countermeasures, are being assembled and produced. A certain factory ships partially motor vehicles which have been adjusted in the CO content of exhaust gas during idling to 2 ± 0.5%. However, as long as the measurement of this survey is concerned, certain new vehicles showed the value as high as over 9%. An automatic high altitude compensator has been provided since 1975 by one of three assembly makers. Other makers provided guidance to perform adjustment on the basis of users' judgement only for motor vehicles other than those equipped with an electronic control fuel injector.

Motor vehicles in Colombia must receive official inspection in a registered place periodically once a year. Though started in 1988, the inspection of CO emission rate during idling was discontinued because of lack of the standard. The CO and hydrocarbon measuring system during idling is used in three assembly makers and a part of private service inspection shops (so-called "Serviteca"). *Note also that we could not find a chassis* dynamometer with exhaust gas measuring unit within Santa Fe de Bogota.

Among fuels, gasoline became practically lead-free beginning in January, 1991. But the standard maximum values of sulfur content are high at 0.15% by weight and 0.8% by weight respectively for gasoline and diesel oil.

8.2.2 Motor Vehicle Emission Gas Regulation and Reduction Target

(1) *Emission Gas Regulation*

It is recommended to issue as early as possible the complete set of emission gas regulations covering emissions of new gasoline vehicles for road running condition and of diesel vehicles, in order to realize the environemtnal air quality as specified in the Air Pollution Control Act of Colombia (#2001). The Ministerio de Salud mentioned that it is taking a leadership to prepare them while referring, as an example, to regulations of Mexico, the foremost country in this field among neighboring countries. Regulations are expected to be issued and the target values are indicated, around three years of an approach period may be necessary before the practical effect of counteractions of assembly makers and service/repair industries becomes evident.

In the current emission gas regulation (#5057) prepared by the Secretaria Distrital de Salud de Santafe de Bogotá D.C., the allowable value from the tail pipes of gasoline motor vehicles is as shown in Table 8.2.1. The allowable emission rate during driving, its measurement method for new gasoline motor vehicles, and regulations related to didsel motor vehicles should be issued as early as possible in view of contribution of replacement with ones in use to pollution control. When these are to be issued, the stepwise regulation values must be determined in the order of the year while taking parts supply, change of the assembly process, and improvement/expansion of the maintenance system, as well as the progress of pollution and traffic growth into account. Issuing of the control act must be made early while allowing the aboves for around three years. The history of regulation values in various countries of interest is shown for the sake of reference in Appendices.

Table 8.2.1 Exhaust Allowance Value during Idling in Bogota (Gasoline Motor Vhicles in Use)

Manufacture model year	CO concentration (%)	Hydrocarbon concentration (ppm)
past - 1972	7.0	1000
1973 - 1976	6.0	850
1977 - 1980	5.5	700
1981 - 1985	5.0	650
1986 - 1989	4.5	550
1990 - 1993	4.0	500
1994 - 1997	3.5	450
1998 - beyond	3.0	300

(2) Reduction Target

When the control measures on motor vehicles are to be studied to reduce the emission, it is necessary to determine the reduction amount on the basis of knowledge of the current emission amount for each kind of motor vehicles. Unlucky to say, the correct emission amount was not known because of lack of a chassis dynamometer. Therefore, in view of reducing the environmental pollution concentration as measured at each stationary measuring point in this survey to a level below the standard set in the Colombian air Pollutant Control Act (#2001) in ten years, the pollutant emission from motor vehicles may become as follows:

Target pollutant emission amount in AD 2001

Carbon monoxide	1/2 of current emission
Hydrocarbons (NHMC)	1/3 of current emission
Others	Equivalent to or below the current value

As the Colombian air quality standard specifies the nitrogen dioxide instead of nitrogen oxides, it will not exceed the standard value in ten years. One of prerequisites for this assumption is that the growth of traffic volume of gasoline and diesel motor vehicles will remain within the range as the team had estimated from the fuel consumption in Bogota. Increase in nitrogen dioxide will be accelerated if the traffic volume grows more than expected or employment of diesel engines is promoted. Another thing to be taken into account is that the life span of motor vehicles in Colombia is long. The nitrogen dioxide concentration will surely exceed the standard value in 2010s if the above conditions apply or no measures taken. It is therefore necessary to take certain measures even if it is delayed after those against carbon monoxide or hydrocarbon.

Diesel motor vehicles are more advantageous than gasoline motor vehicles in terms of transport efficiency if they are large in size. In terms of pollutant emission, however, the use of diesel engines should be avoided in Sanfate de Bogota City at the present stage. This is because of a fact that the emission rate of sulfur oxides as well as nitrogen oxides and fine particles (whose removal technologies are not yet established) remains high, though the emission rate of carbon monoxide and hydrocarbons is fewer than those from gasoline engines.

8.2.3 Control Technologies

(1) Gasoline Motor Vehicles

Refer to Appendices which give additional explanation in this respect.

1) Countermeasures against carbon monoxide and hydrocarbons

Both of them are emitted into exhaust gas in large quantity when the air and gasoline mixing is not satisfactory for combustion or during deceleration, and common measures as described below are taken generally. For abbreviated symbols in parentheses, refer to Table 8.2.2

a) Performance improvement of carburetor
- Enhancement of part accuracy, use of electronic control

b) Employment of electronic fuel injector (EFI) to replace carburetor

c) Air preheating

d) Improvement of configuration of air intake manifold to improve gas distribution to each cylinder

e) Turbulence of mixed gas to improve combustion

f) Prevention of sudden closing of throttle valve during deceleration (TP, DP)

g) Introduction of air into air intake manifold during deceleration

h) Stop of gasoline supply during deceleration

i) Structural improvement of combustion chamber

j) Optimizing of valve timing to avoid leakage of non-combusted gas due to overlap

k) Increase in ignition energy

l) Helping re-combustion of non-combusted gas by raising the exhaust gas temperature through delaying of the ignition timing (SC)

m) Helping re-combustion of non-combusted gas by improving the shape of exhaust manifold

n) Helping re-combustion of non-combusted gas by introducing secondary air into the exhaust manifold (AI, AS)

o) Installation of catalyst in the exhaust system to oxidize non-combusted gas (OC, TWC)

Also available against carbon monoxide and hydrocarbons in blow-by gas are its reduction units, such as a unit (PCV) which returns the leakage gas to the air intake system through forced ventilation of a crankcase. For fuel vapor gases, on the other hand, vapor entrap system (EVAP), such as adsorption by activated carbon, is available.

2) Countermeasures against nitrogen oxides

Emission of nitrogen oxides can be reduced if driving with theoretical air ratio is avoided and the combustion temperature is lowered. For abbreviated symbols in parentheses, refer to Table 8.2.2

a) Maintaining the air-fuel mixture gas in a state where the fuel is thinner than the theoretical ratio

b) Maintaining the air-fuel mixture gas in a state where the fuel is thicker than the theoretical ratio

c) Employment of an exhaust gas re-circulation method to lower the combustion temperature (EGR)

d) Optimization of the valve timing to lower the combustion temperature

e) Acceleration of the flame propagation speed and shortening period on high-temperature by activating the swirl of mixture gas

f) Improvement of a shape of combustion chamber to increase the flame shape speed

g) Installation of decomposition catalyst (TWC) in the exhaust system to eliminate nitrogen oxides.

3) Practical application to new models

The emission gas regulation was put into practical application as a countermeasure against photochemical smog in California, the USA, in 1962. Following this action, regulations have been put into practice in various States of the USA, Japan, European countries, and Canada. Principal technologies which motor vehicle makers employed to comply with these regulations are shown in Table 8.2.2

Regulations began in 1970s in each country, putting the increasingly tight scope of regulation (vehicle types, pollutants covered by regulation, regulated values, etc.) gradually while taking into account the spread of pollution and development state of control technologies. Makers have made effort to satisfy these regulations. For example, the measures taken by the company T of Japan mainly for gasoline cars are shown in Table 8.2.3

Table 8.2.2 Emission Control Devices Adopted by Some Countries

Country	Control Device	HC	CO	NOx
ECE 15	PCV	x		
	TP or DP	x	x	
	SC	x		x
	Lean-Set Car		x	
SWEDEN	PCV	x		
	TP or DP	x	x	
	SC	x		x
	EGR			x
	AI or AS	x	x	
CANADA	PCV	x		
	EVAP	x		
	TP or DP	x	x	
	SC	x		x
	EGR			x
	AI or AS	x	x	
	OC	x	x	
US '83	PCV	x		
	EVAP	x		
	DP	x	x	
	EGR			x
	TWC	x	x	x
	EFI		(Back up TWC)	
JAPAN S53	PCV	x		
	EVAP	x		
	DP	x	x	
	EGR			x
	TWC	x	x	x
	EFI		(Back up TWC)	

Note:
PCV: Positive Crankcase Ventilation system
TP: Throttle Positioner System
DP: Dash Pot System
SC: Ignition Timing Control System
EGR: Exhaust Gas Recirculation System
AI: Secondary Air Injection System
AS: Secondary Air Suction System
EVAP: Fuel Evaporation Emission Control System
OC: Oxidation Catalyst System
TWC: Three-Way Catalyst System
EFI: Electronic Fuel Injection System

Table 8.2.2 History of Emission Regulation on Japan and Counteraction of the Company T (Gasoline Car)

Year	Regulation in Japan	Counteraction of T
1970	CO , 4.5% during idling Obligation to install a blow-by gas reducing unit	Adjustment of the air-fuel ratio and installation of a CO meter in service points over the country
1972		Installation of activated carbon canister Change of engine design
1973	CO 26.0g/km HC 3.8 g/km NOx 3.9 g/km	
1975	CO 2.7g/km HC 0.39g/km NOx 1.6 g/km	Installation of oxidation catalyst and of EGR
1976	NOx GVW< 1 ton 0.84g/km > 1 ton 1.20g/km	Employment of a diluted combustion method
1977		Installation of a three-way catalyst

Installation of the pollutant emission control means to motor vehicles naturally causes rise of the price and maintenance/service cost and change in the fuel consumption. Though no data is available concerning the maintenance/service cost, Table 8.2.4 should be referred to for remaining two factors.

Table 8.2.4 Exhaust Gas Control and Change in the Price and Fuel Economy of 1400cc Cars (#5059)

Control Technology	Price increase (%)	Change in fuel economy (%)
Air-fuel ratio (lean set)	1.0	-2
Introduction of secondary air and EGR	4.5	+3
Air-fuel ratio (lean) and ignition timing control	2.0	+1
Electronic control fuel injection (EFI)	8.0	+2
Air-fuel ratio (lean) and EFI	9.0	-7
Air-fuel ratio (lean) and oxidation catalyst	4.5	-3
Three-way catalyst	4.1	+2
Air-fuel ratio (lean) and oxidation catalyst, EFI, and EGR	15.0	-7
EGR, EFI, and three-way catalyst	13.0	+3

In Colombia, motor vehicles are mostly assembled and produced under license granted by advanced countries in pollution control. If the emission gas control of individual ones is set to a level equivalent to or below that of these countries, makers can select the appropriate technology from among technologies of licensers and cope with control requirements without substantial change to the current assembly/production line and much rise in the production cost.

Sntafe de Bogotá district authority, however, by measuring the emission values using the chassis dynamometer owned by the official agency, must undertake the type approval of new models and the sampling inspection of produced motor vehicles. The cost of the chassis dynamometer varies depending on a size of vehicles to be measured. In the case of Japan, it is about ¥200 million per a unit including a series of measuring equipment such as gas sampling, analyses, data processing for up to 2,000cc, two wheel drive passenger cars, excluding transportation, housing, foundation, assembly, tax, etc.

(2) Diesel Motor Vehicles

Materials concerned with pollution control for diesel vehicles are mainly black smoke and nitrogen oxides, plus sulfur in diesel oil.

Control measures against black smoke include improvement of an air intake system to secure the sufficient amount of air, optimization of the air swirl flow in cylinder to improve mixture with fuel, and improvement of the injection timing and fuel atomization to ensure satisfactory combustion. But these measures are not yet sufficiently effective, and a black smoke collector and catalyst unit are under research for practical application.

Various measures are employed for nitrogen oxides, such as exhaust gas recirculation or the retard method to delay the injection timing. But these methods present problems such as increase in black smoke or engine wear for which the research is expected to produce an appropriate solution.

In view of above reasons, the best way available in terms of environment at present appears to limit driving of diesel vehicles within Santafe de Bogota City as much as possible.

(3) Low-Pollution Motor Vehicles

Low-pollution motor vehicles here means ones using low-pollution fuels and pollution-free energy excluding ones provided with above control measures. Popularization and promotion of the use of low-pollution motor vehicles will prove effective in direct reduction of pollutants, but also raising of interest in pollution among citizens.

1) Low-pollution fuel

Methanol-driven motor vehicles are a typical low-pollution one whose emission of hydrocarbon is 1/100 or less of that of gasoline motor vehicles. Both Otto (gasoline) and diesel types are under experiment and the Otto type is ready for immediate practical application if stable supply and price cut-down of methanol are achieved. Note that both types require installation of the catalyst to eliminate non-combusted methanol and aldehyde from the exhaust gas.

LPG motor vehicles have long been in practical use in Japan. Without catalyst, this type is less in emission of pollutants (30% for carbon monoxide and 15% for hydrocarbon) than gasoline cars. If this is not enough for pollution control, the catalyst need be installed. LPG does not contain lead or sulfur as in the case of methanol, installation of the catalyst will prove advantageous.

CNG motor vehicles driven with compressed natural gas have been put into practical application in Italy in 1930s and, since then, spread in New Zealand, North America, and ex-USSR. The rate of hydrocarbon emission is only slightly lower than that of gasoline cars but said not contributing to generation of ozone because it consists mostly of methane. The emission rate of carbon monoxide and nitrogen oxides is 40% or more lower than that of gasoline cars.

2) Pollution-free energy

Though suffering from problems such as the weight, price, and charge time of batteries, the electric motor vehicles have already been put into practical application for special purposes, such as collection and distribution of small cargoes and mails. It may be advisable that pubic agencies take a leadership in employing this type of cars to use it for advertisement of pollution prevention to Bogota people. Solar cars using solar rays directly are also a representative of pollution-free motor vehicles and used in special races. But they are not yet in a practically applicable stage.

8.2.4. General Control Measures for Motor Vehicles in Use

(1) Augmentation of Registration Renewal System

Emission gas control measures for motor vehilces in use are limited socially, economically, and technologically because they have already been shipped from factories.

In this sense, available measures are extremely limited when compared with the new models. What is possible now is to augment the registration renewal (revision) which must be made once a year in Colombia. The present revision procedure includes payment of the tax and inspection concerning driving safety. Such inspection covers front wheel alignment, direction of head lamps, and brake. Inclusion of emission control measures into the inspection is recommended.

1) Enlarged coverage of motor vehicles for control

According to our survey, around 40% of passenger motor vehicles running in Santafe de Bogota City have been registered outside the city. Air pollution control measures of Santafe de Bogota City, if put into execution, may be meaningless when they cannot be applied to such large number of motor vehicles registered outside the area. At least, ones registered in Department Cundinamarca should be covered by the air pollution control measures of Bogota. Note that the total number of the vehicles registered in Santafe de Bogota D.C. was 330,000 while that in Department Cundinamarca 200,000 in 1989 (#5029).

2) Obligation of periodic inspection/maintenance

It is proposed that all of motor vehicles (gasoline and diesel) should be inspected and maintained in service shops qualified by the government or Santafe de Bogota D.C. and the record be presented at time of registration renewal.

During use, cars develop clogging of air cleaner, change in the air-fuel ratio due to contamination of carburetor, deviation in the ignition timing, degradation of the engine performance due to foulness of ignition plug, or deviation in the idling speed, resulting in increase in emission of pollutants. Actually, there were cars which were releasing the hydrocarbon gas from the hose disconnected from a blow-by gas returning unit. In order to prevent these problems, all of exhaust, blow-by gas, and fuel evaporation gas systems must be checked and maintained periodically.

Table 8.2.5 shows the legal effective inspection period specified in the Road Transport Vehicles Act of Japan for the sake of reference.

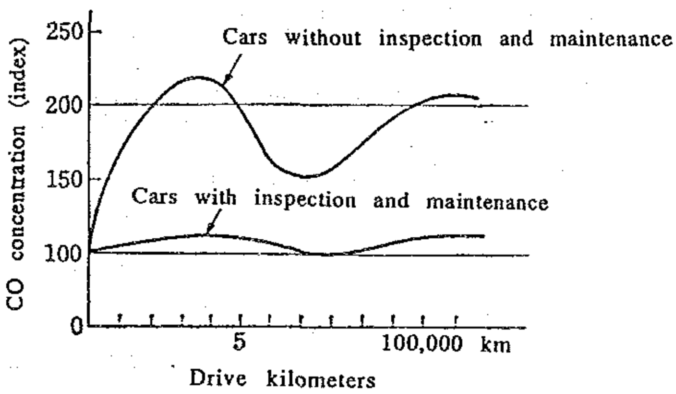
Table 8.2.5 Effective Vehicle Inspection Period in Japan (#5036)

Effective term	Category of motor vehicles	Example
1 year	① Passenger carrier motor vehicles	Taxies, buses
	② Motor vehicles for carriage of goods	Trucks, tank lorries
	③ Motor vehicles for private use which are prescribed by Ministrial Ordinances	
	a) Motor vehicles for private use whose riding capacity is 11 persons or more	Buses for private use
	b) Motor vehicles for private use which are used exclusively for carriage of infants	
	c) Passenger motor vehicles for private use which have been used for more than 10 years (11 years, in the case of motor vehicles which were given a term of three years at their initial inspection)	
2 years	① Passenger motor vehicles for private use, except new motor vehicles, which have been used for less than 10 years.	
	② Two-wheeled motor vehicles, Large-sized special motor vehicles	
3 years	New passenger motor vehicles for private use	

Servicing of extremely aged motor vehicles or ones with long driving distance once a year is not enough. The Road Transport Vehicles Act of Japan also sets forth that, even within the above effective period, periodical inspection and maintenance of every six months for passenger carrier motor vehicles and monthly for public vehicles (taxi, etc.) must be made and the record presented at a time of above official inspection. The Bogota authority must establish the schedule appropriate to the national situation while referring to the case of Japan by taking the handling capacity in service shops and inspection organization into account.

Inspection and maintenance offers substantial effect. As an example, the result of follow-up survey made in Japan in 1968 is shown in Fig. 8.2.1. EPA of the USA reports also that motor vehicles having received periodical inspection and maintenance can achieve reduction of carbon monoxide and hydrocarbons by 25% and nitrogen oxides by 10% (#5059).

Fig. 8.2.1 Effect of Periodical Inspection and Maintenance (1970 White Paper on Pollution, Japan))



3) Measuring during idling

It is proposed to measure the generation amount of carbon monoxide and hydrocarbons during idling along with inspection and maintenance. It is expected that this measurement during idling is to be made (at a time of registration renewal) in accordance with the pollutant emission regulation (#5057) (which is planned to be issued). This measurement was once instituted in Article 74 of the law 1809 (1990) (#5058) set up by Ministry of Public Works and Transport, but has not been implemented.

The measurement system to determine the concentration of carbon monoxide and hydrocarbons during idling is owned by the motor vehicle assembly factories and a part of service shops within Santafe de Bogota City. The system can measure the concentration of both gases through selection in one unit and costs about 4,000,000 pesos per unit. Each import dealers has the maintenance and service organization of the system. In any case, addition of the above measurement system and augmentation of the maintenance organization for such system are naturally essential because such system is indispensable for registration renewal and periodical inspection and servicing of more than 500,000 units of motor vehicles, if our recommendation is observed.

During idling, the CO concentration is high though the exhaust gas amount is small, and the absolute value of CO generation is relatively large. The result of measurement of idling with 47 passenger cars in our survey shows that the average CO concentration was 6.13% while that of hydrocarbons 1505 ppm. The effect of idling adjustment on the pollutant emission rate during driving on the road is as shown in Table 8.2.6: less effect on hydrocarbons though considerable change could be observed with the CO generation amount during low speed driving.

Table 8.2.6 Effect of Adjustment of CO during Idling on Pollutant Generation Amount

1) Report of survey on the smog generation mechanism and influence on plants, 1973 by Tokyo Metropolitan Research Institute for Environmental Protection

CO during idling	CO (vol%)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5
During driving	CO (vol%)	1.0	1.1	1.5	2.0	2.0	1.9	2.1	2.4
	HC (ppm)	530	570	590	590	650	650	700	720

Measurement during driving made in Japanese four modes (max. 40 km/h, average 21 km/h)

2) Measurement by Tokyo Metropolitan Research Institute for Environmental Protection

CO during idling		CO (vol%)	0.52	4.8
During driving		CO (g/km)		
Average speed	18.0 km/h		5.28	11.53
	44.5 km/h		4.42	5.69

(2) Training of Citizens and Drivers

Under guidance of the National Institute of Transport, the municipal Traffic/Transport Bureau is providing training to citizens and drivers in Santafe de Bogota City. Such training is intended to cover rules, driving practice and manner, vehicle mechanism, and safety and emergency measures. Training concerning pollution and its control has not yet been provided.

Pollution control requires among other things increase in interest and cooperation of citizens. It is essential to call citizens' attention to causes and countermeasures concerning the present state of global pollution in a larger scale to local asthma. Motor vehicles are extremely convenient for transport and movement of people and materials, proving highly helpful and indispensable for the society and economy. When motor vehicles get together to such an extent that their exhaust gas exceeds the natural purification capacity to cause harmful effect on human health, however, pollution occurs. Citizens and drivers, as users of vehicles, must therefore have recognition that they are not only a sufferer, but also a person responsible for pollution. Lecturing and pamphlet distribution at time of renewal of licenses as well as education and advertisement activities under cooperation of newspapers may prove effective for the recognition.

The contents of education may include thorough execution of periodical inspection and maintenance, prohibition of sudden start and rapid acceleration, prohibition of long time idling, use of public traffic means as much as possible instead of private cars, prohibition of road parking, and driving at appropriate speed. If drivers are instructed to make it a habit to execute daily check before driving every day, such a trouble as disconnection of hose from the blow-by gas returning unit can be found and repaired immediately.

Among three assembly makers we surveyed, only one has a high altitude automatic compensator installed to the 1975 model and after. Motor vehicles whose air-fuel ratio is adjusted to lower lands than Bogota (an elevation of 2,600m), develops the state with lean air and rich gasoline when driven in Bogota resulting in increase in carbon monoxide and hydrocarbons. Roadside signs to advice checking the adjustment at each return to Santafe de Bogota City will prove helpful.

It is proposed that a committee or society should be founded to undertake such education and advertisement activities. If authorized to carry out planning, execution, and review of result, such organization can undertake satisfactory education of the citizens under the integrated concept.

8.2.5 Control Measures for Motor Vehicles in Use

(1) Gasoline Motor Vehicles

1) Introduction of secondary air into air intake manifold

Introduction of secondary air into the air intake manifold will prove effective for vehicles which emit large quantity of carbon monoxide and HC during idling. If there is a flange interposed between the throttle valve and the engine intake valve, a spacer is to be inserted to add the secondary air valve. Without flange, the tap need be provided to the manifold.

When the throttle valve closes during idling and deceleration, the pressure here is reduced and the secondary air flows through the added valve to help combustion, thereby reducing generation of carbon monoxide and hydrocarbons. This is said to reduce the CO amount to around 1%. Since the secondary air valve closes during acceleration and driving at constant speed, no adverse effect is exerted on the fuel consumption and output. The unit cost required for this purpose is about ¥10,000 in Japan.

2) Introduction of secondary air into exhaust manifold

As a control measure during driving, the secondary air may be introduced into the exhaust manifold as near as possible to the engine exhaust valve. This method can reduce carbon monoxide and hydrocarbons through combustion, provided, however, that the exhaust temperature at the engine exhaust valve outlet should be 600°C or more. The secondary air may be supplied by a secondary air injector (AI) using an air pump or a unit using pulsation of the exhaust pressure (AS). AS does not require much space for additional parts and is inexpensive (about ¥5,000 in Japan) though suffering in that the air amount decreases with rising engine speed. AI and AS are illustrated in Fig. 8.2.2.

Fig. 8.2.2 Secondary air Introducing System

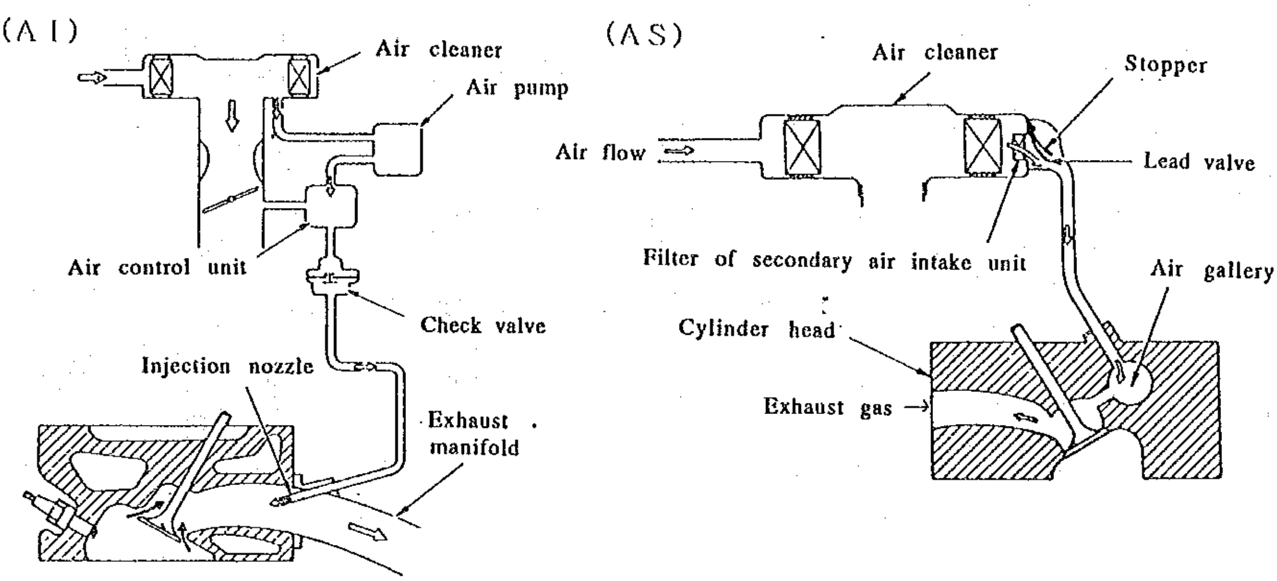


Table 8.2.7 gives experimental data showing the effectiveness. The effect is naturally remarkable in vehicles with the engine air-fuel ratio in which the fuel is richer than the theoretical value.

Table 8.2.7 Effect of Introduction of Secondary Air into Exhaust Gas

Car speed mile/h	Air fuel ratio	No secondary air introduction		With secondary air introduction	
		HC ppm	CO vol%	HC ppm	CO vol%
10	Fuel Rich	1000	2.4	154	0.6
	Lean	200	0	183	0
20	Rich	1000	1.9	91	0.3
	Lean	160	0.2	124	0
30	Rich	1050	2.5	100	0.5
	Lean	180	0.1	153	0.1
40	Rich	1900	1.5	162	1.3
	Lean	250	0.3	139	0.2
50	Rich	1050	1.5	158	1.4
	Lean	160	0.3	83	0.3

Excerpt: Automobile Technology (Japan), vol 27, No.10

If the exhaust temperature at the engine exhaust valve outlet is 600°C or less and subsequent combustion in the exhaust manifold cannot be sustained, the ignition timing may be delayed to raise the exhaust temperature. A resultant secondary effect is decrease in the maximum combustion temperature with reduction in generation of nitrogen oxides. However, the ignition timing is closely related to the engine output and fuel economy and delaying of the ignition timing may cause negative effects when considered from the performance point of view. Recent motor vehicles have the electronic control of ignition timing in response to the signals of engine speed, load, cooling water temperature, and driving speed.

3) Installation of catalyst system

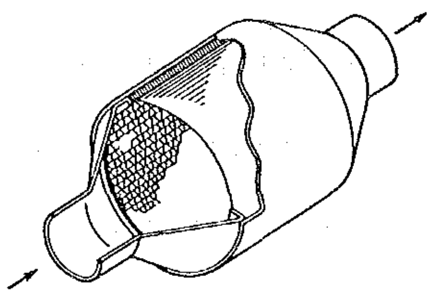
A catalyst unit may be installed in exhaust pipe to decompose and eliminate pollutants. A catalyst to eliminate carbon monoxide and hydrocarbons is called oxidation catalyst (OC), and a three way catalyst (TWC) can decompose nitrogen oxides in addition to the above pollutants. The elimination rate may well exceed 90% if conditions are favorable. TWC can achieve the high elimination rate within a narrow range in the vicinity of theoretical air-fuel ratio and be effective only on vehicles in use which have a control mechanism for that purpose (e.g., electronic fuel injection control). In view of the nitrogen dioxide level currently below the standard value, its installation to motor vehicles currently in use may not be necessary. Note however, that TWC is one of control measures to be installed in new models subsequent to the exhaust gas re-circulation system before 2010s to control nitrogen oxides.

Both catalysts are heavily degraded by lead contained in gasoline and thus cannot be used for the long extended period of time. In Colombia, however, gasoline have become totally lead-free since 1991, making application of these catalysts easier. A problem may be availability of lead-free gasoline during travel in neighboring countries.

Oxidation catalyst requires existence of oxygen in sufficient quantity because it allows residual carbon monoxide and hydrocarbons to burn. It may also be necessary for vehicles driven with the air-fuel ratio around or below the theoretical value (i.e., fuel rich) to introduce the secondary air before the catalyst unit.

Fig. 8.2.3 shows an example of oxidation catalyst. The catalyst itself may be particle pellets, but normally of a monolith type at present which is honeycombed to minimize ventilation resistance. The catalyst consists of a porous carrier to which platinum or platinum and palladium are deposited. The effective life of catalyst is generally said to be equal to the life span of motor vehicles. But this life is related to the sulfur content in fuel, which exists as sulfur oxides in the exhaust gas. The gas attacks gradually the carrier components such as alumina oxide and magnesium oxide. The maximum allowable sulfur content of gasoline is set at 0.15 weight-% in Colombian standard (around 0.07 weight-% in our analyses). If this level continues, it is doubtful whether or not the catalyst can be used up to the car life without replacement when considering the present average car age of 20 years or more in Bogota. Though detailed discussion with specialists in catalyst is necessary, the sulfur content in gasoline should anyway be controlled below 0.01 weight-%. The price of oxidation catalyst is about ¥35,000 in Japan.

Fig. 8.2.3 Monolith Type Oxidation Catalyst



4) Installation of fuel evaporation gas trap

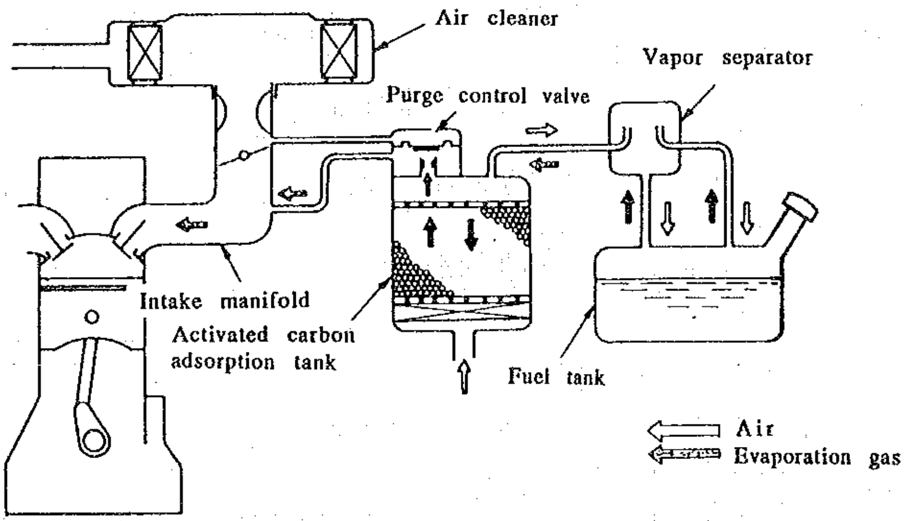
According to the survey result on three automobile assembly makers of Colombia, almost all of motor vehicles have the gasoline fuel tank open to the atmosphere even now. Breathing of the fuel tank along with temperature change causes gasoline vapor (which is hydrocarbon) to be released into air during exhalation.

The Reid vapor pressure of gasoline is allowed to maximum 75.8 KPa in Colombia. By converting the numeral, this means that gasoline reaches the boiling state at around 35°C at the atmospheric pressure of 564 mmHg in Bogota. Namely, if left to stand for long period under direct sunshine, gasoline develops large amount of evaporation. The analytical values made available to us, the Reid vapor pressure ranges from 59.2 to 75.1 KPa. The evaporation rate will considerably decrease by controlling the pressure to the lower value in Bogota.

Inhaling occurs when the fuel tank system cooled in the nighttime, and it expands along with temperature rise after sunrise or when it is heated to expand during driving. Assuming that gasoline with the Reid vapor pressure of 59.2 KPa is filled in the tank with its 20 l empty portion and its temperature rises from 15°C to 25°C, the amount released into air in one exhaling is calculated to be about 0.7 g. If the registered number of gasoline cars in Bogota is 300,000 and each car is exposed to temperature rise once, a total of about 200 kg of gasoline should be released into air.

To prevent evaporation of gasoline into air from the fuel tank, an activated carbon adsorption tank as shown in Fig. 8.2.4 will offer 90% or more effectiveness. Evaporated fuel during shutdown is adsorbed by activated carbon, then desorbed by air as the engine is started and drawn into the air intake system. The activated carbon adsorption tank costs about ¥20,000 in Japan.

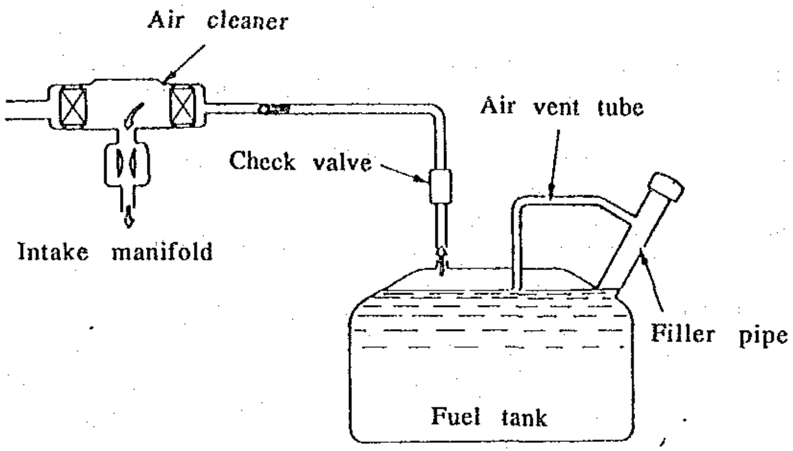
Fig. 8.2.4 Activated Carbon Adsorption Tank System



With the upper space of the fuel tank connected via pipe to the air cleaner or air intake manifold as shown in Fig. 8.2.5, expansion caused by temperature rise can be retained without releasing to the outside atmosphere until the pressure allowed by the check valve is exceeded. The expansion component of fuel is sent to the engine during running to be burnt, thus not causing any pollution. In this construction, the fuel tank partitioned by the check valve should therefore be constructed to withstand more or less pressurization and pressure reduction.

Both types shown in Figs. 8.2.4 and 8.2.5 should have the fuel supply port plug of a sealing type. Besides, they should not have any vent to the atmosphere.

Fig. 8.2.5 Fuel Vapor Storage Type



5) Restrictions and implementation method for control measures on motor vehicles in use

The number of applicable control technologies to gasoline motor vehicles in use is limited as described above. Being in use, these ones present problems such as available space and strength for additional installation, effect on the driving performance and fuel cost, implementation cost, implementation work system, and compensation while implementation is underway and the vehicle is not usable.

According to the National Institute of Transport of Colombia, the vehicle models to be registered include a thousand types or amounts to a ten thousand if the model year is included. In order to obtain the maximum effect with reasonable cost, the countermeasure must be established for an individual type of motor vehicles with consideration of respective restrictive conditions.

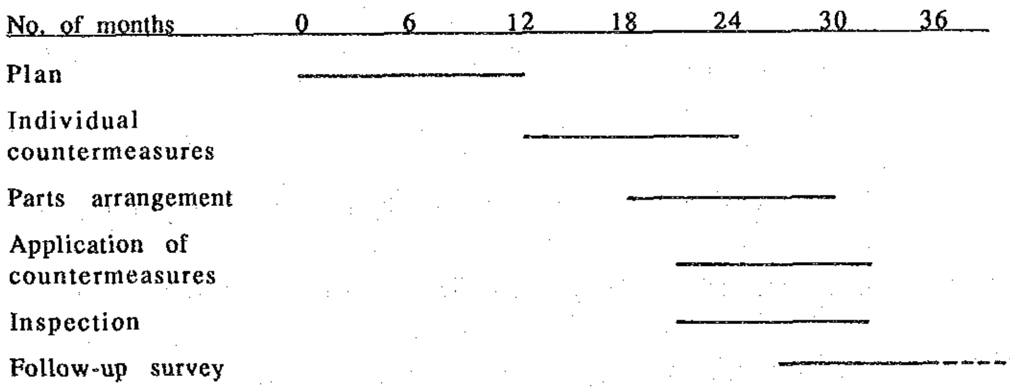
It is proposed to found an official group which can plan and execute the plan, then improve the plan if necessary according to the result and which can also function under the integrated concept. This group will concentrate on drafting of the execution program for the first one year. Since understanding of the present state using a chassis dynamometer is essential, such unit must first be installed before hand (Refer to 8.2.3 (1), 3) for the chassis dynamometer). The next one year will be used for inspection of motor vehicles which come to revision of registration and establishment of countermeasures. Arrangement of necessary parts will be made during the period and practical execution of countermeasures will be started in the 21st month after start of the group activities.

Though actual implementation work may have to be contracted to private shops, the Colombian authority must determine whether the necessary cost is to be born by vehicle owners or any kind of subsidiary will be provided. Since parts have to be ordered in advance and are expensive, the government subsidiary need be considered for financing.

Motor vehicles for which control measures have been applied are to be sequentially checked for the effectiveness by this group using the chassis dynamometer. The sampling inspection may have to be employed because checking of all is impossible. It is also necessary to perform the follow-up survey of performance over a long period on some vehicles.

The implementation process is shown in Fig. 8.2.6.

Fig. 8.2.6 Implementation of Measures for Individual Vehicles in Use



(2) Countermeasures for Diesel Motor Vehicles

As described in terms of control measure technologies for individual diesel, the exhaust problems of diesel include nitrogen oxides and black smoke (suspended particulates). The control measure technology regarding these problems are not yet established sufficiently in spite of gradual improvement. Besides, the diesel oil has high sulfur content, affecting the environmental standard of sulfur oxides, and sulfur trioxide associating sulfur dioxide causes increase in aerosol and SPM. What should be done at present is to reduce diesel motor vehicles running inside the city of Bogota within the current level.

(3) Fuel

1) Supply of low-sulfur fuel

The automobile fuels in Colombia contains sulfur as shown in Table 8.2.8. The sulfur oxides emitted at the exhaust tail pipe is 20 to 45 ppm per exhaust gas volume for gasoline and 150 to 300 ppm for diesel.

Gasoline is treated through extraction and oxidation of mercaptan (hydrocarbon containing sulfur) (so-called "sweetening") in a refinery. Depending on the capability of the system, however, certain amount of sulfur may remain as disulfide (an oxidation product of mercaptan). Gasoline is free from odor (odor sweet) even in this state and can prove satisfactory as a product quality. In the case of Bogota, however, pollution caused by sulfur oxides will exceed the environment standard in ten years. By taking this fact and application of oxidation catalyst in future into account, it must be attempted to reduce the sulfur content of gasoline below 0.01 weight-%. Note that installation of oxidation catalyst causes oxidation of SO_2 into SO_3, resulting in increase in aerosol and SPM.

Table 8.2.8 Sulfur content (Weight-%) of Automobile Fuel

Source	Allowable maximum (#5005)	Analytical value (our analyses)	(#5026)	(#5027)	(#5028)
Regular gasoline	0.15	0.06	-	0.092	0.07
Extra gasoline	0.15	0.07	-	0.066	0.12
Diesel oil	0.8	0.4	0.4	-	0.39

Sulfur is removed from diesel oil by means of hydro-desulfurization and hydro-decomposition in the refinery. Japan plans to reduce sulfur to 0.2 wt-% or less by 1992 and 0.05% or less by 2000 while the USA intends to achieve 0.05% or less after October, 1993 (Clean Air Act, as amended in 1990). In this way, reduction of sulfur is a worldwide trend. If the number of diesel motor vehicles driven in Bogota is to be increased from the present level in view of certain reasons, supply of low-sulfur diesel oil should also be considered in parallel.

2) Supply of oxygenated gasoline

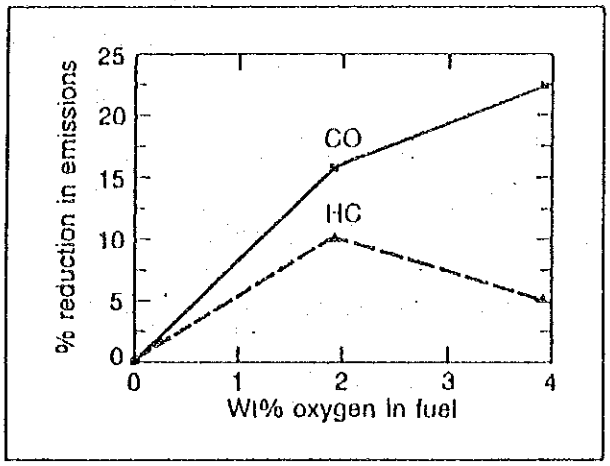
If the gasoline contains oxygen, generation of carbon monoxide can be suppressed. In this context, the use of gasoline containing 2.7% of oxygen has become obligation during winter since 1992 in 44 cities heavily polluted by carbon monoxide in the USA. Similarly in 9 U.S. cities heavily polluted by ozone, the use of reformulated gasoline has been made obligation throughout the year from 1995. Reformulated gasoline contains 2 wt-% or more oxygen while being reduced of benzene and aromatics contents, and suppressed vapor pressure by reducing olefine contents (Clean Air Act, as amended in 1990).

Compounds containing oxygen to be added to gasoline include methanol, MTBE, ethanol, ETBE, etc. Since methanol absorbs water and becomes corrosive when mixed with gasoline, it is necessary to change a part of automotive materials. MTBE is an abbreviation of methyl tertiary butyl ether while "E" of ETBE stands for ethyl. MTBE and ETBE are produced by allowing isobutylene and methanol or ethanol to react.

One (#5055) reported the reduction of carbon monoxide by MTBE at 36% with 1973 to 1978 models, 38% with vehicles up to 1980 model, and 25% with 1983 model, using total 62 motor vehicles. This indicates that the reduction rate is higher with older models.

Fig. 8.2.7 shows the oxygen content and pollutant reduction data taken from experiment using 137 vehicles. Generation of carbon monoxide decreases with increasing oxygen concentration. However, the reduction rate of hydrocarbons decreases after reaching the peak at 10% (#5060).

Fig. 8.2.7 Oxygen Content of Gasoline and Reduction of Pollutants



The use of oxygenated gasoline could be a tentative measure in reducing carbon monoxide in the environment until dissemination of the catalyst unit reaches individual motor vehicles. If this method is considered as a tentative means effective for the short term, either imported compound or utilization of domestic ethanol should be planned instead of constructing the oxygenated compound plant. It is recommended for Colombia to study the feasibility further in future by itself. Currently, the MTBE production plants are being constructed all over the world (50,000 to 500,000 ton/year capacity per plant) in line because of its octane number enhancing ability and of the Clean Air Act amendment of the USA. Colombia may be able to import the product using the difference of the U.S. demand in winter and other seasons.

Assuming the current gasoline consumption at 40,000 BPDC (1.72 MM ton/year) in Santafe de Bogota (#5028), the required amount of oxygenated compounds to produce gasoline with 2.7 wt-% oxygen equivalent to the case of the USA is as shown in Table 8.2.9. below.

Table 8.2.9 Required Amount of Oxygenated Compounds in Santafe de Bogota

Materials containing oxygen compounds	Oxygen content, % by weight	Required amount ton/year
MTBE	18	258,000
ETBE	15.7	295,000
Methanol	50	93,000
Ethanol	34.8	133,000

8.2.6 Countermeasures through Traffic Control

(1) Problems to be Solved

The quickest and most effective countermeasure against air pollution caused by motor vehicles is to decrease the number of vehicles. Traffic congestions contribute to local contamination. Increasing the number of one-way roads and building new roads as a means to dissolve traffic congestions, however, would increase rather than decrease the whole volume of traffic in the city, thus worsening overall pollution. Since cars are very efficient in transporting people and goods directly from door to door, a more efficient road network and economic development will inevitably increase the number of vehicles and the volume of traffic.

The main problem with Santafe de Bogota City (and with any other major cities) is that the roads are occupied during morning and evening rush hours by vehicles with only one or two passengers who use vehicles for convenience' sake. Another problem which is characteristic of Santafe de Bogota is that buses are full of passengers while trolleybuses are completely empty. Taking such circumstance into account, improvement of the public transport system would be among the major subjects in preparation of countermeasures.

(2) Trolley Bus

The trolley bus enterprise of District Enterprise of Urban Transport (EDTU), who had been in depressed situation for a long time, has quit the operation since August 1991 and now is conducting the procedure of dissolution. And at the same time introducing the capital from private sectors, they are preparing a new semigovernmental enterprise which is proposed to start on March 1992.

The principle of the new enterprise says that the city government invests such assets as vehicles, electric equipment, land and that like, totally equivalent to about 4 billion pesos, and on the other hand the private sectors invest about 6 billion pesos and undertake the practical operation of transportation.

The new service will be started with three routes including the old line formerly utilized and the routes will be extended in future up to eight lines covering the whole city area where densely inhabited (Fig. 8.2.8).

The routes are located on the roads with sufficient width or those which are able to expect many demands of person trip, so that even a formerly used route would be abolished unless the route satisfies the requirements mentioned above. Another requirement of new trolley bus routes is that they can connect residential districts to the new railway stations taking the new plan on passenger railway system into consideration.

The fare of trolley bus for one ride will be decided as 130 pesos in order not to exceed the fare of the special bus for seated passengers only of 150 pesos for one ride.

According to the plan, the total length of eight operating routes will reach 65 km in ten years and it is expected that 5% of the total passengers in the city will change from bus to trolley bus.

That is considered to induce the reduction of bus traffics as well as the exhaust gas emitted by those buses.

(3) Passenger Railway

EDTU is also preparing a new business in establishing a passenger railway network under the support of the government of Italy on financing designing, supervising the construction work and technical assistance for railway operation. The construction expense will be provided by loan which is estimated US$1,1 billion during the first stage of four years.

According to the plan, EDTU will complete the line as long as 23 km in the first stage of the project, then continue the construction through the second and the third stage, finally complete three lines of total length of 44 km (Fig. 8.2.9).

In advance of the plan, the central government had promulgated a new law which mandated the local government to collect the special tax for the purpose of solving the traffic problems. Practically the government of Santafe de Bogota City imposes 6 to 18% on gasoline prices for the resources of the project.

The exact time of the completion and the expense of the whole project are still not decided however, the authority expects that the investment will be accelerated by good reputation of railway transit system after the beginning of operation of the stage one section.

Most of the stage one section is constructed in the site of existing railway, and in the central zone the new railway is built on the viaduct.

The railway is planned to run from Bosa at the south-western fringe to the center in 23 minutes where the bus takes almost one hour at present. The proposed fare of railway for one ride is considered to be US$0.2 (120 pesos), so the authority expects that the present passengers of buses may willingly change to railway.

As the result of the full operation in future, the change rate is estimated 15 ~ 17% of the total passengers in the city. That will also induce the reduction of the exhaust gas emitted by buses greatly.

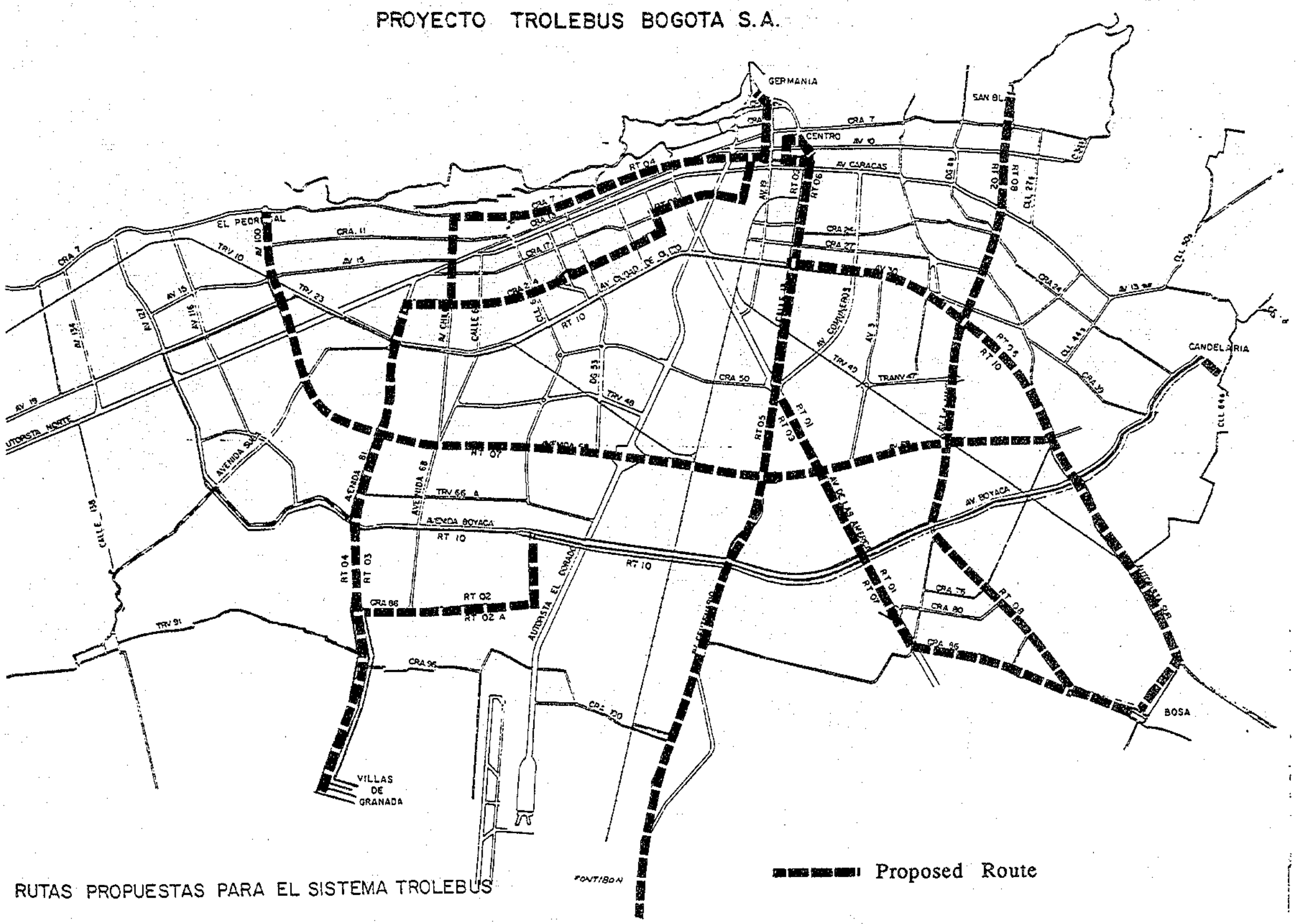


Fig. 8.2.8 Proposed Network of Trolley Bus

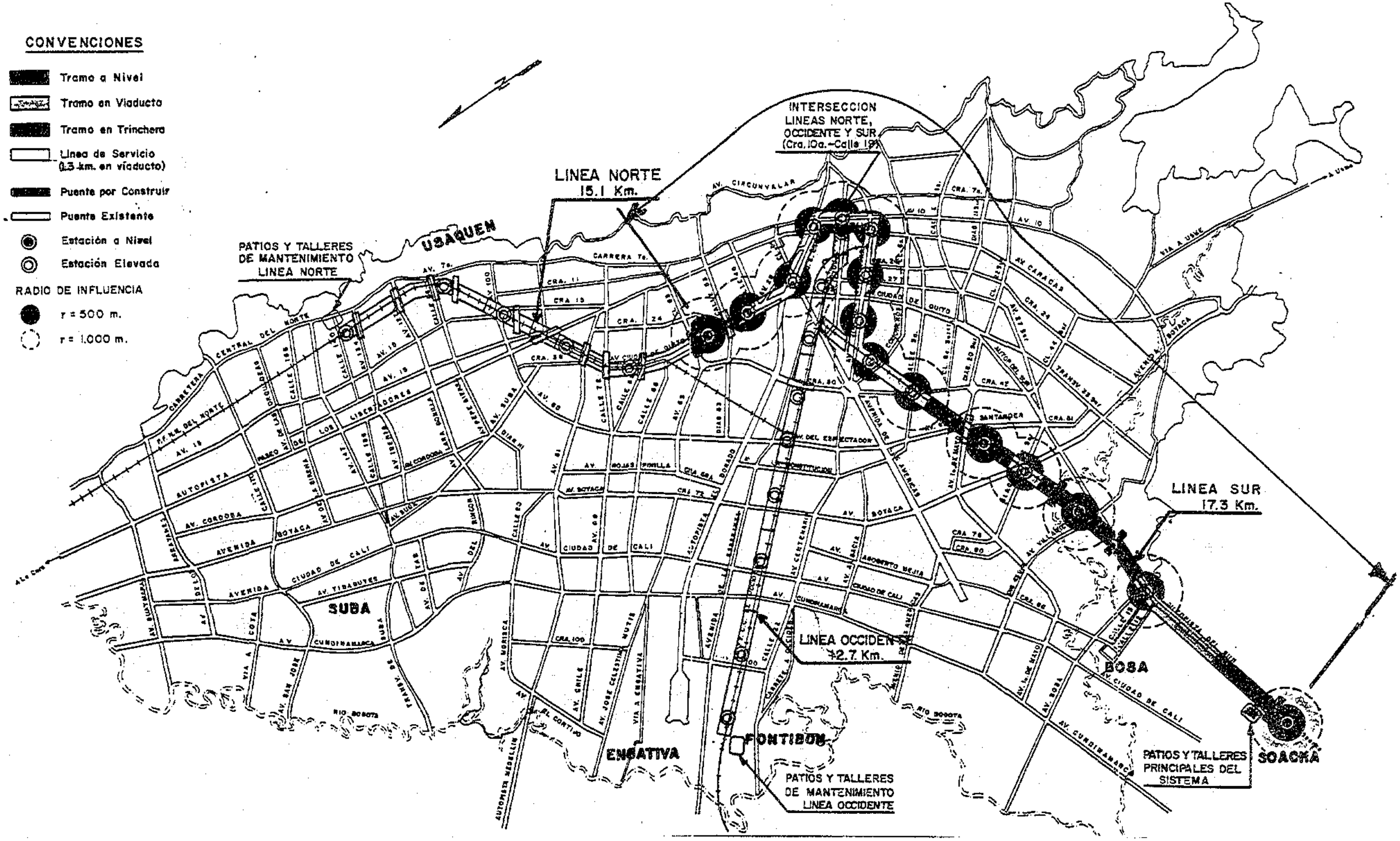


Fig. 8.2.9 Proposed Route of Passenger Railway

(4) Renovation of Bus Traffic System

It is free to ride and alight a bus at anywhere on an assigned route of the bus in Santafe de Bogota. This friendly custom has resulted congestion and chaos on the already flooded traffic in the center of Bogota, causing traffic accidents, longer engine idling and unnecessary throttle pedaling in vain. Both of the latter two emit pollutants to the environment.

These problems have been solved on the south of Ave. Caracas after two lanes out of four were assigned exclusively for buses and bus stops were placed at fixed locations. This smoothed traffic attained about 25 km/hr of average flow rate.

This fact will bring the most reasonable countermeasure for smoothing traffic flow and reducing pollutant emission from motor vehicles, i.e. to install bus exclusive lanes and to allocate bus stops in major congested roads.

The improvement for installation of exclusive bus lanes and bus stops is now on the way to construction in full range of Ave. Caracas, however, there is no such plans in the other arterial roads so far.

Including this type of project, a total plan on improvement of road network is now under implementation throughout the territory of Santafe de Bogota City. The total plan, aiming at mitigating the traffic congestion, prepares such projects are forming two-level crossing at major intersections, extending and widening of arterial roads, geometrical reforming of intersections and maintenance of macadam besides installation of exclusive bus lanes. Its total costs are estimated approximately 90 billion pesos for two fiscal years of 1991 to 1992.

On the other hand, the bus fare payment system seems necessary to be investigated because the present system asks passengers to pay in cash so sometimes the driver or the conductor should return changes; this tiny handing may let the stop larger during the peak hours in the morning and in the evening. To reduce the time spent for bus fare handling, some other paying system such as coupon ticket, special coin exclusively used for bus fare, commutation ticket are likely to be effective.

Also it is suggestible to change small sized buses or buses to larger sized buses in order to reduce traffic volume without lowering transportation capacity.

Because of the improvement of arterial road network, the driving condition will be promoted particularly for large sized cars. For instance, there is a domestic vehicle manufacturer who has developed doubledeckers and applied for the permission about safety function to the National Transportation Agency. One of its prototype bus is now conducting an experimental drive in the city under the tentative permission of the competent authority.

One of the proposed double decker in trailer type, shown in Fig. 8.2.10, has the capacity of 150 passengers, that is equivalent to four ordinary buses or eight small sized buses or 15 microbuses. If they act just as their capacity, they will contribute to reduce the traffic volume to some extent, however, there are some problems to be solved before introduced into practical use.

When the problems, among other things, the treatment of exhaust gas from diesel engine and the quick ride and alight method are solved, the type of bus may be one of the countermeasure to mitigate the traffic congestion.

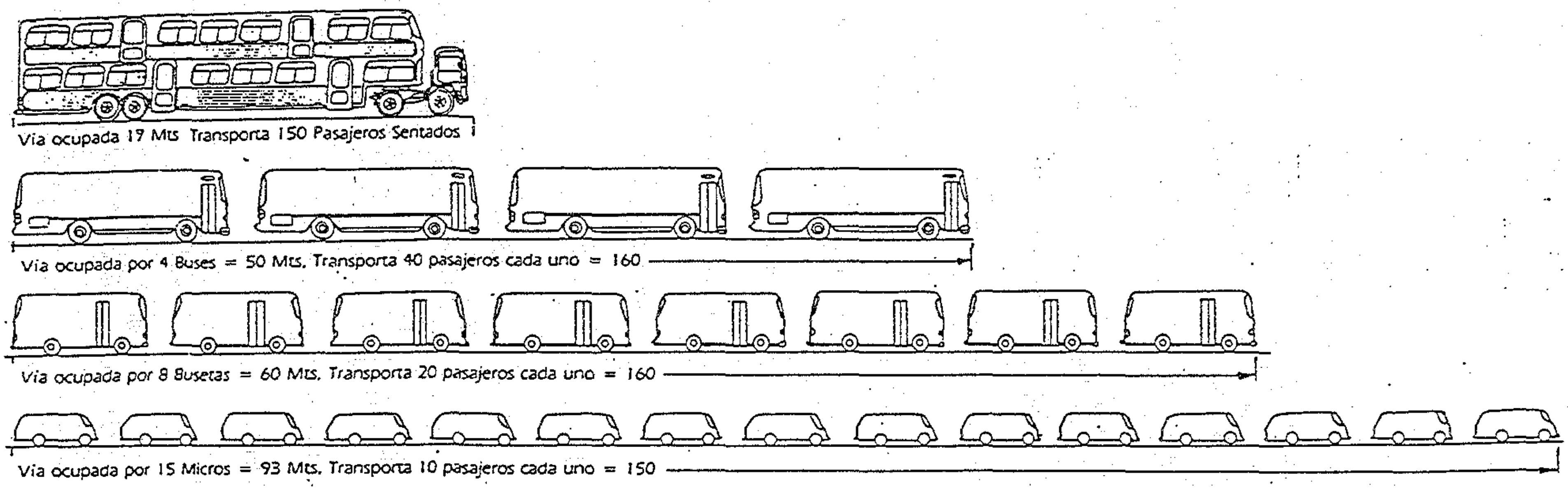


Fig. 8.2.10 Sketch of the Doubledecker

8.2.7 Other Improvement

(1) Review of Vehicle Tax System

The present vehicle taxation system is based on the official evaluation system of the vehicle value. All the vehicles in use are evaluated every year and imposed tax at the designated rate according to the rank of the vehicle value. Because the rate is decided as the progressive taxation, and furthermore the value of the vehicles is descending by the age, the amount of tax on used cars decrease rapidly as shown in Fig. 8.2.11.

The characteristics of the present taxation system has the probability of inducing the following unfavorable reactions:

a) Stimulate the use of used cars of advanced age which is almost impossible to apply the countermeasures for emission control

b) In case of applying the countermeasures, the rise of the vehicle price may cause at the same time the rise of the tax, that prevent the willingness to introduce the emission control

Therefore the system should be reviewed in order to stimulate the change of used cars to new ones or already treated ones from the viewpoint of emission control.

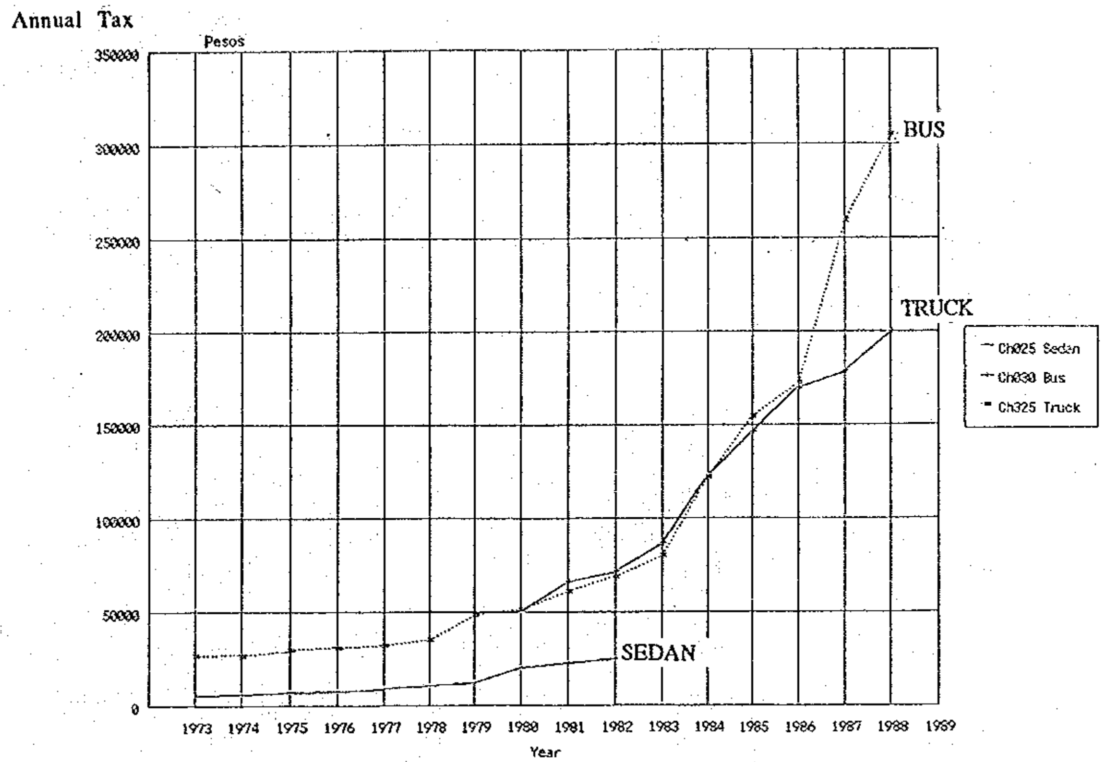


Fig. 8.2.11 Sample of Owners Tax on Used Cars

(2) Prevention of Hydrocarbon Evaporation

Hydrocarbon is one of the prominent air pollutant in Santafe de Bogota City and is not regulated to emit from either running vehicles or stationary equipment. The latter source of hydrocarbon should be also managed to control for the entire regulation on air pollution.

But there has been no official participation in this field, Therefore a new concept of introducing this subject into the administrative activity of the authorities in charge of air pollution control.

That is to say the prevention of hydrocarbon evaporation from the stationary equipment such as gas stations, solvent storage, painting factories, should be now commenced.

For the first step toward the target the following items may be appropriate to establish the basis of the effective administration.

a) grasp the actual situation of object equipment

b) investigate the method for improving such equipment

c) investigate the measuring method of hydrocarbon

d) prepare the guidelines for mitigate the hydrocarbon emission

8.2.8 Selection of Control Measures and Estimation of Costs

Concerning motor vehicle source emission control measures described above, short-term measures possible within the coming five years and medium- to long-term measures possible within 10 years are summarized in the table below.

<table>
<tr><th></th><th>Item</th><th>Short-term</th><th>Medium- to long-term</th></tr>
<tr><td rowspan="7">Control measures for motor vehicles</td><td>Control of emission gas</td><td>a. Early promulgation
b. Installation and operation of chassis dynomometer</td><td>a. Augmentation of control along with growing traffic volume
b. Continuation of emission study</td></tr>
<tr><td>New models</td><td>a. Decision by maker
b. Prevention of increase of diesels
c. Promotion of dissemination of low-pollution motor vehicles</td><td>a. ditto
b. Expecting of control measure development for diesel cars
c. ditto</td></tr>
<tr><td>General control measures for vehicles in use</td><td>a. Enlarge coverage of cars for control
b. Obligation of periodic inspection/maintenance
c. Execution of measurement during idling
d. Execution of education of citizens and drivers</td><td>a. ditto
b. ditto
c. ditto
d. ditto</td></tr>
<tr><td>Gasoline vehicles in use</td><td>a. Introduction of intake secondary air
b. Introduction of exhaust secondary air
c. Installation of an oxidation catalyst system
d. Installation of fuel gas trap</td><td>a. ditto
b. ditto
c. ditto
d. ditto</td></tr>
<tr><td>Diesel vehicles in use</td><td>a. Restriction of driving in Bogota</td><td>a. ditto
b. Expecting of technology development</td></tr>
<tr><td>Gasoline</td><td>a. Supply of low-sulfur gasoline</td><td>a. ditto
b. Supply of oxygenated gasoline</td></tr>
<tr><td>Diesel oil</td><td>a. Study on supply of low-sulfur diesel oil</td><td>a. ditto</td></tr>
<tr><td rowspan="3">Traffic control</td><td>Trolley bus</td><td>a. Foundation of an operating company
b. Start of operation</td><td>a. Completion of a network</td></tr>
<tr><td>Passenger railway</td><td>a. First phase of construction
b. Start of operation</td><td>a. Second and third phases
b. Connection with bus and trolley bus networks</td></tr>
<tr><td>Bus traffic system</td><td>a. Improvement of trunk system
b. Improvement of the operation system</td><td>a. ditto
b. ditto</td></tr>
<tr><td>Other Improvement</td><td>Vehicle taxation system</td><td>a. Understanding of problems</td><td>a. Preparation of a draft of a new system</td></tr>
</table>

The environment will become much cleaner if the environmental control measures are to be taken earlier and to the much deeper degree. The costs necessary tentatively and officially for pollution control measures can be estimated as follows while predicting the maximum possible degree of achievement of control measures to suppress the emission amount below the reduction target described in 8.2.2 (2).

1) Chassis dynamometer

Two units of chassis dynamometers with auxiliary equipment may be satisfactory for Colombia for the time being. According to the issue of United Nation's Development Business, Sep. 30, 1991, Mexico is planing to purchase four chassis dynamometers and three gas measuring units. The equipment cost, shipping and installation expenses are assumed to be 1.5 times of the equipment cost in Japan, and the costs for housing, foundation, test operation, training, etc. and taxes are not included.

$$200{,}000{,}000 \times 1.5 \times 2 = 600 \times 10^6 \text{ Jap. Yen}$$
$$= 2{,}770 \times 10^6 \text{ \$ (Pesos)}$$

Operation expenses after installation are not calculated, although they are general budget required constantly.

2) New motor vehicles

Expenses are not calculated here because they are totally to be born by car owners.

3) CO and HC measuring instruments for idling

Total number of vehicles in Santafe de Bogota D.C. and Department Cundinamarca is assumed to be 550,000 (including 80,000 for public passengers).

One measuring instrument can perform measurement of 50 vehicles a day and is assumed to be operated for 200 days a year.

Required number of units (including 20% allowance)

As-installed in Official agencies -

550,000 x 1.2 /(50 x 200) = 66 units

4,000,000 x 66 = 264 x 10^6

As installed in private facilities

Inspection assumed to be made once a month for public passenger vehicles and twice a year for other vehicles

80,000 x 12 x 1.2/(50 x 200) = 115 units] total 218

430,000 x 21 x 1.2/(50 x 200) = 103 units

4,000,000 x 218 = 872 x 10^6 $

Maintenance and operation expenses of the instruments are to be born by users.

4) Education of citizens and drivers

The necessary cost is considered to be the general budget of Bogota. It is not calculated here.

5) Introduction of intake secondary air for gasoline cars in use

Most of cars may clear the content of the current draft of exhaust gas regulation (cf. Item 8.2.2) if the periodical inspection and maintenance is executed to control idling air-fuel ratio, rotating speed, etc. Accordingly, the cost can be ignored here.

6) Introduction of exhaust secondary air and installation of oxidation catalyst system for gasoline cars in use

Calculation here is made while assuming that the oxidation catalyst system is installed after adjustment of the air-fuel ratio. Installation of the oxidation catalyst system started in 1975 in Japan (cf. Item 8.2.3 (1) 3)) and USA (#5059). Gasoline motor vehicles produced after are considered to have a strength and a space for installation. As of December, 1990, 65% of cars registered in Santafe de Bogota are models of 1976 and after, and thus installation of an oxidation catalyst system is presumed to be relatively easy for 50% of total vehicles.

Though the system size varies depending on the vehicle size, approximation is made using the average price.

Equipment cost (including necessary parts cost and transport expenses, but excluding the import tax)

Exhaust secondary air + oxidation catalyst system = 50,000 ¥
= 230,000 $

These system parts are assumed to be arranged by authority of Santafe de Bogota to be distributed to owners of vehicles. From the understanding that every owner is responsible for pollution and should bear the countermeasure costs equally, the distribution price may be for example, set to low at 1/3, with another 1/3 born by the authority of Santafe de Bogota, and remaining 1/3 collected from owners of vehicles not covered by this measure.

Temporal fund requirement in Bogota D.E.

$230{,}000 \times 550{,}000/2 = 63.25 \times 10^9$ $

Real expense to Bogota D.E. 21.1×10^9 $

The installation cost will be born by owners of cars covered by the measure and thus not included for calculation here.

7) Installation of fuel gas trap

An inexpensive accumulation method is assumed to be used. Though this must be installed in almost all gasoline motor vehicles, some of them cannot have the system installed because of deficient strength. Materials and parts can all be procured within Colombia.

A total of system cost and installation expenses may amount to ¥10,000 and will be born by vehicle owners covered by the measure.

8) Supply of low-sulfur gasoline

The equipment cost varies greatly depending on whether the existing ECOPETROL facility shall be retrofitted or revamped or new facility need be constructed. In any case, the cost will be added to the price of low-sulfur gasoline produced from such facility and born by consumers.

9) Supply of oxygenated gasoline

This measure is considered an temporal emergency one in case of accelerated pollution by carbon monoxide because of delay in installation of the oxidation catalyst system. The additive price will be about 1.5 times that of gasoline, amounting to around 300 US$/ton. The cost for one year of MTBE is as follows:

300 x 258,000 = 77,400,000 US$/year

The required amount of gasoline in turn decreases in proportion to the heat generation amount. In other words, the import amount decreases correspondingly or the reduced amount can be accommodated for export.

Reduced amount of gasoline
258,000 x 8,400/11,000 = 197,000 tons/year
200 x 197,000 = 39,000,000 US$

Amount born by Colombia after deduction
38,400,000 US$ = 23 x 10^9 \$/year

Reflection to the gasoline price will be around \$10/l. This is considered to be born by consumers and paid back within a short period.

10) Trolley bus

Initially, about 100,000 x 10^6 pesos will be invested as an operation fund, whose breakdown is shown below:

Funding by the city	about 40,000 x 10^6 \$
Funding by private sector	about 60,000 x 10^6 \$
Total	100,000 x 10^6 \$

Subsequent equipment investment plan is not yet established.

11) Passenger railway

Construction cost for the first phase about 1,100 x 10^6 US$

Though the cost for second and third phases is not yet established, the amount is considered to be same because the railway length will be same as in the first phase.

$$2{,}200 \times 10^6 \text{ US\$} = 1{,}320 \times 10^9 \text{ \$}$$

12) Bus transport system

For the trunk road which is used also as a bus route, new road construction and improvement are planned at a cost of 90,000 x 10^6 $ for two years beginning with 1991. Included in this plan is new construction of the bus dedicated lane and new bus stops in Caracas Street.

$$90{,}000 \times 10^6 \text{ \$}$$

13) Other improvements

Sequentially estimated along with specific establishment of the contents of measures.

8.3 Prediction of Effect of Source Control Measures

The control plans as described below were set up for factories and motor vehicles in order to ensure the required reduction of air pollutants estimated in 7.4.

8.3.1 Control Measures for Factories

(1) Examination of Effectiveness of Control Measures

The emission standard has been set for boilers and brick and clay-pipe kilns, and it is necessary to employ the reduction method to achieve the reduction amount according to this standard. The reduction method to be employed is prepared by combining various methods available. This section selects improvement of the combustion method, fuel conversion, and raising of the stack height, examining the reduction effect respectively. Facilities concerned are a crude oil combustion boiler (2,560 HP, fuel consumption 540 x 10^4 gal/y), a coal firing boiler (300 HP, fuel consumption 1.6 x 10^4 ton/y), and a brick kiln (batch furnace, fuel consumption 600 ton/y). The effectiveness of each method was calculated using the reduction method and reduction ratio shown in Table 8.3.1.

Table 8.3.1 Reduction Rate by Countermeasure

(%)

	Countermeasure		Dust	SOx	NOx
Crude oil combustion boiler	Improvement of combustion method	• Low excess air combustion	25	-	25
		• Fuel saving	23	-	6
		• Steam injection	-	-	18
	Fuel reforming	• Sulfur content 1.8%	-	21	-
	Fuel conversion	• Light oil	80	83	79
Coal firing boiler	Improvement of combustion method	• Low excess air combustion	7	-	-
		• Fuel saving	5	-	-
		• Steam injection	-	-	18
	Fuel reforming	• Sulfur content 0.5%	-	29	-
	Fuel conversion	• Crude oil	70	-	-
		• Light oil	80	43	48
	Gas treatment	• Multicyclone	70	-	-
Brick and clay pie kiln	Improvement of combustion method	• Stoker	50	-	10
		• Fuel saving	10	-	7
	Fuel reforming	• Sulfur content 0.57%	-	19	-
	Fuel conversion	• Natural gas	90	100	4
Raising of stack height:	Review made with the stack height increased twice or four times while setting the emission rate to a level of the year 2001				

Effectiveness of raising the stack height was checked for the above two boilers. The current pollutant emission rate was calculated from the fuel consumption using the emission factor set in this study. The emission rate for the 2001 was calculated by multiplying the current rate by 1.4.

The reduction rate of the emission standard as proposed in 8.1.3 (1) was applied to determine the reduction target. The reduction rate by countermeasure was set as shown in Table 8.3.1.

The examination result was as shown in Table 8.3.2.

Table 8.3.2 Reduction Method and Effectiveness

Countermeasures		Dust					SO_2					NOx				
		Emission rate (t/y)		Reduction target (%)	Reduction rate (t/Y)	Percentage reduction (%)	Emission rate (t/y)		Reduction target (%)	Reduction rate (t/Y)	Percentage reduction (%)	Emission rate (t/y)		Reduction target (%)	Reduction rate (t/Y)	Percentage reduction (%)
		Present state	2001				Present state	2001				Present state	2001			
Crude oil combustion boiler	Improvement of combustion method	189.5	265.3	58	127.3	48	921.4	1290.0	21	280.0	22	108.0	151.2	50	74.1	49
	Fuel conversion (light oil)	189.5	265.3	58	212.2	80	921.4	1290.0	21	1065.7	83	108.0	151.2	50	119.4	79
Coal firing boiler	Improvement of combustion method and dust collector	187.2	262.0	42	183.4	70	169.3	237.0	21	68.0	29	74.6	104.4	17	18.8	20
	Fuel conversion (crude oil)	187.2	262.0	42	183.4	70	169.3	-	-	-	-	-	-	-	-	-
	Light oil	-	-	-	-	-	-	237.0	21	113.2	48	74.6	104.4	17	50.1	48
Brick and clay pipe kiln	Improvement of combustion method	4.9	69	48	4.1	59	6.5	9.1	21	1.7	19	5.0	7.0	22	1.2	17
	Fuel conversion (natural gas)	4.9	6.9	48	6.2	90	6.5	9.1	21	9.1	100	5.0	7.0	22	2.9	41

Reduction rate in the table is the value achieved by the countermeasure

In the case of crude oil combustion boilers, reduction of SOx and NOx can be achieved as planned only by means of improvement of the combustion method. Fuel conversion to light oil can reduce the dust and NOx substantially.

For coal firing boilers, the dust collector will prove highly effective in reducing dust and the target can be achieved without considering improvement of the combustion method. It is essential however to ensure complete combustion because generation of unburnt dust means loss of the fuel.

Fuel conversion to crude oil is not appropriate because it may lead to increase in SOx, and thus conversion to light oil is desirable. Though the dust reduction effect achieved by conversion to light oil is not shown in Table 8.3.2, the effect may be considered nearly equivalent to the case of crude oil.

In the case of brick kilns, fuel conversion to natural gas will prove highly effective in reduction of SOx and NOx. Since immediate conversion is not possible in the present state, improvement of the combustion method or fuel reforming will be the best means for the time being.

As regards raising of the stack height, examination was made with a single stack while setting the emission rate to a level of the year 2001. The result is shown in Table 8.3.3.

Table 8.3.3 Maximum Concentration on Ground (one-hour value) in each facility

Smoke source	Wind speed	Atmospheric stability (m)	Height of stack (m)	Xmax (m)	Cmax		
					Dust ($\mu g/m3$)	SOx (ppb)	NOx (ppb)
Crude oil combustion boiler	2	C	25	571	29.7	32.9	14.4
			50	611	19.4	21.7	9.4
			100	683	10.3	11.3	5.0
Coal firing boiler	2	C	25	530	31.3	9.8	11.0
			50	573	19.4	6.0	6.8
			100	650	9.6	3.0	3.4

The result shows that the distance (Xmax) at which the maximum concentration on ground appeared increased by about 26% when the stack height was increased from 25m to 50m and about 78% when it was further increased to 100m in both facilities.

It is also known that the maximum concentration on ground (Cmax) was diluted by about 35% for the height of 50m and by about 70% for 100m.

When no countermeasure is taken up to the year 2001, the concentration on ground for crude oil combustion boiler will be 52 ppb when calculated with the atmospheric stability of A and the wind speed of 1 m/sec.

This factory has four boilers of approximately equal scale, and thus the actual emission rate is four-fold. This means that the concentration on ground becomes nearly four-fold at around 200 ppb.

When the relation of Mead et al, that is, "the value in 24 hours will become one half (0.59) of the one-hour value", is applied, this is 100 ppb. This SO_2 concentration complies with the daily average standard of 152.8 ppb for SO_2, but the localized high concentration may appear. Therefore, if raising of the stack height is to be applied to this facility, the stack must be more than 50m in height.

(2) Emission Reduction Rate

Based upon the result of the above examination, pollutant reduction rate in 2001 was set as follows for each facility for which the emission standard has been established:

$$\text{Reduction rate} = \frac{\text{Current emission standard (or theoretical value)} - \text{Long-term emission standard}}{\text{Current emission standard (or theoretical value)}}$$

Note that the boilers and brick and clay-pipe kilns to be covered here were those with the fuel consumption of 50 l/h or more for liquid fuel and 71.5 kg/h or more for coal. It was assumed that the target reduction can be achieved through the countermeasures shown in Table 8.3.1. The target reduction rate and reduction amount for each facility concerned are shown in Table 8.3.4.

Table 8.3.4 Air Pollutant Emission Reduction Rate by Facility Type in 2001

(Unit:%)

Facility Type	Fuel Type	Dust	SOx	NOx
Boiler	Light oil	-	-	25.0
	Other oils	57.7	21.7	50.0
	Coal	42.3	21.7	16.7
Kiln for bricks and clay pipes	Coal	42.3	23.7	22.2
Incinerator	Light oil	-	-	28.6
Other furnaces	Light oil	-	-	28.6

Note With boilers and kiln for bricks and clay pipes, pollutant emission reductions are applied only to those facilities that consume 50 ℓ/h and more of liquid fuels or 71.5 kg/h and more of coal

(3) Emission Reduction Amount

Air pollutant emission by facility type in 2001 when the control measures are taken is shown in Table 8.3.5. As was expected, it may safely be said boilers and brick and clay-pipe kilns are the target facilities.

Table 8.3.5 Air Pollutant Emission Reduction by Facility Type in 2001

(Unit:ton)

Facility Type	Dust		SOx		NOx	
	W.N.C	W.C	W.N.C	W.C	W.N.C	W.C
Boiler	1934.9	1058.0	6951.9	5605.8	1187.2	786.0
Kiln for bricks and clay pipes	1092.2	630.1	1674.7	1277.7	1109.6	863.1
Incinerator	-	-	-	-	0.4	0.3
Other furnaces	-	-	-	-	130.7	94.0
Total	3027.1	1688.1	8626.6	6883.5	2427.9	1743.9

Note W.N.C : Without control measures

W.C : With control measures

Air pollutant emission by industrial type is shown in Table 8.3.6.

The total annual emissions of Dust, SOx and NOx after the control measures are taken are 1,816 tons, 7,333 tons and 1,791 tons respectively. The reduction rates of Dust, SOx and NOx are 442.4%, 19.2% and 27.6% respectively.

Table 8.3.6 Air Pollutant Emission Reduction by Industrial Type in 2001

(Unit: ton/year)

No.	Industry	Dust		SOx		NOx	
		W.N.C	W.C	W.N.C	W.C	W.N.C	W.C
1	Food and kindered products	415.5	198.8	2022.3	1626.1	287.3	170.3
2	Drink feed	1028.9	562.2	2484.6	1946.3	550.0	385.3
3	Tobacco	6.0	6.0	29.1	29.1	3.4	3.4
4	Textile	171.5	118.6	949.3	789.0	123.7	79.4
5	Leather, leather products	2.5	2.5	34.8	27.4	4.3	2.3
6	Footgear products	14.9	8.3	73.7	61.5	8.7	5.4
7	Lumber and wood products	4.6	4.6	22.5	18.4	18.0	16.3
8	Furniture and fixtures	40.2	40.2	138.4	138.4	116.9	86.0
9	Pulp, paper and allied products	89.2	43.6	286.8	225.1	48.0	29.5
10	Industrial chemical products	20.0	10.0	96.1	77.5	12.4	7.1
11	Other chemical products	14.0	10.0	62.3	56.3	19.5	15.1
12	Petroleum, coal and products	32.6	24.0	72.5	56.8	9.2	5.0
13	Rubber products	15.8	15.8	88.5	88.5	16.4	14.6
14	Plastic products	0.2	0.2	0.0	0.0	1.1	1.1
15	Ceramic, stone and clay products	1088.3	628.0	1671.4	1275.3	1105.6	860.2
16	Glass products	7.2	7.2	66.2	66.2	8.4	8.4
17	Mineral and nonmetal products	0.0	0.0	7.0	7.0	3.0	2.4
18	Iron and steel	14.1	10.2	90.8	83.5	9.2	7.3
19	Non-ferrous metals and products	18.8	18.8	2.9	2.9	3.6	2.8
20	Transportation equipment	28.7	28.7	166.5	166.5	23.9	23.9
21	Auto industry	0.8	0.8	9.9	9.9	4.5	3.4
22	Other manufacturing industries	96.3	53.4	459.0	377.6	60.7	37.5
23	Hospitals	26.6	13.9	153.0	129.1	21.2	13.9
24	Hotels	15.7	8.1	86.8	73.0	15.7	10.1
25	Other establishments	2.7	2.7	1.5	1.5	0.4	0.4
	Total	3155.3	1816.6	9075.9	7332.8	2475.1	1790.8

Note W.N.C : Without control measures

W.C : *With control measures*

8.3.2 Control Measures for Motor Vehicles

(1) Control Measures Examined

As countermeasures for motor vehicles, were chosen exhaust emission control for new and used motor vehicles, supply of low-sulfur gasoline and control of traffic volume and flow.

① Exhaust gas regulation

a. New motor vehicles

As regards new automobiles (passenger car, jeep, light truck and microbus) of 1995 year and after, their emission rates of CO and HC per unit will be reduced to 1/10 of the current rates by introducing oxidation catalyst.

b. Used cars

Japan has have the experience of attaching the oxidation catalyst to passenger cars of 1975 year and after. Therefore, with all automobiles of 1975 year and after, their emission rates of CO and HC per unit will be reduced to 1/10 of the current rates by introducing the oxidation catalyst and secondary air into exhaust manifold.

Note that the effect of idling regulation was not estimated taking into consideration that it is a short-term measure, and its effect is very small because all automobiles of 1975 year and after will be under emission regulation in 2001.

The average emission rates of CO and HC for automobiles are shown in Table 8.3.7 assuming that automobiles of 1964 year and before are all scrapped before the year 2001.

Table 8.3.7 Average Emission Rates for Motor Vehicles with Control Measures in 2001

(Unit: g/km)

Vehicle	Item	Average Speed(km/h)								
		10	15	20	25	30	35	40	45	50
Automobiles	HC	1.24	0.87	0.68	0.59	0.52	0.47	0.44	0.41	0.38
	CO	12.12	9.15	7.45	6.56	5.98	5.56	5.21	4.80	4.50
	NOx	1.24	1.09	1.03	1.04	1.10	1.18	1.28	1.37	1.45
	SOx	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Buses	HC	17.96	13.59	10.75	8.75	7.30	6.24	5.39	4.70	4.20
	CO	309.15	236.41	187.86	154.69	130.77	112.25	98.81	88.29	79.98
	NOx	4.90	4.56	4.32	4.19	4.13	4.11	4.10	4.16	4.22
	SOx	0.84	0.72	0.67	0.63	0.61	0.59	0.58	0.57	0.56
Trucks	HC	17.51	13.82	11.09	9.03	7.47	6.32	5.38	4.63	4.11
	CO	301.85	234.75	186.09	151.25	125.69	105.99	92.02	81.49	73.35
	NOx	10.18	9.31	8.60	8.07	7.66	7.37	7.12	7.06	6.99
	SOx	1.73	1.49	1.37	1.30	1.26	1.22	1.20	1.18	1.16

② Supply of low-sulfur gasoline

The sulfur content in gasoline need be reduced to 0.01% or less if the oxidation catalyst is to be installed to automóviles. This time, the sulfur content was planned to be reduced from 0.06% to 0.01%. The average emission rates for SOx will change as shown in Table 8.3.7.

③ Control of traffic volume

Now introduction of the passenger railway and improvement of the trolley bus service are being planned. 15% of the total bus users will change into passenger railway users, and 5% of them will change into trolley bus users. So, 20% of the total traffic volume of buses will be reduced.

④ Control of traffic flow

It was assumed that the measures taken for buses in Caracas Street would raise the vehicle driving speed by 5 km/h for buses, automóviles, and camiones during week days.

The control measure to be taken are summarized in Table 8.3.8.

Table 8.3.8 Summary for Countermeasures for Motor Vehicles

Item	Target	Contents	Target Air Pollutant			
			CO	HC	SOx	NOx
Exhaust gas regulation	New automobiles of 1995 year and after	Introduction of Oxidation catalyst	O	O		
	Used automobiles of 1975 year and after	Introduction of Oxidation catalyst and secondary air into the exhaust manifold (start year: 1995 end year: 2001)	O	O		
		Periodic inspection at idling	O	O		
Control of traffic volume	Buses	Improvement of trolly bus system	O	O	O	O
		Introduction of passenger railway	O	O	O	O
Control of traffic flow	Buses	Speed-up by improving bus stop system	O	O	O	O

(2) Pollutant Reduction Amount

The air pollutant reduction amount achieved by the control measures described above is shown in Table 8.3.9.

Table 8.3.9 Air Pollutant Emission Reduction from Motor Vehicles in 2001

(Unit:ton/year)

	HC		CO		SOx		NOx	
Vehicle Type	W.N.C	W.C	W.N.C	W.C	W.N.C	W.C	W.N.C	W.C
Automobiles	18,419	3,355	214,435	38,385	701	118	7,458	7,461
Buses	7,905	6,263	139,675	110,706	814	649	3,695	2,950
Trucks	2,623	2,612	44,265	44,092	542	542	2,733	2,731
Total	28,947	12,230	393,375	193,183	2,057	1,309	13,886	13,142

Note W.N.C : Without cotrol measures

W.C : With control measures

The total annual emission of CO, HC, SOx and NOx in 2001 when the control measures are taken are 193,183 tons, 12,228 tons, 1,307 tons and 13,142 tons respectively. The reduction ratios of CO, HC, SOx and NOx are 51.5%, 57.8%, 36.5% and 5.4% respectively.

8.3.3 Summary for Air Pollutant Reduction Amount

The reduction amount by source when the control measures for factories and motor vehicles are taken is shown in Table 8.3.10.

Table 8.3.10 Air Pollutant Emission Reduction by Source in 2001

(Unit:ton/year)

Classification	Source	Dust		SOx		NOx		CO		HC	
		W.N.C	W.C	W.N.C	W.C	W.N.C	W.C	W.N.C	W.C	W.N.C	W.C
Stationary Sources	Factories and Establishments	3,155	1,816	9,076	7,333	2,475	1,791	-	-	-	-
Mobile Sources	Motor Vehicles	-	-	2,057	1,309	13,886	13,142	398,375	193,183	28,947	12,230
	Aircraft	-	-	29	29	114	114	-	-	-	-
Total		3,155	1,816	11,162	8,671	16,475	15,047	398,375	193,183	28,947	12,230

Note W.N.C : Without control measures

W.C : With control measures

The annual emission in 2001 when the control measures are taken is 1,816 tons, 193,183 tons, 8,671 tons, 15,047 tons and 12,230 tons for Dust, CO, SOx, NOx, and HC. The emission reduction rate of Dust, CO, SOx, NOx and HC is 42.4%, 51.5%, 22.3%, 8.7% and 57.8% respectively.

The total air pollutant emission in 1991 and that in 2001 with the control measures is summarized in Table 8.3.11.

Adoption of the control measures will reduce the total annual amount of Dust, CO and HC compared to that in 1991 by 17%, 33% and 38% respectively.

Table 8.3.11 Summary for Air Pollutant Emission

(Unit:ton/year)

Pollutant	1991	2001	
		W.N.C	W.C
Dust	2,198 (1.0)	3,155 (1.44)	1,816 (0.83)
CO	288,433 (1.0)	398,375 (1.38)	193,183 (0.67)
SOx	7,802 (1.0)	11,162 (1.43)	8,671 (1.11)
NOx	11,052 (1.0)	16,475 (1.49)	15,047 (1.36)
HC	19,845 (1.0)	28,947 (1.46)	12,230 (0.62)

Note W.N.C: Without control measures

W.C : With control measures

( ) : Emission ratio to that in 1991

8.3.4 Prediction of Concentration Distribution after Execution of Control Measure

(1) Prediction of Concentration at Monitoring Stations and Maximum Concentration Point

Predicted result of each pollutants with control measure at monitoring stations and maximum concentration point is shown in Table 8.3.12.

Note that predicted value contains background concentration same as the present state.

Though predicted concentration is averaged value of 6 months, compared result of these concentration to the target concentration is follows.

SO_2 concentration at all predicted points is less than the target concentration (38.2 ppb).

NO_2 concentrations at all predicted points is also less than the target concentration (53.2 ppb).

Though CO concentration is reduced by control measure at each predicted points and number of points which is less than the target concentration, increases, concentration at E. San Juan de Dios and maximum concentration point is more than the target (3.6 ppm).

Table 8.3.12 Computed Concentration with Control Measure

Items / Stations	SO_2 (ppb)	NOx (ppb)	NO_2 (ppb)	CO (ppm)
A. Servicio de Salud	13.4	90.9	36.7	3.46
B. Laboratorio	15.1	64.3	30.6	2.62
C. Puente Aranda	21.7	66.0	31.0	2.38
D. El Tunal	9.8	20.1	16.6	1.37
E. San Juan de Dios	20.1	130.2	44.4	4.91
Cmax Point Mesh Index	34.6 (12,15)	154.1 (12,15)	48.5 (12,15)	4.42 (12,15)

The concentration change of present state, in future and with control measure is shown in Fig. 8.3.1 - Fig. 8.3.3.

In future, SO_2 concentration is increased according to increasing of fuel consumption at factories and of traffic volume, and concentration at a few points becomes more than the target.

However the concentration is reduced to the level of present state on account of control measure, and target concentration is cleared at all points.

NO_2 concentration is increased in future same as the case with SO_2.

However the concentration is reduced to be less than the level in future on account of control measure, and target concentration is cleared at all points.

CO concentration is more than the target at a few points under present state.

In future, the concentration is increased according to increasing of traffic volume, and concentration at most of points becomes more than the target.

However the concentration is reduced less than the level of present state on account of control measure, and target concentration is generally cleared excluding along roads.

Note that, as CO dispersion model has probability to under estimate the concentration along roads, CO concentration in future may become more than that predicted.

So attention shall be paid to change of the concentration along roads from now to future.

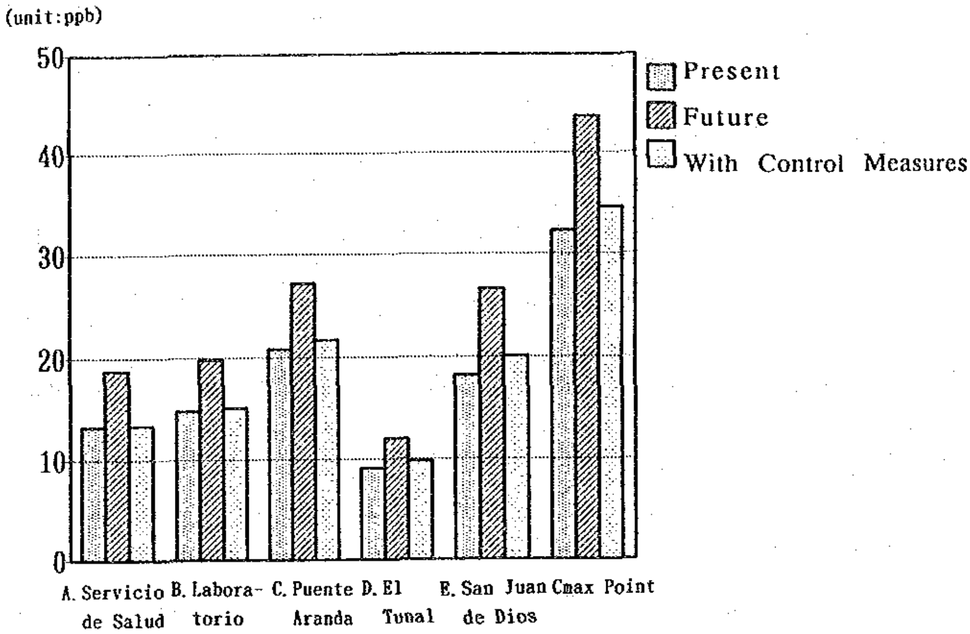


Fig. 8.3.1 SO_2 Concentration by Computed Cases

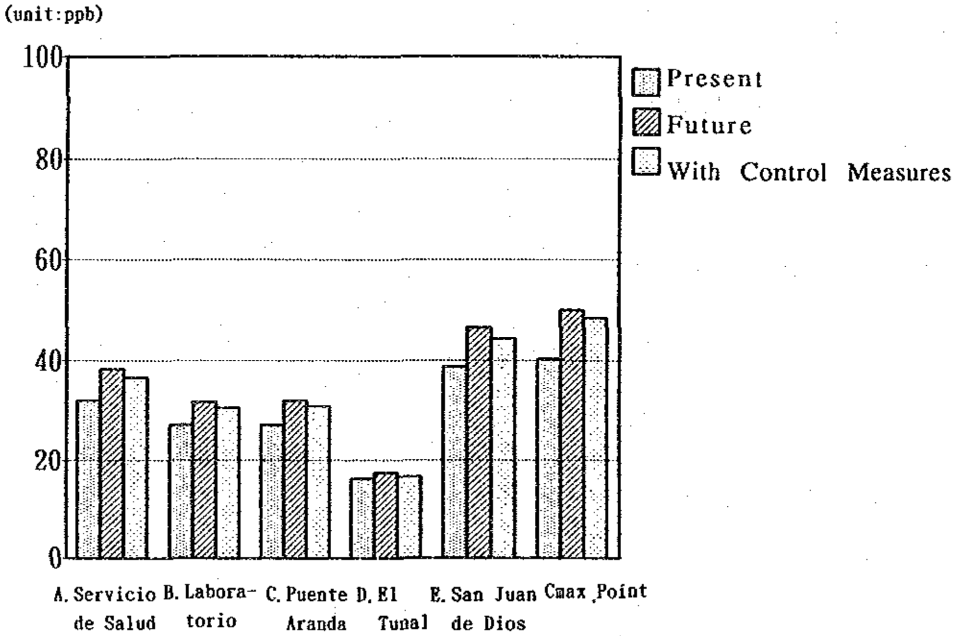


Fig.8.3.2 NO_2 Concentration by Computed Cases

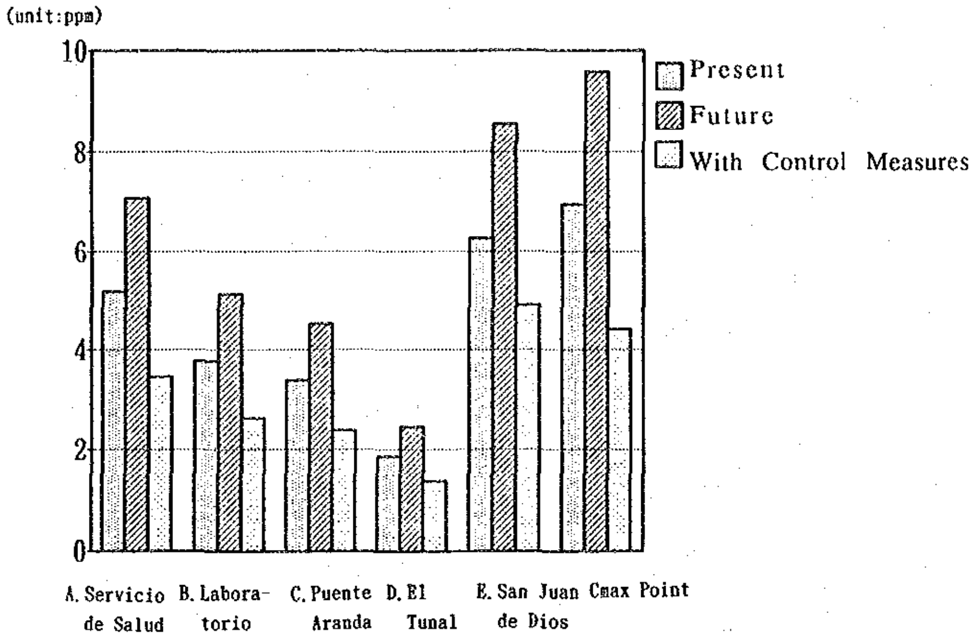


Fig. 8.3.3 CO Concentration by Computed Cases

(2) Prediction of Plane Concentration Distribution

The plane distribution of concentration when the control measures described in the previous item are assumed to have been taken can be predicted as follows.

The contribution concentration distribution by source is described in Appendices.

① SO_2

The result of prediction on the SO_2 plane concentration distribution after control measures is shown in Fig. 8.3.4. The concentration of 20 ppb or more will be distributed over the area similar to the present state and the maximum concentration appearing in the mesh index (12, 15) similar to the present state will drop to 34.6 ppb which is nearly equivalent to the present level.

② NO_x, NO_2

The result of prediction on the NO_x plane concentration distribution after control measures is shown in Fig. 8.3.5. The concentration of 80 ppb or more will be distributed in the area similar to the future prediction, but its size will decrease. The maximum concentration of

154.1 ppb (slightly lower than the predicted future level) will appear in the mesh index (12, 15) similar to the future prediction.

The result of prediction on the NO_2 plane concentration distribution is shown in Fig. 8.3.6. The trend of concentration distribution is similar to the case with NOx, with the maximum concentration at 48.5 ppb (slightly lower than the predicted future level) in the mesh index (12, 15).

③ CO

The result of prediction on the CO plane concentration distribution is shown in Fig. 8.3.7, The trend of concentration distribution is similar to the case with NOx, and the maximum concentration of 4.4 ppm (lower than the current level) appears in the mesh index (12, 15) similar to the case with SO_2 and NOx.

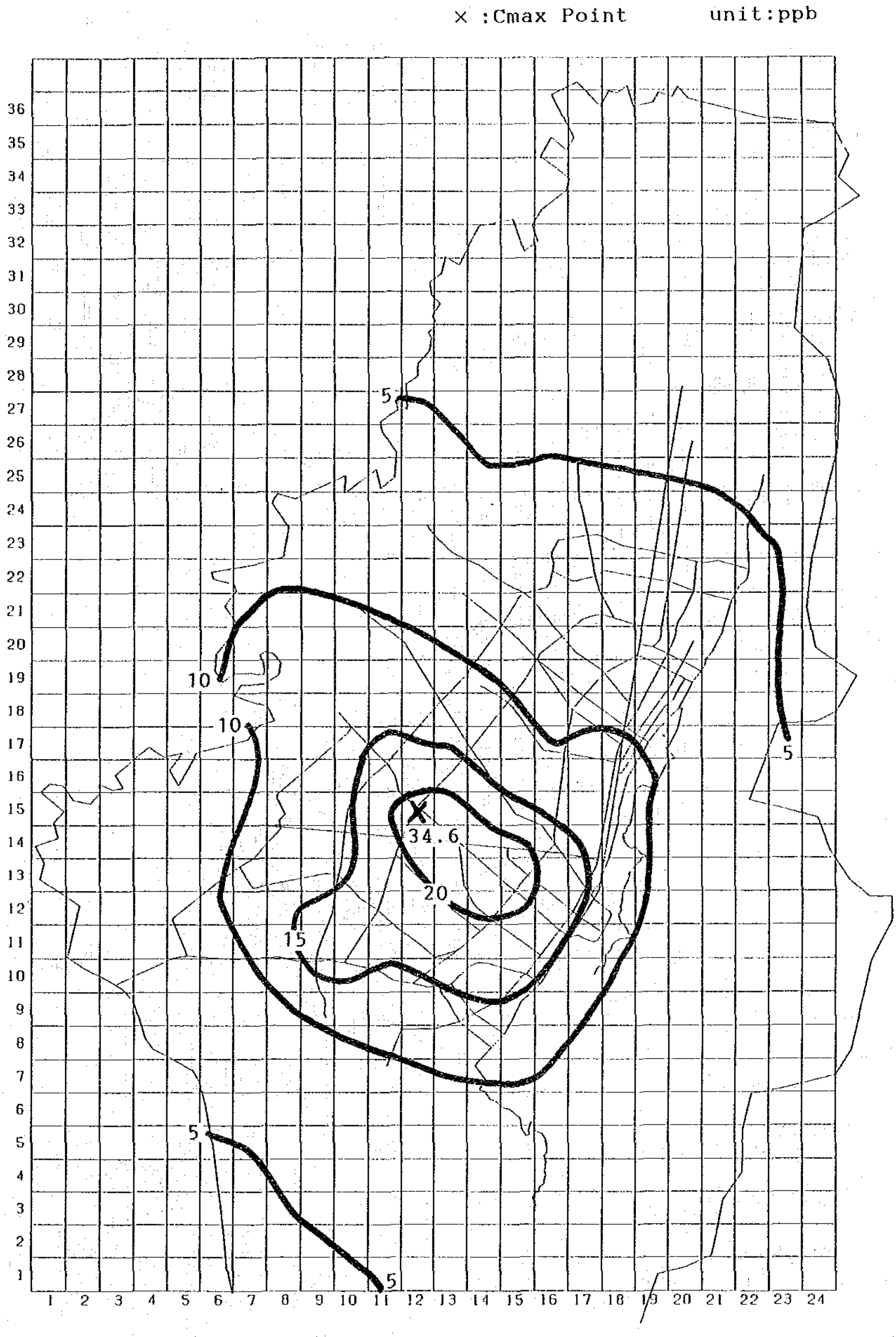


Fig. 8.3.4 Average Concentration Isopleths for SO_2 (All Source)

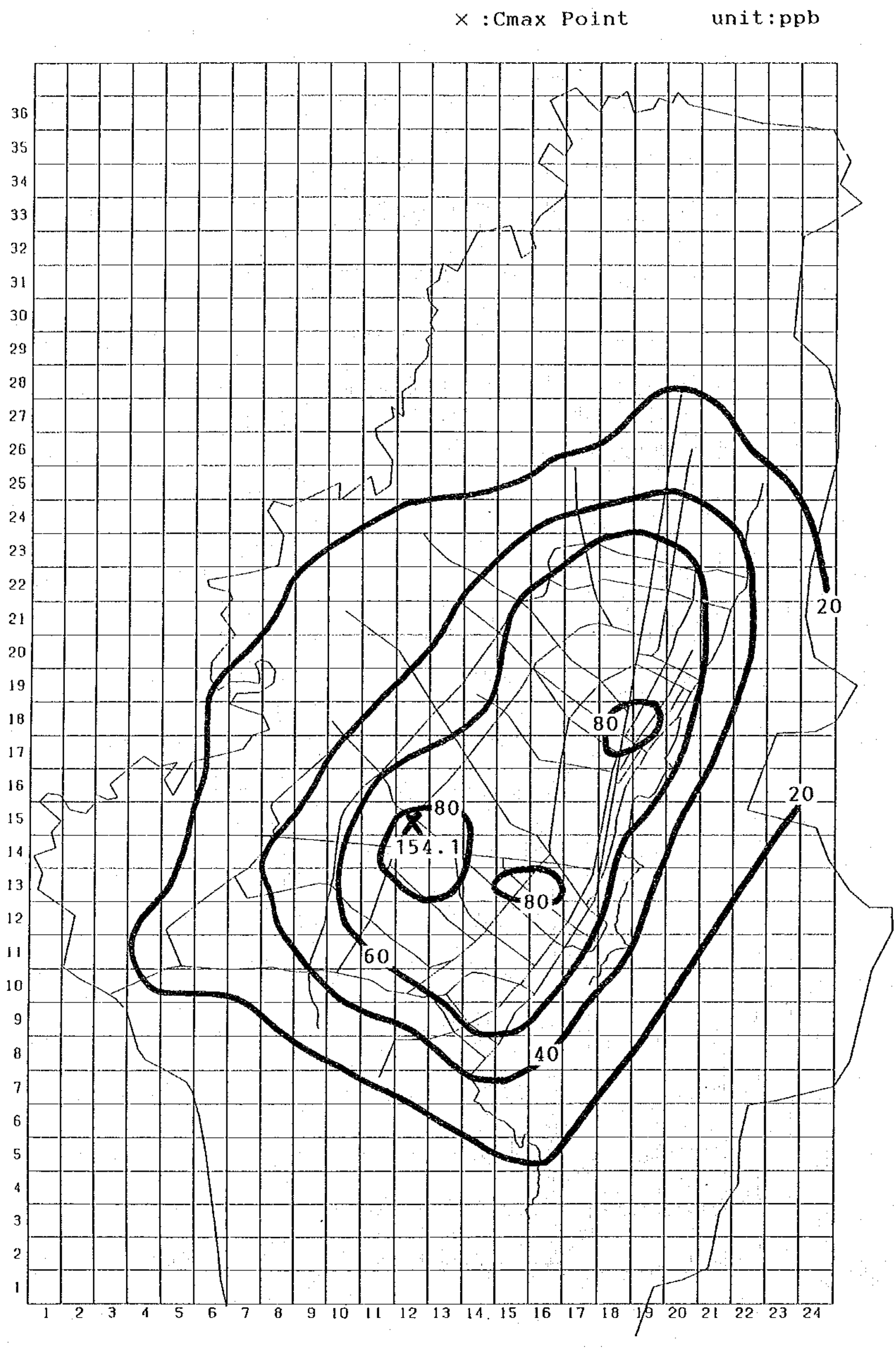


Fig. 8.3.5 Average Concentration Isopleths for NOx (All Sources)

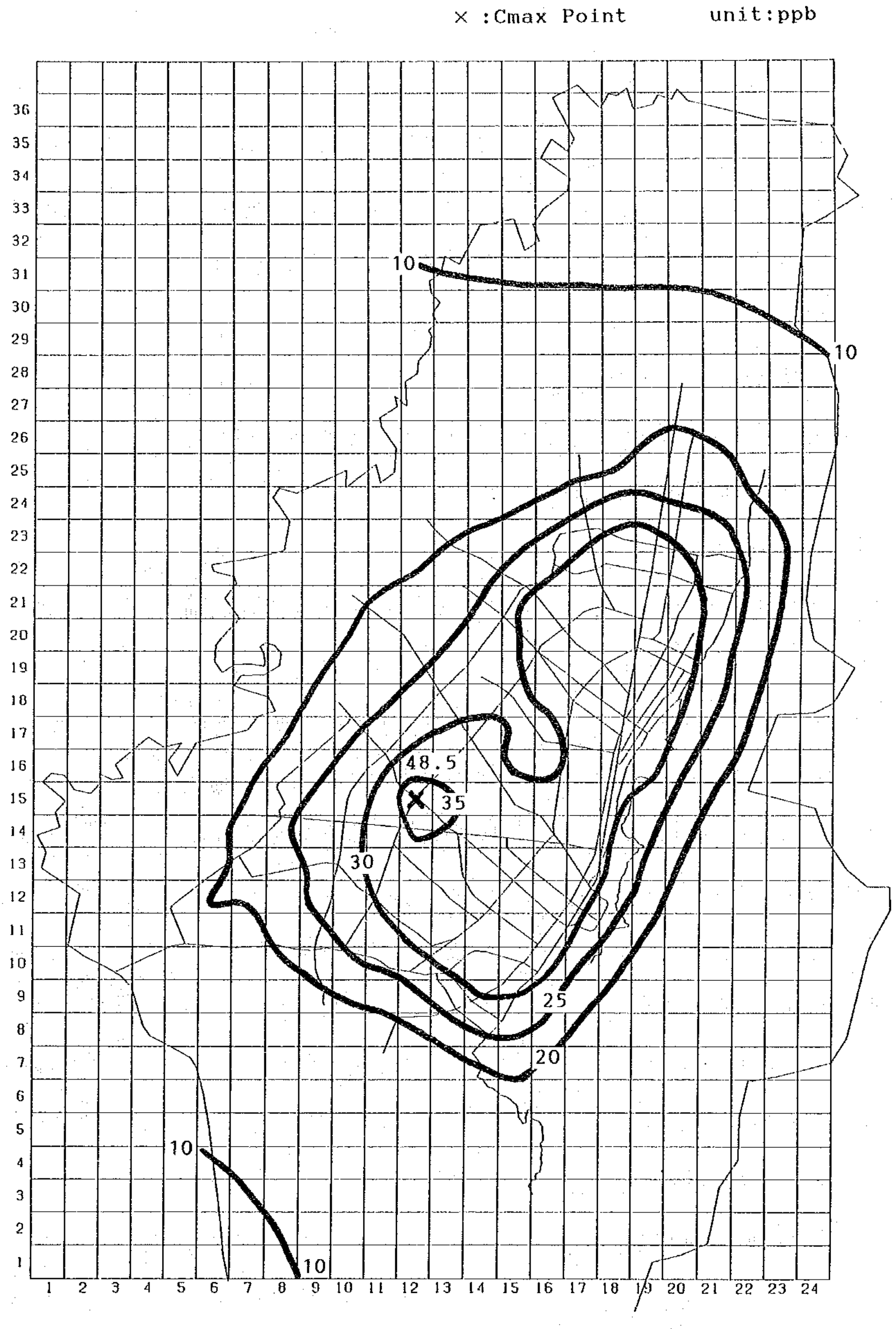


Fig. 8.3.6 Average Concentration Isopleths for NO_2 (All Sources)

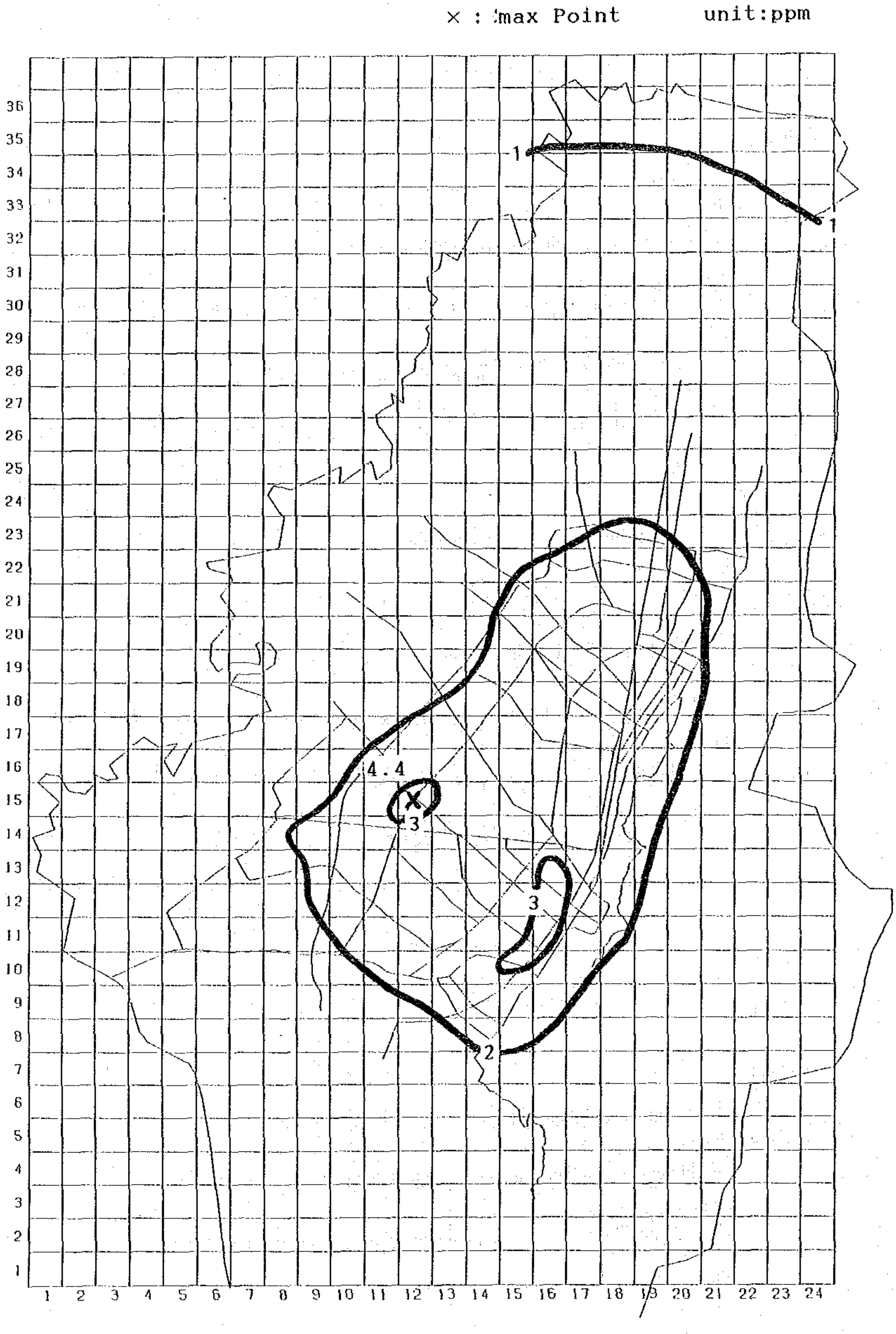


Fig. 8.3.7 Average Concentration Isopleths for CO (All Sources)

CHAPTER 9 GUIDELINE FOR CONTROL MEASURES

CHAPTER 9 GUIDELINE FOR CONTROL MEASURES

9.1 Target

9.1.1 Basic Concept

The City of Bogota, which is the capital of Colombia, has grown up rapidly as the center of government and economy, so that the population has now reached near five million whereas it was one million in 1950s. Air pollution has become more and more grave on the contrary to the active state of economy. The process of population growth has been at the same time the process of urban expansion. As the fringe area of the city shifts gradually outward, plants which were originally located in the suburbs have come to be involved in a new urban area. On the other hand, the expansion has brought the new traffic demand to connect the city center with surrounding residential areas.

The government of Colombia, who established the environmental standard on ambient air quality and the emission standard for stationary sources in 1982, has made efforts to prevent air pollution since then, however, according to the result obtained in this study, the concentration of carbon monoxide (CO) and ozone (O_3) exceeded the environmental standard on ambient air quality in certain areas. In connection with the high concentration of ozone, the concentration of hydrocarbon (HC) showed also the considerably high level though no standard value is given.

On the other hand, the result of sampling inspection concerning diseases in Santafe de Bogota shows that respiratory diseases have been top ranked constantly in disease incidence rate since 1985.

Bogota is still in the course of growth and will have the concentration of about 20% of the national population in the beginning of the 21st century. In order to protect the health of citizens and to preserve the comfortable living environment, air pollution control measures corresponding to the economic development are indispensable. These control measures should cover not only direct pollutant sources (factories, motor vehicles, etc.), but also their background conditions, such as improvement of the traffic flow, rationalization of the public transport, fuel improvement, and rationalization of land utilization.

In this context, the guideline is intended to propose systematized policies to settle problems fundamentally toward the future, taking into account all phenomena forming the background of air pollution.

9.1.2 Target Level of Ambient Air Quality

Pollutants to be covered by this guideline are SO_2, NO_2, SPM, CO, non-methane hydrocarbon, and O_3 originated from factories, motor vehicles, and their pertinent facilities. The target level is fundamentally defined as the same level to the ambient air quality standard now in power, however for O_3, there is no direct reduction measure so that the target level should be attained indirectly through reducing non-methane hydrocarbon (NMHC), which is source substance of O_3. As for non-methane hydrocarbon, because there is no substantive enactment in the ambient air quality standard, the target level is to be defined by referring to the standard of Japan. But it is necessary in future to review the target value through the analysis on the relation between the concentration of O_3 and NMHC, which will be based on the accumulated data of air quality monitoring. Therefor the tentative target value is given as Table 9.1.1.

Table 9.1.1 Target Level of Ambient Air Quality

Item	Value	Standard Value
SPM	Annual Mean Value	76.8 μg/m³
	Daily Mean Value	307.2 μg/m³
SO_2	Annual Mean Value	76.8 μg/m³
	Daily Mean Value	307.2 μg/m³
	3-hour Value	1152.0 μg/m³
CO	8-hour Value	11.5 mg/m³
	1-hour Value	38.4 mg/m³
O_3	1-hour Value	130.6 μg/m³
NOx	Annual Mean Value	76.8 μg/m³
N.M.HC	Annual Mean Value	0.5 ppmC

9.1.3 Pollutant Reduction Target

It is essential for achievement and maintenance of the above-described ambient air quality in future to take into consideration the expected growth of pollutant generation from the current level (Table 9.1.2) to the presumed along with the growth of the society (Table 9.1.3).

Accordingly, the pollutant reduction target on Table 9.1.3 is to be estimated as follows for each pollutant.

a) Dust: Reduction of pollutant emission amount from stationary sources by 10 to 20% for short term and by about 40% for long term.

b) Nitrogen oxides: The estimated NOx amount in Table 9.1.3 may be below the limit of Colombian Air Pollution Control Act. However, following measures are considered to obtain the target value. Reduction of emission amount from stationary sources is about 50% for crude oil combustion boilers and about 17% for coal firing boilers.

As the reduction from motor vehicles in use is difficult, traffic control measures are taken into account for the purpose.

However, the authority of Bogota should try to keep the emission amount below the current one in Table 9.1.2 by other means.

c) Sulfur oxides: Reduction of emission amount from stationary sources should be 7% for short term and 20% for medium to long terms.

d) Carbon monoxide: Reduction of emission amount should be 50% in 2001 AD from the one in Table 9.1.3. However, in order to reduce concentration within the limitation around raods, 60% of reduction from Table 9.1.3 is required.

e) Non-methane hydrocarbon: Reduction of emission intensity from motor vehicles should be 2/3 for long term.

The current emission standard need to be modified as required to achieve the target values described above. Namely, expansion of the scope of applicable facilities and augmentation of the standard values necessary to reduce emission from stationary sources. It is necessary to establish the new emission standard for motor vehicles, which requires improvement and addition of measuring instruments and an organization for execution.

Achievement of the above reduction target means successful suppression of the pollutant emission amount over the entire city as of 2001 to the level shown in Table 9.1.4.

Table 9.1.2 Estimated Air Pollutant Emission Amount over the Entire City (Present)

(unit: ton/y)

	SOx	NOx	CO	Dust	HC
Factories and Establishments	6,504	1,688	-	2,198	-
Motor Vehicles	1,269	9,250	288,433	-	19,845
Airplanes	29	114	-	-	-
Total	7,802	11,052	288,433	2,198	19,845

Table 9.1.3 Estimated Air Pollutant Emission Amount over the Entire City (with no control measures taken, in 2001)

(unit: ton/y)

	SOx	NOx	CO	Dust	HC
Factories and Establishments	9,076	2,475	-	3,155	-
Motor Vehicles	2,057	13,886	398,377	-	28,945
Airplanes	29	114	-	-	-
Total	11,162	16,475	398,377	3,155	28,945

Table 9.1.4 Estimated Air Pollutant Emission Amount over the Entire City (Reduction target achieved: in 2001)

(unit: ton/y)

	SOx	NOx	CO	Dust	HC
Factories and Establishments	7,333	1,791	-	1,816	-
Motor Vehicles	1,307	13,142	193,183	-	12,228
Airplanes	29	114	-	-	-
Total	8,669	15,047	193,183	1,816	12,228

Note: Vacant columns mean the relevant emission are not included in the range of this study.

9.2 Execution Plan

9.2.1 Description of Control Measures

(1) Basic Policy

Since the control measure plan is to be executed in line with the environmental reduction targets described in the previous section, the pre-requisite thing is the institutional preparation on which the measures rest as a definite administrative subject to achieve the targets.

Especially, the current air pollutant emission standard must be revised. That is to say, the scope of regulation must be expanded and the standard made more strict for stationary sources while the new emission standard must be introduced for motor vehicles.

Measures for the whole area and for specific area will be proposed below. The former can be divided into short-term and long to medium term measures. Short-term measures are intended to improve the current state with relatively small economical burden through execution as early as possible. Long to medium term measures are aimed at structural improvement compatible with the future economical growth through steady and careful preparation. The short term measures are scheduled to be completed by 1995 while the target year for completion of long to medium term measures are set at 2001 in view of the scope covered by the population estimation. Note that long to medium term measures may have to be extended further according to the social development state or the progress of measures in future.

Among the measures for the whole area, those related to the organization are assumed to be started early and continued for medium to long periods in order to maintain and develop the effect of control measures. The measures for the specific area are to propose certain candidate countermeasures to be added further to specific areas where achievement of the environmental target cannot be confirmed, if necessary based on the estimated effectiveness of general measures.

The kind of pollutants which highly require wide-area control measures includes CO and non-methane hydrocarbon, for which the high reduction target has been set, followed by NOx, SOx, and dust in the order. This fact should be taken into account when the priority order is to be established among control measures. If the necessity of local control measures requires particular consideration, the conditions of an area concerned should be preferred.

(2) Countermeasure for the Whole Area (Institutional)

1) Revision of Emission Standards

a) Competent Authorities

- National and metropolitan government (MS and SSB, MOPT•INTRA and their corresponding local authorities)

b) Relevant Persons

- Owners of stationary sources and their association
- Car assemblers, dealers and repair shop owners
- Car owners

c) Content of Countermeasure

The emission standard is to be revised to regulate pollutant emission more severely that ever. As for the standard for mobile sources, which has not ever promulgated, it is now under preparation by MS and SSB It is desirable to establish the emission standard for mobile sources as early as possible. As for the standard for stationary sources, a series of revision is proposed as shown in Table 9.2.1.

Table 9.2.1 Proposed Emission Standard for Stationary Sources

① Standard for Boiler

• Dust

Fuel	x ($kg/10^6kcal$)	Standard Value ($kg/10^6kcal$)			
		Existing	for Short Term Measure	for Medium to Long Term Measure	On
Mixed oil	1.14	(1.42)	1.18	0.06	4%
Coal	0.77	1.68	1.39	0.97	6%
Others	-	(1.61)	1.34	0.84	6%

Note: ①x : actually measured value through this study

②On : oxygen concentration regarded as normal condition

③( ) : assumed value

• NOx

Fuel	x (ppm)	Standard Value (ppm)		
		for Short Term Measure	for Medium to Long Term Measure	On
Mixed oil	240	500	250	4%
Light oil	214	400	300	4%
Coal	213	420	350	6%
Others	-	400	300	6%

• SOx

Fuel	Theoretical value (ppm)	Standard Value (ppm)			
		For Short Term Measure	for Medium Term Measure	for Long Term Measure	On
Mixed oil	1,340	1,250	1,200	1,060	4%
Coal	353	330	320	280	6%
Others	1,340	1,250	1,200	1,060	4%

② Other Facilities

- The standard value of dust for coal boiler is also applied to this kind of facilities, however, the designated facility should be limited to two types: asphalt plant and kiln for brick or earthen pipe.

• NO_2

Facility Type	Fuel	Standard Value (ppm)		
		for Short Term Measure	for Medium to Long Term Measure	On
Kiln for brick or clay pipe	coal	450	350	16%
Heating furnace	diesel oil	280	200	15%
Asphalt plant	diesel oil	250	230	16%
Incinerator	diesel oil	300	250	12%
Direct heating furnace	diesel oil	220	170	6%

• SOx

Facility Type	Fuel	Theoretical Value (ppm)	Standard Value (ppm)			
			For short Term Measure	for Medium Term Measure	for Long Term Measure	On
Kiln for brick or clay pipe	coal	118	110	100	90	16%
Asphalt plant	crude oil	395	370	360	310	16%

d) Time of Implementation: as soon as possible

e) Expense and Bearer

The expense for the process of preparing the system should be paid officially. On the other hand the expense for implementation of control measure to each facility concerned should be paid by respective owner.

f) Source of Revenue

The official source should be supplied from general accounts, and the payment of private sectors should be done by their own funds.

2) Cultivation of Operator of Stationary Sources

a) Competent Authorities

- National and metropolitan government (MS·SSB,MDE·MEN and their corresponding local authorities)

b) Relevant Persons

- Owners of stationary sources and their operators

c) Content of Countermeasure

- Cultivate combustion engineer
- Cultivate boiler inspection engineer
- Cultivate watchmen on discharged smoke
- Establish an organization or a division inside to cope with the duty mentioned above
- Found a research institute on combustion and exhaust gas treatment

d) Time of Implementation: by the year of 1995

e) Expense and Bearer

The expense for establishment of new organization or division should be paid officially by means of diversion of existing manpower and facility to new organization. A part of expense of cultivating cost should be paid by the relevant enterprises.

f) Source of Revenue

The official source should be supplied from general accounts.

3) Reinforcement of Regulation on Stationary Sources

a) Competent Authorities

- National and metropolitan government (MS·SSB MDE·MOSO and their corresponding local authorities)

b) Relevant Persons

- Owners of stationary sources and their operator of the facility concerned

c) Content of Countermeasure

- Establish the qualification system for combustion manager
- Establish the official inspection system on boilers
- Establish the official watching system on discharged smoke, which is conducted by qualified watchman through measuring of Ringermann concentration with the target of No.2
- Establish the system of self monitoring and data recording
- Investigate corresponding urgent measure in case that casually intensive pollution has been caused

d) Time of Implementation

The equipment and personnel should be provided by the year of 1995 and be brought into practice by the year of 2001.

e) Expense and Bearer

The expense for establishment of new system should be paid by the competent authorities as well as the expense for the equipment. And the amount is estimated as follows.

- Equipment for bolder inspection
  2 set x @ $500,000 = $1 million
- Equipment for measuring smoke concentration
  10 set x @ $18,000 = $0.2 million
- Subtotal $1.2 million

f) Source of Revenue

- supplied from general accounts

4) Revision of Motor Vehicle Inspection and Registration System

a) Competent Authorities

- National and metropolitan government (MOPT-INTRA and their corresponding local authorities)
- Police

b) Relevant Persons

- Vehicle owners and repair shop owners

c) Content of Countermeasure

- Designate the registration office for those used in the City of Bogotá
- Introduce the compulsory periodical examination in view of pollutant emission reduction with the report on the result of compliance to the emission standard when revising the annual resistration
- Stipulate the requirement of private repair shop to be assigned the compulsory examination.
- Resume the inspection on exhaust gas in idling mode
- Install the measuring equipment mentioned above to the private repair shops and to the resistration office.
- Stipulate the detail of the inspection such as inspection method, compliance requirement and interval of inspection

d) Time of Implementation

The establishment of legal system and the acquisition of equipment should be attained by the year of 1995 and the system should be brought into practice by the year of 2001.

e) Expense and Bearer

The expense for the equipment should be paid by both private car repair shops and the competent authorities according to the ownership. The amount of investment is estimated assuming CO and HC measuring units are installed enough to measure half of the total vehicles of about 550,000 in Cundinamarca state and Bogota City, with the interval of once a year, as follows.

- for private repair shops
  30 set x @ $4 million = $120 million
- for official inspection office
  30 set x @ $4 million = $120 million
- Subtotal $240 million

f) Source of Revenue
The official source should be supplied year by year from the special accounts, and the payment of private sectors should be done by their own funds. The capital will be gotten back by the charge of measuring service in future. Assuming the capacity of measuring unit is 1,000 vehicles per year and its span of life is 5 years, the depreciation will be approximately $800 per vehicle.

5) Establishment of Type Approval System of Motor Vehicle about Exhaust Gas

a) Competent Authorities
- National government (MOPT, INTRA)

b) Relevant Persons
- Vehicle owners, assemblers, dealers and repair shops

c) Content of Countermeasure
- Establish the type approval system for new model about exhaust gas
- Found a new inspection agency to cope with the submission of type approval
- Install Chassis dynamometers to the new inspection agency

d) Time of Implementation: by the year of 2001

e) Expense and Bearer
The expense for the equipment should be paid by the competent authorities. The amount of expense is estimated assuming to install 2 set, as follows.
  2 set x @ $1,385 million = $2,770 million

f) Source of Revenue

The source should be supplied from the special accounts, however, it is worth consideration to introduce the loan from the international development finance organization. The capital invested will be gotten back by the charge of inspection, which the buyers of new model will eventually pay.

6) General Instruction of Drivers on Motor Vehicle Operation

a) Competent Authorities

- National and metropolitan government (MOPT, INTRA and their corresponding local authorities)
- Police

b) Relevant Persons

- Vehicle owners
- Enterprises of public transportation

c) Content of Countermeasure

Through the driver eduction which is excuted when driving license issued or renewed, or the propaganda by means of mass media, the following instruction should be given for the purpose of preventing the air pollution.

- Excute the periodical examination and maintenance of the vehicle
- Avoid rapid start or acceleration
- Avoid long time idling
- Promote the use of public transit system as far as possible
- Avoid parking at the roadside
- Drive at an appropriate speed
- Check the vehicle at the beginning of every ride
- Tune up the air-fuel ratio according to the altitude of the place where the vehicle is to be used

d) Time of Implementation: by the year of 1995

e) Expense and Bearer

- paid by the competent authorities

f) Source of Revenue

- from general accounts

7) Treatment of Diesel Motor Vehicles

a) Competent Authorities

- National and metropolitan government (MOPT, INTRA and their corresponding local authorities)
- Police

b) Relevant Persons

- Diesel motor vehicle owners

c) Content of Countermeasure

- Restrain diesel vehicles from driving into the central zone of the City

d) Time of Implementation

- Complete the legal basis by the year of 1995

e) Expense and Bearer

- paid by the competent authorities

f) Source of Revenue

- from general accounts

8) Review of the Tax Imposing System on Vehicles

a) Competent Authorities

- National and metropolitan government (MOPT·INTRA·MHCP and their corresponding local authorities)
- Police

b) Relevant Persons

- Vehicle owners, assemblers, dealers and repair shops

c) Content of Countermeasure

- Introduce progressive assessment system according to the age of vehicles

- Tax reduction for those vehicles already treated in view of pollutant emission reduction
- Plan to increase revenue totally and appropriate the extra income to the fund for providing subsidy to those who conduct emission control measures

d) Time of Implementation : by the year of 2001

e) Expense and Bearer

The expense for establishment of new system should be paid by the competent authorities, and the expense for the increment of tax should be paid by vehicle owners.

f) Source of Revenue

The official source should be supplied from general accounts.

9) Establishment of Prevention System against Hydrocarbon Evaporation from Stationary Sources

a) Competent Authorities

- National and metropolitan government (MS·SSB, MDE and its corresponding local authority)
- ECOPETROL

b) Relevant Persons

- Petroleum distributors
- Paint and solvent distributors and their users

c) Content of Countermeasure

This item has not been regarded as the object of regulation, however, it is needed to regurate in near future, so the following activities are requested to set about.

- Grasp the present situation of object facilities
- Investigate the improvement of object facilities
- Investigate the measuring technic on HC emission
- Prepare a guideline on HC emission reduction

d) Time of Implementation : by the year of 2001

e) Expense and Bearer
The expense for establishment of new system should be paid by the competent authorities.

f) Source of Revenue
The official source should be supplied from general accounts.

10) Establishment of Subsidy System for Private Investment on Air Pollution Control

a) Competent Authorities
- National and metropolitan government (MS·SSB, MDE·MOPT·INTRA MHCP and their corresponding local authorities)

b) Relevant Persons
- Owners of stationary sources
- Manufacturers and distributors of equipment concerned
- Vehicle owners, dealers and repair shops
- Enterprises of public transportation
- Distributors of measuring equipment
- Enterprises of measuring services

c) Content of Countermeasure
The countermeasures against air pollution should be done fundamentally on account of the owners of the facilities concerned, however, it is liable that the owners do not have enough financial capability or the early response brings the owners a certain disadvantage in economical competition, so that the following assistance by governmental authorities will be necessary.

- Reduce income tax for those small enterprises who have invested on pollution control measures.
- Establish a long-term low-interest loan system for the investment on equipment for pollution control or move the facilities out of the City.
- Apply the same system to bus owners in charge of public transportation in case of changing their buses to new ones or adopting countermeasures for pollution control.

- Assist private vehicle owners to install catalyst unit to their vehicles by way of supplying subsidy.

d) Time of Implementation : by the year of 2001

e) Expense and Bearer

The bearer is fundamentally the owner of vehicle or facility.

f) Source of Revenue

The source of the expense for stationary sources is to be collected basically from the whole enterprises which keep the facilities to be treated for pollution control in proportion to the contribution to air pollution. The source of the expense for mobile source is to be supplied from the fund which will be formed through the review of tax imposing system on vehicles.

11) Deliberate Reorganization of land Use in the City

a) Competent Authorities

- National and metropolitan government (DNP·MOPT·IDU and their corresponding local authority)

b) Relevant Persons

- Resident, businessman and land owner in the City

c) Content of Countermeasure

Aiming to construct low-polluted city, reorganization of land use should be planned. Particularly the following items are to be taken into consideration under the process of planning.

- Reconstruct the structure into the multi-centrafized type for the purpose of dispersing the present traffic flow concentrating to the central zone.
- Connect the multi-center by mass transit system without air pollutant emission
- Stimulate those factories who are difficult to adopt countermeasures against air pollution to move out of the City, and at the same time restrain the new construction or extension of such factories as is liable to cause air pollution.

- Preserve green area in the City, and promote forestation around the intersections and roadsides of arterial roads.

d) Time of Implementation : by the year of 2001

e) Expense and Bearer
- to be paid by the competent authorities

f) Source of Revenue
The official source should be supplied from general accounts or the other fund for the public works like road network construction.

(3) Countermeasures for the Whole Area (for Short Term)

1) Improvement of Combustion

a) Competent Authorities
- National and metropolitan government (MS·SSB, MDE and its corresponding local authority)

b) Relevant Persons
- Owners of stationary sources and their operators
- Manufacturers and distributors of equipment concerned
- Distributors of measuring equipment

c) Content of Countermeasure
- Attain perfect combustion by installing proper measuring equipment for appropriate operation, as the result, reduce dust emission and fuel consumption
- Install mechanical coal feeder to reduce dark smoke liable to generate when supplying coal to the furnace

d) Time of Implementation : by the year of 1995

e) Expense and Bearer
The expense for the equipment should be paid by the owners of stationary sources concerned, and the amount is estimated as follows.
- Measuring equipment for appropriate operation

Oil boilers (fuel consumption 50*l*/h or more)	96
Coal boilers	27
Ceramic furnaces	83

Others 56

Subtotal 262

262 x @ $3.43 million = $899 million

- Mechanical coal feeder

  Large coal boilers (equivalent fuel consumption 50l/h or more) 13 set

  Large ceramic furnaces 38 x @ 4 set/furnace = 152 set

  Subtotal 165 set

  165 x @ $4 million = $660 million

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds. And they should be subsidized partly by a competent governmental fund or authority.

2) Fuel Improvement or Conversion

a) Competent Authorities

- National and metropolitan government (MS-SSB, MDE and its corresponding local authority)
- ECOPETROL

b) Relevant Persons

- Owners of stationary sources
- Manufacturers and distributors of equipment concerned
- Gasoline user

c) Content of Countermeasure

- Add diesel oil to crude oil which is used for large oil boilers to reduce sulfur content to 2% in weight
- Add the oxygen supplying substance such as MTBE (Methyl Tertiary Butyl Ether), ETBE (Ethyl Tertiary Butyl Ether) to gasoline to promote perfect combustion which reduces CO and HC emission in exhaust gas

d) Time of Implementation : by the year of 1995

e) Expense and Bearer

The increment of fuel cost is estimated as follows, and is to be born by the relevant persons.

- For large oil boilers : approximately 20% up
- Oxygen added gasoline : approximately 3% up

f) Source of Revenue
- Users' own fund

3) Installation of Dust Collector

a) Competent Authorities
- National and metropolitan government (MS·SSB, MDE and its corresponding local authory)

b) Relevant Persons
- Owners of stationary sources
- Manufacturers and distributors of equipment concerned

c) Content of Countermeasure

Dust collectors such as multi-cyclon and scrubber should be introduced emphasizing larger facilities shown below.

• Oil boilers (fuel consumption 50*l*/h or more)	96
• *Coal boilers (equivalent fuel consumption 50l/h or more)*	13
• Large ceramic furnaces (continuous type)	28
• Asphalt plants	7
• Other furnaces	93
• Subtotal	237

In addition to those facilities mentioned above, two cupolas are also to be treated by installing the water cooling duct to collect dust in exhaust gas. Besides this attachment, by nstalling a train of propane gas at the top of the duct, CO in exhaust gas can be burnt out before discharged out of duct.

d) Time of Implementation : by the year of 1995

e) Expense and Bearer

The expense for the equipment should be paid by the owners of stationary sources concerned, and the amount is estimated as follows.

- Dust collectors (as multi-cyclon)
  237 x @ $3.8 million = $901 million
- Exhaust duct for cupola
  2 x @ $0.5 million = $1 million
- Subtotal $902 million

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds. And they should be subsidized partly by a competent governmental fund or authority.

4) Reduction of Heat Radiation Loss

a) Competent Authorities

- National and metropolitan government (MS·SSB, MDE and its corresponding local authority)

b) Relevant Persons

- Owners of stationary sources
- Builders of facilities concerned

c) Content of Countermeasure

- Cover the body of boilers with heat insulating material to drop the surface temperature to approximately 50°C. As the result, reduce fuel consumption and exhaust gas volume.

d) Time of Implementation : by the year of 1995

e) Expense and Bearer

The expense for the improvement should be paid by the owners concerned, and the amount is estimated as follows.

- Oil boilers (fuel consumption 50l/h or more) 35
- Coal boilers 27
- Subtotal 62
  62 x @ $0.46 million = $29 million

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds.

5) Prevention of Soil Dust Dispersion from Soil Mining Site or Asphalt Mixing Plant

a) Competent Authorities

- National and metropolitan government (MS·SSB, MDE and its corresponding local authority)

b) Relevant Persons

- Owners of stationary sources
- Builders of facilities concerned
- Manufacturers and distributors of facilities concerned

c) Content of Countermeasure

To prevent dispersion of soil dust from soil mining sites or asphalt mixing plants, the following measures are to be excuted.

- At a soil mining site, sprinkle water over the ground surface, cover the loading machines and pave the passage provisionally
- Put the milling and sieving process into the building, and collect dust out of building by dust collector.
- Sprinkle water and cover with dust collecting hood at the points of process conducted outside such as end or midway joint of conveyers.
- Forestation at the edge of minining sites and the area where excavation were finished.

d) Time of Implementation

- by the year of 1995 for adjacent premises to urbanized area

e) Expense and Bearer

The expense for the improvement should be paid by the owners concerned, and the amount is estimated approximately $10 million per site.

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds. And they should be subsidized partly by a competent governmental fund or authority.

(4) Countermeasures for the whole Area (for medium to Long Term)

1) Improvement of Combustion

a) Competent Authorities
- National and metropolitan government (MS·SSB MDE and its corresponding local authority)

b) Relevant Persons
- Owners of stationary sources and their operators
- Manufacturers and distributors of equipment concerned

c) Content of Countermeasure
- Introduce low-NOx burner to the largest 10 oil boilers to reduce NOx emission

d) Time of Implementation : by the year of 2001

e) Expense and Bearer
The expense for the equipment should be paid by the owners concerned, and the total amount is estimated approximately as follows.
- Low-NOx burner 10 x @ $24 million = $240 million

f) Source of Revenue
The investment should be done by the relevant enterprises with their own funds. And they should be subsidized partly by a competent governmental fund or authority.

2) Fuel Improvement or Conversion

a) Competent Authorities
- National and metropolitan government (MS·SSB, MME·MDE and their corresponding local authorities)
- ECOPETROL

b) Relevant Persons
- Owners of stationary sources
- Manufacturers and distributors of equipment concerned
- Gasoline user

- CARBOCOL, COLGAS and other manufacturers and distributors of coal or fuel gas

c) Content of Countermeasure

- Raise the mixing rate of diesel oil to crude oil to reduce sulfur content to 1.8% in weight.
- Change the ordinary coal which is used for coal boilers or ceramic furnaces to reformed low-sulfur coal.
- Change the fuel used for batch type ceramic furnaces to natural gas.
- Reduce sulfur content of gasoline to 0.01% or less in weight to reduce SO_2 in exhaust gas.

d) Time of Implementation

- Start supplying reformed low-sulfur coal by the year of 2001.
- Fuel conversion to natural gas would depend on the fuel supplying plan by the competent authorities including COLGAS.
- Supply of low-sulfur gasoline is desirable to be started immediately after the beginning of introduction of catalyst to used vehicles.

e) Expense and Bearer

- Construction cost of low-sulfur reforming plant is estimated to be approximately $440 million excluding land expense. The total cost added operational expense will reflect the coal price as the increment of about 20%. The investment on the plant is to be born by such coal miners and distributors as CARBOCOL and others.
- Construction costs of natural gas or low-sulfur gasoline producing plant and distributing facilities are not able to be estimated at present because it is difficult to decide the target capacity of production. Anyway the expense for the plants should be born by ECOPETROL and its subsidiary company of COLGAS.

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds. And they should be subsidized partly by a competent governmental fund if necessary. The invested capital will be eventually gotten back as the increment of sales according to fuel price.

3) Installation of Dust Collector with High Efficiency

a) Competent Authorities

- National and metropolitan government (MS-SSB, MDE and its corresponding local authority)

b) Relevant Persons

- Owners of stationary sources
- Manufacturers and distributors of equipment concerned

c) Content of Countermeasure

High efficiency dust collector (bag filter) should be introduced emphasizing larger facilities shown below.

• Boilers (equivalent fuel consumption 50*l*/h or more)	109
• Ceramic furnaces (continuous type and batch type)	30
• Asphalt plants	7
• Other furnaces	93
• Subtotal	239

d) Time of Implementation : by the year of 2001

e) Expense and Bearer

The expense for the equipment should be paid by the owners concerned, and the amount is estimated approximated as follows.

- bag filter 239 x @ \$6.4 million = \$1,530 million

f) Source of Revenue

The investment should be done by the relevant enterprises with their own funds, however, they should be subsidized partly by a competent governmental fund or authority.

4) Reform of Used Gasoline Motor Vehicle

a) Competent Authorities

- National and metropolitan government (MS-SSB MOPT-INTRA-MDE and their corresponding local authorities)

b) Relevant Persons

- Vehicle owners, assemblers, dealers and repair shops
- Manufacturers and distributors of apparatus concerned

c) Content of Countermeasure

- Take secondary air into intake manifold to combust CO and HC in exhaust gas.
- Take secondary air into exhaust manifold to combust CO and HC in exhaust gas.
- Install catalyst to eliminate CO, HC, in exhaust gas.
- Install evaporation gas trap to reduce HC emission.

d) Time of Implementation

- As for taking secondary air into intake manifold, it is attained through the periodical check and maintenance work mentioned before.
- As for the other measures are to be attained by the year of 2001.

e) Expense and Bearer

- As for taking secondary air into intake manifold, it is attained through the periodical check and maintenance work, so the expense is not needed to count additionally.
- Taking secondary air into outlet manifold and installation of catalyst are dealt in one body.

  Assuming the object vehicle number is half of the total of 550,000 cars of both Bogota City and Cundinamarca State, the total cost is estimated as follows

  275,000 x @ \$230,000 = \$63 billion
- Total cost of fuel evaporation gas trap is estimated for the same object vehicles of 275,000 as follows.

  275,000 x @ \$46,000 = \$13 billion
- The expense for the improvement should be paid by vehicle owners, however, the unit cost is so expensive compared to the size of ordinary household that the improvement should not be compulsory and further more a certain amount of subsidy is to be considered.

f) Source of Revenue

The source of subsidy is proposed to be transfered from the fund supplied by vehicle taxes.

5) Reconstruction of Torolley Bus Network

a) Competent Authorities

- National and metropolitan government (MHCP, EDTU)

b) Relevant Persons

- Private investors
- Resident, commuter and land owner around the bus routes

c) Content of Countermeasure

- Resume *trolley bus transportation with three lines by a newly* established semi-governmental enterprise.
- Complete the whole network with eight operating lines and expect to share 5% of the whole person trip in the City.

d) Time of Implementation

- In 10 years since 1992

e) Expense and Bearer

Among the whole initial cost, EDTU will share approximately \$4 billion and the private sectors will share approximately \$6 billion.

f) Source of Revenue

EDTU's source of revenue are decided to bring from the assets of existing trolley bus system such as cars, power supplying facilities, factories and land and others.

6) Construction of Passenger railway Lines

a) Competent Authorities

- National and metropolitan government (EDTU, MHCP, MRE)

b) Relevant Persons

- Resident, commuter and land owner around the railway lines

c) Content of Countermeasure

- Initiate railway transportation services with a line of 23 km in length.
- Extend railway up to three lines of 44 km in length and expect to share approximately 15% or more of the whole person trip in the City.

d) Time of Implementation

- First block is planned to be completed in 1995
- Second and third block are expected to start building successively

e) Expense and Bearer

The expense for the construction of the first block is already calculated to be approximately $660 billion and is borne by EDTU under the assistance of the government of Italy.

7) Improvement of Public Bus System

a) Competent Authorities

- National and metropolitan government (DNP, MOPT, INTRA, IDU and their corresponding local authorities)

b) Relevant Persons

- Resident, commuter and land owner around the bus routes
- Enterprises of public transportation
- Bus manufacturers, dealers and repair shops

c) Content of Countermeasure

- Improve the operation roots by those means to increase exclusive bus lane and station, to extend or lengthen arterial roads, promote tow-level intersection and to reform the plane shape of intersections to raise the travelling speed.
- Improve the fare collecting method to shorten stop time
- Investigate to introduce larger sized buses to reduce the total number of vehicle traffics.

d) Time of Implementation

- Improvement of road network is planned and excuted by every two years, and now under construction of the plan for 1991 ~ 1992 by the competent authorities. After finishing present plan the next plan will be prepared and excuted in succession.

- The latter two countermeasures should be completed by the year of 1995.

e) Expense and Bearer

- The expense for improvement road network is to be borne by the competent authorities, and the figure for the period of 1991 to 1992 is approximately $90 billion including land expenses.
- The expense for the latter two countermeasures is impossible to estimate at present however, the bearer should be both the competent authorities and relevant enterprises. The expense by the competent authorities may be given as a subsidy to some appropriate proposer who submit a productive improvement plan to the authorities.

f) Source of Revenue

The private source is proposed to be supplied from a new fund founded by donation of relevant enterprises. The official source are to be supplied from general accounts.

(5) Countermeasure for the Specific Area

The above-mentioned proposal of countermeasure has based on the target reduction volume of pollutants which will attain the environmental standards of air quality throughout the City of Bogota under the specific structure of pollutant diffusion that was deducted through the onsite observation and analysis in this study.

But the number of observation points of meteorology and pollutant concentration which forms the vital basis of analysis was limited to five, therefore it is somewhat difficult to explain completely the relation between the whole pollutant emission and air quality in the City of Bogota which has the area of approximately $300km^2$, and where the pollutant sources do not locate homogeneously.

Consequently those places where many pollutant sources are integrated like intersections or adjacent area of stationary sources, may need to be

considered separately the countermeasure for mitigating air pollution under their specific condition.
Typical countermeasures for the specific area are stated below.

1) Large Intersections

The large intersections have inevitably concentrated traffics, so that not to cause stagnation, special consideration on the structure is required more keenly than any other area along the road. And on the other hand, intersections surrounded by tall buildings where the diffusion of exhaust gas emitted from vehicles is prevented by its bad condition of atmospheric circulation so that intensive air pollution is liable to happen.

Therefor the surrounding area of large intersections should be kept open as far as possible by means of administrative guidance on land use. From the similar view point, to keep the distance of residential area form major intersections is good for prevention of health damage.

The consideration mentioned above is effective not only to large intersections but also to the other intersections or the area along the arterial roads, therefor it is desirable to be taken in the administrative measure on formulation of urbanized area as the part of measure for roadside area.

2) Specific Stationary Source

A local air pollution caused by some specific sources derives from the scale of sources as it may, largely from the distance between the discharge point and residential area. In case the site of stationary source is small or the location is on the slope or narrow valley, the smoke sometimes intrudes into the ground surface of the neighboring residential area without diffusing sufficiently.

As for the small chimney, the emission standards are not applied however, when the concentration of pollutant designated by the environmental air quality standards at the surface of the ground exceed the standard value, certain countermeasures should be adopted equally to the large sources. In that case an effective measure is raising of chimney height, which is cheap in cost and suitable for coping with complaint of neighbors.

9.2.2 Cost of Control Measures

The investment amount that can be estimated for control measures is shown in Table 9.2.1, excluding those necessary for traffic control measures. The investment for stationary sources applies principally to about 380 plants covered by this survey, and the investment sum of 2.5 billion pesos for short term and 2.2 billion pesos for long to medium terms should all be made by the enterprisers.

The investment amounting to 2.9 billion pesos for short term for motor vehicles is an official investment related to vehicle inspection. Investment for long and medium terms should be made by owners of estimated 550,000 units of vehicles, one half of vehicles estimated in Bogota and Department Cundinamarca, with the total sum increasing remarkably to the amount of 76 billion pesos.

The annual equipment investment made by manufacturing industries was totally 37 billion pesos in Santafe de Bogotá City in 1987. Comparing to this amount, the investment on short-term countermeasures made by private sector will be 1.8% as an average annual amot through the four years' period, and the investment on intermediate-term countermeasures will be twice as much totally.

On the other hand, the revenue of Santafe de Bogotá City was 78 billion pesos in 1988. Comparing to this amount, the investment made by government will be 0.9% as an average annual amount through the four years' period.

Besides those investment mentioned above, the operational cost for the monitoring system should be borne by Secretaria de Salud de Bogotá D.C. The amount is estimated to be about 50 million pesos per year and is planned to be prepared as the part of general accounts of Santafe de Bogotá City.

To assist the investment, the possibility of official bearing in a form of introduction of the subsidy program should be studied in view of a fact that the beneficiaries of the effect of control measures are wide-ranging citizens. In the similar manner, the official subsidy should be needed in regard to countermeasure investment on stationary sources when the investment sum is large for the enterprise scale.

For the fuel conversion of motor vehicles and stationary sources, the fuel cost is expected to increase. The expected increment is about 20% when the crude oil is converted to the mixed oil with the sulfur content of 2% for short term and about 40% in case of conversion to the mixed oil with the sulfur content of 1.8% for long to medium terms. The increment is about 20% when the coal is converted to the low-sulfur reformed coal. For gasoline, the rise of about 3%, that is, 9 pesos per liter, is expected through addition of oxygen supplier in fuel. Since the fuel price is of an official nature, study need to be made in future whether or not the people should bear the burden of increase directly.

Table 9.2.1 Estimated Investment Sum of Control Measures (excluding for traffic control)

Kind of control measure	Short-term measures			Long to medium term measures		Average unit ($million)
	Private investment		Public investment			
	No. of cases	Sum ($million)	Sum ($million)	No. of cases	($million)	
Control measures related to institutions						
1. Reinforcement of stationary source control			1.2			
2. Revision of motor vehicle registration system	30	120	120			4
3. Type approval system of emission gas	2	-	2,770			1,385
Sub-total		120	2,891			
Short term measures						
1. Improvement of combustion						
① Control instruments	262	899				3.4
② Mechanical coal feeder	165	660				4.0
1. Introduction of dust collector	239	902				3.8
2. Reduction of radiation loss	62	29				0.5
3. Prevention of dispersion of dust	(1)	(10)				10
Sub-total	728	2,490				
Long to medium term measures						
1. Improvement of combustion: Low NOx burner				10	240	24
2. Coal reforming plant				1	440	440
3. High-efficiency dust collector				239	1,530	6.4
4. Control measures for gasoline cars in use				275,000	76,000	0.3
Sub-total					78,210	
Total of control measures for stationary sources	758	2,490	1	250	2,210	
Total of control measures for mobile sources		120	2,890	275,000	76,000	
Total		2,610	2,891		78,210	

9.2.3 Promotion of Plans

(1) Execution System

The Ministry of Health and Welfare and the Health and Santafe de Bogota City will be the agency in charge of planning and coordination for air pollution control, to which various levels of governmental agencies controlling the pertinent field, the Health and Welfare Bureau of Santafe de Bogota City, and neighboring autonomous authority organizations will provide cooperation (refer to Fig.9.2.1).

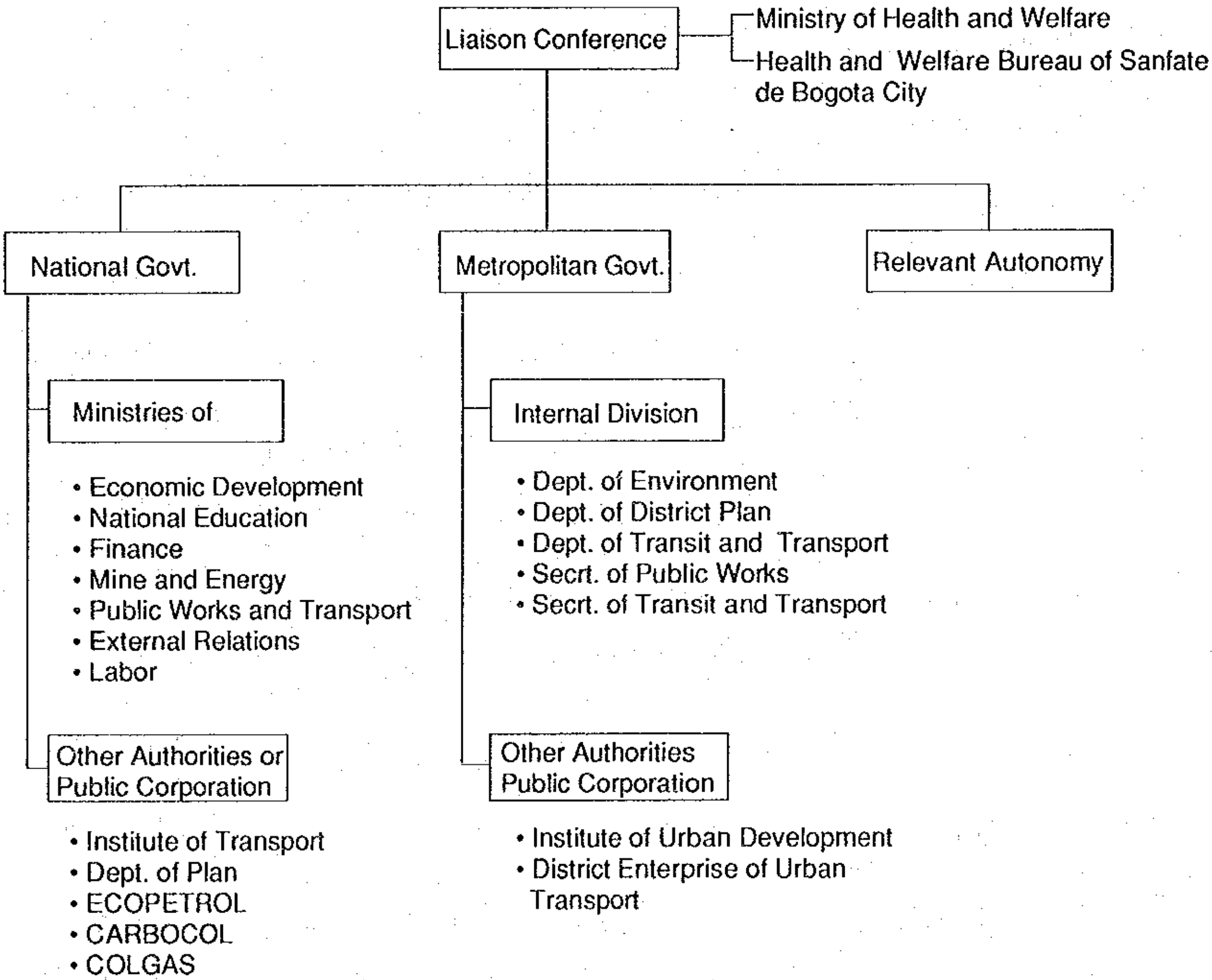


Fig.9.2.1 Competent Authorities on Air Pollution Control

The related administrative agencies will put the control plan into practice while attempting coordination with existing social and economic plans, urban plans, and traffic plans. At the same time, these agencies will establish a liaison conference to control the progress of the plan.

On executing the plans, the authorities will call upon positive participation and cooperation of citizens and enterprisers while paying due attention to preservation of healthy environment and stabilization of the life of citizens.

Individual citizens must recognize that they are not only victims, but also can cause pollution through production and utilization of motor vehicles. They have to give active cooperation in policies presented by administrative agencies.

Enterprisers contribute greatly to the social and economical activities through production and transport activities. On the other hand, however, they have to recognize the social position that they are inflicting considerable effects on the citizen life. It is essential for them to cooperate positively and do their best to realization of the planned target and policies.

(2) Improvement and expansion of the monitoring and measurement systems

1) Monitoring of air pollution

Monitoring of the ambient air quality must be made to see if the air pollutant concentration in Santafe de Bogota City meets the environmental standard, which is a target of the air pollution control plan, and if the plan has proved effective. It is essential that five continual monitoring stations, (whose operation was started as a part of this study), are to be maintained and 13 stations which had been operated by the municipal authority are to continue measurement for the purpose of monitoring the annual change and regional distribution of the SP concentration. For places where SP and SO_2 are expected to appear in high concentration, it is necessary to conduct the simplified measurement to check the ambient air concentration. In regard to SP, measurement and analysis of the content of heavy metals and the grain size must be made to obtain data for clarifying the cause of pollutant sources and finding out countermeasures.

2) Monitoring of pollutant sources

Concerning plants, the enterprisers are encouraged to conduct self-monitoring and independent improvement to ensure thorough control of emission related to pollutant sources. At the same time, the witness inspection by the municipal authority is to be augmented. In addition to these measures, such survey on stationary sources including fuel consumption, actual state of air pollutant emission, and stack condition must be continued for preparing the material to analyze the further characteristics of air pollution.

For motor vehicles, the annual survey is to be made on the regional traffic volume, car type composition. Also necessary is improvement and expansion of statistical data including the number of cars by engine model and displacement and the number of registered cars.

When the emission gas regulation of motor vehicles has been put into practice, it is necessary to survey and record the actual driving mode in a region and to measure the air pollutant (CO, NOx, SO_2, CO, HC in g/km) emission rate in the regulated mode, so that the effect of regulation can be confirmed.

3) Compiling of environmental information

It is necessary to build up a database system about the general environmental information for promotion of the air pollution control. The database should cover mainly ambient air concentration and meteorological measurement data and pollutant source data, and it should be developed to the comprehensive basis for general management system of environmental information.

9.3 Summary and Priority Countermeasures

As a conclusion of this study, proposed countermeasures are shown systematically in Fig.9.3.1

Among these countermeasures, several countermeasures has been selected from the viewpoint of fundamental improvement of pollution structure in Bogota City as follows.

9.3.1. Priority Countermeasures by Institutional System

(1) Revision of Emission Standard

The emission standard should be revised and reinforced, and furthermore be established a new standard for mobile sources. On this legal basis the obligation of those relevant persons and competent authorities to attain the target of air pollution control would be defined.

(2) Cultivation of Stationary Source Operators

To operate the stationary source facilities such as boilers and furnaces efficiently and to reduce the emission of pollutant, it is necessary to cultivate such experts as combustion controller, inspector and measurement technician of pollutant in exhaust gas. On this basis of human resource the system for complying the emission standard by enterprisers themselves should be set up.

(3) Revision of Vehicle Inspection and Registration System

As the requirement of vehicle registration, certain necessary items on maintenance work should be decided and at the same time the system should be revised to take the above-mentioned maintenance work into the compulsory periodical check list for the applier to renew the registration. To enable this system, it is necessary to formulate the capability of car repair shops to respond the legal periodical check and also necessary to introduce indispensable apparatus such as exhaust gas measuring equipment during idling.

(4) Establishment of Type Approval System about Exhaust Gas

A new approval system of vehicle at the time of registration of new model vehicle should be established, which requires every new model vehicle to satisfy the emission standard for its type registration. To excute unitarily the examination for this system, a official inspection agency should be founded and install chassis dynamometers to the agency as the tool of the examination.

(5) Review of the Tax Assessment System on Vehicles

It is necessary to review the assessment system of vehicle tax in order to reflect the grade of contribution to the activities for air pollution control, and through this revision, the vehicle change to new model or one with emission control should be accelerated.

(6) Establishment of Subsidy System for Private Investor on air Pollution Control

To encourage the investment on air pollution control, some official assistance system should be established, the type of assistance may be:

- Reduction of income tax
- Long-term low-interest loan system
- Subsidy

9.3.2 Priority Countermeasures for Short Term

(1) Improvement of Combustion

Operating combustion equipments rationally, the reduction of dust emission and energy consumption would be attained.

(2) Reduction of Heat Radiation

It is possible to reduce exhaust gas volume and fuel consumption by small investment for heat insulation. The effect of saving fuel will be expected to compensate the investment in a year or so.