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THE REPUBLIC OF COLOMBIA

THE STUDY ON AIR POLLUTION CONTROL PLAN IN SANTAFE DE BOGOTA CITY AREA

FINAL REPORT

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JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Republic of Colombia, the Government of Japan decided to conduct a study on Air Pollution Control Plan in Santafe de Bogota City Area and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Colombia a study team headed by Mr. Yoshikazu Sugita, SUURI-KEIKAKU CO., LTD. and composed of members from SUURI-KEIKAKU CO., LTD. and Pacific Consultants International, five times between August 1990 and December 1991.

The team held discussions with the officials concerned of the Government of Colombia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Colombia for their close cooperation extended to the team.

February 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

EXECUTIVE SUMMARY

1. Introduction

1.1 Background and Objective of the Study

In Santafe de Bogota City, the capital of the Republic of Colombia, air pollution is getting heavier by pollutants emitted from motor vehicles and factories increasing year by year. The air pollution there is worsened by the meteorological factors due to the topographical condition that it is located in a highland basin at 2,600m above sea level.

The objective of the study was to investigate and analyze air pollution, meteorology, air pollutant sources, socio-economic conditions and air pollution control measures in Santafe de Bogota City, on the basis of which to propose a guideline for the air pollution control measures there. And through this study was aimed technology transfer from the study team to Colombian counterpart on various aspects of the study.

1.2 Outline of the Study

The study area is the area under the jurisdiction of the Health and Welfare Bureau of Santafe de Bogota City approximately 35 km from south to north and 24 km from east to west, which includes the urban area of the city.

The study consisted of the basic study and the analytical study with the following components shown in Fig. 1.1.

1.3 Overview of the Study Area

(1) Natural Environment

The study area is located in the southeast part of the basin on the plateau 2,600 m above sea level, and there are mountains about 3,000 m high in the eastern part of the area.

The meteorology here is characterized by the low annual mean air temperature at 14°C with small fluctuation of temperature along with seasonal change.

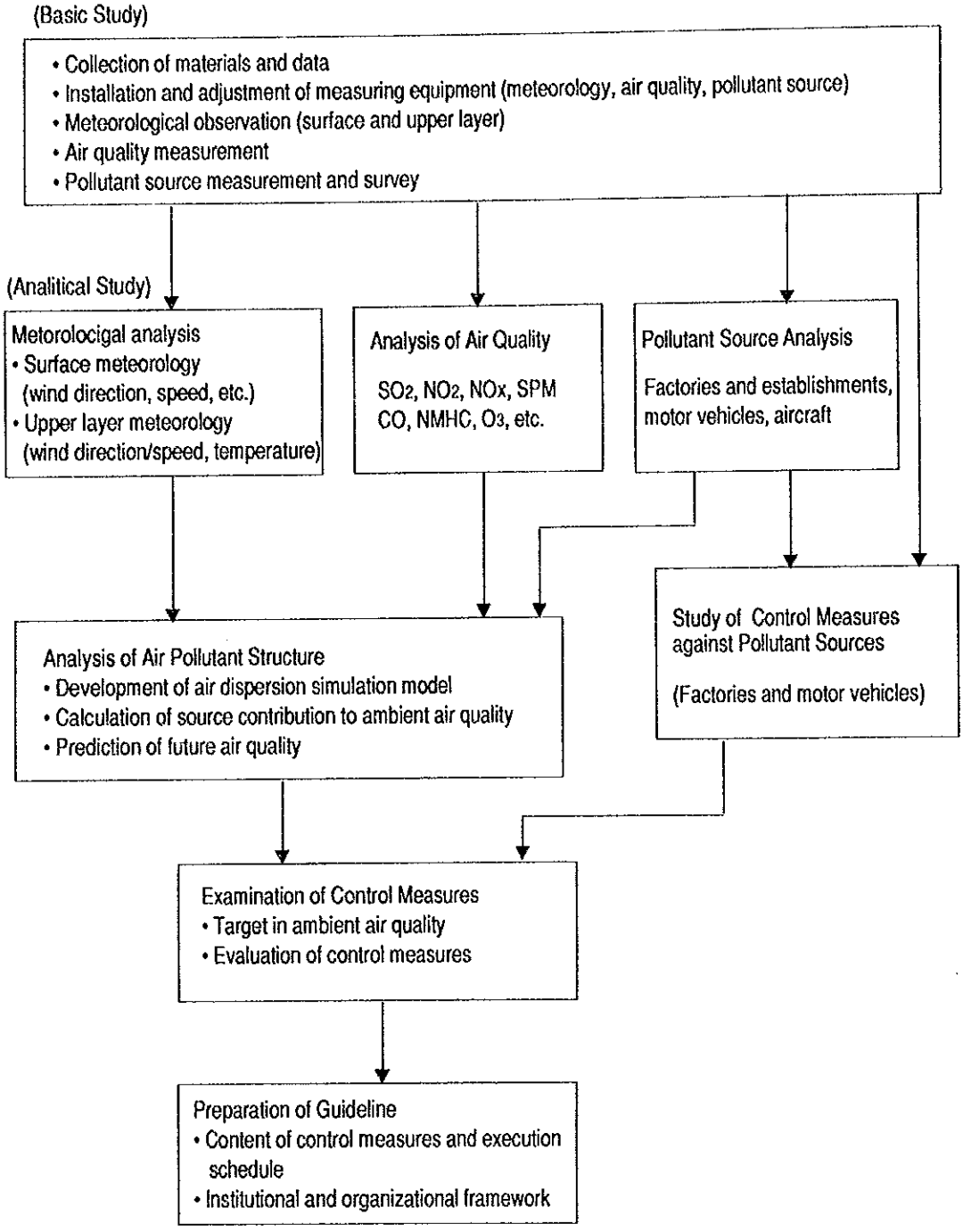

Fig. 1.1 Outline of the Study

The annual mean wind speed is low; 1.9 m/sec, and the annual precipitation is 919 mm, and the rainy seasons come twice a year; from March to May and from October to November.

(2) Social Conditions

Santafe de Bogota City had the population of 4,236,000 in 1985, while it was only a local city having a population of around 100,000 in the early years of the present century. The majority of the present inhabitants is the immigrant from outside the City. As for the population distribution, a so called doughnut tendency is observed; namely showing decrease of population in the central area and increase in the surrounding area.

Among the GDP components, the tertiary industry is the overwhelming majority at 71.4%, mainly comprising commerce, transportation, and communications sectors. The secondary industry is the runner-up at 28.6%. In sector point of view, manufacture at 22.2%, government service at 14.0%, and personal service at 13.8% are the top three, followed by housing rent at 10.4%, commerce at 10.3%, and transportation at 9.3%. The agriculture-cattle industry and the mining industry are minor.

(3) Traffic Conditions

In Santafe de Bogota City, nearly 89% of the traffic means is motor vehicles, and nearly 61% of the traffic use vehicles are small buses (buseta), followed by bus, the two accounting for 84% of the total, but their road space occupancy ratio is around 27%.

The registered number of vehicles in Santafe de Bogota City in 1991 was around 350,000, of which passenger cars accounted for 63.3%, or 221,000, followed by trucks (18.6%), jeep (10.6%). Number of vehicles per 100 people was 6.8. The number of vehicles increased at an average annual rate of 7.9% during 5 years (1985-1990), exceeding the population growth rate.

Although no detailed survey has been made, some 580,000 vehicles are said to be in operation in the city, with around 50,000 increasing annually.

At present, as public traffic means, some 14,000 buses and small buses are operated by the city authority and by 39 private companies. There are 450 routes, and of these, 268 run through the city center area. The average

operation distance is 20 to 30 km. The average passengers per day are over 2.5 million.

Vehicles in service over 20 years are 22.5%, over 10 years are 69.5%, and less than 5 years are 4.3%, indicating the generally decrepit composition of the fleet.

At present, no railway system is in service except for tourism, and the trolley bus system is interrupted its operation since last August.

(4) Energy Consumption

Household demand in energy mainly depends on kerosene (cocinol), propane gas and electricity. Electric power is delivered to 98% of the household in the city.

The main fuel types for industrial use are coal and crude oil.

The coal consumption in the whole Cundinamarca Department was 1,063,000 tons (1987), of which 67.0% was for the manufacture, followed by power generation (23.6%) and household (9.4%).

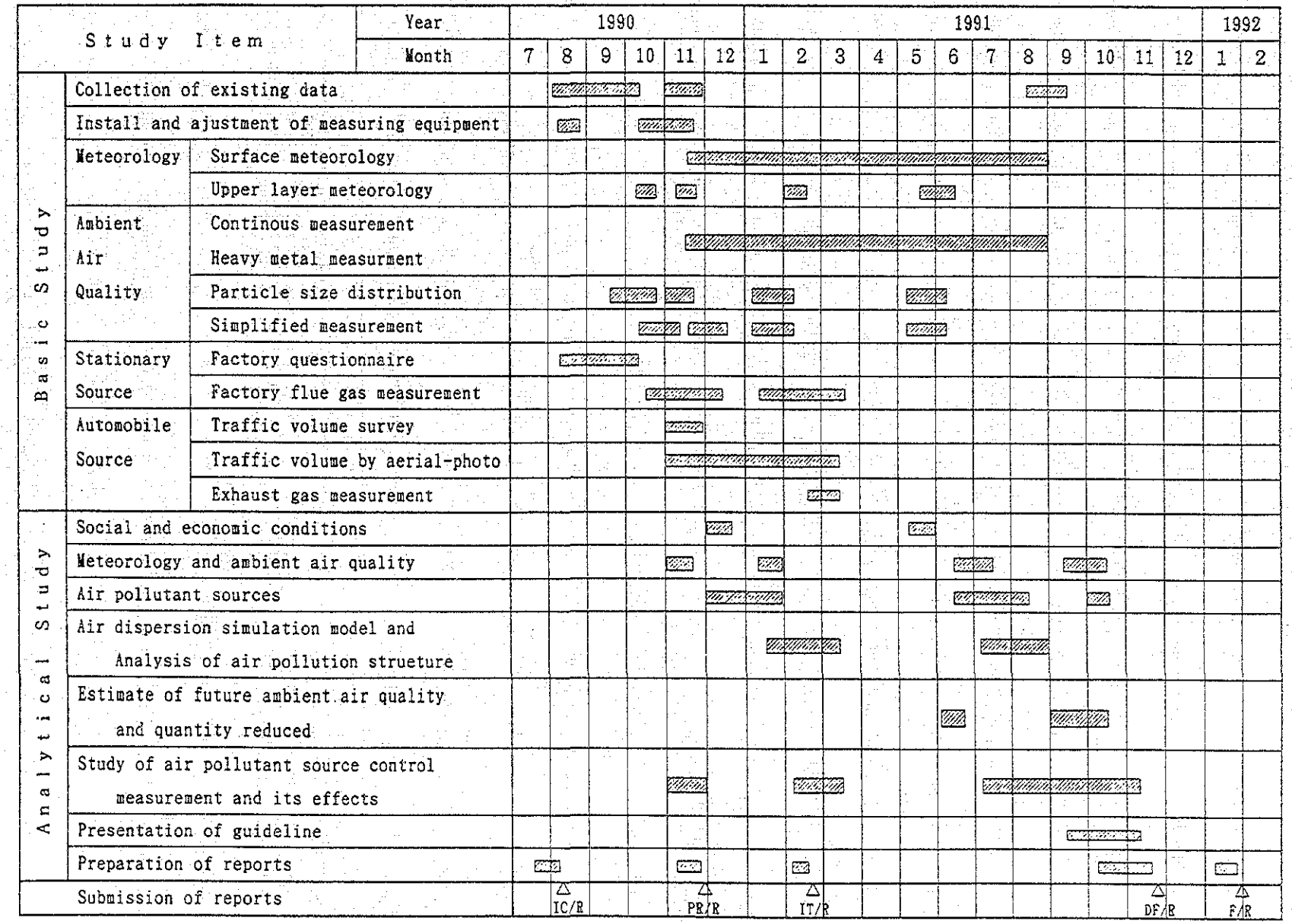

Fig. 1.2 Study Components and Time Schedule

2. Present State of Ambient Air Quality

2.1 Features of Air Pollution

The results of measurement at 5 monitoring stations installed in this study are shown in Table 2.1.

The SO_2 value ranged from 7.0 to 25.2 ppb in average. The CO value ranged from 1.5 to 8.5 ppm in average. The NOx value ranged from 27.1 to 101.2 ppb in average while the NO_2 value ranged from 16.5 to 33.3 ppb. As regards SPM, the average value ranged from 43 to 70 $\mu g/m^3$.

Table 2.2 shows the state of compliance with the national ambient air quality standard of Colombia.

The CO value exceeded the standard at stations A (Servicio de Salud) and E (San Juan de Dios). At station E, the excess was high at 13% of 8 hours value. The O_3 value exceeded the standard at both stations.

Values of SO_2, NO_2, and SPM were all below the standards. As regards SPM, however, the national standard of Colombia is based on measurement with the high-volume air sampler, but in this study the β-ray absorption method was used at monitoring stations, focusing the particle diameter of 10 μm or less. It is difficult to compare the results to the standards, however, the difference may be clarified through comparison if the data for the same period were available.

Table 2.1 Summary of the Measurement at Monitoring Stations

Item / Station	SO_2 ppb	CO ppm	NOx ppb	NO ppb	NO_2 ppb	SPM $\mu g/m^3$	T-HC ppmC	n-CH4 ppmC	O_3 ppb
A: Servicio de Salud	7.0	4.7	60.4	33.1	27.2	53	-	-	-
B: Laboratorio	9.9	2.3	27.4	7.3	20.0	43	-	-	-
C: Puente Aranda	22.9	2.0	39.2	16.0	23.2	70	3.87	1.86	10.7
D: El Tunal	8.6	1.5	27.1	10.6	16.5	59	-	-	-
E: San Juan de Dios	25.2	8.5	101.2	68.0	33.3	62	4.69	2.70	6.7

Table 2.2 State of Compliance with the Ambient Air Quality Standard

Item / Station / Standard	SO_2			NO_2	SPM		CO		O_3
	3 Hour 573.1	Daily 152.8	Ann. 38.2	Ann. 53.2	Daily 400.0	Ann. 100.0	1 Hour 43.7	8 Hour 13.1	1 Hour 86.6
A : Servicio de Salud	O	O	O	O	O	O	O	1.4%	
B : Laboratorio	O	O	O	O	O	O	O	O	
C : Puente Aranda	O	O	O	O	O	O	O	O	0.4%
D : El Tunal	O	O	O	O	O	O	O	O	
E : San Juan de Dios	O	O	O	O	O	O	O	13.0%	0.2%

Note 1. For SPM arithmetic average is used.
2. '%' indicates appearance frequency ratio when values exceeded the standard.

2.2 Hourly Change

Fig. 2.1 shows hourly change of pollutant concentration at the monitoring station E as an example.

Change of SO_2 was one-peak type, with the peak appearing at 8:00 to 9:00 corresponding to the morning traffic peak.

As regards CO, it was two-peak type, with sharp peaks appearing at 7:00 to 9:00 in the morning and with dull one at 18:00 to 20:00 in the evening.

NOx had two peaks in a day. The first was a morning peak at 7:00 to 8:00 and the second was evening one at 18:00 to 22:00. The peak of NO appeared early at 7:00 while that of NO_2 appeared with one or two hours delay.

As regards SPM, the morning peak at 8:00 to 9:00 was remarkable and there was no particular peak in the evening.

As for CH_4, it was nearly constant in concentration while NMHC and T-HC had a peak at 8:00.

O_3 had a sharp peak, which started at around 8:00 and reached its height at around 10:00.

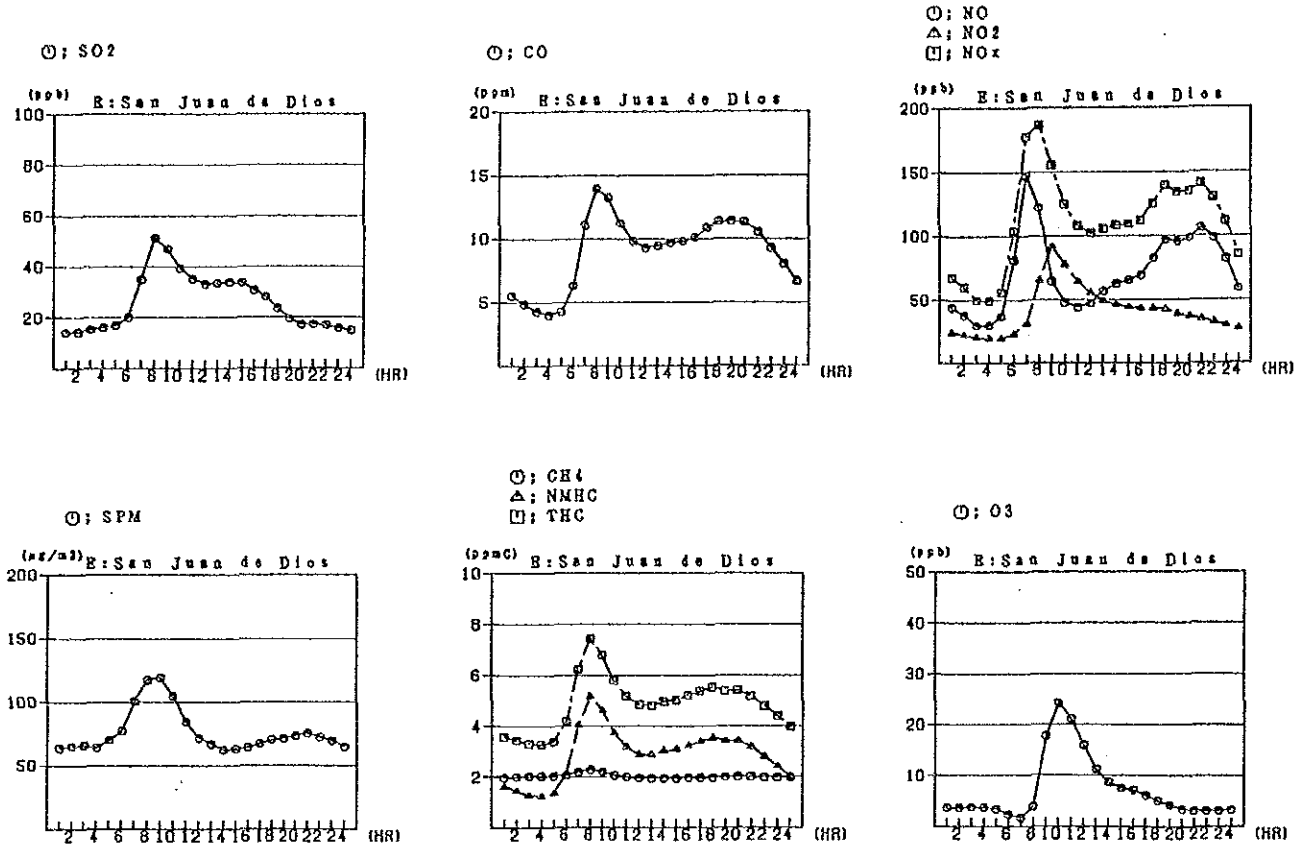

Fig. 2.1 Hourly Change of Pollutant Concentration at Station E (San Juan dc Dios)

3. Structure of Air Pollution

3.1 Pollutant Emission Quantity by Source

The present quantity of pollutant emission by source is estimated as shown in Table 3.1. Dust emission quantity was calculated solely for stationary sources as 2,198 tons/year. CO emission was calculated solely for motor vehicles as 288,433 tons/year. The SOx emission from factories is 6,504 tons/year (83.4%) among the total of 7,802 tons/year. The NOx emission from motor vehicles is 9,250 tons/year (83.7%) among the total of 11,052 tons/year.

Table 3.1 Air Pollutant Emission by Source

(Unit:ton/year)

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

Note: - means the said pollutant source is not included in this study or its emission is negligibly small.

3.2 Source Contribution to Pollutant Concentration

Using a dispersion model, the air pollutant concentration at each monitoring station and mesh point was calculated. Then by adding the background concentration to the calculated value, the estimated concentration was acquired.

In this study difference between measured value and computed value was set as the background concentration.

Contribution to the concentration by sources at each monitoring stations and maximum concentration point is shown in Fig. 3.1 and Fig. 3.2, and the following results were obtained.

(1) SO_2

The contribution ratio of factories to the estimated value was 22% - 64%, and the contribution of motor vehicles to the estimated value was 5% - 50%.

The contribution of factories took greater part than the other sources at estimated points excluding Station E (San Juan de Dios).

(2) NOx

The contribution ratio of motor vehicles to the estimated value was very high at 71% - 96%.

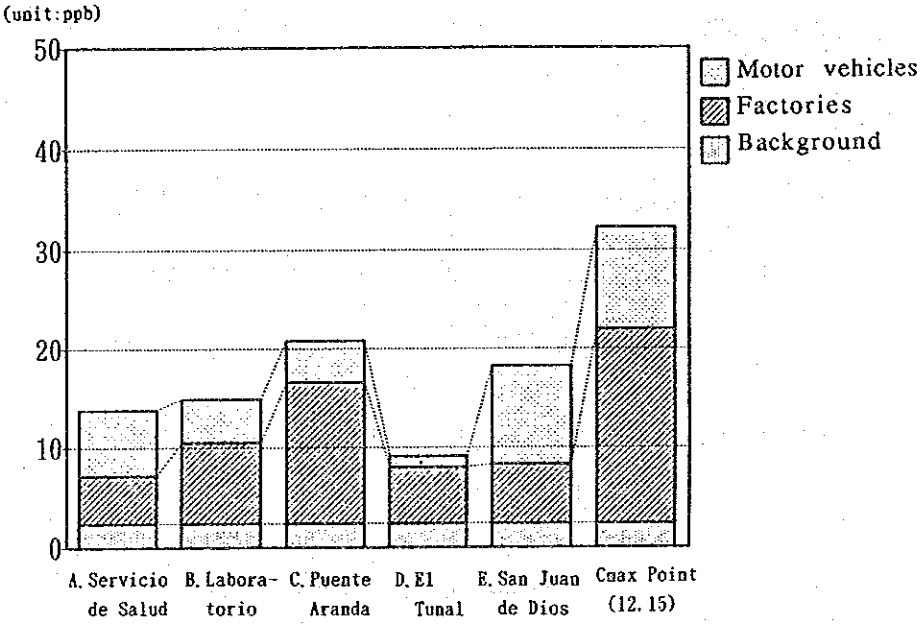

Fig. 3.1 Contribution of Sources to SO_2 Concentration

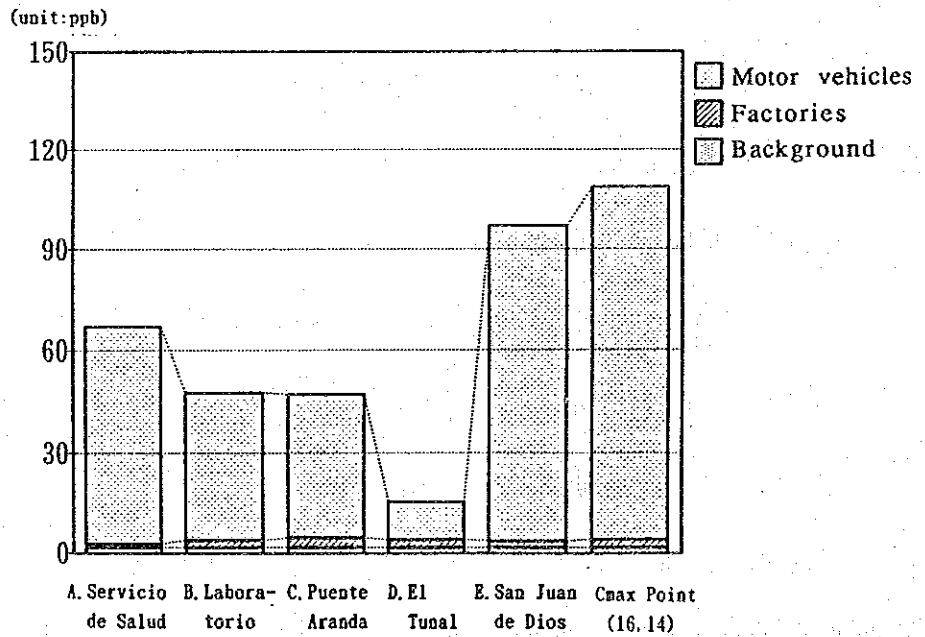

Fig. 3.2 Contribution of Sources to NOx Concentration

3.3 Background of Air Pollution

The City of Santafe de 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, factories 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. These aspects of development of the city are at the same time forming the sources that degrade air quality.

4. Future Situation of Air Pollution

4.1 Estimated Quantity of Air Pollutant Emission

The pollutant emission quantity by source is estimated as shown in Table 4.1. The total annual emissions of Dust, CO, SO_x and NO_x in 2001 are 3,155 tons, 398,375 tons, 11,162 tons and 16,475 tons respectively. The growth rates of Dust, CO, SO_x and NO_x between 1990 and 2001 are 1.44, 1.38, 1.43, and 1.49 respectively.

Table 4.1 Predicted Air Pollutant Emission by Source in 2001

Source		Dust	SOx	NOx	CO	HC
Stationary Sources	Factories and Establishments	3,155	9,076	2,475	-	-
Mobil Sources	Motor vehicles	-	2,057	13,886	398,375	28,947
	Aircraft	-	29	114	-	-
Total		3,155	11,162	16,475	398,375	28,947
Growth Rate (2001/1990)		+44%	+43%	+49%	+38%	+46%

4.2 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 analysis on the relation between the concentration of O_3 and NMHC. Therefore the tentative target value is given as Table 4.2.

Table 4.2 Target Level of Air Quality

Pollutant	Target Concentration
SO_2	38.2 ppb
NO_2	53.2 ppb
SP	100 $\mu g/m^3$
CO	3.6 ppm
n-CH_4	0.5 ppmC

4.3 Required Pollutant Reduction

Table 4.3 gives a comparison between the predicted air pollutant concentration in 2001 and the required reduction rate.

With CO, the predicted concentration exceeds the target concentration in the four monitoring stations other than the Station D (El Tunal).

As regards SO_2, the concentration of the monitoring stations is lower than the target level while exceeding the target value in certain areas including the points where the concentration becomes maximum.

Table 4.3 Predicted Concentration (2001) and required Reduction

Monitoring station	Air pollutant	CO (ppm)		NO_2 (ppb)		SO_2 (ppb)	
	Target concentration	3.6		53.2		38.2	
		Predicted concentration	Reduction rate (%)	Predicted concentration	Reduction rate (%)	Predicted concentration	Reduction rate (%)
(A) Servicio de Salud		7.1	49	38.4	-	18.8	-
(B) Lavoratorio		5.1	29	31.8	-	19.8	-
(C) Puente Aranda		4.5	20	32.1	-	27.2	-
(D) El Tunal		2.5	-	17.4	-	12.0	-
(E) San Juan de Dios		8.6	58	46.6	-	26.6	-
Max. concentration		9.6	63	50.0	-	43.7	13 %

4.4 Predicted Air Quality after Execution of Control Measure

(1) Prediction of Concentration

Predicted concentration for each pollutant with control measure at monitoring stations and the maximum point is shown in Table 4.4, which contains the background concentration same as the present state.

Table 4.4 Predicted Concentration with Control Measure

Items / Stations	SO2 (ppb)	NOx (ppb)	NO2 (ppb)	CO (ppm)
A. Servicio de Salud	13.4	90.9	36.7	3.5
B. Laboratorio	15.1	64.3	30.6	2.6
C. Puente Aranda	21.7	66.0	31.0	2.4
D. El Tunal	9.8	20.1	16.6	1.4
E. San Juan de Dios	20.1	130.2	44.4	4.9
Cmax Point	34.6	154.1	48.5	4.4

The concentration will shift from the present state as shown in Fig. 4.1 to Fig. 4.3; the future state is described separately by the case whether any proper countermeasures are adopted or not.

In future, the concentration of SO_2 and NO_2 will rise according to the increase of emission quantity, and at some points, exceed the target level, however, by taking some proper control measures, the target level will be achieved at all points.

Because CO concentration exceeds the target level at some points at present, it will go by far above the target level at most points according to the increase of traffic volume.

If any proper control measures are adopted, the concentration will be dropped to the present level or below, and also the target level will be achieved except roadside areas.

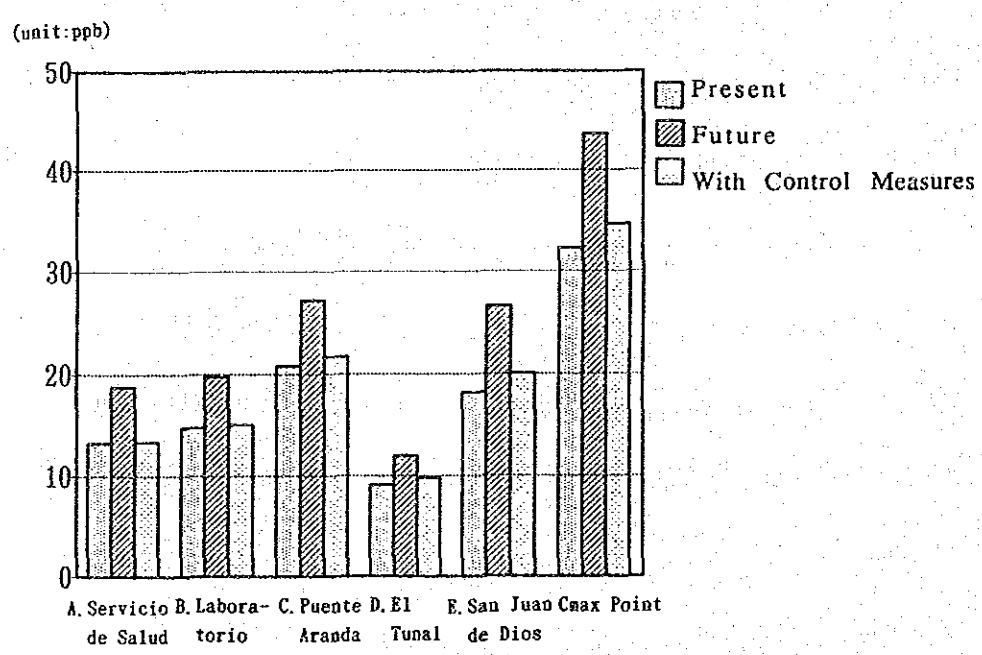

Fig. 4.1 SO_2 Concentration with and without Countermeasures in Future

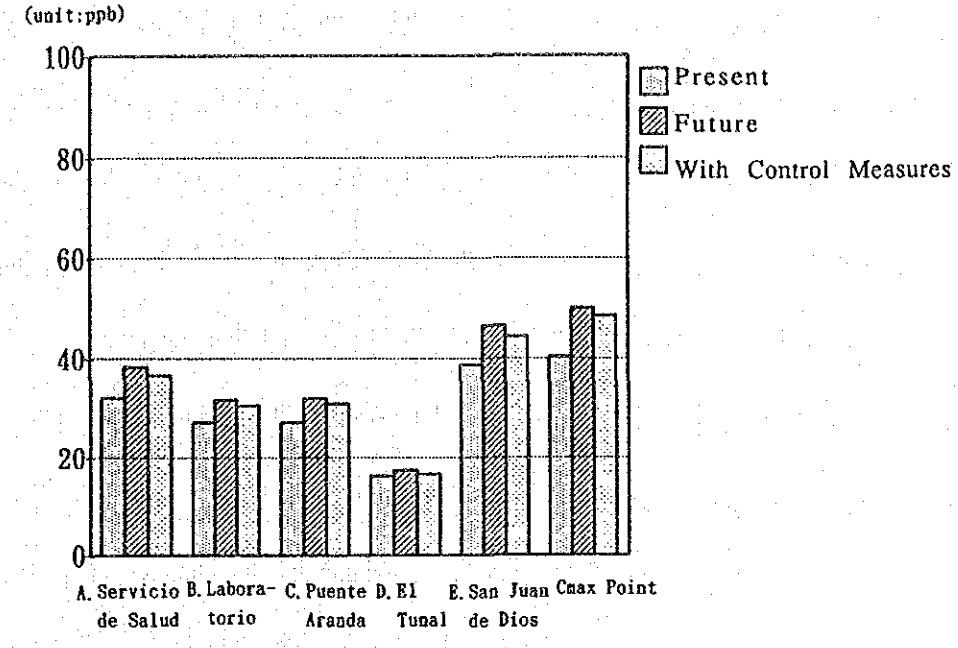

Fig.4.2 NO_2 Concentration with and without Countermeasures in Future

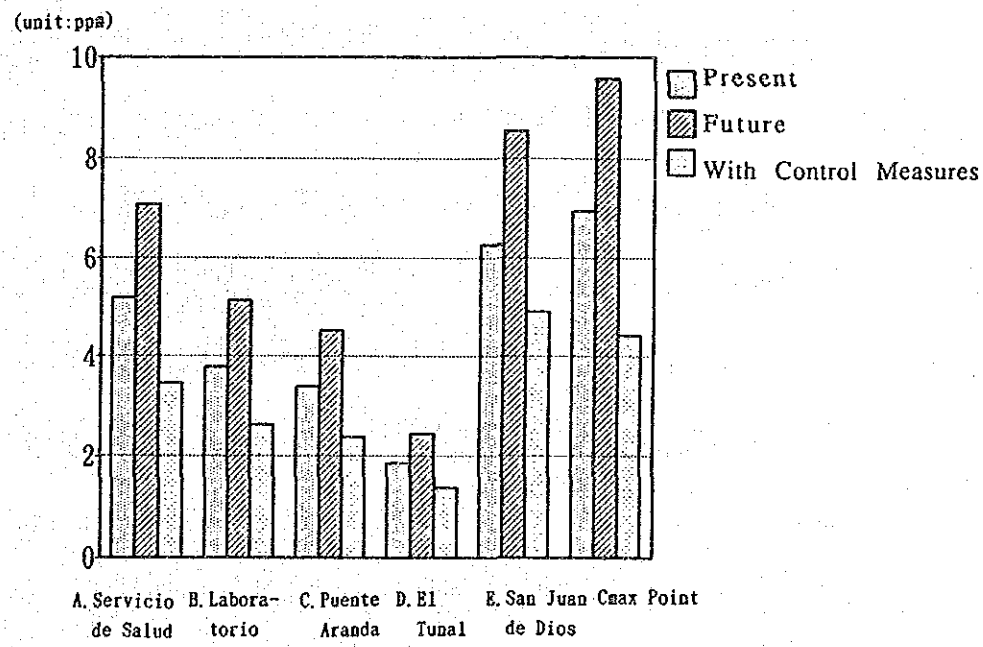

Fig. 4.3 CO Concentration with and without Countermeasures in Future

5. Presentation of Guideline for Pollution

5.1 Basic Concept

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.

Santafe de 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.

5.2 Proposed Control Measures

(1) General Consideration

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.

Measures for the whole area 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.

The kind of pollutants which highly require wide-area control measures are CO and non-methane hydrocarbon, for which the high reduction target has been set, followed by NOx, SOx, and dust in the order.

As a conclusion of this study, various kinds of countermeasures are proposed.

Among these countermeasures, several priority countermeasures have been selected from the viewpoint of fundamental improvement of pollution structure in Santafe de Bogota City as stated in the following section.

(2) Priority Countermeasure 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 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.

③ Revision of Vehicle Inspection and Registration System

As the requirement of vehicle registration, certain necessary items on maintenance work should be revised as the compulsory periodical check list for which the owner subject to.

④ Establishment of Type Approval System about Exhaust Gas

A new approval system of vehicle at the time of registration of new model should be established, which requires every new model vehicle to satisfy the emission standard for its type registration.

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 in proportion to the contribution for air pollution control.

⑥ Establishment of Subsidy System

It is necessary to introduce a subsidy system to the investment on pollution control measures by private sector in order to encourage the adoption of control measures.

(3) Priority Countermeasures for Short Term

① Improvement of Combustion

Operating combustion equipment 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.

③ Prevention of Soil Dust Dispersion from Soil Mining Site or Asphalt Plant

To prevent the dispersion of soil dust from soil mining site or asphalt plant, such equipment as dust collector, sprinkler and enclosure should be introduced to the relevant sites.

④ Installation of Dust Collector

This countermeasure contributes to solve the problem with the factories which have already violated the existing emission standard on dust or have been discharging soot.

⑤ Reduction of Sulfur Content of Gasoline

To prepare the introduction of catalyst to vehicles, the sulfur content of gasoline should be reduced to 0.01% in weight in order to prevent forming SO3 in exhaust gas.

(4) Countermeasures for Medium to Long Term

① Supply of Reformed Coal

Not only reduction of SOx and dust emission but also improvement of combustion efficiency can be expected by this countermeasure. For the supplier, to introduce its processing plant is necessary, however, it is not very difficult technically, because it can be composed of fully ordinary domestic products.

② Reduction of Traffic Volume by Constructing and Innovating Mass Transit System

The new trolly bus system, which has already started preparation work, and a new passenger railway should be accelerated to construct for reducing the motor vehicle traffic volume. At the same time the ordinary public bus system should also be improved to extend the capacity of transportation and to smooth the traffic flow in the central zone of the City.

③ Supply of Oxygenated Gasoline

The countermeasure is effective in reducing CO and HC emission from vehicles greatly in spite of fuel cost increment is rather small.

5.3 Cost of Control Measures

The investment amount for short-term measures is estimated 5.5 billion pesos in total, excluding those for traffic control measures. The investment for stationary sources, which will be applied principally to about 380 factories covered by this survey, is estimated as the 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 up to 76 billion pesos.

5.4 Execution of Pollution Control

(1) Execution Organization

The Ministry of Health and Welfare and Santafe de Bogota City will be the agency in charge of planning 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.

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.

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 play an active cooperative role for 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 responsibility 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) Monitoring and Public Relations

Monitoring of the ambient air quality must be made to see if the air pollution concentration in Santafe de Bogota City meets the environmental standard, 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), and 13 stations which had been operated by the municipal authority are to be maintained. 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.

Concerning factories, 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 reinforced. 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 motor vehicles by engine model and displacement and the number of registered vehicles.

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 emission rate (CO, NOx, SO_2, CO, HC in g/km) in the regulated mode, so that the effect of regulation can be confirmed.

It is necessary to build up a database system about the general environmental information for promotion of the air pollution control. The database should be developed to the comprehensive basis for both general management of environmental and response to the emergent situation of air pollution. And those information compiled from the data base should be utilized for the purpose that stimulates citizens to participate in the activities for mitigating air pollution in their homeland.

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CHAPTER 9 GUIDELINE FOR CONTROL MEASURES

Acronyms

ACOPI	Asociación Colombiano Popular de Industriales	Colombian Assoc. of Popular Industry	コロンビア中小企業協会
ANDI	Asociación Nacional de Industriales	National Assoc. of Industry	全国産業協会
CAR	Corporación Autónoma Regional de la Sabana de Bogotá, Chiquinquirá y Suárez	Regional Public Corporation	(ボゴタ平原、チキンキラ、スアレス) 地域開発公団
CARBOCOL	Carbones de Colombia S.A.	Colombia Coal Co., Ltd.	コロンビア石炭株式会社
CCB	Camara de Comercio de Bogotá	Chamber of Commerce of Bogota	ボゴタ商工会議所
COLGAS	Compañia Colombiana de Gas	Colombia Gas Co., Ltd.	コロンビアガス会社
DAMA	Departamento Administrativo de Medio Ambiente	Administrative Dept. of Environment	市環境局
DANE	Departamento Administrativo Nacional de Estadistica	National Administrative Dept. of Stastics	国家統計庁
DAPD	Departamento Administrativo de Planeación Distrital	Administrative Dept. of District Plan	市計画局
DATT	Departamento Administrativo de Tránsito y Transporte	Administrative Dept. of Transit and Transport	市交通運輸局
DNP	Departamento Nacional de Planeación	National Dept. of Planning	国家計画庁
EAAB	Empresa de Acueducto y Arcantarillado de Bogotá	Bogota Enterprise of Water Supply and Sewage	ボゴタ水路下水公社
ECOPETROL	Empresa Colombiana de Petroleos	Colombia Petroleum Enterprise	コロンビア石油公社
EDTU	Empresa Distrital de Transportes Urbanos	District Enterprise of Urban Transport	都市交通地方公社
EPA		Environmental Protection Agency, U.S.A.	アメリカ環境庁
GIT	Grupo Interinstitucional de Transporte	Interinstitutional Group of Transport	連合交通グループ
HIMAT	Instituto Colombiano de Hidrologia, Meteorologia y Adecuación de Tierras	Institute of Hydrology and Meteorology	コロンビア気象庁
IDU	Instituto de Desarrollo Urbano	Institute of Urban Development	都市開発庁
IGAC	Instituto Geográfico Agustin Codazzi	A.G. Institute of Geography	国土地理院
INDERENA	Instituto Nacional de los Recursos Naturales Renovables y del Ambiente	National Institute of Natural and Environmental Resources	国家再生天然資源環境庁
INTRA	Instituto Nacional del Transporte	National Institute of Transport	国家運輸庁

MDE	Ministerio de Desarrollo Económico	Ministry of Economic Development	経済開発省
MES	Ministerio de Educación National	Ministry of National Education	文部省
MHCP	Ministerio de Hacienda y Crédito Público	Ministry of Finance	大蔵省
MME	Ministerio de Minas y Energía	Ministry of Mine and Energy	鉱物エネルギー省
MOPT	Ministerio de Obras Públicas y Transporte	Ministry of Public Works and Transport	公共事業運輸省
MS	Ministerio de Salud	Ministry of Health and Welfare Bureau	厚生省
MRE	Ministerio de Relaciones Exteriores	Ministry of External Relations	外務省
MTSS	Ministerio de Trabajo y Segridad Social	Ministry of Labor	労働省
SNS	Sistema Nacional de Salud	National Health System	国家保健機構
SOP	Secretaria de Obras Públicas	Public Works Bureau	市公共事業局
SSB	Servicio de Salud de Bogotá	Bogota Health Service	ボゴタ保健サービス
SSB	Secretaria de Salud de Bogotá (Old) Secretaria Distrital de Salud de Santafe de Bogota D.C. (New)	Bogota Health and Welfare Bureau	市厚生局
STT	Secretaria de Tránsito y Transporte	Secretariat of Transit and Transport	市交通運輸局

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background and Objective of the Study

1.1.1 Background of the Study

In Santafe de Bogota City, the capital of the Republic of Colombia, air pollution is getting heavier by pollutants emitted from motor vehicles and factories increasing year by year. The air pollution there is worsened by the meteorological factors due to the topographical condition that it is located in a highland basin at 2,600m above sea level. In this situation, the Secretaria Distrital de Salud de Santafe de Bogotá D.C. began measuring the ambient air quality with a semi-automatic monitoring system in 1984, taking air pollution control measures. In the present state, however, collection of basic data and an organization, which is indispensable to put air pollution control measures into effect, have not yet been established. The Republic of Colombia decided to establish the air pollution control plan comprising understanding of the actual state of air pollution and air pollutant sources, countermeasures against pollutant sources, improvement of the monitoring system, and environmental information system. In February, 1988, the Government of Colombia requested the Government of Japan for technical cooperation concerning the air pollution control measures there. In response to this request, the preliminary survey team was dispatched to Colombia in January, 1989 and determined the scope of the work through negotiation with Colombia authorities concerned. This study was made from July, 1990 to February, 1992. This report summarizes the contents of the study.

1.1.2 Objective of the Study

The objective of the study was to investigate and analyze air pollution, meteorology, air pollutant sources, socio-economic conditions and air pollution control measures in Santafe de Bogota City, on the basis of which to propose a guideline for the air pollution control measures there. And through this study was aimed technology transfer from the study team to Colombian counterpart on various surveys, analysis and air pollution control measures.

1.2 Outline of the Study

1.2.1 Scope of the Study

(1) Study Area

As shown in Fig. 1.2.1, the study area is the area under the jurisdiction of the Secretaria Distrital de Salud de Santafe de Bogotá D.C., approximately 35 km from south to north and 24 km from east to west, which includes the urban area of Santafe de Bogota City.

(2) Scope of the Study

This study was executed in Santafe de Bogota City and Japan. As shown in Fig. 1.2.2, the study includes the basic study and the analytical study. Detailed description is given below.

Fig. 1.2.1 Study Area

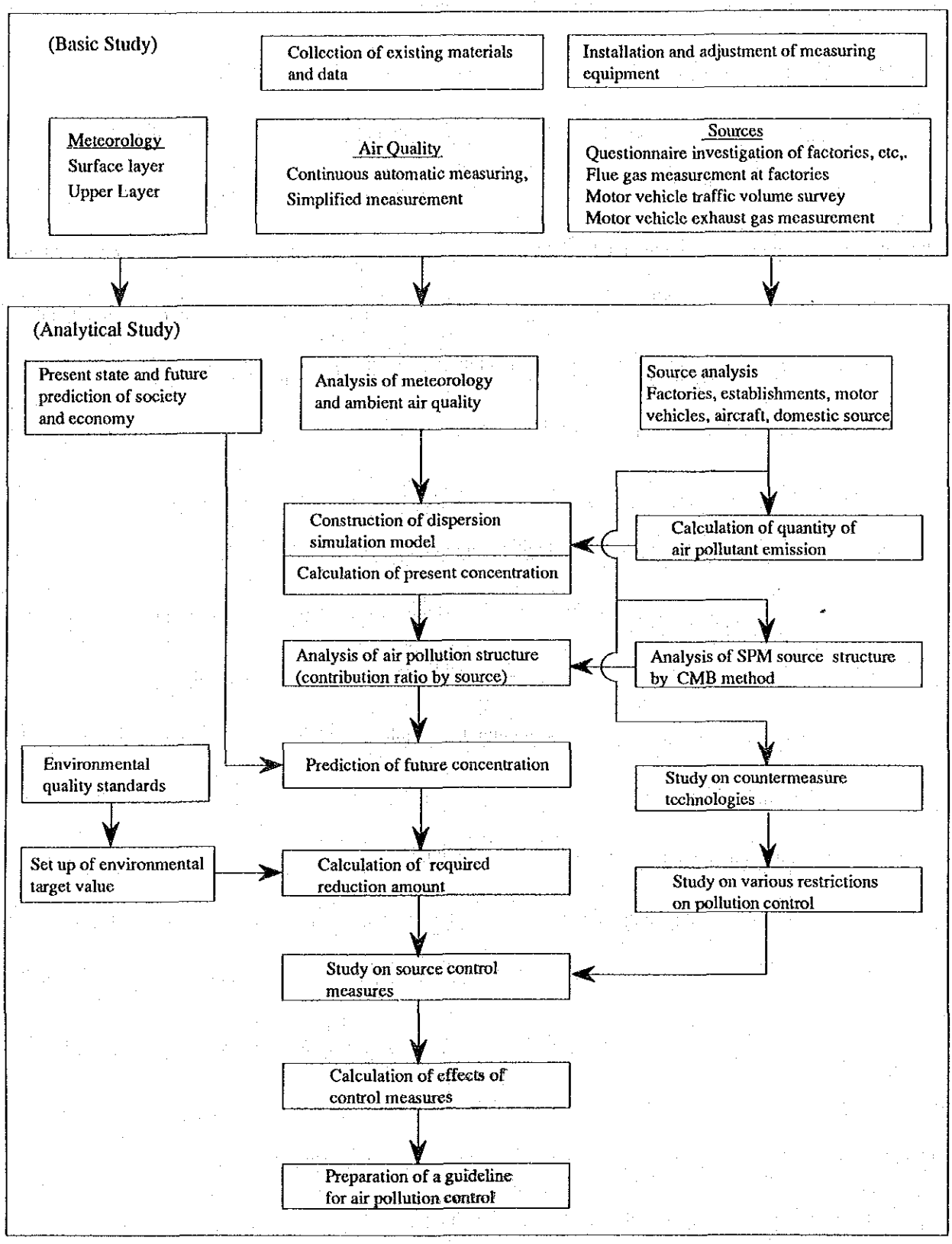

Fig. 1.2.2 Outline of the Study

1) Basic Study

a) Collection of existing materials and data

- o Meteorology, climate
- o Ambient air quality
- o Mobile sources: motor vehicles, aircraft
- o Stationary sources: factories, establishments and domestic source
- o Socio-economic conditions
- o Source control measures
- o Laws, regulations, standards, etc.

b) Installation and adjustment of measuring equipment

- o Monitoring station
  - air quality monitoring equipment, wind vane and anemometer, pyranometer and balance meter
- o Upper layer meteorology
  - tethered sonde, radio sonde, wind vane and anemometer
- o Factory flue gas measuring vehicle
- o Motor vehicle exhaust gas measuring vehicle

c) Field Investigation

- o Meteorology
  - observation of surface meteorology: wind direction and speed, solar radiation, net radiation
  - observation of upper layer meteorology: vertical distribution of wind direction, wind speed and temperature
- o Ambient air quality
  - monitoring at 5 stations
    SO_2, NO, NO_2, NOx, SPM, CO, NMHC, CH_4, THC,
    particle size distribution and heavy metal components of SP
  - measurement of SO_2, NO_2, NOx, CO by simplified method
- o Pollutant sources
  - investigation of factories by questionnaire
    type of facility, type of fuel and its consumption, stack height and its position, etc.
  - measurement of factory flue gas
    SO_2, NOx, PM (Particulate matters), O_2, temperature and quantity of flue gas

- survey of traffic volume and vehicle driving speed
- measurement of motor vehicle exhaust gas
  CO, HC, NOx
- analysis of sulfur content in fuels
- analysis of heavy metal components of surface soils

2) Analytical Study

o Analysis of social and economic conditions
  - society, economy, land use, traffic and transportation, energy
  - laws, regulations, standards, administrative organization

o Analysis of meteorological data
  - surface meteorology
  - upper layer meteorology

o Analysis of ambient air quality
  - monitoring station
  - simplified method

o Analysis of pollutant source
  - factories, establishments, motor vehicles, aircraft, domestic source

o Development of air dispersion simulation model and analysis of air pollution structure
  - air dispersion simulation for SO_2, NOx, NO_2 and CO
    meteorological model, source model, dispersion model
  - contribution of pollutant sources
  - contribution of SPM sources by Chemical Mass Balance Method

o Prediction of air quality and required reduction amount
  - prediction of air pollutant emission from sources
    factories, establishments, motor vehicles
  - prediction of ambient air quality
  - target value of ambient air quality
  - Air pollutant reduction amount

o Study of air pollutant source control measures and their effects
  - control measures against factory exhaust gas
    technology, restriction, cost
  - control measures against motor vehicle emission gas
    technology, restriction, cost
  - prediction of effect of control measures
    factories, motor vehicles

- o Presentation of guideline for air pollution control
  - targets
    basic concept
  - implementation of pollutant reduction mreasures
    summary of control measures, schedule
  - execution organization
    organization, institution, legal regulation, monitoring system

(2) Study Time Schedule

The study was made from July, 1990 to February, 1992.
The study time schedule is shown in Figure 1.2.3.

(3) Technology Transfer

The study team achieved technology transfer to the counterpart of Santafe de Bogota D.C. concerning fundamental knowledge of measurement, measurement method, and equipment maintenance technique on meteorology, ambient air quality, and pollutant sources.

Technology transfer was also made on the measured data analysis by explaining the analytical results.

The contents of technology transfer is described below:

- o Meteorological Observation
  - surface meteorology
  - upper meteorology
- o Measurement of Ambient Air Quality
  - continuous measurement at the monitoring station (SO_2, NO, NO_2, NOx, SPM, CO, NMHC, CH_4, THC, O_3)
  - measurement and analysis by simplified method in the wide area and around the road (SO_2, NO, NO_2, CO)
  - measurement by high-volume air sampler and analysis of Suspended Particulates by particle size
  - measurement by low-volume air sampler and analysis of metalic component by atomic absorption spectrophotometry
- o Measurement of Pollutant Sources
  - measurement of factory flue gas

(2) Measurement of Ambient Air Quality

° Continuous measurement at the monitoring station

SO_2, NO, NO_2, NO_x, SPM, CO, NMHC, CH_4, THC, O_3

° Measurement and analysis by simplified method in the wide area and around the road

SO_2, NO, NO_2, CO

° Measurement and analysis of Suspended Particulates by particle size, and analysis of heavy metalic components

° Sampling by Andersen high-volume air sampler, metalic component analysis by atomic absorption spectrophotometry

(3) Measurement of Pollutant Source

° Measurement of factory flue gas

° Measurement of motor vehicle exhaust gas

° Survey of traffic volume and driving speed

(4) Analytical Study

o Meteorology, ambient air quality, air pollution sources

o Air dispersion simulation model

o Control measures for air pollution

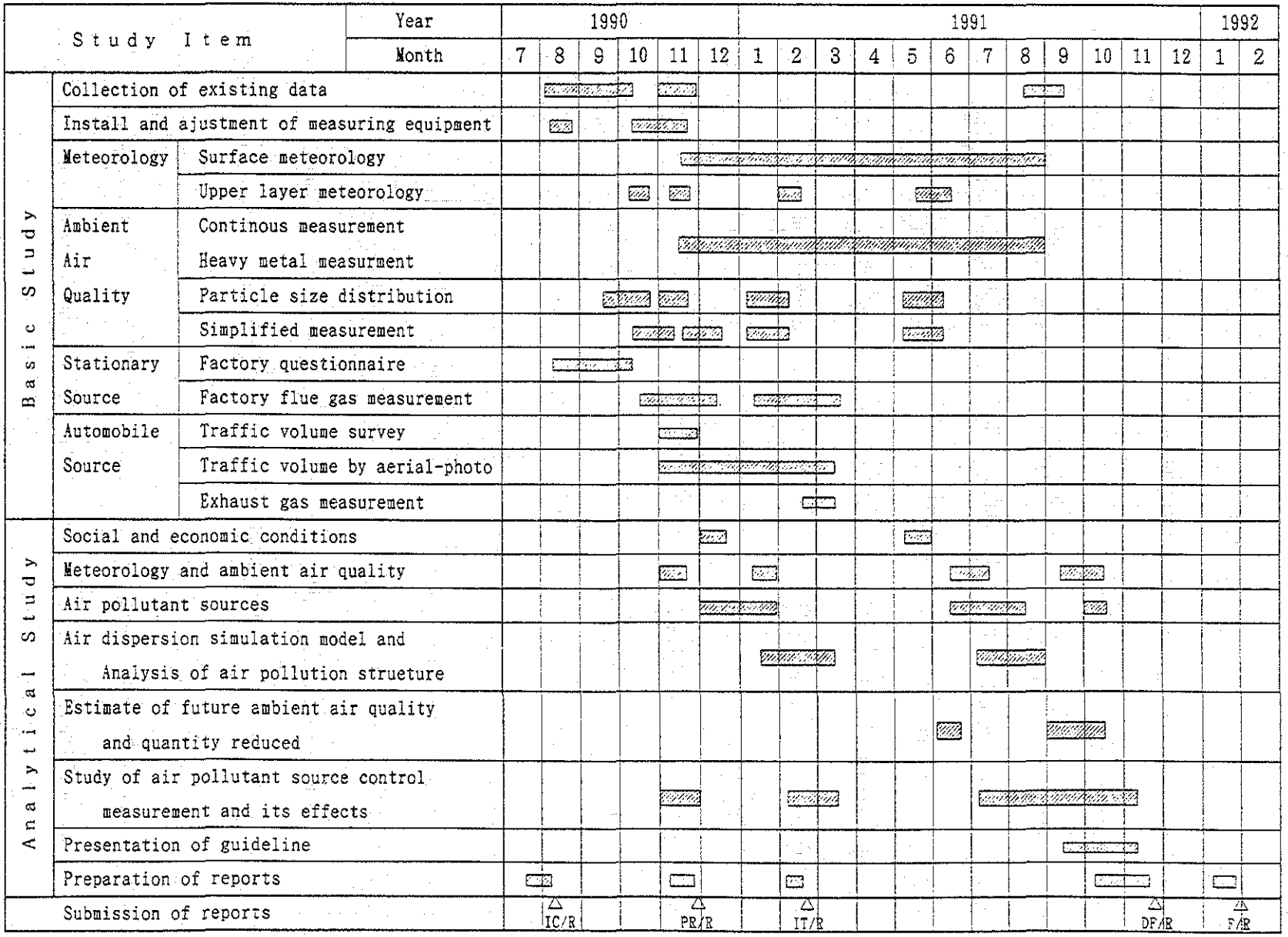

Fig. 1.2.3 Time Schedule for the Study

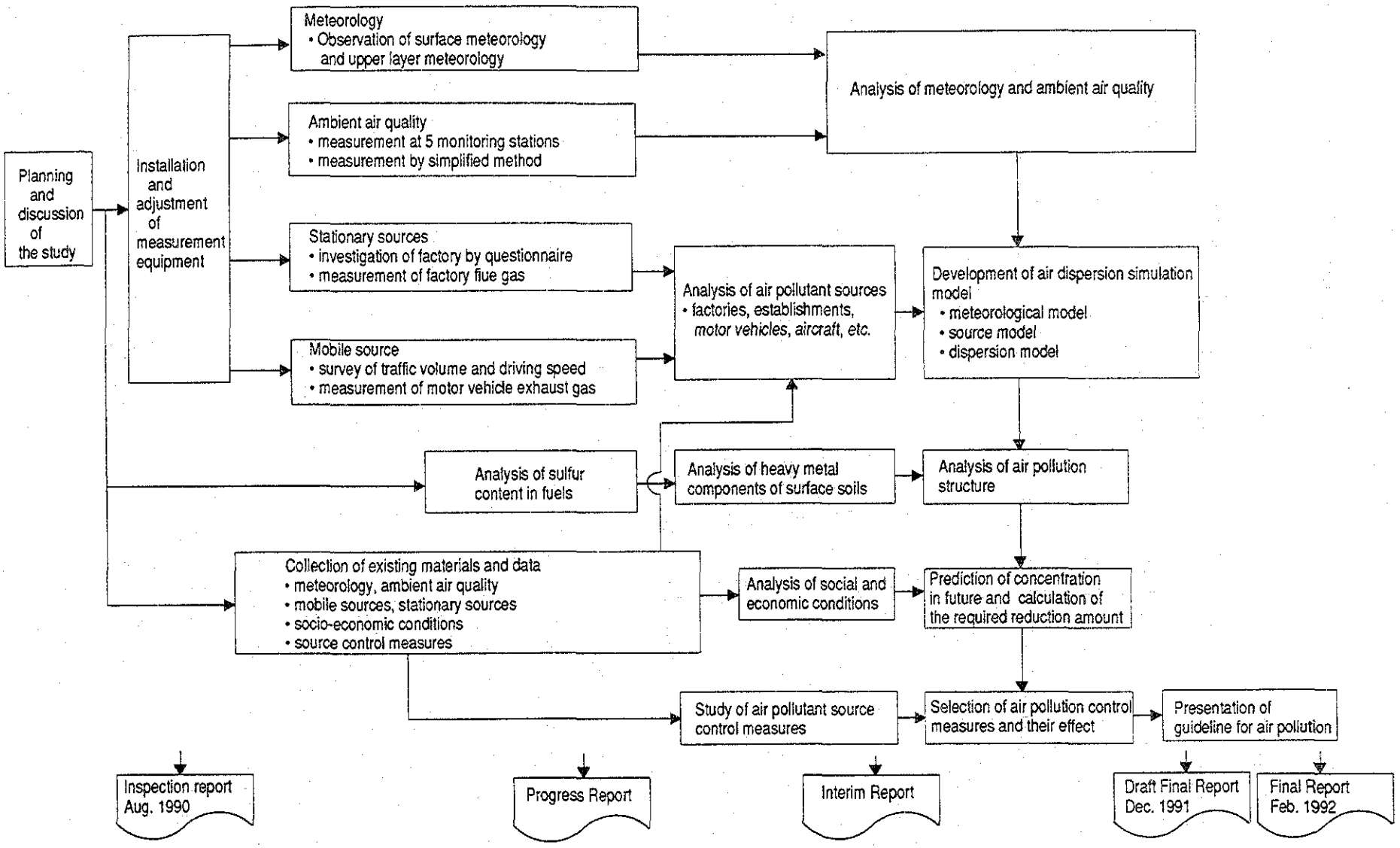

Fig. 1.2.4 Study Work Flow

1.3 Organization for the Study

1.3.1 Organization of the Secretaria Distrital de Salud de Santafe de Bogotá D. C.

For conducting the Study, the Secretaria Distrital de Salud de Santafe de Bogotá D.C. established a counterpart team (hereinafter called "Counterpart Team") of thirteen members headed by Dr. Edgar Camilo Luengas Pinzon, the Jefe Section Proteccion Ambiente, La Secretaria Distrital de Salud de Santafe de Bogotá D. C. The members of the team are as shown in Table 1.3.1.

Table 1.3.1 Members of the Counterpart Team

Field	Items in Charge	Name
Supervision	Entire Study	ING. EDGAR CAMILO LUENGAS PINZON
Socio-economic Analysis	Present state of society and economy and urban plan	TEC. JAIME MERCHAN PULIDO
Meteorological Measurement	Upper Layer and Surface Meteorological Measurement	TEC. JOSE ARDILA MORENO TEC. JAIME MERCHAN PULIDO
Air Quality Measurement	Measurement at stationary measuring points and simplified measurement	ING. CESAR A. GARCIA UBAQUE TEC. MIGUEL ANTONIO CARO TEC. JAIRO TELLEZ BALLEN
Air Quality Chemical Analysis	Chemical Analysis of Samples	ING. MAURICIO DIAZ ZAPATA ING. EDGAR BELTRAN
Stationary Source	Stationary Source Measurement and Analysis	TEC. HERNAN G. PATINO GARZON TEC. DIEGO RAYO ANTURY TEC. RICARDO CEBALLOS QUINTERO
Mobile Source Measurement	Mobile source analysis and Measurement	ING. RAFAEL OSPINA LOPEZ TEC. ANGELA GOMEZ FORERO TEC. ERNESTO HERRAN PRIETO TEC. JAIME MERCHAN PULIDO
Modeling and Simulation	Simulation Analysis	ING. RAFAEL OSPINA LOPEZ
Pollutant Source Control	Stationary and Mobile Source Control	ING. RAFAEL OSPINA LOPEZ TEC. HERNAN G. PATINO GARZON
Guideline Preparing	Organization and Regulation for Air Pollution Control	ING. EDGAR CAMILO LUENGAS PINZON

1.3.2 Japanese Organization

The Japanese organization for the Study consists of the Advisory Committee and the Study Team which had been organized by JICA. The members of the Advisory Committee and the Study Team are shown in Tables 1.3.2 and 1.3 .3 respectively.

Table 1.3.2 Members of the Advisory Committee

Name	Field in Charge	Present Post	Remark
Tomokazu Okumura	Chairman/Overall Supervision	Head of Planning Division Planning and Coordination Bureau, Environment Agency	July, 1990 ~
Kenzi Kazuno	Pollutant Source Measurement	Staff of Air Pollution Control Section, Environmental Protection Bureau, Yokohama City	July, 1990 ~
Gen Inoue	Air Pollution Analysis	Chief of Section of Atmospheric Measurement, Division of Atmospheric Environment, The National Institute for Environmental Studies	July, 1990 ~
Satoru Mizuno	Stationary Source Control	Chief of Total Pollution Control Section, Air Pollution Control Division, Air Quality Bureau, Environment Agency	July, 1990 ~ Aug., 1991
Takashi Shimodaira	Stationary Source Control	Head of Automotive Pollution Control Division, Air Quality Bureau, Environment Agency	Sept. 1991 ~
Shinsuke Unisuga	Mobile Source Control	Chief of Section, Automotive Pollution Control Division, Air Quality Bureau, Environment Agency	July, 1990 ~ July, 1991
Motoharu Yamazaki	Mobile Source Control	Chief of Section, Automotive Pollution Control Division, Air Quality Bureau, Environment Agency	Aug., 1991 ~

Table 1.3.3 Members of the Study Team

Name	Field in Charge
Yoshikazu Sugita	Overall Supervision
Nobuo Araki	Meteorological and Air Quality Analysis
Makoto Miyakawa	Pollutant Source Analysis
Haruo Kikuchi	Modeling and Simulation Analysis
Kihachiro Urushibata	Air Pollution Control Planning
Shinzo Hirasawa	Stationary Source Control
Masaaki Noguchi	Mobile Source Control
Yutaka Nozaki	Socio-economic Analysis
Masanori Fuzikawa	Meteorological Observation
Yoichiro Okayama	Air Quality Monitoring
Kazuo Watanabe	Stationary Source Investigation
Tsutomu Kurihara	Mobile Source Investigation
Nobumasa Morita	Equipment Maintenance

CHAPTER 2 OVERVIEW OF THE STUDY AREA

CHAPTER 2 OVERVIEW OF THE STUDY AREA

The natural and social environment of the study area summarized from the existing data collected in Santafe de Bogota City, is as follows:

2.1 Natural Environment

2.1.1 Geography

The study area is located in the southeast part of the basin on the plateau 2,600 m above sea level, as shown in Fig. 2.1.1, and there are mountains about 3,000 m high in the eastern part of the area.

The land of the urban area of Santafe de Bogota City is generally flat and gradually becomes higher towards eastern mountains.

In the Bogota plain, the Bogota river runs gently in the center, and here and there remain ponds and damp areas. In the area, there are many places reclaimed from marshes.

2.1.2 Climate

According to the Koeppen's classification, Santafe de Bogota City is situated meteorologically in Cw, (clima humedo de tierras templodas y frias at an elevation of 1800 - 2800m and air temperature of 18 - 12°C), which in turn belongs to the clima de montana tropical observed at an elevation of 1800m or more and air temperature of 18°C or less. Though the Santafe de Bogota's position is in the low altitudes near the equator, the meteorology here is characterized by the annual mean air temperature as low as 14°C because it is located in the highland basin. Other characteristics include small fluctuation of temperature along with seasonal change, rainy seasons twice a year, and low wind speed.

Fig. 2.1.2 shows the monthly changes of temperature, hours of sunshine, humidity and precipitation of MET Nacional Meteorological Station located in the town. The wind velocity is that of APTO Eldorado Meteorological Station close to Eldorado Airport.

The annual mean wind speed is low; 1.9 m/sec, and April, October and December are months with relatively low wind speed, while in March, June and July, wind is relatively strong.

The annual mean temperature is 14°C, and throughout the year the monthly mean temperature is almost constant, though there is slight rise between March and May. The minimum temperature falls between October and January, and at the same time there are plenty hours of sunshine, which suggests that there is much appearance of fine weather during this period.

The annual precipitation is 919 mm, and the rainy seasons come twice a year; from March to May and from October to November. The annual mean humidity is 73%, and its monthly change is similar to that of precipitation.

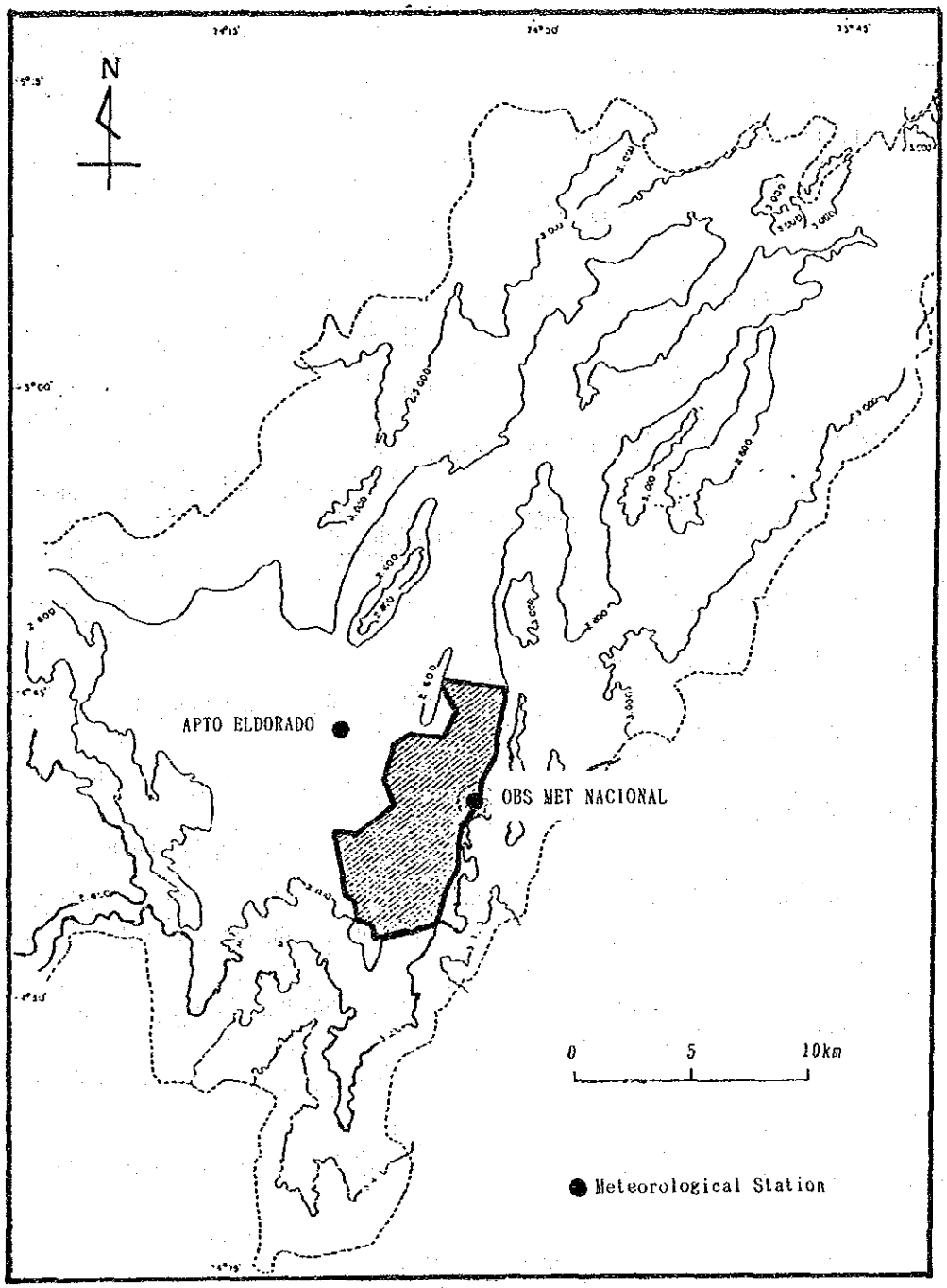

Fig. 2.1.1 Topography Map Around Bogota City

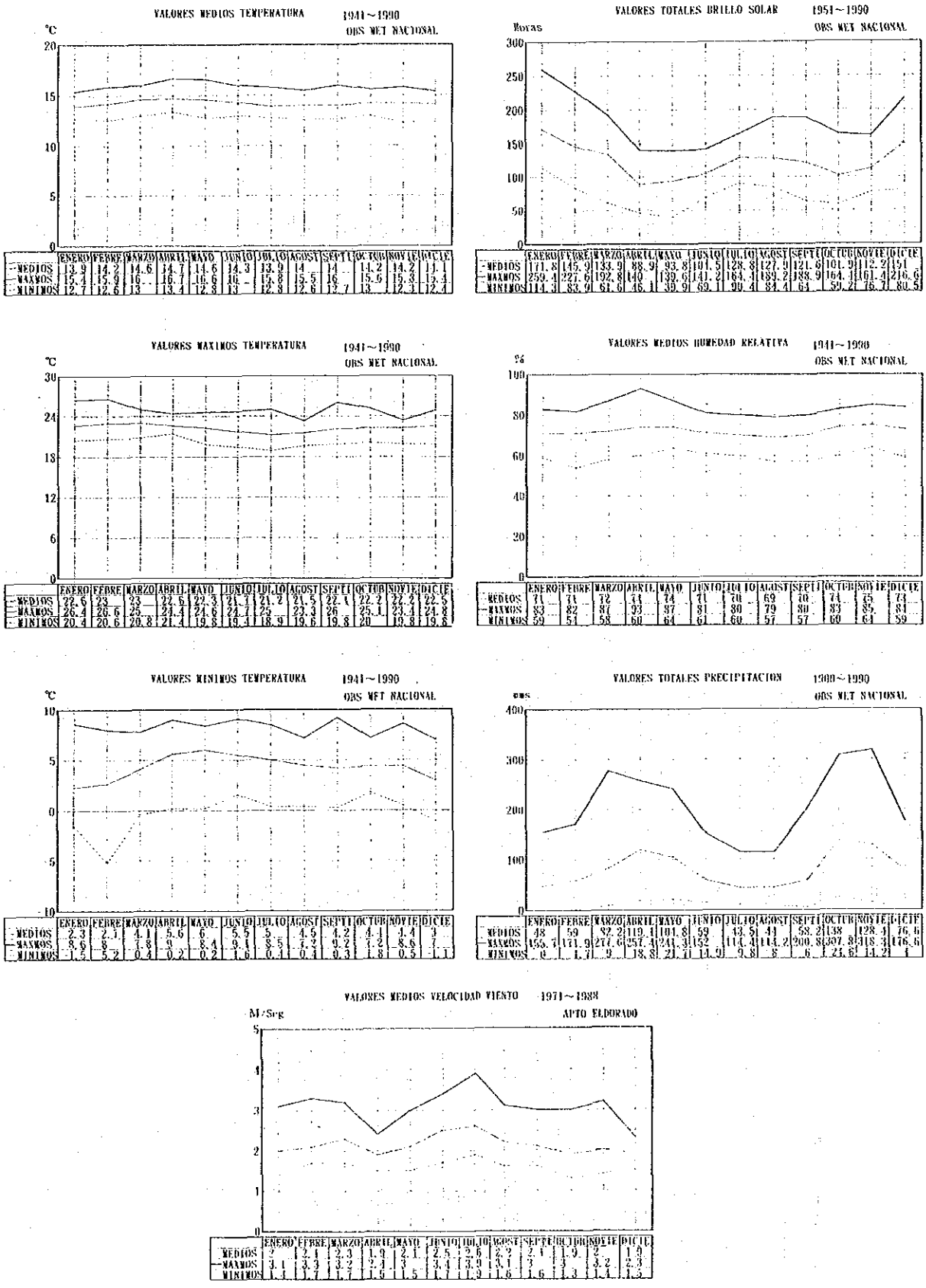

Fig. 2.1.2 Monthly Meteorological Data of El Dorado and OBS MET Nacional Station

2.2 Social Conditions

2.2.1 Society

(1) Political Institution

Colombia is a Constitutional Republic and the parliamentary democracy is firmly rooted. Practically two major parties, the Liberals and the Conservatives have been vying for years. President Gaviria of the Liberal Party has been incumbent since August 1990. Their guideline is firm ties with free countries, the U.S. in particular, Latin American countries and Asian countries as well.

The capital city is Santafe de Bogota, and the entire country consists of 23 Departamentos, 5 Intendencias and 5 Comisarias. Similar to 6 autonomies of Bosa, Engativa, Fontibon, Suba, Usaquen and Usme, Santafe de Bogota City was accorded with the status of Distrito Especial (Special District) as the capital of the Republic by the Legislative Decree No. 3640 of 1954. The city of Bogota consists of 560 Sectores, in 39 Comunas or 20 Alcaldia Menors. As the Mayor of Bogotá D.E., Liberal Party member Caicedo was elected in March 1990 by a direct voting.

(2) Population

1) National Population

According to the 15th nationwide census of 1985, the total population of Colombia was 30,061,000, of which urban population was approximately 67%. The overall mean population density was 26.3/km^2 (#1055). The mean population growth between 1964 and 1973 was 2.9%, but is declining since then; 2.0% between 1974 and 1985 and 1.7% in 1987 (#1046).

Recently, both the birth rate and the death rate have been declining; the gross rates between 1983 and 1988 are 27.9% and 7.4% respectively. The average life expectancy has been increasing year after year; 66 years of age between 1980 and 1985. The birth rate per mother has declined sharply from 6.0 children (1967 - 1968) to 3.4 (1981 - 1986) (#1046).

(#***): Number of reference list shown in Part 6 in Supporting Report

2) Population of Santafe de Bogota City

The population of Bogotá D.E. (total area is 1,587 km^2) in 1985 was 4,236,000, accounting for 14.1% of the national population. Of the total, 99.8% are urban dwellers. The mean population density of Bogota City was 2,669/km^2, that for the whole area (311 km^2) was 12,700/km^2, and that for the urbanized area (164 km^2) was 24,000/km^2 (#1055, #1021, #1030).

The population density for the city area is higher in the south and lower in the north. The density at the southernmost 25th Comuna is the highest, 45,400/km^2, followed by the 24th Comuna. The density is the lowest at 6,600/km^2 in the middlewest 62th Comuna followed by the northern 83rd and 84th Comunas and middlewest 63rd Comuna (Fig. 2.2.1).

The city of Bogota was a local city having a population of around 100,000 in the early years of the present century. The majority of the present population is immigrants from other areas (#1034).

Table 2.2.1 Population Growth during the 20th Century (#1034)

Year	Population	Mean Annual Growth Rate
1905	100,000 Persons	2.79%
1938	355,506	4.21
1951	715,250	5.52
1964	1,697,311	6.87
1973	2,861,913	5.98
1985	3,967,988 (Tentative figure)	2.76

Although the annual mean growth had been slightly below 3% at the beginning of the present century, it reached a summit of 6.8% between 1951 and 1964, and then, sharply declined to 5.98% for 1964-1973 and to 2.76% for 1973-1985 (Table 2.2.1).

According to the Planning Bureau's census, the population of Bogota City in 1981 and 1985 was 3,775,007 and 3,950,401 respectively, increasing 175,394 or 4.65% in 4 years, or 1.14% annually (Table 2.2.2). Generally, population is declining in many Comunas. But in both the

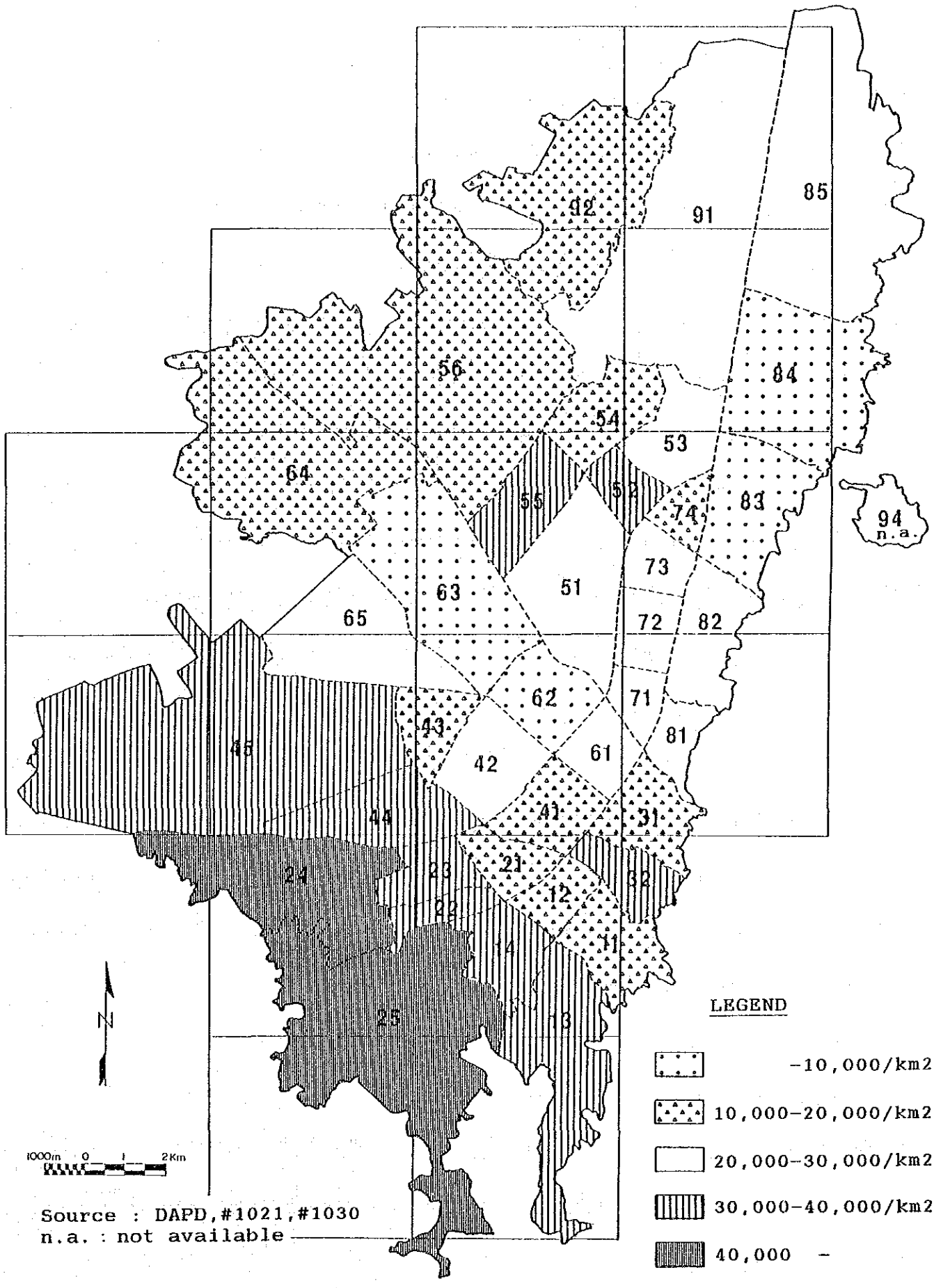

Fig.2.2.1 Population Density (1985)

Table 2.2.2 Population at Each Comuna

Comuna No.	Area			Population				Dwelling		
	Total Area km2	Urbanized Area km2	Urbanized Ratio %	1981	1985	Annual Growth%	Population Density/km2	1981	1985	Growth %
11	4.33	1.88	44	59,856	50,131	-4.06	26,630	9,265	10,969	18.4
12	2.32	2.03	87	45,543	43,705	-1.01	21,576	7,810	9,838	26.0
13	9.43	7.06	76	182,281	214,140	4.37	30,316	27,227	47,223	73.4
14	4.10	2.51	61	88,757	84,235	-1.27	33,620	14,409	18,731	30.0
21	2.38	2.40	100	64,382	56,172	-3.19	23,397	11,666	13,797	18.3
22	1.61	1.62	100	65,677	51,260	-5.49	31,583	10,332	9,526	-7.8
23	2.84	2.56	93	103,833	84,725	-4.60	33,136	13,541	21,308	57.4
24	11.70	4.29	37	167,093	188,668	3.23	44,023	21,763	47,108	116.5
25	23.29	8.76	38	307,369	397,475	7.32	45,359	43,383	90,967	109.7
31	3.86	3.41	87	55,149	92,344	16.90	27,106	15,674	26,060	66.3
32	3.39	2.27	68	80,452	77,052	-1.06	34,017	12,480	18,708	49.9
41	3.81	3.31	87	97,829	72,884	-6.37	22,018	18,585	16,823	-9.5
42	4.81	4.04	83	77,821	76,369	-0.47	18,891	13,508	16,516	22.3
43	2.66	2.62	96	85,309	76,134	-2.69	29,048	13,889	18,511	33.3
44	5.88	4.75	80	169,915	145,203	-3.64	30,591	25,036	31,318	25.1
45	31.76	14.83	47	466,332	558,182	4.92	37,629	72,756	120,109	65.1
51	8.78	3.54	40	56,522	57,311	0.35	16,206	11,355	12,784	12.6
52	2.12	1.73	81	68,550	58,450	-3.68	33,866	11,002	14,862	35.1
53	4.18	3.56	86	56,658	52,385	-1.89	14,732	10,061	12,018	19.5
54	4.15	3.22	76	89,180	71,891	-4.85	22,359	13,145	17,346	32.0
55	4.83	2.79	58	115,873	99,258	-3.58	35,527	17,417	22,730	30.5
56	30.03	11.97	40	315,581	353,360	2.99	29,512	48,217	78,056	61.9
61	2.87	2.32	79	41,859	32,607	-5.53	14,070	9,585	9,777	2.0
62	3.98	3.66	93	29,256	24,075	-4.43	6,581	6,409	6,111	-4.6
63	11.52	3.80	33	39,175	35,210	-2.53	9,267	6,572	7,382	12.3
64	16.88	5.27	31	116,887	122,332	1.16	23,211	19,009	27,627	45.3
65	9.08	3.20	35	48,041	44,688	-1.74	13,957	7,822	9,731	24.4
71	1.93	1.87	100	34,339	26,521	-5.69	14,176	7,843	7,403	-5.6
72	2.69	2.65	100	54,039	43,696	-4.78	16,479	11,703	11,189	-4.4
73	2.37	2.37	100	54,422	44,339	-4.63	18,728	10,370	11,337	9.3
74	1.64	1.59	100	36,561	31,791	-3.26	20,009	6,596	7,819	18.5
81	2.53	1.25	52	25,698	18,055	-7.44	14,397	6,232	5,874	-5.7
82	5.18	3.35	63	60,216	46,892	-5.53	14,001	14,828	14,027	-5.4
83	7.25	5.71	78	56,795	50,649	-2.71	8,874	14,082	15,281	8.5
84	12.12	7.55	62	71,608	70,397	-0.42	9,325	13,217	17,762	34.4
85	21.28	11.04	52	97,093	129,569	8.36	11,736	16,594	31,693	91.0
91	24.21	8.89	37	105,981	133,542	6.56	15,024	17,825	31,847	78.7
92	13.03	4.69	36	83,077	121,317	11.50	25,844	11,909	29,651	149.0
94					13,387				3,042	
Total	310.82	164.36	53	3,775,009	3,950,401	1.16	23,957	623,120	922,861	48.1

southernmost and northernmost areas it is increasing at high rates, while in the middle areas it is decreasing sharply. This means a doughnut tendency, showing decrease of population in the high urbanization areas and increase in the low urbanization areas. The growth rate is the highest in the northernmost 92nd Comuna, annual average being 9.92%, followed by the 85th and 91st Comunas, and the southernmost 25th Comuna, over 20% in 4 years (Fig. 2.2.2 and Table 2.2.4). The marked growth in the middle 31st Comuna was due to the urbanization of the parks under the Parque Central Bavaria Plan (#1051). The decrease rate is highest at an annual rate of 6.72% in the middle 81st Comuna, followed by the 41st, 71st, 61st, 72nd and 22nd Comunas, showing over 20% in 4 years. The total number of dwellings is 922,861 (1985), and its growth rate is high, 48.1% in 4 years and 10.3% in annual average (#1021).

The characteristic feature of the population trend between 1986 and 1990 includes average 16% decrease in 90% of the city area, and the 32% increase in the remaining 10% area located east of Avenida Caracas with Calle 26-40, as the aftermath of Parque Central Bavaria Plan (#1065).

A future population prediction is given in the Chamber of Commerce and Industry's "Bogotá: Prioridad Social". Annual population increase rates of 3.0% (1985-1990), 2.8% (1990-1995), 2.7% (1995-2000) and 2.6% (2000-2005) were assumed on the basis of the 1985 census analysis, and the future populations were calculated to be 4,899,000 (1990), 5,628,000 (1995), 6,425,000 (2000) and 7,300,000 (2005) (Table 2.2.3). The declining tendency of the population growth rate is ascribed to the decrease of birth rate and of immigration rate. However, the ratio to the national total population is expected to increase to 15% (2000) and to 17% (2005) (#1004).

Table 2.2.3 Population Project (#1004)

Year	Bogota D.E.	National Total
1985	4,225,858	29,879,331
1990	4,899,180	32,978,172
1995	5,627,748	36,181,862
2000	6,424,666	39,397,193
2005	7,300,436	42,556,036

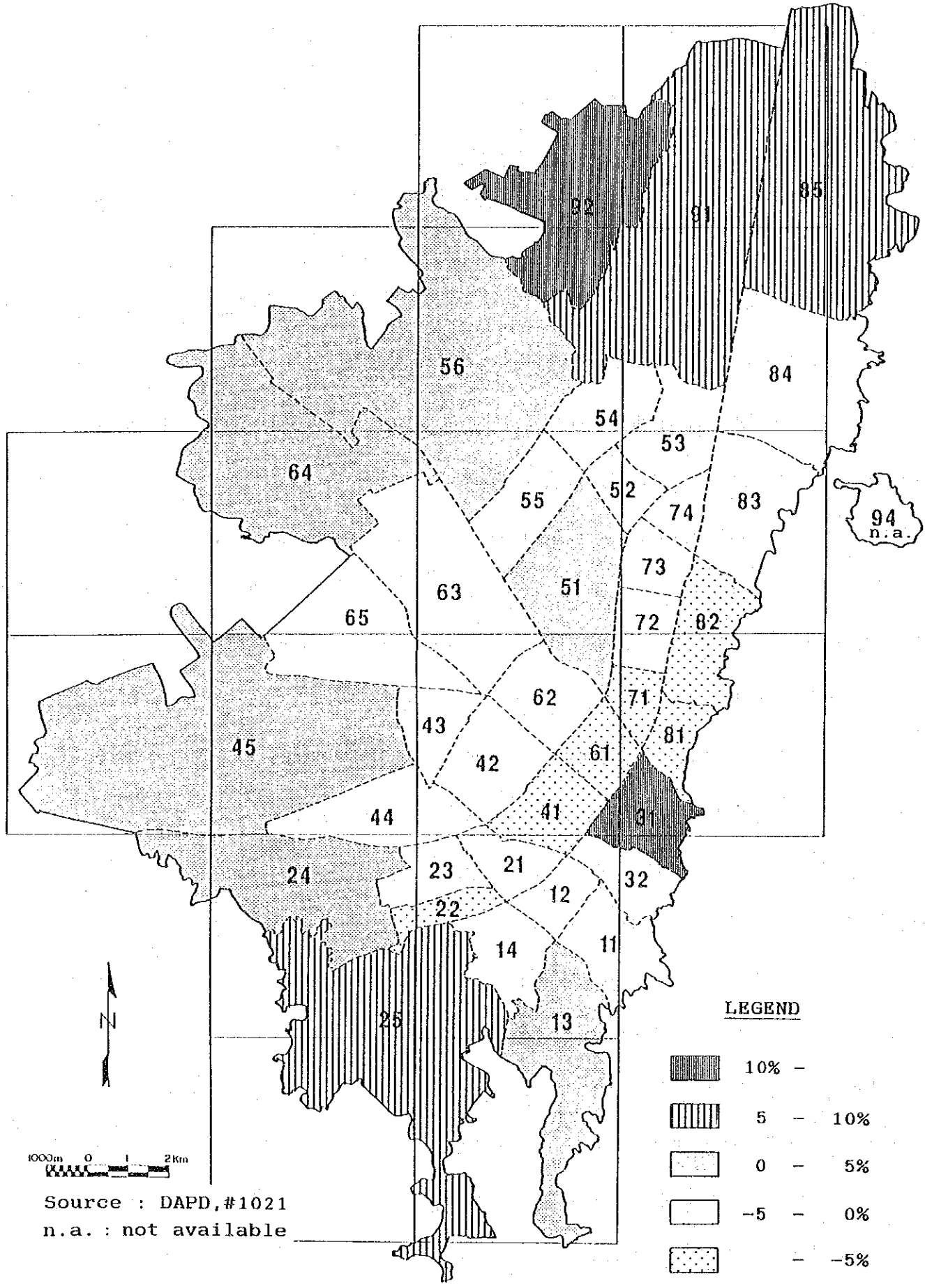

Fig.2.2.2 Population Growth Rate
(Mean Annual Growth Rate,1981-1985)

Table 2.2.4 Estimated Population (1)

COMUNAS	1986	1987	1988	1989	1990	1991	1992	1993
11	54.581	55.004	55.402	55.776	56.121	56.334	56.514	56.659
12	47.012	46.552	46.022	45.418	44.736	43.891	42.964	41.950
13	238.860	249.057	259.650	270.655	282.086	293.419	305.167	316.544
14	92.291	93.897	95.515	97.146	98.789	100.258	101.732	103.209
21	58.971	56.225	53.261	50.069	46.637	42.875	38.865	34.595
22	53.667	50.930	47.982	44.810	41.405	37.685	33.724	29.510
23	89.530	86.213	82.615	78.724	74.525	69.875	64.904	59.598
24	209.071	216.048	223.256	230.702	238.394	245.886	253.612	261.045
25	502.689	533.897	566.526	600.633	636.276	672.280	709.804	748.908
31	47.407	45.227	42.873	40.336	37.609	34.618	31.429	28.034
32	82.172	80.242	78.122	75.802	73.273	70.393	67.294	63.965
41	76.163	72.063	67.649	62.905	57.815	52.267	46.361	40.081
42	84.038	86.016	88.038	90.103	92.214	94.196	96.216	98.276
43	81.678	80.512	79.202	77.742	76.122	74.198	72.106	69.838
44	159.670	163.261	166.923	170.658	174.467	178.023	181.641	185.322
45	636.351	682.813	731.492	782.477	835.863	890.109	946.744	1.005.860
51	62.364	62.868	63.345	63.794	64.213	64.481	64.714	64.908
52	61.017	57.628	53.980	50.062	45.860	41.285	36.416	31.240
53	56.658	56.606	56.501	56.338	56.115	55.725	55.269	54.742
54	76.951	75.632	74.164	72.540	70.752	68.665	66.405	63.963
55	89.737	88.410	86.923	85.268	83.434	81.264	78.906	76.352
56	413.258	433.111	453.783	475.306	497.712	520.076	540.456	561.572
61	35.079	34.730	34.329	33.872	33.357	32.720	32.020	31.256
62	25.609	24.943	24.213	23.417	22.552	21.574	20.523	19.396
63	38.885	40.020	41.187	42.389	43.626	44.816	46.038	47.294
64	135.371	139.626	144.016	148.542	153.211	157.736	162.393	167.188
65	49.513	51.176	52.896	54.672	56.507	58.295	60.140	62.042
71	27.652	26.111	24.452	22.670	20.760	18.679	18.019	17.307
72	45.807	43.626	41.272	38.738	36.015	33.032	29.854	26.470
73	46.332	43.861	41.200	38.340	35.271	31.925	28.363	25.906
74	33.323	31.595	29.733	27.731	25.583	23.237	22.034	20.745
81	20.597	22.143	23.762	25.459	27.237	29.045	30.933	32.904
82	50.274	49.575	48.790	47.912	46.938	45.778	44.516	43.146
83	54.553	54.224	53.827	53.356	52.809	52.086	51.279	50.387
84	78.218	81.257	84.408	87.675	91.062	94.399	97.852	101.425
85	146.177	154.560	163.314	172.455	181.997	191.604	201.607	212.021
91	152.040	163.114	174.716	186.867	199.590	212.517	226.013	240.099
92	139.111	150.531	162.511	175.074	188.246	201.678	215.718	230.387
94								
TOTAL	4.352.677	4.483.303	4.617.850	4.756.436	4.899.180	5.036.926	5.178.544	5.324.146

Source : CCB,#1004

Table 2.2.4 Estimated Population (2)

COMUNAS	1994	1995	1996	1997	1998	1999	2000
11	56.768	56.839	56.798	56.713	56.584	56.406	56.178
12	40.845	39.644	38.297	36.848	35.294	33.630	31.851
13	328.320	340.509	349.795	359.334	369.134	379.201	389.542
14	104.689	106.171	107.519	108.864	110.203	111.536	112.861
21	30.055	25.231	22.978	20.585	18.047	15.358	12.512
22	25.033	20.281	15.222	11.658	7.891	6.416	6.399
23	53.943	47.922	41.469	34.635	27.404	19.760	15.540
24	268.695	276.570	284.321	292.290	300.481	308.902	317.558
25	789.649	832.089	872.315	913.211	955.673	999.758	1.043.593
31	24.423	20.586	16.494	14.126	11.618	8.966	8.091
32	60.396	56.575	52.427	48.015	43.329	38.356	33.086
41	33.412	26.336	21.702	16.800	11.619	8.964	8.085
42	100.376	102.516	104.567	106.654	108.778	110.939	113.138
43	67.385	64.739	61.814	58.686	55.345	51.782	47.988
44	189.066	192.875	196.503	196.628	196.617	196.464	196.162
45	1.067.553	1.131.920	1.197.574	1.265.937	1.337.107	1.408.684	1.478.643
51	65.063	65.174	65.160	65.098	64.985	64.820	64.599
52	25.745	22.167	18.345	15.904	13.319	12.148	10.904
53	54.143	53.467	52.644	51.739	50.747	49.664	48.487
54	61.331	58.501	55.394	52.078	48.545	44.784	40.786
55	73.591	70.615	67.329	63.816	60.066	56.069	51.814
56	583.447	606.109	628.802	652.277	676.559	701.675	723.798
61	30.424	29.519	28.505	27.415	26.245	24.994	23.656
62	18.189	16.899	15.503	14.020	12.446	10.778	9.010
63	48.584	49.909	51.207	52.539	53.905	55.306	56.744
64	172.125	177.207	182.212	187.358	192.649	198.089	203.683
65	64.003	66.026	68.028	70.089	72.212	74.395	76.650
71	16.541	15.718	14.817	13.856	12.834	11.746	10.591
72	22.873	21.866	20.759	19.576	18.315	16.972	15.544
73	23.288	20.503	17.521	14.365	11.026	9.124	7.112
74	19.366	17.893	16.302	14.612	12.820	10.921	9.939
81	34.961	37.109	39.300	41.582	43.959	46.433	49.009
82	41.665	40.066	38.296	36.403	34.380	32.223	29.925
83	49.403	48.324	47.088	45.750	44.306	42.752	41.082
84	105.121	108.945	112.760	116.702	120.775	124.982	129.328
85	222.861	234.143	245.578	256.569	267.972	277.551	287.450
91	254.800	268.449	282.313	296.728	311.714	325.413	339.623
92	245.711	259.337	271.143	284.450	298.276	310.762	323.704
94							
TOTAL	5.473.842	5.627.748	5.778.800	5.933.408	6.093.179	6.256.727	6.424.666

Source : CCB,#1004

3) Working Population

The average percentages of working age population above 12-year old and economically active population in the 7 major cities of Bogota, Medellin, Cali, Barranquilla, Bucaramanga, Manizales and Pasto in 1988 were 75.4% and 44.4% respectively, and in Bogota City were 75.0% and 46.2% respectively (#1055). In the city of Bogota, the working age population had increased from 57.6% (1973) to 65.3% (1985) and to 75.0% (1988), being mainly ascribable to increase of immigrants of working age population and feminine. The working population of Bogota City in 1985 comprised 28.7% in service, 25.1% in commerce, 23.0% in manufacture, 8.9% in finance, and 6.0% in construction industry (#1051).

The unemployment rate had reached 13-15% during the economically low growth years of 1981-1985. But it is around 10% recently. The average unemployment ratio of the 7 major cities in 1989 was 9.4%, and of Bogota City, 6.3% (Table 2.2.5). The lower unemployment in the city of Bogota was ascribable to increase of security employment such as military and police, and transfer of city cleaning service to private sector. The unemployment ratio however again increased in 1990 (June) to 10.1% (#1057).

Table 2.2.5 Unemployment Ratio (#1057)

year	Bogota City	7 Major Cities
1986	11.3%	12.2%
1987	8.7	10.3
1988	9.5	10.4
1989	6.3	9.4
1990/9	9.0	10.3

2.2.2 Economical Conditions

(1) Economy

The economical development of Colombia ranks as Lower Middle-Income Country by the Development Assistance Committee's Classification, next to Brazil and Mexico among Latin American countries. Its gross national product (GNP) in 1987 was US$36,582 million, its gross domestic product

(GDP) was US$36,027 million, and its mean real growth rate was 3.3% (1980-1987). The per capita GDP was US$1,220, and the mean real growth rate was 1.2% (1980-1987) (90, WB, World Development Report). The current balance is US$336 million in the black (90, IMF, International Financial Statistics).

The economy is based mainly on agriculture centered around coffee; agricultural sector accounting for 21.7% of the GDP in 1989, and 21-23% between 1980 and 1989. The agricultural population in the total working population is 25%, coffee accounting for 38.4% (1989) of the total export (#1048). The total export (FOB) in 1987 was US$5,739 million against the total import (CIF) of US$5,010 million, yielding US$729 million surplus (#1048).

In the recent decades, Colombia gained much foreign currency in the 1970s from the booming global coffee consumption. Its economy substantially developed with the annual GDP growth above 5% from the late 60s through the 80s. During the 80s, however, the coffee export turned to decrease, under the influence of stagnant world economy, and with the drop of international price. The national economy receded to an annual mean growth of 2.1% during 1981-1984 (Table 2.2.6). With the success of adjustment in 1984 and the rise of international coffee price, the annual growth improved to over 5%. The growth, however, began to redecline from the latter 1987. Presently the mean annual growth is 3.5% (1988-1989).

Table 2.2.6 GDP Growth (in 1975 Price: #1056)

Year	Growth Ratio	Year	Growth Ratio
1979	5.4%	1984	3.4 %
1980	4.1	1985	3.1
1981	2.3	1986	5.8
1982	0.9	1987	5.4
1983	1.6	1988	3.7 (Tentative figure)
		1989	3.2 (Estimate)

Table 2.2.7 GDP Share by Sectors (1989 Estimate: #1048)

Sector	Ratio	Sector	Ratio
Agriculture	21.7%	Transportation, Communication	8.7
Manufacture	20.9		
Finance	14.6	Mining	4.5
Service	13.6	Construction	3.8
Commerce, Restaurant, Hotel	11.6	Electric, Gas, Water	1.1

The manufacturing industry has been advancing in industrialization under the Government's policy of import-substitute industry promotion and export promotion policies started from late 1960s. Already, primitive import-substitute industries have almost fully developed, however full-scale industrialization has not developed yet. The GDP share of the manufacturing sector in 1989 was 20.9% (Table 2.2.7), and slight decline was observed from the level of 22.4% in 1980 and 21.2% in 1985 (#1048). The 1989 annual growth of manufacturing industry production index was 2.7% (Table 2.2.8).

Table 2.2.8 Manufacturing Industry Production Index Annual Growth (#1057)

Year	Growth Ratio
1987	6.4%
1988	-0.3%
1989	2.7
1990/6	6.4

The 1989 foreign debt balance was US$16,249 million, while the foreign currency reserve was US$3,867 million (Table 2.2.9), both on increase. The 1988 debt service ratio (DSR) was 43.8% (90, WB), the foreign exchange rate as of September 1990 was CL$530.54/US$, and CL$ dropped 28.9% in 1989.

Table 2.2.9 Foreign Debt Balance, Foreign Currency Reserve, Foreign Exchange Rate (#1048, #1057)

Year	Foreign Debt Balance	Foreign Currency Reserve	Exchange Rate (at term end)	Rate of Decrease
1985	US$14,063 million	US$2,067 million		
1986	14,987	3,478		
1987	15,663	3,450	CL$262.08/US$	20.8%
1988	16,434	3,810	332.97	27.0
1989	16,249	3,867	429.30	28.9
1990/9			530.54	32.0

The annual rate of consumer price increase has been comparatively stable, at 26-28% between 1988 and 1990 (Table 2.2.10).

Table 2.2.10 Annual Rise Rate of Price Index (#1048)

Year	Consumer Price	Wholesale Price
1987	24.0%	25.2%
1988	28.1	29.5
1989	26.1	25.6
1990 (Estimate)	28.0	25.1

(2) Economical Structure of Santafe de Bogota City

In 1985, Bogota City yielded CL$1.09 billion, accounting for 22% of the GDP. The real growth rates from 1986 to 1989 were 5.0%, 5.4%, and 4.6% respectively. The per capita amount was CL$258,151, 55% above the national average, and the real growth rates from 1986 to 1989 were 1.9%, 2.3% and 1.5% (#1004).

Among the GDP components, the tertiary industry is the overwhelming majority at 71.4%, mainly comprising commerce, transportation, and communications sectors. The secondary industry is the runner-up at 28.6%. In sector point of view, manufacture at 22.2%, government service at 14.0%, and personal service at 13.8% are the top three, followed by housing rent at 10.4%, commerce at 10.3%, and transportation at 9.3%. The agriculture-cattle industry and the mining industry are minor. Within the scope of the manufacturing industry, food at 3.6%, chemical and rubber at

2.8%, fiber at 2.6%, machinery at 1.9% and the transportation material at 1.5% are major branches (#1004).

As to sectors' share to the national GDP, communication at 48.5%, import-related at 42.2%, housing rent at 37.0%, government service at 35.9% and personal service at 35.7% are by far largest. Among the manufacturing industry, transportation material at 54.7%, machinery at 51.4%, beverage at 36.2%, food at 31.5% and chemical and rubber at 29.6% are significant (#1004). Because of these conditions, move and trend of economical situation of Bogota City are said to exactly reflect those of the whole nation.

As for manufacturing industry in 1987, the employees were 144,323 (30.2% of national total), the gloss production was CL$1,073,520 million (25.0%), and the profit was CL$385,408 million (23.8% of national total) (Table 2.2.11). As for investment, investment for machinery was greatest, followed by building and facilities (Table 2.2.12). The annual growth rate of manufacturing production index had been declining between 1987 and 1989 from 4.7% through 2.2% to -1.1% (#1004).

Table 2.2.11 Bogota City Manufacturing Industry (#1005)

Year	Employees	Gross Production	Profit
1983	132.0 thousand	CL$326 billion	CL$141 billion
1984	132.8	443	184
1985	131.2	583	246
1986	137.0	788	314
1987	144.3	1,074	385

Table 2.2.12 Bogota City Manufacturing Industry Investment (CL$million; #1004)

Year	Total	Land	Building Facility	Machinery	Transport Material	Office Equipment
1983	11,288	420	3,749	6,168	580	372
1984	11,928	1,228	1,327	7,921	447	1,005
1985	12,240	675	3,899	6,275	795	598
1986	19,802	1,041	3,840	12,294	701	1,918
1987	36,773	1,048	3,863	25,613	3,479	2,771

The inflation rate of Bogota City had been 21.8%, 27.1% and 26.1% during the 1987 to 1989 period (#1055).

The 1988 revenue of Bogota City was CL$77,666 million (ordinary revenue: CL$55,733 million, capital revenue: CL$21,933 million), the annual expenditure was CL$78,876 million (ordinary expenditure: CL$28,809 million, capital expenditure: CL$21,545 million, debt expenditure: CL$15,008 million, and transfer expenditure: CL$13,514 million), resulting in the deficit of CL$1,210 million (#1055).

(3) Development Plan

As of today, Gaviria Administration's national development plan starting in 1990 is under formulation.

Since in Colombia, customarily, no major national plan is drastically changed at the transfer of power, the new development plan is expected to adopt the basic structure of the existing one.

The features of the 1987-1990 "Plan de Economia Social (economical society plan)" aimed primarily at nationwide living standard improvement, through maintenance of an annual GDP growth rate of 5-6%, a decreased unemployment rate (target: below 10%) and restriction of price rise (target: 20%) (#1058).

In that plan, although no direct mention of atmospheric environmental conservation policy was made, the sharp increase of respiratory organ diseases was pointed out. This can be interpreted as priority item in the context of sound living environment upgrading. To make a concrete air pollution control plan, the Environmental Conservation Bureau of the Ministry of Welfare had formulated an air pollution control program comprized of main activities listed below:

1. Factory operation approval system: preparation and its execution
2. Air pollution monitoring: intensification
3. Environmental impact assessment regarding air quality
4. Air pollution control measure: upgrading
5. Establishment of organization for implementation of Decree No. 2 and No. 2206
6. Eduction and training of assigned technicians
7. Purchase of measuring instruments
8. Publication of permissible standard values

On the other hand, the previous Bogotá Mayor counted air pollution control for one of his major official promises. New mayor Caicedo also emphasized urgent necessity of air pollution control in his "Plan Integral de Desarrollo de Bogota (integral development plan for Bogota)" (90, El Tiempo). According to "Bogota: Prioridad Social" formulated by the Chamber of Commerce and Industry, the priority themes of the development plan are as follows (#1004):

1. Increase of Bogota City's role
2. Clarification of scope of responsibility of Bogota City Government
3. Full presentation of basic public service to all citizens
4. Adjustment of environmental issues for Bogota City plan
5. Development of political and administration system and their modernization
6. Finance reinforcement and investment return sustenance

In addition, the following 6 strategic areas are listed:

1. Population, economical growth and employment
2. Systematized urbanization
3. Environment
4. Social service to residents
5. Development of laws, regimes, politics and administration
6. Finance reinforcement and investment return sustenance

As can be seen from the foregoing, the environmental quality restoration and maintenance are the most important elements for resident living quality improvement which is a target set by the state and the city. The most significant causes of the environmental quality degradation are considered to be urbanization and industrialization. Furthermore, concentration of manufacturing factories, increase of vehicles, and disorderly urbanization are pointed out as the fundamental causes of air pollution in Santafe de Bogota City.

2.2.3 Land Use

(1) Present Condition

In the city of Santafe de Bogota, residential lands are located in the northern and the southern parts, and the area between them are covered by industrial lands and metropolitan facility lands. In addition, in the eastern hill areas and in the western Bogoté River watershed areas, preservation lands are set up. Urbanization is now expanding to the outskirt agriculture lands where agricultural potential is high. The main road network consists of the trunks running parallel to and perpendicular to the hill regions and three loop roads, with Avenida Caracas being the most important road.

According to the 1985 census, the average urbanization ratio of the 38 Comunas were around 53%. The urbanization ratio is high in the area directly west of the centrally located Avenida Caracas, the 21st, 22nd, 71st, 72nd, 73rd and 74th Comunas being urbanized almost 100%, and the 23rd, 43rd and 62nd Comunas, over 90%. On the other hand, in the west, agricultural lands and preservation lands are extensive, and urbanization ratio is generally low. The 64th Comuna is the lowest at 31%, followed by the 24th, 25th, 63rd, 64th, 91st and 92nd Comunas all ranging below 40% (Fig. 2.2.3).

As a land use plan, the Planning Bureau had formulated "Ordenamiento y Administracion del Espacio Urbanismo en Bogota 1981" with the target year set at 1985 (Fig. 2.2.4), and at present, a new one is under deliberation.

(2) History

The expansion of urbanization and metropolitan area formulation in Bogota City started in the 1950s, and the characteristic features of this process were the shifting of urban functions towards north and the establishment of specialized business bases. During the past 40 years, the population has grown from 650,000 to 4 million.

The major events that contributed to the formation of the city of Bogota up to now have been (#1034): the significant development of service center in Chapinero in the 1950s, the mushrooming of super market chain stores, the northward expansion in the Carrera 15 peripheral area, and the major

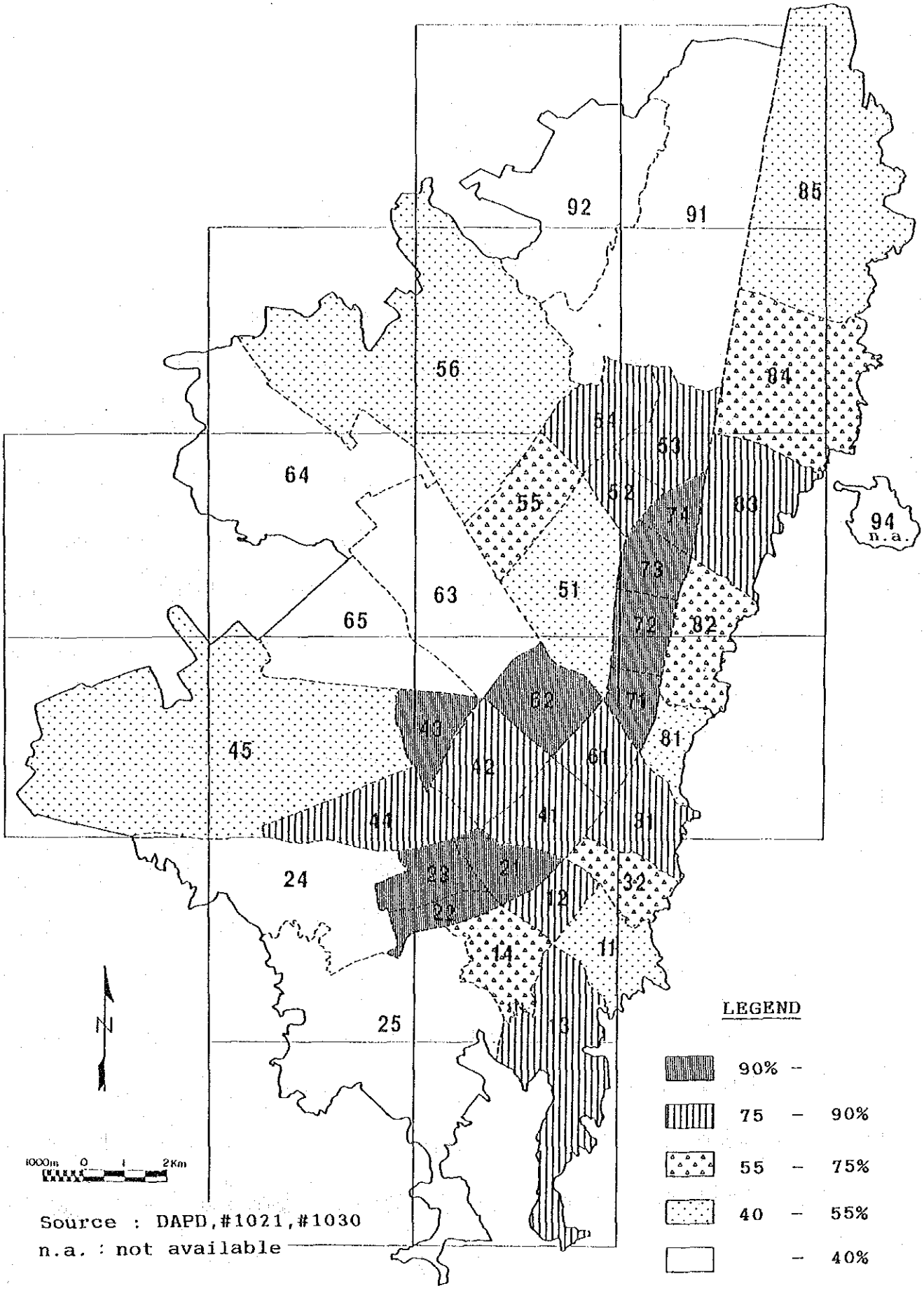

Fig.2.2.3 Urbanization Ratio (1985)

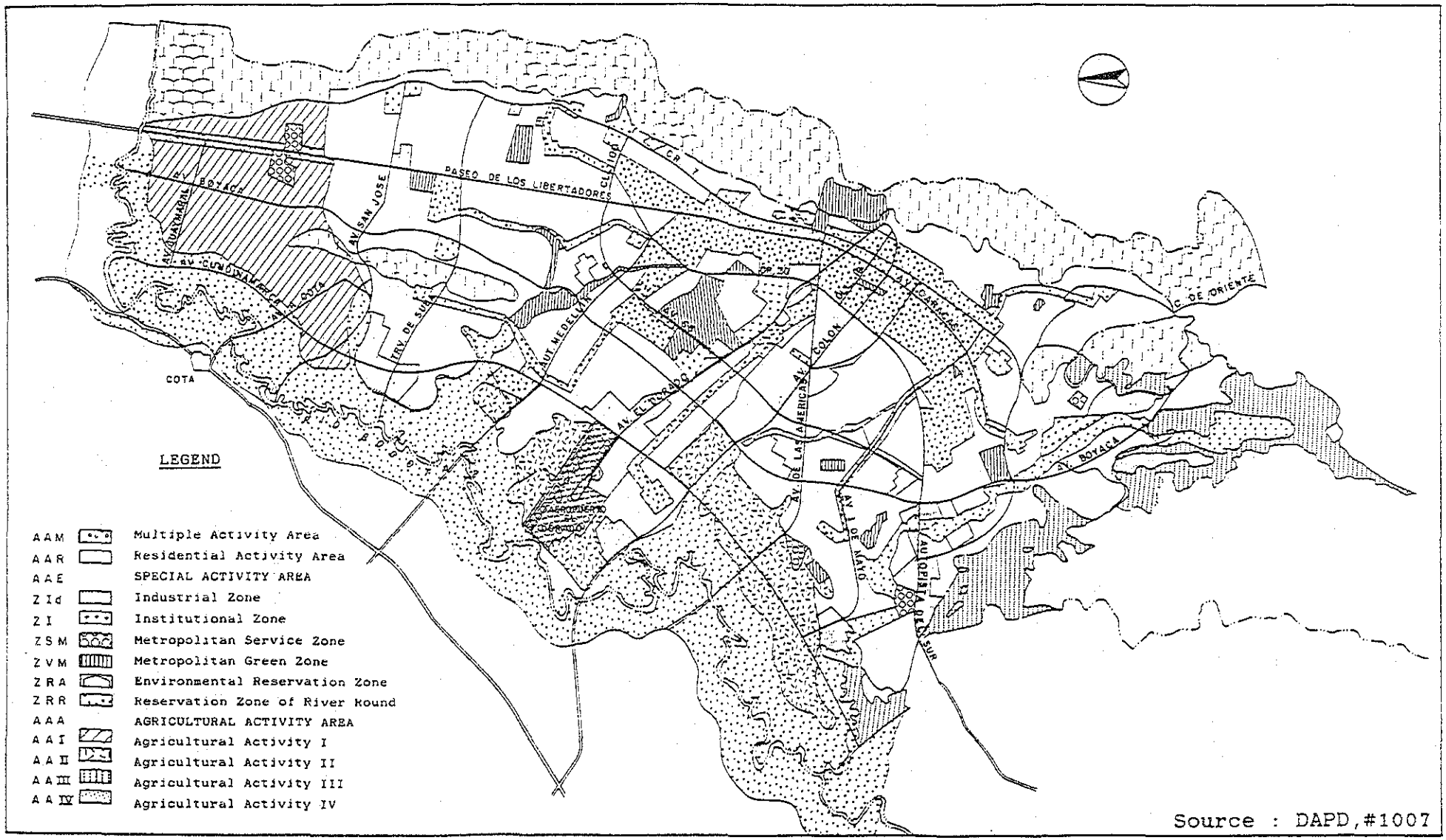

Fig.2.2.4 Zoning of Land Utilization for 1985

development in the sectors northwest of Las Ferias around 1955. In the south, the construction of Avenida 10 de Mayo induced a rapid development of the southwestern region of the city, a major development of industrial districts around Avenida Colon, followed by the construction of El Dorado Airport, Narino Center, and the relocation of the administration organization to C.A.N. (National Administration Center).

During the 1960s, the main road structure was clarified by the progress of the 1961 road pilot plan. The main features of the plan were the completion of the central loop road (Avenida 26 - Avenida Jimenez - Avenida Caracas), the construction of Avenida 19, the construction of loop segment road (Calle 100 - Avenida 68 - Avenida 10 de Mayo) including branches Calle 53, 63 and Autopista Medellin, the expansion of Avenida Ciuda de Quito directly connecting to Autopista Medellin and Autopista Sur, and the expansion of Carretera Suba.

The relocation of the economy operations to the north continued, and the development of the international center started. Chapinero has established as a major commercial center, and the area around Carrera 15 has intensified commercialization. Similarly, the establishment of Chico commercial center in the Calle 92 and that of El Lago commercial center in the Calle 77 markedly augmented the value of the areas, and changed the land use type around Carrera 15. On the other hand, the urbanization in the southern and western regions induced the development of commercial centers in Ferias, Quirigua, Fontibou and Kenedy.

During the 1970s, the sectors not developed up to that time started to develop. The northward expansion trend continued further north from Calle 100, and the development of sectors around Suba, Tunjuelito, alto Usme and San Cristobal continued. The major road constructions were the extension of Avenida 92 to Autopista Norte, the broadening of Avenida 30 between Autopista El Dorado and Autopista Sur, and the broadening of Avenida 10 de Mayo. The broadening of Avenida Boyaca towards the end of the 1970s enabled the traffic between Autopista Medellin and Avenida 10 de Mayo, forming a new road loop. The construction of Avenida 127 up to Avenida de Suba promoted the development of the northern regions.

With the annexation of Soacha sector, the city of Bogota had acquired the full function of a metropolitan area, and the sign of land use differentiation and specification was manifested in Madrid, Funza,

Mosquera, Cota and Chia. The first three sectors became the major growth centers of industrial lands and residential lands. The northern centers of Cota, Chia and Cajica transformed themselves into the residential lands for commuters to the city of Bogota.

The development in the 1980s succeeded the trend of the previous decades. The notable developments in residential lands and industrial lands were in the areas around Autopista Norte, Niza and Suba sectors, areas next to Autopista Medellin, urbanized areas close to Autopista Sur, Tunal residential center, Chapinero, Porciuncula and Restrepo new commercial centers, the construction of passenger terminal, and the recent marked growth areas around the projects of Bolivar City and Salitre City. The most important development in road network was the expansion of Autopista Norte, the northward and southward extension of Avenida Boyaca, expansion of Avenida El Dorado and Autopista Sur, the construction of Autopista Llano between Tunal and Carretera Oriente, the expansion of Avenida Ciudad de Quito, and the construction of Avenida circunvalar.

According to the industry and commerce survey in 1987 by the Finance Bureau, the current features are: the significant tendency of ordinary residences changing into retail shops and offices, and the business land increase by the evacuation of residences in Quinta Camacho, Marly, Palermo, Chapinero Occidental, La Macarena, and Teusaquillo (#1064).

2.2.4 Traffic and Transportation

(1) Road Network

The road network in Santafe de Bogota City comprises two systems; the trunk roads and local roads. The trunk road network is formed of 53 longitudinal roads and 81 transversal roads, which are 25 to 100 m in width for public transport. Their total extension is 850 km, which means the total of 5,527 km lane is under plan, with its 39%, or 2,135 km lane, having been completed (Fig. 2.2.5). On the other hand, for the local road network, 10,385 km lane length is under plan, and 4,865 km, or 47%, has been completed. The service area is 27,800 ha in the urban area and 2,500 ha outside the urban area. With the two road systems combined, approximately 7,000 km lane is paved. However, the annual increase rate of road length is only 1% in an average, which is far too low compared with the vehicle increase rate of 8% (#1065).

The current road network plan was finalized by "Plan Vial para el Distrito Especial de Bogota" which was formulated on the basis of the Decree No. 2 of 1980, adopted in replacement of Decree No. 38 of 1961 and Decree No. 59 of 1974. In the road plan "el Plan Cuatrienal de Obras Viales 1989-1992" formulated by IDU in 1989, the construction of approximately 667 km of new roads is scheduled at a total budget of CL$103 billion (IDU, #1034). In addition, the city authority formulated "Plan Integral de Transporte Urbano", for the purpose of securing aid from the World Bank (AMB, #1063, 1064).

(2) Traffic

In Santafe de Bogota City, nearly 89% of the traffic means is vehicles, and nearly 61% of the traffic use vehicles are buseta, followed by bus, the two accounting for 84% of the total, but their road space occupancy ratio is around 27% (Table 2.2.13).

Table 2.2.13 Share of Traffic Means in Bogota City (#1051)

Traffic Means	Share	Share in Vehicle Traffic
Buseta (Small Bus)	54.1%	60.8%
Bus (Bus)	20.7	23.3
Special (mainly School Bus)	3.6	4.0
Colectivo (Microbus)	1.9	2.0
Taxi (Taxi)	1.4	1.6
Automovile (Passenger Car)	7.4	8.3
Bicycle	0.4	
Pedestrian	9.1	
Others	1.6	
Total	100.2	100.0

The per capita daily vehicle traffic frequency during 1990 was 1.62/day, and the frequency is increasing. The vehicle daily average speed was 16.5 km/h (#1065).

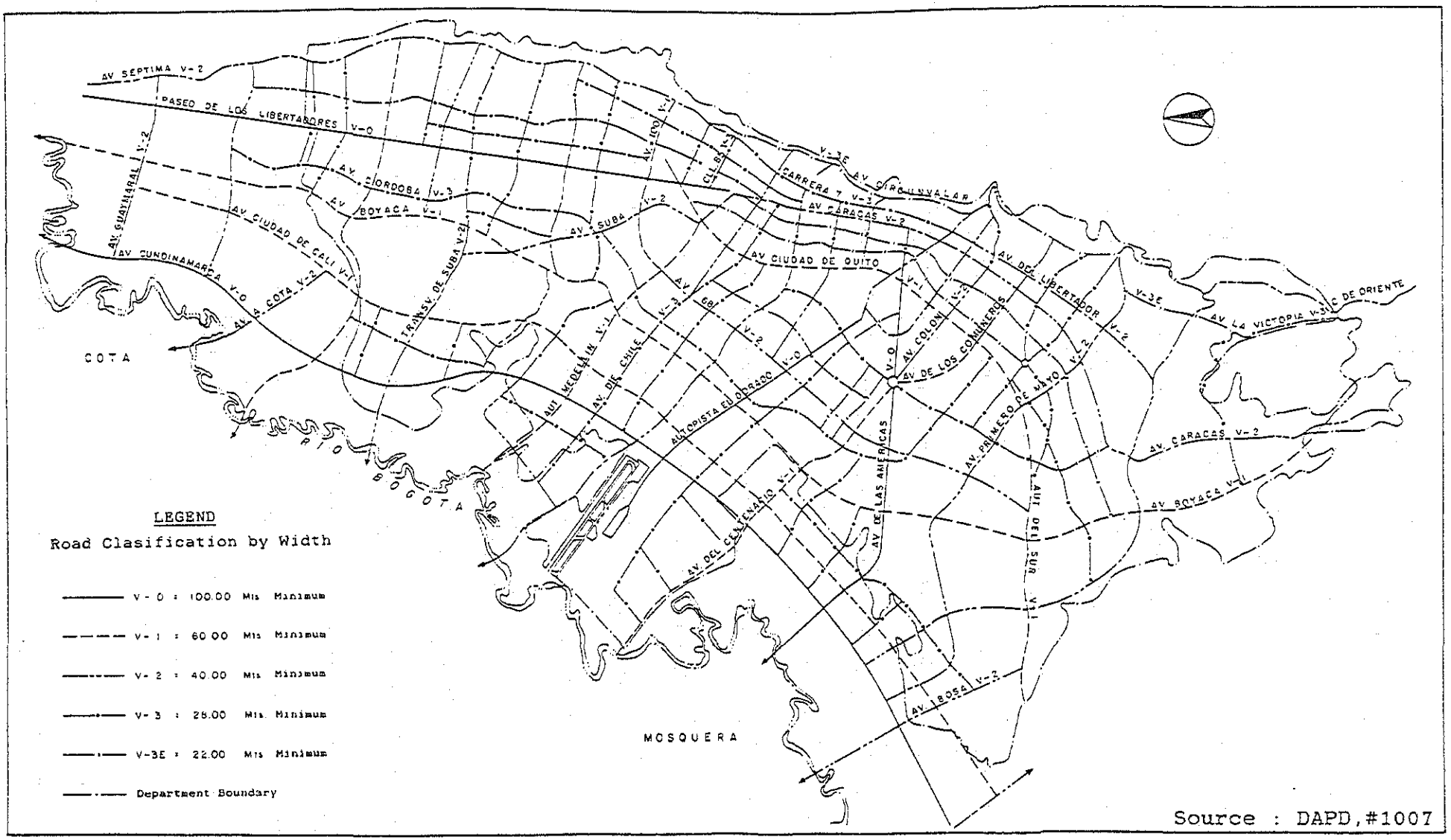

Fig. 2.2.5 Road Network and Classification

The registered number of vehicles in Bogota City in 1991 was around 350,000, of which automobile account for 63.3%, or 221,000, followed by camioneta (14.0%), campero (10.6%) and camion (4.6%). Private vehicles are 80.3% of the total, followed by public vehicles (18.0%) (Table 2.2.14). Number of vehicles per 100 people was 6.8. The number of vehicles increased at an average annual rate of 7.9% during 5 years (1985-1990), exceeding the population growth rate. Especially, private vehicles grew at a high rate of 8.1% (#1065).

Table 2.2.14 Motor Vehicles in Bogotá City. in 1991 (#6022)

Vehicle Type	Number
Automovile (Passenger car)	220,962
Campero (Jeep)	36,806
Camioneta (Light truck)	48,683
Microbus (Microbus)	1,525
Buseta (Small bus)	6,955
Bus (Bus)	11,889
Camion (Truck)	16,082
Volqueta (Dump truck)	458
Tractmula (Trailer)	1,674
Other	3,790
Total	348,824

Although no detailed survey has been made, some 580,000 vehicles are said to be in operation in the city, with around 50,000 increasing annually. This increase is nearly half of the total national increase, and the number of vehicles in excess of the registered number are considered to be those entering from the outside areas. The number of vehicles registered with the local autonomies around Bogota City (Caqueza, Chia, Facatativa, Fusagasuga, Guirardot, Mosquera, Soacha, Ubaque, Vhlleta and Zipaquira) as of 1985 was around 170,000, of which 84% were private automoviles cars, camperos and camionetas. Compared with the city of Bogota, the shares of public vehicles such as buses and busetas are small, and those of camiones and tractors are large. The annual average increase rate is around 105, which is higher than that of Bogota city (#1051).

At present, at least 60% of the air pollution in Bogota City is said to be caused by vehicles (#1034).

(3) Transportation

At present, as public traffic means, some 14,000 buses and busetas are operated by the city authority and by 39 private companies. There are 450 routes, and of these, 268 runs through the city central area. The average operation distance is 20 to 30 km. The average passengers per day are over 2.5 million, the average daily ride frequency is 6.3 million, and the annual growth rate is around 3% (#1065).

The growth rate of public traffic vehicles has dropped from 3.8% during 1980 - 1985 to 1.9% during 1985 - 1990. While busetas increased by 90% from 1980 to 1985, buses increased only by 8%. The riding capacity of a bus is 70 persons, and that of a buseta is 30, but on an average, it carries 50.9 persons per vehicles. Vehicles in service over 20 years are 22.5%, over 10 years are 69.5%, and less than 5 years are 4.3%, indicating the generally decrepit composition of the fleet. The mean operating speed was improved from 8 km/h to 18 km/h as a result of the allocation of exclusive bus lanes by Avenida Caracas plan (#1051). This plan has been in force from 1991 between Call 8a and Los Heroes in the northern part (#1065).

Public traffic problems needing attention are the extreme shortage of traffic means, the irrational operating organizations, and the low service standard.

At present, no railway system is in service except for those for tourisms, and subway plan has been suspended since the survey stage. In the west of Bogota City El Dorado airport is located and is offering international and domestic flight services (Table 2.2.15). Of the passengers, 82 to 84% are domestic. With the international passengers, departures outnumber, and with the domestic passengers, arrivals outnumber. On the other hand, with cargoes, international and domestic cargoes are nearly equal in volume, but more cargoes are departing than arriving.

Table 2.2.15 El Dorado Airport Passengers and Cargoes (#1055)

		Passengers (Persons)		Cargoes (t)	
		Arrival	Departure	Incoming	Outgoing
1987	International Flight	354,018	374,225	35,954	52,561
	Domestic flight	1,799,494	1,770,137	30,214	40,208
1988	International Flight	371,514	393,235	34,018	55,467
	Domestic Flight	1,788,351	1,760,087	27,983	38,123

2.2.5 Energy

(1) Household Demand

Around 60% of the household energy consumption is for cooking and hot water, and also refrigerators (12%), lighting (19%) and other electric household units (10%) are major consumers (1986). Among the cooking heat sources, major items are cocinol (37.5%), electricity (32.1%), propane gas (20.8%) and kerosine (8.5%) (1985), and especially, among low-income people, cocinol is much used. From cost performance viewpoint, coal is the best energy source, followed by gas and electricity. At present, the establishment of utility gas facilities is under plan to provide a household energy source to replace cocinol and electricity (#1004).

Electric power is delivered to 98.4% of the households in the city, with the illegal resident areas in the southernmost and northernmost parts of the city being poorly supplied. In these areas, there are cases of power stealing from time to time (#1003).

(2) Industrial Demand

The majority of industrial energy consumption is for steam generation and for heating. The main fuel types are coal, crude oil and natural gas. Electric power is not much used and its use is mainly for mechanical drive (#1004).

The coal consumption in the whole Cundinamarca Department is 1,063,000 tons (1987), of which 67.0% is for the manufacture, followed by power generation (23.6%) and household (9.4%). In the manufacturing industry, brick production and cement production are heavy power consumers (#1055).

(3) Power Consumption

In the city of Santafe de Bogota, electric power is delivered by EEEB (Bogota Electric Power Company). The 1989 consumption was 5,771,000 Mwh, of which 29.8% was consumed by the manufacturing industry (1989). The annual mean growth rate is 6.7% (1986-1989) (Table 2.2.16).

Table 2.2.16 Bogota City Power Consumption (#1048)

	Total	Manufacture	Commerce, Household
1985	4,458 Mwh	1,286 Mwh	2,662 Mwh
1986	4,800	1,453	2,842
1987	5,052	1,555	2,962
1988	5,348	1,611	3,175
1989	5,771	1,722	3,431

2.3 Institutional Framework for Air Pollution Control

2.3.1 Law

The fundamental law on environmental protection is the National Cord of Innovatable Natural Resources and Environmental Protection promulgated in 1974, Though it has been amended some times, it is still in power over the affairs on environmental administration. The new Political Constitution established this year also emphasizes the significance of environmental conservation.

As a statute on air pollution, Decree No. 2 of 1982 and No. 2206 of 1983, enacted pursuant to the Sanitation Law (Law No. 9) of 1979, are in force. The former provides air quality environmental criteria and measuring methods, smoke measuring methods, measuring instrument maintenance and control, environmental impact assessment, outdoor combustion, legal measures against criteria violation, report formality, operation approval criteria, monitoring, enforcement, punishment, etc., and the latter is a partial amendment of the former. In addition, Decree No. 2 specifies the environmental criteria for suspended particulates (SP), SO_2, CO, Photochemical oxidant (O_3) and NO_x.

2.3.2 Administrative Organization

The responsibility for management on environment is assigned to various authorities of national government.

National Institute for Innovatable Natural Resources and Environmental (hereinafter referred to as INDERENA) is responsible for both natural resources and natural environment and covers 75% of national territory where live the 40% inhabitants of the whole population. On the other hand the Regional Autonomy Corporation (hereinafter referred to as CAR) is responsible for the same affairs to INDERENA, and rules the rest of national territory where live the 60% inhabitants of the whole population.

The Ministerio de Salud is responsible for the control on sanitary use of water, management on liquid and solid waste, and disposal of excrement and atmospheric emission.

Particularly the main national organization of Colombia responsible for air pollution control is the Ministerio de Salud, and under it, Servicio Seccional

de Salud (Regional Health System) of Sistema Nacional de Salud (National Health System) is active in each department. In Santafe de Bogota D.C., there is an organization called Secretaria Distrital de Salud which is responsible for the same task. Both "Servicio" and "Secretaria" are local organizations having their own budget and personnel, legally independent each other, but in practice the personnel is common between the two (Fig. 2.3.1).

The 1990 budget of the Secretaria Distrital de Salud was CL$3,501 million ordinary expenditure (personnel: CL$3,472 million, general expenses: CL$29 million) and CL$3,681 million capital expenditure, totaling to CL$7,182 million. The budget of Environmental Sanitation Department was CL$3,904,000 (#1061).

In 1990, a new administration office DAMA (environment Bureau) was inaugurated for the purpose of promoting environmental control program and project, under Resolution No. 9. Its task includes air pollution control, and its program includes the air pollution control study under JICA aid and air pollution mitigation plan with mass transportation means ($1065).

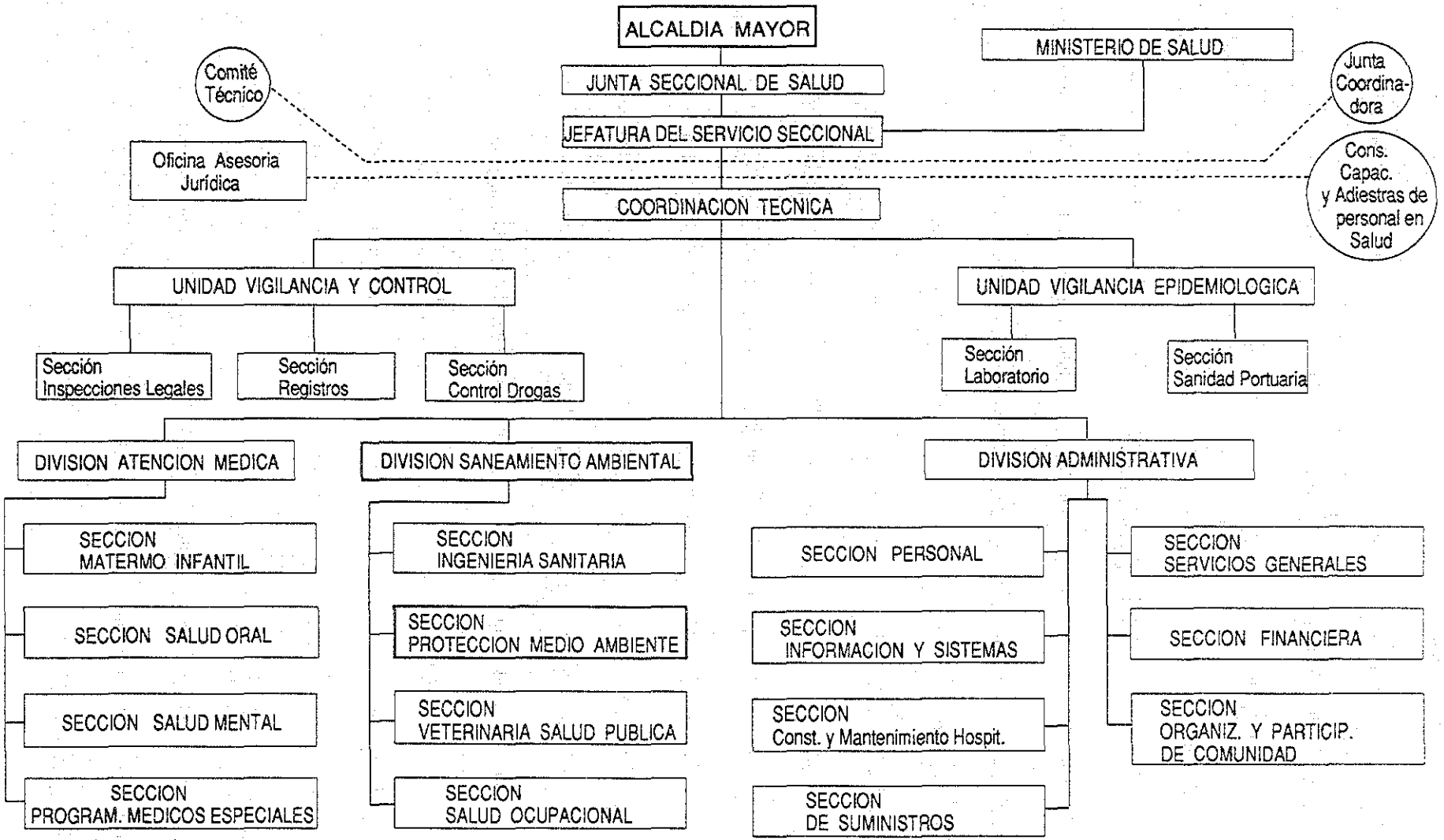

Fig. 2.3.1 Organization Chart of Secretaria-Servicio de Salud de Bogota D.E.

2.3.3 Ambient Air Quality Standards

The ambient air quality standards in Colombia was promulgated in the Decree number 2 of 1982 as follows.

(1) SP

1) Standard

The geometrical mean value of the whole sample collected continually by 24 hours during twelve months should not exceed the value of 100 $\mu g/m^3$. But the maximum value of daily mean concentration which is taken by continual sampling by 24 hours is permitted to exceed the value of 400 $\mu g/m^3$ for once per twelve months only.

2) Measuring Method

a) Method

specific weight analysis by high-volume air sampler

b) Minimum Frequency of Sampling

continual sampling by 24 hours for every three days

(2) Sulfur Dioxide (SO_2)

1) Standard

The arithmetical mean value of the whole sample collected continually by 24 hours during twelve months should not exceed the value of 100 $\mu g/m^3$. But the maximum value of daily mean concentration which is taken by continual sampling by 24 hours is permitted to exceed the value of 400 $\mu g/m^3$ for once per twelve months only.

2) Measuring Method

a) Method

para-rosanilin method

b) Minimum Frequency of Sampling

continual sampling by 24 hours for every three days

(3) Carbon Monoxide (CO)

1) Standard

The maximum concentration of the sample collected continually by eight hours should not exceed the value of 15 $\mu g/m^3$. And the maximum concentration of the sample collected continually by one hour is 50 $\mu g/m^3$.

2) Measuring Method

a) Method

by non-dispersive infra-red ray analyzer

b) Minimum Frequency of Sampling

continual sampling by eight-hour period from 6 a.m. to 10 p.m.

(4) Photo-chemical Oxidants Expressed as Ozone (O_3)

1) Standard

The maximum concentration of the sample collected continually by one hour should be the value of 170 $\mu g/m^3$, however it is permitted to exceed the value for once per twelve months only.

2) Measuring Method

a) Method

chemical luminescence method in gaseous phase

b) Minimum Frequency of Sampling

continual sampling from 6 a.m. to 6 p.m.

(5) Nitrogen Dioxide (NO_2)

1) Standards

The arithmetical mean concentration of the sample collected continually by 24 hours a day during twelve months is 100 $\mu g/m^3$.

2) Measuring Method

a) Method

Jacobs and Hochheiser method

b) Minimum Frequency of Sampling