A DIAGNOSIS AND PRESCRIPTION SYSTEM FOR TRANSPORT RELATED ENVIRONMENTAL PROBLEMS IN THE METROPOLITAN AREAS OF DEVELOPING COUNTRIES

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abstract: One of the most emerging concerns in the metropolitan areas of developing countries is the intolerable problem of environmental deterioration. The aim of this study is to establish a methodology to first of all diagnose the present, as well as future, situation of urban transport related environmental problems, and then to prescribe countermeasures to improve the situation. A pilot system for the diagnosis and prescription is being developed with Jakarta, Indonesia as a case study area. This study project is one of the Official Development Assistance Projects implemented by the Government of Japan.

1. INTRODUCTION

Almost all metropolitan areas in developing countries are suffering from an intolerable deterioration of the urban environment. As most elements of urban problems are interrelated with each other, "transport and the environment" is one of the most representative urban environmental problems in the metropolitan areas of developing countries. The transport related environmental situation is becoming a significant hindrance to the economic development of these areas, to say nothing of the increase in health related problems.

Although there are several kinds of problems in the transport related environment, air pollution is one of the most serious and urgent environmental problems in the metropolitan areas of developing countries. Consequently, the present paper focuses on the air pollution problem caused by road transport in the metropolitan areas of developing countries.

There have been many transport related studies conducted in the metropolitan areas of developing countries, most of which are supported by either international organizations or foreign countries through their Official Development Assistance Projects. The aim of almost all the studies, however, is mainly to improve the capacity of transport systems to cope with increasing traffic demand. Even if there are some studies dealing with the environment, it is regarded as one of the effects, either positive or negative, caused by some proposed projects. Very few studies have investigated the transport related environment of the whole metropolitan area as the main focus.

Since 1993 the Japanese Ministry of Transport has been implementing a project to improve the transport related environment in the metropolitan areas of developing countries as a part of the Japanese Official Development Assistance. The objective of the project is to propose, to the local or central government in charge of the area, prescriptions for transport related environmental problems based on a diagnosis of the present situation, as well as future forecast, of the transport related environment. To complete the project, the Ministry has set up a committee to establish a methodology to diagnose the present, as well as future, situation of the urban transport related environment and to prescribe countermeasures to improve the situation.

This paper presents the intermediate results of the system development based on the methodology of the said project. In this paper, principles of the system development are described first and follow the elements of the system: such as initial investigation of environmental conditions, analysis and estimation of air pollution, diagnosis of the present and future situation, and selection of policy measures. In the last part of the paper, the intermediate results of the system application with Jakarta, Indonesia as a case study, are explained.

2. PRINCIPLES OF THE SYSTEM DEVELOPMENT

2.1 Principles

Since this study deals with transport and the environment in metropolitan areas of developing countries, methodologies to be developed in this study should be applicable to most of such areas. This means that the system, composed of methodologies developed in this study, be simple in principle and adaptable to the study area in terms of conditions such as availability of data.

In addition to the diagnosis of transport related environmental situations and prescriptions of countermeasures, the system should cover the spectrum from initial data collection survey to follow-up work after the implementation of countermeasures proposed by the study.

At first, this study employs a very simple and easily applicable data collection method for air pollution, described later, which can be implemented without difficulties even by non-experts. The data obtained by the method are used for the calibration of analysis models of air pollution. In the case that a regular monitoring system is available, the collected data can be used to check the reliability of existing data and to supplement the data stock.

The analysis model in this study, which is being developed in the workstation system, can be convertible to personal computers. The model is adaptable to various hardware systems depending on the application conditions of the analysis model.

The system is composed of not only such quantitative tools as described above, but also qualitative or descriptive analysis and evaluation methods as follows. Before conducting a quantitative survey and analysis, we conduct an initial investigation of the environment and transport related conditions. In this investigation, an overall rough diagnosis and prescription can be made. In addition, as for the results of model simulation, it is necessary to interpret them not from a strictly quantitative viewpoint but from a viewpoint that shows a general tendency of air pollution in the whole area.

2.2 Analogy to the Medical Examination

In this study, the system is being developed on the model of a medical examination whereby the metropolitan area is regarded as a patient.

(1) Initial Investigation: In a medical examination, the diagnosis starts with a quick check list filled in by the patient followed by an interview by the medical doctor to ask an outline of overall health conditions. In the system of this study, we first establish an outline checklist which composes a set of items to diagnosis the overall condition of transport and the environment of the study area.

(2) Survey and Analysis: In a medical examination, following the first outline check for patients, some kinds of tests such as blood and X-ray, are executed. In the system of this study, transport and environment related surveys are conducted to obtain basic information for quantitative analysis. In addition, a simulation model of traffic and air pollution is calibrated with the data obtained.

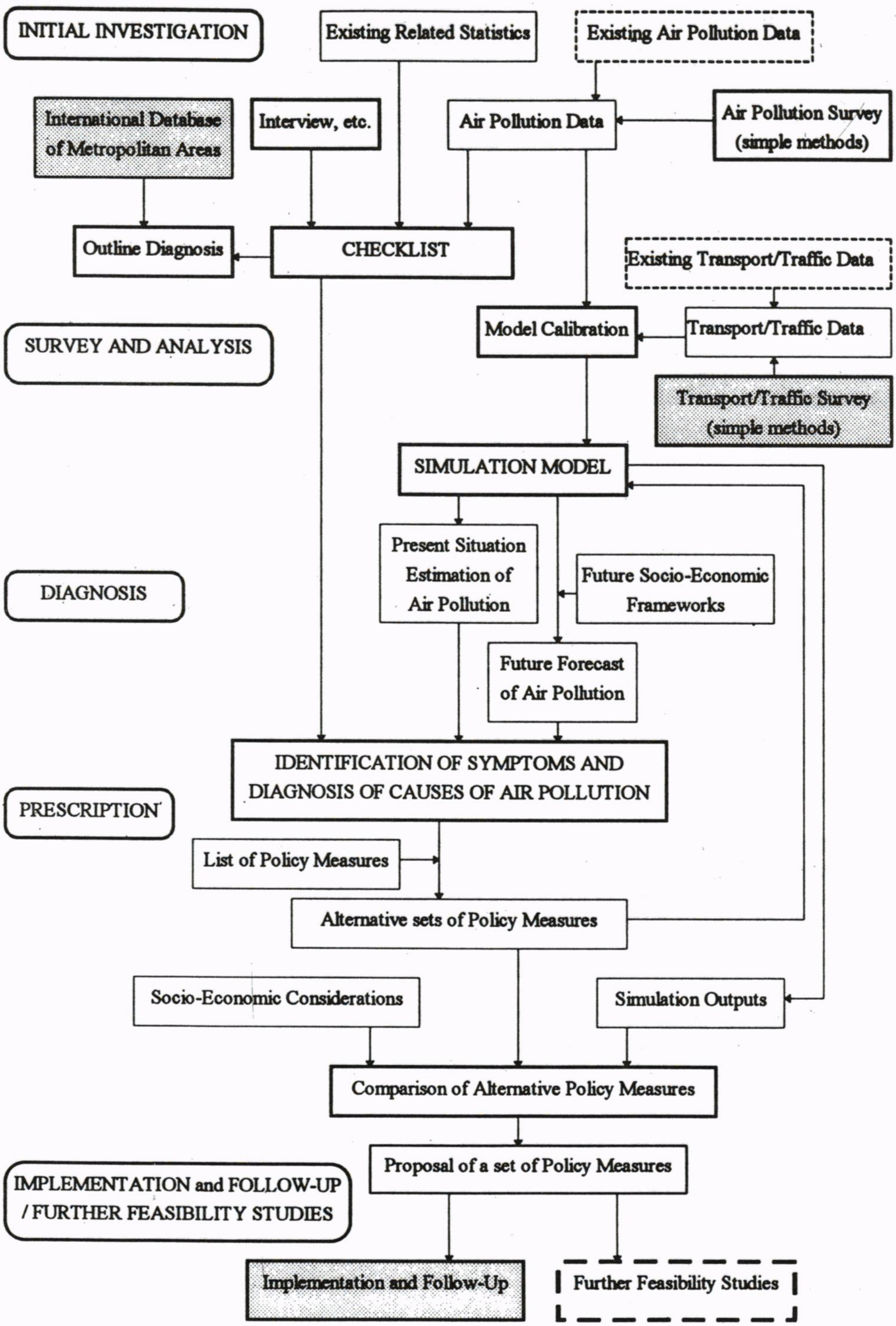


Figure 1 A Diagnosis and Prescription System for Transport Related Environment

(3) Diagnosis and Prescription; In a medical examination, based on the total information gathered, the doctor diagnoses the disease and presents a prescription for the patient. If further inspection is required, the patient has to have further tests to identify the disease. In the system of this study, the way of diagnosis and prescription for the transport related environment is very similar. In addition, in the case that a big project, such as a mass rail transit, is proposed, a detail feasibility study would be required to carefully investigate the related effects and costs.

2.3 System Structure for Diagnosis and Prescription of the Transport Related Environment

Figure 1 shows the configuration of the diagnosis and prescription system of this study. The system structure follows the steps which are explained in the previous section.

Since we are applying our system to the metropolitan areas of developing countries, we have to assume that very limited data are available. We are providing the system with simple survey methods to substitute for or supplement such data as are surrounded by dotted line in Figure 1. A pilot system has been completed except for the items in the shaded boxes.

In the system, a simulation model of traffic and air pollution is built. The model is used not only for forecasting the future situation and simulating effects in the case that alternative countermeasures are implemented, but also for estimating the present distribution of air pollution which is not directly measured in the study area.

In the case of environmental problems, it is seldom effective to implement only a single countermeasure. A comprehensive countermeasure composed of some kinds of policy measures is usually required. In this study, such a kind of comprehensive countermeasure is called a set of policy measures. The policy ranges among the fields of investment for new infrastructures, taxation or pricing, regulations, operation of facilities and education(Miyamoto, 1995).

3. INITIAL INVESTIGATION OF ENVIRONMENTAL CONDITIONS

3.1 An Outline Checklist

Before conducting simulation analysis, this study intends to diagnosis the outline situation of the study area based on information which can be obtained without a full-scale survey. For this purpose this study provides an outline checklist which will be filled in either by interviews with responsible persons of the study area or by retrieving documents and statistics.

3.2 Items of the Outline of Transport Related Environmental problems

Table 1 shows example questions in the outline checklist which will be asked to responsible persons through the interview. We set up a simple set of options for answers to the questions as "definitely yes", "yes", "no" or "unclear" to easily respond to them. These answers will show an outline of the pollution level of the study area.

3.3 Simple Survey Methods for NO_2 and SPM

With regard to air pollution data, we have provided simple methods to facilitate an on-site understanding of the extent of traffic pollution with which measuring concentration of NO_2 and Suspended Particle Matters (SPM) at some representative sites in the study area can be made easily with acceptable accuracy. Since simple measuring methods are available for the two kinds of pollutants, they are used as representative concentration data of air pollution.

Although there are some air pollutants such as lead and SOx which are more serious and detrimental to health in the metropolitan areas of developing countries, the measurement of such pollutants is not easily conducted in the area with simple equipment. NO_2 is selected as a representative pollutant simply because of the availability of easy measuring method.

Simplified measurement equipment, both of which are economical and allow on-site measurement of the extent of traffic pollution, are currently available for measuring the concentrations of NO_2 and SPM.

The simplified NO_2 measuring equipment consists of a scavenger unit fitted with a TEA-impregnated paper filter exposed to the atmosphere for a fixed period (1~30 days). After recovery the filter is immersed in a color developer and its light absorption characteristics measured.

The simplified SPM measuring equipment measures the mass of suspended particles by measuring changes in the frequency of vibration of a piezo-electric crystal.

Both the simplified NO_2 and SPM measuring equipment returned values within 10% of those obtained with well-maintained measuring equipment located in an environmental monitoring station in Japan.

Measurement of traffic pollution with using these equipment are conducted at intersections and on trunk roads with high traffic volume at a distance of 1~2m from the edge of the road. Background concentrations are measured in housing areas as a comparison to the roadside measurements.

Table 1 Example Items of Outline Checklist for the Initial Investigation (by interviews with responsive persons of the study area)

- ☐ Has a transport and traffic survey been conducted ?
- ☐ Have environmental authorities been established ?
- ☐ Are the numbers of motor vehicles increasing significantly ?
- ☐ Do you feel that the air is polluted ?
- ☐ Do vehicles emit black smoke ?
- ☐ Is the mass media concerned with traffic pollution ?
- ☐ Does smog (haze) develop ?
- ☐ Is air pollution a subject of interest among the local people ?
- ☐ Do health problems such as asthma appear ?
- ☐ Do traffic jams develop ?
- ☐ Does the area have geographic conditions (basins, coastal location, inland location) due to which air pollution develops readily ?
- ☐ Does the area have weather conditions (wind direction, wind speed, inversion layers) due to which air pollution develops readily ?

3.4 Items of Air Pollution Levels

Since the number of measuring sites of air pollution is generally very limited in the metropolitan areas in developing countries, we have to conduct a survey of NO_2 and SPM, with the simple methods explained in the previous section, to supplement existing data.

The items listed in Table 2 show the pollution level of the study area quantitatively. We can identify the symptoms of air pollution at the sites where such data are available. Even if we collect the data by the simple survey, the number of sites will be still limited. Therefore, only an outline diagnosis can be made at this stage.

3.5 Items of Causes of Transport Related Environmental Problems

To diagnosis environmental problems, we have to obtain basic information to analyze the causes and effects between transport and the environment. The items listed in the Table 3 are examples of data items for the first step descriptive analysis. It will be effective to provide a database composing the data items of metropolitan areas in the world for comparing the condition of the study area with other areas. This study is now being accumulated over international database for this purpose.

Based on the information obtained through the checklist, an outline diagnosis can be made for the study area.

Table 2 Example Items of Outline Checklist for the Initial Investigation (by existing documents and statistics together with a simple survey)

- ☐ Concentration of SO_2 in existing data (mean annual value)
- ☐ Concentration of NO_2 in existing data (mean annual value)
- ☐ Concentration of SPM in existing data (mean annual value)
- ☐ Concentration of Pb in existing data (mean annual value)
- ☐ Concentration of NO_2 at site obtained by a simple survey(mean daily value)
- ☐ Concentration of SPM at site obtained by a simple survey(mean daily value)
- ☐ Concentration of Pb in the blood(%)
- ☐ Proportion of asthma patients (%)
- ☐ Number of complaints due to traffic pollution (air pollution, noise, vibration)

Table 3 Example Items of Outline Checklist for the Initial Investigation (background information of the transport related environment al problems)

- ☐ Length of road with a daily traffic volume of 10,000 vehicles or more
- ☐ Length of road on which sectional daily traffic volume exceeds design capacity
- ☐ Length of road on which traffic jams occur
- ☐ Number of hours per day for which the worst location is subjected to traffic jams
- ☐ Rate of increase in vehicle ownership (%/year)
- ☐ Total road length per unit area (km/km^2)
- ☐ Total road area per unit area (%)
- ☐ Number of vehicles per unit road length (vehicles/km)
- ☐ Proportion of leaded gasoline used (%).
- ☐ Price of gasoline.
- ☐ Price of kerosene.
- ☐ Sulfur content in gasoline (%)
- ☐ Sulfur content in kerosene (%)
- ☐ Situation as regards implementation of emission control.
- ☐ Situation as regards implementation of vehicle inspection system.
- ☐ Modal share of rail transit
- ☐ Modal share of bus
- ☐ Situation as regards installation of traffic signals
- ☐ Situation as regards implementation of traffic control.
- ☐ Situation as regards implementation of traffic regulations.
- ☐ Situation as regards driving behavior
- ☐ Residents' consciousness of traffic pollution

4. ESTIMATION SYSTEM OF AIR POLLUTION

4.1 The Structure of a Simulation Model of Transport and the Environment

Since air pollution caused by road traffic is mainly discussed in this study, this study has provided the diagnosis and prescription system with a simulation model which can estimate the present situation, as well as forecast the future situation, of both traffic volumes by road link and concentration distribution of air pollutants based on the traffic volumes in the study area.

In developing the model, we intend to build one which can be easily used and for which calculations can be performed on either a work-station or a personal computer. The configuration of this model is shown in Figure 2. It is composed of a traffic volume distribution model, an emissions model, a weather model, and a dispersion model.

In order to develop a reliable simulation model for air pollution caused by road traffic, we took the following approach. First, we select a city as a model city where we can obtain all the data which are necessary for model calibration. We chose Nagoya, Japan, for the model city. We have developed a reliable simulation model after careful calibration and performance check of the model with the case of Nagoya. Then, we are applying the model to cities in developing countries.

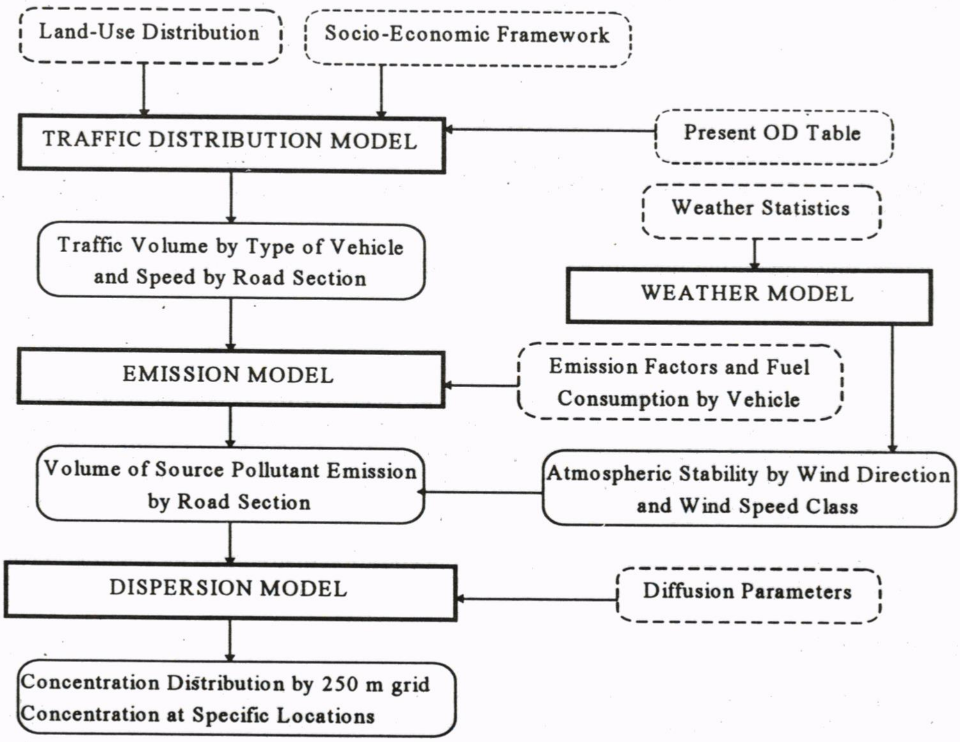


Figure 2 The Structure of a Simulation Model of Transport and the Environment

4.2 The Traffic Distribution Model

The model, which is a conventional 4-step demand forecasting model , estimates traffic distribution by means of calculations of traffic distribution for trunk roads and other major roads in the study area (The Urban Analysis Group). The output of the model are traffic related data such as volumes by type of vehicle and speeds by road section, which become the input of the emission model.

This model requires the following data as input; road network, distance by link and volume and speed relation (QV), number of trips by origin and destination (OD) by vehicle type, and other road information such as tolls, characteristics of intersections. The data regarding the road information can be input to the model according to the available data in the study area. Very simplified data can be obtained based on the rough topographic map followed by field surveys. However, the problem is the data of trip distribution by origin and destination by vehicle in the application to developing countries. We are now developing a simple estimation method, which can be applicable even to developing countries, for such data related to the distribution of economic activities in the study area.

4.3 The Emission Model

The emission model calculates the volume of source pollutant emissions by road section on the basis of traffic volume and speed estimated by the traffic distribution model, based on emission factors for each vehicle type. It outputs volume of emitted pollutants by road section which are used to determine the distribution of air pollution concentrations in the dispersion model.

The data required by the model are emission factors and fuel consumption by vehicle type. In the application to the developing countries, they might have to be substituted by existing data of some country.

4.4 The Weather Model

The weather model calculates the meteorological frequency parameters which determine the dispersion of pollutants. It classifies wind direction into 16 directions, and wind speed into 7 classes. Atmospheric stability is determined by using Pasquill scheme on the basis of solar radiation (cloud over) and wind speed (Pasquill, 1976).

The weather model gives an output file with a joint frequency matrix of wind directions, wind speed classes and stability.

4.5 The Dispersion Model

The dispersion model firstly sets the effective source height based on the height of road sections and buildings in the study area. It then uses puff approximation equation in conditions of calm, and a plume equation otherwise. The diffusion parameters of the model are dispersion width and initial dispersion width with differences in road situation as noted in the Japanese Environmental Agency manual (Japan Environmental Agency, 1993).

The model can output such air pollution information as concentration distribution by 250m grid and concentration at specific locations.

4.6 Evaluation of the Simulation Model

A performance test was made with Nagoya, Japan as a case study, to verify this simulation model. A comparison of NO_2 concentration between calculated values and those measured at monitoring stations in the study area is shown in Figure 3. The correlation coefficient between calculated and observed values is of 0.75. Judging from the result, we consider the performance of the simulation model will be sufficient for applying to this study.

It has been proven that the simulation model well performs as a physical simulation model of air pollution if data are sufficiently given to the model. Consequently, data availability determines the level of accuracy of the model simulation. We are now developing further methods to substitute non-existing data by the estimates based on easily obtainable data in developing countries.

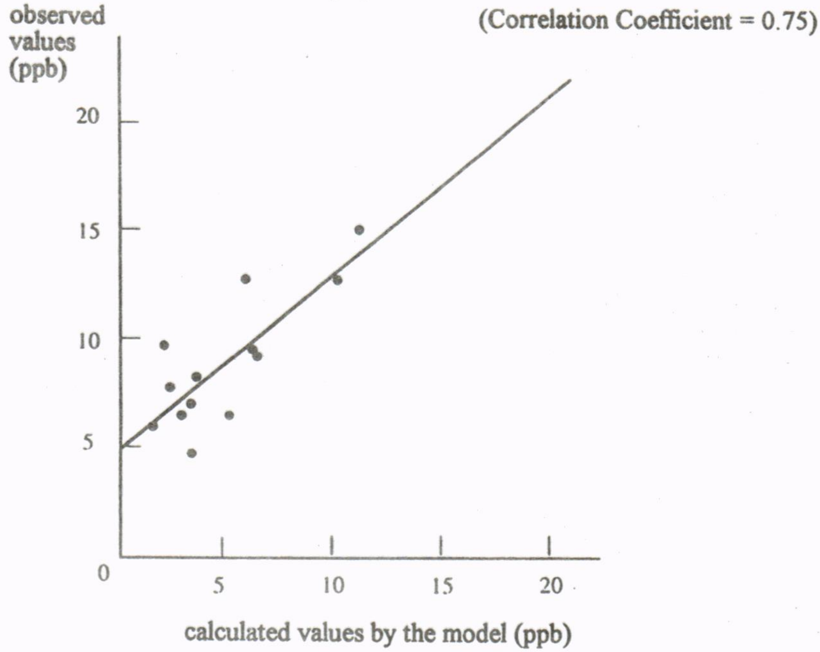


Figure 3 Correlation between Observed and Calculated Values of Concentration of NO_2 (in the case of Nagoya, Japan)

5. DIAGNOSIS OF THE PRESENT AND FUTURE SITUATIONS

5.1 Identification of Symptoms

The first step for the diagnosis of transport related environmental problems is to identify the symptoms of pollution. Since we have prepared simple methods to measure NO_2 and SPM concentrations, it is not so difficult to increase, to some extent, the number of measuring locations for the two kinds of pollutant. However, even in this case, the total number of measuring locations will still be limited. A simulation model of NO_2 can supplement the actual measuring locations, which might not be sufficient by themselves to represent the situation in the entire area, and it presents the overall situation of NO_2 concentration of the entire study area. In addition, there are very few measuring methods which are easy to implement in a large number of locations for measuring pollutants other than NO_2 and SPM. Since the model endogenously calculate traffic volume by vehicle type and vehicle speed by road section, the simulation model can also estimate concentration distribution of other kinds of pollutant to some extent. Both on-site measurement and simulation output must supplement each other if they are to show present pollution symptoms.

In order to identify the symptoms of pollution, it is also very important to forecast future situation of pollutant concentration under the condition of future socio-economic frameworks. The simulation model also works for this purpose.

On the other hand, this study discusses the level of seriousness of pollutant concentration in comparison with the air quality standards of the country or World Health Organization. In addition, it might give the residents an idea of the pollution if concentration values of specific locations are compared with those in other representative cities for reference, although figures regarding measurement can seldom be compared to directly, for they are not necessarily measured in the same manner.

Based on the above idea, using on-site measurement together with the simulation output, the symptoms of pollution can be identified as to how and to what extent the pollution is, and will be, distributed in the study area.

5.2 Diagnosis of Causes

Diagnosis is made for the transport related environmental problems based on both the symptoms of pollution identified and the related information obtained from the checklist by the initial investigation. If the areas where the pollution level is, and will be, very high are limited, some of the causes are related to the areas and their surroundings. Since the simulation model has a function of traffic flow analysis, it can provide information about road traffic and this is also very important information for the diagnosis of pollution causes. In addition, comparison of infrastructure provision levels with other representative metropolitan areas in the world will provide useful material for diagnosis. Such data is very effective in diagnosis for relations between infrastructure provision and economic development. We are now collecting such data on metropolitan areas which can be compared.

Since metropolitan areas are so various in nature, diagnosis of environmental problems cannot be made mechanically, for example by following a kind of worksheet. We shall have to accumulate experiences in diagnosis in the course of actual case studies.

6. PRESCRIPTIONS FOR ENVIRONMENTAL PROBLEMS

6.1 Policies and Measures for Implementing Them

Based on the diagnosis of the causes of transport related environmental problems, countermeasures are proposed as a prescription for the study area. As described above, the countermeasures should be a set of policy measures, for example "pull and push", such as the restriction of car use and improvements in public transport; otherwise no substantial effects can be expected. In addition, sets of policy measures should be composed of both measures to improve the local situation, for example by widening of road, and measures that can be effective for the whole area, for example through pricing and taxation on private car uses.

The policy measures will be classified from the viewpoint of their manner of implementation into five groups, i.e. regulation, taxation and pricing, investment for infrastructures, operation of facilities and education. On the other hand, they can also be grouped into three groups from the viewpoint of object for which measures are implemented; emission source, traffic flow and car traffic demand. Table 4 shows examples of policy measures grouped by the second viewpoint.

In addition, it is very important to consider the time required before the effects are produced. Policy measures are again grouped into several categories such as urgent, short-, middle and long-range. In the selection of a set of policy measures, it is also important to consider the time scale.

6.2 Selection Criteria for a Set of Policy Measures

A set of policy measures as a prescription to improve the pollution symptoms of the study area is provided, based on the degree of seriousness of pollution level, expected effects and socio-economic conditions which determine the feasibility of implementing the measures.

Since effects of policy measures are mutually interrelated, it is rather difficult to provide the prescription without conducting simulations by the model.

Table 4 Examples of Policy Measures for Prescription

- ☐ Vehicle emissions control with testing equipment and regulatory activity
- ☐ Change to unleaded gasoline
- ☐ Education of drivers

- ☐ Installation of traffic signals
- ☐ Construction of overpasses
- ☐ Road widening
- ☐ Prohibition of on-street parking
- ☐ Construction of new road

- ☐ Introduction of bus lanes
- ☐ Development of bus network
- ☐ Improvements in rail services
- ☐ Introduction of a park-and-ride system

- ☐ Area license
- ☐ Road pricing
- ☐ Land use zoning
- ☐ Relocation of facilities
- ☐ Air pollution monitoring equipment and continuous observation

7. AN APPLICATION TO JAKARTA

7.1 Selection of a Case Study Area

Jakarta, Indonesia was selected as a case study area in the development of the system of this study. Jakarta is now subject to considerable growth in the number of motorized vehicles, with resultant traffic jams, and the Government of Indonesia considers countermeasures against air pollution to be of paramount importance. Furthermore, traffic surveys have already been conducted for transportation projects currently underway and traffic data is therefore readily available. And finally, cooperative relationships with the Indonesian transportation authorities are easily formed.

Application of the outline checklist for the initial investigation in Table 3 clearly showed the city to be subject to traffic pollution problems.

7.2 On-site Traffic Pollution Survey

Concentrations of NO_2 and SPM in Jakarta were measured using simple methods over a period of three days, from a Sunday to a Tuesday, in September 1994. At the same time, sectional traffic volume at the measuring locations was also counted.

The equipment for measuring NO_2 concentration was placed at twenty-four locations along, and at intersections of, trunk roads as well as in the center of blocks, In addition, at two roadside locations, measurements were made at three different distances from the roadside to measure the tendency of decrement with the distance.

Table 5 shows NO_2 measurements by site and area, separately for the two weekdays and the holiday. This result shows that the base level of NO_2 is 0.05 ppm for weekdays, exceeding the Indonesian Environmental Standard at all locations except for those in blocks. Concentrations along roads in coastal areas were lower than in inland areas because of less traffic and the effect of wind.

Table 5 Results of NO_2 Measurements in Jakarta

(ppm)

Measurement Points	Holiday	(average)	Weekdays	(average)
Trunk Road Side in Coastal areas	0.05 - 0.04	(0.045)	0.05 - 0.04	(0.045)
Intersections of Trunk Roads in Inland Areas	0.14 - 0.06	(0.085)	0.11 - 0.07	(0.082)
Trunk Road Side in Inland Areas	0.08 - 0.05	(0.063)	0.10 - 0.04	(0.068)
Center of Residential Blocks	0.04	(0.040)	0.05 - 0.04	(0.042)

SPM was measured hourly at four locations between 10:00 h and 17:00 h. No significant differences were noted between measurement locations. However, as shown in Table 6, fluctuations were observed during the course of the day. As Jakarta is located close to the coast, it is subject to a weak sea breeze in the morning which increases SPM concentrations, while the strong sea breeze in the afternoon acts to clear this pollution and thus reduce concentrations.

Table 6 Results of SPM Measurements in Jakarta (average of four measuring points)
(SPM: Suspended Particle Matter) (mg/m3)

Time	10	11	12	13	14	15	16	17
Weekdays	0.16	0.12	0.10	0.08	0.08	0.09	0.10	0.10
Holiday	0.10	0.10	0.09	0.07	0.07	0.06	0.06	0.07

7.3 Checklist of Transport and the Environment in Jakarta

Information on transport and on the environmental situation in Jakarta was assembled from existing documents and statistics according to the checklist (BAPEDAL,1993).

The population of Jakarta in 1980 was 6,5 million, 9 million in 1990, and is expected to raise up to 12 million by the year 2005. This population increase has resulted in the drastic spread of urbanized areas, and improvement of transportation services, both in terms of public transport provision and infrastructure development, has become a matter of paramount importance.

The transportation modes between the suburbs and the city center in 1990 consisted of buses (51%), private cars (24%), and rail (less than 0.3%). The number of motorized vehicles in 1994 was 2,310,000 (private cars 28%, trucks 10%, buses 10%, and motorcycles 51%), a 40% increase in four years (see Table 7). For this reason therefore, the traffic capacity of 60% on trunk roads is exceeded, with traffic jams apparent over a wide area. Traffic jams are particularly bad at the junctions of arterial roads and trunk roads, and at the interchanges to motorways.

Table 7 Number of Motorized Vehicles Registered in Jakarta

	1990	1994	(ratio of increase from 1990)
Private Cars	485,844	658,380	(+36%)
Trucks	189,980	239,238	(+26%)
Buses	169,027	234,750	(+39%)
Motorcycles	804,186	1,182,366	(+47%)

Bus lanes have been introduced on trunk roads, and considerable efforts are being expended to ensure regular schedules. However, this is made difficult by the unauthorized use of minibuses and private cars.

As railway stations and bus terminals are not efficiently arranged between each other, there is almost no complementary functionality between these two transportation modes. Furthermore, worsening traffic jams have resulted in a major decrease in the efficiency of the bus transport system.

The most significant problem of the transport system in Jakarta is the lack of efficient Mass Rail Transit systems commensurate with the size of the metropolitan area. Regarding the road network, Jakarta has a little bit better road stock in terms of length and area than most of other Southeast Asian metropolises, although this is still nowhere near sufficient to accommodate present, to say nothing of future, traffic demand. However, there exist many kinds of problems in Jakarta such as the ineffective design and signal control of intersections, and inefficient traffic controls that necessitate unnecessarily long drives before a U-turn is possible.

Regarding traffic regulations, for example most regulations such as the "three in one" regulation on the arterial road named Tamrin Road, methods of bypassing such regulations are constantly appearing, so that the benefits of the regulations are not realized. ("Three in one" is a regulation that says a private car can enter Tamrin Road only when it is occupied by three people or more.

In addition to traffic jams, the emission of black smoke from ill-maintained vehicles, the use of leaded gasoline, and inadequately prosecuted emission controls are leading to worsening of air pollution.

Furthermore, there are few points in Jakarta at which air pollution is constantly monitored. Moreover, it is difficult to maintain the accuracy of the measurements due to a lack of appropriate equipment. These problems in monitoring air pollution result in a situation which makes it difficult to obtain an understanding of the real situation of traffic pollution in the city.

7.4 Estimation of the Present and the Future Distributions of NO_2 Concentration

Information from maps was applied to the traffic environment model described in chapter 4. to produce a model applicable to the city of Jakarta. The on-site measurement of NO_2 and the data collected were used initially to verify the reproducibility of the traffic environment model in the city of Jakarta. Weather data was obtained from the Indonesian Weather Bureau (BMG). However as data on traffic volume, and current data on vehicle emission coefficients were unobtainable, it was estimated as described below.

The OD table of trip distribution in 1995 for four types of vehicles is estimated based on the data used for the "Outer Ring Road Project in Jakarta" of 1993 and the "Arterial Road System Development Study in the Jakarta Metropolitan Area" of 1985. The data on road networks which were updated for 1993 based on the 1985 survey are used. Traffic volume distribution is estimated by setting QV conditions for each road section, and setting fee resistance for each intra-city and inter-city motorway. Since there is no data on current vehicle emission factors, data for the unregulated emissions period in Japan (1973) are substituted with the consideration of the vehicle conditions in the city,

Figure 4 shows a comparison of NO_2 concentration between the observed data by on-site measurement and the values calculated by the simulation model. While the results of the model estimation are obtained in terms of values for each 250m square grid, and in consideration of the fact that the measurements are taken at specific locations such as beside roads and in the center of blocks, It can be said that the simulation model well represents the present distribution of NO_2 concentration.

Figure 5 shows the present distribution of NO_2 concentration calculated by the model, while Figure 6 shows a future forecast of the distribution, also by the model, in the year 2000 assuming that no countermeasures are taken for the environment.

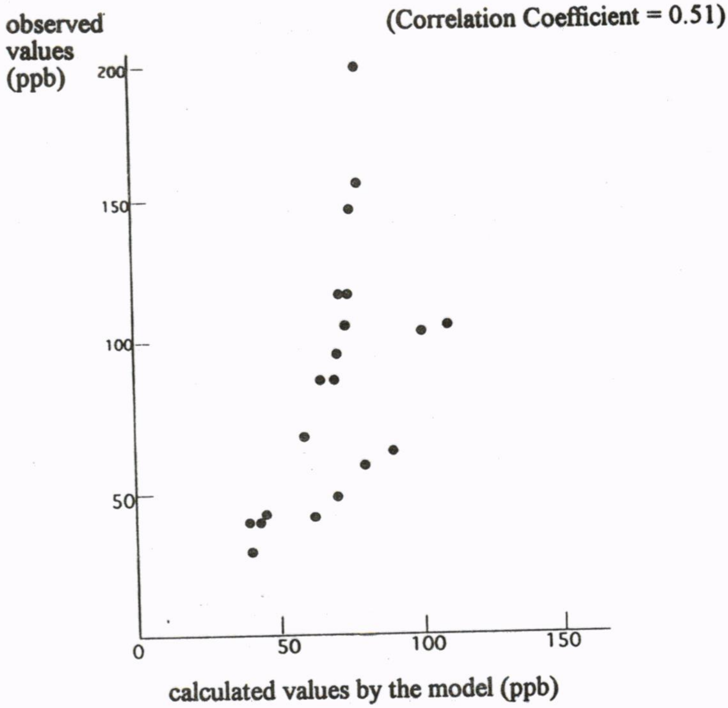


Figure 4 Correlation between Observed and Calculated Values of Concentration of NO_2 in Jakarta

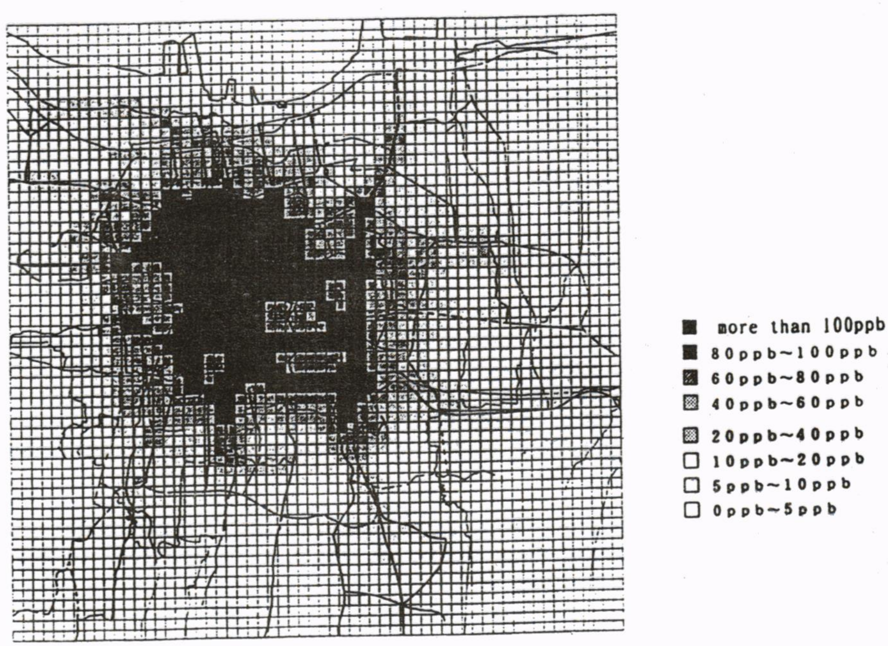


Figure 5 Calculated Present Distribution of NO_2 Concentration

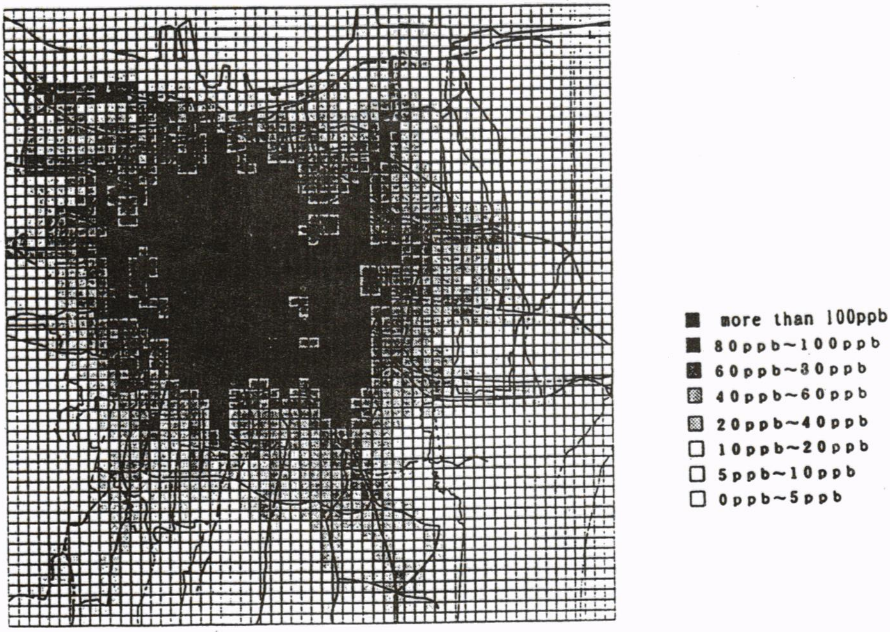


Figure 6 Distribution Forecast of NO_2 Concentration in 2000 (in the case of "do nothing")

7.5 Diagnosis of the Transport related Environmental Problems of Jakarta

There is no need to conduct an initial investigation to recognize fully that the most significant environmental problem caused by transport in Jakarta is air pollution due to heavy road traffic and traffic jams. The on-site measurement result of NO_2 concentrations that most measurements exceed the Indonesian air quality standard of 50 ppb indicates the degree of seriousness. In addition to the measurement of NO_2 concentrations, data provided by DKI Jakarta show very high concentration of lead, although the number of measurements is very limited.

Since it can be assumed that the calculated present distribution of NO_2 concentration shown in Figure 5 is very similar to the distribution of most air pollutants, the distribution is regarded to represent the present situation of overall air pollution in Jakarta. Judging from the distribution, the areas where the situation is very serious are still limited, although air pollution is widespread more or less throughout the entire area. These are the central area of the city and area along the ring arterial roads. However, in the case of the 2000 forecast, almost every area in Jakarta will suffer from the most serious pollution.

Although it might be effective to improve the conditions of roads along which the pollution level in Figure 5 is very serious, either through investment or management measures, it cannot bring about a fundamental improvement of the situation. Besides improving the conditions of each road, policy measures for the entire study area are indispensable. Figures 5 and 6 show this necessity very clearly.

7.6 A Trial to Prepare Prescriptions for Jakarta

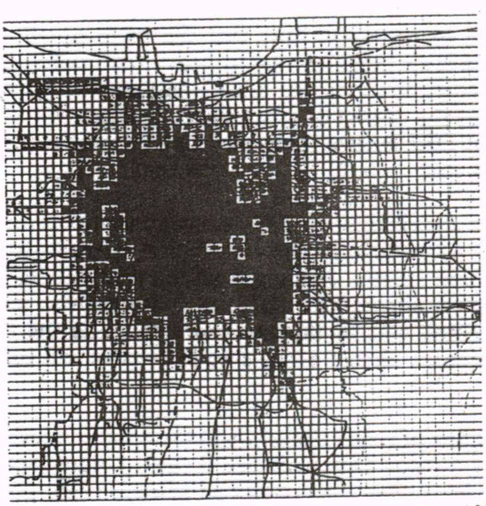
As trials to prepare alternative prescriptions for Jakarta, the effects of some policy measures have been simulated by the transport and environment model. Figures 7 and 8 show examples of the simulation results. Since the simulation model is sufficiently operational, these kinds of simulations can be conducted easily.

Figure 7 shows the case in which private cars are reduced by 10%, regardless of the policy measure to realize this, and buses increased by 2%, by the year 2000. In comparison with a case of "do nothing", pollution is slightly reduced, while the environmental standard cannot be satisfied, particularly in the central area of the city.

Figure 8 shows the case of present NOx emission criteria of motor vehicles in Japan, which means a reduction of approximately 60% from the present situation in Indonesia, being introduced. This would likely to bring about a dramatic effect on the situation in the study area. In the case of this kind of simulation related to emission controls, we have to be careful with the age of vehicles which emission coefficients depend upon. The simulation should consider a cohort analysis model to estimate the distribution of vehicle age before calculating the emission. However, such a distribution is not considered well in this case, because this simulation is one of trial cases.

It is abundantly clear from the above mentioned result that a policy of implementing emission regulations is required, in order to reduce traffic pollution. In this case, improvements in vehicle engines, and improvements in maintenance standards, will be required; and this, in turn, will require investments in equipment and facilities. None of this can be achieved without either financial resources or a national consensus. To make such a policy substantially effective, we have to provide prescription and measures for implementing it which would be really feasible in the conditions that apply in Jakarta.

Since the current application to Jakarta is not yet completed, we cannot present a prescription for the city. We are now conducting further analysis, not only based on the simulation analysis, but also from a socio-economic viewpoint.



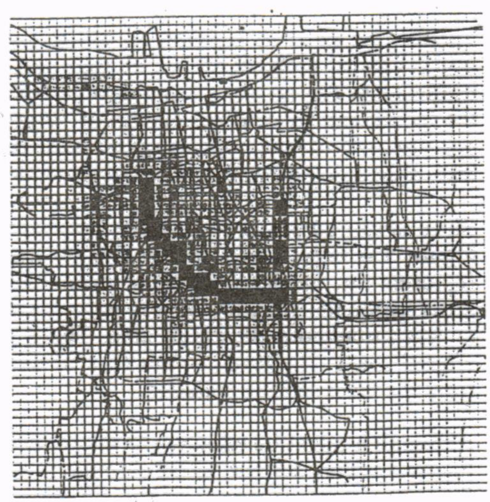


Figure 7 A case of Simulation in 2000 (Private Car Use reduced by 10% to transfer to Buses)

Figure 8 A Case of Simulation in 2000 (NOx Emissions factors Reduced by 60%)

8. CONCLUDING REMARKS

In this study, we have established a pilot system by which diagnosis and prescription can be made for a metropolitan area in developing countries. The case study in Jakarta has shown that this approach is easily applicable to such a metropolitan areas and can produce a substantial proposal as a prescription for the government in charge of the metropolitan area. However, this study is not yet completed either in methodology development or in the Jakarta case study. There are many items to be developed and improved, as described in this text. It is scheduled that a pilot system would be completed in two years.

In addition to the application in Jakarta, this project intends to apply the system of this study to other metropolitan areas of developing countries where transport related environmental problems are emerging. This has been a continuous program of the Japanese Ministry of Transport over the years. We do hope that this project can contribute to a substantial improvement in the environmental degradation caused by transport in developing countries.

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REFERENCES

Air Pollution Control Division, Japan Environmental Agency (1993) **Nitrogen Oxides Concentration Operation manual for Area-wide Total Pollutant Load Control**, Japan Environmental Agency (in Japanese)

BAPEDAL (1993) **Environmental Protection and Pollution Control Strategy and Action Plan in the third JABOTABEK Urban Development Project -part B**, State Ministry of Environment and Environmental Impact Control Agency, Indonesia

Miyamoto, K. (1995) **A Pilot System For Evaluating Policy Measures of Land-Use, Transport and The Environment in A Metropolis**, Regional Development Dialogue, 16-1, pp. 78-86

Pasquill, F.(1976) **Atmospheric Diffusion**, Ellis Horwood Book Co., London

The Urban Analysis Group (1993) Transportation Software **TRANPLAN** ver. 7.2, California