THE NAIROBI BYPASS CONSTRUCTION PROJECT FEASIBILITY STUDY VOLUME 1 FEBRUARY 1988

REPUBLIC OF KENYA

MINISTRY OF TRANSPORT AND COMMUNICATIONS

THE NAIROBI BYPASS CONSTRUCTION PROJECT

FEASIBILITY STUDY

FINAL REPORT

VOLUME 1

(SUMMARY)

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P R E F A C E

It is with great pleasure that I present this Feasibility Study Report on the Nairobi Bypass Construction Project to the Government of the Republic of Kenya.

This report embodies the result of the study which was carried out from November, 1986 to November, 1987 by a Japanese study team commissioned by the Japan International Cooperation Agency following the request of the Government of Kenya to the Government of Japan.

The study team, headed by Mr. Hirokazu Itoh, comprising experts from Japan Engineering Consultants Co., Ltd. and Nippon Koei Co., Ltd., had a series of close discussions on the project with the officials concerned of the Government of Kenya and conducted a wide scope of 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 be useful as a basic reference for the development of the Project.

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

February, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

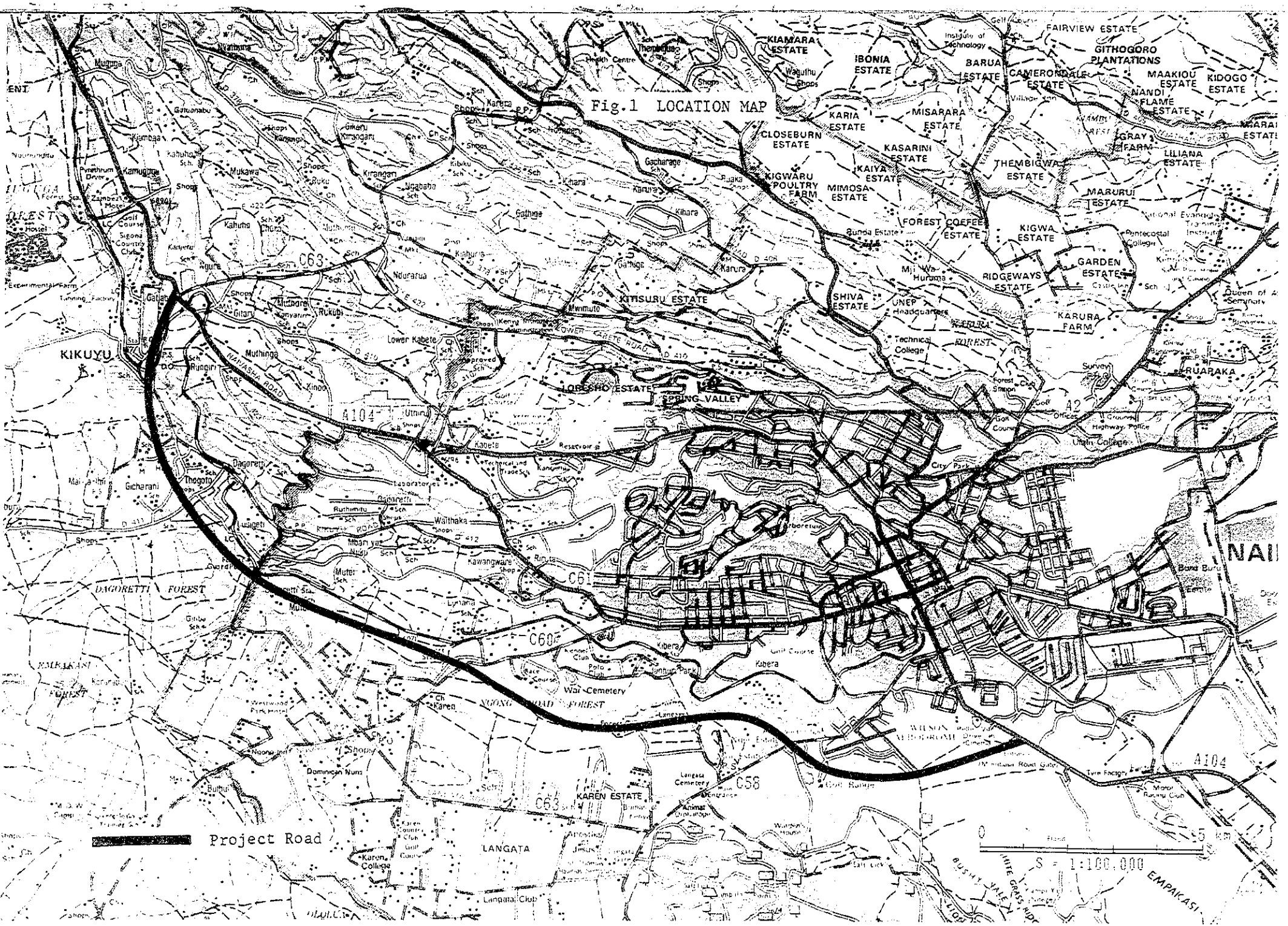


Fig.1 LOCATION MAP

Currency Equivalents

Currency Unit = Kenyan shillings

US$1.0 = Kshs 16.0 = ¥150.0 (August, 1987)

System of Weights and Measures: Metric

1 meter (m) = 3.28 feet (ft)

1 cubic meter (m^3) = 35.29 cubic feet (ft^3)

1 kilometer (km) = 0.62 mile

1 square kilometer (km^2) = 0.39 square miles

1 hectare (ha) = 2.47 acres

1 metric ton = 2,204 pounds (ℓbs)

Abbreviation

Kshs	:	Kenyan shillings
K£	:	Kenyan pound (1 K£ = 20 Kshs)
¥	:	Japanese Yen
MOTC	:	Ministry of Transport and Communications
JICA	:	Japan International Cooperation Agency
Km/h	:	Kilometers per hour
JIS	:	Japan Industrial Standards
AASHTO	:	American Association of State Highway and Transportation Officials
CBR	:	California Bearing Ratio
GDP	:	Gross Domestic Products
AADT	:	Average Annual Daily Traffic
PCU	:	Passenger Car Unit
VPD	:	Vehicle Per Day
O-D	:	Origin-Destination
VOC	:	Vehicle Operating Cost
NPV	:	Net Present Value
B/C Ratio	:	Benefit/Cost Ratio
IRR	:	Internal Rate of Return

CONCLUSION AND RECOMMENDATIONS

1. Conclusion

1.1 Optimum Route

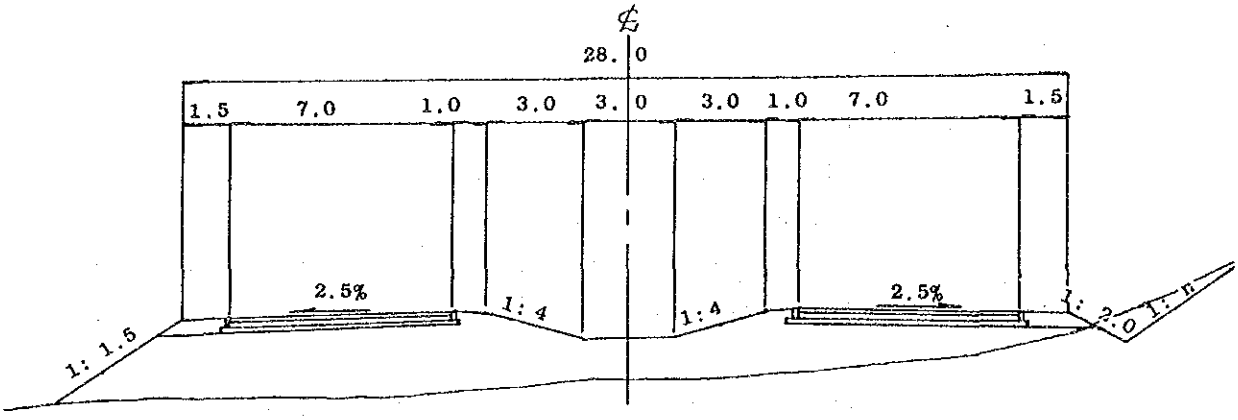
As shown in Figure 1, an optimum route has been determined by taking into consideration careful techno-economic studies after selecting two alternative routes from Mombasa Road (beginning point) to Dagoretti Road Junction and three alternative routes from Dagoretti Road Junction to Naivasha Road (ending point).

The project road starts to divert from an International Trunk Road A104 (Mombasa Road) at the Northeast edge of Nairobi National Park; passes over Langata Road (C58) at the east edge of Army Cantonment tracing the proposed right of way for the Trans-African Highway; goes along the right bank of Motoine River avoiding the housing estate; passes through the Ngong Road forest; passes over Ngong Road (C60) and Motoine River; and then, goes along the left bank of Motoine River in the Ngong Road forest; passes through private land and crosses over the Dagoretti Road (C63); goes up the east edge of the Dagoretti forest with a gradient of 5%; after that, passes through Thogoto village avoiding a built up area; then, goes around outside both Alliance Boys and Girls High School to the west; then crosses slightly the Ondiri Swamp and joins the C63; after that, passes under existing railway and finally connects an International Trunk Road A104 (Naivasha Road) at Kikuyu Junction, representing the dual carriage way of 29.2km in total length.

Table 1. Design Standards of Project Road

Design Speed	100 - 70 km/h
Road Reserve	60 m
Width of Carriageway	7 m
Minimum Curve Radius	600 m
Maximum Longitudinal Grade	5 %
Vertical Clearance	5.2 m

Fig. 2 Typical Cross Sections of Project Road



1.2 Construction Schedule and Costs

Construction schedule and construction cost are shown as follows:

(1) Construction Schedule

Table 2 Construction Schedule

Year	1st Year				2nd Year				3rd Year				4th Year				5th Year	
Month	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
Detailed Design	1			12														
Land Acquisition		7			15													
Tender and Contract						13			25									
Construction										26								55

(2) Construction Costs

The construction cost for the project is estimated on the basis of the preliminary design and construction plan and schedule as follows:

Table 3 Costs for Construction

(Unit: Million Kshs.)

	Foreign Currency	Local Currency	Total
1. Direct Construction Cost	204.39	134.47	338.86
2. Engineering Services	20.44	13.44	33.88
3. Land Acquisition and Compensation	0	22.81	22.81
4. Physical Contingency	20.44	13.44	33.88
Sub-Total (1 to 4)	245.27	184.16	429.43
5. Price Escalation	18.44	68.56	87.00
Total	263.71	252.72	516.43

(3) Annual Disbursement Schedule

The annual disbursement is estimated according to the construction schedule and summarised as follows:

Table 4 Disbursement Schedule of the Construction Cost

(Unit: Million Kshs.)

Year	Foreign Currency	Local Currency	Total
1st	6.6	4.52	11.12
2nd	2.95	28.51	31.46
3rd	18.54	35.51	54.05
4th	147.73	118.27	266.00
5th	87.89	65.91	153.80
Total	263.71	252.72	516.43

(4) Maintenance Cost

Apart from the above-mentioned construction costs, the maintenance cost is estimated for annual routin maintenance cost: Kshs. 414,500/ year.

1.3 Economic Evaluation

The economic evaluation of the optimum plan is summarized as follows:

Discount Rate (%)	Kshs Million Cost	Benefit	B/C Ratio	Internal Rate of Return (%)
12%	279.4	424.8	1.52	18.26

Results of sensitivity analysis are as follows:

Sensitivity Case		I.R.R.
(1)		
Cost	: 20% up	15.58%
Benefit:	-	
(2)		
Cost	: -	
Benefit:	20% down	14.86%
(3)		
Cost	: 20% up	
Benefit:	20% down	12.22%

2. Recommendations

(1) As the project is justifiable technically, economically and socially, it is strongly recommended to take necessary actions so as to implement the project as scheduled.

(2) The alignment and the design of the proposed road involves many problems requiring a high level of engineering to solve them. On the other hand, it does not seem that special techniques or special types of equipment would be required for the construction therefore construction execution by joint venture of a local and a foreign contractor is reasonable.

(3) The detailed design work for the project would involve highly complex engineering problems, especially for junctions with a different class roads, so it is desirable to employ qualified and experienced consulting engineers for the detailed design work.

(4) The massive amount of fund is required for the development of the project, it will be one of the possible measures to arrange with an external source for financing the project.

(5) The construction cost of 266 million K.Shs is to be invested for the 4th year construction cost of this project, which would be specially appropriated in the Government budget as the amount will occupy a high percentage of it.

(6) About 10m difference in altitude between maps made by the survey of Kenya and the maps prepared by the survey section of MOTC for this study is found, which should be corrected in due course by the governments authorities concerned. Incidentally preliminary design in this feasibility study was carried out using the maps prepared by the MOTC. At the detailed design stage of the bypass project, special attentions should be paid to this problem.

C O N T E N T S

I. Introduction

I. Introduction

This project is designed to alleviate the current traffic congestion in the City on A104 road which is part of the Trans-African Highway extending into Uganda and Zaire. It is also intended to provide a solution to the future growth in traffic demand.

The Government of Kenya has requested the Government of Japan to undertake a feasibility study for the Nairobi Bypass Construction Project.

Japan International Cooperation Agency (hereafter JICA) an executing agency of the Japanese Government, organized a feasibility study team, which has performed the field investigation and studies since November 1986 and completed the draft final report in mid-November 1987 and the final report in mid-February 1988.

This report sets forth the preliminary design, cost estimation, economic analysis and others for the Final Report.

The full report is presented in the following four volumes.

Volume 1 : Summary

Volume 2 : Main

Volume 3 : Appendix

Volume 4 : Drawing

II. Background

II. Background

II.1 Outline of Kenya

Kenya covers an area of about 583,000 km^2 and is bordered by the Indian Ocean and Somalia to the East, Ethiopia and Sudan to the North, Uganda to the West and Tanzania to the South.

The Nyika Plateau running from the Central South to the whole of Northern Kenya is between 1,000m and 1,500m above sea level, and the central highlands are more than 1,700m above sea-level. The coastal areas are less than 200m above sea-level.

The lake region and the vicinity of Mt. Kenya receive over 1,200mm of rainfall annually while the coastal region receives between 800mm and 1,000mm of rainfall. Northern and northeastern Kenya receives less than 500mm.

The vegetation consists of semi-arid dry land with scattered shrubs in northern and northeastern Kenya, tropical forest in most of central Kenya and savanna towards the southern part.

An agriculture-oriented economy growing maize, beans, sugarcane, coffee and tea as well as live stock products, provides enough food supply for Kenya and a high quality cash crop exportable to the international market.

The country has a population of about 21 million people (1986 estimate), and it is estimated that Kenya will have a population of about 35 million at the end of this century, a 67% increase over 1986.

II.2 Transportation of Kenya

Kenya serves as a transportation link between the port of Mombasa and Uganda, Rwanda and the eastern part of Zaire through both railway and road.

The transport network in Kenya is characterized as the main trunk of the east/west corridor starting from Mombasa via Nairobi, crossing the Lake Victoria region thereafter to reach Uganda.

Total length of road in Kenya is 54,584 km of which trunk roads comprise 6,391 km, primary roads 8,782 km and remaining roads including secondary, minor and special purpose, 39,411 km.

Paved ratio is 12.3% in total. Total length of railway in Kenya is 2,651 km of minor and branch lines and private lines and cidings.

The port of Mombasa is Kenya's principal gateway to the sea as it faces the Indian Ocean. Kilifi, Malindi and Lamu ports hold minor positions. There are also Kisumu, Homa-Bay and Kendu-Bay along Lake Victoria.

Kenya has two International Airports, Jomo Kenyatta International Airport in Nairobi and Moi International Airport in Mombasa. There are also medium-sized airports as Kisumu, Malindi, and Wilson Airport, Nairobi.

Nairobi has approximately 1.2 million people with an annual growth rate of over 5%, the traffic volume in the central business district of Nairobi increases year after year, as it is the center of social and economic activities of the country.

III. Project Area

III. Project Area

III.1 Natural Conditions

The climate at the project area is tropical. Since Nairobi is located close to the equator and is at a high altitude, it is characterized by two distinct seasons, the rainy season from March to May and November to December and the dry season in the other months. The temperature in the area is warm and cool throughout the year. The annual average temperature is 20°C, and ranges between 26°C - 15°C.

The proposed Bypass area lies at an altitude between 1,660 m and 2,000m above sealevel, on a grass field sloping gently from west terrace to east plain.

Nairobi and its environs are located on the east side highland of the Rift Valley. Nairobi's Western and Northern parts are hilly and about 2000m above sea level. Southern and eastern parts of Nairobi are spread on the plains called Athi and Kapili which are about 1800m above sea-level. From west to east, the topography inclines gently. Rocky mountains lie in the Machakos District about 50-60 km east of Nairobi. Highland regions in the west and north of Nairobi are mainly used as farm land. The surface of the Athi plain is covered with black cotton soil which is very cohesive.

The route of the Bypass diverges to the west from A104 in the vicinity of the northeast edge of the Nairobi National Park and extends to the west of the border of the Wilson Airport and the National Park. After crossing C58, it passes through the Ngong Road Forest, and then crosses C60. Thereafter it runs approximately parallel to the Kenya Railway at southern side. Further on, it crosses C63, and passes through the northern part of the Dagoretti Forest, accessing to C63 once again. Finally it joins A104 (Naivasha Road at the northern part of the Kikuyu Village), representing the dual carriage way of 29.2 km in total length.

III.2 Socio-Economy Profile

(1) Economic Activity

Kenya's economy recovered strongly from the ravages of the 1984 drought, thanks to the decreased price of world oil and the booming price of world coffee together with favourable weather conditions.

The GDP grew by 4.1% in 1985, compared with a mere 0.9% growth achieved in 1984.

In order to challenge the development and the provision of basic needs, the Government of Kenya has established a target average GDP growth rate of 5.6% a year from 1984 to 2000.

Agriculture and manufacturing are the dominant sectors in Kenya's economy, providing 32% and 14% of the GDP, respectively. The manufacturing growth rate is about the same as that of the GDP while the growth rate of agriculture is below the average.

(2) Government Finance

Deficit as a percentage of current revenue declined from 45.8%, 1984/85 to 34.0%, 1985/86. External loans and grants dropped to 50.0%, 1985/86 of investment and development expenditures, compared to 84.5%, 1982/83.

It would be difficult to improve Kenya's economy considering the state of development, though it is acceptable that deficit of government budget to GDP and to revenue are to be 5% and 20%, respectively. Debt service ratio (revenue to debt servicing charge) became about 30% as of 1986.

(3) International Economy

The balance of payments in 1985 deteriorated due to the weakening of the balance of trade with current account deficit of K£ 69 million in 1985.

In order to close the deficit gap, the Government has been promoting long term capital inflow as well as borrowing from international institutions and acquiring short term loans.

Balance of Trade, 1981-1985

K£ million

Item	1981	1982	1983	1984	1985 [1]
Export	537.23	568.64	652.18	776.91	802.34
Import	932.41	900.30	905.62	1,097.21	1,201.13
Balance of Trade	△395.18	△331.66	△253.44	△320.30	△398.78

Source : Economic Survey, 1986

Coffee, tea and petroleum products are the principal export commodities, having shares of 29.7%, 24.7% and 14.0%, respectively with 44.07 Ksh/kg of coffee and 30.36 Ksh./kg of tea in 1985.

It is projected that overall export will increase by 5.1% up to the year 2,000 with a 7.2% increase in coffee and a 4.6% increase in tea. Petroleum products export is up to the economy of Uganda, Rwanda and Burungi. Development of transportation (through traffic) and tourism are also expected to expand.

III.3 Road Network and Traffic

(1) General

The transport network in Kenya is characterized as the main trunk of the east/west corridor starting from Mombasa, gateway to the sea, via Nairobi, the nation's capital, crossing the Lake Victoria region thereafter to reach Uganda.

At 1985, gross output from transport sector is K£ 514 million (1985), up 19% from 1984 and about 5% of GDP. It is continuing its upward swing due to the general recovery of the economy.

Model inventories with rough review are as follows:

a) Total length of roads in Kenya is 54,584 km of which trunk roads comprise 6,391 km, primary roads 8,782 km and remaining roads including secondary, minor and special purpose roads 39,411 km. Pavement ratio is 12.3% in total.

b) Total length of railways in Kenya is 2,651 km. Main and principal lines comprise 1,450 km in addition to 1,201 km of minor and branch lines and private lines and cidings. The rail and rolling stock of railways are decrepit. Although diesel engines have been introduced recently, the average speed of operation remains slow.

c) The port of Mombasa is Kenya's principal gateway to the sea, facing the Indian Ocean. Kilifi, Malindi and Lamu ports have minor positions. There are also Kisumu, Homa Bay and Kendu Bay along Lake Victoria. Port facilities have deteriorated, thereby delaying containerization.

d) Pipeline with total length of 449 km was laid between Mombasa and Nairobi in 1987. The system is of the latest model and transports five different types of light petroleum products.

e) Kenya has two international airports, Jomo Kenyatta International Airport in Nairobi and Moi International Airport in Mombasa. There are also medium-sized airports as Kusumu, Malindi and Wilson Airport, Nairobi. Kenya has as many as 460 Aerodromes, including those which are privately owned. Overall passenger kilometers and freight carried by Kenya Airways reached 1,152 million km and 136.3 million kg·km, respectively in 1985 with more than 60% utility ratio.

f) Inland water transport is, at present, operated in Lake Victoria by Kenya Railways Corporation.

According to the study by the Japan International Cooperation Agency, modal split ratios of railway and road, based on passenger km were 12.1% and 87.9%, respectively, in 1982. As for freight, modal split ratios of railway and road based on ton ·km were 45% and 55%, respectively, in 1982.

However, both passenger · km and ton · km of freight for railway are on the downward trends as they have decreased 6.9% and 4.8%, respectively, between 1981 and 1985.

(2) Road Transport

At present, 95% of the passenger flow and more than half of the commodity flow are to be transported by road, based on the study by the Japan International Cooperation Agency, 1984, considered together with the facts of the decreasing trend in the railway's share year by year. Despite the relatively high unit cost, the private sector has played a leading role in the development of the Mode.

Owing to the intensive efforts for road improvement by the Government, 54,584.2 km of road at present (1986), is classified as bitumen and gravel/earth standard. As for paved ratio of 12.3% of total length has been realized.

Registered vehicle population in the Country was estimated to be 266,613 in 1984 with a 2.6% growth rate between 1980 and 1984.

It is a difficult matter to assess the exact growth rate of road transport, even though 4.7% is forecast as the growth rate of road transport between 1981 and 1985.

A 4.7% growth rate is considered reasonable as GDP growth rate is 3.2% during the same period, considering the stage of development of Kenya's economy and the decreasing trend of railway's share.

As for the reference, several other macroscopic data which have high correlation with traffic, are listed as follows:

a) Real GDP growth rate, between 1979 and 1986 was 3.2%
b) Nominal GDP growth rate, between 1979 and 1986 was 13.3%
c) Fuel sales of motor spirits and diesel fuel growth rate between 1977 and 1984 was 2.0%
d) Registered vehicle population growth rate between 1980 and 1984 was 2.6%
e) 60 points census traffic growth rate of 1983 to 1982 by MOTC are as follows:

i) by types of vehicle

Type	Passenger Vehicle	Light Good	Medium Good	Heavy Good	Bus	Total
Growth Rate %	17	6	22	22	1	6

ii) by province

Province	Coast	Eastern	North Eastern	Central	Rift Valley	Western	Nyanza
Growth Rate %	4	7	4	8	2	8	11

iii) by class of road

Class of road	Trunk (Class A,B)	Primary C	Secondary D	Minor E	Total
Growth Rate %	4	8	6	9	5

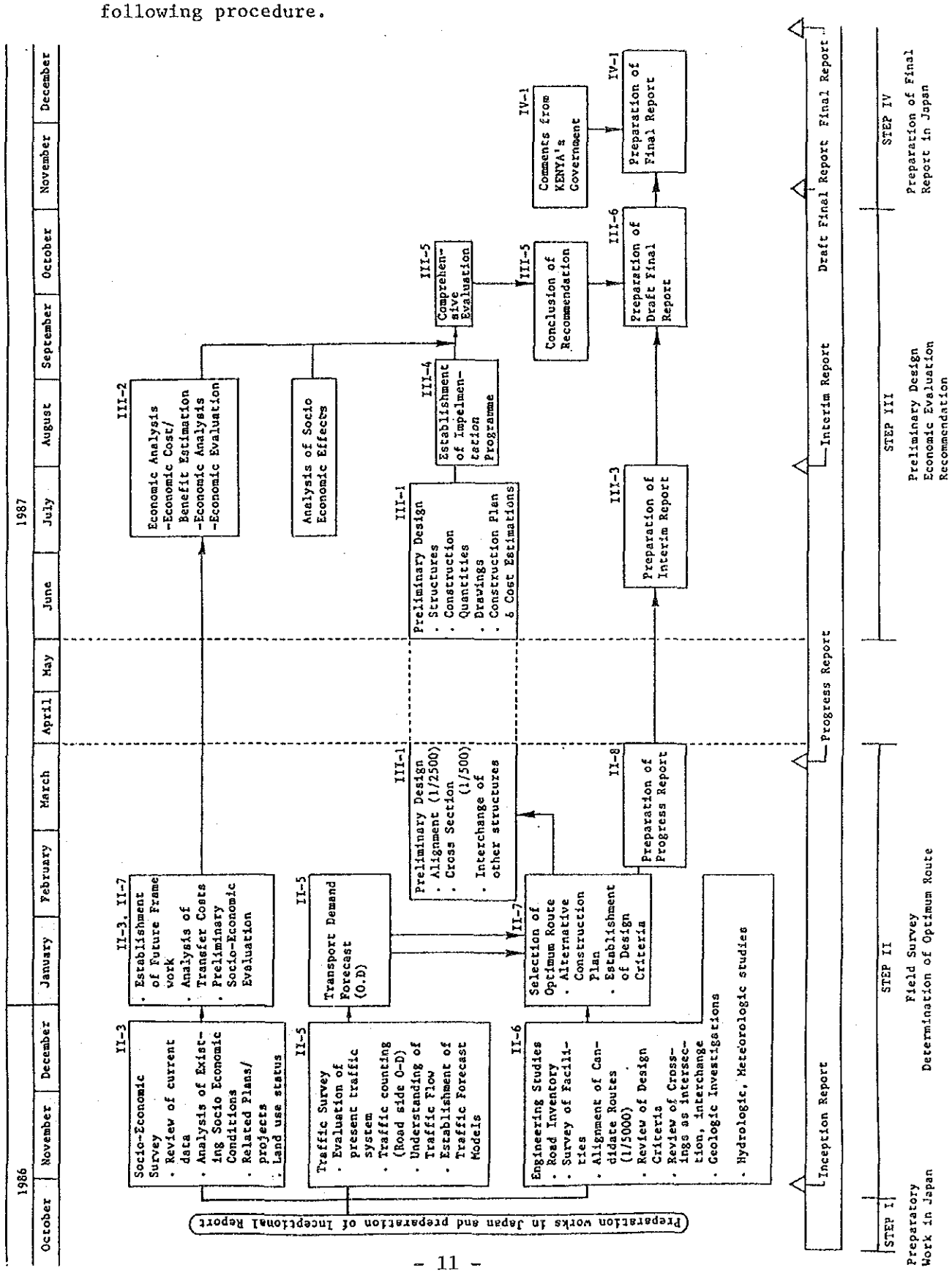
IV. The Project

IV. The Project

IV.1 Methodology.

Feasibility Study has been conducted in accordance with the following procedure.

Fig. IV-1 Work Flow



IV.2 Alternative Routes

IV.2.1 Basic Ideas on Selection of Alternative Routes

In selecting alternative routes the following factors as well as other general matters of technology have been carefully taken into consideration:

(1) Harmony with such regional development schemes as the Structural Plan by the Nairobi City Commission.

(2) Connection with Langatta Road (C58), Ngong Road (C60) and Dagoretti Roads (C63).

(3) Harmony with the future expansion plan of the road in the project road section.

(4) Possibility of widening and improving the alignment of the existing C58 and C63.

(5) Non-destruction of the natural environment as much as possible.

(6) To consider that the project road is a part of the Trans-African Highway.

IV.2.2 Comparison of Alternative Routes

Two alternative routes from the beginning point at Mombasa Road to Dagoretti Forest and three alternatives from Dagoretti Forest to the end point at Naivasha Road were selected as shown in Fig. IV-2 Proposed Alternative Routes.

The route comparison was made by a simplified method considering five major factors: route length, engineering aspect, difficulty of implementation, social environment impact, costs including land acquisition, compensation and construction.

In order to select the optimum route a rating method was employed for evaluation of the alternative route from section 1 to section 3.

For alternative routes in Section 4, a tentative design was carried out and the alternatives were compared from the point of view of engineering, construction quantities and construction cost. Results of the route comparison are shown in Table IV-1, Comparison of Alternative Routes.

IV.2.3 Selection of Optimum Route

The selection of optimum route has been carried out on the rational consideration, so as for the first step, establishment of Route Alternatives was mentioned in Chapter VII in the Volume 2 (Main) to evaluate the route from geology, route alignment, road network with other trunk and feeder roads and many a ristricting control points of view.

In the Table VII-4-1 Chapter VII in Volume 2 (Main) a comparison of Tentative construction cost, Construction cost/length, Transport efficiency showing the construction cost required for the future one vehicle running one km was given by alternative plans.

As seen on the Table VII-4-1, A-1 (so called shortest Route) was the most applicable route for the bypass.

Besides A104 (Naivasha Road) in the vicinity of Kikuyu Junction, where junction with the bypass, will be improved by MOTC to a dual carriageway road in near future, that would be the more encouragement to this route.

Fig. IV-2

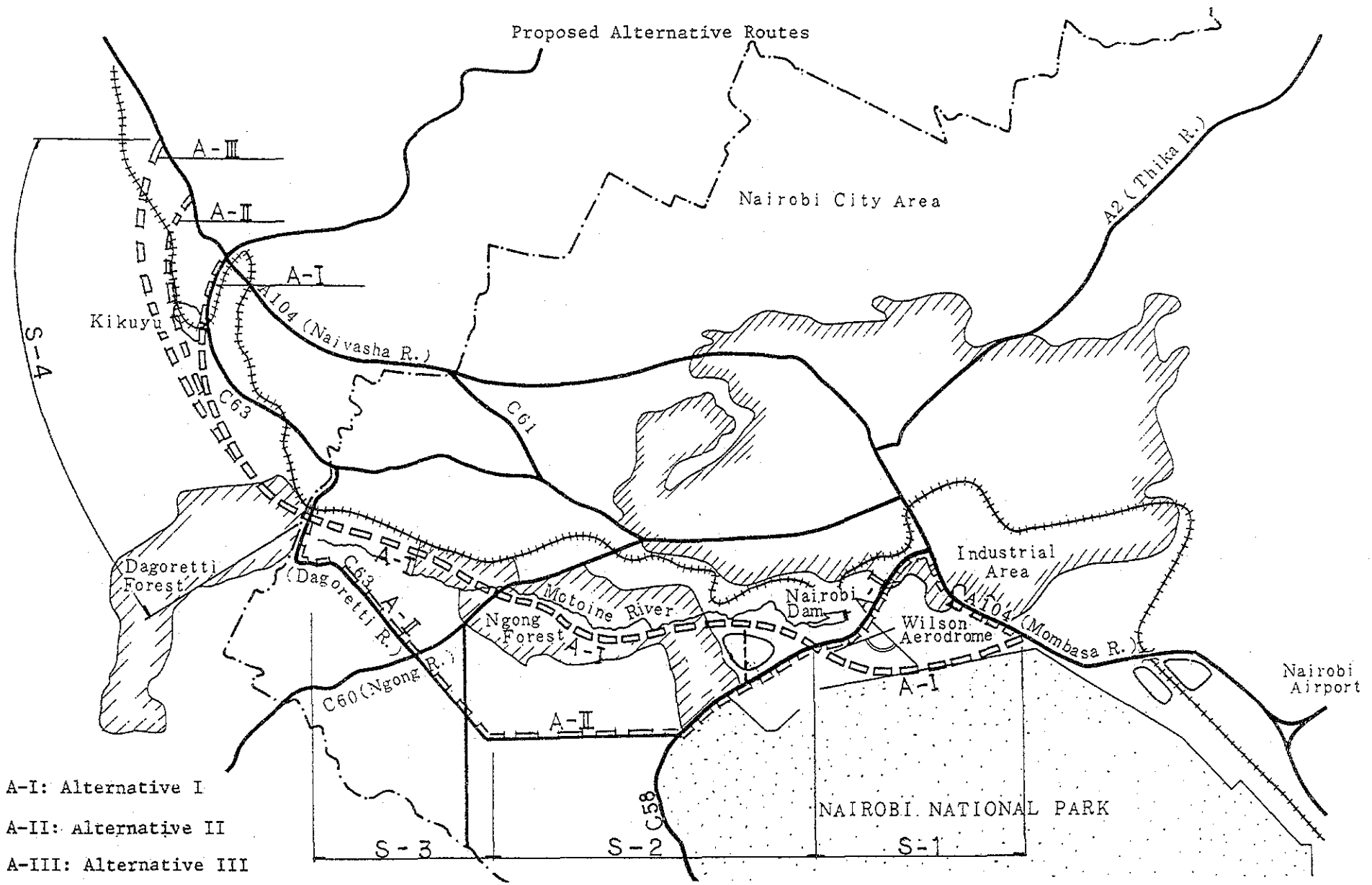

Proposed Alternative Routes
Nairobi City Area
A-III
A-II
A-I
S-4
Kikuyu
A104 (Naivasha R.)
C63
C61
A2 (Thika R.)
Dagoretti Forest
(Dagoretti R.)
C63
A-I
A-II
Mctoine River
Ngong Forest
Nairobi Dam
Industrial Area
A104 (Mombasa R.)
Wilson Aerodrome
Nairobi Airport
C60 (Ngong R.)
A-II
C58
NAIROBI NATIONAL PARK
S-3
S-2
S-1
A-I: Alternative I
A-II: Alternative II
A-III: Alternative III

Table IV-1

Comparison of Alternative Routes

Description	WT	Section 1		Section 2		Section 3		Section 4		
		A-I	A-II	A-I	A-II	A-I	A-II	A-I	A-II	A-III
Length	(15)	15	12	15	13	15	13	15	12	12
Road Network	(5)	4	4	4	3	4	3	3	3	3
Engineering Aspect	(20	14	10	13	12	12	15	12	11	13
Difficulty of Implementation	(15)	10	6	12	7	10	7	10	9	10
Social Environment Impact	(10)	7	4	9	6	9	4	6	6	7
Cost	(35)	28	20	21	18	21	21	24	21	21
	(100)	78	56	74	59	71	65	70	62	66

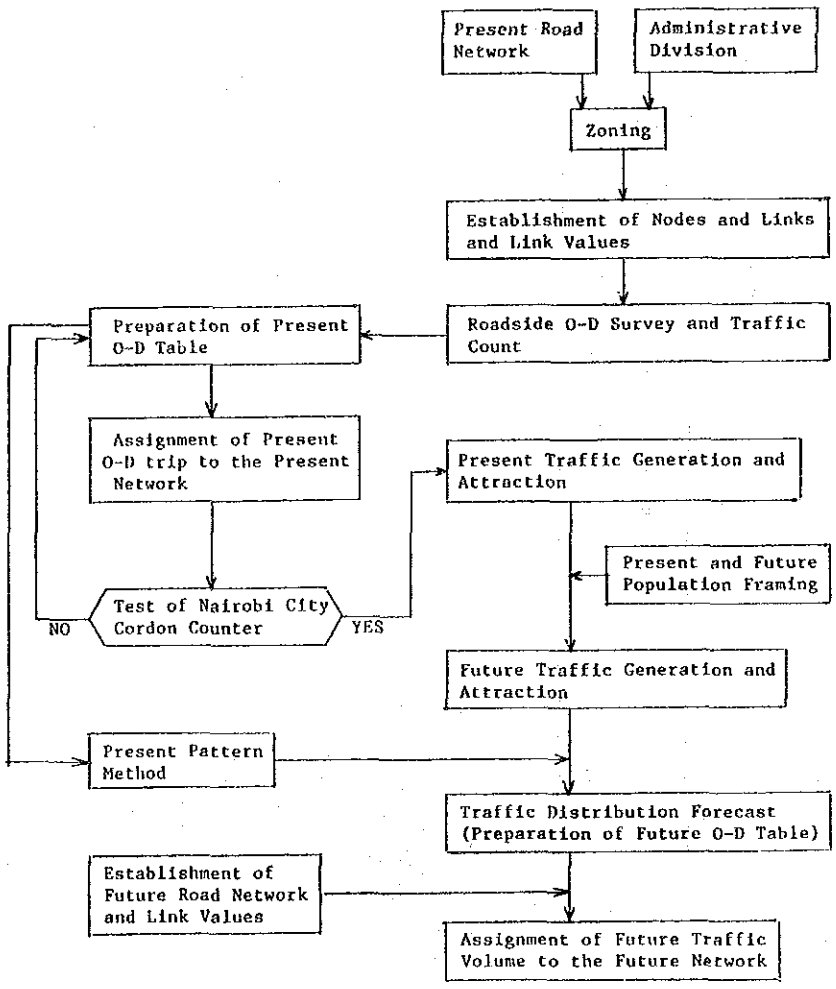
IV.3 Traffic Analysis

IV.3.1 Methodology

Traffic analysis were carried out using the following procedure; (1) the current level and characteristics of traffic were obtained from the traffic surveys, (2) Future traffic demand was forecasted using the results of (1) above and of forecasts of major economic indices and regional development schemes, etc., (3) Future traffic volume was assigned to the road network including the project road and (4) the anticipated traffic problems were solved. The overall framework of the above-mentioned procedure is shown in Fig. IV-3.

Fig. IV-3

Flow Chart of Traffic Demand Forecast



IV.3.2 Traffic Surveys Conducted

A number of traffic surveys in the project area were conducted with the cooperation of the MOTC traffic survey unit and Police Department as follows:

Survey	Objective
a) O-D Survey at road-side station	Preparation of O-D table and traffic analysis
b) Traffic Count Survey	Supplementary to complete O-D Table and Intersection Analysis
c) Vehicle Running Speed Survey	Evaluation of Traffic Network Traffic Analysis and Benefit Calculation

Site investigation and confirmation was done with the help of Police officers and MOTC traffic surveyors.

The results of the surveys conducted at representative points in the project area are shown in Table IV-2 Present Traffic Congestion Rate.

IV.3.3 Evaluation of present traffic system

(1) Links where the congestion rate exceeds 1.0

These links are seen on the three routes of A104, Ngong Road of C61 and Lusaka Road as shown in Table IV-2. Of these, the links on A104 are the 1) Uhuru Highway in the metropolitan center, 2) the single carriage way near Aga Khan High School and 3) the single carriage way with many slopes west of Kikuyu. On link 2) above, the problem will be solved as the project for widening the link into four lanes is likely to be implemented right away. On links 1 and 3, the traffic congestion rate is anticipated to turn for the better by the construction of Nairobi Bypass. Particularly on link 3, the effect of the sharp reduction in the traffic capacity is prominent as the ratio of the medium and heavy goods vehicles mixed in the traffic being high at 30% and the link being sloped.

On Ngong Road, the project of widening it into a four-lane road is about to begin any time, and when it is widened and improved, the problem of congestion would be eliminated.

Lusaka Road indicates a high congestion rate since it serves as an access road to the industrial area. In order to eliminate the congestion in this link, the problem shall be solved by connecting the starting point (near Wilson Aerodrome) of the bypass road and the center of the industrial zone with another access road.

(2) Link where the congestion rate is close to 1.0

The links where the congestion rate exceeds 0.7 and is close to 1.0 are observed in some parts of A104, A2, C61, Langata Road (C58), and Outer Ring Road (C54).

Of these, such links on A104 are seen 1) near Museum Hill and 2) Between Kabete and Kikuyu. While the situation is likely to improve by the construction of the bypass, link 2) does not pose any problem as the widening of this link into four lanes is in the stage of execution. Likewise, the link between Dagoretti Corner to Kabete on C61 exceeds 0.7 in congestion rate, but the congestion rate is not anticipated to rise any further due to the improvement of A104 and the construction of the bypass.

The link between Nyayo Stadium and Animal Orphanage on Langata Road also indicates a high congestion rate, but the problem would be eliminated in the future as the widening of this link into four lanes being considered.

On the link of the A-2 Road in the metropolitan center and some parts of the Outer Ring Road (C59), it was pointed that the problem of congestion will not be generated immediately. There is a future necessity to build a new eastern bypass that detours the eastern side of the center of Nairobi.

IV.3.4 Study of future network

(1) Target year

Out of the roads in Nairobi or in its environment which are to be constructed, widened or improved by the year 1991, estimated as the target year of the construction of Nairobi Bypass, following are selected.

(2) Roads to be widened and improved

- A104 (Upper Parkland Estate - Orthopaedic Hospital)
- A104 (Kabete - Limuru)
- Ngong Road (Intersection of Uhuru Highway and Haile Selassie Avenue - Dagoretti Corner)
- Langata Road (Uhuru Highway - Animal Orphanage)

(3) New Road

- Link Road between Ngong Road and Langata Road

Table IV-2 (1)

Present Traffic Congestion Rate.

Station No.	1	2	3		4	5	6		7
Date	14-23/11/86	24/11/86	21/11/86		25/11/86	17/11/86	19/11/86		14/11/86
Road Name	A104 at Aga Khan H.S	C62 at Ruaraka Trading Centre.	A2 at Safari Park Hotel		C59	Lusaka Road	A104 at Drive-in Cinema		C58
Direction	Both	Both	NRB -Thika	Thika - NRB	Both	Both	Nairobi	Mombasa	Both
A.A.D.T.									
1. Car, Taxi	9,254	1,473	3,114	2,963	3,199	12,174	4,939	5,991	7,014
2. Light G.V.	3,308	898	1,722	1,998	1,614	7,011	2,063	1,852	2,555
3. Medium G.V.	522	267	589	661	1,367	866	562	488	544
4. Heavy G.V	487	108	169	146	325	692	292	176	60
5. Bus	859	150	355	365	146	116	88	81	386
6. Matatu	1,393	368	744	912	689	469	332	499	729
7. Motorcycle	132	40	54	64	41	415	60	42	58
Total	15,955	3,304	6,747	7,109	7,381	21,743	8,336	9,129	11,346
PCU Rate									
1. Medium G.V. Heavy G.V./Bus	3.1	2.0	3.5	3.5	2.0	2.0	2.0	2.0	2.0
2. Matatu	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3. Motorcycle	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AADT Total Traffic (PUB)	20,508	3,993	9,875	10,463	9,543	23,444	9,414	10,102	12,671
Traffic Capacity									
12Hrs 1/	10,000	9,300	14,600	14,600	7,200	11,100	13,800	13,800	11,100
24Hr/12Hr Rate	1.27	1.22	1.17	1.17	1.33	1.15	1.23	1.19	1.27
24Hrs	12,700	11,300	17,100	17,100	9,700	12.800	17,000	16,400	14,100
Congestion Rate	1.61	0.35	0.58	0.61	0.98	1.83	0.55	0.62	0.90

1/ Source : MOTC "Traffic Census Estimated Daily Traffic and Historical Traffic Flow Data 1985"

Table IV-2 (2)

Present Traffic Congestion Rate.

Station No.	8	9	10	11	12	13	14	15	16
Date	18/11/86	26/11/86	1/12/86	28/11/86	29/11/86	24/11/86	28/11/86	25/11/86	1/12/86
Road Name	C61	A104 At The Rest-Club	C58	C60	A104 Naivash/Rd.	C64	C63	C98	C63
Direction	Both	Both	Both	Both	Both	Both	Both	Both	Both
A.A.D.T.									
1. Car Taxi	5,940	1,885	1,641	2,088	1,173	2,667	753	2,360	2,653
2. Light G.V.	2,314	968	698	1,225	1,005	1,371	368	1,249	1,047
3. Medium G.V.	354	880	219	310	423	195	98	1,193	171
4. Heavy G.V.	63	602	26	11	433	24	11	114	116
5. Bus	706	239	84	133	322	201	37	125	59
6. Matatu	747	274	236	312	292	438	30	448	54
7. Motorcycle	96	27	19	37	27	18	9	38	37
Total	10,220	4,875	2,923	4,116	3,675	4,914	1,306	5,527	4,139
PCU Rate.									
1. Medium G.V. Heavy G.V./Bus	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2. Matatu	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
3. Motorcycle	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
AADT Total Traffic (PCU)	11,668	6,720	3,361	4,708	4,986	5,544	1,463	7,164	4,494
Traffic Capacity 12Hrs	7,700	8,200	6,500	9,000	6,400	8,000	10,100	11,400	7,400
24Hr /12Hr Rate 1/	1.23	1.23	1.21	1.26	1.27	1.22	1.24	1.17	1.27
24Hrs	9,500	9,900	7,900	11,300	8,100	9,800	12,500	13,300	9,400
Congestion Rate	1.23	0.68	0.43	0.42	0.62	0.57	0.12	0.54	0.48

IV.3.5 Future Traffic Forecast

(1) Establishment of Alternative Network for Future Traffic Forecast

Three alternative routes are prepared for the bypass, all of which start from the neighbourhood of Wilson Aerodrome and take the same route as far as the eastern end of the Dagoretti Forest, but from there until the bypass merge with the existing A104, each takes the shortest, the longest and the intermediate route respectively. The objects of traffic assignment here is the shortest route and the longest route only. Functionally, the intermediate route is almost the same as the longest route. Furthermore, both four-lane and two-lane traffic shall be considered for each proposed plan, as a result of which the following cases have been set up.

Alternative A-0	Without Byapss	Target year 2000
A-3-4	Longest Byapss (4-Lane)	"
A-3-2	Longest Bypass (2-Lane)	"
A-1-4	Shortest Bypass (4-Lane)	"
A-1-2	Shortest Bypass (2-Lane)	"

Alternative A-0 consists of the present trunk roads mainly, the roads under construction and the anticipated planning roads in and around the Nairobi. Another Alternative networks are consisting of Alternative A-0 and the Bypass.

(2) Results of Future Traffic Forecast

With increasing of future trip generation/attraction, the number of bottleneck links, over 1,00 congestion rate, for the alternative A-0 will be 15 links on the representative roads (A104, C58/63, C60/61) and 30 on all the network.

The decrease of traffic congestion attributable to the bypass is shown in Table IV-3 as bottleneck link numbers.
This suggests that alternative plan A-1-4 is most effective. It would be most advisable, therefore, to establish a 4-lane bypass on the shortest route by 2,000 year from the results of Future Traffic Forecast.

Table IV-3

Number of Bottleneck Links by Alternative Plan

Alternative	Future AADT in pcu On the Bypass	No. of Bottleneck Links Over 1.00 Congestion Rate					
		Representative Roads					All Network
		Bypass	A104	C58/63	C60/61	Subtotal	
A-0	-	-	5	4	6	15(100%)	30(100%)
A-1-4	18-26 x 10^3	-	3	1	4	8(53%)	24(80%)
A-3-4	11-24 x 10^3	-	4	1	4	9(60%)	25(83%)
A-1-2	11-12 x 10^3	3	5	3	4	15(100%)	31(103%)
A-3-2	8-11 x 10^3	1	5	3	5	14(93%)	30(100%)

Additionally, when the Bypass is completed as a dual carriage, the following measures will be required for the future road network to improve the traffic congestion in the city of Nairobi.

a) Construction of the Nairobi Eastern Bypass
b) Improvement of radial road in the Eastern area of Nairobi, such as The Jogoo Road Widening and the Koma Rock Road Widening
c) Intensification of the public transport
d) Improvement of the Roundabout on the Uhuru Highway to increase traffic capacity
e) Improvement of the parking facilities in the city centre of Nairobi.

The stage construction of the Bypass should be referred to the growth rate of the diverted traffic and the capacity of the single carriageway.

The Table IV-4 shown the growth of traffic by link. According to the Road Design Manual of Kenya, where the traffic volume over AADT 8,000 in PCU, dual carriageway should be considered and the year to be exchanged for dual carriageway would be in 1992 at latest.

Table IV-4

FUTURE TRAFFIC GROWTH OF THE BYPASS BY LINK

		B.P. link-1 (131-132)			BP link-2(132-133)		BP link-3(133-134)		B.P. link-4 (134-22)						
		Both direction			Both direction		Both direction		frem 22 to 134		from 134 to 22			Both direction	
		AADT	pcu rate	AADT in pcu	AADT	AADT in pcu	AADT	AADT in pcu	AADT	AADT in pcu	AADT	pcu rate	AADT in pcu	AADT	AADT in pcu
2 lane shortest Bypass in 1986	Car,taxi	898	1.0	898	1,208	1,208	3,468	3,468				1.0		3,812	3,812
	Light goods V.	414	1.0	414	934	934	1,675	1,675				1.0		1,846	1,846
	Medium goods V.	588	2.0	1,176	575	1,150	224	448				3.8		295	1,112
	Heavy goods V.	491	2.0	982	465	930	374	748				3.8		412	1,583
	Bus	313	2.0	626	172	344	104	208				3.8		112	429
	Matatu	-	1.5	-	-	-	-	-				1.5		-	-
	Total	2,704		4,096	3,354	4,566	5,845	6,547						6,477	8,782
		100.0		100.0	100.0	100.0	100.0	100.0						100.0	100.0
2 lane shortest Bypass in 2000	Car,taxi	5,790	1.0	5,790	4,517	4,517	5,274	5,274				1.0		3,853	3,853
	Light goods V.	4,200	1.0	4,200	3,534	3,534	3,620	3,620				1.0		2,628	2,628
	Medium goods V.	943	2.0	1,886	771	1,542	259	518				3.8		383	1,459
	Heavy goods V.	855	2.0	1,710	749	1,498	597	1,194				3.8		701	2,711
	Bus	449	2.0	898	287	574	121	242				3.8		148	571
	Matatu	-	1.5	-	-	-	-	-				1.5		-	-
	Total	12,237		14,484	9,858	11,665	9,871	10,848						7,713	11,222
		452.6		353.6	293.9	255.5	168.9	165.6						119.1	127. 8
4 lane shortest Bypass in 2000	Car,taxi	12,750	1.0	12,750	8,780	8,780	9,371	9,371	4,973	4,973	5,498	1.0	5,498	10,921	10,921
	Light goods V.	8,272	1.0	8,272	6,547	6,547	5,220	5,220	3,549	3,549	3,039	1.0	3,039	6,588	6,588
	Medium goods V.	965	2.0	1,930	771	1,542	659	1,318	303	606	380	3.8	1,444	683	2,050
	Heavy goods V.	1,066	2.0	2,131	999	1,998	1,027	2,054	581	1,162	520	3.8	1,976	1,101	3,138
	Bus	255	2.0	510	37	74	41	82	27	54	21	3.8	80	48	134
	Matatu	-	1.5	-	-	-	-	-	-	-	-	1.5	-	-	-
	Total	23,308		25,594	17,134	18,941	16,318	18,045	9,433	10,344	9,908		12,037	19,341	22,831
		862.0		624.9	510.8	414.8	279.2	275.6						298.6	260.0
Annual average growth rate of 4-lane Bypass (from 1986 to 2000)		16.6%		14.0%	12.4%	10.7%	7.6%	7.5%						8.1%	7.0%

Accordingly, it would be said that a dual carriageway will be recommendable in view of traffic planning in the opening year.

(3) Analysis of Converted Traffic

The construction of the bypass has two major purposes, that is, converting the through traffic of Nairobi from A104 (international trunk road) and eliminating traffic congestion on the roads inside the city. It is necessary, therefore, to divide the bypass traffic according to the purposes of utilization, and then the benefits pertaining to each division constitute the effects of improvement to be measured.

In addition, the benefits arising from this project ought to be calculated conservatively, as a basic rule, regarding the items capable of being quantified. There is something numerically uncertain the negligible amount on the urban road network about the development traffic and induced traffic which arise incidentally after completion of the bypass. Because, most of development schems are including in the future Land-use plan and most of existing roads are already paved. Excluding these, therefore, the future traffic assigned to the bypass should include only the normal traffic converted from the existing roads.

Table IV-5 shows the distribution ratio and conversion rate of the traffic utilizing the bypass classified by Bypass link and itemized by traffic category. Using both of the Table IV-5 and the converted OD trip table (given in appendix Table A-VI-5, the trends of bypass utilization and the characteristics of bypass traffic were analyzed and the volume of traffic converted from A104 into the bypass was calculated.

The results of analysis are summarized as follows.

a) Regarding the bypass traffic volume itemized by traffic category, the internal plus external traffic represent more than 90% in every section, whereas the through traffic ranges

approximately from about 1,200 to 1,300 vehicle/day, accounting for less than 10% of the total traffic.

b) The bypass conversion rate becomes higher as the direction of the desired line between zones becomes closer to that of the bypass route.

c) The through traffic has its trip ends over the extensions of both beginning and ending points of the bypass. For reasons started in b) above, the through traffic shows a very high conversion rate (over 95%).

d) The conversion rates of external and internal traffics were about 80% and 50% respectively. This is suggestive of a tendency that the bypass conversion rate becomes lower as the gap between the direction of the bypass route and that of the desired line becomes greater. Such a tendency seems to reflect the effect of the traffic assignment method that is capable of selecting the shortest time route.

e) The traffic converted from A104 and running throughout the bypass was considered to include both the through traffic and external traffic which has its origin around the beginning point of the bypass (in or around the airport, industrial area, and other districts) and its destination beyond the ending point of the bypass. The results of an analysis of converted OD trips on the Bypass show that the volume of converted-throughout traffic amounts to a total of 6,282 vehicle/day, consisting of 1,213 through and 5,069 external trips (see Table IV-6). The bypass conversion rates of these cars are almost 100%.

f) Therefore, the traffic volume excluding 6,282 vehicle/day constitutes the volume of other converted traffic (see Table IV-6).

The volume of converted traffic other than from A104 to the bypass were estimated to reach 10,040 to 17,030 VPD (depending on different bypass links) by 2,000 years. These trips most often originate in Nairobi City. In the case of closer direction of their OD pairs to that of the bypass route, the higher conversion rate to the bypass was assigned. In addition, there are OD pairs with high growth potential, linking the increasingly populous districts to urban centers and industrial areas such as South-west and South-east development area of Nairobi. The direction of these OD pairs is close to that of the bypass route and therefore the high conversion rates was assigned in these pairs.

Due to the reasons described above, it was forcasted that much of the traffic from roads other than A104 was assigned to the bypass.

Concerning the forecasted bypass traffic in 2000, the volume of bypass traffic in 1991 is also shown in Table IV-6 for the benefit calculation.

The traffic volume in 1991 was determined on the basis of interpolation between the traffic volumes in 1986 and 2000.

Table IV-5 Trends of Bypass Utilization in 2000 by the Bypass Link

Bypass Link / Traffic Category	Link 1			Link 2			Link 3			Link 4		
	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)	Traffic Volume (100 VPD)	Distribution ratio (%)	Conversion rate (%)
Internal Traffic	138	60	64	80	47	49	61	38	47	75	39	51
External Traffic	82	35	84	79	46	80	90	55	78	105	54	74
Through Traffic	12	5	95	12	7	98	12	7	100	13	7	99
Total	232	100	71	171	100	62	163	100	63	193	100	64

Note:

Internal Traffic : Zone pairs having both trip ends inside Nairobi City

External Traffic : Zone pairs having their trip ends both inside and outside of Nairobi City

THrough Traffic : Zone pairs passing through Nairobi City

Table IV-6 Total Converted Traffic to the Bypass by link

Unite: AADT

Bypass Link No.	Converted Traffic from	Year in 1991							Year in 2000						
		Car	L.G.V.	M.G.V.	H.G.V.	BUS	MA.	Total	Car	L.G.V.	M.G.V.	H.G.V.	BUS	MA.	Total
1	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
	from A104 (2)	1,009	1,336	415	424	18	--	3,202	1,778	2,309	460	502	20	--	5,069
	(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads	3,990	1,799	186	13	135	--	6,123	10,621	5,919	373	68	223	--	17,026
	Total	5,236	3,285	723	825	164	--	10,233	12,750	8,272	965	1,066	255	--	23,308
2	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
	from A104 (2)	1,009	1,336	415	424	18	--	3,202	1,778	2,309	460	502	20	--	5,069
	(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads	3,009	1,626	38	4	4	--	4,681	6,651	4,194	179	1	5	--	10,852
	Total	4,255	3,112	575	816	33	--	8,791	8,780	6,547	771	999	37	--	17,134
3	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
	from A104 (2)	1,009	1,336	415	425	18	--	3,202	1,778	2,309	460	502	20	--	5,069
	(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads	3,871	1,136	105	78	4	--	5,194	7,242	2,867	67	29	9	--	10,036
	Total	5,117	2,622	642	890	33	--	9,304	9,371	5,220	659	1,027	41	--	16,318
4	(1)	237	150	122	388	11	--	908	351	222	132	496	12	--	1,213
	from A104 (2)	1,009	1,336	415	425	18	--	3,202	1,778	2,309	460	502	20	--	5,069
	(1)+(2)	1,246	1,486	537	812	29	--	4,110	2,129	2,353	592	998	32	--	6,282
	from other roads	5,727	1,940	89	103	16	--	7,875	8,792	4,235	91	103	16	--	13,059
	Total	6,973	3,426	626	915	45	--	11,985	10,921	6,588	683	1,101	48	--	19,341

Note: L.G.V. : Light Goods Vehicle
M.G.V. : Medium Goods Vehicle
H.G.V. : Heavy Goods Vehicle
MA. : Matatu

(1) : Through-Traffic of Nairobi converted from A104 to Bypass
(2) : Converted from A104 to Bypass of both or either O-D inside Nairobi (External Traffic)

IV.4 Geometric Design Standard

Geometric design standards depend on the Road Design Manual Part 1 MOTC Kenya as follows: -

Geometric Design Standard for Main Road

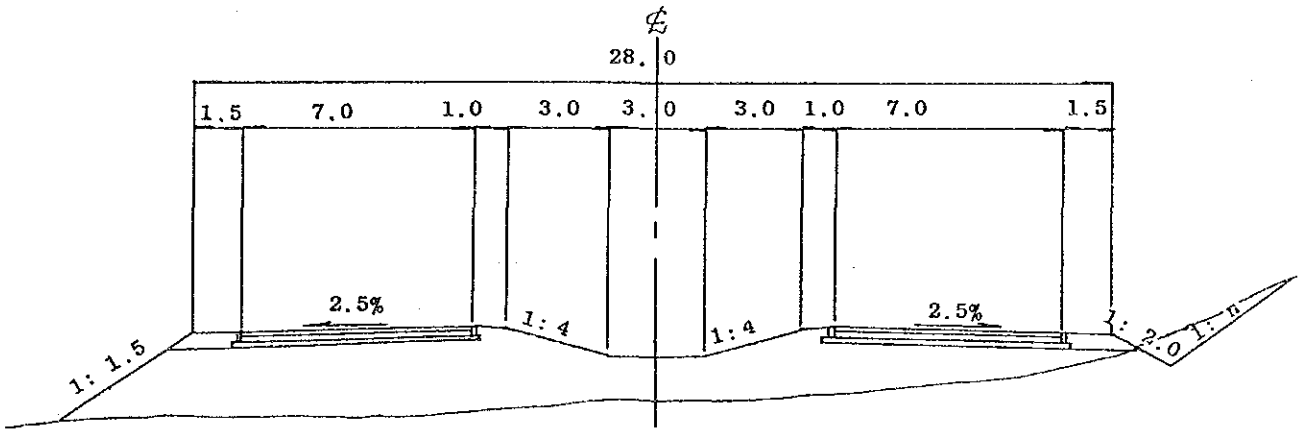
Item	Description
Road Classification	Class A
Design Speed	100 - 70 km/h
Lane width	3.5m
Shoulder width	
Right	1.0m
Left	1.5m
Central Reserve	11.0 - 3.5m
Crossfall	2.5%
Longitudinal Maximum Gradient	
Flat	3.0%
Rolling	4.0%
Mountainous	7.0%
Minimum Horizontal Curve	
Radii	600m
Right of Way	60m

Geometric Design Standard for Intersection

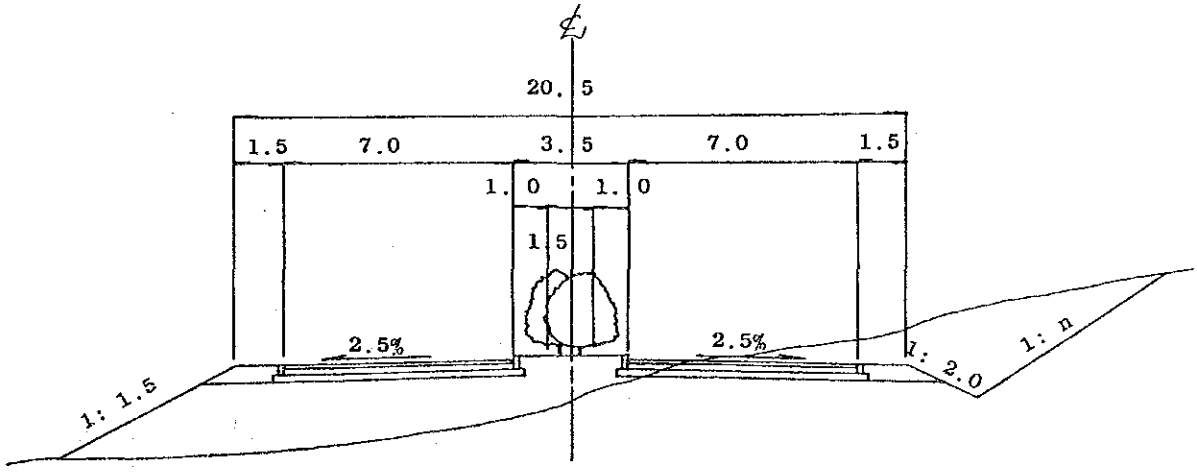
Item	Description
Design Speed	50 - 40 km/h
Lane Width	One way : W = 4.0m
	Two way : W = 6.0m
Shoulder Width	Right : W = 1.0m
	Left : W = 1.5 (for one lane)
	: W = 1.0 (for two lane)
Cross fall	2.5%
Minimum Radius	50.00m
Acceleration lane	240m for design speed 100 Km/h
	210m for design speed 80 Km/h
Deceleration lane	150m for design speed 100 Km/h
	130m for design speed 80 Km/h

Typical Cross Section of the Bypass

Typical cross section of the Nairobi Bypass has been proposed in accordance with the Geometric Design Standard of Kenya (1979) as follows:



TYPICAL CROSS SECTION (CENTRAL RESERVE, $W_c \cong 11.0^m$)



TYPICAL CROSS SECTION (CENTRAL RESERVE, $W_c = 3.5^m$)

IV.5 Preliminary Design

Preliminary design of the project road was carried out on topographical maps (scale = 1: 2500) in accordance with the tentative design by JICA Study Team on maps (scale = 1: 5000) which were prepared by MOTC.

Geometric design of the project road was done in accordance with the Road Design Manual Part 1, Geometric Design of Rural Roads and close discussions between MOTC and JICA Study Team.

IV.5.1 Route Design

Nairobi Southern Bypass begins on the Mombasa Road A104 at the northeast edge of Nairobi National Park and ends at Kikuyu Junction (A104).

Horizontal alignment from the beginning point to Langata Estate was planned in accordance with the structural plans of Nairobi (Departmental Reference No. 42-28 85-9) by the Department of Physical Planning of the Ministry of Works, Housing and Physical Planning. Then the alignment was planned as much as possible to pass through the Ngong Road Forest and Dagoretti Forest (namely Government land) in view of reducing land acquisition costs.

The outline of the horizontal alignment and the vertical alignment is shown in Fig. IV-4 and Fig. IV-5.

(1) Mombasa Road Junction - Uhuru Junction (Langata Road Junction).

Referring to a Nairobi Structure plan by the Ministry of Works, Housing and Physical Planning, the horizontal alignment was designed in the right of way of the proposed Trans-African Highway and Railway Reserve and in consideration of Uhuru Monument and an existing restaurant.

Vertical alignment was designed slightly rising over existing ground level to make it easy to drain rain water from the road surface. After passing through the edge of the National Park, the vertical alignment rises to cross over Langata Road (C58).

(2) Uhuru Monument Junction - Ngong Road Junction

The Bypass was designed along the right bank of Motoine River avoiding the Housing Estate. After that it stretches along the south edge of Ngong Road Forest and crosses over the intersection of Ngong Road Forest and Motoine River. In this section, the proposed route was designed in consideration of the existing housing estates and the forest station as much as possible.

(3) Ngong Road Junction - Dagoretti Road Junction

The Bypass crosses over Ngong Road and Motoine River and stretches through the Ngong Road Forest on the left bank of the Motoine River.

After passing through the forest the route stretches on the top of the left slope of the Motoine River avoiding a lot of houses and crosses over Dagoretti Road (C63) at the foot of Dagoretti Forest near the railway.

In this section, an attempt was made to take an existing road for the Bypass, but there are many houses along the existing road. Moving the people to construct the Bypass will cause much disturbance, thus after a discussion between MOTC and the JICA Team on the tentative design, it was decided to have the horizontal alignment along the edge of the left bank of Motoine River.

(4) Dagoretti Road Junction - Kikuyu Junction

The topography of the beginning point of this section is very steep and the rock below the top soil was found, from a geological survey, to be hard. Therefore a 5% gradient was adopted for vertical alignment so as to reduce the earth volume, especially rock excavation.

The proposed alignment climbs up the Dagoretti Forest and passes through the northeast edge of the forest and Thogoto Village avoiding a built up area.

After that the Bypass goes around both Alliance Boys and Girls High Schools to the West, thus avoiding breaking the school community and destroying a famous church. The Bypass then crosses slightly the Ondiri Swamp with a high embankment and joins the route C63 avoiding the swamp as much as possible. After that it passes under an existing railway and joins Naivasha Road (A104) at Kikuyu Junction.

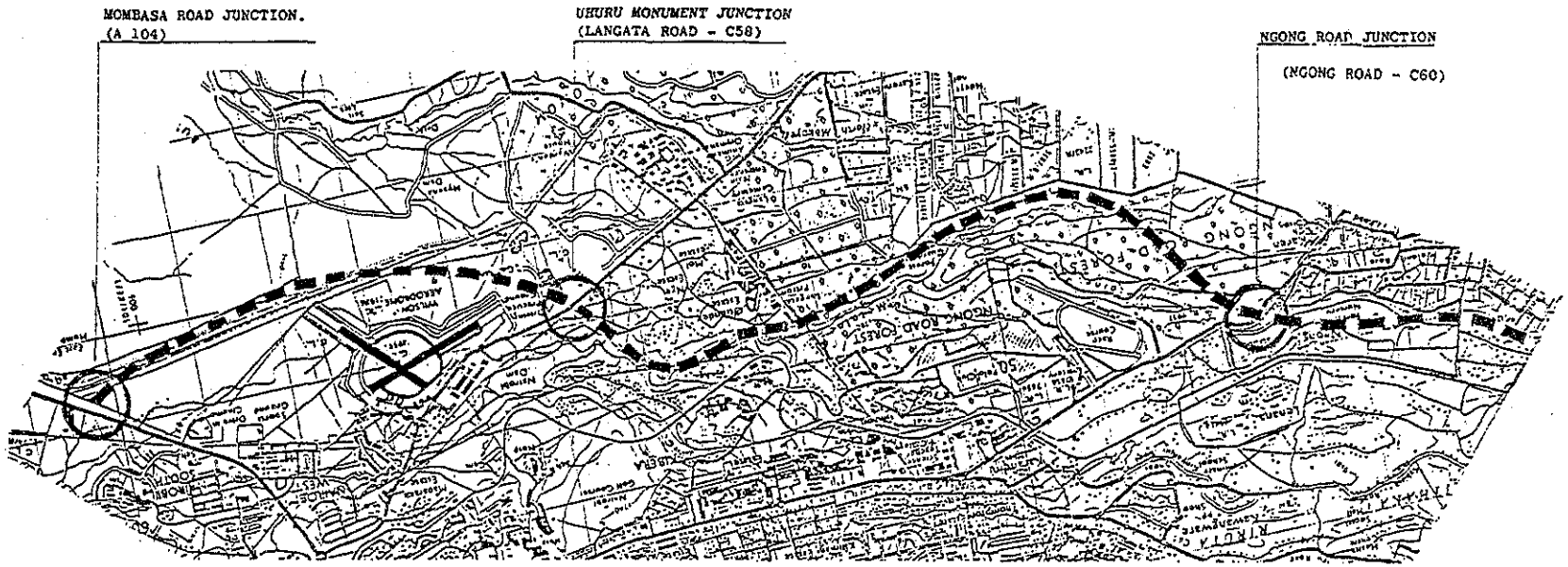
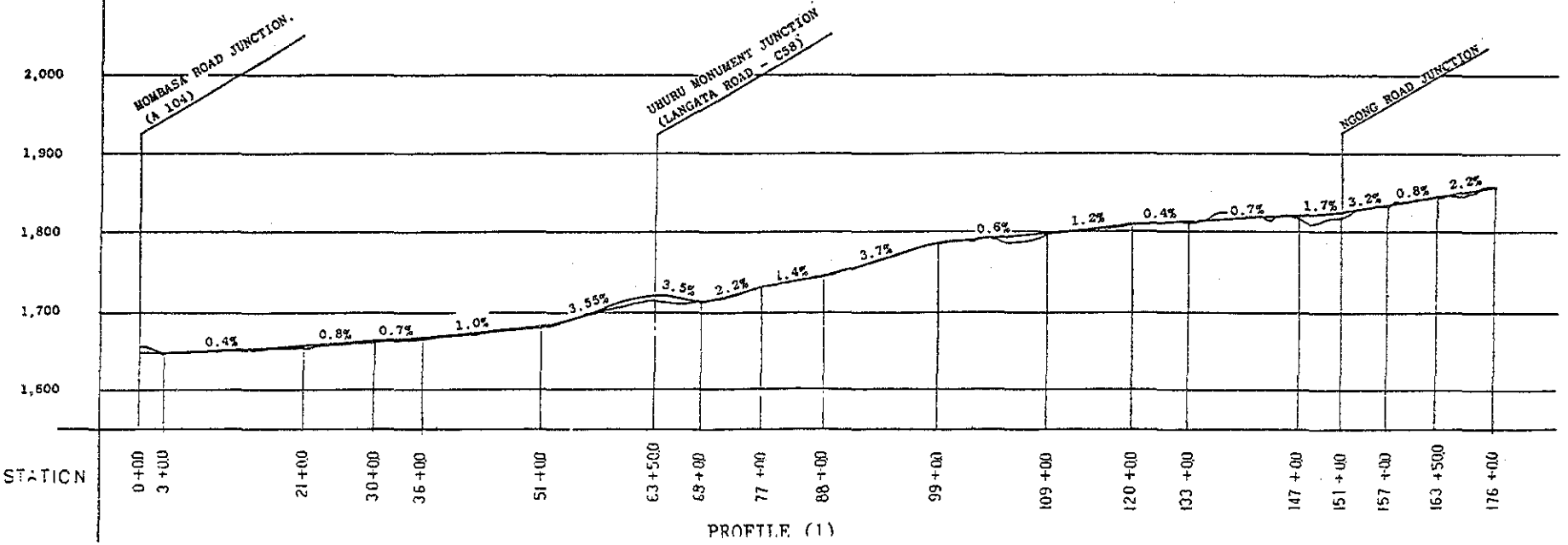


Fig. IV-4 PLAN (1)



PROFILE (1)

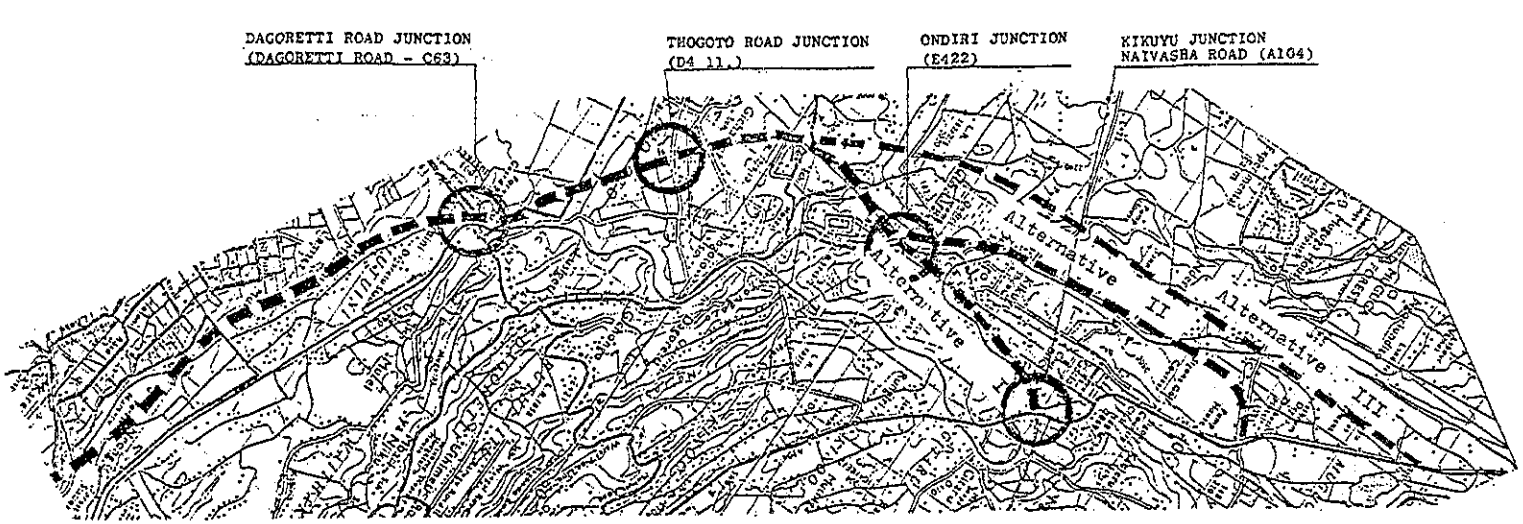
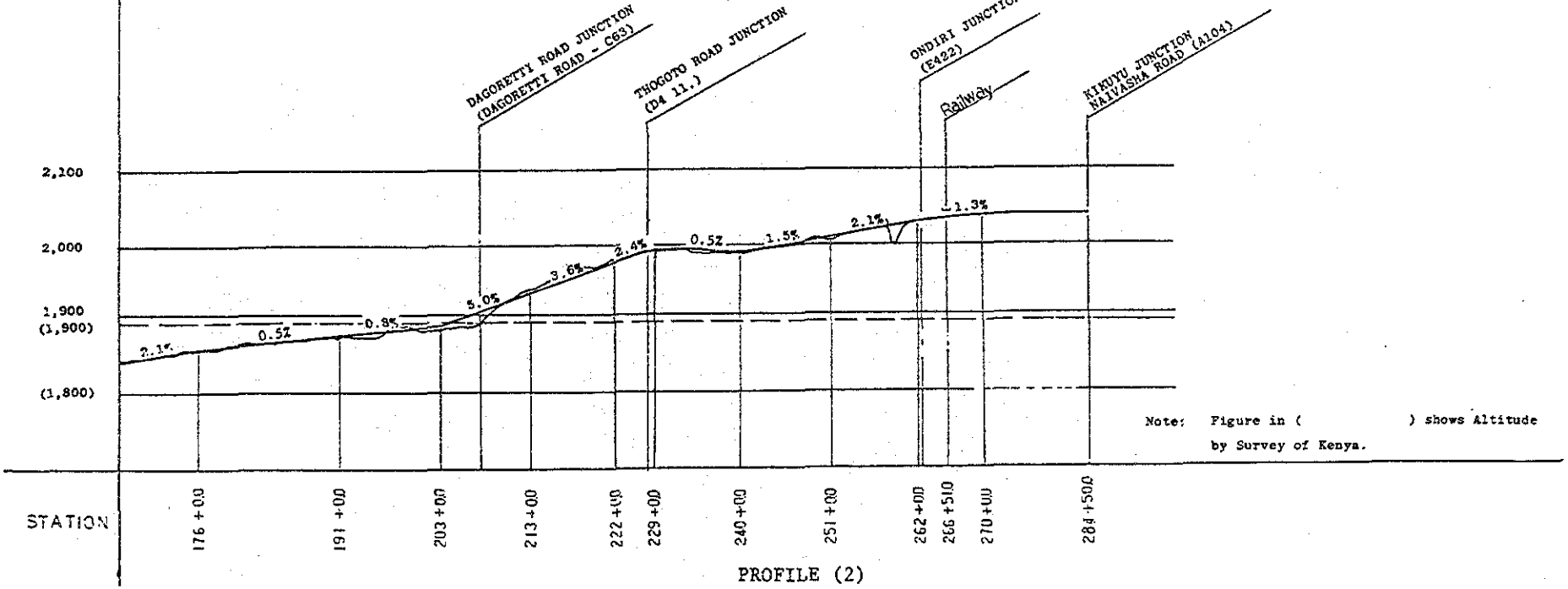


Fig. IV-5 PLAN (2)



PROFILE (2)

IV.5.2 Geology and Soil

The project area belongs to the Athi River Drainage System and has been dissected by many rivers (Motoine River, Mokoyoti River, Nairobi River etc.) which flow from the eastern highlands of the Rift Valley to the east forming alluvial deposit plains in places.

The bedrock of the East Africa, including Kenya, is formed by Precambrian crystalline rocks belonging to the Mozambique Belt. The geological structure is specialized by the Great Rift Valley stretching South and North.

Bedrock in this area has been cut by a lot of faults along the Rift Valley and the environs have been covered with thick volcanic rock produced by aggressive igneous action after the tertiary period.

Accordingly, phonolite, trachyte, tuff etc., which were spouted sometimes from tertiary to pleistocene have been distributed on the east highlands of the Rift Valley including Nairobi.

Surface soil in the northwest highland region of Nairobi is composed of soil from volcanic ash, weathered volcanic rocks etc. Black cotton soil, however, which is cohesive and hygroscopic is distributed in the Athi Plain on the southeast side of Nairobi.

The proposed road starts on the Mombasa Road (104) near the northeast edge of the Nairobi National Park and reaches the Kikuyu Junction of Naivasha Road (A104) passing through Ngong Road Forest located to the south and Dagoretti Forest to the west of Nairobi City.

The filed survey area has been dissected by a lot of rivers belonging to the Athi River Drainage System, and there is some intermittent distribution of alluvial deposit. Some of this alluvial deposit shows locally in the swamp during the rainy season. The geological conditions of Nairobi and environs is shown in Fig. IV-6 and geological conditions of the project road are shown in fig. IV-7 and Fig. IV-8.

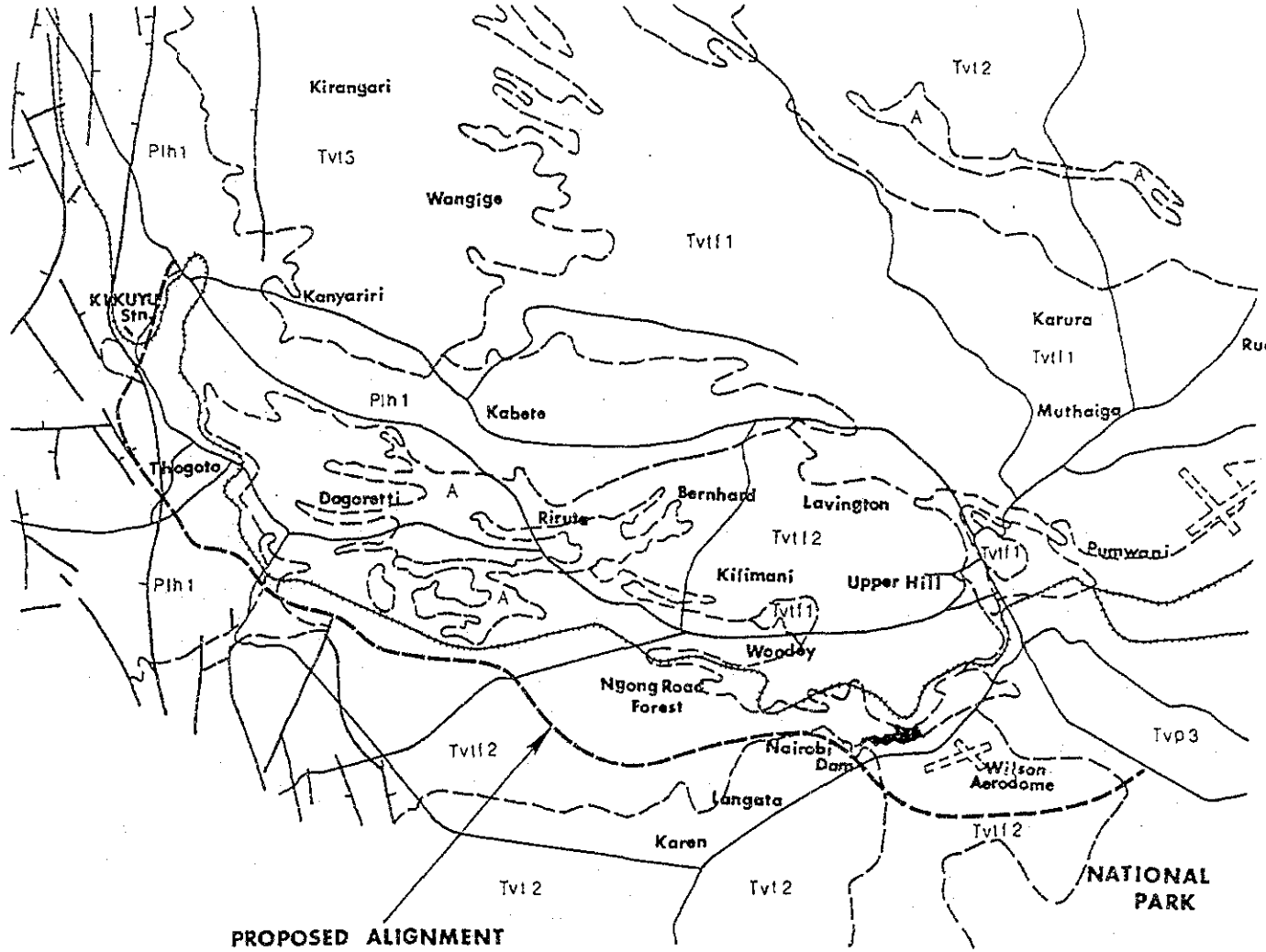


Fig. IV-6

GEOLOGICAL MAP

Scale 1:125,000

EXPLANATON

A	Alluvium
Plh 1	Limuru Trachytes and Quartz Trachytes
Tvt 5	Kabete Trachytes and Ruiru Dam Trachytes
Tvtf2	Middle and Upoer Kerichwa Valley Tuffs
Tvtf1	Lower Kerichwa Valley Tuffs
Tvt 2	Nairobi Trachytes
Tvp 3	Nairobi Phonolites

Geological boundaries

Faults

Fig. IV-7

GEOLOGICAL SECTION (A)

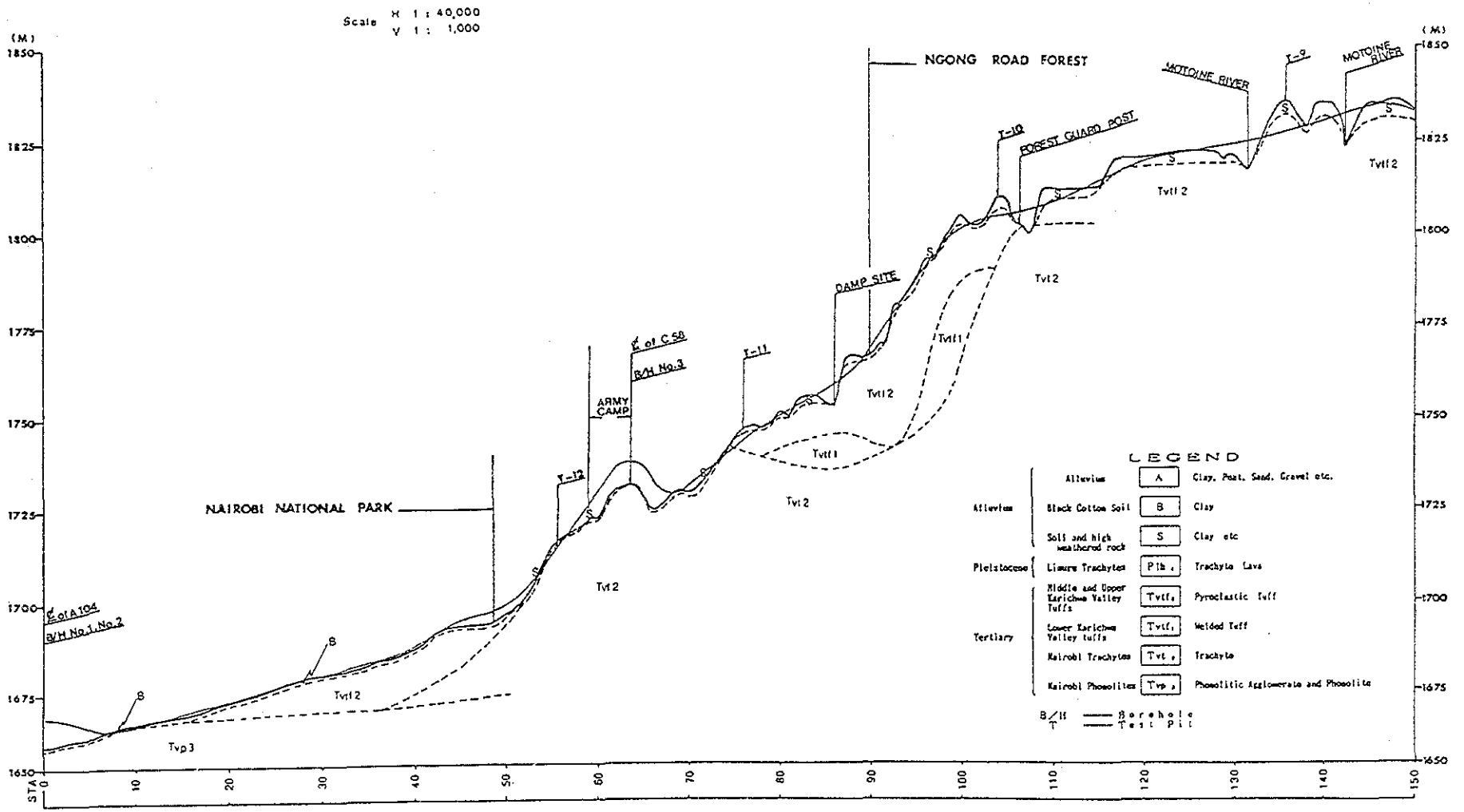
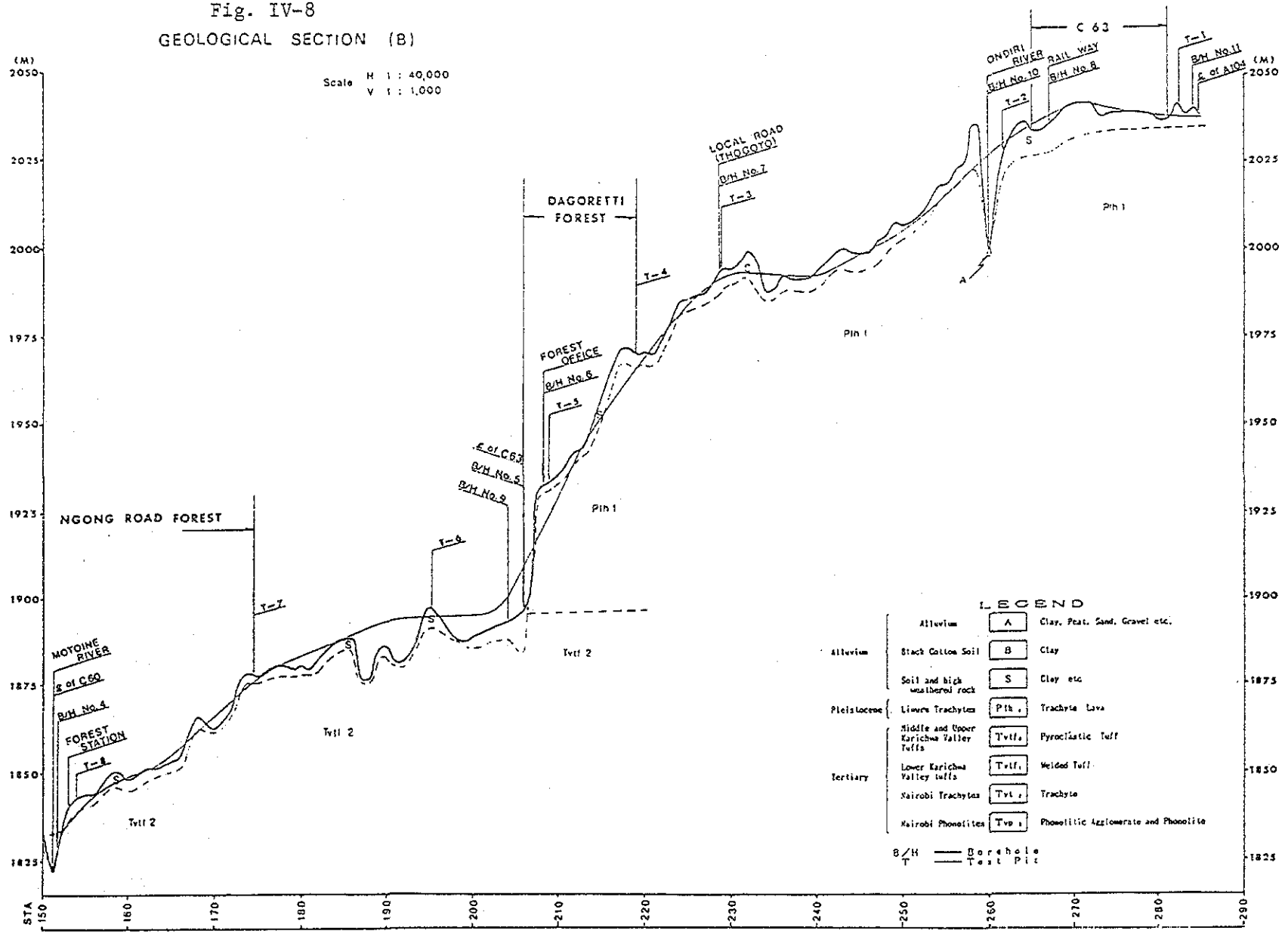


Fig. IV-8

GEOLOGICAL SECTION (B)



IV.5.3 Pavement Design

Pavement design was carried out in accordance with Road Design Manual Part III by MOTC Kenya.

The Material Branch of MOTC and the JICA team discussed the procedure of pavement design and the pavement material to be used. The proposed pavement structures are as follows.

Note: Detailed soil investigation should be carried out at the detailed design stage to design suitable pavement structures in every section.

Crushed stone for subbase course would be imported from quarries in Eastland. Cement stabilized material in this case is similar to lean concrete.

Proposed Pavement Structure by Section

Section	Traffic	Subgrade	Proposed Pavement Structure	
STA 0 + 0.0 -STA 90 + 0.0	T_1	S5	100mm	Surface
			200mm	Cement Stabilized Material
			175mm	Cement improved Material (or crushed stone)
STA 90 + 0.0 -End	T_1	S4	100mm	Surface
			200mm	Cement Stabilized Material
			225mm	Cement improved Material (or crushed stone)
STA 207 + 0.0 -STA	T_1	S6	100mm	Surface
			200mm	Cement Stabilized Material
STA 214 + 0.0 -STA	T_1	S6		

IV.5.4 Intersection Design

(1) Intersection Alignments and Traffic Control Policy

Intersection designs have been made for the intersections at which the project road crosses the major trunk roads. Structural type and traffic control policy of each major intersection are summarized as follows:-

Name of Intersection	Name of Road	Traffic Control Policy and Structural Type
Mombasa Junction	Mombasa Road (A104)	Partial clover leafs interchange.
Uhuru Monument Junction	Langata Road (C58)	Diamond Interchange. To provide for traffic from all directions
Ngong Road Junction	Ngong Road (C60)	Compound T-Junction. To provide for traffic from all directions
Dagoretti Road Junction	Dagoretti Road (C63)	Compound T-Junction . To provide for traffic from all directions
Kikuyu Junction	Naivasha Road (A104)	Directional Interchange. To provide for traffics of full direction

IV.5.5 Design of Structures

Three bridges, five road box culverts and five box culverts, were designed. After discussion with the structural engineer of MOTC, Design Criteria for structural design have been referred to the Road Earthwork Manual by Japan Road Association. Live load for preliminary design of bridge was adopted TL-20, and earthquake load was not considered.

Types of structures are studied and selected with due consideration of low construction cost and especially the following items:

1. Easy construction work by Kenya Contractors
2. Construction using local material and easily imported material in Kenya
3. Easy maintenance work after construction
4. Beauty (Not to interfere with natural sights).

IV.6 Construction Schedule and Costs

IV.6.1 Construction Period and Time Target

The total construction period of the Nairobi Bypass Project is scheduled to be about 4.5 years. The first 2 years are required for such pre-construction works as detailed engineering design, land acquisition, tendering and contractual events. The later 2.5 years are required for actual construction works of the project.

IV.6.2 Construction Schedule

The construction schedule is shown in Fig. IV-9 and Fig. IV-10 by bar chart.

IV.6.3 Annual Disbursement Schedule

The disbursement schedule of the construction cost is tabulated as follows.

Year	Foreign Currency (Million Kshs)	Local Currency (Million Kshs)	Total (Million Kshs)
1st Year	6.60	4.52	11.12
2nd Year	2.95	28.51	31.46
3rd Year	18.54	35.51	54.05
4th Year	147.73	118.27	266.00
5th Year	87.89	65.91	153.80
Total	263.71	252.72	516.43

IV.6.4 Maintenance Cost

The road maintenance cost is estimated for the following items: Annual routine maintenance cost and periodical maintenance cost. The annual maintenance cost consisting of cleaning cost and repairing cost is estimated based on the "BREAKDOWN OF ROAD MAINTENANCE RATES FOR 1987/88 FINANCIAL YEAR, MOTC". The periodical maintenance cost for overlays is estimated at intervals of 5 years after completion of construction.

(1) Annual routine maintenance cost: 6,600 Kshs/km/year is adopted for a single carriage road. The maintenance rate is reflected by the level of financial allocation from the Treasury (Ministry of Finance). The main road is planned to be a dual carriage road and the ramp is to be single carriage road. The annual routine maintenance cost is estimated below:

Main road

6,600 Kshs/km/year x 2 x 29.220km = Kshs. 385,700

Ramp

6,600 Kshs/km/year x 1 x 4.365km = Kshs. 28,800

Sub-Total Kshs.414,500/year.

(2) Periodical Maintenance cost:

The periodical maintenance cost is estimated at the overlays cost after 5 years, 10 years and 15 years.

The overlays are planned as 35mm thick asphalt pavement at intervals of 5 years. Therefore, each overlay cost is estimated below:

Main Road

1,500 Kshs/m^3 x 0.035m x 7m x 2 x 29,220m
= Kshs.21,476,700

Ramp (1-lane)

1,500 Kshs/m^3 x 0.035m x 4m x. 3,345m
= Kshs. 702,500

Ramp (2-lane)

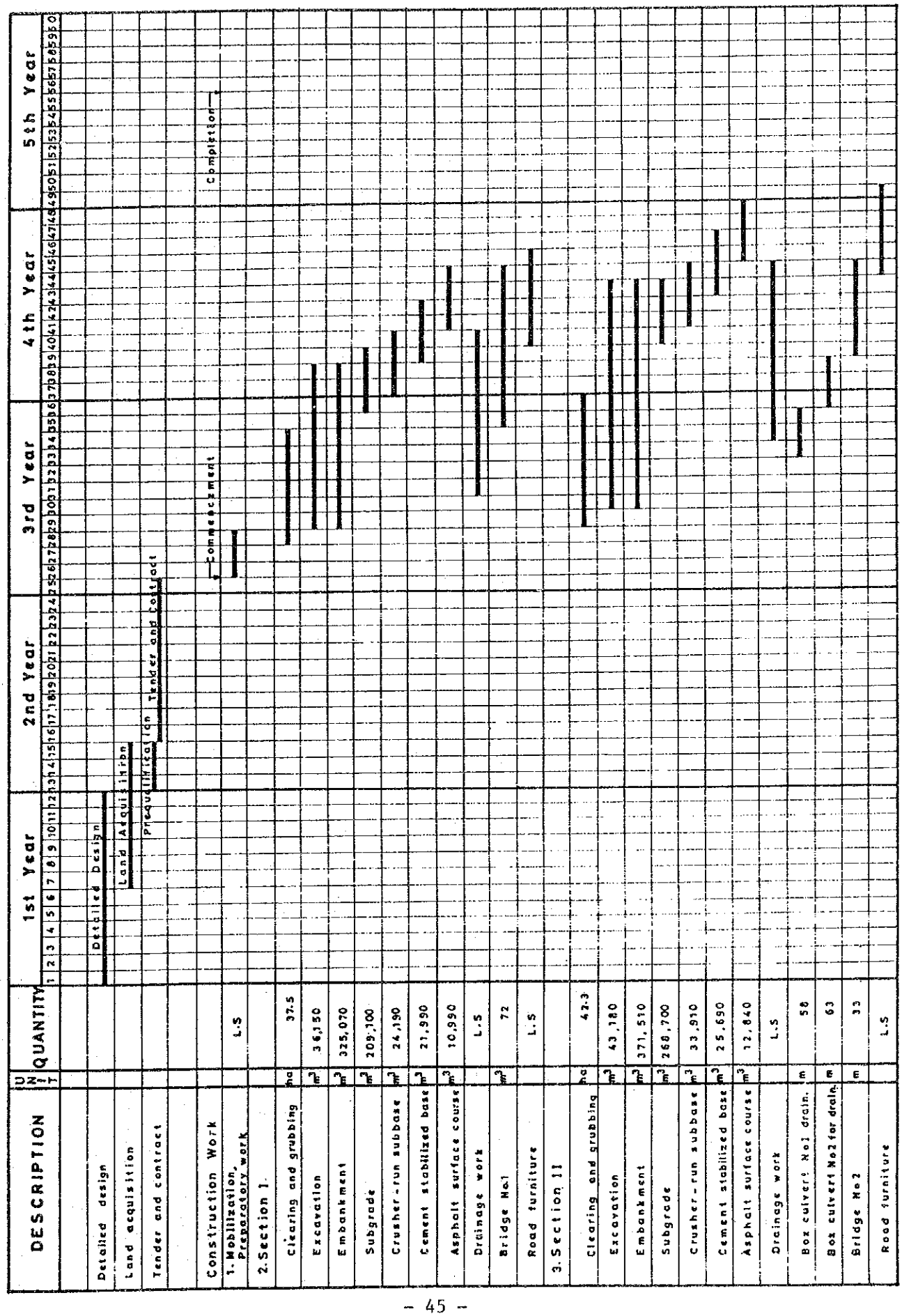
1,500 Kshs/m^3 x 0.035m x 6m x 1,020m
= Kshs. 321,300

Sub-Total Kshs.22,500,500/each.

Period	Periodical Maintenance.
After 5 years	Kshs.22,500,500
After 10 years	Kshs.22,500,500
After 15 years	Kshs.22,500,500

Fig. IV-9

Construction Schedule (1/2)



Construction Schedule (2/2)

DESCRIPTION	UNIT	QUANTITY
4. Section III		
Clearing and grubbing	ha	18.5
Excavation	m^3	50,330
Embankment	m^3	165,400
Subgrade	m^2	93,300
Crusher-run subbase	m^3	21,750
Cement stabilized base	m^3	15,430
Asphalt surface course	m^3	7,710
Drainage work	m	L.S
Box culvert No3-1 for drain.	m	62
Box culvert No3-2 for drain.	m	37
Box culvert No1 for road	m	24
Road furniture		L.S.
5. Section IV		
Clearing and grubbing	ha	31.6
Embankment	m^3	520,510
Subgrade	m^2	220,530
Crusher-run subbase	m^2	135,210
Cement stabilized base	m^3	24,980
Asphalt surface course	m^3	12,490
Drainage work		L.S
Box culvert No4 for drain.	m	119
Box culvert No2 for road	m	43
Box culvert No3 for road	m	37
Box culvert No4-1 for road	m	33
Box culvert No4-2 for road	m	26
Bridge No 3	m	15
Road furniture		L.S.

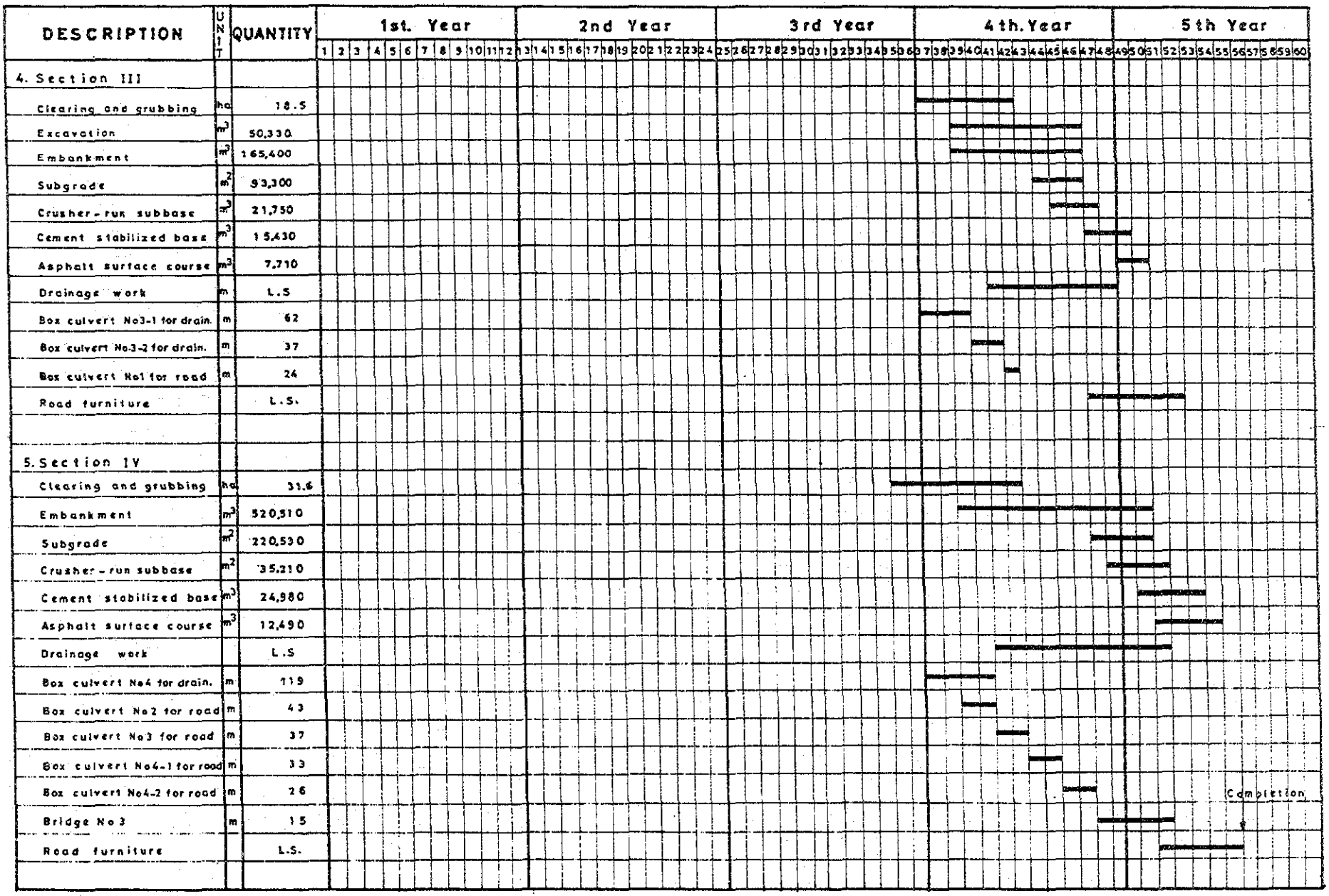


Fig. IV-10
Construction Schedule (2/2)

Table IV-7

Summary of Construction Cost

Unit: 1,000 Kshs.

Description	Foreign Currency	Local Currency	Total
1. Direct Construction Cost			
1.1 General	0	16,136	16,136
1.2 Site clearing and topsoil stripping	2,962	1,410	4,372
1.3 Earthwork	59,976	31,267	91,243
1.4 Pavement work	110,325	44,956	155,281
1.5 Drainage work	2,802	9,163	11,965
1.6 Road Furniture	6,440	11,026	17,466
1.7 Box Culvert	14,035	12,871	26,906
1.8 Bridge	7,848	7,640	15,488
Sub-total (1.1 to 1.8)	204,388	134,469	338,857
2. Engineering Services			
Detailed design, supervision and administration	20,439	13,447	33,886
3. Land Acquisition and Compensation	0	22,805	22,805
4. Physical Contingency	20,439	13,447	33,886
Total (1 to 4)	245,266	184,168	429,434
5. Price Escalation	18,443	68,556	86,999
Grand Total	263,709	252,724	516,433

V. Economic Assessment

V. Economic Assessment

The procedure of the economic assessment is illustrated in Fig. V-1.

V.1 Economic Costs

(1) Initial Capital Investment Cost

516,433,000 Shill. is estimated, based on the preliminary design in the financial term at August, 1987.
Approximately 17,670,000 Shill. per km is considered reasonable for a dual carriageway for a 29.22 km long Bypass with grade separation of main junctions having an additional 4.4 km of ramp way.

A financial cost of 516,433,000 Shill. is to be converted into economic cost using the following procedures.

- Deduction of land acquisition cost
- Deduction of Tax and Duty
- Adjustment of the shadow price of unskilled labour
- Exemption of price escalation

Thus, initial economic investment cost becomes 338,374,000 Shill.

(2) Maintenance Cost

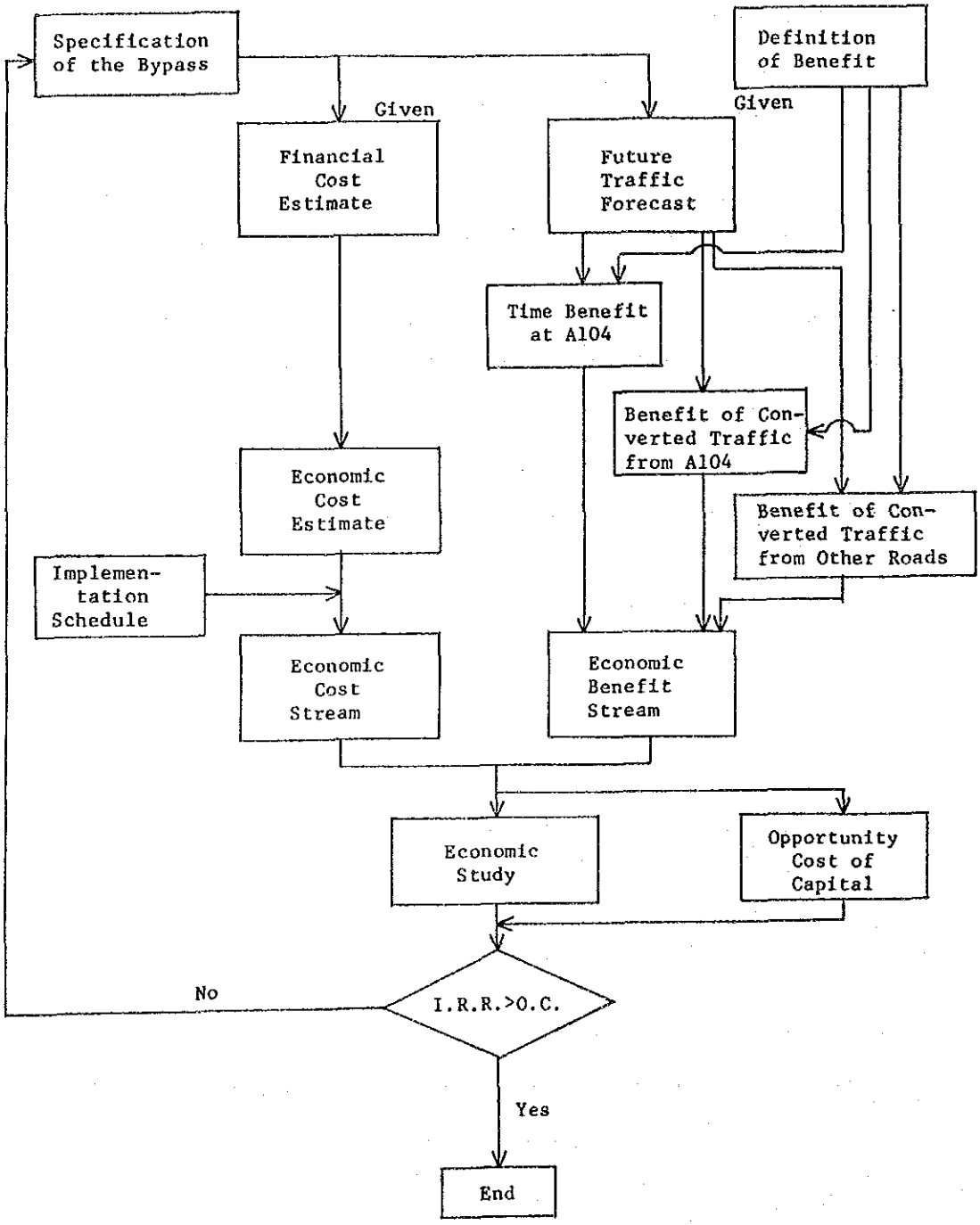
Total maintenance cost per year is estimated as 414,500 Shill.
414,500 Shill. is converted into 271,498 Shill. in economic terms which is used for Economic Assessment.
Periodical maintenance costs for the overlay after each 5 years is estimated as 22,500 x 10^3 Shill. in financial terms and 14,838 x 10^3 Shill. in economic terms.

(3) Implementation Schedule

A Preliminary Implementation Schedule is established as follows:

- Starting with detailed design at 1988
- Completion at 1992
- Full utilization at 1993
- Partial utilization at 1992 of 42%

Fig. V-1 Flow Chart for Economic Assessment



(4) Economic Cost Stream

Table V-1

Economic Cost Stream

Unit: Economic, mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Initial Capital Investment Cost	Maintenance Cost	Total Cost	Discounted by 12% 1/
1	1988	4,418	0	4,418	4,418
2	89	8,263	0	8,263	7,378
3	90	41,479	0	41,479	33,067
4	91	214,092	0	214,092	152,386
5	92	127,344	0	127,344	80,929
6	93	0	272	272	154
7	94	0	272	272	138
8	95	0	272	272	123
9	96	0	272	272	110
10	97	0	14,738	14,738	5,315
11	98	0	272	272	88
12	99	0	272	272	78
13	2000	0	272	272	70
14	1	0	272	272	62
15	2	0	14,738	14,738	3,016
16	3	0	272	272	50
17	4	0	272	272	44
18	5	0	272	272	40
19	6	0	272	272	35
20	7	0	14,738	14,738	1,711
		△84,344 2/		△84,344	△ 9,793
	20	311,252 3/	47,478	358,730	279,419

1/ : Opportunity cost of capital See IX.3.1

2/ : Residual value, △: Minus

3/ : Included price change

V.2 Economic Benefits

(1) Definition of Benefit

Based on direct benefit considered, the following 3 items which can be quantified logically are adopted for the calculation of the benefit in the Study.

a) The difference of required passing time with and without project at A104.

b) The differences of Vehicle Operating Costs and required passing time in the case of using A104 and the Bypass.

c) The difference of transport cost in the case of using other roads and Bypass.

(2) Vehicle Operating Cost

Vehicle Operating Cost is assessed, based on the formula established by Japan's Ministry of Construction with the latest data collected from interviews with manufacturers, forwarders and dealers in Nairobi.

VOC is calculated by types of vehicle, speed, slopes of roads and conditions of roads with the cost per km in economic term.

(3) Time Value

Time Values are estimated separately for passenger car passengers and the mass-transit passengers (bus and matatu) with working hours and non-working hours.

a) The passenger vehicle passenger

- working hours, 68 cents/minute
- non-working hours, 41 cents/minute

b) The mass-transit passenger

- working hours, 17 cents/minute
- non-working hours, 4 cents/minute

(4) Economic Benefit Stream

In order to calculate the figures of benefit, future traffic unit indices for benefit as VOC and time value as well as the speed of vehicles, design speed, legal speed limit, the velocity curve and the traffic capacity were adopted.

The calculated stream of the economic benefits is shown in Table V-2.

V.3 Economic Assessment

(1) NPV

NPV based on Economic Cost Stream and Economic Benefit Stream is calculated to be 145,332 x 10^3 Shill.

NPV for the project has a positive figure.

(2) Benefit Cost Ratio

B/C Ratio is calculated to be 1.52, which is above the figure of acceptability, based on Economic Cost Stream and Economic Benefit Stream.

(3) IRR of 18.26% is calculated, based on Cost and Benefit Stream, which is considered an acceptable figure.

(4) Sensitivity Analysis

a) A Case Study of Cost Alternatives based on Table V-2, Economic Benefit Stream and the Cost of 20% higher to Table V-1, whereas 20% was adopted as the admissable error of the cost based on preliminary design.

IRR 15.58%

b) A Case Study of Benefit Alternative based on Table V-1, Economic Cost Stream and the benefit having been decreased by 20% against Table V-2, Economic Benefit Stream.

IRR 14.86%

Table V-2

Economic Benefit Stream

mid 1987, 10^3 Shill.

Project Year	Fiscal Year	Time Benefit at A104	Benefit of Converted Traffic at Bypass from A104	Benefit of Converted Traffic at Bypass from other Roads	Total Benefit	Discounted 1/ by 12% 2/
1	1988	0	0	0	0	0
2	89	0	0	0	0	0
3	90	0	0	0	0	0
4	91	0	0	0	0	0
5	92	5,755	6,033	3,820	15,608	9,919 3/
6	93	14,840	16,760	11,697	43,297	24,568
7	94	15,943	19,399	14,925	50,267	25,467
8	95	17,128	22,455	19,045	58,628	26,520
9	96	18,400	25,991	24,301	68,692	27,744
10	97	19,767	30,085	31,008	80,860	29,159
11	98	21,236	34,824	39,567	95,627	30,789
12	99	22,814	40,309	50,487	113,610	32,660
13	2000	24,509	46,663	64,421	135,593	34,803
14	1	25,489	48,530	66,998	141,017	32,317
15	2	26,509	50,471	69,678	146,658	30,009
16	3	27,569	52,490	72,465	152,524	27,866
17	4	28,672	54,589	75,364	158,625	25,875
18	5	29,819	56,773	78,378	164,970	24,027
19	6	31,012	59,044	81,513	171,569	22,311
20	7	32,252	61,405	84,774	178,431	20,717
Σ	20	361,714	625,821	788,441	1,775,976	424,751

1/ : discounted to initial year, 1988 2/ : 12%, opportunity cost of capital, PLZ refer to IX.3.1

3/ : estimated yearly benefit of 42%, considering partial utilization, based on implementation schedule

c) A Case Study of Cost Alternative and Benefit Alternative based on the benefit of 20% decreased to the Table V-2, Economic Benefit Stream and the cost of 20% increased to the Table V-1, Economic Cost Stream.

IRR 12.22%

(5) Qualitative Benefit

Indirect Benefit

- Economic Development Effect
- Transport Network Improvement Effect
- Introduction of Highly Sophisticated Transport Infrastructure
- Regional Development Effect

(6) It can be concluded that the Project is firmly acceptable as the positive effect of congestion mitigation at A104 is clearly anticipated with the traffic conversion from A104 to the Bypass being 4,110 ADT and 6,282 ADT at 1991 and 2000, respectively.

VI. Overall Evaluation

VI. Overall Evaluation

(1) As the project is justifiable technically, economically and socially, it is strongly recommended to take necessary actions so as to implement the project as scheduled.

(2) The project is firmly acceptable as the positive effect of congestion mitigation at A104 is clearly anticipated with the traffic conversion from A104 to the Bypass being, 4,110 ADT and 6,282 ADT at 1991 and 2000, respectively.

(3) In the case of no Bypass, according to a future traffic assignment estimation, a congestion rate (traffic/traffic capacity) as of the year 2000, will become 2.30 on A104 at City Centre and 1.29 on Ngong Road and 1.18 on Langatta Road. Therefore it is quite necessary for the City to commence the Bypass construction.

(4) In accordance with the economic assessment for the project, the Internal Rate of Return of 18.26% is calculated based on Cost and Benefit Stream, which is considered an acceptable figure for the project.

(5) The alignment and the design of the proposed road involves many problems requiring a high level of engineering to solve them. On the other hand, it does not seem that special techniques or special types of equipment would be required for the construction therefore construction execution by joint venture of a local and a foreign contractor is reasonable.

(6) The detailed design work for the project would involve highly complex engineering problems, especially for junctions with a different class roads, so it is desirable to employ qualified and experienced consulting engineers for the detailed design work.

(7) The massive amount of funds required for the development of the project, will be one of the possible measures to arrange with an external source for financing the project.

(8) The construction cost of 266 million K.Shs is to be invested for the 4th year construction cost of this project, which would be specially appropriated in the Government budget as the amount will occupy a high percentage of it.

JICA