuters.

This Module will help in making decisions regarding exposure to transport-related air pollution

C. Health Effects of Transport-Related Air Pollution

Transport-related air pollution affects a number of health outcomes, including mortality, nonallergic respiratory morbidity, allergic illness and symptoms (such as asthma), cardiovascular morbidity, cancer, pregnancy, birth outcomes and male fertility. Transport-related air pollution increases the risk of death, particularly from cardiopulmonary causes, and of non-allergic respiratory symptoms and disease. Experimental research indicates that the effects are linked to changes in the formation of reactive oxygen species (ROS), changes in antioxidant defense, and increased non-allergic inflammation, thus articulating some parameters of susceptibility. While laboratory studies indicate that transport-related air pollution may increase the risk of developing an allergy and can exacerbate symptoms, particularly in susceptible subgroups, the evidence from population studies that supports this conclusion is inconsistent.

Only a few intervention studies have been conducted, most of them not specific to transport related air pollution. They show, however, that reducing such pollution may directly reduce acute asthma attacks and related medical care for children. They also show that long-term decreases in air pollution levels are associated with a gain in life expectancy and with declines in bronchial hyperactivity, the average annual trend in deaths from all causes, and respiratory and cardiovascular diseases.

Often, the effects observed in epidemiological studies cannot be attributed to the specific indicators addressed, but to a mixture of pollutants. Fine PM (including black smoke) and ozone are associated with increased risks of mortality and respiratory morbidity, while exposure to nitrogen dioxide, ozone and PM has been linked to allergic responses. Other indicators of exposure to transport-related air pollution, such as residence near or distance to major roads and, in part, self-reported traffic intensity at a residence, were associated with several adverse health outcomes. A drawback of self-reported transport-related air pollution exposure, however, is that it might overestimate the effect of self-assessed health. This Module consists of various rules to identify health effects of transport-related air pollution. Sample rules are:

Rule 1

If route id is 1 and travel time is peak hour then traffic flow is low
If traffic flow is low and road space is minimum then speed is slow
If speed is slow and volume of traffic is high then congestion

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Rule 2
If congestion is high then pollution is high
If pollution is high and time of exposure > 1 hour and commuter age <7 yrs then allergic respiratory illness

Rule 3
If allergic respiratory illness and symptoms is wheeze then diseases asthma

CONCLUSION

Owing to continuing urbanization and expansion of urban areas, an increasing share of the population is likely to be exposed to elevated levels of traffi c-related pollutants, in spite of the general decrease in overall air pollution levels. Also, exposure to traffi c-related air pollutants is probably increasing, as a result of the increasing share of passenger vehicles in commuting and the increasing amount of time vehicles spend in congested traffic on high-volume roads. Thus the developed HDSS will help to identify the hazardous nature of transport-related air pollution. The Support System will help in the Transportation Decision Making System to improve the Quality of Life of the Commuters through the best use of the existing facilities. The HDSS will not only contribute an efficient mechanism to find an optimal or sub-optimal solution, given any set of whimsical preferences, but will also contribute a mechanism to make the entire process more open and transparent. In this context, the System is a tool designed to cope with the multidisciplinary nature and high complexity of transportation decision making problems.

In the meantime, policymakers need to design programs, set standards, and take action to mitigate adverse health effects of air pollution. These efforts need to carefully adapt available knowledge from other settings, keeping in mind the differences in pollutant mixtures, concentration levels, exposure patterns, and various underlying population characteristics.

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