THE REPUBLIC OF COLOMBIA

THE BOGOTA-BUENAVENTURA ROAD PROJECT

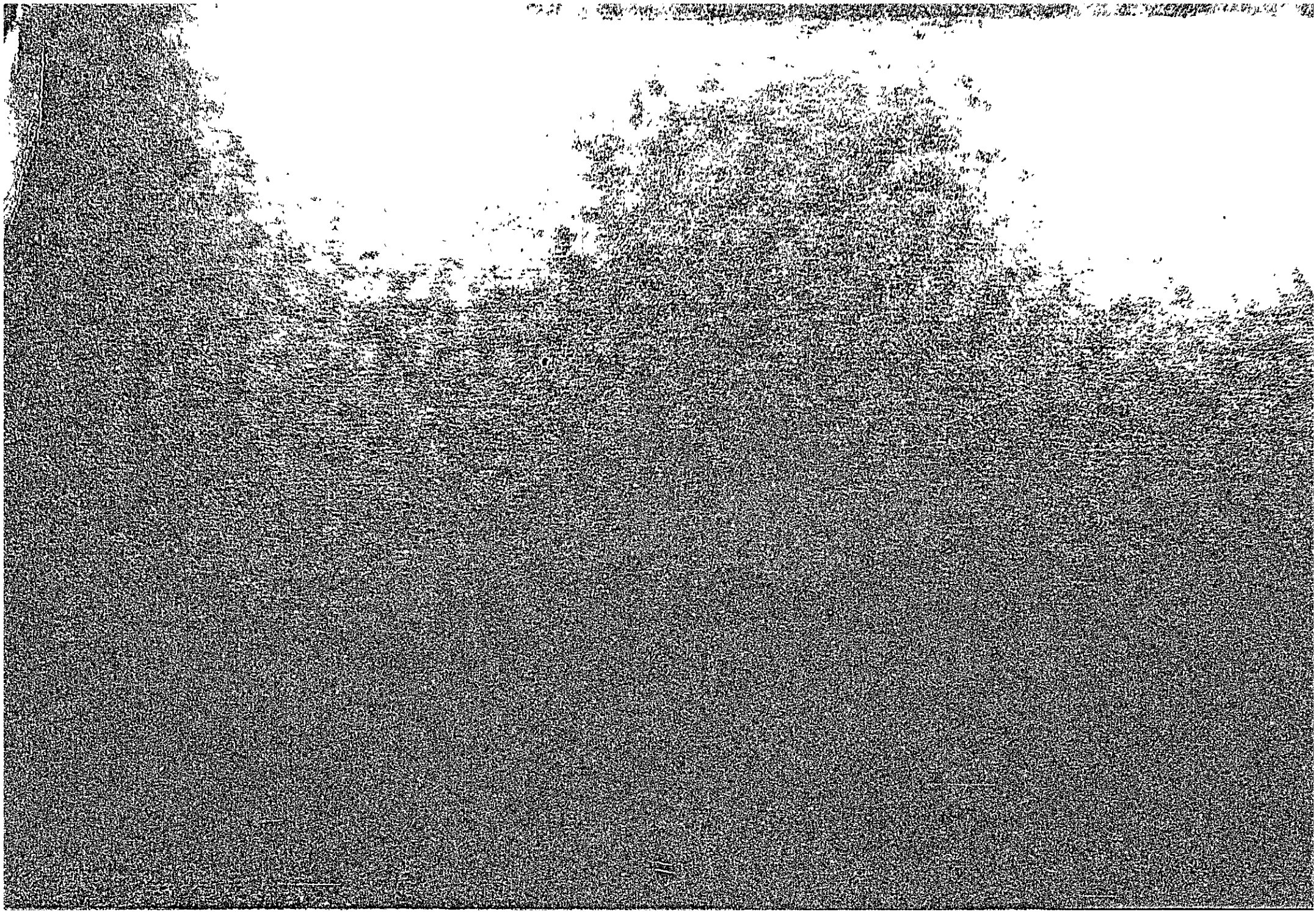
FEASIBILITY SURVEY

VOLUME I (SUMMARY AND CONCLUSION, [illegible])

FINAL REPORT

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY



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VOLUME I (SUMMARY AND CONCLUSION)
IMPROVEMENT OF EXISTING ROAD

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PREFACE

In response to the request of the Government of the Republic of Colombia, the Government of Japan decided to conduct a feasibility study on the Bogota-Buenaventura Road Project and entrusted it to the Japan International Cooperation Agency (JICA).

The JICA organized a steering committee for the project chaired by Mr. Hiroaki Tamamitsu, Ministry of Construction, and sent to Colombia a survey team headed by Mr. Kanenari Ijuin, Long Span Bridge Consultants. INC. in July 1979.

The team discussed the Project with officials concerned of the Government of Colombia and conducted a field survey.

After the team returned to Japan, further studies were made and the present report has been prepared.

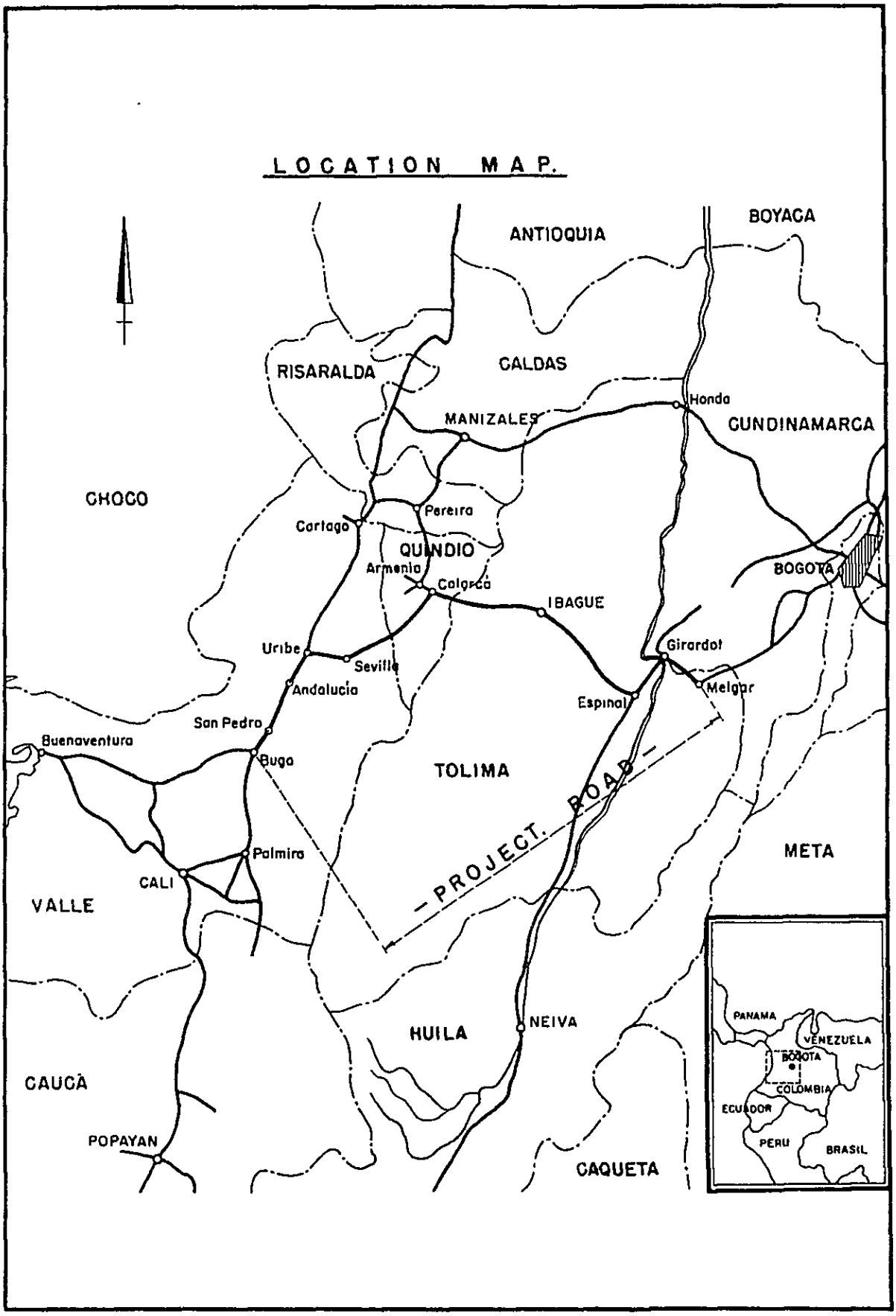
I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

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

March, 1982

Keisuke Arita
President
Japan International Cooperation Agency

Perspective View of the Existing Road


LOCATION MAP.
ANTIOQUIA
BOYACA
RISARALDA
CALDAS
MANIZALES
Honda
CUNDINAMARCA
CHOCO
Pereira
Cartago
QUINDIO
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CAQUETA
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COLOMBIA
ECUADOR
PERU
BRASIL

SUMMARY

AND

CONCLUSIONS

SUMMARY AND CONCLUSIONS

1. OBJECTIVES OF THE STUDY

This report involves the study of a road section 310 Km long from Melgar to Buga which is part of the East-West road network linking Bogota, the Capital of Colombia in the East and Buenaventura, the largest Pacific coast port in Colombia.

A portion of the Project Road, namely, Ibague to Calarca crosses the Cordillera mountain range. This segment has a very poor alignment, steep grades with side slopes characterized by failures, landslides and rockfalls.

The study aims to find the solution of the increasing traffic demand problem between Bogota and Buenaventura East-West trunk road.

For the purpose above mentioned, the following objectives of the study are set up.

(1) To analize the economic situation of the Project Area at present and in the future

(2) To analize the traffic on existing Project Road and to forecast the future traffic demand on the Project Road.

(3) To find the Alternatives.

In this study, improvement of existing road, bypass construction and the new road construction are considered.

(4) To estimate the cost of alternatives.

(5) To assess the economic possibility of alternatives.

(6) To make the maps of the project mountainous area by aerial photography.

This report consists of five volumes as follows.

Volume 1 ; Summary and Conclusion, Main Report for the improvement of the existing road.

2 ; Annices for the improvement of the existing road.

3 ; Drawings for the improvement of the existing road.

4 ; Main Report and Annices for the construction of the new road.

5 ; Drawings for the construction of the new road

2. PROGRESS OF THE STUDY

2-1. Original Plan

The study had required three years. The following Scope of Work was agreed between the Colombian Government and the Japanese Government, before the study implementation.

(1) In order to solve the transportation problem between Bogota and Buenaventura, it is most important to provide an effective highway to cross over the Central Cordillera. From the view point of the above mentioned, both of the improvement of the existing road and the new road construction will be investigated.

(2) Judging from the results of the previous studies about the new road construction, with the road geometry and alignment similar to the existing road, the new road will not provide profit on vehicle operating and disaster prevention, compared with the existing road. Therefore, for the improvement of existing traffic conditions, it is necessary to apply higher degree standards for the new road construction, which requires a large number of bridges and tunnels, resulting in high cost of construction.

(3) Technically the best alternatives of both existing road improvement and the new road construction will be proposed and assessed through further economic evaluation.

(4) The maps of the central mountain range area are required to be made by aerophoto survey.

2-2. Execution of Study

In the first year, the following surveys were carried out.

2-2-1. First Year Study

(1) Aerophoto survey

(2) Route survey of the new road

(3) General economic and technical survey

Aerophoto survey were not completed due to the bad weather of Mountain Ranges. Little progress of investigation on the new road construction were obtained.

Aug. 1979, Progress Report 1

2-2-2. Second Year Study

(1) Aerophoto survey

(2) Detail engineering surveys of the existing road

(3) Traffic survey of the existing road

From the success of aerophoto survey (not completed) and the detailed engineering surveys of the existing road, it was concluded that the alternative of the existing road improvement was economically more feasible than the new road construction with high road standard.

Feb. 1980, Progress Report 2

Aug. 1980, Progress Report on Traffic Analysis
Progress Report in Regional Development

Nov. 1980, Progress Report 3

Mar. 1981, Interium Report

2-2-3. Third Year Study

In the last year, the following surveys were carried out.

(1) Aerophoto survey (remaining area)

(2) Investigation of a possibility of the new road construction

Aerophoto survey were not succeeded due to the bad weather. As for the new road construction, from the view point that the new road would be needed in near future by the requirements of the existing road supplement, Colombian road network development and regional area development, technical and economical possibility of the new road construction with low standard were examined besides the study of the existing road improvement.

Jan. 1982, Draft Final Report

3. METHODOLOGY

3-1 The work carried out by the Study Team involved several work elements including but not limited to the following:

(1) The study of the Economy of Colombia and Project Area.

(2) Traffic Study Including O-D Studies and Related Work.

(3) Traffic Forecast to the Year 2010.

(4) Vehicle Running Survey and Road Capacity.

(5) Existing Conditions of Project Road. This work included Geometrics, Pavement Analysis, Soils and Materials Studies, Bridges and Road Structures Evaluation, Geological Conditions, Aerial Photography and Other Related Work.

(6) Improvement Plans related to Geometrics, Bridge Rehabilitation, Protection Work Against Landslides, etc.

(7) New Road Construction Plans related Route Alignment, Geometrics, etc.

(8) Cost of the Improvement Plans including Unit Price Analysis and Construction Cost Estimates.

(9) Cost of New Road Construction Plans.

(10) Economic Evaluation including Benefit/Cost ratios, Traffic Cost, etc.

3-2 The Study of existing road improvement took into consideration different levels of improvements and their impact on the traffic safety, vehicle operation costs, costs of the improvement and economic justification.

It was determined that certain improvements are necessary and need to be implemented as soon as possible.

Although the extent of improvement is different among the sections subject for betterment, the following features of the improvement plans are incorporated in the recommendation.

(1) Improvement in the horizontal alignment by widening curves and increasing radius of curvature.

(2) Widening to allow for passage of vehicles.

(3) Reducing steep grades wherever possible.

(4) Improvement of culverts and bridges and construction of new ones, wherever it was determined to be necessary.

(5) Improvement of shoulders by paving at widened curves.

(6) Improvement of drainage.

(7) Provision of means to prevent the occurrence of landslides, slope failures or rock falls.

(8) Improvement of passing sight distance.

The study of the new road construction took into consideration three route alternatives and the alternative of the minumum construction cost was selected for the economic assessment.

A comprehensive traffic and economic analysis were carried out to study the impact of the new road construction on the traffic and the economy of the affected area and the benefits to be derived.

4. CONSIDERATION OF ALTERNATIVES

The study considered three levels of existing road improvement described in Chapter 7 in Volume 1. There are:

(1) Minimum Scale Improvement Plan

A plan by which the minimum radius of curvature is increased to over 25 m, with the roadway widened so that two trailer trucks can pass each other by driving over the shoulders without stopping.

(2) Medium Scale Improvement Plan

A plan in which both profile and alignment in the mountainous section are improved or by which some potential landslide zones are avoided by a short cut.

(3) Large Scale Improvement Plan

A plan by which new bypasses are constructed for the purpose of improving the bottlenecks of the existing road such as poor road alignment, bridge of low capacity, urban crowded area or other.

The study of the new road construction considered three alternatives of route described in Chapter 7 in Volume 4.

These are:

(1) Northern Route (Roncesvalles Route)

This alternative begins from the point between Girardot and Espinal of existing road and passes through the towns of El Corazon, Roncesvalles and Santa Lucia and ends at Buga. Total length of route is 256.8 Km.

(2) Southern Route (Chaparral Route)

This alternative uses the already asphalt-paved road of Bogota-Neiva road as far as Castilla and then runs to west and passes through the towns of Chaparral and San Jose de las Hermozas, and near the Santa Lucia joins with the northern route. Total length 260.3 Km.

(3) North-South Route

This alternative is the same alignment as the northern route as far as Roncesvalles and there diverts to the south and at San Jose de las Hermozas joins with the southern route. Total length 247.8 Km.

5. ECONOMIC EVALUATION

(1) Minimum and Medium Scale Improvement Plan

The section between Ibague and Calarca is divided into 18 subsections as defined in the study. Each subsection has one or two alternative plans for economic assessment.

Benefit/Cost studies were carried out for the alternative levels of improvement, resulting in the adoption of specific choices in accordance with the economic feasibility. These levels of improvement are indicated in the Table of Improvements and Costs in the following page. The total economic cost is $646 million in terms of 1980 prices.

A work program for the section Ibague-Calarca is established by considering only these feasible plans, and the B/C figures for the improvement plans are summarized as follows:

Present Worth Cost	(i=12%)	$462.1 million
Present Worth Benefit	(i=12%)	$544.5 million
Present Worth B - C	(i=12%)	$ 82.4 million
Benefit/Cost		1.78
IRR		14.1%

With regard to the preventive measures against slope failures, no economic evaluation of such measures was made, since statistical data for the probable occurrence, magnitude and frequencies are not available.

(2) Large Scala Improvement Plan

Four bypass plans are investigated. Each plan has more than two alternatives for economic assessment.

By the economic evaluation, the Girardot and Ibague bypass plan are feasible and its figures are summarized as follows:

	Girardot bypass	Ibague bypass
Present Worth Cost (i=12%)	$583.8 million	$312.7 million
Present Worth Benefit(i=12%)	$2,550.3 million	$428.2 million
Present Worth B-C	$1,966.5 million	$115.5 million
Benefit/Cost	4.37	1.37
IRR	39.0%	16.5%

Summary of Improvement and Costs

Road Section	Location (Ibague-Calarca) Km	Improvement Plans									Preventive Measures against Slope Failures										Cost in Total	Selected Plans
		Number of Improved Sharp Curves	Proposed Bridge	Construction Cost			Total Cost	Road Length (km)			Number of Sites				Total	Construction Cost				Total Cost		
				Earth Work & Pavement	Bridge	Structures & Slope Protection		Existing	Improved	Balance	Landslide	Falls	Valley Side Failure	Debris Flow		Land-Slide	Falls	Valley Side Failure	Debris Flow			
01	61.3-62.8	2	0	4.2	0	1.8	6.0	-	-	-	1	0	2	0	3	15.0	0	1.6	0	16.6	22.6	MIN
02	62.8-63.9	2	0	22.6	0	10.0	32.6	1.1	1.0	0.1	0	3	0	0	3	0	4.4	0	0	4.4	37.0	MED
03	63.9-68.4	7	0	58.4	0	8.7	67.1	-	-	-	0	10	3	8	21	0	11.6	4.4	7.0	23.0	90.1	MIN
04	68.4-69.2	5	20m Bridge	40.3	8.9	8.4	57.6	0.8	0.7	0.1	0	3	0	2	5	0	3.1	0	2.0	5.1	62.7	MED
05-10	69.2-81.1	14	0	17.3	17.6	11.0	45.9	-	-	-	7	10	10	13	40	96.5	11.7	17.1	20.7	146.0	191.9	MIN
11	81.1-81.6	1	20 30m Bridge	2.7	30.7	0.9	34.3	0.5	0.3	0.2	0	1	0	0	1	0	1.6	0	0	1.6	35.9	MED
12-16	81.6-100.7	15	0	14.3	7.9	6.7	28.9	-	-	-	2	27	25	13	67	43.8	54.5	109.3	19.2	226.8	255.6	MIN
17	100.7-102.1	2	(170m+ 188m) Bridge	6.2	158.0	30.1	194.3	1.4	0.7	0.7	0	0	0	0	0	0	0	0	0	0	194.3	MED
18	102.1-135.6	54	0	157.9	0	78.8	236.7	-	-	-	14	21	33	2	70	104.3	26.6	222.7	3.0	356.8	593.4	MIN
Total		102	438m	323.9	223.1	156.4	703.4	-	-	-	24	75	73	38	210	259.3	113.5	355.1	51.9	780.3	1,483.7	

Note: Costs are shown as the Financial Cost in million pesos in prices of 1980.
MIN : Minimum Scale Improvement Plan
MED : Medium Scale Improvement Plan

Summary of Bypass Costs (Large Scale Improvement Plan)

	Earth Work	Pavement	Bridge	Drainage and Structure	Land Acquisition	Total
Girardot Btpass (A1)	19.0	154.9	359.4	25.6	(22.1)	558.9
Espinal Bypass (B1)	23.0	187.8	28.2	34.6	(26.7)	273.6
Ibague Bypass (A)	96.0	47.5	179.6	110.0	(11.8)	433.1
Total	138.0	390.2	567.2	170.2	(60.6)	1,265.6

Note: 1) Costs are shown as the Financial Cost in million pesos in prices 1980.

2) Land acquisition costs are not included in Total Cost.

Disbursment Schedule of the Project Cost

(million Colombian pesos in 1980 Prices)

Ibague - Calarca				Melgar - Chicoral			Ibague		
Year	Improvement cost	Cost of Preventive Work against Failures	Remarks	Year	Girardot Bypass	'Remarks	Year	Ibague Bypass	Remarks
1983	22.3	24.6	Eng. and Preparation	1983	74.0	Land Acquisition Eng. and Preparation			
1984	9.7	10.9		1984	98.0		1984	24.8	Land Acquisition
1985	171.1	375.7		1985	366.0		1985	6.7	Eng. and Preparation
1986	335.1	369.1	Construction and Supervision	1986	343.2	Construction and Supervision	1986	228.4	Construction and
1987	165.2	0		1987			1987	185.0	Supervision
Total	703.4	780.3		Total	881.2		Total	444.9	

(3) New Road Construction

Chaparral route is examined for economic assessment. According to the economic evaluation, economic contribution of the Project to national economy is not considered to be quite enough as shown below.

Present Worth Cost (i=12%)	$4,697.2 million in 1984
Present Worth Benefit (i=12%)	$2,905.0 million
Present Worth B-C (i=12%)	$-1,792.2 million
B/C	0.62
Internal Rate of Return	7.9%

However, there exist several uncountable benefits which are not included above; the development benefit acrued from the road construction and the benefit from road closure of existing Bogota-Buenaventura route are excluded due to the lack of supporting informations.

6. CONCLUSIONS

Although the study covered the 310 Km long section of road from Melgar to Buga, the improvement plans, which were found economically feasible for implementation, and the recommended preventive measures against slope failures are concentrated in the section between Ibague and Calarca, a total distance of 79 Km. The estimated construction costs of the improvement and the preventive work against failures are $703 million and $780 million respectively in terms of financial cost at 1980 prices.

The bypass plans which detour the towns of Girardot-Espinal and Ibague have a total length of 27.1 Km and 6.6 Km, respectively.

The estimated project cost is $1,326 million in terms of financial cost at 1980 prices.

Project Cost (million Colombian pesos in 1980 prices)

	Project Cost for Improvement	Project Cost for Preventive Work Against Failures	Project Cost for Bypass
Foreign Component	375.1 (53.3%)	390.3 (50.0%)	710.0 (56.1%)
Local Component	270.6 (38.5%)	348.7 (44.7%)	454.2 (35.9%)
Tax	57.7 (8.2%)	41.3 (5.3%)	101.4 (8.0%)
Sub-Total	703.4 (100%)	780.3 (100.0%)	1,265.6 (100%)
Land Acquisition Cost	-	-	60.6
Total	703.4	780.3	1,326.2

Although the economic evaluation of the new road construction from Melgar to Buga does not indicate the enough economic efficiency commenced in 1984, it becomes worthwhile to construct the new road because of the following reasons, not considered in the economic analysis.

(1) Traffic capacity shortage of existing route

The existing road will be almost at its full capacity before the year 2000. It needs a seven or more years period to construct the new road.

(2) Need for another trunk road

In case of road closure of existing road by slope failure, the economic and social impact to the Project Area are supposed to be great considering this existing road situations.

(3) Impact for rural area development

The rural area development is one of the major national policy and it is surely expected to give the impact for rural area development to the Project Area.

Project Cost (Million Colombian pesos in 1980 prices)

Foreign Component	4,285.4	(53.2%)
Local Component	3,067.1	(38.3%)
Tax	684.9	(8.5%)
Sub Total	8,010.4	(100.0%)
Land Acquisition Cost	372.1	
Total	8,382.5	

7. RECOMMENDATIONS

7-1 Preventive Works Against Failures

The preventive work against slope failures is extremely important in ensuring an uninterrupted traffic movement between Bogota and Buenaventura. Even in the section between Ibague and Calarca, more than 500 locations indicate a possibility of occurrence of slope failures. However, it is very difficult to estimate the magnitude and frequency of such failures, due to lack of past records.

Therefore, it is recommended that the records of slope failures be kept in order to make an effective preventive plans.

7-2 Passing Sight Distances

The Project Road has several sections where passing sight distance is not adequately provided at present but which can be easily improved without any overly extensive expenditure. It is recommended that such sections be improved as part of the maintenance work undertaken by MOPT.

7-3 Construction and Repair Works

Historical records of construction and repair works of road structures, pavement etc., were in general not available, since such records were either not prepared or were not properly maintained. Therefore, it is also recommended that such records be properly kept and documented in order to facilitate the maintenance work.

7-4 Development Plan of the New Road Project Area

In order to make the new road construction feasible, the development of the Project Area along the new road are most important, and it is necessary to assess the development potential of the Project Area and to formulate the comprehensive development plan relating to the new road.

8. IMPLEMENTATION PROGRAM

8-1 Schedule

Upon approval from the Government of Colombia of the various aspects of the improvement program and upon securing the proper financing, work will be carried out including the preparation of specifications, bidding documents and other associated services. Bidding, bid analysis and construction contract award will follow. Construction will thereafter be carried out. The schedule for the above efforts is shown in the chart below.

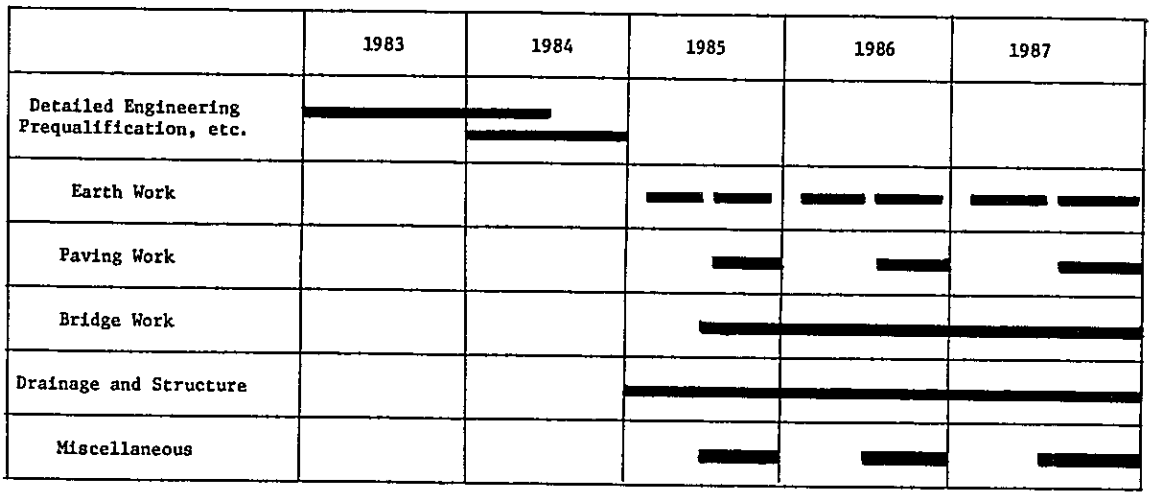
These schedule can be modified if the Government of Colombia wishes an earlier starting date or an earlier completion date. Such a change in schedule is entirely feasible and can be explored further.

For example, if starting the Girardot bypass construction early in 1984, then the benefits will be reduced at some extent. But the bypass construction is entirely feasible.

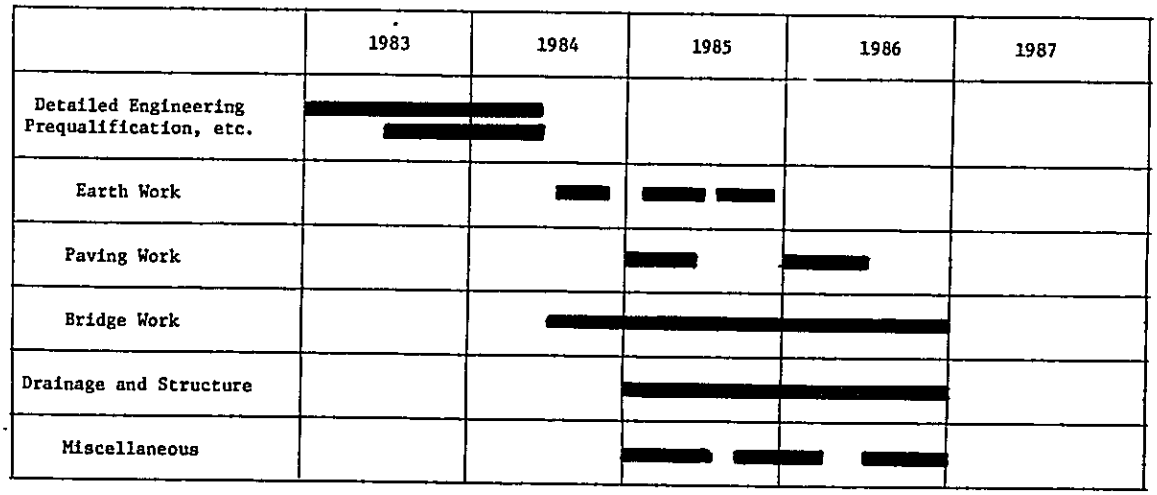
8-2 Sequence of Construction

It should be aimed that the scheduling of construction will be such that the inconvenience to traffic will be kept to a minimum and that the contractors' operations will be organized so that the work can be performed in a reasonably efficient manner considering the difficulties of the terrain, the road width and the curves.

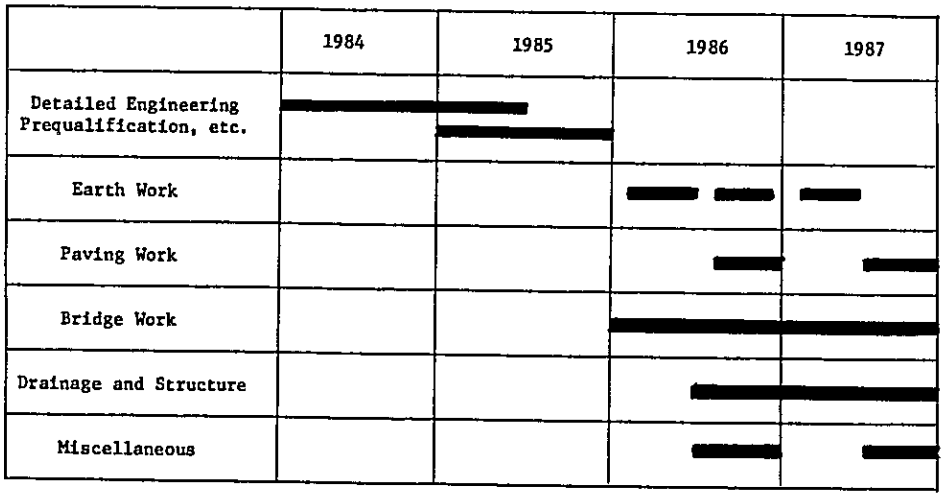
Implementation Schedule : Improvement Plans and Preventive Works against Slope Failures



Implementation Schedule : Girardot Bypass



Implementation Schedule : Ibague Bypass



ABBREVIATION

1.	AASHTO	:	American Association of State Highway and Transportation Officials.
	ACIC	:	Associacion Colombiana de Ingenieros Constructores
	Bogota D.E.	:	Bogota Departamento Especial
	DANE	:	Departamento Administrativo Nacional de Estadistica.
	HCM, H.C.M.	:	Highway Capacity Manual
	IGAC	:	Instituto Geografico "Agustin Codazzi"
	JICA	:	Japan International Cooperation Agency
	MOPT, M.O.P.T.	:	Ministerio de Obras Publicas y Transporte. (Ministay of Public Works and Trasport)
	NEI	:	Netherland Economic Institute
	TRRL	:	Transport and Road Research Laboratory.
	U.K.	:	United Kingdom
	U.S.A.	:	United States of America.
2.	AADT	:	Annual Average Daily Traffic.
	ADT	:	Average Daily Traffic.
	ACPM	:	Diesel
	B/C	:	Benefit / Cost
	FC	:	Foreign Currency
	GDP	:	Gross Domestic Product
	GNP	:	Gross National Product
	LC	:	Local Currency
	OD, O-D	:	Origin and Destination
	Tr.Mula, Tractomula	:	Semi Trailer
	US$	:	United States Dollar
	VOC	:	Vehicle Operating Cost
	$	:	Colombian Pesos ($49.00 = US$1.00)
	p.a.	:	Per Annum
3.	CBR	:	California Bearing Ratio
	PC	:	Prestressed Concrete
	RC	:	Reinforced Concrete

4. G, g : Gram
   H : Height
   ha : Hectare
   L, l : Length
   lbs : pounds
   Lit : Liter
   K, Km : Kilometer
   Km/h, Kph : Kilometer per hour
   m : meter
   U : unit

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CHAPTER - 1

INTRODUCTION

Chapter 1 Introduction

1-1 Aims of the Investigation

This report is a study of the proposed upgrading of a portion of the road between Bogota and Buenaventura, and has been carried out on the basis of an agreement for technical cooperation between the Colombian Government and the Japanese Government. The Project Road is a 310 km segment of the aforementioned road beginning at Melgar and ending at Buga. This road runs in an East-West direction and serves as a main trunk road crossing the rugged central mountain ranges. Due to the ruggedness of the terrain, the road is not adequately maintained. Considering the importance of this road to the national economy, the Colombian Government gave serious consideration to its improvement and to the possibility of constructing the new road in order to improve traffic capacity, running performance and to insure regular uninterrupted passage.

The upgrading of the existing road and the alternative for construction of the new road are handled separately. The work pertaining to the upgrading of the present road is the specific subject of this Volume. The alternative for the new road is described in Volume 4.

1-2 Investigation Background

Domestic transport in Colombia depends heavily on a highway network that has been developed in a North-South direction along three mountain ranges running in the same direction. Consequently any East-West road would of necessity have to cross over the mountain ranges. The development of such roads has therefore been extremely poor.

The capital, Bogota, an inland city with a population of four million people is the seat of Colombia's government, and the center of its economy and culture. Buenaventura which has the country's largest harbour on the Pacific Ocean, handles approximately fifty percent of imports and exports.

The Bogota-Buenaventura road is the main East-West trunk road connecting these two cities. It also connects the major urban areas of Espinal, Ibague, Calarca, and Buga. The portion of the road from Ibague to Calarca crosses the central mountain range at an altitude of approximately three thousand meters through some very rugged terrain complicated by steep slopes and poor alignment.

Due to the mountain range obstruction, there is no railway connection between Bogota and Buenaventura. Therefore all East-

West transport depends heavily on the highway system. These facts are clearly known to the Colombian Government and have been identified in a national transportation survey which documents the inadequacy of the present road running through the rugged terrain across the mountain ranges.

With the exception of the pavement improvements carried out by the Colombian Government, the road conditions remain deficient. Furthermore, the area is of volcanic origin and has consistently been plagued with landslides, slope failures, rock falls, and other general failures.

The Colombian Government had been working with this transport problem for fifteen years prior to carrying out a pre-feasibility survey in 1977. From the results of the 1977 study the conclusion was reached that this road should be handled on a high priority basis and that a heavy investment is necessary to bring about the necessary improvements to allow for an increased traffic load over the central mountain ranges.

The Colombian Government decided to continue with economic surveys for upgrading the existing road and/or consideration for construction of a new one. For this effort, a request was made to the Japanese Government.

1-3 Details of the Investigation

In October 1977 an agreement for technical cooperation was reached. The Colombian Government then requested the Japanese Government to carry out the survey as part of the technical cooperation agreement. Japan International Cooperation Agency (JICA) took charge of its execution.

In February 1979 JICA dispatched a Preliminary Survey Team to the Republic of Colombia to determine the scope of work and draw up a feasibility study.

The investigation was started in July 1979 and by November 1980 specialists in various fields had made four trips to the Republic of Colombia and carried out the work plan in accordance with the Terms of Reference and the Scope of Services

The results and details of the investigation are described in the following chapters of this report.

CHAPTER - 2

THE COLOMBIAN ECONOMY

Chapter 2 The Colombian Economy

2-1 Present Status

2-1-1 Postwar Economic Development

Economic development in Colombia since 1950 has gone through three distinct periods: (1) the period from 1950 to 1966 during which import substitution industries rose, (2) the period of rapid economic growth from 1967 to 1975 which saw an emphasis on export of non-traditional commodities, and (3) the period from 1975 to date which emphasized the struggle against inflation under a tight money policy and which saw a continuing growth in the economy, albeit at a modest rate.

From 1950 to 1966, the Colombian economy suffered from the wild fluctuations of international coffee prices and domestic political and social unrest.

During this period of postwar economic development, almost all feasible simple industries for import substitutions were established. However, new types of industries were not developed. The instability of coffee prices created financial difficulties as well as foreign exchange shortages, which together greatly hindered economic progress. In this situation, the government had intensified its planning and initiatives in the management of the national economy.

Since 1967 the government adopted a new economic policy which emphasized stimulation of the economy. This stimulation took the form of the fine adjustment of foreign exchange rate, the increase in the exportation of commodities other than coffee, and the expansion of investments in the infrastructure whose development was essential to industrialization. As a result, non-coffee exportation quickly swelled and the share of coffee in total exportation shrunk from the over 60% in 1967 to about 45% in 1974. Gross Domestic Product (GDP) grew by an average rate of 6.6% per annum from 1967 to 1974, while average per capita GDP grew by slightly less than 4% per annum in the same period.

2-1-2 Recent Economic Trend

The Colombian economy, which continued to grow, with the highest growth rate being the 8.9% attained in 1978, grew only by 3.8% in 1975. (See Annex Table 2-1 for the trend of Colombian GDP in the 1970s.) The economic growth rate continued to rise despite the powerful tight money policy of the government and reached 4.6% in 1976, 4.9% in 1977, and the 20 year high of 8.9% in 1978. (It is estimated that the growth rate will drop to 5.1% in 1979). The indicated high growth rates are believed to be largely attributable to rises in coffee prices and resultant improvements of the people's income level which, in turn, caused an augmentation of domestic demand. Although the industrial and service sectors stepped up

their productions to keep pace with the increases in domestic consumption, demand swelled even faster and brought about so-called "demand-pulled" inflation in addition to the inflation which was already in existence.

A review of the composition of GDP which is presented in Annex Table 2-2 reveals that the contribution of the agricultural sector to GDP has continued to keep a steady pace and was 25.3% in 1970 and 26.9% in 1978. In 1978, the contribution of the second largest economic sector after agriculture - that is, manufacturing - was only 20.6% and had not surpassed that of agriculture as yet.

Mining, whose contribution to GDP is still small, is expected to bring great impacts on the Colombian economy in the long run because of its unexplored resourses. However, for the past decade, the mining sector showed a negative growth in terms of constant prices and this was due to the decreases in crude oil production in recent years.

The government which fully realizes the importance of the energy problem, is currently making efforts in the development of coal, whose proven deposit is very substantial. Additional efforts for hydro-power generation and for the exploitation of petroleum resources are being also made through the introduction of foreign investments. Service sectors including the commerce, transportation and the personal and public services showed an increase from 48.6% in 1970 to 52.1% in 1978. The increase as a percentage of GDP during these years resulted in a higher growth rate in this sector of domestic production. Refer to Annex Table 2-2.

The trends of gross demand and gross supply, presented in Annex Table 2-3, show that the gross demand and the gross supply increased steadily during the years from 1970 to 1978. The percent share of the imports in the gross supply was in the range of 11% to 14.4% and that of the exports in the gross demand was in the range of 9.8% to 12.5% during the same period.

Changes in the physical production of the sectors of the domestic product are shown by the indices of production in Annex Table 2-4. The sectoral increases between 1970 and 1978 ranged from 44.2% to 74.1% except for mining and construction. Mining actually dropped by 13% while construction increased by 14.3% in the same eight years. However, it is felt strongly that the increased number of buildings and structures in the country should have indicated a larger value than 14.3%.

The review of economic data indicates that the national economy has developed steadily without radical change, although only with gradual change in the composition of the sectoral share. The overall tendency including rapid growths or reductions in some minor sectors, indicates that these rapid fluctuations have not been significant in influencing the overall tendency of development in these years.

2-1-3 Transport Sector

Table 2-1 presents the summary of the national statistical data in the transport sector, together with the data on GDP and population. The tendencies in this sector are stated as follows: Fuel consumption statistics indicate that in the period 1975 to 1979, the increase in gasoline consumption was 4.9% p.a. and for ACPM was 4.7% p.a. While vehicle registration increased at 7.1% p.a. during the years, 1971-78, the figures indicate that the movement on the roads of the country has increased at 5 to 6% p.a.

Passengers on the national railways increased till the mid-1970s, and have decreased since then. Passenger service is negligibly small at present. Cargo volume on the railways has decreased slightly from 1971 to 1979. In general, in the Project Area, the tendency was the same, however, the train movements are not frequent and have no significant competition with road transport. Railroads serve to transport bulky commodities and continue on doing so as in the past. No construction of new lines is likely to be seen in the Project Area

From 1971 to 1979 the international movement of commodities through the Colombian ports has increased at 7.2% p.a. The high rate of increase could have resulted from increased imports under liberal trade regulations and the growth of the economy since 1978. Of these exports and imports, approximately 50% have passed through the port of Buenaventura.

Travel on civil airlines of the country increased at a far larger rate than of GDP: the number of international passengers increased at 12.3% p.a. and that of the domestic passengers at 8.4% p.a. In the Project Area, the airport of Cali is the largest one on which the number of passengers, mostly of domestic lines, increased at 11.5% p.a.

2-2 Project Influence Area

The Bogota-Buenaventura road starts in Bogota, the nation's capital and one of the three major industrial areas in Colombia. The road continues through Ibague of Tolima Department and reaches Buenaventura, the largest foreign trade port of Colombia. Cali, the capital of Valle Department, located 70 km south of Buga, is one of the three major industrial areas along with Bogota and Medellin.

The road under the study is a part of the above national trunk road. The traffic on this trunk road reflects not only the economic and social activities of the direct Influence Area along the road, but also those in other parts of the country. Taking into account the locations of the road network, urban centers, economic activities, and the availabilities of statistical data, it was decided to study the Project Influence Area by covering all of the Department of Tolima, Quindio and Valle.

Table 2-1 Major Indices of the Economy and the Transportation: 1971-79.

	1971	1972	1973	1974	1975	1976	1977	1978	1979	79/71(p.a.) % 1)	75/71(p.a.) % 1)	79/75(p.a) % 1)
1. Population ('000)												
Total in Colombia	21347.8	21941.5	22551.8	23179.1	23823.8	24486.4	25167.5	25867.5	26587.0	1.245(2.8)	1.116(2.8)	1.116(2.8)
Bogota, D.E.	2552.3	2699.4	2855.1	3019.7	3234.0	3427.1	3632.0	3849.3	4079.8	1.598(6.0)	1.267(6.1)	1.262(6.0)
Tolima Dpto.	930.1	942.9	956.7	969.3	985.4	1000.7	1016.6	1032.9	1049.8	1.129(1.5)	1.060)(1.5)	1.060(1.6)
Ibague Municip.	195.1	199.8	205.0	231.0	239.0	246.0	255.0	264.0	272.0	1.497(5.2)	1.225(5.2)	1.222(5.1)
Quindio Dpto.	330.1	333.5	337.2	340.7	344.5	348.3	352.2	356.1	360.1	1.091(1.1)	1.044(1.1)	1.045(1.1)
Armenia Municip.	143.9	144.9	146.0	163.0	166.0	168.0	172.0	174.0	177.0	1.230(2.6)	1.154(3.6)	1.066(1.6)
Valle Dpto.	2204.0	2277.0	2353.0	2433.0	2518.5	2606.1	2697.1	2791.7	2890.0	1.311(3.4)	1.143(3.4)	1.148(3.5)
Cali Municip.	852.7	887.3	923.0	1038.0	1081.0	1142.0	1197.0	1255.0	1316.0	1.543(5.6)	1.268(6.1)	1.217(5.0)
2. GDP.(million in 1970 prices)												
Total in Colombia	137.889	148.630	159.195	168.787	175.226	183.296	192.187	209.236	219.885	1.595(6.0)	1.271(6.2)	1.255(5.8)
Per capita National Income(in 1970 prices) pesos/person	5273	5638	5973	6986	6157	6462	6883	7127	7355	1.395(4.2)	1.168(3.9)	1.195(4.5)
3. Regional Gross Product (1970 prices of million)												
Tolima	5713	6032	6369	6725	7103	-	-	-	-	-	1.243(5.6)	-
Quindio	1623	1684	1747	1813	1880	-	-	-	-	-	1.158(3.7)	-
Valle	17064	18003	19049	19724	19270	19732	19382	-	-	1.136(2.1)	1.129(3.1)	1.006(0.3)
4. Fuel Consumption												
Total necessary crude oil (million barrels of crude oil)					-	-	-	160.47	163.95	-	-	1.022(2.2)
Gasoline consumption ('000 gallons) in transport sector	722.220	761,668	814,434	848,500	893,298	916,272	988,554	1053,318	1080,324	1.496(5.2)	1.237(5.4)	1.209(4.9)
Diesel (ACPM) Consumption('000 gallons) in transport sector	-	-	-	-	301,644	324,660	327,684	338,688	362,838	-	-	1.202(4.7)
5. Registered vehicles.												
Small Vehicles	-	-	385,819	416,475	447,069	478,630	504,329	551,711	-	1.430(7.4)	1.159(7.7)	1.234(7.3)
Buses & Busetas	-	-	38,474	39,863	42,047	44,922	46,329	48,905	-	1.271(4.9)	1.093(4.5)	1.163(5.2)
Trucks	-	-	62,294	65,930	70,097	74,307	77,577	84,960	-	1.364(6.4)	1.125(6.0)	1.212(6.6)
Total	-	-	486,587	522,268	559,213	597,859	628,235	685,576	-	1.409(7.1)	1.149(7.2)	1.226(7.0)
6. Passengers on the Railway('000 persons)												
	2269	3085	3143	3586	4218	4038	2968	2568	2456	1.082(1.0)	1.859(16.8)	0.582(-14.5)
7. Cargo on the Railway ('000 tons).												
	2653	2731	2760	2899	2439	2411	2519	2682	2394	0.902(-1.3)	0.919(-2.1)	0.826(-3.9)
8. International Marine Transport('000 tons).												
Arrival	1,788.6	1,525.3	2,033.8	2,130.4	1,566.0	1,718.1	2,799.5	2,618.4	3,206.3	1.793(7.6)	0.876(-2.7)	2.047(19.6)
Departure	920.3	1,126.4	1,034.5	1,015.4	1,297.8	977.8	700.7	1,189.2	1,503.8	1.634(6.3)	1.410(7.1)	1.159(3.8)
Total	2,708.9	2,651.7	3,068.3	3,145.8	2,863.8	2,695.9	3,500.2	3,807.6	4,710.1	1.739(7.2)	1.057(1.1)	1.634(13.3)

9. Civil Aviation

International passengers('000 persons)												
Arrival & Dep.	520.5	595.4	684,8	814.9	890.9	965.7	1,014.1	1,139.9	1,317.4	2,531(12.3)	1,712(14.4)	1,479(10.3)
International cargo ('000 tons).												
Arrival & Dep.	24.5	28.0	30.7	45.8	48.2	50.8	71.2	92.9	97.6	3,984(18.9)	1,967(18.4)	2,025(19.3)
Domestic Passengers('000 persons)												
Departure	2,689.7	2,905.5	2,898.1	3,086.8	3,392.7	4,033.1	4,249.8	4,924.7	5,116.0	1,902(8.4)	1,261(6.0)	1,508(10.8)
Domestic Cargo('000 tons).												
Departure	87.8	83.7	81.7	87.8	83.0	84.7	75.4	-	-	0.859(-2.6)	0.945(-1.4)	0.908(4.9)

Sources
1. DANE, Banco de Datos.
2. Banco de la Republica, Division de Cuentas Nacionales.
3. DANE, Anuario Estadistico del Valle del Cauca 1978 y Anuario Estadistico de Caldas, Quindio y Risaralda 1976, y FONADE INANDES, El Desarrollo Economico Departamental, 1960-75 (Bogota 1977).
4. Ministerio de Minas y Energia, Oficina de Planeacion..
5. INTRA, Oficina de Planeacion, Parque Automotor en Colombia, 1978
6. Ferrocarriles Nacionales, Unidad de Planeacion
7. Colpuertos, Boletin Tecnico Estadistico No.13.
8. Departamento Administrativo de Aeronautica Civil, Grupo Estadistica.

Note : 1) The average annual growth rate is calculated by the formula of $F = (1+i)^n$. The "i" is shown in percentage in the table.

2-2-1 Population

The population for the Project Area together with Bogota D.E. and the country for the years from 1971 to 1979 is shown in Table 2-1. The table indicates that the total population in the three Departments has increased at 2.7% p.a. The concentration in larger urban areas has continued on increasing, resulting in larger growth rates in urban areas. Cali registered a growth rate of 5.6% p.a.; Ibague 5.2% p.a.; and Armenia 2.6% p.a. during this period.

Annex Tables 2-5 and 2-6 show the population in the Departmental Capitals of the Influence Area from 1973 to 1987 and in the Departments of the Influence Area from 1975-1990, as forecasted by DANE. The forecasted figures for the Capitals indicate a lower growth rate in the 80s than in the 70s. The population in each Department is assumed to increase at the same rate for the years 1975-1999, even though there are differences in the growth rates of the various Departments and in the growth rates of the various urban areas.

MOPT has conducted its own population estimate in Plan Nacional de Transporte Anexo I, Table No.13 (Bogota Noviembre de 1979). This applies a lower growth rate for 1990-2000 than that for 1980-90. The difference between the MOPT and the DANE estimates is considered negligible since the intent is to develop an overall tendency for the project study, rather than to determine detailed estimates for future years.

The investigation by the study team supports the tendency to apply a lower growth rate because all of the development plans to be implemented in these Departments are modest in scale and do not indicate drastic changes in the distribution of population. Also, there is no evidence to support radical economic structural changes which may be accompanied by rapid increases, decreases and movements of the population in the coming decades.

2-2-2 Regional Gross Product (RGP)

Using Annex Table 2-7, from 1965 to 1975 the regional gross product in those Departments in the Project Influence Area grew at the rate of 3.5% p.a., while GDP of the country grew at the rate of 6.1% p.a. during the same period. The sectors which registered high rates of growth included the total of commerce, financing, real estate and service sectors in the Departments which grew at the rate of 5.4% p.a., those in the public utility sector (including transport sector) with 6.3% p.a. and the manufacturing sector with 6.0% p.a.

The agricultural sector increased at 4.2% p.a. and the mining decreased at 0.9% p.a. Other characteristics indicated in Annex Table 2-7 are that in 1975, in Valle, manufacturing represented 29.5% and the agriculture 21.6% of RGP; whereas, in Tolima the manufacturing sector represented 4.8% and the agriculture 49.3%. Likewise in 1975 in Quindio, manufacturing was 12.6% and the agriculture 32.3%. No data is available after 1975, however it is

generally noted that the economy has had no radical changes in this period and that the economy in the Project Area has grown at a rate slightly lower than that of the national level which indicates an annual average growth rate of 5.8% during the years of 1975-79.

2-2-3 Agriculture, Livestock and Forestry

Annex Table 2-7 indicates that as a percentage of the RGP, agriculture shows a drop from 1965 to 1975. The same Table also shows that in terms of 1970 prices the value of these products has actually increased but at a lower rate than in the other sectors.

Annex Table 2-8 indicates that the value of agriculture, livestock, etc. in terms of 1970 prices has increased by nearly 55% in Tolima and Valle during the period 1965 to 1974. In Quindio, however, it has remained at the same level. The impact of fishing and forestry has been consistently small, representing approximately less than 3% in all the Departments.

Annex Table 2-9 shows the cultivated areas for major crops in 1965, 1970 and 1974 in the three Departments of the Project Influence Area. It is found that in Quindio, the area cultivated with coffee represents nearly 70% of the total cultivated area. Coffee, sugar-cane, corn, soya and cotton are the major crops in Valle; whereas, coffee, rice, sorghum, cotton and sesame are the major ones in Tolima. Due to the need for crop rotation, the areas cultivated with certain type of crops are cultivated with other crops from year to year.

In Valle, the cultivation of sugar-cane has increased in recent years, prompted by the rise in the price of sugar on the international markets. However, the price fluctuation on the international sugar markets has varied widely, causing a great deal of concern that the agricultural sector, particularly the sugar-cane producers, would be affected severely when the market price drops sharply. People associated with the agricultural development of the Project Area seem to think that agriculture should not depend heavily on the sugar-cane cultivation.

Annex Table 2-9 also indicates that from 1965 to 1974, the total cultivated area increased by 10% in Valle, by 4% in Tolima and by 21% in Quindio. While other sources present different rates of increase and different cultivated hectarege in these Departments, it appears that the expansion of cultivated areas including coffee plantation in the same period had been quite modest.

La Asociacion para el Desarrollo del Tolima has published other data which have been summarized in Annex Table 2-10.A. According to this source, the total cultivated area in 1960 was 386,000 hectares, and in 1979 was 403,000 ha., an increase of 4.4%. However, in the same period, the production in tonnage increased from 524,000 tons to 1,107,000 tons, an increase of 113%. In the case of Valle, (See Annex Table 2-10.B), the cultivated area of principal crops was 420,000 hectares in 1970 and 411,000 hectares in 1977, a decrease of

2.1%; whereas the production in tonnage increased from 5,888,000 tons to 6,960,000 tons in the same period, an increase of 18.2%. In Quindio, however, no similar statistical data was available at the Department's office.

Regarding coffee production, it is known generally that the traditional type of Arabico has been replaced gradually by the new type of Caturra which yields a higher output per hectare than the previous type. This replacement has increased and will increase the annual output in the Departments without significant increase in the cultivated area.

Changes in the areas used as cattle fields are not available. Instead, the changes in the number of slaughtered cattle for the period from 1970 to 1978 are shown in Annex Table 2-11. Assuming that the average area of grass land necessary for raising one head of cattle is constant, the change in the area of the grass field for cattle can be approximated by checking the number of slaughtered cattle. Since the figures in Annex Table 2-11 indicate that the Departments had maintained approximately the same level of outputs in these years, it can be implied that the area of cattle fields would have remained the same during this period.

From the above findings, visits to the Project Area, and interviews with several officials in the Departments, it is concluded that suitable areas for cultivation and cattle breeding have already been used extensively, and that lands which have not yet been explored actually have certain disadvantages because of the nature of soils, geography, climate, etc. In the case of Valle, the hilly and mountain areas between the Pacific coast and the river of Cauca include certain unexplored lands on which studies have been conducted to find types of crops it can support and other means for its development.

There are arguments that the protection and/or the development of forest areas in some parts of the Departments are necessary from the viewpoint of natural conservation. However, forest development has been rather modest.

2-2-4 Manufacturing

Regarding production in the manufacturing sector in 1974, the combined production in Tolima and Quindio was 10% and the balance of 90% was produced in Valle. As shown in Annex Tables 2-12 and 2-13, for the period of 9 years from 1965 to 1974, some sub-sectors in the manufacturing such as textile, rubberchemical in Tolima and leather and transport materials in Quindio show a decrease in the output while the total for manufacturing in the Departments increased at 6.4% p.a. The main reason for such decreases is the location disadvantage of these subsectors compared to those located near the large markets of Bogota and Cali.

During the period from 1965 to 1974, the share of the Departments in the Area of Influence as percentage of the total

manufacturing in the whole country declined from 21% to 19.8%.

(1) The reasons for the relative stagnation of this region are many and have been identified through several discussions with the persons associated with the problems of the regional development. They are described below:

1) Due to the rapid growth of the urban area of Bogota, the factories located in this urban area have a decided advantage over those located in other part of the country because of their proximity to the largest market in the country. Previous changes in relative locational factors did not favorably influence the growth of the manufacturing sector in the Project Area. These changes however, resulted in lower growth in an investment and production of the manufacturing sector in the area and were magnified by the difficulty in finding alternative markets in and out of the country.

2) Encouragement policies and the provision of easy credit were not sufficient.

3) There was no proper zoning and land use allocation. Excessive concentration of establishments took place in Cali.

4) The surplus earnings from coffee export were not reinvested in the area which produced these earnings. They were in fact spread out over the total country.

5) Social problems such as labor disputes, shortages in qualified human resources, etc. contributed to stifle the industrial development.

6) High taxation levies.

7) Funds were invested in more lucrative sectors such as commerce, real estate, etc.

8) Conservative and traditional ways of economic activities were predominant in most parts of the manufacturing sector.

(2) Of the above mentioned points, some have been already improved fairly well, but some remain unimproved till this day. In recent years a number of industrial development plans have been established or are under study by the Departments and by the Chambers of Commerce. Some of the plans to renovate and stimulate the activities in the manufacturing are listed below:

1) Encouragement in establishing new factories, particularly for processing crops, grains, livestock product, coffee, etc.

2) Study on the location of experimental plants for producing fuel from sugar-cane. The proposed plans are for one plant in Quindio and for three plants in Valle.

3) Study for establishing a chemical plant to produce chlorine and bicarbonate of soda, and a paper plant, both in Buga-Tulua District. Another study which proposes establishing factories in Cartago-Zarzal area to extract oil from soya bean and cotton seed has been completed.

4) Expansion of the existing free industrial zone in Yumbo and Buenaventura. There are also plans to establish a new industrial zone in Calarca, Yumbo, Chaparral, Espinal and Purificacion. Of these plans, the ones to be located in Tolima and Quindio are summarized below:

4)-(1) La Asociacion para el Desarrollo del Tolima will shortly present a report, Plan de Desarrollo Agroindustrial del Tolima in which they propose to develop an agroindustrial zone in Chaparral, Espinal and Purificacion. The plan will develop new manufacturing establishments in these zones, which will process the output of agriculture and livestock. However, it will take a few more years to finalize the detailed plans of the construction.

4)-(2) In Quindio, the Department and the private sector with the assistance of the Chamber of Commerce have been preparing the development of an industrial park in Calarca. The park is to be located at the southern end of the urban area of Calarca along the Project Road. In the initial stage, an area of 84,000 m^2 with infrastructure facilities will be completed by the end of 1982. The construction was due to start late in 1980. It is planned that 24 establishments already located in Armenia and Calarca will relocate in this park in addition to seven new factories. El Parque Industrial del Quindio S.A. is now campaigning to locate additional firms in the area. It is expected to have a total area of 500,000 m2 in the final stage.

The industrial park is the only project which is to be realized in the direct Influence Area of the Project Road. Since 80% of the firms are relocated from Armenia-Calarca urban area, it is considered that they will not generate much new traffic on the Project Road.

5) Establishment of a stock exchange market in Cali.

6) Expansion of the supply of credit and loan through various financial institutions.

Steady growth of the industry is urgently required since the growth will provide employment opportunities for those immigrants from rural areas as well as for those living in the urban area. Continuous efforts by the administrative sector as well as by the private sector are required to achieve an accelerated growth of the manufacturing sector in the Project Area. It is considered that even if these development plans are realized with the magnitude

being planned, their effect on the increase in traffic volumes of the Project Road is hard to estimate at this stage. It appears that these development plans will not result in substantial additional growth in traffic volumes as forecasted in Chapter 4, since the plans are generally modest in scale compared with the current economy of the Project Area.

2-2-5 Transport Services in the Project Area

Reviews of other modes of transport in the Project Area were carried out as related to the network linking the major urban centers. The statistical data obtained are tabulated in Annex Table 2-14. Airlines expanded the volume of services rapidly particularly at the major airports, while the railways decreased their services particularly in the late 1970s. The decrease in the railways usage was more in the passenger service than in the cargo service. Export and import at the port of Buenaventura registered a higher rate of increase in the late 1970s than in the early years of the same decade.

During the same period it is noted that these changes were accompanied by a steady increase in the traffic volume on the Project Road. This was verified by the regular traffic counting data of MOPT. Changes in the demand and service of these modes would not be significant as to result in a radical change on the vehicle traffic on the Project Road. It is likely that this overall tendency will continue in the future of the transport sector in the region.

Identified projects in the sectors of transport except the roads in the Project Area are as follows: 1) The feasibility study of improvement and containerization of the Colombian ports including Buenaventura which will be completed in April 1981, 2) A study to develop a water transport system along the Pacific Coast and the related rivers which will be completed in early 1981, 3) An urban renewal project including the improvement of the urban street network in Buenaventura which will be completed in 1985, and 4) A study to construct a terminal area with accomodation for drivers in Cali and Buenaventura respectively. It is expected that these projects will serve to meet the growing transport demand of the region, but will not be so influential as to alter the trend of traffic growth on the Project Road.

The following are comments on the data in Annex Table 2-14.

(1) The civil airline service registered a high development during the seventies. From 1971 to 1979, the total of domestic and international passengers increased at 11% and 14% p.a. in the airports of Bogota and Cali respectively. The movement of cargo for international lines at Bogota and Cali increased even at a higher rate than that of passengers. The growth for domestic lines was modest and the volumes were small.

From 1971 to 1979, the volume of passengers travelling on the

airline between Bogota and Cali has shown a rate of increase of 8.2% p.a., while the volume between Bogota and Armenia increased only 4.8% p.a. The line between Bogota and Ibague had fewer passengers and there is only one round trip per day by a small plane at present. The movement of cargo on these short distance lines is quite modest in volume.

(2) The movement of ocean-going cargo at the port of Buenaventura saw a large increase during the late seventies caused mainly by a policy of liberal trade and the growth of the national economy in these years. It is noted that the average annual growth rate was 8.6% for the years from 1971 to 1979 and that the percent share of the port of Buenaventura in the total of the movement at the international ports was approximately 50% through these years. According to the statistical data of COLPUERTOS, the major exports at the port are coffee and sugar while the major imports are wheat, fuel, steel metals and paper.

(3) The passengers using the lines of the Central Division of the Ferro-Carriles Nacionales have decreased during the years of the seventies with particularly large decreases in the final years of the seventies. The station in Ibague terminated the operation of passenger trains in 1972. At present only the section of Neiva-Espinal-Girardot has a few passenger trains with a very small number of users. For example, an average of 45 persons arrived or departed daily at the station of Girardot in 1979. The passengers on the lines of the Pacific Division had increased during the first half of seventies, when locomotives and coaches were newly installed, however, they began to decrease in the following years. At present there is one round trip train daily between Cali and Armenia and two trains between Cali and Cartago. The Pacific Division is isolated from the other divisions since a section between Cartago and Medellin was flooded away in 1973 and the section between Ibague and Armenia is not yet constructed. The cargo service by the railway has shown generally a slight decrease in the Project Area, but not to the same extent suffered by the passenger service. The main cargo carried by the rail consists of bulky items such as sugar, coffee, grains, cotton, and heavy construction materials and equipment. It is likely that in the future the railway service will be limited to carrying these bulky cargoes under specific contract with the customers.

It should be noted that the traffic on the Project Road has increased simultaneously with the development of the above national and regional economic activities. These developments have shown steady and gradual changes over the decade of the seventies with high correlation between the transportation data and economic indices in most cases. Furthermore it has been observed that there will be no radical change in the national economy and the economy of the Project Area in the coming years. Therefore, it is considered reasonable to forecast the traffic on the Project Road by extrapolating from past data.

Photo 2-1 Colombian National Railway

Photo 2-2 Project Road Perspective
(Existing Road)

CHAPTER - 3

TRAFFIC ON THE PROJECT ROAD

Chapter 3 Traffic on the Project Road

3-1 Traffic Volumes on the Road Between Bogota-Buenaventura

The Average Daily Traffic (ADT) volumes on the road between Bogota-Buenaventura in 1978 are shown in Fig. 3-1. In terms of the level of ADT, the road between Bogota and Buenaventura can be subdivided into 5 sections; namely the section in the vicinity of Bogota, the section between T del Salto and Ibague, the mountainous section between Ibague and Uribe, the section between Uribe and Buga, and the last section from Buga to Buenaventura. Due to local characteristics the ADT varies from 881 to 21,741 veh/day.

In the most mountainous region between Ibague and Calarca which is the critical section of this project, the ADT is about 2,000 veh/day.

The vehicle composition also varies depending on the location. The percentage of heavy vehicles to the total traffic volume generally tends to be higher in the areas far from large cities. In the mountainous section of Ibague to Calarca, this percentage becomes extremely high, representing about 70% of ADT in 1978.

Regarding the traffic patterns, the records for the past several years at the three stations, Fusagasuga, Cajamarca, and Guacari were obtained from the Estaciones Automaticas de Conteo de Transito of MOPT and are presented in Fig. 3-2.

The hourly patterns are reasonably uniform and the variations are rather gradual. The weekly pattern is rather irregular, and varies according to location, the variation reaching a maximum on Sundays. The monthly pattern shows a relatively minor seasonal variation, the peak and the low do not differ by more than 15% from the average.

3-2 Origin and Destination (O-D)

Several O-D survey results are available for the road project Bogota-Buenaventura, however, any one of them is not sufficient for estimating the current traffic movements and their relationships with the road. Therefore, a traffic survey, including traffic counting and O-D survey, was conducted on Feb. 12, 1980 at the three stations; Buga, Coello, and Espinal on the existing road. The locations of the three stations are illustrated in Annex Fig.3-1. The survey was carried out over a period of 16 hrs. from 6:00 a.m. to 10:00 p.m. The number of vehicles sampled for O-D survey was approximately 20%, 50% and 20% of the total traffic at each of the three stations respectively.

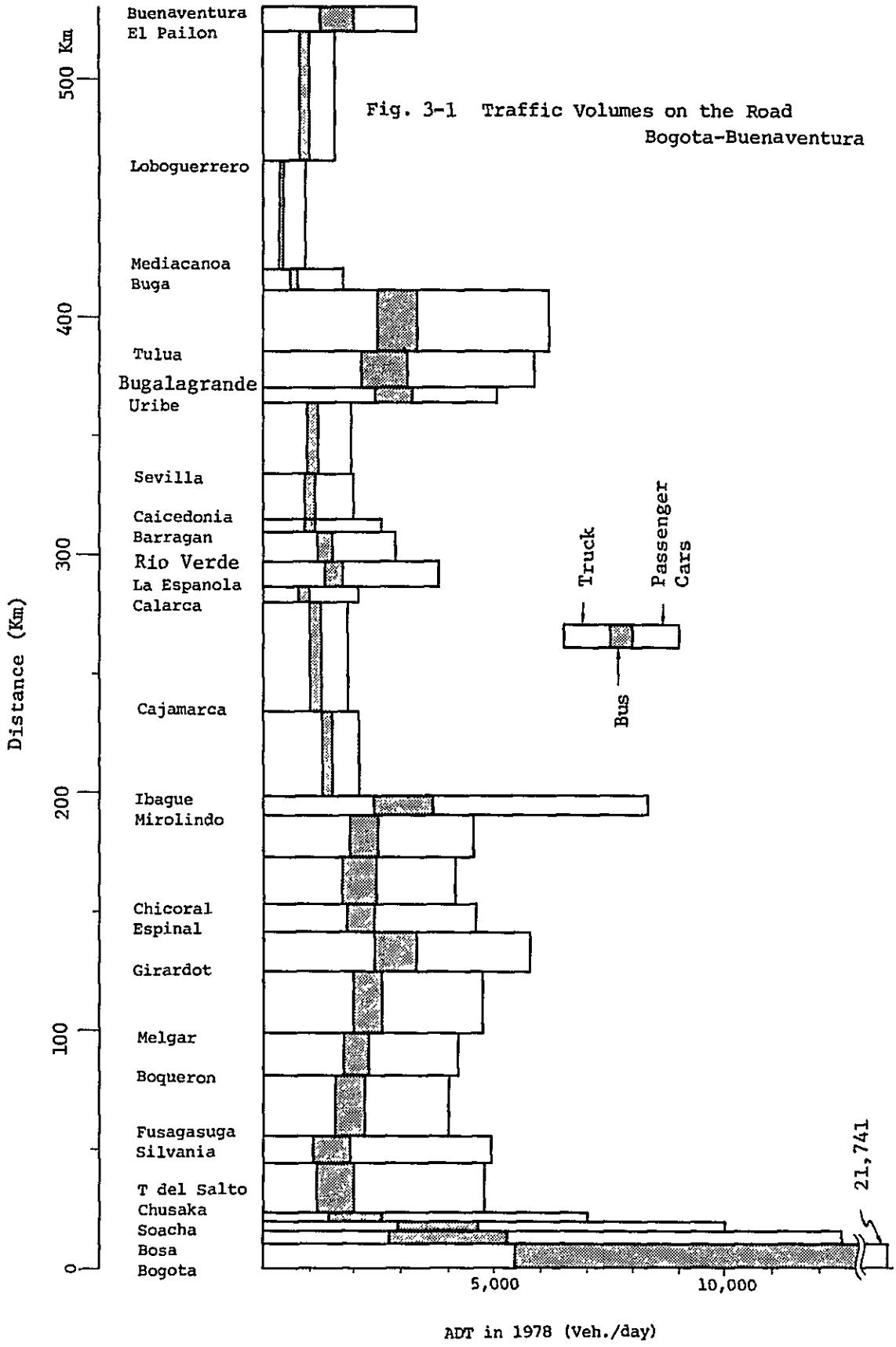
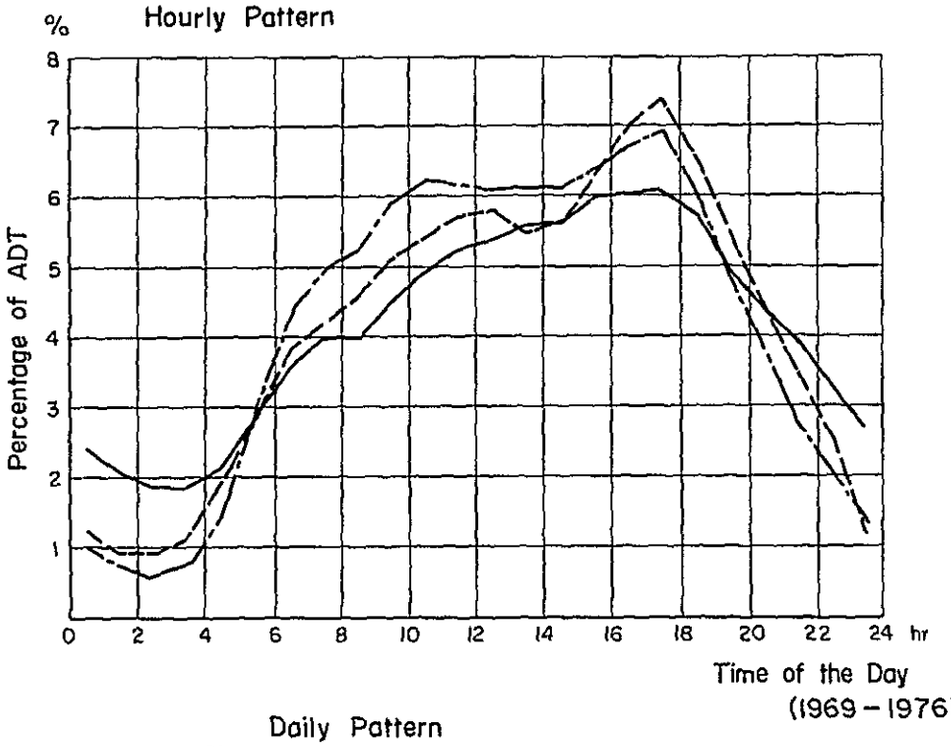
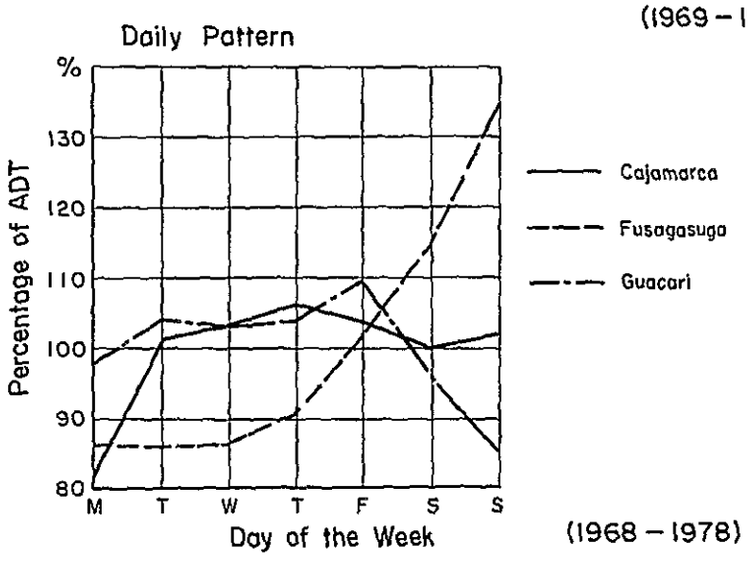
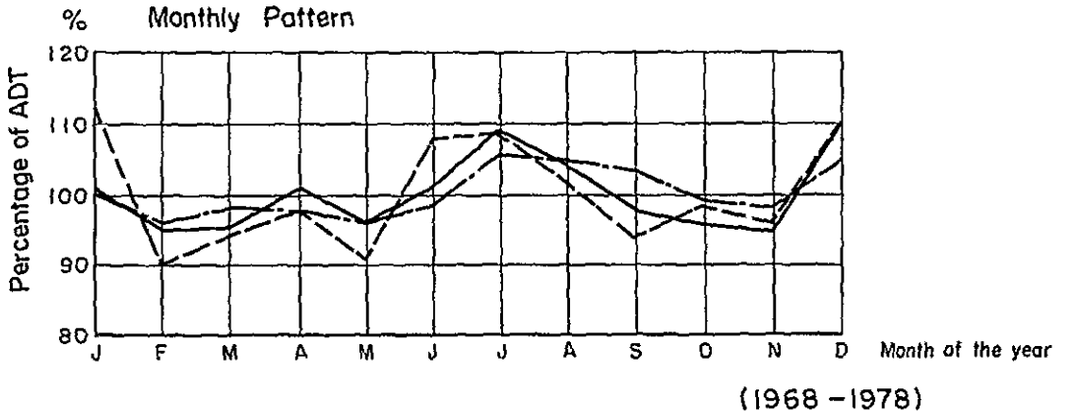


Fig. 3-1 Traffic Volumes on the Road Bogota-Buenaventura

Fig. 3-2 Traffic Pattern







(1968 - 1978)
(Source : MOPT)

3-2-1 Observed Traffic Volumes

Table 3-1 gives the observed vehicle composition at the three stations.

Table 3-1 Observed Vehicle Composition
(Volume during observation hours)

Station	Automobile	Bus	Truck	Total
1 (Buga)	3,359 (50.9%)	601 (9.1%)	2,637 (40.0%)	6,597 (100.0%)
2 (Coello)	543 (29.1%)	141 (7.6%)	1,181 (63.3%)	1,865 (100.0%)
3 (Espinal)	2,045 (43.6%)	542 (11.6%)	2,101 (44.8%)	4,688 (100.0%)

The figures above compare very favorably with the vehicle compositions counted by MOPT in 1978, except for the percentage of buses which is slightly lower in the new count than the MOPT records in 1978 at all three stations. The reason for this discrepancy may be due to the relatively high rate of buses operating near midnight which is a period during which the traffic count was not carried out.

With regard to automobiles and trucks, a further classification can be made from the results of the interviews for O-D. As seen in Tables 3-2, 3-3, passenger cars and trucks with 2 axles are the most dominant among automobiles and trucks respectively at all three stations. A relatively higher count of heavier trucks was encountered at the station No.2 as compared to the other stations.

There are 21 automatic traffic counting stations in Colombia. These stations provide the hourly and monthly variations in the traffic volume. From these records, the data at Guacari, Cajamarca and Fusagasuga were used to extrapolate the traffic volumes at the three stations from the total of 16 hrs to 24 hrs.

It was thence found that the total observed traffic volumes at the three stations correspond to 84.5%, 80.6% and 86.5% of ADT of Guacari, Cajamarca and Fusagasuga respectively. Consequently, the daily traffic volumes are estimated to be 7,802 veh/day, 2,313 and 5,418 veh/day at Buga, Coello and Espinal respectively.

The daily traffic volume estimated above should be further converted to annual average daily traffic (AADT) by taking into account the daily variation in one week and the monthly variation in one year. The conversion factors and AADT at the three stations were then calculated and tabulated in Table 3-4.

Table 3-2 Classification of Automobiles

Vehicle Type	Station No.1 (Buga) Number of vehicles	%	Station No. 2 (Coello) Number of vehicles	%	Station No.3 (Espinal) Number of vehicles	%
Passenger Car	210	69.3	205	75.9	168	47.6
Jeep	46	15.2	47	17.4	95	26.9
Light Motor Van	47	15.5	18	6.7	90	25.5
Sub-total	303	100.0	270	100.0	353	100.0
Unclassified	317	-	12	-	41	-
Total	620	-	282	-	394	-

Table 3-3 Classification of Trucks

Vehicle Type	Station No. 1 (Buga) Number of vehicles	%	Station No. 2 (Coello) Number of vehicles	%	Station No. 3 (Espinal) Number of vehicles	%
Truck 2 axles	434	83.1	442	73.1	301	75.8
Truck 3 axles	42	8.0	92	15.2	61	15.4
Semi Trailer 3 axles	4	0.8	8	1.3	4	1.0
Semi Trailer 4 axles	5	1.0	3	0.5	1	0.3
Trailer 4 axles	5	1.0	0	0.0	0	0.0
Trailer 5 axles	32	6.1	60	9.9	30	7.5
Total	522	100.0	605	100.0	397	100.0

Note: The classification of vehicle type is subject to the illustration in the survey sheet for O-D. (See Annex Fig. 3-2)

These vehicles are also referred to as Tractomulas in the economic study.

Table 3-4 Conversion Factors & AADT

Station No.	Conversion Factor	AADT (Veh/day)
1. (Buga)	1.041 x 0.959 = 0.998	7,818
2. (Coello)	1.014 x 0.948 = 0.961	2,407
3. (Espinal)	0.86 x 0.902 = 0.776	6,982

Source: Estaciones Automaticas permanentes
De conteo De Transito, 1968-1978 MOPT

3-2-2 O-D Matrices

First of all, the whole country was divided into 40 zones. (See Annex Fig. 3-3). According to this zoning, the O-D results were coded and processed by the computer. The processing was made through the following three steps.

1) Expansion of the sampled data to give the whole traffic for 16 hours.
2) Expansion from the 16 hr-traffic to the 24 hour daily traffic by station.
3) Integration of the matrices at the three stations into one matrix, taking into consideration of the conversion factor for the annual average daily traffic.

At integration of OD matrices, following considerations were taken.

1) The data at station No. 2 is given the highest priority since the sampling ratio is the highest among the three stations. Therefore, if the same O-D elements are found in the data at more than two stations including the station No.2, the data at No. 2 will be used.
2) Where the same O-D elements are found in the data at No. 1 and No. 3 stations only, the larger of the two will be adopted.

The result of the processing using 40 zones is given in Annex Table 3-3. The results in the form of aggregated zones are shown in Tables 3-5 and 3-6. They are expressed in terms of triangle type. Therefore, each entry indicates the total number of trip ends.

From Table 3-5, the diverted traffic to the new road, if constructed between Melgar and Buga can be roughly estimated. The rough estimate gives 800-900 veh/day in 1980 traffic volume levels. This volume represents approximately 35% of AADT at Coello.

Table 3-5 Origin Destination Table (1980) for Total Vehicles

(Veh/day)

Zones	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Zones	Bogota	Cundi	Tol 1	Tol 2	Quind	Valle 1	Valle 2	Risar	Cald	Anti	NE of BGT	S of BGT	S of Valle	
1. Bogota	8	0	566	854	145	29	623	133	5	171	0	540	59	3,133
2. Cundinamarca		14	2253	785	39	9	77	31	19	29	7	88	2	3,353
3. Tolima 1			276	141	14	5	12	4	2	11	34	8	2	3,328
4. Tolima 2				848	121	8	116	43	10	13	6	29	4	2,978
5. Quindio					10	0	321	0	11	6	8	7	5	687
6. Valle 1						12	1080	6	2	0	16	2	10	1,179
7. Valle 2							7042	523	493	678	76	13	36	11,090
8. Risaralda								0	0	6	15	30	18	809
9. Caldas									0	0	2	7	21	572
10. Antioquia										12	8	48	33	1,015
11. NE of Bogota											0	12	15	199
12. S of Bogota (Neiva)												0	2	786
13. S of Valle													10	217
Total														29,346

Table 3-6 Origin Destination Table (1980) for Trucks (Veh/day)

Zones / Zones	1 Bogota	2 Cundi	3 Quind	4 Tolima	5 Quind	6 Valle 1	7 Valle 2	8 Risar	9 Cald	10 Anti	11 NE of BGT	12 S of BGT	13 S of Valle	Total
1. Bogota	0	0	364	203	91	25	473	60	2	145	0	288	32	1,683
2. Cundinamarca		0	693	263	30	9	67	21	13	29	0	44	0	1,169
3. Tolima 1			70	55	10	5	4	4	0	5	13	8	2	1,233
4. Tolima 2				298	97	6	79	27	5	5	0	29	4	1,071
5. Quindio					10	0	184	0	4	6	6	7	5	450
6. Valle 1						0	438	0	0	0	5	2	10	500
7. Valle 2							1504	217	168	630	31	9	4	3,808
8. Risaralda								0	0	6	4	28	7	374
9. Caldas									0	0	0	7	21	220
10. Antioquia										12	8	43	27	916
11. NE of Bogota											0	0	7	74
12. S of Bogota												0	2	467
13. S of Valle													10	131
Total														12,096

3-3 Effects of Other Related Road Projects

According to the transportation sector development program "Plan de Integracion Nacional-Sector Transporte Oct. 19, 1979" by the Departmento Nacional de Planeacion, new highways between Bogota-Medellin and between Armenia-Zarzal are now under construction and are to be completed in 1982. It is obviously important for the planning of the Project Road to estimate the diverted traffic from the existing road to the new roads mentioned above.

3-3-1 Diverted Traffic to the New Highway Bogota-Medellin

From Table 3-5, the diverted traffic to the new highway between Bogota-Medellin is estimated to be 186 veh/day in 1980 traffic volume level. This volume will be about 8% of AADT at Coello.

3-3-2 Diverted Traffic to the New Highway Armenia-Zarzal

For estimating the diverted traffic to the new highway between Armenia-Zarzal the O-D matrices of Valle area derived from O-D survey conducted at many stations in Valle in 1976 can be utilized. It is reported that this survey which consists of traffic counting and interviews for O-D, was made for one week during Nov. 3-Nov. 10, 1976. The ADT for the section Armenia-Uribe in this period was as follows.

ADT in 1976

Section	ADT
Armenia-Caicedonia	1,800 veh/day
Caicedonia-Sevilla	1,792 "
Sevilla-Uribe	1,595 "

Using the O-D matrix developed in the "Estudio del Plan del Valle", the composition of O-D elements at the three Sections has been estimated and tabulated in Tables 3-7, 3-8 and 3-9. The total volume of the estimated O-D elements and the ADT in 1976 were compared by section, and were found to be sufficiently close to each other. This implies that most of estimated O-D elements correspond closely to the unknown actual O-D elements and that the missing elements in the total are considered insignificant.

Among the O-D elements the ones denoted as type B refer to traffic which will divert to the new road between Armenia-Zarzal from the existing road after the new road is completed. As for type C, whether or not it diverts to the new road depends on the condition of the new road.

In the event the travel time between Armenia-Uribe via the new road and that via the existing road is not significantly different, then about one half of the traffic of type C will divert to the new road. In this case, the diverted traffic volume will be 29.5% of ADT at the section Armenia-Caicedonia, 33.9% at the section Caicedonia-Sevilla and 33.3% at the section Sevilla-Uribe.

Table 3-7 Estimated Composition of O-D Elements for the Section Armenia-Caicedonia in 1976

O-D Elements		Veh/day	%	Type [1]
Bogota, Neiva area	-Caicedonia	22	1.2	A
ditto	-Sevilla	34	1.9	A
ditto	-South Valle (South of Uribe)	499	27.7	C
ditto	-North Valle (between Uribe-Obando)	14	0.8	B
Armenia	-Caicedonia	342	19.0	A
ditto	-Sevilla	278	15.4	A
ditto	-South Valle	365	20.3	C
ditto	-North Valle (Uribe-Obando)	85	4.7	B
Pereira	-Caicedonia	44	2.5	A
ditto	-Sevilla	48	2.7	A
Manizales	-Caicedonia	2	0.1	A
ditto	-Sevilla	8	0.4	A
Ulloa, Alcara area	-Caicedonia	22	1.2	A
ditto	-Sevilla	12	0.7	A
Total		1,775	98.6	
Others		25	1.4	
ADT		1,800	100.0	

1) See notes under Table 3-9

Table 3-8 Estimated Composition of O-D Elements for the Section Caicedonia - Sevilla in 1976

O-D Elements		Veh/day	%	Type [1]
Bogota, Neiva area	- Sevilla	34	1.9	A
ditto	- South Valle (South of Uribe)	499	27.8	C
ditto	- North Valle (between Uribe-Obando)	14	0.8	B
Armenia	- Sevilla	278	15.5	A
ditto	- South Valle	365	20.4	C
ditto	- North Valle (Uribe-Oband)	85	4.7	B
Pereira	- Sevilla	48	2.7	A
Manizales	- "	8	0.4	A
Ulloa, Arcara area	- "	12	0.7	A
Caicedonia	- "	272	15.2	A
ditto	- South Valle	97	5.4	C
ditto	- North Valle (Uribe-Obando)	28	1.6	B
Total		1,740	97.1	
Others		52	2.9	
ADT		1,792	100.0	

1): See notes under Table 3-9

Table 3-9 Estimated Composition of O-D Elements for the Section Sevilla - Uribe in 1976

O-D Elements		Veh/day	%	Type [1]
Bogota, Neiva area	- South Valle (South of Uribe)	499	31.3	C
ditto	- North Valle (Uribe-Obando)	14	0.9	B
Armenia	- South Valle	365	22.9	C
ditto	- North Valle (Uribe-Obando)	85	5.3	B
Caicedonia	- South Valle	97	6.1	A
ditto	- North Valle (Uribe-Obando)	28	1.7	A
Sevilla	- South Valle	373	23.4	A
ditto	- North Valle (Uribe-Obando)	58	3.6	A
ditto	- Medellin and rest of Valle (Cartago area)	46	2.9	A
Total		1,565	98.1	
Others		30	1.9	
ADT		1,595	100.0	

1) : Type A: will remain on the existing road after the completion of new road between Armenia-Zarzal

Type B: will divert to the new road.

Type C: depends on the condition of the new road.

3-4 Other Findings on the Characteristics of the Existing Traffic

3-4-1 Cargo Movement

From the results of O-D surveys, the kind of cargo, its volume, and its origin and destination can be classified. In terms of tonnage, the main transportation goods are manufacturing and agricultural products, which reach almost 70% of the total, as shown in Table 3-10.

Table 3-10 Type of Cargo and Average Loadgd Weight

	Tonnage		Nos of Vehicles	Tons/veh
Agricultural Products	2,617	23.6	28	9.11
Livestocks	148	1.4	21	7.05
Forest Products	301	2.7	35	8.6
Mineral Products	1,090	9.8	112	9.73
Manufacturing Products	5,121	46.1	515	9.94
Others	1,100	9.9	163	6.75
Vacant	0	0.0	319	0.0
Unknown	719	6.5	75	9.59
Total	11,105	100.0	1,527	7.27

Note: The above figures represent the total tonnage at the three stations.

The average loading volume is about 7.3 tons/veh, the vacant vehicles are relatively few, only about 20% of the total vehicles. The main origins and destinations are Bogota, Cali, Buenaventura and Medellin. The O-D table of cargo flows is shown in Annex Table 3-4.

3-4-2 Number of Passengers

Average number of passengers including driver by type of vehicles is shown in Table 3-11.

Table 3-11 Average Number of Passengers (Persons/ veh)

Vehicle type	Passenger Cars	Buses	Trucks 2 axles	Trucks 3 or more axles
Ave. No. of Passengers	2.2	19.0	1.8	1.6

Source: O-D survey results Feb. 1980
(see in more detail Annex Table 3-6)

3-4-3 Type of Fuel

As shown in Table 3-12, generally both types of fuel, gasoline and diesel, are used. For heavy trucks, diesel fuel is most commonly used whereas gasoline is more commonly used by automobiles, light trucks and buses.

Table 3-12 Type of Fuel

Type of Fuel	Passenger Cars	Buses	Trucks 2 axles	Trucks 3 or more axles
Gasoline	100%	81.6%	80.4%	17.1%
Diesel	0	18.4%	18.4%	82.9%

Source: O-D survey result Feb. 1980
(See in more detail Annex Table 3-7)

CHAPTER - 4

FORECASTED TRAFFIC ON THE ROAD

Chapter 4 Forecasted Traffic on the Road

Traffic data obtained through manual traffic counting from 1971-1979, including changes in the traffic volume as well as changes in the main economic indicators are tabulated in Table 4-1. Traffic volume and its annual change in the main sections of the road are shown in Annex Tables 4-1 and 4-2. The major findings are as follows.

4-1 General Trend

In general, the increases in the count during the last four years are less than those in the first four years. In some sections there was a decrease in one year from the count of the previous year. It is observed that the rate of overall increase has tapered off during these eight years due perhaps to the increase in the capacity of buses and trucks as further described in the following paragraphs.

4-2 Buses

The increase in the size of buses could reflect the lower rate of increase in the traffic count, however, there is no definite proof to substantiate increases in the seat capacity or in passenger occupancy over the eight year period (1971-1979). In the Ibague-Calarca-Uribe section, it is observed that the percentage of busetas and buses in service in 1979 was 10% and 90% respectively; suggesting that a higher usage of buses is taking place; and the forecast is for an increase in the number of buses rather than an increase in capacity.

4-3 Trucks

The use of tractomulas has increased resulting in a larger rate of increase for this type of vehicle than for others. However, the tractomulas represent the smallest percentage of all of the four types, amounting actually to less than 15% of the total vehicles in 1979. Meanwhile, trucks with two axles, which represent 33% of the total traffic in 1979, have increased at a lower rate than the tractomulas between 1971 and 1979. Annex Table 4-3 shows the percent composition of the truck type using selected sections of the road for the past period of 1971-1979 and the projected changes for the years up to 2000. Using these values the percent composition of future traffic can be predicted.

4-4 Data from Automatic Counting

The automatic counting system of MOPT, which provides the AADT for the years from 1968 to 1978 has been generated from two observation points in relation to this Project Road. They are shown below together with the annual average growth rate during these years.

AADT in	1968	1971	1975	1978	(Changes during these years)
No.2 Cajamarca	-	1,530	1,991	2,122	(4.8% p.a.)
No.4 Guacari	3,421	4,183	5,317	6,180	(6.1% p.a.)

The above growth rates are considered to be similar to the tendency from 1971 to 1979 on the Project Road as shown in Annex Table 4-4. The differences between AADT and ADT at these observation points are found to be negligible. Accordingly, ADT in manual counting is assumed to represent AADT on the Project Road.

4-5 Forecast of the Growth Rate

The growth rates applied in the Estudio de Prefactibilidad, Corredor Bogota-Cali, Buenaventura-Bogota, Octubre de 1978: (MOPT and NEI) were 5.5% p.a. for 1985-2000. Those applied for the traffic on the rural trunk roads in the Plan Nacional de Transporte, Bogota, Octubre de 1979 (MOPT and NEI) were 6.0% p.a. up to the year 2000. The trend of ADTs in 1970s indicates that the increase of the traffic on this road is a little lower than the values applied in the above studies. In addition to the past historical tendencies of traffic, the potential of the growth in the regional economy (see Chapter 2) seems to support a conservative assumption in the growth rate. It is determined to apply 5.0% per annum up to 2000 as the overall annual growth rate of the traffic on the road between Melgar and Buga.

4-6 Determination of Growth Rates by Vehicle Type

In determining the future traffic volumes for the individual sections, the different past trends in each of the four major sections were studied. The Uribe-Buga section shows the largest growth rate, followed by the Melgar-Espinal section. The remaining two sections Espinal-Ibague and Ibague-Uribe are found to register the lowest annual growth rate of ADT.

Although growth trends of types of vehicles are different at each of the four sections and although the traffic volumes are different in each of the four sections under this study, it was decided that the same growth rate would be used for each type of vehicle at all four sections. Thus, the growth rate values used at all four sections were 5.5%, 3.4%, 4.6%, 5.9%, 5.1% and 5.0% for small vehicles, buses, trucks with 2 axles, trucks with 3 or more axles, trucks in general and total of all vehicles respectively. Refer to Annex Table 4-4.

The estimated traffic volumes for the years 1971 projected to the year 2000 are tabulated in Annex Table 4-5. In presenting this Annex Table 4-5, the completion of the new bypasses between Armenia and Zarzal and between Bogota and Medellin through Honda has been taken into account. The diverted traffic to these new routes is estimated by studying the data of O-D and has already been deducted from the forecasted traffic after 1983.

Table 4-1 Selected Indicators of Economy and Traffic, 1971-1979.

	1971[1]	72[1]	73[1]	74[1]	75[1]	76[1]	77[1]	78[1]	79[1]	80-85 growth rate per annum.	85-90	90-2000
1. Population('000)	21,347.8	21,941.5	22,551.8	23,179.1	23,823.8	24,486.4	25,167.5	25,867.5	26,587.0	2.1%[2]	2.0%[2]	1.8%[2]
					2.8% p.a.							
2. G.D.P.(in million of 1970 prices)	137,889	148,630	159,195	168,787	175,226	183,296	192,187	209,236	219,885	5.5%[3]	5.5%[3]	5.5%[3]
			6.2% p.a.			5.8% p.a.						
					6.0% p.a.							
3. Fuels consumed on roads (million gallons)												
Gasoline	722.2	761.7	814.4	848.5	893.3	916.3	988.6	1053.3	1080.3	5.3%[4][5]	5.3%[5]	5.3%[5]
			5.4% p.a.				4.9% p.a.					
					5.2% p.a.							
Diesel(ACPM)					301.6	324.7	327.7	338.7	362.8	5.0%[4][5]	5.0%[5]	5.0%[5]
							4.7% p.a.					
4. Registred vehicles in total ('000)	-	-	486.6	522.3	559.2	597.9	628.2	685.6	-	6.7%[2]	6.3%[2]	6.3%[2]
			7.2% p.a.			7.0%p.a.						
5. Traffic on the project Road(TPD or ADT and annual growth tare).												
Melgar-Espinal 44 km.	3,557	3,963	4,150	4,620	4,578	4,782	4,807	5,165	5,144	5.0%	5.0%	5.0%
					4.7%p.a.							
Espinal-Ibague 55 km.	3,490	3,940	4,373	4,592	4,777	4,361	4,900	4,995	4,835	5.0%	5.0%	5.0%
					4.1% p.a.							
Ibague-Uribe 164 km.	1,630	1,439	1,791	1,679	1,918	1,860	2,072	2,177	2,197	5.0%	5.0%	5.0%
					3.9%p.a.							
Uribe-Buga 44 km.	3,897	4,005	4,176	4,791	4,915	4,706	5,500	5,890	6,107	5.0%	5.0%	5.0%
					5.8%p.a.							
Overall average of Melgar-Buga 307 km.	2,564	2,617	2,933	3,068	3,241	3,135	3,462	3,642	3,652	5.0%	5.0%	5.0%
					4.5%p.a.							

Sources: 1) Selected from the data in tables.
2) MOPT, Oficina de Planeacion, Plan Nacional de Transporte Anexo I, (Bogota, Noviembre de 1979).
3) MOPT, Oficina de Planeacion, Estudio de Prefactibilidad: Corredor Bogota-Cali-Buenaventura(Bogota, Octubre de 1978) and INANDES, El Desarrollo Economico Departamental 1960-75 (Bogota, 1977).
4) Ministerio de Minas y Energia, Politica, Obras y Proyecciones del Sector de Minas y Energia, 1979).
5) Assumed to be same as in the begining 5 years.

CHAPTER - 5

VEHICLE RUNNING SURVEY

AND

ROAD CAPACITY

Chapter 5. Vehicle Running Survey and Road Capacity

5-1 Fuel Consumption Survey

The MOPT has extensive data on fuel consumption based on the empirical tests made in 1974. In 1975 MOPT and Netherlands Economic Institute (NEI) made an additional study on fuel consumption by using several types of heavy vehicles. The results are reasonably applicable to the traffic running on the Project Road. The specific characteristics of the Project Road, such as steep grades and high altitude require additional vehicle running experiments in order to obtain actual data of fuel consumption.

A fuel consumption survey was conducted on the Project Road between Espinal and Calarca by using three types of vehicles: passenger car, truck and semi-trailer truck. Although the tests were conducted on limited sections of the Project Road, the results seem to be reasonable for the development of a relationship between the fuel consumptions, grades and vehicle speeds.

5-1-1 Execution of the Survey

The measurement of fuel consumption was conducted on the 29 road sections between Espinal and Calarca, in close cooperation with the MOPT and COLMOTORES during the period from September 15 to October 25, 1980. Prior to the execution, the selection of road section was made in such a way that the respective characteristic such as gradient, curvature, width, etc. in each section would be homogeneous as much as possible. The sections were determined by the data from the inventory study and the site inspection. All the sections were paved with asphalt concrete and the surface condition varied from very good to fair. The main characteristics of the sections are shown in Table 5-1.

Measurements were conducted using 3 types of test vehicles under uninterrupted running conditions. The characteristics of the tested vehicles are shown in Table 5-2.

At first, the equipment for the measurement of the fuel consumption was an automatic fuel economy meter "Fludyne Model 1250". This sophisticated device is able to measure the fuel consumption units of cubic centimeters and the elapsed time in seconds. The measurement error is expected to be less than 1%.

From the second week of the test, a cylinder type device was introduced, because of the mechanical malfunction of the Fludyne Model 1250. The fuel consumption can be measured by reading the scale which is attached to the cylinder. The probable error for this equipment is equivalent to 0.05 liter of fuel for each section. It implies that the result includes an error ranging from 2% to 20% depending on the length of the section.

It is recognized that fuel consumption is significantly affected by operating speed, therefore, the speed was assumed to be the average speed for the whole section. The average velocity by type of vehicle and by road section was derived from the survey results by MOPT-NEI.

Table 5-1 Characteristics of Road Sections

Section	Length (Km)	Ave. Altitude (m)	Gradient (%)
ESPINAL-IBAGUE			
1. K6.500 - K11.330	4.830	500	0.7
2. K12.712 - K13.520	0.808	500	-3.3
3. K17.100 - K18.000	0.900	550	2.3
4. K24.200 - K25.150	0.950	700	6.7
5. K38.170 - K40.700	2.530	1,000	2.3
IBAGUE - CAJAMARCA			
1. K58.055 - K60.280	2.225	1,300	6.5
2. K61.000 - K64.674	3.674	1,250	-6.4
3. K64.800 - K66.550	1.750	1,200	7.5
4. K69.714 - K70.860	1.146	1,450	5.8
5. K72.4]8 - K73.585	1.167	1,500	4.7
6. K81.406 - K82.779	1.373	1,550	-1.0
7. K83.147 - K84.102	0.955	1,600	7.0
8. K87.130 - K88.135	1.005	1,700	0.4
CAJAMARCA - LA LINEA			
1. K93.985 - K95.400	1.455	1,900	7.0
2. K100.559 - K102.958	2.399	2,350	4.6
3. K105.249 - K107.000	1.751	2,600	8.3
4. K107.000 - K110.263	3.263	3,000	7.4
5. K110.861 - K112.370	1.509	3,050	8.1
6. K111.540 - K112.370	0.830	3,100	8.1
7. K112.370 - K113.400	1.030	3,200	8.4
LA LINEA - CALARCA			
8. K113.400 - K114.180	0.780	3,200	-4.9
9. K114.180 - K118.540	4.360	3,000	-8.9
10. K118.540 - K120.260	1.720	2,700	-9.4
11. K118.540 - K119.380	0.840	2,800	-8.8
12. K119.380 - K120.260	0.880	2,650	-10.0
13. K120.260 - K124.189	3.929	2,500	-8.8
14. K124.189 - K125.371	1.182	2,300	-3.7
15. K125.371 - K126.491	1.120	2,250	-6.2
16. K126.491 - K131.306	4.815	2,000	-7.4

Table 5-2 Characteristics of Tested Vehicles[1)]

	I	II	III	IV
Maker	Dodge	Dodge	Dodge	Dodge
Type	Dart	D600	D600	CNT900
Model	1979	1978	1978	1978
Type of Fuel	Gas	Gas	Gas	ACPM
Curb Weight (Lbs)	2,430	7,293	7,293	(15,214 Front Section) (13,230 Rear Section)
Gross HP	145	210	210	250
Cargo (Lbs)	-	-	Rocks 19,200	-
Gross Vehicle Weight (Lbs)	2,430	7,293	26,493	28,444[2)]
WPR (Gross vehicle weight/Gross HP)	17	35	126	114

Notes: 1) These vehicles are supplied to MOPT by Fabrica Colombiana de Automotores S.A., who agreed to cooperate in the experiment.

2) In this case no cargo was loaded.

In addition, the changes in the rate of fuel consumption in response to the changes of speed were tested for selected sections with D-Dart and D-600.

5-1-2 Results of the Fuel Consumption Survey

The records of the fuel consumption test are shown in Annex Table 5-1. These were plotted on graphs showing the relationships between the fuel consumption and the grades, see figures Fig. 5-1 to Fig. 5-3. With regard to the case of D-600 without cargo, no meaningful result could be obtained due to equipment malfunction.

The values for the fuel consumption in Fig. 5-1 to 5-3 are similar to the results of the study by MOPT-NEI. This means that the relationship between the fuel consumption and the grades is presented by a linear line for up-hill and by an exponential curve for down-hill. Although the differences in fuel consumption related to changes in altitute were not available from existing data, there seems to exist some relationship between them as indicated in Fig. 5-1 to Fig. 5-3. The results indicate that the additional 1,000 m of altitude requires higher fuel consumption ranging from 10% to 50% depending on the relationship between vehicle type and

Fig. 5 – 1 Fuel Consumption (D–Dart)

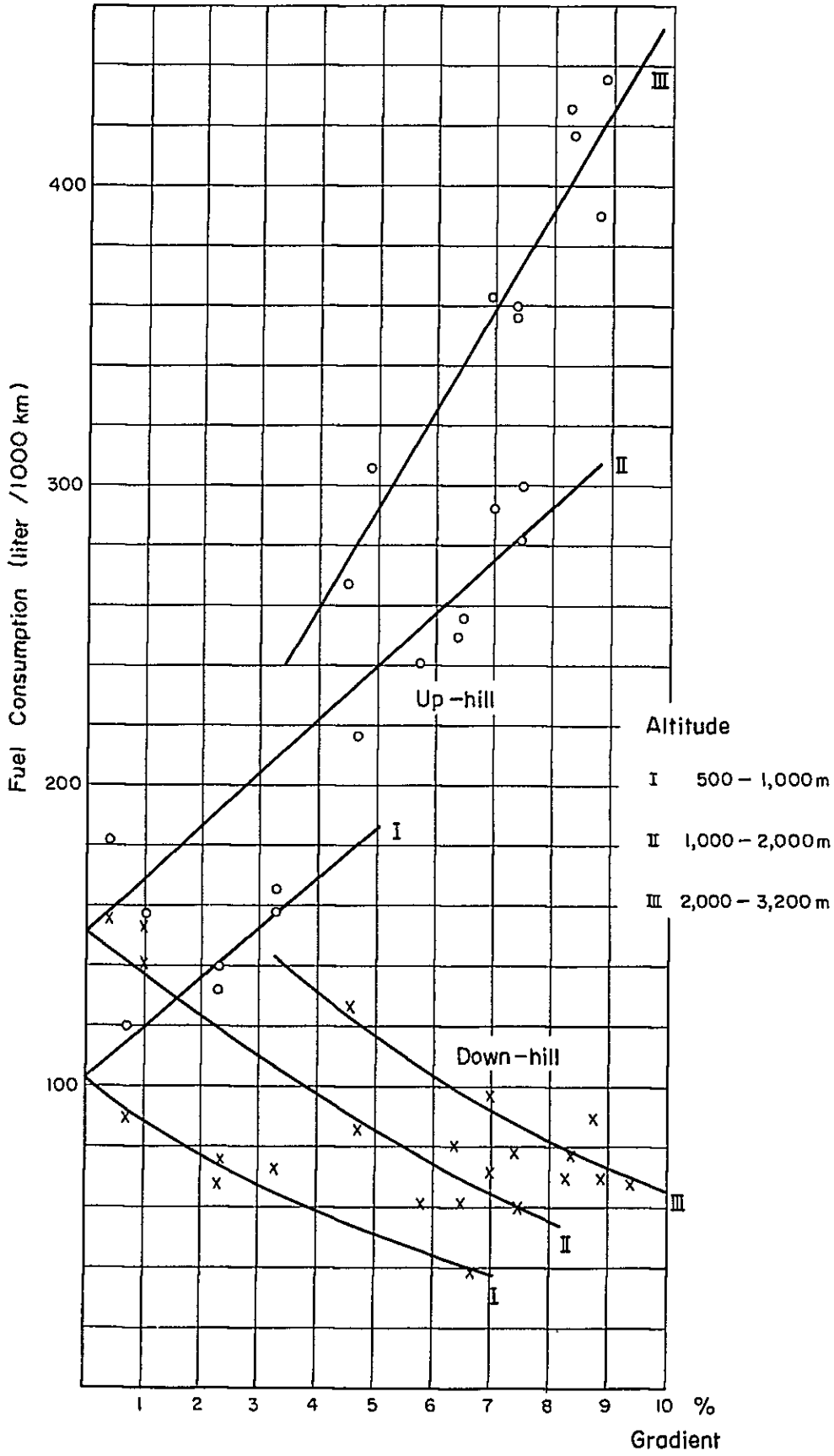


Fig. 5 – 2 Fuel Consumption (D-600 w. cargo)

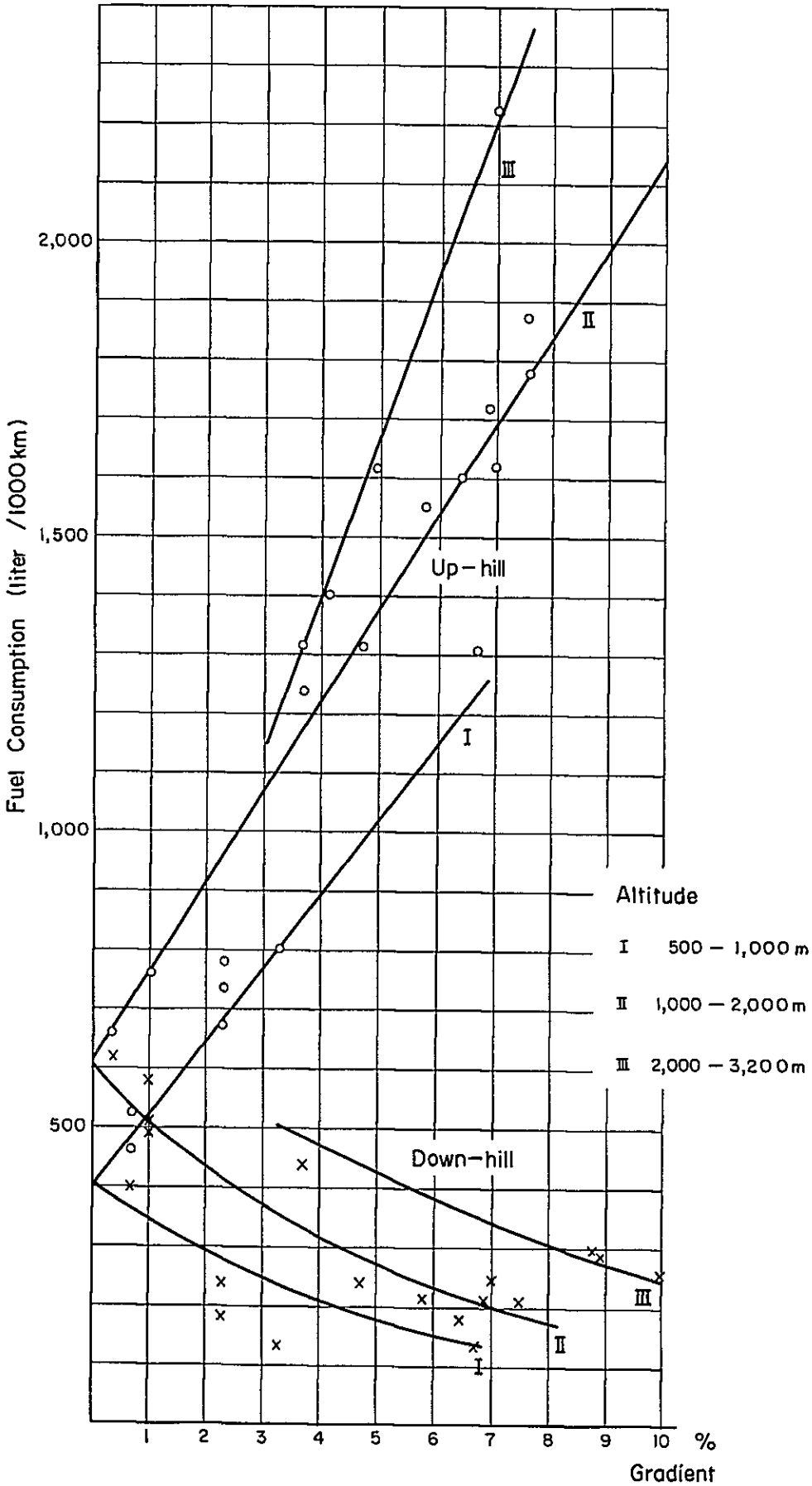
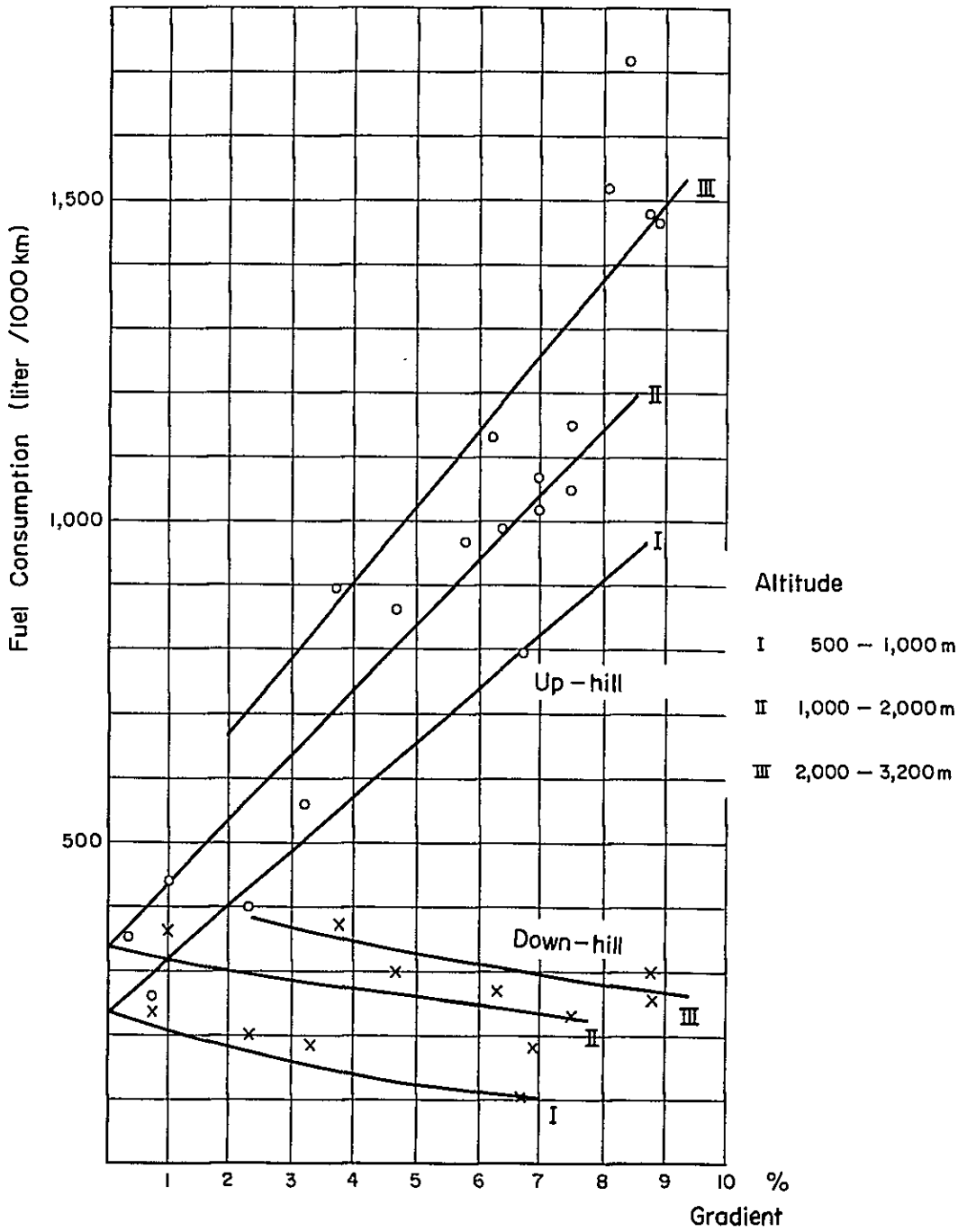


Fig. 5 – 3 Fuel Consumption (CNT 900)



the grade for a given length of road with the same degree of curvature and gradient.

Due to the topographic condition, in areas of high altitude, the road usually has a steeper grade. In this survey, the tested sections at altitudes of 2,000 - 3,200 m did not include any portions with a grade of less than 4%. Consequently, the regressed lines for altitudes of 2,000 - 3,200 would be effective only for grades larger than 4%.

It should also be noted that with ragard to the rate of fuel consumption on a steep grade, the rate for a D-600 truck is much higher than that for a Dodge Dart automobile. For example, comparing the consumption at grades of 8% and 1%, the former requires a quantity from 2.5 to 4 times of the latter in the case of the D-600, while only about two times for the Dodge Dart. This confirms that a steep slope causes a higher fuel consumption by heavy vehicles than by light vehicles.

Table 5-3 shows the comparision between the above results and the existing data based on the test in 1974. With respect to the D-600, the gross vehicle weight of the test vehicle used by MOPT was 22,000 Lbs., whereas the weight used in the current study was about 26,500 Lbs. According to the NEI survey, the fuel consumption by the vehicle with the gross weight of 26,500 Lbs. is higher than the consumption by the 22,000 Lbs. MOPT vehicle by as much as 20%. Therefore, if the MOPT test vehicle was the same as that used for this study the figures for D-600 of MOPT data would have to be 420, 530, 740 instead of 341, 445 and 620.

Table 5-3 Comparison of Fuel Consumptions

(Litres/1,000 km)

	Grade		D-Dart			D-600			
	Altitude		±1%	±3%	±5.5%	±1%	±3%	±5.5%	
Current Tests by Study Team	0 ∿ 1,000m	up (a)	121	153	194	531	778	1,088	Note (1)
		down (b)	92	70	50	345	248	165	
		(c)=(a)+(b)/2	106	111	122	438	513	626	
	1,000 ∿ 2,000m	up (a)	171	206	250	771	1,081	1,467	
		down (b)	134	102	73	526	383	259	
		(c)	152	154	161	649	732	863	
	2,000 ∿ 3,200 m	up (a)	219	254	310	50	1,159	1,828	
		down (b)	181	145	111	628	512	397	
		(c)	200	200	210	739	835	1,112	
Existing data from MOPT	0 ∿ 3,200 m		112	122	158	341	445	620	Note (2)
						420	530	740	Note (3)

Note: (1) From current tests pertaining to 26,500 lbs. vehicle by study team.

(2) Pertains to 22,000 lbs. vehicle previously tested by MOPT. (Plan Nacional de Transporte Annex II Jan. 1980)

(3) Adjusted values of MOPT figures derived by multiplying figures of Note (2) by 26,500/22,000.

In the case where the grade is 1% or 3%, the existing data of MOPT are almost equal to the new results from the current tests at an altitude of 0 - 1,000 m, and in the case where the grade is 5.5%, the existing data of the MOPT compare favorably with the new results at an altitude of 1,000 - 2,000 m. Accordingly, it is concluded that both results are fairly close, and that the discrepancies are mainly due to the difference in the conditions of the roads where the tests were made.

Figures 5-4 and 5-5 represent the relationship between the fuel consumption, operating speeds, and grades. The optimum speed, which is the speed at which the rate of consumption is the lowest, has been derived by plotting the relationships between fuel consumption, grades and operating speeds. The relationships between the optimum speed and the grade of road sections were obtained as follows.

$Vo = 41.0 - 1.1074\ g$ (D-Dart)

$Vo = 37.7 - 2.1688\ g$ (D-600 with cargo)

where Vo : optimum velocity (km/hr.)

g : grade in percent, positive for uphill, and negative for downhill. e.g. when g=5%, vo=41.0-1.1074x5=35.5 kph.

It is to be noted from the above that the larger the uphill grade, the lower the optimum speed.

Comparing the optimum speed with the average operating speed actually observed, the following results are derived. With regard to the D-Dart, as shown in Fig. 5-6, the average operating speed is higher than the optimum when the grade is less than about 4% for both of ascending and the descending grades. However, in the case where the grade is larger than 4% the average operating speed is lower than the optimum for descending and almost the same as for ascending. Similar results were obtained for the D-600 with cargo, as shown in Fig. 5-7, except that the change occurs at 3% grade instead of 4%.

5-2 Vehicle Speed Survey

The main objective of this survey is to provide basic information on the distribution of speed of vehicle, particularly on the mountainous road sections between Melgar and Buga. It is quite obvious that vertical and horizontal alignment as well as vehicle condition have strong influences on the speed. In this

Fig. 5－4 Fuel Consumption by Operating Speed
(D－Dart)

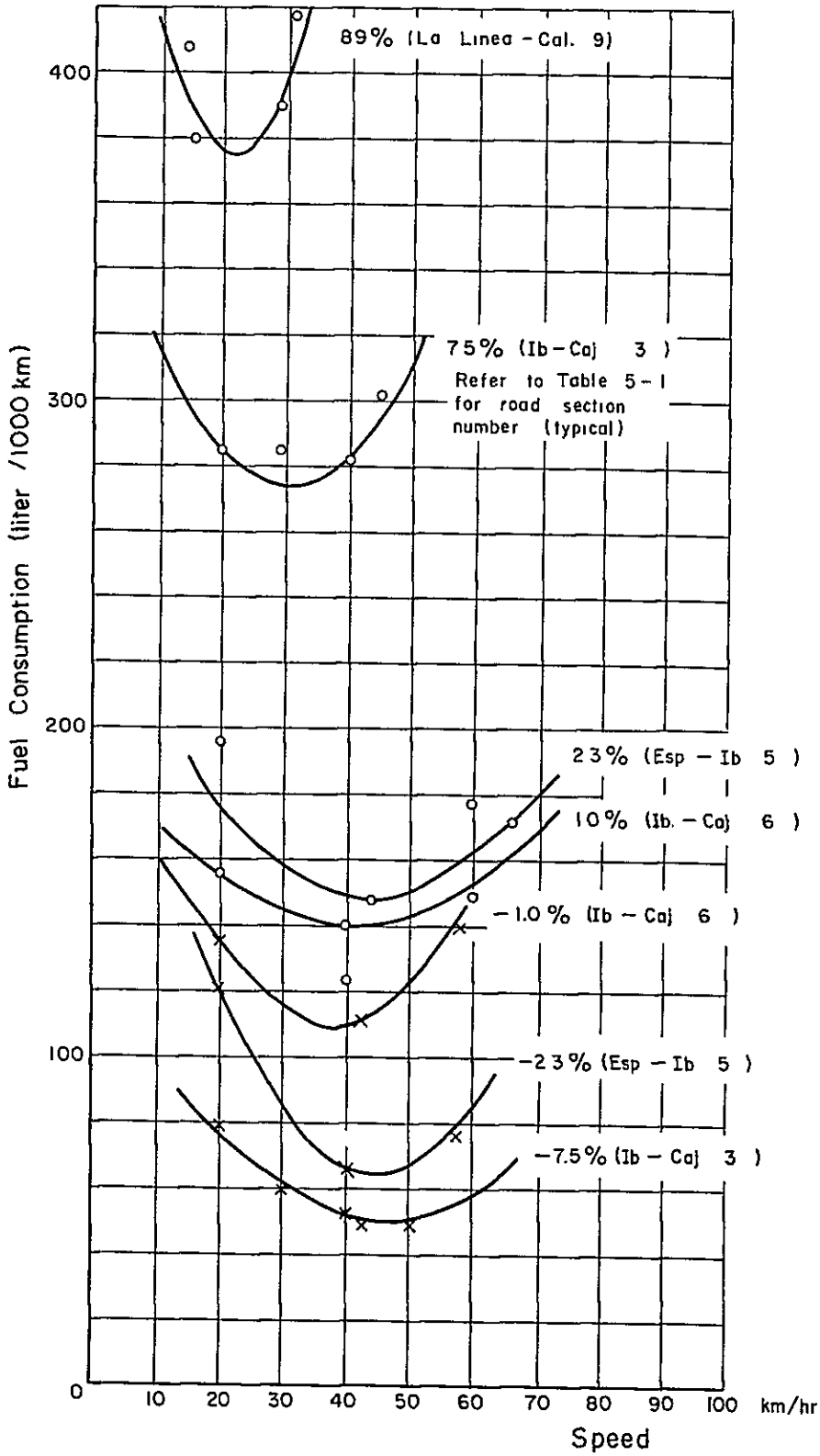


Fig. 5 – 5 Fuel Consumption by Operating Speed
(D – 600 with cargo)

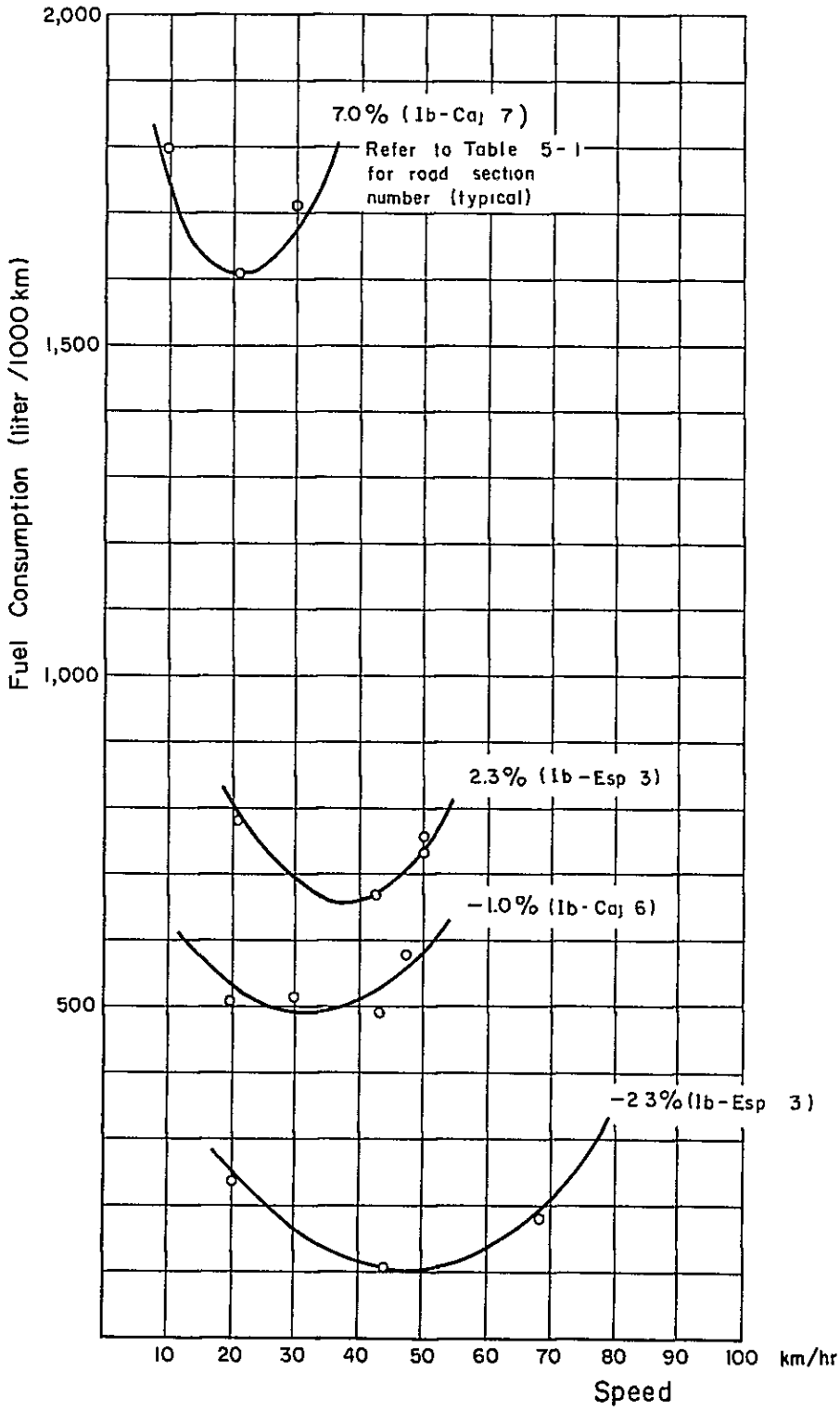


Fig. 5-6 Average Operating Speed and Optimum Speed
(D - Dart)

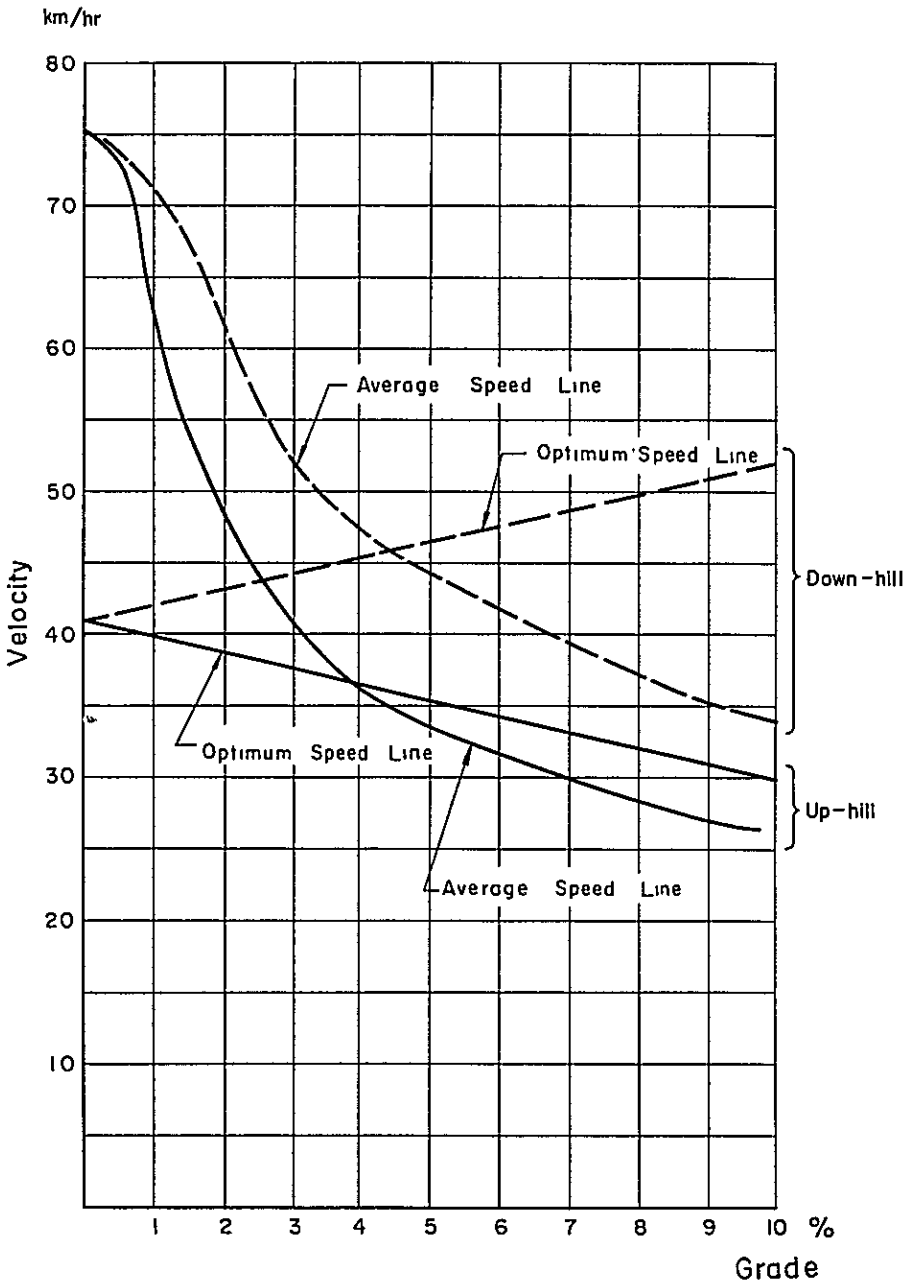
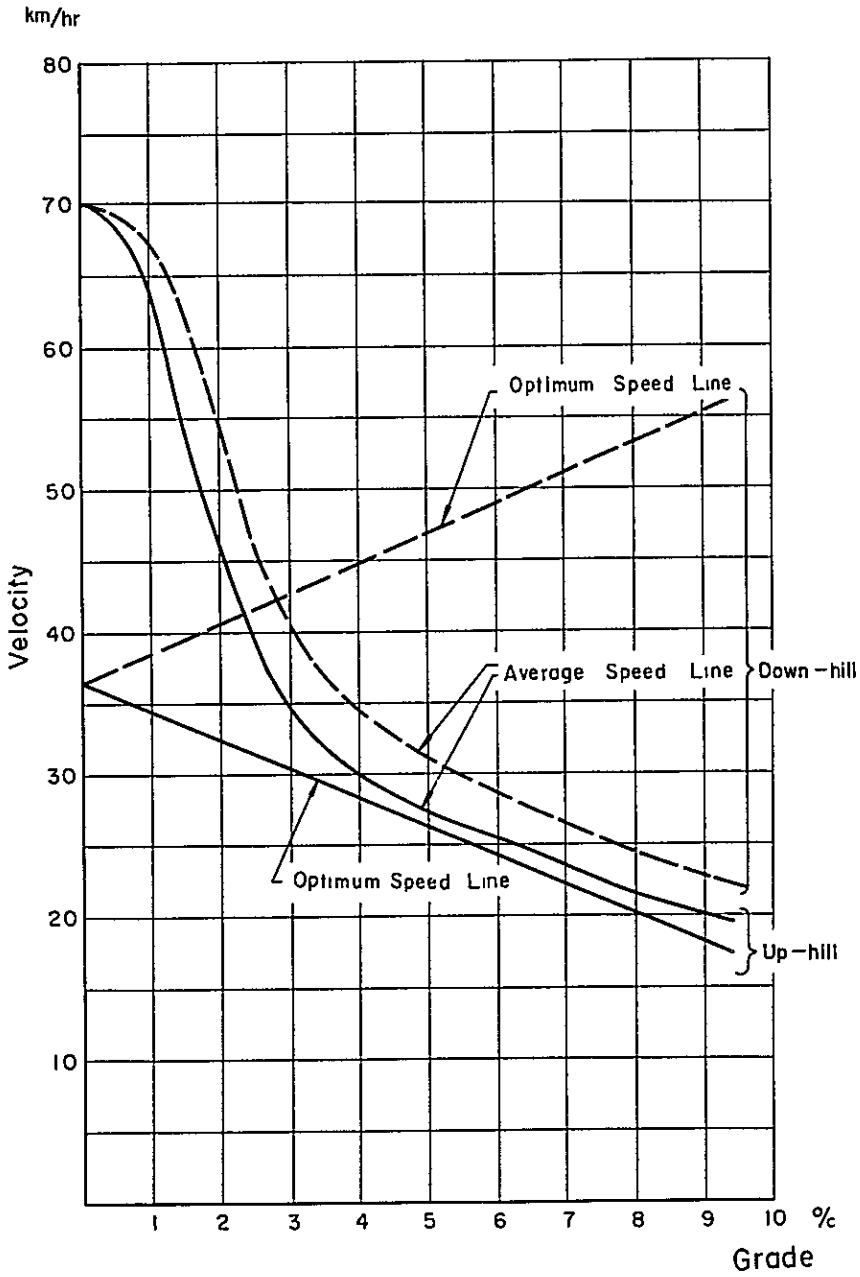


Fig. 5-7 Average Operating Speed and Optimum Speed.
(D-600 with cargo)



survey, time mean speed (the speed on a roadway based on the average of the individual speeds) was measured by type of vehicles.

5-2-1 Execution of the Survey

The survey was conducted for 28 road sections between Espinal and Calarca. It was undertaken jointly by the staff of MOPT, local people and the Study Team, during the consecutive eight days from September 22 to October 1, 1980. The road sections which were used in the fuel consumption survey were also used to measure the speed of vehicles.

The observation was made in the following way. At first, four sections were defined and observers were assigned at stations located at both ends of each section. At each station the observers recorded the plate number and passing time of vehicle. The survey continued for two hours in one direction, and for an additional two hours in the opposite direction. When the observations were completed, the observers moved to the next four sections. The operating speed is calculated for each section by checking the plate number of the vehicle and the elapsed time from the data sheets of the two stations.

5-2-2 Conclusions derived from the Vehicle Speed Survey

Annex Fig. 5-1 is an example of the accumulated speed distribution in the typical mountainous sections. The average speed is found approximately at the 50% value of the ordinate. By calculating the average speeds which are shown in Annex Table 5-2, the Annex Figs. 5-2 to 5-5 are obtained.

Using the observed speeds at 1% grade, the average speeds at a grade of 0% are estimated as follows:

Automobiles: 75 km/hr.

Buses : 75 "

Trucks with 2 axles: 70 km/hr.

Trucks with 3 or more axles: 60 km/hr.

From the above figures the following findings are noted.

(1) The variation of the speed of the light vehicle is larger than that of heavy vehicle on the section with the same grade. Therefore, overtakings by light vehicle occur more frequently than those by heavy vehicle.

(2) Variation of speeds was also noted for heavy vehicles. This may be due to the difference of loading volume and the running capability of the vehicle. Accordingly overtakings by heavy vehicle were also seen at some points in the section.

(3) Comparing with the survey results by NEI, the average speeds determined by this survey are lower than those by NEI for all

the types of vehicles. This may be due to the difference in the topographical conditions, particularly the sight distance where the two surveys were made.

(4) Although trying to analyze the influences of the horizontal alignment and the altitude on the operating speed, a meaningful interpretation could not be found.

5-2-3 Decrease of Operating Speed due to Traffic Growth

In general, vehicle operating speed decreases in proportion to the increase of traffic volume. The Highway Capacity Manual gives several relationships between traffic volume and operating speed on the basis of the observations in the North America. These, however, cannot be applied to the project road, because of the differences in the topographic conditions of the roads. Hence, the main purpose of this study is to find out a relationship applicable to a mountainous road.

The study was focused on the mountainous section between Ibague - Calarca, since most of the improvement plans are concentrated in this section as elaborated in Chapter 7. The operating speeds observed, which are mentioned in paragraph 5-2, are considered to be the speeds under the conditions of free flow, since the existing traffic volume between Ibague - Calarca is still at a low level and is much less than the capacity described in paragraph 5-3.

It is foreseeable that the operating speed will be reduced in accordance with the traffic growth in future. The decrease of the operating speed due to traffic growth was estimated by applying the concept of overtaking which will be explained in paragraph 5-3.

Comparing average vehicle headway with total distance required for overtaking, if the former is longer than the latter, overtaking can take place wherever passing sight distance is provided. In this case, a fast vehicle can run at the same speed as under conditions of free flow. On the contrary, if the overtaking cannot be done, the faster vehicle has to follow after the slower one as long as the same condition lasts. As such, the decrease in operating speed can be estimated by studying whether or not overtaking is possible for a certain volume of traffic. The calculation for a road with a grade of 7% is illustrated below. In the year 1995, the traffic volume between Ibague - Calarca is forecast to be 4053 veh/day. The average hourly volume during the daytime 12 hrs is estimated to be 207 veh/hr.

Using the equation $$Q = V.d = \frac{2V}{la}$$

where Q: hourly volume (veh/h..)

V: average speed (km/h..)

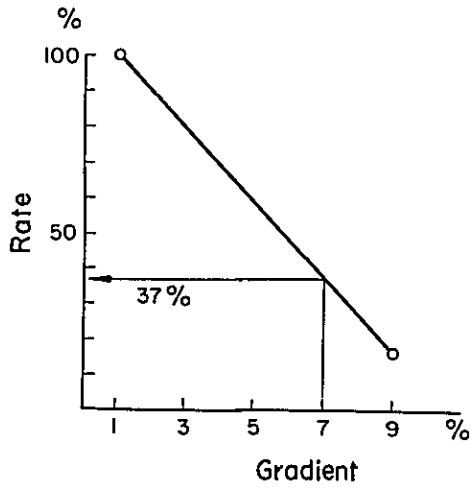
d: average density (veh/km)

la: average headway (Km)

The average headway is calculated to be 271 m in the case of a grade of 7%.

The ratio of the total road length, where the passing sight distance is adequately available, to the total length is heavily dependent on the topographic condition; it is low in the mountainous section and high in the plain section. For the section between La Linea and Calarca, which has an average grade of about 9%, it was calculated to be 17.5%. Hence, the ratio was assumed to be 17.5% on a road section with 9% grade and 100% for 1% grade. The values in between are assumed to vary linearly, as shown in Fig. 5-8.

Fig. 5-8 Rate of the Road Length where Passing Sight Distance is Provided.



* Ratio of road length where passing sight distance is available to total length of road.

From Annex Figs. 5-2 to 5-5, the average speeds on a road with 7% grade can be derived by vehicle type. Hence, the total distances required for overtaking are calculated as follows:

Table 5-4 Total Overtaking Distance in Meters

		Vehicle type which is overtaken		
		Bus	T2	T3
Vehicle type which overtakes	Passenger Car	588*	241	163
	Bus	-	443*	229
	T2	-	-	377*

Note: T2: Truck with 2 axles

T3: Truck with 3 or more axles

In the table above, the mark * means that overtaking by two different types of vehicles cannot take place because distance required is larger than the average headway (271m). As a consequence, the average speed of automobiles at the traffic volume level in 1995 is estimated as follows:

$$Va = 35 \times 0.367 + 27 \times 0.098 + (0.37 \times 35 + 0.63 \times 23) \times 0.341$$

$$+ (0.37 \times 35 + 0.63 \times 17) \times 0.194 = 29.5 \text{ km/hr.}$$

Likewise, the average speeds of buses, trucks with 2 axles and trucks with more than 3 axles are obtained as

$Vb = 26.6$ km/hr.

$V_{T2} = 23.4$ km/hr.

$V_{T3} = 17.1$ km/hr.

Similarly the average speeds for other grades are calculated as shown in Table 5-5.

Table 5-5 Average Speed in Km/hr on the Road between Ibague - Calarca

		Grade				
		1%	3%	5%	7%	9%
Passenger Cars	1980	69	48	40	35	31
	1995	67	45	36	30	24
Buses	1980	68	44	36	31	27
	1995	66	41	32	27	22
Trucks with 2 axles	1980	66	38	29	25	21
	1995	65	36	28	23	19
Trucks with 3 or more axles	1980	52	31	23	18	14
	1995	51	30	22	17	13

5-3 Analysis of the Road Capacity

5-3-1 General

The Highway Capacity Manual (H.C.M.) is widely known as the most reliable and the leading standard for the analysis of the road capacity. However, the H.C.M. is based entirely on the terrain and roads in North America which are quite different from those in Colombia, particularly because of the mountainous terrain which is characteristic of Colombia. The difference in the traffic and road conditions makes the application of H.C.M. to the roads in Colombia extremely difficult.

To cope with this problem, the MOPT has tried to establish a new methodology which is applicable to the roads in Colombia. Among them, a document [1)] of MOPT gives valuable suggestions for the analysis of capacity. In addition to the MOPT document, the Study Team has tried to develop its own methodology to identify the capacity.

The study team methodology defines the traffic volume under the service at level "C" by introducing the concept of overtaking. This procedure and its application to the Project Road are explained in Annex 5-1.

By applying the methodology disclosed by the MOPT document [1)] and the methodology developed by the study team, it was found that comparable results would be obtained by both procedures. For estimating actual capacity, a reduction of capacity due to sharp curves was also taken into account by the study team.

In road sections with sharp curves under present traffic conditions, it is known that a vehicle has to stop for several seconds to allow for the passage of traffic in the opposite direction. This occurs at curves where the road width is not adequate. The methodologies developed by MOPT and by the study team for estimating the capacity are based on a stable and undisturbed traffic flow, therefore these encounters are not taken into account. When the traffic grows year by year, the number of such encounters is certain to increase. The encounters should be taken into account in estimating the capacity of the existing road. The method for estimating the encounters is shown in Annex 5-2.

5-3-2 The Capacity of the Road between Melgar - Buga

The capacity of the existing road between Melgar and Buga was calculated by applying the above methodology.

The calculation was made through the following procedures.

(1) The road between Melgar and Buga was subdivided into 15 sections as shown in Table 5-6.

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1): Luis Holguin Pardo Conceptos de Diseno y de Nivel de Servicio y Evaluacion de la Capacidad en Carreteras de Montana, MOPT, OP-3-21-021, September 1980.

(2) The vehicle operation speeds corresponding to the characteristics of each section were derived from Fig. 4 and Fig. 5 in the MOPT document, OP-3-21-021[2].

(3) The volume of service at level C is obtained through the application of the above methodology.

(4) Adjustment factor for lane width is obtained by referring to the Table 10.8 in the HCM. Assuming that the peak hourly rate is 7%, the daily capacity is calculated.

(5) The reduction of the capacity due to sharp curves is estimated.

Table 5-6 Road Sections

No.	Section	Ave. Grade	Ave. Road Width
1.	Melgar - Girardot	1.8%	2.0 m + 7.2 m + 2.0 m [1]
2.	Girardot - Espinal	1.2	"
3.	Espinal - Mirolindo	2.0	"
4.	Mirolindo - Ibague	2.6	1.5m + 7.2m + 2.0 m + 7.2 m + 1.5m [2]
5.	Ibague - Coello (K56) (K65)	5.8	1.0 m + 7.2 m + 1.0 m
6.	Coello - K73	5.7	"
7.	K73 - Cajamarca (K90)	5.5	"
8.	Cajamarca - K104.3 (K90)	5.0	"
9.	K104.3 - La Linea (K113.5)	8.2	"
10.	La Linea - K124.5 (K114)	8.8	"
11.	K124.5 - Calarca (K135)	7.4	"
12.	Calarca - La Espanola	1.7	2.0 m + 6.0 m + 2.0 m
13.	La Espanola - Sevilla	3.1	"
14.	Sevilla - Uribe	3.8	"
15.	Uribe - Buga	1.3	2.0 m + 7.2 m + 2.0 m

Notes: 1) shoulder + roadway + shoulder

2) shoulder + roadway + median strip + roadway + shoulder

Consequently, the capacity of the existing road is summarized in Table 5-7, taking into consideration the completion of the alternative improvement plans, as proposed in Chapter 7.
The capacity of the existing road varies with the characteristics of road sections. The maximum capacity, 37,000 veh/day is found at the section between Mirolindo - Ibague, which is the only section with 4 lanes. While the capacity is approximately 11,000 veh/day in the plain area, it decreases to 4,600 veh/day in the mountainous area.

With regard to the effect of the proposed improvement plans, the influence on the capacity is generally negligibly small, because all the improvements are partial for each section and do not provide a drastic improvement of the alignment.
A relatively large expansion of capacity is found in the case of the section between Coello and K73 and the case of the medium scale improvement for the section between K73 and Cajamanca. In these cases, the capacity will be expanded by as much as 10 to 30% of the present capacity.

Fig. 5-9 shows the comparison between the road capacity and the estimated traffic volume in the year 2000. In the several sections of the existing road between Melgar and Buga, a shortage of road capacity can be found. In the section between Melgar - Mirolindo, and the section between KM104.3 and KM124.5, the traffic demand will slightly exceed the capacity, but the construction of additional lanes will not be urgently required, if a slight downgrading of the service level such as from "C" to "D" is allowed.
A substantial shortage of the capacity is found only in the section between Uribe - Buga. Hence, the construction of additional 2 lanes in this section will be required by the year 2000.

Table 5-7 Road Capacity (Veh/day)

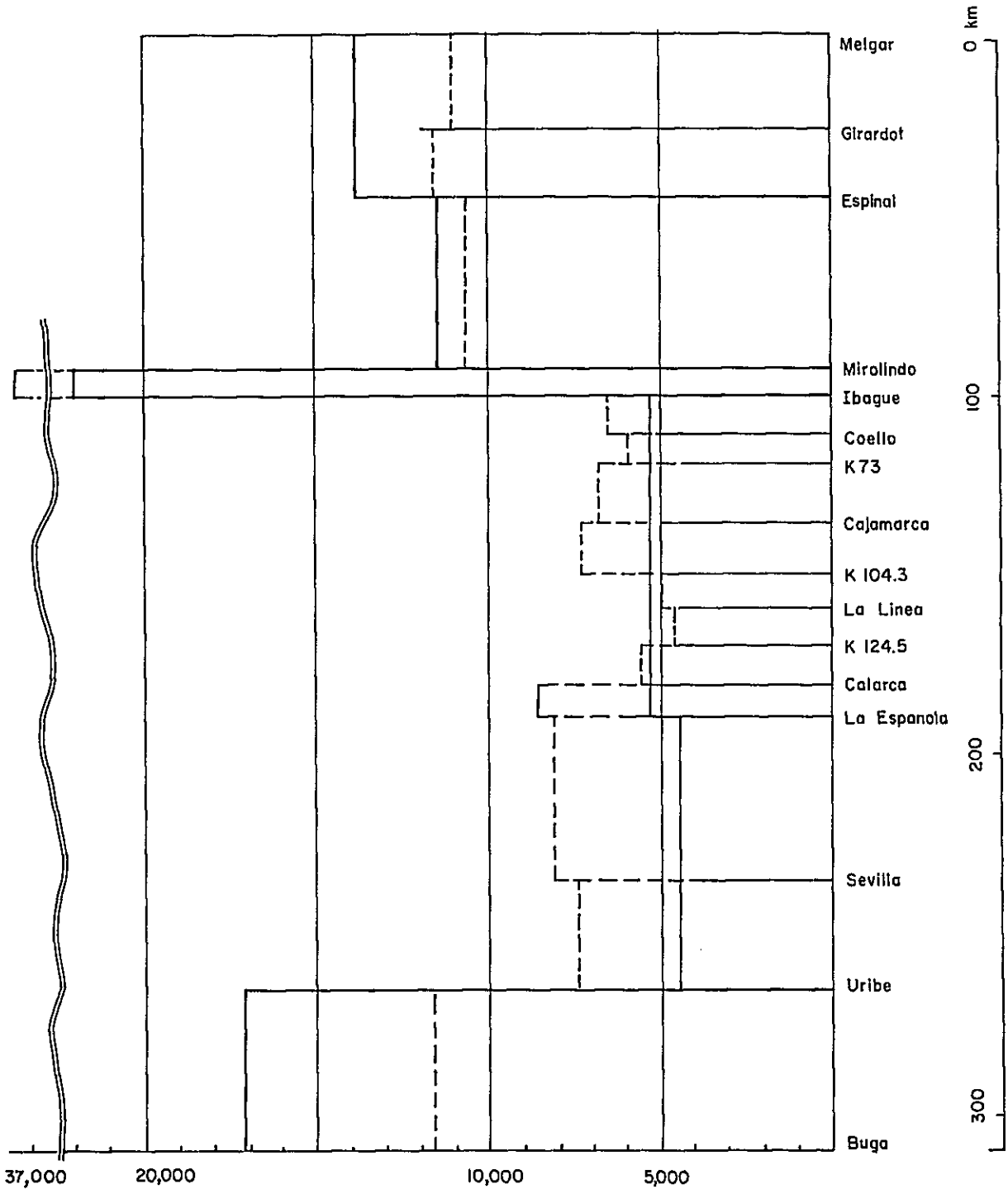
	Road Section	Existing Status	P-2 2)	P-3 2)
1.	Melgar - Girardot	11,000		
2.	Girardot - Espinal	11,600		
3.	Espinal - Mirolindo	10,700		
4.	Mirolindo - Ibague	37,000		
5.	Ibague - Coello	6,500	6,600	6,600
6.	Coello - K73	5,900	6,600	6,900
7.	K73 - Cajamarca	6,800	6,900	8,700
8.	Cajamanca - K104.3	7,300	7,400	7,300
9.	K104.3 - La Linea	5,000	5,100	
10.	La Linea - K124.5	4,600	4,700	
11.	K124.5 - Calarca	5.500	5,600	
12.	Calarca - La Espanola	8,700		
13.	La Espanola - Sevilla	8,100		
14.	Sevilla - Uribe	7,400		
15.	Uribe - Buga	11,600		

Note 2): Alternative Improvement Plans

P-2: Minimum Scale Improvement

P-3: Medium Scale Improvement

Fig. 5-9 Traffic Volume and Road Capacity



5-3-3 Estimation of the Frequency of Encounters at Sharp Curves

In order to figure out one of the economic benefits to be derived from the proposed improvement plans, the encounters at sharp curves, where two vehicles cannot pass by at the same time, were estimated.

The encounters were calculated in terms of the average frequency in a day of the occurrences of stopping at curves through the following procedures.
First of all, all sharp curves where such an encounter is likely to occur were identified. At the same time, the combination of vehicle types which makes the encounters is also clearly defined. Then the possibility of the occurrences is calculated for each type of vehicles by the following formula.

$$P_t = 2\ell \cdot N \cdot r_s / L$$

where P_t the possibility of the occurrence for vehicle type t

ℓ: curve length (m)

N: the total number of vehicles in a road section L

r_s: the composition ratio of vehicle type s to the total traffic volume

L: the length of the road section (m)

In the above formula, the combination of vehicle types, which makes the encounters at the curve, is represented by t and s. (More detailed explanation of the formula is shown in Annex 5-2.)

Finally, the total frequency of encounters can be calculated by the following equation.

$$N_t = \frac{1}{2} \cdot Q \cdot r_t \cdot P_t$$

where N_t: the frequency of encounters for vehicle type t

Q : ADT (veh/day)

r_t: the composition ratio of vehicle type t to the total traffic volume

If the stopping due to the encounter by the vehicle running ahead is also taken into account, the total frequency N_t' of the encounter will be given by:

$$N_t' = N_t + r_t \cdot f\left[t_o / \frac{l_a - a - d}{V}\right] \sum_{t=1}^{k} N_t$$

where t_o: waiting time at the curve (hour)

V: passing velocity at the curve (Km/h)

l_a: average headway (Km)

a: average length of a heavy vehicle (Km)

d: stopping distance of vehicle type t (Km)

k: total number of vehicle types which make an encounter at the curve

f(x): an integer function

if $x < 1$, then $f(x) = 0$

if $1 < x < 2$, then $f(x) = 1$, etc.

Consequently, there exist 102 curves, where such encounters occur, on the road between Ibague - Calarca in the existing status. Then the total frequent time of encounters between Ibague - Calarca is calculated as follows:

Table 5-8 Total Frequency in the Existing Status

Year	1983		1995	
Type of Vehicle	Truck & Bus	Tractomula	Truck & Bus	Tractomula
Total Frequency	713	827	2,508	3,476

The frequency of encounters at each curve is given in Annex Tabel 5-3.

Photo 5-1 Traffic Condition of Project Road

Photo 5-2 Traffic Accident at Sharp Curve