INVITED PAPER

COMPUTER-AIDED DIAGNOSIS AND PRESCRIPTION SYSTEM FOR TRAFFIC-RELATED ENVIRONMENT IN METROPOLISES OF DEVELOPING COUNTRIES

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Abstract: This paper briefly describes a computer-aided proposal system for mitigating air-pollution problems caused by traffic. The proposal system was developed and then represented by the analogy of a regular medical check-up, and a traffic-induced environmental analysis. The system should be useful to both environmental planners and to traffic planners, in their efforts to identify appropriate countermeasures in large cities of developing country.

1. INTRODUCTION

Motorization in East Asia originated in the late 1950's in Japan and gradually spread to other countries in accordance with their subsequent economic development. As motorization and economic development are mutually dependent and inevitably accompanied by urbanization, metropolises in this region rapidly expanded, resulting in an explosive increase of the road traffic volume.

In contrast, the traffic infrastructure, vehicle inspection system, traffic rules and traffic training, all of which should have been developed to deal with this traffic increase, lagged behind, making such negative impacts as traffic congestion, accidents and pollution ever more prominent. In some cases, these negative impacts were detrimental to public health, reduced the efficiency of urban activities and hampered economic development.

This study was conducted for the purpose of contributing to the improvement of traffic problems in metropolises in developing countries. Furthermore, the study identifies appropriate measures to deal with environmental problems originating from car traffic, particularly measures to mitigate the problem of air pollution. As air pollution is the most typical pollution caused by traffic in any metropolis, and is extremely serious in metropolises of Asian developing countries, this study particularly focuses particularly on the air pollution problems in these metropolises. The basic concept of the measures discussed here, however, can also be applied to other traffic-related environmental problems, such as noise problem in local area as well as greenhouse effect gas problems as the global scale .

Traffic pollution occurred in Japan prior to any other Asian country subsequently to the motorization. Even though Japan has made strenuous efforts over the years to apply various measures to mitigate pollution, the problem has not been completely solved, making the further development and implementation of effective measures necessary. Many measures have been attempted with associated technological development and much experience has been acquired. There is now a large number of people with special expertise in regard to this problem. Accordingly, it is believed that the conveyance of Japan's experience and knowledge to metropolises in other countries suffering from traffic pollution should prove useful for these countries to prepare more appropriate measures relevant to their own circumstances.

There are truly diverse measures to tackle the problem of air pollution caused by traffic and the effects vary from one measure to another. Any proposal of suitable measures requires experts with thorough knowledge of both environmental issues and traffic issues. However,

because there are few experts with such ability, a computer-aid expert system could substitute effectively such experts. The establishment of such a system should enable the accumulation of vital experience which can be effectively used when necessary. An expert system based on this concept is described below.

2. CONCEPT OF THE COMPUTER-AIDED SYSTEM

2.1 Principles of System Configuration

It is by no means an easy task to establish a proper understanding of traffic pollution in a metropolis, to identify the causes in a very complicated causal relationship and to extract and propose effective measures. It is, therefore, essential to clarify these processes as much as possible.

For the present study, the basic concept was borrowed from that of a regular medical check-up at hospital. A medical check-up is designed to systematically diagnose a patient's problems in order to identify a suitable prescription, relying on accumulated experience and statistical data. A diversity of patients implies diverse symptoms and wide-ranging prescriptions. The traffic environment problems in a metropolis have many similarities to the problems to be dealt with by a medical check-up.

Here, metropolises in developing countries are the equivalent of patients. While evaluation of the examination results, diagnosis and prescription at a clinic are conducted by a doctor, identification of environmental problems, estimation of the causes and proposal of countermeasures are largely conducted by a conceived expert system on a computer.

A graphic user interface (GUI) type expert system is applied to build a computer-aided system. Thus the system can be easily used by those people in charge of traffic and environmental issues, who may not be very familiar with measures to deal with traffic-induced pollution. The diagnosis and prescription processes are designed to move forward through the exchange of information between the system and users.

2.2 Knowledge Database of Measures for Mitigating Pollution

Existing knowledge and experience are very useful for finding appropriate measures. This is the same for both a medical case and a traffic environment issue. Unlike the medical process, however, such accumulation of knowledge and experience are limited in regard to a traffic environment. Facing this situation, a computer-aided expert system is used not only to present appropriate measures based on survey findings but to accumulate measures and their effects in the form of a database.

The system contains four types of databases as described below.

【Survey Method Database】

A guideline for simple field surveys on the symptoms, causes and implementation of some measures regarding traffic pollution is compiled in the system.

【Diagnosis Criteria Database】

Evaluation criteria for the survey findings are set forth using data collected from various cities including industrial countries, and are used to evaluate the current state of the cities.

【Relationship between Measures Database】

This database contains information on the causal relationship between different measures and between the causes of pollution and these measures. It also has information on the priority of measures for implementation.

【Precèdents Database】

This database contains useful information for the selection and implementation of the

measures, including their contents, anticipated effects, necessary cost, feasibility and implementation process. It compiles information on the implementation of similar measures in various countries and can be used to examine draft measures and consultations to local experts.

By incorporating these databases, the expert system can be used as a reference material for the planning of pollution improvement measures and should prove highly useful for planners in developing countries to prepare such measures.

3. EXPERT SYSTEM PROCESSES

The system consists of five stages as follows.

3.1 Interviews (Preliminary Survey)

The preliminary survey under the expert system is equivalent to the interview at a medical check-up. A survey sheet is fill up by data and reference documents which are readily available in the city. The problems and causes can be roughly described by this information.

The survey items are divided into seven major categories, these are (i)socioeconomic condition, (ii)natural condition, (iii)awareness of pollution and applied measures, (iv)land use, (v)traffic facilities, (vi)traffic conditions, (vii)air pollution. Each of the categories have detailed individual items.

3.2 Examination - Field Survey

The field survey corresponds to such examinations as X-ray photography and blood testing at a medical check-up. This survey involves (i) measurement of air pollution, (ii) a causal survey and (iii) a survey on the implementation of measures.

【Measurement of Air Pollution】

For the study, a sample of air is procured on the spot in the city and then the concentration of NO2 and SPM is analyzes in a Laboratory in Japan.

As the measurement results only indicate the air pollution density at limited sampling sites, a simulation model is used to estimate the air pollution density at arbitrarily determined sites in the city. This simulation model incorporates an estimation of models of traffic flow, emission volume, climatic conditions, and dispersion of the pollution etc. Using this model, simulation of the effects of various measures is conducted.

The simulation model is calibrated by data of Nagoya, the reference city. A correlation coefficient of 0.80 has been established between the actual measurement and the estimated values concentration of NO_2 using the simulation model, suggesting that the simulation model is applicable for surveys on current conditions, future prediction and analysis of the effects of the measures. When this model is applied to a real situation, the predicted results and field survey findings must be compared to confirm the fitness of the model.

【Survey on Causal Elements】

This survey aims at clarifying the situation of traffic pollution and its causes, and also at obtaining basic data for the formulation of a simulation model. The survey data includes fuel composition, average age of vehicle in use and traffic congestion rate etc.. The necessary data is obtained from existing statistical data and field survey findings.

【Survey on Implementation】

This survey aims to obtain information for finding measures by identifying the stage of implementation. For example, this survey may attempt to find whether various measures, such as regulations on fuel composition and vehicle emission control, are already being implemented or at the planning stage.

Details of this survey are shown in Figure1-(b), featuring the state of implementation and evaluation result for each item.

The survey of causal elements and the survey on the implementation of measures are hierarchically divided into four primary categories, i.e. sources of air pollution, traffic volume, traffic flow and others (awareness of the environment, etc.). These categories are classified into secondary categories. Surveyed data on each item is added on the survey sheet.

3.3 Diagnosis - Identification of Situation and Cause

Identification of the cause and the situation corresponds to diagnosis at a medical check-up. In the situation analysis, the on-the-spot measurement results and simulation results are compared with the reference values to evaluate the seriousness of pollution. The measurement results of the causal survey are then compared with the reference values to identify the causes. These processes are similar to a medical check-up process where the examination result shows high blood pressure and too much drinking is identified as one cause. In short, the problems of current conditions and their causes are clearly identified.

Reference values for comparison are required for judgement of the conditions. For example, so-called normal values at a medical check-up simply mean the average values for healthy people. If accumulated urban data is available, reference values can be produced by calculating the average values for "healthy" cities. Such data, however, does not necessarily exist in regard to the urban traffic environment. Accordingly, the values for Nagoya, which is relatively healthy in terms of air pollution, are used to provide reference values for this study to evaluate the conditions of air pollution, and those causes. in the cities in five grades (A to E).

In addition, data is collected for as many cities as possible, including 13 cities in Japan, to calculate the statistical average for its comparison with the corresponding value for Nagoya in order to improve reliability of the reference value.

Examples of the judgement of causes based on the causal survey are shown in Figure1-(a) and diagnosis is conducted for each item.

3.4 Prescription - Planning of Measures

This stage corresponds to finding the treatment at a medical check-up. For traffic environment problems, this is a process to suggest menu of the measures. The extracted menu indicates effective measures to solve specific causes and the priority order of measures is determined to clarify the required measures for implementation in the city.

To establish this menu, the scope of the effectiveness of individual measures must be clearly understood. Based on this knowledge, specific medicine is prescribed for individual requirements. There are wide-ranging measures. In the case of traffic volume-related measures for example, these vary from control of incoming traffic to a CBD and restrictions on vehicle ownership, to improvement of railway services.

To determine truly effective measures, the degree of the effectiveness of individual measures vis-a-vis the identified causes must be understood. By establishing a comprehensive matrix of causes and measures, it is possible to indicate which measures will be effective to eradicate which causes (Figure1-(c)).

However, this is not enough. It is still necessary to establish the implementation order of measures, as some measures require the effectiveness of other measures which are already being implemented. For example, the improvement of an inspection workshop is meaningless unless a strict emission regulation and vehicle inspection system are in place. Using the causes-measures matrix and inter-relation diagramme of measures, it is possible to establish what impacts the implementation/implementation of individual measures have on the causes of air pollution, and which measure is impeded by the non-implementation of some other measures. Examples of the pollution source in Jakarta are shown in Figure2.

The priority measure tables show this relationship of priority together with the cost of

individual measures and the immediate effects. In order to judge the implementation priority, each measure is scored one of four grades, i.e. high, medium, low and unnecessary.

Using these tables which are prepared for common application to all cities, if the evaluation results on the conditions and causes are input and the expert system output the recommended measures based on the programmed IF-THEN rules.

The implementation order of measures is indicated by the interrelation diagramme of measures, visually showing which items in groups of measures have a causal relationship and are more critical than others.

3.5 Consultation - Consultation on Measures

This is the stage that corresponds to the establishment of informed consent in the medical process. The process of selecting measures in the expert system is based on the causal relationship between measures and between causes and measures which can be commonly applicable to any city. In other words, as the expert system primarily aims at establishing a systematic method, which can be widely used in any metropolis for the comprehensive identification of measures and evaluation of the priority of measures, the particular circumstances of individual cities are ignored. Consequently, it is essential to make a draft plan of the measures more feasible through consultations with those who are responsible for the implementation of the measures in the city.

To assist such discussions, a list of the proposed measures for consultation should be prepared. A table of this list shows the measures selected in an order of priority. Together with (i) the state of implementation of measures, (ii) the implementation cost (iii) degree of effectiveness and (iv) existing measures which should become more effective with the implementation of new measures. Referring to this list, the problems of implementing measures in the city are discussed with local experts finalized measures will be recommended reflecting the actual conditions of the city.

During the consultation, local experts often request information on actual implementation examples of the selected measures. For this use, the expert system has a built in precedents database, having accumulated examples of the actual implementation of various measures in different cities. This database incorporates (i) details of implemented measures and the detailed implementation processes employed, (ii) background of implementation, (iii) anticipated effects, (iv) cost and feasibility, (v) public response prior to and after implementation and (vi) introduction of techniques to predict the effects of various measures and required data for prediction. Any such data can be retrieved from the expert system and supplied together with a draft programme for the implementation of various measures.

The simulation results are also used to display the anticipated effects of the recommended measures. For example, the likely state of further deterioration can be displayed if measures are not taken to address the current conditions of air pollution. At the same time a improved density distribution is shown if emission control equivalent to Japanese standards are enforced while. The presentation of concrete measures and their results is designed to urge policy makers to opt for the implementation of appropriate measures.

3.6 Treatment - Implementation of Measures

The stages described so far are followed by the stage of implementing concrete measures. If necessary, a more detailed study should be conducted.

4.CONCLUSIONS

While the expert system to deal with air pollution caused by traffic is described in this paper, the techniques used can be equally applied to noise, traffic safety, and other global environmental problems.

As these problems are characterized by diverse symptoms and remedial measures, few experts can understand every detail and is capable of planning effective measures for all problems single-handedly. If further pollution mitigation experience and achievements

throughout the world are integrated into this expert system, it may serve as a large volume medical book or a highly experienced doctor, proving very useful to solve the problems.

Improvement of traffic-related air pollution in developing countries, particularly newly industrialized countries, can greatly contribute to mitigating local environmental problems as well as to global environmental improvement. Accordingly, use of this system for the formulation of the measures to mitigate the problems, should prove extremely significant for people in all countries wishing to continue enjoying a high level of mobility for years to come.

This work was carried out by a study team aiming to develop a computer-aided proposal system for traffic-induced pollution. The team, handed by the author, consisted of a large number of scholars and experts in Japan. The author wishes to express appreciation for their individual efforts and contributions.

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(a) Cause Diagnosis Table [c]

P*			Secondary Category	Individual Items	Survey Results	Diagnosis Results		
Source	Fuel	Ingredient	lead content of petrol	Average lead content of fuel sold		E	E	E
				Average lead content of leaded petrol		E		
			sulphur content of petrol	Average sulphur content of fuel sold		–	E	
				Average sulphur content of petrol		C		
				Average sulphur content of gas oil		E		
		Consumption	sales share	Sales volume of leaded petrol/total sales volume of petrol		E	E	E
				Sales volume of gas oil/total sales volume of petrol		–		
				Gas oil price/petrol price		–		
			price and taxes	Petrol price/minimum daily wage		–	–	
				Petrol tax/minimum daily wage		–		
				Gas oil tax/minimum daily wage		–		

P: Primary Category

(b) Measures Implementation Evaluation Table [m]

P	1. Emission sources																				
S	1.1 Fuel improvement						1.2 Introduction and strengthening of emission controls						1.3 Introduction and strengthening of vehicle inspection system						1.4 Introduction of low pollution vehicles		
Individual Items	1. Control of sulphur content of fuel	2. Facility improvement to reduce sulphur content	3. Restrictions on the use of leaded petrol	4. Development of unleaded petrol production facilities	5. Preferential taxation of low pollution fuel and subsidy for relevant production facilities	6. Preferential taxation for vehicles using unleaded petrol	1. Application to new vehicles	2. Application to existing vehicles	3. Expanded scope of applicable vehicle types	4. Introduction of stricter thresholds	5. Preferential taxation and subsidy for development efforts to produce vehicles meeting thresholds	6. Preferential taxation for import of vehicles meeting thresholds	1. Strengthening of traffic law enforcement (on emission control)	2. Introduction of type approval system	3. Strengthening of vehicle inspection system	4. Improvement of vehicle inspection workshops	5. Introduction of vehicle maintenance system	6. Improvement of organization and staff	1. Preferential taxation and subsidy for development of low pollution vehicles	2. Development of low pollution vehicles	3. Consolidation of low pollution vehicle-related facilities
J	×	×	△	△	△	△	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△
	×						△						△						△		

(c) Comprehensive Matrix of Causes and Measures [R]

Causal Factors		Measures	Secondary Category	Emission sources				Traffic volume						Traffic flow			Others	
			Individual Item	Fuel improvement	Introduction and strengthening of emission controls	Introduction and strengthening of vehicle inspection and maintenance system	Introduction of low pollution vehicles	Restricted traffic inflow in city centre	Restrictions on vehicle ownership	Improvement of bus service	Improvement of railway service	Improvement of taxi service and modal change facilities	Improvement of terminal functions	Road improvement	Enactment and enforcement of traffic regulations	Improvement of traffic control	Improved social awareness of air pollution	Environmental consideration in urban planning
Primary Category		Secondary Category	Judgement Result	×	△	△	△	○	×	△	△	×	△	△	△	△	△	×
Pollution Source	Fuel	Ingredients	E															
		Consumption volume	E															
	Vehicle	Emission thresholds	E															
		Level of maintenance	E															
		Age distribution	–															
Traffic Volume	Personal transport	Passenger cars	A															
		Motorcycles	E															
	Public transport	Buses	D															
		Railway systems	E															
		Taxis and para-transit systems	E															
	Cargo traffic	Trucks	C															
	Traffic control	Traffic volume control	C															
Traffic Flow	Level of road stock	Road network	C															
	Traffic management	Traffic flow management	–															
		Separation of pedestrians from vehicle traffic	D															

(d) Priority Measures Evaluation Table (Secondary Categories)

Primary Category	1. Emission Source				2.Traffic Volume
Secondary Category	1.1 Fuel Improvement	1.2 Strengthening of Emission Controls	1.3 Introduction and Strengthening of Vehicle Inspection and Maintenance System	1.4 Introduction of Low Pollution Vehicles	2.1 Restriction of Traffic Inflow to City Center
Judgement Result of Implementation State of Measure	×	△	△	△	○
Related/Poor Diagnosis Result/Number of Causal Factors	3	4	2	0	2
Implementation Cost	Medium	Small	Medium	Large	Small
Implementation Priority	Medium	High	Medium		High (Re-examination Required)

(e) Priority Measures Evaluation Table (Individual Items) [p]

Secondary Category		1.1 Fuel improvement						2 Emission Control
Individual Items		1. Control of sulfur content of fuel	2. Facility improvement to reduce sulfur contain	3. Restrictions on the use of leaded petrol	4. Facility improvement for unleaded petrol	5. Preferential fuel tax for unleaded petrol	6. Preferential taxation for vehicles using unleaded petrol	1. Application to new vehicles
Judgement Results on Implementation State of Measure		×	×	△	△	△	△	○
From Inter-Relation Diagramme of Measures	Number of superior measures already implemented	No superior measures	0	No superior measures	0	0	0	1
	Number of subordinate measures already implemented	0	No subordinate measures	2	2	2	2	0
Implementation Cost		Small	Medium	Small	Medium	Small	Small	Small
Degree of Quick Effect		Large	Large	Large	Large	Medium	Small	Medium
Implementation Priority		High	Low	High	Medium	Medium	Medium	Superior measures not implemented

Figure1 Relationship Between Different Tables for Prescription

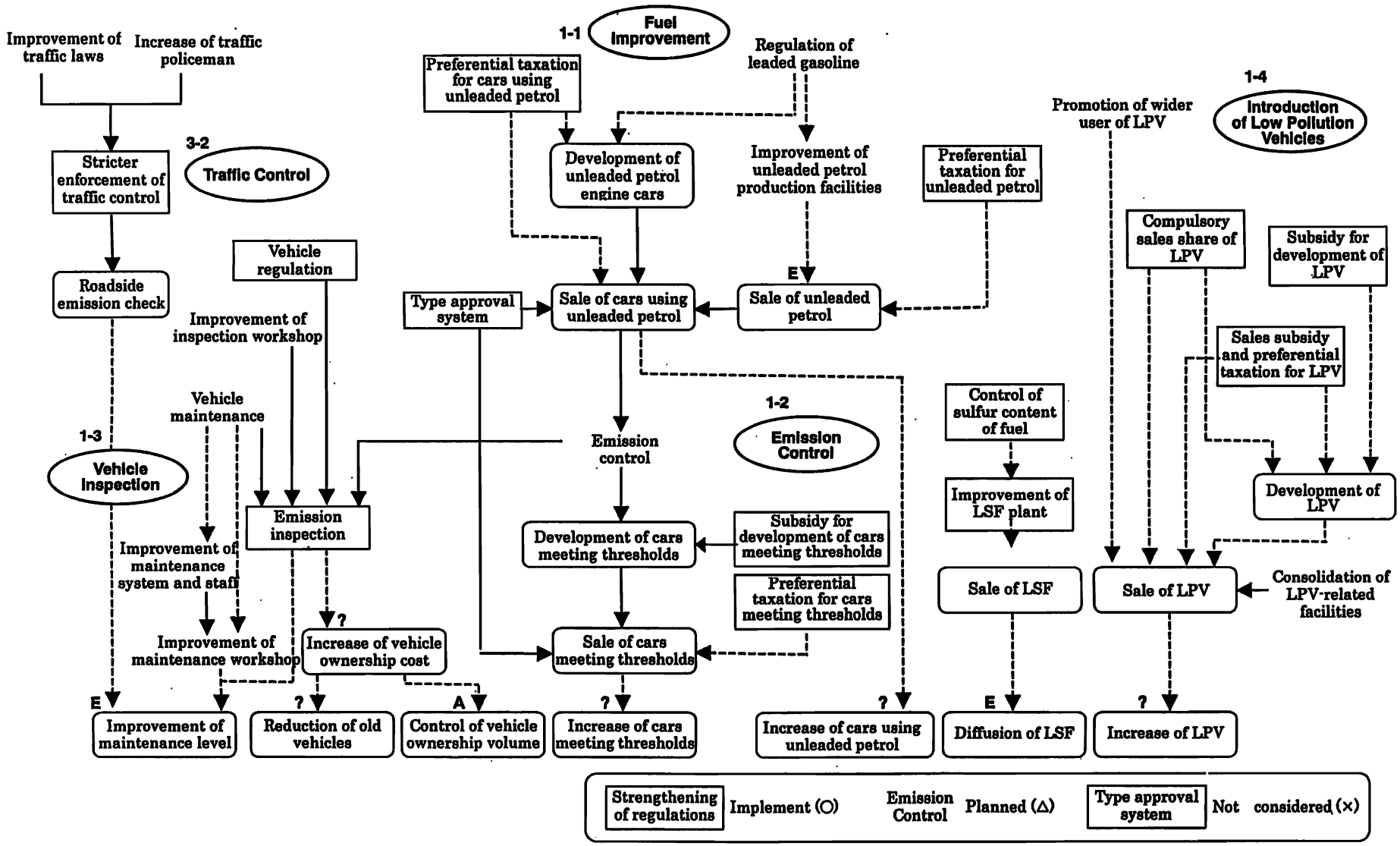

Figure2 Inter-Relation Diagramme of Measures (Pollution Source-Related Measures in Jakarta).