# REPUBLIC OF KENYA FEASIBILITY STUDY ON KILIFI BRIDGE CONSTRUCTION PROJECT



JICA LIBRARY

REPUBLIC OF KENYA FEASIBILITY STUDY ON KILIFI BRIDGE CONSTRUCTION PROJECT

# FINAL REPORT MAIN VOLUME

FEBRUARY 1984

# JAPAN INTERNATIONAL COOPERATION AGENCY

国際協力事	「業団			
受入 月日 '85. 6.14	407			
叠録No. 11601	61.5 SDE		. *	

#### PREFACE

In response to the request of the Government of the Republic of Kenya, the Government of Japan decided to conduct a feasibility study on the Kilifi Bridge Construction Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Kenya a study team headed by Mr. Mamoru Kikuno (Central Consultant Inc.) from February 1983 to August 1983 under the guidance of the Supervisory Committee chaired by Mr. Takeshi Nakayama, Honshu Shikoku Bridge Authority of Japan.

The team held discussions with the officials concerned of the Government of Kenya on the Project and conducted a field survey in Kenya. Subsequently, further studies were made in Japan 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 Kenya for their close cooperation extended to the team.

February 1984

Keisuke Arita President Japan International Cooperation Agency



BIRD'S-EYE VIEW OF KILIFI BRIDGE

. .



14.51

# PROJECT LOCATION MAP-2



:		т. 1. т
	CONTENTS	
Α.	CONCLUSION AND RECOMMENDATION	Δ.1
A.1 A.2	RECOMMENDATION	A.1
в.	SUMMARY	
B.1 B.2	BACKGROUND	в.1 В.1
B.2.1 B.2.2 B.2.3 B.2.4	Traffic Survey	B.1 B.1 B.1 B.2
B.3	FIELD SURVEY	B.2
В.4	ALTERNATIVE ROUTE STUDY	B.4
B.4.1 B.4.2 B.4.3	Preparation of Alternative Routes Description of Alternative Routes Screening of Alternative Routes	в.4 В.4 В.4
B.5	ALTERNATIVE BRIDGE STUDY	B.6
B.5.1 B.5.2 B.5.3 B.5.4 B.5.5 B.5.6	General         Superstructure Type         Foundation Structure Type         Supplementary Bridge Alternative Study         Construction Cost         Screening of Bridge Alternatives	B.6 B.6 B.6 B.9 B.9
B.6	PRELIMINARY ROAD DESIGN	В.9 во
B.6.1 B.6.2 B.6.3	Alignment Design         Cross-section Design         Intersection Design	B.9 B.9 B.10
B.7	PRELIMINARY BRIDGE DESIGN	B.10
B.7.1 B.7.2 B.7.3 B.7.4	General	B.10 B.10 B.12 B.14
B.8	ESTIMATION OF PROJECT COSTS	B.15
<b>B.9</b> B.9.1 B.9.2 B.9.3 B.9.4 B.9.5 <b>B 10</b>	ECONOMIC ANALYSIS         Premises         Economic Cost         Traffic Cost Estimate         Result of Economic Analysis         Sensitivity Analysis         EIMANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM	B.16 B.16 B.16 B.17 B.18 B.18 B.18 B.19
B.10.1 B.10.2	Implementation Schedule Investment Requirement	B.19 B.19
	— i —	

n	VIATIV V		
1	1.	INTRODUCTION	·
1	11	Background	1.
. 1	1.1	Organization of Project	1.
ر. ب	1.2	Study Approach	1
· !	121	Objectives of the Study	1.
, ,	1.3.1	Objectives of the Study	. 1
1	1.3.2	Study Area	1
, ,	1.3.3	Outline of the Study	1
1	1.4	Progress to Date	
	2.	TRAFFIC STUDY	2
7	2.1	General	2
í	2.2	Characteristics of Existing Traffic	2.
	2.2.1	Traffic Flow	2.
-	2.2.2	Traffic Volume	-2.
	2.2.3	Vehicle Composition	2,
	2.2.4	Fluctuation of Traffic Volume	2.
	2.3	Framework for Traffic Projection	2
í.	2.3.1	Procedure	2.
	2.3.2	Traffic Zoning	2.
	2.3.3	Development Outline	2
	2.3.4	Population.	2
-	2.3.5	Tourism	2
,	2.4	Traffic Projection	2
1	2.4.1	General	2.
	242	Normal Traffic	2.
	243	Induced Traffic	2
	2.1.0	Future Traffic Volume	2.
	3.	CHARACTERISTICS OF THE STUDY AREA	
t L	3.1	Natural Condition	3.
	3.1.1	Temperature	3.
	3.1.2	Rainfall	3
	3.1.3	Wind	3
	3.1.4	Tide	3
1	3.1.5	Earthquake	3
	3.2	Field Survey	3
•	3.2.1	Conducted Survey	3.
/	3.3	Subsurface Investigation	3.
	3.3.1	General	3
	3.3.2	Outline of Physiography and Geology	3
	3.3.3	Results of Subsurface Ground Conditions	3
	3.3.4	Some Comments on Coral Limestone and Weak Calcareous Standstone	3.
	335	Aggregate Materials Investigation	3
	34	Development Features of Study Area	3
	341	Existing Landuse Pattern	3
• •	J. 7.1	Existing Road Condition	3
	310	DAMME INDU NOUTION	2
	3.4.2	Existing Institution	J.
	3.4.2 3.4.3	Existing Institution	3. 3

4.	ALTERNATIVE ROUTE STUDY	
4.1	Basic Consideration of Route Location.	4.1
4.1	1 General	4.1
4.1	2 Control Point of Route Location	4.1
4.1	3 Future Landuse	4.2
4.1	4 Kilifi Creek Conditions	4.2
4.2	Design Criteria for Road	4.2
4.3	Proposed Alternative Routes.	4.3
4.3	1 Preparation of Proposed Alternative Routes	4.3
4.3	2 Description of Proposed Alternative Routes	4.3
4.4	Screening of Alternative Routes	4.4
4.4	1 Comparison of Alternative Routes	4.4
4.4	2 Selection	4.4
4.4	3 Conclusion	4.5
5	AT TERMATIVE REINCE STUDY	
э. 		5 1
5.1		5.1
5.2	Alternative Bridge Design	5.1
5.2 5.2	Bridge Length	5.1
5.2	2 Positioning of Piers	53
5.2	Superstructure Design     C. Letweetere Design	5.5
5.2	4 Substructure Design	55
່ ວ.ວ ່	Maior Construction Proceedure	5.5
5.5	Major Construction Procedure     Construction Motorial Quantities	5.5
. 3.3	2 Construction Material Quantities.	5.7
5,3	Supplement to Pridge Alternatives Analysis	5.10
5.4	1 Be exemination of Concrete Circler Bridge	5.10
5.4	2 Be examination of Cohle staved Concrete Girder Bridge	5.12
55	Screening of Alternatives	5.19
5.5	1 Evaluation of Alternatives	5.19
5.5	2 Selection	5.20
J.J		
6.	PRELIMINARY ROAD ENGINEERING	
6.1	General	6.1
6.2	Alignment	6.1
6.2	1 Horizontal Alignment	6.1
6.2	2 Vertical Alignment	6.2
6.3	Cross-section	6.6
6.3	1 Basic Considerations	6.6
6.3	2 Typical Cross-section	6.7
6.4	Pavement Design	6.9
6.4	1 Traffic Class	6.9
6.4	2 Climate	6.9
6.4	3 Subgrade	0.9
6.4	4 Pavement Structure	0.9 6 10
.6.5	Intersection Design	0.10
6.5	Basic Considerations	0.10
6.5	2 I ype of Intersection	0.10
		·
	· · · · · · · · · · · · · · · · · · ·	

1	6.5.3	Intersection Interval	6.11
	6.5.4	Description of Intersection	6.11
	6.6	Resting Areas	6.13
	7	PRELIMINARY BRIDGE DESIGN	
•.	т. т.		7.1
	1.1	introduction	7.1
	7.2	Positioning of Piers and Additions.	71
	7.2.1	Positioning of Piers	71
	7.2.2	Positioning of Abutments	/
	7.3	Superstructure Design	7.5
	7.3.1	Design Criteria.	7.5
	7.3.2	Skeleton	7.9
	7.3.3	Design of Cables	7.13
	7.3.4	Design of Main Girder	7.16
	7,3,5	Design of Tower	7.21
	7.4	Substructure Design	7.24
	7.4.1	Design Criteria	7,24
	7.4.2	Design of Abutments	7.25
	7.4.3	Design of Tower Foundation	7.25
	7.5	Execution Scheme	7.31
	7.5.1	General	7.31
	7.5.2	Temporary Work	7.31
	7.5.3	Construction of Tower	7 34
	7.5.4	Construction of Superstructure	7 36
	7.5.5	Working Process and Main Equipments	7.40
	~	CONTRACTION OF DECISION COST	1.10
	8.	ESTIMATION OF PROJECT COST	0 i.
	8.1	General	Q 1
	8.1.1	Cost Estimation Method	0.1
	8.1.2	Conditions.	0,1
	8.1.3	Basic Cost	0.1
	8.1.4	Construction Cost	0.1
	8.1.5	Foreign Currency	8.1
	8.1.6	Local Currency	8.3
	8.2	Unit Cost Analysis.	8.3
	8.2.1	Components of Unit Cost	8.3
	8.2.2	Cost of Construction Materials and Equipment	8.3
	8.2.3	Labour Cost	8.4
	8.2.4	Hourly Rate of Construction Equipment	8.6
	8.2.5	Result of Unit Cost Analysis	8.6
	8.3	Construction Quantities Estimate	8.12
	8.3.1	General	8.12
	8.3.2	Construction Quantities	8.12
•	8.4	Construction Cost Estimate	8.12
	8.4.1	Bridge Construction Cost	8.12
	8.4.2	Approach Road Construction Cost	8.12
	8.5	Land Acquisition Cost and Compensation.	8.17
÷.	851	Land Acquisition Cost.	8.17
•	857	Compensation	8.18
	U .J . H		
		— iv —	

8.6       Project Cost Estimate       8.18         8.7       Annual Maintenance Cost       8.20         9.       ECONOMIC ANALYSIS       9.1         9.1       General       9.1         9.1.1       Standpoints and Objectives.       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Pactors       9.6         9.1.5       Indices of Investment Efficiency and Evaluation Priod.       9.6         9.2       Economic Cost of Project       9.7         9.3.5       Salvage Values of Facilities at the End of 2013.       9.7         9.3.5       Salvage Values of Facilities at the End of 2013.       9.7         9.3.5       Basefit of Investment Efficiency of Project Pacifities       9.8         9.3.6       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facilities       9.8         9.3.8       Benefit Due to Travel Time Swings.       9.11         9.3.4       Benefit Due to Induced Trafitic       9.22         9.4       Investiment Efficiency of Project       9.22         9.4       Investiment Efficiency of Project       9.22         9.4       Investiment Efficiency of Project       9.22         9.5       Intangible Benefit </th <th>1 . </th> <th></th> <th></th> <th></th> <th></th>	1 . 				
8.6       Project Cost Estimate       8.18         8.7       Annual Maintenance Cost       8.20         9.       ECONOMIC ANALYSIS       9.1         9.1.1       Standpoints and Objectives       9.1         9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Convesion Factors       9.6         9.1.4       Evaluation of Project       9.7         9.2.3       Economic Cost of Project       9.7         9.2.4       Economic Cost       9.7         9.2.3       Salvage Values of Facilities at the End of 2013       9.7         9.3       Tanaglie Benefit of Project       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of Percy Facilities       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of Percy Facilities       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of Percy Facilities       9.1         9.4.4       Investiment Efficiency of Project       9.22         9.3.5       Benefit Due to Avoided Cost of Expansion and Maintenance of Percy Facilities       9.22         9.4.5       Benefit Due to Avoided Cost of Expansion and Maintenance of Percy Facilities					
8.6       Project Cost Estimate       8.18         8.7       Annual Maintenance Cost       8.20         9.       ECONOMIC ANALYSIS       9.1         9.1       General       9.1         9.1.1       Standpoints and Objectives.       9.1         9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Factors       9.6         9.1.5       Indices of Investment Efficiency and Evaluation Priod       9.6         9.2.1       Economic Cost       9.7         9.2.2       Maintenance Cost       9.7         9.2.3       Salvage Values of Facilities at the End of 2013       9.7         9.3       Beineff to Increasing Kenya CDP Through Demand for Domestic       0.6         9.3.3       Beineff to Increasing Kenya CDP Through Demand for Domestic       0.6         9.3.4       Beineff to Increasing Kenya CDP Through Demand for Domestic       0.7         9.3.5       Beineff to Une to Avoide Cost of Expansion and Maintenance of       Perry Yacilities       9.8         9.3.5       Benefit Due to Avoide Cost of Expansion       9.11       9.3       Benefit Due to Veinide Operating Cost Swings       9.17         9.3.6       Sammary of Tan		1		1.11	
8.6       Project Cost Fatimate       8.18         8.7       Annual Maintenance Cost       8.20         9.       ECONOMIC ANALYSIS       9.1         9.1.1       Standpoints and Objectives.       9.1         9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Factors       9.6         9.1.4       Evaluation of Project       9.7         9.2.1       Economic Cost of Project       9.7         9.2.2       Maintenance Cost       9.7         9.2.3       Satvage Values of Project       9.8         9.3.1       Benefit of Increasing Kenya GIP Through Demand for Domestic       0.08         0.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Trayel Time Swings       9.11         9.4       Benefit Due to Trayel Time Swings       9.17         9.3.3       Benefit Due to Trayel Time Swings       9.22         9.4.3       Benefit Due to Trayel Time Swings       9.22         9.4.4       Benefit Due to Trayel Time Swings       9.22         9.4.5       Benefit Due to Valide Or Project       9.22         9.4.6 <td< td=""><td></td><td></td><td></td><td></td><td></td></td<>					
8.6       Project Cost Istimate       8.18         8.7       Annual Maintenange Cost       8.20         9.       ECONOMIC ANALYSIS       9.1         9.1.1       General       9.1         9.1.2       Preinises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Weulexino of Base Price and Conversion Pactors       9.6         9.1.5       Indices of Irvestment Efficiency and Evaluation Priod       9.6         9.2.1       Economic Cost       9.7         9.2.2       Bonomic Cost       9.7         9.2.3       Salvage Values of Pacilities at the End of 2013       9.7         9.3.1       Benefit Of Project       9.8         9.3.1       Benefit On Increasing Kenya GDP. Through Demand for Domestic       0.6         9.3.2       Benefit Due to Anvide Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Tayled Tartike       9.8         9.3.4       Benefit Due to Tayled Tartike Serings       9.17         9.3.5       Benefit Due to Anduce Tartike       9.22         9.4       Investiment Efficiency of Project       9.22         9.4       Investiment Efficiency of Project       9.23         9.5.2       Int		1. A.			
8.7       Annual Maintenance Cost       8.20         9.1       ECONOMIC ANALYSIS         9.1       General       9.1         9.1.1       Standpoints and Objectives       9.1         9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Pactors       9.6         9.1.5       fadices of Investment Efficiency and Pavaluation Priod       9.6         9.2       Economic Cost       9.7         9.2.1       Economic Cost       9.7         9.2.2       Maintenance Cost       9.7         9.3       Tangble Benefit of Project       9.7         9.3.1       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facilities       9.8         9.3.3       Benefit Due to Tavel Time Savings       9.11         9.3.4       Benefit Due to Tavel Time Savings       9.17         9.3.5       Benefit Due to Tavel Time Savings       9.17         9.3.4       Benefit Due to Tavel Time Savings       9.17         9.3.5       Benefit Due to Tavel Time Savings       9.22         9.4.1       Basic Case       9.22         9.4.2       Saving of Tangible Benefit       9.20		8.6	Project Cost Estimate	8.18	
9.         ECONOMIC ANALYSIS         9.1           9.1.1         Standpoints and Objectives         9.1           9.1.2         Premises         9.1           9.1.3         Scope of Economic Analysis         9.2           9.1.4         Evaluation of Base Price and Conversion Pactors         9.6           9.1.5         Indices of Investment Efficiency and Evaluation Priod         9.6           9.2.1         Reconomic Cost         9.7           9.2.2         Maintenance Cost         9.7           9.2.3         Satwage Values of Facilities at the End of 2013         9.7           9.2.3         Bavage Values of Facilities at the End of 2013         9.7           9.3.1         Benefit for Increasing Kenya GDP Through Dennand for Domestic         9.8           9.3.1         Benefit Due to Avoided Cost of Expansion and Maintenance of         9.8           9.3.3         Benefit Due to Tarvel Time Savings         9.11           9.3.4         Benefit Due to Tarvel Time Savings         9.17           9.3.5         Benefit Due to Nulueed Tarific         9.22           9.4.1         Basic Case         9.22           9.4.1         Basic Case         9.22           9.4.1         Basic Case         9.22           9.4		8.7	Annual Maintenance Cost	8.20	
9.1       General.       9.1         9.1.1       Standpoints and Objectives.       9.1         9.1.3       Scope of Economic Analysis.       9.2         9.1.4       Evaluation of Base Price and Conversion Factors       9.6         9.1.5       Indices of Investment Efficiency and Pauluation Priod       9.6         9.1.5       Indices of Investment Efficiency and Pauluation Priod       9.6         9.1.6       Economic Cost       9.7         9.2.1       Balvage Values of Facilities at the End of 2013.       9.7         9.3.1       Balvage Values of Facilities at the End of Domestic       0.00         1.6       Coods and Scruces in Construction Stage of Facilities       9.8         9.3.1       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Vavided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Vavide Operating Cost Savings       9.17         9.3.4       Benefit Due to Vavide Operating Cost Savings       9.17         9.3.5       Benefit Due to Vavide Operating Cost Savings       9.17         9.3.4       Benefit Due to Vavide Operating Cost Savings       9.17         9.3.4<		9.	ECONOMIC ANALYSIS	·	
9.1.1       Standpoints and Objectives       9.1         9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Factors       9.6         9.1.5       Indices of Investment Efficiency and Evaluation Priod       9.6         9.2.1       Economic Cost of Project       9.7         9.2.2       Maintenance Cost       9.7         9.3.3       Satvage Values of Pacilities at the End of 2013       9.7         9.3.1       Benefit Of Increasing Kenya GDP Through Demand for Domestic       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.4       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.4       Benefit Due to Vende Operating Cost Savings       9.11         9.3.5       Benefit Due to Vende Operating Cost Savings       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Tangible Benefit       9.24         9.5       Intangible Benefit of Efficiency of Project       9.23		91	General	01	
9.1.2       Premises       9.1         9.1.3       Scope of Economic Analysis       9.2         9.1.4       Bvaluation of Base Price and Conversion Factors       9.6         9.1.5       Indices of Investment Fficiency and Evaluation Priod       9.6         9.2.1       Economic Cost       9.7         9.2.2       Maintenance Cost       9.7         9.2.3       Salvage Values of Facilities at the End of 2013       9.7         9.3       Tangible Bonefit of Project       9.8         9.3.1       Benefit of Increasing Konya GDP Through Demand for Domestic       60ods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facilities       9.8       9.3         9.3.3       Benefit Due to Induced Traffic       9.15       9.3.5       Benefit Due to Induced Traffic       9.11         9.3.4       Benefit Due to Vacide Operating Cost Savings       9.17       9.3.6       Summary of Tangible Benefit       9.22         9.4.1       Basic Case       9.22       9.4.1       Basic Case       9.22         9.4.3       Summary of Invastment Efficiency of Project       9.23       9.24       9.5         9.4.3       Summary of Invastment Efficiency of Project       9.23 <td< td=""><td></td><td>911</td><td>Standnoints and Objectives</td><td>0.1</td><td></td></td<>		911	Standnoints and Objectives	0.1	
9.1.3       Scope of Economic Analysis       9.2         9.1.4       Evaluation of Base Price and Conversion Factors       9.6         9.1.5       Indices of Investment Efficiency and Evaluation Priod       9.6         9.2       Economic Cost of Project       9.7         9.2.1       Beonomic Cost of Project       9.7         9.2.2       Maintenance Cost       9.7         9.3.1       Banefit of Increasing Konya GDP Through Demand for Domestic       9.8         9.3.1       Benefit Due to Avoided Cost of Expansion and Mintenance of       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Mintenance of       9.8         9.3.3       Benefit Due to Travel Time Savings.       9.11         9.3.4       Benefit Due to Ventice Operating Cost Savings       9.11         9.3.5       Benefit Due to Travel Time Savings.       9.12         9.4       Investiment Efficiency of Project       9.22         9.4       Investiment Efficiency of Project       9.22         9.4       Investiment Efficiency of Project       9.23         9.5       Intargible Benefit       9.24         9.5       Intargible Benefit       9.24         9.5       Intravestiment Efficiency of Project       9.23         9.5		912	Prémises	91	* a
9.1.4       Evaluation of Base Price and Conversion Pactors       9.6         9.1.5       Indices of Investment Efficiency and Evaluation Priod       9.6         9.2.1       Economic Cost       9.7         9.2.2       Maintennoe Cost       9.7         9.2.3       Salvage Values of Facilities at the End of 2013       9.7         9.2.3       Salvage Values of Facilities at the End of 2013       9.7         9.3.1       Benefit of Project       9.8         9.3.2       Benefit for Increasing Kenya GDP Through Demand for Domestic       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Avoided Testings       9.11         9.3.4       Benefit Due to Travel Time Savings       9.11         9.3.5       Benefit Due to Induced Traffic       9.15         9.3.6       Suminary of Tangible Benefits       9.20         9.4.1       Investiment Efficiency of Project       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.22         9.4.4       Investment Efficiency of Project       9.23         9.5       Intrasec of Emalysis       9.22         9.5.1       Intras		913	Scope of Economic Analysis	92	
9.1.5       Indices of Investment Efficiency and Evaluation Priod.       9.6         9.2       Economic Cost       9.7         9.2.1       Economic Cost       9.7         9.2.2       Maintenance Cost       9.7         9.3.3       Salvage Values of Facilities at the End of 2013.       9.7         9.3.7       Tangible Benefit of Project       9.8         9.3.1       Benefit of Increasing Kanya GDP Through Dennand for Domestic       Goods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       Ferry Facilities       9.1         9.3.4       Benefit Due to Induced Traffic       9.1       9.3         9.3.5       Benefit Due to Taylet Time Savings       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.4       Investiment Efficiency of Project       9.24         9.5.1       Intraggible Benefit       9.24         9.5.2       Increase of Employments at Construction Stage		9.1.4	Evaluation of Base Price and Conversion Factors	9.6	
9.2       Economic Cost of Project       9.7         9.2.1       Economic Cost       9.7         9.2.2       Salvage Values of Facilities at the End of 2013.       9.7         9.3       Tangible Benefit of Project       9.8         9.3.1       Benefit of Increasing Konya GDP Through Demand for Domestic       6         Goods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Travel Time Savings.       9.11         9.3.4       Benefit Due to Tavel Time Savings.       9.11         9.3.5       Benefit Due to Vehicle Operating Cost Savings.       9.17         9.3.6       Summary of Tangible Benefits       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5.1       Introvenent in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.5.5		9.1.5	Indices of Investment Efficiency and Evaluation Priod	9.6	
9.2.1       Economic Cost       9.7         9.2.2       Maintenance Cost       9.7         9.3       Salvage Values of Pacilities at the End of 2013       9.7         9.3       Tangible Benefit of Project       9.8         9.3.1       Benefit of Increasing Kenya GDP Through Demand for Domestic       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Travel Time Savings       9.17         9.3.5       Benefit Due to Induced Traffic       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       National Economy         9.5.2       9.6 <t< td=""><td></td><td>9.2</td><td>Economic Cost of Project</td><td>9.7</td><td></td></t<>		9.2	Economic Cost of Project	9.7	
9.2.2       Maintenance Cost       9.7         9.3       Salvage Values of Pacifities at the End of 2013       9.7         9.3       Tangible Benefit of Project       9.8         9.3.1       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facifities       9.8         9.3.3       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facifities       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Induced Traffic       9.15         9.3.5       Benefit Due to Induced Traffic       9.15         9.3.6       Bunmary of Tangible Benefit       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Insettivity Analysis       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Tangible Benefit       9.24         9.5       Intangible Benefit       9.24         9.5.1       Intangible Benefit       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Efficiency of Project on Kenya       9.25         9.5.3       Technolo		9.2.1	Economic Cost	9.7	
9.2.3       Salvage Values of Facilities at the End of 2013		9.2.2	Maintenance Cost	9.7	
9.3       Tangible Benefit of Project       9.8         9.3.1       Benefit of Increasing Konya GDP Through Demand for Domestic Goods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Pacilities       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Induced Traffic       9.15         9.3.5       Benefit Due to Vehicle Operating Cost Savings       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Tangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.1       Improvement in Transport Functions Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.6       Conclusion of Economic Analysis       10.1         10.1       Standpoints and Objectives       10.1         10.1.1       Standpoints and Objectives       10.1<		9.2.3	Salvage Values of Facilities at the End of 2013	9.7	
9.3.1       Benefit of Increasing Kenya GDP Through Demand for Domestic         Goods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of       9.8         9.3.3       Benefit Due to Induced Traffic       9.15         9.3.4       Benefit Due to Induced Traffic       9.15         9.3.5       Benefit Due to Induced Traffic       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.4.4       Investment Efficiency of Project       9.23         9.5.1       Intragible Benefit       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.5.4       Promotion of Economic Analysis       9.26         10.       FiNANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       Standpoints and Objectives	. · · .	9.3	Tangible Benefit of Project	9.8	
Goods and Services in Construction Stage of Facilities       9.8         9.3.2       Benefit Due to Avoided Cost of Expansion and Maintenance of Ferry Facilities       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Travel Time Savings       9.17         9.3.5       Benefit Due to Vehicle Operating Cost Savings       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.6       Conclusion of Economic Analysis       9.26         9.6       FinANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1.3       Standpoints and Objectives       10.1         10.1.3       Standpoints and Objectives       10.2         10.4		9.3.1	Benefit of Increasing Kenya GDP Through Demand for Domestic		
9.3.2       Benefit Due to Avoided Cosi of Expansion and Maintenance of Ferry Facilities       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Travel Time Savings       9.15         9.3.5       Benefit Due to Vehicle Operating Cost Savings       9.17         9.3.6       Summary of Tangible Benefit       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.3       Technology Transfer.       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       0.2         10.1       General       10.1         10.1.2       Promises of Financial Analysis       10.2         10.2       Project Cost at Current Price       10.4         10.3       Scope of Financial Analysis       10.2         10.4       Evaluation Indication Price Used in this Analysis       10.2         10.4<			Goods and Services in Construction Stage of Facilities	9.8	
Ferry Facilities       9.8         9.3.3       Benefit Due to Travel Time Savings       9.11         9.3.4       Benefit Due to Induced Traffic       9.15         9.3.5       Benefit Due to Vehicle Operating Cost Savings       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.26         9.6       Conclusion of Economic Analysis       9.26         9.6       Conclusion of Economic Analysis       10.1         10.1       General       10.1         10.2       Premises of Financial Analysis       10.2         10.4		9.3.2	Benefit Due to Avoided Cost of Expansion and Maintenance of	5. E 14	
9.3.3       Benefit Due to Travel Time Savings.       9.11         9.3.4       Benefit Due to Induced Traffic.       9.15         9.3.5       Benefit Due to Vehicle Operating Cost Savings.       9.17         9.3.6       Summary of Tangible Benefits.       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5.1       Introvernent in Transport Functions and Its Impacts       9.24         9.5.1       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.26         0       Conclusion of Economic Analysis       9.26         9.6       Conclusion of Economic Analysis       0.26         10.1       General       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.2       Forecast of Related Prices       10.4 <td></td> <td></td> <td>Ferry Facilities</td> <td>9.8</td> <td>:</td>			Ferry Facilities	9.8	:
9.3.4       Benefit Due to Induced Traffic.       9.15         9.3.5       Benefit Due to Vehicle Operating Cost Savings.       9.17         9.3.6       Summary of Tangible Benefits.       9.20         9.4       Investiment Efficiency of Project.       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis.       9.22         9.4.3       Summary of Investment Efficiency of Project.       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.2       Estination of Project Cost at	•	9.3.3	Benefit Due to Travel Time Savings.	9.11	
9.3.5       Benefit Due to Vehicle Operating Cost Savings       9.17         9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4		9.3.4	Benefit Due to Induced Traffic	9.15	•
9.3.6       Summary of Tangible Benefits       9.20         9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sentivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5.1       Intragible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.26         9.6       Conclusion of Economic Analysis       9.26         9.6       Conclusion of Economic Analysis       9.26         9.6       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       General       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4		9.3.5	Benefit Due to Vehicle Operating Cost Savings	9.17	
9.4       Investiment Efficiency of Project       9.22         9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.5.4       Promotion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost at Current Price       10.4         10.3.1       Condition and Methodology       10.4		9.3.6	Summary of Tangible Benefits	9.20	:
9.4.1       Basic Case       9.22         9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project.       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3       Raising of Project Funds       10.4         10.3.1       C		9.4	Investiment Efficiency of Project	9,22	
9.4.2       Sensitivity Analysis       9.22         9.4.3       Summary of Investment Efficiency of Project       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.6       Conclusion of Economic Analysis       9.26         9.6       Conclusion of Economic Analysis       9.26         9.6       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1       Bestimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment		9.4.1	Basic Case	9.22	
9.4.3       Summary of Investment Efficiency of Project.       9.23         9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.5.4       Promotion of Economic Analysis       9.26         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       Standpoints and Objectives       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Fore		9.4.2	Sensitivity Analysis	9.22	
9.5       Intangible Benefit       9.24         9.5.1       Improvement in Transport Functions and Its Impacts on Local Community       9.24         9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1       Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7		9.4.3	Summary of Investment Efficiency of Project.	9.23	
<ul> <li>9.5.1 Improvement in Transport Functions and Its Impacts on Local Community 9.24</li> <li>9.5.2 Increase of Employments at Construction Stage 9.25</li> <li>9.5.3 Technology Transfer 9.25</li> <li>9.5.4 Promotion of Tourist Industry and Its Effects on Kenya National Economy 9.25</li> <li>9.6 Conclusion of Economic Analysis 9.26</li> <li>10. FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM</li> <li>10.1 General 10.1</li> <li>10.1.1 Standpoints and Objectives 10.1</li> <li>10.1.2 Premises of Financial Analysis 10.2</li> <li>10.1.4 Evaluation Indication Price Used in this Analysis 10.2</li> <li>10.2 Estimation of Project Cost at Current Price 10.4</li> <li>10.2.1 Forecast of Related Prices 10.4</li> <li>10.3.1 Condition and Methodology 10.4</li> <li>10.3.2 Plan for Raising Foreign Currency of Project Cost and its Repayment 10.7</li> </ul>		9.5	Intangible Benefit	9.24	
on Local Community9.249.5.2Increase of Employments at Construction Stage9.259.5.3Technology Transfer9.259.5.4Promotion of Tourist Industry and Its Effects on Kenya9.259.6Conclusion of Economic Analysis9.2610.FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM10.1General10.110.1.1Standpoints and Objectives10.110.1.2Premises of Financial Analysis10.210.1.4Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price10.410.3Raising of Project Funds10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		9.5.1	Improvement in Transport Functions and Its Impacts		
9.5.2       Increase of Employments at Construction Stage       9.25         9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM       10.1         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.2         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7	1	0.5.0	on Local Community	9.24	
9.5.3       Technology Transfer       9.25         9.5.4       Promotion of Tourist Industry and Its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.2       Premises of Financial Analysis       10.1         10.1.2       Premises of Financial Analysis       10.1         10.1.3       Scope of Financial Analysis       10.2         10.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3       Raising of Project Funds       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7		9.5.2	Increase of Employments at Construction Stage	9.25	· .
9.3.4       Promotion of Fourist industry and its Effects on Kenya National Economy       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.2       Premises of Financial Analysis       10.1         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.3.2       Project Cost of Current Price       10.4         10.3.3       Condition and Methodology       10.4         10.3.4       Toroid roin and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7		9.5.3	Lechnology Transfer	9.25	
9.6       Conclusion of Economic Analysis       9.25         9.6       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.1         10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3       Raising of Project Funds       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7		9.3.4	Notional Research States and its Effects on Kenya	0.05	
9.0       Conclusion of Economic Analysis       9.26         10.       FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM         10.1       General       10.1         10.1.1       Standpoints and Objectives       10.1         10.1.2       Premises of Financial Analysis       10.1         10.1.3       Scope of Financial Analysis       10.2         10.1       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.3       Raising of Project Funds       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7		06	Conduction of Reenomia Analysis	9.25	
10.FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM10.1General10.110.1.1Standpoints and Objectives10.110.1.2Premises of Financial Analysis10.110.1.3Scope of Financial Analysis10.210.1.4Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price10.410.2.1Forecast of Related Prices10.410.2.2Project Cost of Current Price10.410.3Raising of Project Funds10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		9.0		9.20	
10.1General10.110.1.1Standpoints and Objectives10.110.1.2Premises of Financial Analysis10.110.1.3Scope of Financial Analysis10.210.14Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price10.410.2.1Forecast of Related Prices10.410.2.2Project Cost of Current Price10.410.3Raising of Project Funds10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		10.	FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM		
10.1.1Standpoints and Objectives10.110.1.2Premises of Financial Analysis10.110.1.3Scope of Financial Analysis10.210.14Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price10.410.2.1Forecast of Related Prices10.410.2.2Project Cost of Current Price10.410.3Raising of Project Funds10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		10.1	General	10.1	•
10.1.2Premises of Financial Analysis.10.110.1.3Scope of Financial Analysis.10.210.1.4Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price.10.410.2.1Forecast of Related Prices.10.410.2.2Project Cost of Current Price.10.410.3Raising of Project Funds.10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		10.1.1	Standpoints and Objectives	10.1	
10.1.3       Scope of Financial Analysis       10.2         10.1.4       Evaluation Indication Price Used in this Analysis       10.2         10.2       Estimation of Project Cost at Current Price       10.4         10.2.1       Forecast of Related Prices       10.4         10.2.2       Project Cost of Current Price       10.4         10.2.3       Raising of Project Funds       10.4         10.3       Raising of Project Funds       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7         -v -		10.1.2	Premises of Financial Analysis	10.1	a da ser da s
10.1.4Evaluation Indication Price Used in this Analysis10.210.2Estimation of Project Cost at Current Price.10.410.2.1Forecast of Related Prices10.410.2.2Project Cost of Current Price.10.410.3Raising of Project Funds10.410.3.1Condition and Methodology10.410.3.2Plan for Raising Foreign Currency of Project Cost and its Repayment10.7		10.1.3	Scope of Financial Analysis	10.2	
10.2       Estimation of Project Cost at Current Price.       10.4         10.2.1       Forecast of Related Prices.       10.4         10.2.2       Project Cost of Current Price.       10.4         10.3       Raising of Project Funds.       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7         -v -       -v -       -v -		10.1.4	Evaluation Indication Price Used in this Analysis	10.2	
10.2.1       Forecast of Related Prices.       10.4         10.2.2       Project Cost of Current Price.       10.4         10.3       Raising of Project Funds.       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7         -v -		10.2	Estimation of Project Cost at Current Price.	10.4	
10.2.2       Project Cost of Current Price		10.2.1	Forecast of Related Prices	10.4	-
10.5       Raising of Project Funds       10.4         10.3.1       Condition and Methodology       10.4         10.3.2       Plan for Raising Foreign Currency of Project Cost and its Repayment       10.7         -v -       -v -		10.2.2	Project Cost of Current Price.	10.4	
10.3.1 Condition and Methodology 10.4 10.3.2 Plan for Raising Foreign Currency of Project Cost and its Repayment 10.7 -v -		10.3	Kaising of Project Funds	10.4	
- v -		10.3.1	Condition and Methodology	10.4	
		10.3.2	rian for Raising Poreign Currency of Project Cost and its Repayment	10.7	
	· · ·			n senta. R	
				• •	
			$\mathcal{T}_{\mathbf{r}}$ , we have $\mathcal{T}_{\mathbf{r}}$ , $\mathcal{T}$		1 - 1 - <sup>1</sup>
		. :	n en		
	÷ .				

1033	Fund Raising for Local Currency of Project	10.7
10.3.4	Possibility of Road Users' Bearing Maintenance Cost, Repayment of	
	Project Cost and Interest on Fund	10.10
10.4	Conclusion	10.14
10.4.1	Investment Requirement for This Project	10.14
10.4.2	Fund Raising for Investment Requirement	10.14
10.4.3	Implementation Schedule	10.14

÷	1.	DATA FOR DESIGN OF BRIDGE	AP-1
	2.	JETTY CONSTRUCTION COST ESTIMATE	AP-5
	3.	LIST OF STAFFING	AP-7
	4.	LIST OF REPORTS	AP-10

Ne av La L

# MAIN VOLUME

		. · ·
	LIST OF TABLES	
	이는 사람들은 것 같아요. 이는 것 않아요. 이는 집 않아요. 이는 것 않아요. 이는 것 않아요. 이는 것 않아요. 이는 않아요. 이는 것 이는 것 않아요. 이는 않아요. 이는 것 않아요. 이는 않아요. 이는 것 않아요. 이는 않아요. 이는 않아요. 이는 않아요. 이는 것 않아요. 이는 않아요. 이 않아요. 이는 않아	
MAIN VOLU	n de la companya de IME	
Table 2–1	TRAFFIC VOLUME	2.2
Table 2–2	NUMBER OF VEHICLE BY VEHICLE TYPE	2.2
Table 2–3	PRINCIPAL PROGRAMMES OF DEVELOPMENT PLAN	2.7
Table 2-4	PROJECTED POPULATION BY AREA (1979 TO 2010)	2.8
Table 2–5	HOTEL BEDS OCCUPANCY AT COASTAL-BEACH AREA	2.9
Table 2–6	ESTIMATED FUTURE TRAFFIC VOLUME BY YEAR AND BY PURPOSE	2.11
Table 2–7	ESTIMATED FUTURE TRAFFIC VOLUME BY YEAR	
	AND BY VEHICULAR TYPE	2.12
Table 3–1	DESCRIPTIONS OF LAYERS	3.10
Table 4–1	DESIGN ELEMENTS OF ROAD	4.2
Table 4–2	COMPARISON OF ALTERNATIVE ROUTES	4.6
Table 51	ALTERNATIVE SUPERSTRUCTURE TYPES	5.3
Table 5-2	STEEL BRIDGE CONSTRUCTION QUANTITIES.	5.8
Table $5-3$	P.C. BRIDGE CONSTRUCTION QUANTITIES	5.9
Table $5-4$	PROJECT COST	5.10
Table $5-5$	COMPARISON OF BRIDGE CONSTRUCTION COST	5.10
Table 5 -6	CONSTRUCTION COST OF P.C. GIRDER ( $x \approx 210 \text{ m}$ )	5.11
Table $5-7$	VARIATIONS OF ALTERNATIVE (3).	3.12
Table 5–8	(CABLE STAYED CONCRETE GIRDER)	5.14
Table 5–9	CONSTRUCTION COST OF CABLE STAYED CONCRETE GIRDER ( $\varrho = 250 \text{ m}$ ) ALT. (3)-1	5.15
Table 5-10	CONSTRUCTION COST OF CABLE STAYED CONCRETE GIRDER ( $\ell$ = 280 m) ALT. (3)-2	5.16
Table 5-11	CONSTRUCTION COST OF CABLE STAYED CONCRETE GIRDER ( $\ell = 320$ m) ALT, (3)-3	5.17
Table 512	CONSTRUCTION OCST OF CABLE STAYED CONCRETE GIRDER ( $g = 210 \text{ m}$ ) ALT (3)	5.18
Table 6–1	SCALE USED IN DESIGN	6.1
Table 6–2	TYPE OF INTERSECTION	6.11
Table 7–1	UNIT WEIGHTS OF MATERIALS	7.6
Table 7–2	T-LOADINGS	7.6
Table 7–3	L-LOADINGS	77
Table 7–4	UNIFORM LOAD FOR SIDEWALKS	7.7
Table 7–5	REINFORCEMENT	70
Table 7–6	PRESTRESSING BAR	7.9
Table 7-7	CABLE	70
Table 7–8	DESIGN UNIT STRESS OF MAIN GIRDER	7.20
Table 7–9	DESIGN FORCE AND WORKING STRESS OF TOWER	7 01
Table 7–10	RESULT OF CALCULATION FOR STABILITY	1 21
	OF ABUTMENT	7.27

vii –

÷	Table 7-11	STABILITY OF PILES	7.30
	Table 7–12	WORKING PROCESS OF CONSTRUCTION OF BRIDGE	7.40
	Table 7–13	MAIN EQUIPMENTS FOR BRIDGE WORKS AND THEIR PERIOD FOR USE (1)	7.41
	Table 7–14	MAIN EQUIPMENTS FOR BRIDGE WORKS AND THEIR PERIOD FOR USE (2)	7.42
	Table 8–1	MARKET PRICE OF MAJOR DOMESTIC MATERIALS	8.4
	Table 8–2	COST OF FOREIGN PRODUCTS	8.5
	Table 8-3	LABOUR COST.	8.6
	Table 8-4(A)	SCHEDULE OF DAYWORKS	8.7
	Table 8–4(B)	SCHEDULE OF DAYWORKS	8.8
	Table 8-4(C)	SCHEDULE OF DAYWORKS	8.9
	Table 8–5	UNIT COST FOR BRIDGE	8.10
	Table 8–6	UNIT COST FOR APPROACH ROAD	8.11
	Table 8–7	BRIDGE CONSTRUCTION QUANTITIES	8.13
	Table 8–8	APPROACH ROAD QUANTITIES	8,14
	Table 8–9	BRIDGE CONSTRUCTION COST	8.15
	Table 8–10	APPROACH ROAD CONSTRUCTION COST	8.16
	Table 8–11	PROJECT COST	8.18
	Table 8-12	CONSTRUCTION SCHEDULE	8.19
	Table 8–13	PROJECT COST BY YEAR	8.19
	Table 8-14	ANNUAL MAINTENANCE COST OF BRIDGE	8.20
	Table 9–1	PROJECTION OF TRAFFIC VOLUMES	9.2
	Table 9–2	CONVERSION FACTORS FOR VALUES AT DOMESTIC MARKET PRICE	9.6
	Table 9–3	PROJECT COST	9.7
	Table 9–4	ANNUAL MAINTENANCE COST	9.7
	Table 9–5	BENEFIT OF INCREASING KENYA GDP	9.8
	Table 9–6	PURCHASE/CONSTRUCTION COSTS OF FERRY FACILITIES	9.10
	Table 9–7	EXPANSION PLAN OF FERRY FACILITIES	9.10
	Table 98	PROJECTION OF PURCHASE/CONSTRUCTION COST AND OPERATING/MAINTENANCE COST OF FERRY FACILITIES	9.11
	Table 9-9	ANNUAL HOURS SAVED BY THE PROJECT. WHEN	
		PASSING THROUGH THE PROJECT PLANNED AREA	9:13
	Table 9–10	PASSENGER NUMBERS	9 14
	Table 9–11	TIME VALUE PER HOUR IN 1983	9 14
1 1	Table 9–12	BENEFIT DUE TO TIME SAVINGS	9.15
	Table 9–13	BENEFIT DUE TO INDUCED TRAFFIC.	9.16
	Table 9–14	VEHICLE OPERATING COST (VOC) PER KILO METERS	9.19
	Table 9–15	FIXED COST IN VOC PER OPERATING HOUR	9.19
	Table 9–16	BENEFIT DUE TO VEHICLE OPERATING COST SAVINGS	9.20
	Table 9–17	ECONOMIC BENEFITS OF THE PROJECT	9.21
		<b>– viii</b> –	

			a a t
			1.
	Table 9–18	BENEFIT COST RATIOS AND ECONOMIC INTERNAL RATES OF RETURN OF THE PROJECT, CHANGING THE PROJECT COST AND THE CONSTRUCTION PERIOD	9.23
	Table 9–19	LOCAL EMPLOYEES FOR CONSTRUCTION OF	
		FACILITIES	9.25
	Table 9–20	PROJECTION OF TOURIST TRAFFIC	9.25
	Table 921	BENEFIT OF INCREASING KENYA GDP THROUGH TOURIST EXPENDITURE	9.26
	Table 10-1	PROJECTION OF ANNUAL INCREASING RATE OF UNIT PRICE	10.4
	Table 10-2	PROJECT COST AT CURRENT PRICE BY FOREIGN CURRENCY (F.C) AND LOCAL CURRENCY (L.C)	10.5
	Table 10-3	PROBABLE METHODS OF FUNDING PROJECT COST	10.6
	Table 10–4	SUPPOSED METHOD OF RAISING FUNDS FOR PROJECT COST AND MAINTENANCE COST	10.6
	Table 10–5	FOREIGN CURRENCY	10.7
	Table 10-6	ANNUAL AMOUNT OF REPAYMENT OF CAPITAL AND INTEREST	10.8
	Table 10–7	AMOUNT OF LOCAL CURRENCY NEED TO BE RAISED DURING THE CONSTRUCTION PERIOD	10.9
	Table 10-8	CURRENT AND CAPITAL EXPENDITURE ON ROADS IN KENYA	10.9
	Table 10–9	AMOUNT OF LOCAL CURRENCY NEEDED TO BE RAISED DURING OPERATION PERIOD (1990 ~ 2013)	10.10
	Table 10-10	TOLL CHARGE AT NEW NYALI BRIDGE	10.11
	Table 10-11	BALANCE OF EXPANDITURE AND REVENUE OF BUSINESS ENTITY	10.12
	Table 10-12	TOLL CHARGES TO COVER THE MAINTENANCE COST DURING THE OPERATING PERIOD	10.13
	Table 10-13	INVESTMENT REQUIREMENT.	10.14
	Table 10–14	IMPLEMENTATION SCHEDULE	10.15
	5. S.		
• •			· · ·

— ix —

## LIST OF FIGURES

## MAIN VOLUME

	-		
Fig	g. 1−1	LOCATION OF THE STUDY AREA	1.3
Fi	g. 2—1	MONTHLY VARIATION	2.3
Fig	g. 22	DAILY VARIATION	2.3
Fi	g. 2–3	HOURLY FLUCTUATION	2.4
Fig	g. 2–4	GENERAL FLOW CHART	2.5
Fig	g. 2-5	LOCATION OF TRAFFIC ZONES	2.6
Fi	g. 26	ESTIMATED FUTURE TRAFFIC VOLUME	2.12
Fi	g. 3−1	AVERAGE MONTHLY TEMPERATURE	3.1
Fi	g. 3–2	AVERAGE MONTHLY RAINFALL	3.1
Fi	g. 3–3	DATUM LINE OF THE STUDY	3.2
Fi	g. 3–4	SURVEY SITE LOCATION	3.3
Fi	g. 3—5	PHYSIOGRAPHICAL MAP OF KILIFI-MAZERAS AREA	3.6
Fi	g. 3–6	GEOLOGICAL MAP	3.7
Fi	g. 3–7	PHYGICAL GEOLOGY OF THE STUDY AREA	3.8
Fi	g. 3–8	TYPICAL CROSS-SECTION FOR SOUTH OF CREEK	3.8
Fi	g. 3–9	SOIL PROFILE ALONG KILIFI BRIDGE LINE	3.9
Fi	g. 3–10	SUMMARIZED GRADING MIXTURE	3.10
Fi	g. 3–11	PRIMARY POROSITY SOLUTION ENLARGEMENT	3.11
Fi	g. 3–12	SECONDARY POROSITY ENLARGED	3.11
Fi	g. 3–13	GRADING OF AGGREGATE MATERIAL	3.13
Fi	g. 3–14	LOCATION OF POTENTIAL SOURCES OF AGGREGATES	3.13
Fi	g. 3–15	FUTURE DEVELOPMENT PLAN OF KILIFI	3.21
Fi	g. 4–1	LOCATION OF PROPOSED ALTERNATIVE ROUTES	4.7
Fi	g. 5–1	POSITIONING OF PIERS	5.2
Fi	g. 5–2	ALTERNATIVE BRIDGE PLAN	5.4
Fi	g. 5–3	PROFILES OF VARIATIONS OF ALTERNATIVE (3)	5.13
Fi	g. 6–1	HORIZONTAL ALIGNMENT PLAN	6.4
Fi	g. 6–2	VERTICAL ALIGNMENT PLAN	6.5
Fi	g. 6–3	CROSS-SECTION TYPE	6.8
Fi	g. 6–4	MEASUREMENT OF PAVEMENT STRUCTURE	6.10
Fi	g. 65	LOCATION OF INTERSECTION.	6.12
Fi	g. 71	PROFILE AND SUBSURFACE CONDITION OF SEABED AROUND PIERS	7.2
Fi	g. 7-2	PROFILE AND SUBSURFACE CONDITION OF AROUND ABUTMENTS	7.3
$\mathbf{F}^{\mathrm{i}}$	ig. 73	GENERAL VIEW OF KILIFI BRIDGE	7.4
Fi	g. 7–4	WIDTH OF BRIDGE	7.5
Fi	g. 7–5	T-LOADINGS	7.6
Fi	g. 7–6	L-LOADINGS	7.7
Fi	ig. 7–7	POSITIONING OF CABLE PLANES	7.11

— x -

17:0 7 8	MECHANICAL CONFICUE ATION
Fig, 7=0	DESIGN TENSILE STRENGTH AND CROSS SECTION
г.ц. /9	OF STAYED CABLE
Fig. 7–10	DETAIL OF ANCHORAGE
Fig. 7-11	CROSS-SECTION OF CABLE
Fig. 7–12	CROSS-SECTION OF MAIN GIRDER
Fig. 7–13	BENDING MOMENT DIAGRAM OF MAIN GIRDER
Fig. 7–14	TOWER
Fig. 7–15	REINFORCEMENTS ARRANGEMENT OF TYPICAL
	CROSS-SECTION OF TOWER
Fig. 7–16	ABUTMENT
Fig. 7–17	SOIL CONDITION AND PENETRATION OF PILES
Fig. 7–18	ARRAGNEMENT OF PILES 7.29
Fig. 7–19	CONSTRUCTION PROCEDURE
Fig. 720	CONSTRUCTION METHOD
Fig. 721	CONCEPTIONAL PLAN OF PILE CONSTRUCTION
Fig. 7-22	BOTTOM SCAFFOLDING FOR FOOTING
Fig. 7-23	CONCEPTIONAL WORKING PLAN OF MAIN GIRDER
Fig. 7–24	CONCEPTIONAL PLAN OF CANTILEVER CARRIAGE
Fig. 8–1	FLOW OF COST ESTIMATION PROCESS
Fig. 9-1	SCOPE OF ECONOMIC ANALYSIS 9.4
Fig. 9-2	BENEFIT OF KILIFI BRIDGE PROJECT
Fig. 9–3	METHOD OF CALCULATION OF BENEFITS FOR
Fig 94	TIMES CONSUMED TO PASS THROUGH PLANNED
8,	AREA IN THIS PROJECT 912
Fig. 101	SCOPE OF THE FINANCIAL ANALYSIS
<u> </u>	
· · · ·	

-xi

# **CONCLUSION AND RECOMMENDATION**



# A . CONCLUSION AND RECOMMENDATION

### A.1 CONCLUSION

- 1. The result of the economic study shows that the Benefit Cost Ratio (B/C) is 1,088 and Economic Internal Rate of Return (EIRR) is 12.89%, hence this project can be considered as firmly profitable.
- 2. The project cost is estimated at 359,608,000 K.Shs. at 1983 prices. A major portion of which is for the construction of the bridge.
- 3. The selected crossing point of the bridge over the creek is at about 400 meters down stream from the existing ferry crossing (B-Route).
- 4. The selected bridge design is the cable stayed concrete girder type that has a total length of 420 meters and a central span of 250 meters.

#### A.2 RECOMMENDATION

- 1. This project is judged to be a very benefitial project from the Kenya national economy and social perspectives, its implementation at the earliest possible time is recommended.
- 2. Before the preparation of any detailed engineering design of the project, further investigation such as the topographic survey, the subsurface investigation, the material survey and the bathymetric survey should be carried out.
- 3. The technology for the construction of the cable stayed concrete bridge has made a remarkable progress in recent years. The proposed bridge in this study, having a central span of 250 meters would be one of the longest bridge of this kind in the world.

Therefore, it is desirable that the new construction technology and the valuable knowledge of the experts will be employed and reflected in the design and the construction of this bridge.



## **B**. SUMMARY

#### B.1 BACKGROUND

The east coast of Kenya especially the coastal line has a high potential for development. The historical, meteorological, socio-economic and environmental conditions of this area are very promising. The B--8 road on which the Kilifi Bridge will be constructed and which passes through this high potential area is therefore a very important link in the transportation network of these area.

The development plans for Kilifi, Malindi, Tana River and Lamu were prepared by the Ministry of Urban Development and Housing Physical planning Department and be implemented gradually. Following their implementation, the traffic volume on the B-8 road will be expected to increase rapidly. The crossing on the Kilifi creek is currently done by selfpropelled pontoon ferries whose load capacity restrictions prohibit heavy trucks which are over 15 ton load. The crossing has for a long time been a major bottleneck on this important road and subsequently a constraint to development along the B-8 road. Taking into account the high development potential area and the problems of the crossing of the Kilifi creek, the Kilifi Bridge is required to be constructed as soon as possible. The construction of this bridge will mean that the traffic flow and the activities along the B-8 road will be supported.

#### B.2 TRAFFIC STUDY

#### B.2.1 Traffic Survey

The following traffic surveys were carried out in this project:

- (a) Supplementary origin-destination survey for vehicles.
- (b) Traffic counting survey of vehicles.
- (c) Spent time survey at Kilifi Ferry.
- (d) Passengers counting survey at ferries and bus/matatu stops.

#### B.2.2 Characteristics of Existing Traffic Flow

From the result of the traffic surveys, the following characteristics are arraived at;

- (a) The main generative and attractive zones of trips passing through Kilifi Creek Crossing are Mombasa, Malindi and Kilifi. The ratio for all generated and attracted traffic volume is 87%.
- (b) Peak hours in the morning and the evening can be seen at 7.00 to 8.00 and 17.00 to 18.00 from the hourly flow with Kilifi Ferry Census data.
- (c) Average ferry waiting time of vehicles moving from north to south at 7.00 to 10.00 and 16.00 to 18.00 on 16th March, are found to be 11.9 minutes and 11.0 minutes respectively. An average waiting time for vehicle moving from the reverse direction at 7.00 to 10.00, 16.00 to 18.00 on 16th March, are 12.8 minutes respectively.

(d) It can be seen from the hourly pedestrians flow that the maximum number of pedestrians moving from north to south are 235 persons and the maximum number of pedestrians moving from south to north are 342 persons per day. Also the average pedestrians for 12 hours are 134 persons from north to south and 202 persons from south to north respectively.

#### B.2.3 Forecast of Future Traffic Volume

The following components are taken into consideration:

(a) Normal traffic

Normal traffic growth, i.e. the growth when the ferry service is retained and regularly expanded to maintain the present level of service is forecasted on the basis of the O-D Table.

(b) Induced traffic

Induced traffic volume is forecasted at 30 percent of the normal traffic volume based on the notable variation of traffic volume before and after the construction of the New Mtwapa bridge.

#### B.2.4 Future Traffic Volume

On the basis of the traffic survey, population and development analysis, the future traffic volume is forecasted as shown in Table B-1.

Year		Vehicle	Total	Total		
	Light	Medium	Heavy	Bus	Vehicles	P.C.U.
1983	589	201	93	: 100	983	1,617
1990	1,108	361	166	179	1,814	2,949
2000	1,913	574	266	284	3,037	4,847
2010	3,303	887	410	438	5,038	7,831

#### Table B-1 FUTURE TRAFFIC VOLUME

#### **B.3 FIELD SURVEY**

In order to gain knowledge of the physical conditions of the study area, the following surveys were conducted in June and July, 1983:

- (a) Bathymetric Survey.
- (b) Sub-surface Investigation.
- (c) Topographic Survey.

The survey sites are illustrated in Fig. B-1.




– B.3 –

## **B.4 ALTERNATIVE ROUTE STUDY**

#### B.4.1 Preparation of Alternative Routes

Taking into account the various considerations of route location, topographic feature, existing and future development situation, three alternative routes: route A, route B and route C are prepared as shown in Fig. B-2.

#### **B.4.2** Description of Alternative Routes

## (a) Alternative Route A:

This route A is selected with its creek crossing at the shallowest part of the Kilifi Creek, located at 450 meters upstream from the 132 KV clectric power line and runs parallels to this electric power line.

#### (b) Alternative Route B:

Route B is selected with its crossing at the narrowest section of the Kilifi Creek at which the telephone and telegram communication line passes and is 400 meters downstream from the existing ferry operating line.

### (c) Alternative Route C:

Route C is selected with its crossing at a comparatively narrow and comparatively shallow area of the Kilifi Creek. There is a ford which is located in front of the Kilifi Club, the depth of which is between 2 and 7 meters. This area is 150 meters off-shore.

# B.4.3 Screening of Alternative Routes

Judging from the economic, technical and environmental perspectives, the alternative Route B is selected for preliminary design.



Fig. B-2 LOCATION OF PROPOSED ALTERNATIVE ROUTES

# **B.5 ALTERNATIVE BRIDGE STUDY**

## B.5.1 General

The alternative bridge study is carried out on the base of the topographic survey, subsurface investigation, bathymetric survey and sufficient reconnaissance survey.

A total bridge length of 420 meters is selected and design for the positioning of bridge piers is much dependent on the Kilifi creek condition.

Considering the positioning of piers are illustrated in Fig. B--3.

# B.5.2 Superstructure Type

Judging the span length from case 1 to case 4, suitable superstructure types are examined. Drawing the knowledge and experience of the bridge engineer and the examination of the actual bridge construction in the past, the superstructure type is decided. Additionally, the input of the following planning perspectives are considered:

- (a) Economic perspective.
- (b) Technical perspective.
  - \* Structural stability.
  - \* Construction method and condition.
  - \* Maintenance.
- (c) Environmental Aesthetics.

With these considerations and perspectives, five (5) different superstructure types are arrived at:

- (a) Cable Stayed Steel Girder.
- (b) Steel Truss.
- (c) Cable Stayed Concrete Girder.
- (d) Concrete Girder with a hinge by free cantilevering method.
- (e) Concrete Girder with three Hinges free Cantilevering method.

The prepared superstructure types are illustrated in Fig. B-4.

#### **B.5.3** Foundation Structure Type

Taking into account the economical aspects, the construction difficulty, site condition and the construction materials situation, the Pile Bent Type is adopted.

#### B.5.4 Supplementory Bridge Alternative Study

The supplementary study is carried out to examine the effects of varying the central span length on alternative (3) on the construction costs.

The supplementary alternatives bridge type are as follows;

(a)	Alternative (3)–1	Central span length	250 meters
(b)	Alternative (3)-2	Central span length	280 meters
(c)	Alternative (3)-3	Central span length	300 meters
	·]	B.6 —	



Fig. B-3 POSITIONING OF PIERS

– B.7 –



#### B.5.5 Construction Cost

The construction costs for the bridge alternatives are shown in Table B-2.

Table B-2	CONSTRUCTION	COST	OF	ALTERNATIVES

(Unit 1,000 K.Shs.)

ARRANGE AND A STREET	Alt.(1)	Alt.(2)		Alt	Alt(4)	Alt.(5)		
Item			(3)	(3)–1	(3)-2	(3)3	· · · · · · ·	
Bridge	296,889	282,292	282,655	264,164	303,739	336,967	283,877	274,697

# B.5.6 Screening of Bridge Alternatives

The cable-stayed concrete girder bridge with a central span of 250 meters in length Alt. (3)-1 is selected for this feasibility study.

The reasons are as follows:

- (a) The construction costs of Alt. (3)-1 is the minimum as shown in the alternative construction cost analysis.
- (b) The construction workability of foundation for Alt. (3)-1 is superior from the others due to its location at shallower water.
- (c) Alt. (3)-1 has a wide under-clearance, with ample rooms for the passage of ships both recreational and commercial. Moreover, the profile of this alternative is also compatible to the surrounding natural features.

# B.6 PRELIMINARY ROAD DESIGN

# B.6.1 Alignment Design

1) Horizontal Alignment

On the basis of the alternative Route B alignment, the horizontal alignment is planned.

In the project site, the arrangement between the alignment on the map and actual site is carried out by highway engineer and the final alignment is arrived.

2) Vertical Alignment

Taking into consideration the existing ground level, navigation clearance, and environmental aesthetics, a 1.5 percent grade on both sides of the bridge is adopted for the bridge.

### B.6.2 Cross-Section Design

Using the Design Manual prepared by M.O.T.C., the following element of the cross-section are adopted.

(a) Lane width is 7.0 meter (2 lane road).

- B.9 -

- (b) Shoulder width is 2.50 meter for the road and 0.75 meter for the bridge.
- (c) Pedestrianway width is 2.00 meters on both sides in urban areas.

### B.6.3 Intersection Design

At grade intersections are planned for the intersections between the project road and the existing roads.

# **B.7 PRELIMINARY BRIDGE DESIGN**

# B.7.1 General

In this chapter, a more detailed study is carried out on the design of the cable stayed prestressed concrete girder bridge with a central span of 250 meters and a total bridge length of 420 meters which is proposed as the result of the alternative bridge study.

#### B.7.2 Design Criteria

The study is in accordance with the following design criteria.

#### 1) Dimension

(a)	Design of bridge	Cable stayed presstressed concrete girder

(b) Length of bridge420 m(c) Length of spans85 m + 250 m + 85 m

Width of bridge	
Total width	12.5 m
Width of carriageway	8.5 m
Width of sidewalk	$2 \times 2.0 \text{ m} = 4.0 \text{ m}$
	Width of bridge Total width Width of carriageway Width of sidewalk

(e) Horizontal road alignment Straight

- (f) Angle of bridge Rectangular (90°)
- (g) Head Clearance
   Carriageway
   Sidewalk
   5.25 m above the top of the road surface
   2.50 m above the top of the road surface

#### 2) Design Loads

(a) Live loading (Traffic loads)

The live loading for the main structure shall be in accordance with the Specifications for Highway Bridges published by the Japan Raod Association to a carry TL-20 Loading.

(b) Wind load

A design wind speed of 30 m/sec shall be applied for the girder, tower and stayed cables. This is determined using the data recorded at the Mombasa Ras Serani Station which is the nearest station at Kilifi.

– B.10 –



- B.11 --

----

# (c) Effect of Temperature

The range of the effective bridge temperature shall be  $\pm 5^{\circ}$ c and the effective temperature difference within the superstructures shall be  $5^{\circ}$ c. These are determined using the data recorded at three stations in Malindi, Kilifi and Mombasa.

### B.7.3 Superstructure

### B.7.3.1 Skeleton

1) Arrangement of cables

Arrangement of cables is designed as follows:

(a) Multi-cable design

The multi-cable design which has many cables stretched between the tower and main girder and arranged with relatively small intermediate supporting points is selected. This design is recommendable for such a bridge that has a relatively long span and must be constructed by cantilevering method.

(b) Harp-shaped pattern

The harp-shaped pattern which is considered to be the most rational for this bridge is adopted.

(c) Double-cable-plane arrangement

The double-cable-plane arrangement is adopted to avoid the carriageway being divided into two and ensuring a higher utility of the road space.

## 2) Height of tower

The height of tower above the road surface is determined to be 60.75 meters. The ratio of the height of the tower to the central span is 1 : 4.1 and the angle of the top cable in the central span is placed at  $27^{\circ}$ .

3) Mechanical configuration

The mechanics configuration as shown in Fig. B-6 is adopted from the economical point of view.





The main girder is rigidly connected with the towers. As a result of this design, a movable hinge is required at the centre of the central span to release the expansion and shrinkage caused by the temperature change.

# B.7.3.2 Design of Cables

1) Kind of cable

The spiral wire strand is adopted for the stayed cable considering that this must be a popular one though it must be protected completely against corrosion.

Each strand has a diameter of 15.2 millimeters and is composed of wires each with a diameter of 5 millimeters. Each cable is inturn composed of 19 to 37 strands in demand to the design tensile strength.

# 2) Anchorage

For the ancorage of cables, the Fressinet anchor which is one of the more popular anchorages is applied.

#### B.7.3.3 Design of Main Girder

The cross-sectional configuration of the main girder is shown in Fig. B-7. As shown in the figure, the main girder has a mono-box configuration and the web of the box form an angle of  $27^{\circ}$  with the vertical (pitch 1 : 2) in due consideration of the aerodynamic stability.

The depth of the main girder is 2.40 meters except a portion near the tower where the main girder has a greater depth of 3.70 m to sustain the greater bending moment.

#### B.7.3.4 Design of Tower

The tower which is made of reinforced concrete has two pillars corresponding to the cables of double planes. The bottom part the pillar is connected directly with the footing on the foundation piles.

Two pillars are connected with thick beam which supports the main girder and strut which against such horizontal thrust as wind force, and make up a rigid frame.



Fig. B-7 CROSS-SECTION OF MAIN GIRDER

# B.7.4 Substructure

# B.7.4.1 Design of Abutments

As known from the results of the geotechnical investigation, on either land side, the stiff coral limestone which is expected to be the bedrock is encountered within 3 meters to 5 meters deep below the ground surface.

The foundation of the abutment shall be the spread footing type that is to rest on this coral limestone layer.

The height of the abutment and the breadth of footing are 10 meters and 6 meters. These dimensions are the same on both Mnarani side and Kilifi side.

The negative force of 25 tons to 429 tons works from the superstructure to the abutment. In order to use the abutment as a counter weight, the main girder of superstructure is ancored to the abutment by P.C. strands.

# B.7.4.2 Design of Tower Foundation

1) Foundation type

As described in the Alternative study, the pile foundation which is composed

of the cast-in-place piles by the reverse circulation method is adopted.

2) Diameter of pile

The design diameter of piles shall be 2.0 meters from the following reason;

The diameter generally used in the cast-in-place by the reverse circulation drilling method is 1.0 meters to 2.0 meters. In the case where the diameter of the pile is over 2.0 meters, the construction cost rises radically because a special drilling machine in needed. For diameter of 1.0 to 2.0 meters, the result of comparison indicates that the diameter of 2.0 meters is the most economical.

#### 3) Penetration depth

As known from the results of the geotechnical investigation, the stiff silty sand is encountered within 2 meters to 4 meters below the seabed. Although most of this silty sand layer is very hard and compact with N-Value of over 60, relatively loose layer with N-Value of approximately 25 to 40 is encountered in 25 meters to 32 meters deep below MSL. At these points, the pile shall penetrate through this loose layer to a 35 meters depth below MSL.

4) Arrangement of piles

Number of piles of each foundation designed is eighteen (18). These are arranged in three rows in the direction of span each having six piles.

# **B.8 ESTIMATION OF PROJECT COSTS**

- 1) The project costs consists of the construction cost, engineering fee, land acquisition, compensation and contingency.
- 2) Based on the preliminary engineering study, the quantities for main work items are calculated. Subsequently, the unit cost by main work items are analysed from the aspects of material cost, labour cost, construction equipment, etc. taking also into consideration the local condition in Kenya.
- 3) The project costs are split into two comportents, that is foreign currency and local currency.
- 4) The Project costs are culculated in 1983 prices.
- 5) The project costs are shown in Table B-3.

		100201 00	(In <sup>.</sup> 1	,000 K.Shs.)
Item	Currency	F.C.	L.C.	T.C.
	Bridge	219,582	46,071	265,653
	Approach Road	13,618	10,849	24,467
	Construction Cost	233,200	56,920	290,120
	Engineering Fee	27,851	6,963	34,814
	Land Aquisition	·	1,612	1,612
	Compensation	-	370	370
	Sub-Total	261,051	65,865	326,916
Coi	ntingency	26,105	6,587	32,692
Total		287,156	72,452	359,608

# Table B-3 PROJECT COST

Note: 1) The project cost is expressed in July 1983 prices. 2) The price contingency is not considered.

# **B.9 ECONOMIC ANALYSIS**

#### B.9.1 Premises

Basic premises for the economic analysis are as follows;

- (a) Construction period Six (6) years,  $1984 \sim 1989$
- (b) Project cost
- (c) Raise of project cost
- (d) Projection of traffic volumes
- (e) Level of ferry survice

Keeping the existing level

Abroad (Soft Loan)

in Chapter 2

359,608,000 K.Shs. at 1983 constant price

# B.9.2 Economic Cost

The economic cost is estimated considering the conversion factors of the main construction working items, materials, and labor cost. The total economic cost is 339,771,000 K.Shs., and detailed costs are shown in Table B-4.

#### Table B-4 ECONOMIC COST

- - - -

			(Unit: 1.0	<u>00 K shs. 1</u>	<u>.983 Const</u>	<u>ant/Econo</u>	mic Price)
At	1984	1985	1986	1987	1988	1989	Total
Financial Price	6,382	12,767	50,967	90,171	119,230	80,091	359,608
Economic Price	6,275	12,552	48,288	84,020	113,088	75,548	339,771
Economic Cost/Financial Cost							

# B.9.3 Traffic Cost Estimate

# B.9.3.1 Time Value

The time values in 1983 estimated on the incomes of the vehicle users, waiting charge of heavy goods vehicle and numbers of persons whose time values are shown in Table B-5.

				(Unit: K	.Shs./Hour, 1	983 Price)
Type of Vehicle	0	Light Goods Vehicle		Medium	Heavy	
At	Car	Owner	Matatu	Vehicle	Vehicle	Dus
Market Price	94	84	99			240
Economic Price	88	79	93	40	150	224

Table B5	TIME	VALUES	PER	HOUR	IN	1983	

### B.9.3.2 Vehicle Operation Cost

Taking into account the characteristics and the accuracy of the related information collected at Mombasa, sub-classifications and definitions of the vehicle operating costs are estimated as shown in Table B-6 and B-7.

# Table B-6 VEHICLE OPERATING COST (VOC) PER KILO METERS

			- 1 C			
Typc of Vehicle	Car	Light Goo	ds Vehicle	Medium Goods	Heavy Goods	Bus
VOC Item	Cai	Owner	Matatu	Vehicle	Vehicle	
Variable Costs	0.901	1.397	1.397	2.284	4.189	2.533
Fuel	0.686	0.979	0.979	1.640	3.055	1.603
Engine oil	0.024	0.037	0.037	0.067	0.084	0.078
Repair	0.191	0.381	0.381	0.577	1.050	0.852
Fixed Costs	0.884	1.454	2.048	2.907	10.479	7.786
Depreciation	0.411	0.958	0.958	0.695	3.489	4.559
Interest Costs	0.258	0.271	0.271	0.442	0.070	0.966
Crew Costs			0.594	0.818	1.164	0.701
General Admi- nistration				0.584	1.168	0.758
Insurance Costs	0.215	0.225	0.225	0.368	2.588	0.802
Total	1.785	2.851	3.445	5.191	14.668	10.319

(Unit: K.Shs./Km, 1983 Economic Price)

Table B-7 FIXED COST IN VOC PER OPERATING HOUR

Type of Vehicle Light Goods Vehicle Medium Heavy Fixed Costs Item Car Goods. Goods Bus Owner Matatu Vehicle Vehicle Depreciation 6.58 26.09 26.09 18.35 74.54 48.70 **Interest Costs** 7.37 7.37 4.13 11.79 44.23 41.28 Crew Costs 3) 16.18 21.85 29.97 24.86 General Administ-12.48 24.96 32.39 ration Insurance Costs 3.44 6.14 6.14 9.83 55.29 34.40 Total 14.15 39.60 55.78 74.50 223.88 186.74

(Unit: K.shs/Hour, 1983 Ecohomic Price)

# B.9.4 Result of Economic Analysis

On the basis of the future traffic volume, traffic cost and economic cost, the following results of the economic analysis are arrived.

(a) Net Present Values\*

Economic cost	200,331,000 K.shs.
Economic benefit	217,882,000 K.shs.
NPV	17,551,000 K.shs.
Note * : in 1983	•
Annual disco	ount rate 12%

(b) Benefit Cost Ratio (B/C) 1.088

(c) Economic Internal Rate of Return (EIRR) 12.89%

# B.9.5 Sensitivity Analysis

The sensitivity analysis is carried out on the basis of the changing project cost and construction period. The results of the sensitivity analysis are shown in Table B-8.

	Table B-8	RESULT	OF	SENSITIVITY	ANALYSIS
--	-----------	--------	----	-------------	----------

(Unit: %)

Project Cost Construction Period	10% Increase	Base	10% Decrease
One Year Prolongation (7 years)	11.81	12.65	13.62
Base (6 years)	12.01	12.89	14.22
One Year Shortening (5 years)	12.08	12.97	14.02

# B.10 FINANCIAL ANALYSIS AND IMPLEMENTATION PROGRAM

# B.10.1 Implementation Schedule

Taking into account the results of the economic analysis, construction cost and the construction method on the project road, the implementation schedule is arrived as shown in Table B-9.

Worki	ing Item		1984	1985	1986	1987	1988	1989
Engin	neering and Evaluation		N.C.					
Land	sation							
Temp				<b>PAGE</b>		1		
	Foundations	P.						
	roundations	P <sub>1</sub>				, in the second s	<b>7</b> .	
	Abutments	A <sub>1</sub>				類		
Bridge		Α,				1		
		P,				22		
	Towers	P <sub>2</sub>		:			(CENT	
	Superstructure	- <b>I</b>						
	Surface and Facilities						:	
	Approach Roads							
Roads	Access Roads	<u> </u>						

Table B-9 IMPLEMENTATION PROGRAM

# B.10.2 Investment Requirement

Based on the implementation schedule and financial analysis, the investment requirement on each year is estimated as shown in Table B--10.

Table B-10 INVESTMENT REQUIREMENT

		(Unit: 1,0	00 K.shs, Current Price)
Year	Foreign Currency	Local Currency	Total
1984	5,642	1,424	7,066
1985	12,470	3,405	15,875
1986	54,209	16,240	70,449
1987	102,273	37,644	139,917
1988	162,784	44,305	207,089
1989	116,889	45,991	162,880
Total	454,267	149,009	603,276

– B.19 –



# MAIN VOLUME

# **1.INTRODUCTION**

# 1.1 BACKGROUND

The east coast of Kenya especially the coastal line has a high potential for development. The historical, meteorological, socio-economic and environmental conditions of this area are very promising. The B-8 road on which the Kilifi Bridge will be constructed and which passes through this high potential area is therefore a very important link in the transportation network of these area.

The development plans for Kilifi, Malindi, Tana River and Lamu were prepared by the Ministry of Urban Development and Housing Physical Planning Department and be implemented gradually. Following their implementation, the traffic volume on the B-8 road will be expected to increase rapidly. The crossing on the Kilifi creek is operated by selfpropelled pontoon ferries whose load capacity restrictions prohibit heavy trucks which are over 15 ton load. The crossing has for a long time been a major bottleneck on this important road and subsequently a constraint to development along the B--8 road. Taking into account the high development potential area and the problems of the crossing of the Kilifi creek, the Kilifi Bridge is required to be constructed as soon as possible. The construction of this bridge will mean that the traffic flow and the activities along the B-8 road will be supported.

# 1.2 ORGANIZATION OF PROJECT

The project is being carried out jointly by JICA and the Government of Kenya, in collaboration with other related agencies. The organization for the Study is as follows.



# 1.3 STUDY APPROACH

#### 1,3.1 Objectives of the Study

- (1) To carry out a feasibility study for the construction of the Kilifi Bridge, including its approach roads.
- (2) The Study is to act as a means of technology transfer from JICA to the counterparts of the Republic of Kenya.

# 1.3.2 Study Area

The study area covers the proposed bridge site at the Kilifi creek and its vicinity. The latter is necessary for the planning of the bridge approach roads. The study area is shown in Fig. 1-1.

### 1,3,3 Outline of the Study

The major study items are as follows:

- (1) Traffic and Socio-Economic Study
  - a) Traffic data collection, traffic survey and analysis
  - b) Collection and analysis of socio-economic data
  - c) Review of population and socio-economic conditions
  - d) Forecast of future traffic demand
- (2) Engineering Study
  - a) Topographic map acquisition
  - b) Collection and analysis of engieering data
    - b-1 soil and geological data
    - b-2 hydrological and hydrographic data
    - b-3 materials data
    - b-4 meteorological data
  - c) Surveying
    - c-1 bathymetric survey
    - c-2 subsurface investigation
    - c-3 topographic survey
  - d) Design criteria
    - d-1 geometric design standards
    - d-2 structural design standards
  - e) Engineering works
    - e-1 design works
    - e-2 quantity estimation
  - f) Construction program
    - f-1 construction method
    - f-2 construction schedule
  - g) Cost estimates
    - g-1 right-of-way acquisition cost
    - g-2 construction cost
    - g-3 maintenance cost
- (3) Economic Evaluation
  - a) Estimates of benefit
  - b) Estimates of NPV, IRR, and B/C
  - c) Sensitivity analysis

- 1.2 --



- 1.3 -

- (4) Budget and Financial Study
- (5) Implementation Program

An implementation program be prepared based on the construction program and the budget and financial study.

# 1.4 PROGRESS TO DATE

- (1) The Study was commenced on 23rd of February, 1983 when the meeting between the MOTC officials, the Supervisory Committee of JICA and the Study Team was held to discuss the Inception Report to be executed in the study.
- (2) In March, the reconnaissance survey, data collection and various traffic surveys were carried out.
- (3) In April, analysis of the collected data, identifications of the design criteria and preparation of the alternative routes were carried out and on the 15th of April, a meeting between the Study Team and MOTC was held to discuss the basic technical matters.
- (4) In May, examinations of the technical problems for design and selection of the alternative routes were carried out and on these basis the Progress Report was prepared.
- (5) On the 31st of May, 1983 a meeting between the Supervisory Committee of JICA, the MOTC officials and the Study Team was held to discuss the Progress Report to be executed in the Study. The Progress Report was submitted to the MOTC officials.
- (6) In June and July, the subsurface investigation, bathymetric survey, topographic survey, the examination of the bridge type, cost estimation and preliminary economic study were carried out.
- (7) On the 25th of August, 1983 a meeting between the Supervisory Committee of JICA, the MOTC officials and the Study Team was held to discuss the Interim Report. The Interim Report was submitted to the MOTC officials.
- (8) In September, October and November, the preliminary design was carried out and the Draft Final Report was prepared in Japan.
- (9) On the 14th of December, 1983 a meeting between the Supervisory Committee of JICA, the MOTC officials and the Study Team was held to discuss the Draft Final Report. The Draft Final Report was submitted to the MOTC officials.

- 1.4 -

# 2. TRAFFIC STUDY

# 2,1 GENERAL

- (1) The Kilifi creek crossing is situated on the national trunk road B-8 between Mombasa and Malindi, approximately 55 kilometers north of Mombasa. The present crossing transportation facilities consist of a 24 hours ferry service operated by the Ministry of Transport and Communications. The ferry is free of charge to the road-users.
- (2) Several traffic surveys are conducted upon an examination of the existing traffic data. The surveys are to obtain the information of vehicles using the ferry on Kilifi creek crossing.
- (3) The results of these surveys are used for the future traffic projection after the construction of the Kilifi bridge.

The survey that is carried out consists of the following:

- a) Supplementary origin-destination survey for vehicles
- b) Traffic counting survey for vehicles
- c) Spent time survey for Kilifi ferry transportation
- d) Passengers counting survey in ferries and at bus/matatu stops

# 2.2 CHARACTERISTICS OF EXISTING TRAFFIC

#### 2.2.1 Traffic Flow

Based on the origin-destination (O-D) survey data, the traffic flow can be recognized as follows.

- (1) The main traffic flow passing through the Kilifi creek crossing is composed of trips between Mombasa and Malindi. This traffic accounts for 50 percent or more of all vehicles.
- (2) The ratio accounted by the main O-D pairs (Mombasa Malindi, Mombasa Kilifi, Kilifi Central and Mombasa Tana River, Lamu, Garrissa) is approximately 90% of the total traffic volume on Kilifi creek crossing.
- (3) The main generation and attraction places of trips passing through Kilifi creek crossing are Mombasa, Malindi and Kilifi. The ratio for all the generated and attracted traffic volume is 87%.

# 2.2.2 Traffic Volume

Based on the traffic volume counting survey data and O–D survey data, the traffic volume by purpose on the Kilifi creek crossing for a period of 12 hours (7 a.m - 7 p.m) is shown in Table 2–1.

-- 2.1 --

					Ministra President	ante d'Anna Managataile			<u>(V/12H)</u>
Place Purpose	Kilifi	Central	Malindi	Northern	Southern	Mombasa	Tana River Lamu Garissa	Nairobi	Total
Going to work	25	10	17	→	1	51	2	-	106
Business	68	17	139	7	15	191	13	2	452
Going home	9	1	12	_	_	9	1	-	32
Tourism	3	2	20	-	-	37	0	3	65
Personal	3	0	4 *	-	: 	· 1		-	8
Others	2	-	5	<u> </u>	-	1	· <u>-</u>	· _	8
Total	110	30	197	7	16	290	16	5	671

Table 2-1 TRAFFIC VOLUME

# 2.2.3 Vehicle Composition

The vehicle composition on the Kilifi creek crossing is shown in Table 2-2.

Table 2-2	NUMBER	OF	VEHICLES	BY VEHICLE	TYPE
	(converted	to p	assenger car	unit)	

Vehicle Date Type	Car	Light	Medium	Heavy	Bus	Motor Cycle	Total
16th/3	156	257	470	59	138	12	1,092
	(14.3)	(23.5)	(43.0)	(5.9)	(12.6)	(1.1)	(100.0)
17th/3	149	262	417	59	162	7	1,056
	(14.1)	(24.8)	(39.5)	(5.6)	(15.3)	(0.7)	(100.0)
Average	153	260	445	59	150	9	1,076
	(14.2)	(24.2)	(41.4)	(5.5)	(13.9)	(0.8)	(100.0)

Note: the upper: No. of vehicles/12hrs PCU the lower: percentage (%)

# 2.2.4 Fluctuation of Traffic Volume

#### (1) Monthly Variation

A monthly variation correction factor, expressed as the Average Monthly Daily Traffic divided by the ADT (Average Annual Daily Traffic), has been calculated for each month in 1982 and is given in Fig. 2-1. Fig. 2-1 shows that January, April and December are the peak months and May, June, July, October and November are the low months, while February, March, August and September have average daily traffic flows close to the annual average.

(2) Daily Variation

The daily variation pattern is given in Fig. 2-2, which indicates that Tuesdays and Saturdays are the peak days while Sundays are the low days. The vehicular composition on Sundays is observed to differ from other days.



Fig. 2-1 MONTHLY VARIATION





(3) Hourly Variation

The hourly fluctuation is shown in Fig. 2–3 which shows that 7:00 to 10:00 and 15:00 to 18:00 are the peak hours. The peak hour ratios are 11.0% at 15:00 to 16:00 on 16th March and 9.2% at 16:00 to 17:00 on 17th March, 1983. The ratio of 24 hours to 12 hours is 1.18 which coincides with the result of Traffic Census.

- 2.3 --





2.4

# 2.3 FRAMEWORK FOR TRAFFIC PROJECTION

# 2.3.1 Procedure

On the basis of the various traffic surveys which were carried out in March, 1983, examination of population trend, analysis of the hotel bed occupancy, consideration of the development pressure and analysis of the related traffic data, the projection of the future traffic volume is carried out. The general flow chart of the traffic projection procedure is shown in Fig. 2-4.





- 2.5 -

1. 1.

# 2.3.2 Traffic Zoning

Based on the result of the O–D survey, the existing road network, existing and future landuse pattern and characteristics of the areas, the traffic zoning is decided. Basically, the traffic zones are divided equally by each division in the Kilifi district. The traffic zoning is illustrated in Fig. 2–5.



Fig. 2-5 LOCATION OF TRAFFIC ZONES

# 2.3.3 Development Outline

This section contains the summary of development outline which complies with the "District Development Plan" 1979–83 (January 1980) for the coastal area consisting of Kilifi, Tana River, Lamu and Garissa districts.

Generally, these areas are regarded as high potential areas with respect to the growth of population and the agriculture sector. However, the present road network is not adequate to (facilitate the flow of goods between) the centres of production and marketing as well as the movement of labour power.

The principal programmes and projects are depicted in Table 2-3.

Table 2-3 PRINCIPAL PROGRAMMES OF DEVELOPMENT PLAN (1979-83)

				Kilifi (Coast Pr)	Tana River (Coast Pr)	Lamu (Coast Pr)	Garissa (Eastern Pr)	Total
	1965	) Sensu	S	307,563	50,696	23,961	64,521	446,741
ion	1979	) Sensu	s	430,986	92,401	42,299	128,867	694,553
ulat	(Anı	ual Gr	owth Ratio)	(5.3%)	(6.2%)	(6.5%)	(7.2%)	(4.5%)
Pop	1983	Projec	sted	507,100	N/A	N/A	N/A	N/A
	2000	) Projec	sted	1,058,800	N/A	N/A	N/Á	N/A
	s		Cashewnuts	9	18	72	N/A	
	crea %)	~ ^	Coconuts	67	1	295	N/A	
	t In te (9	975	Mangoes	N/A	81	371	N/A	·
	oduc Ra		Simsim	88	71	222	N/A	. at
iltúr	Pro	Cotton		. 9	63	162	N/A	· · · · · · · · · · · · · · · · · · ·
Agrict	iture n)	Integrated Agriculture Development Programme		15	9	0	. 9	33
	pend	Tract	or Hire Service	2	2	0	2	6
	р. Ехі Shs. п	Small Progr	-Scale Irrigation amme	··· 4	0	2	1	7
•	Dev (	Total		21	11	2	12	46
Live (Shs	stock millio	Develo n)	pment Expenditure	36	25	19	4	84
		Rural	Water Supplies	11	1	9	2	
vp.	ure ion)	Water	Conservation	8	N/A	3	N/A	
r De	ndit mill	Mino	r Water Programme	4	1	1	1	
Vatei	xpe shs.	Mino	r Irrigation	- 1	N/A	N/A	1	
~	ਗ਼ਗ਼	. Lives ment	tock Water Develop-	N/A	30	N/A	51	

# 2,3,4 Population

The projected future population in each zone is shown in Table 2-4. The future population is forecasted by the growth rate method based on Population Census data with reference to the District Development Plans.

Further, this projected future population in each zone is adjusted to fit the estimated future population in each province that was projected in the National Transport Study in 1983.

			and the second state	Name and Address of the Owner of	-		States of the second	C. TRANSPORT	and the second
Zone	1969	1979	1983	1985	1990	1995	2000	2005	2010
TEZO/ROKA (KILIFI)	10,797	42,605 (7.44)	58,100	67,100	95,800	135,800	191,300	260,100	351,100
CENTRAL (Excluding) TEZO/ROKA)	33,425	42,732 (2.48)	48,200 1.0	50,700 1.052	57,200 1.187	64,100 1.330	71,300 1.479	76,500 1.587	81,600 1.693
MALINDI Div.	71,956	124,476 (5.83)	158,600 1.0	177,100 1.117	232,400 1.465	302,800 1.909	391,800 2.470	489,600 3.087	807,300 3.829
NORTHERN Div.	47,239	65,983 (3.40)	77,200 1.0	82,500 1.069	97,200 1.259	113,800 1.474	132,400 1.715	148,600 1.925	165,700 2.146
SOUTHERN Div.	112,493	149,749 (2.90)	171,800	182,100 1.060	209,500 1.219	239,500 1.394	271,900 1.583	29,800 1.735	324,300 1.888
KILIFI District	307,568	433,510 (3.49)	513,900 1.0	559,500 1.089	692,100 1.347	856,000 1.666	1,058,800 2.060	1,272,800 2,477	1,530,000 2.977
MOMBASA	247,073 (4.70)	341,148 (3.30)	388,500 1.0	414,500 1.067	487,600 1.255	573,500 1.476	674,600 1.736	793,500 2.042	933,400 2.403
TANA RIVER	50,696	92,321 (8.20)	117,400 1.0	132,400 1.128	178,900 1.524	241,700 2.059	326,500 2.781	441,100 3.757	595,900 5.076
LAMU	22,401	42,000 (8.50)	54,000 1.0	61,300 1.135	84,000 1.556	115,000 2.130	157,600 2.919	215,900 3.998	295,800 5.478
GARISSA	84,521	129,000 (7.20)	147,500 1.0	157,700 1.069	188,300 1.263	220,300 1.494	260,300 1.765	307,700 2.086	363,700 2.466
NAIROBI	509,000 (5.60)	828,000 (5.00)	1,018,000 1.0	1,128,000 1,108	1,434,000 1.409	1,803,000 1.771	2,293,000 2.252	2,916,000 2.864	3,709,000 3,643

Table 2-4 PROJECTED POPULATION BY AREA, (1979 to 2010)

Note: The future population in each zone was forecasted based on population Census data. The growth rate of population in each zone is prepared as the following:

> KILIFE MOMBASA TANA RIVER LAMU GARISSA NAIROBI

District = 4.3% (1983-2000), 3.75% (2000-2010) District = 3.3% District = 6.2% District = 6.5% District = 3.4% District = 5.3% (1983-1985), 4.9% (1985-2010)

# 2.3.5 Tourism

Data of hotel beds occupancy from 1972 to 1981 at the Coastal-Beach area is prepared for the forecasting of tourist traffic. The time series data is shown in Table 2-5.

A hotel bed-nights data is analysed and a future annual growth rate of 8.5 percent is obtained.

									(01111.10	oo bea mgi
Average	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Coastal Beach	763.2 (100)	812.5 (108)	950.9 (125)	1,149.4 (151)	1,354.4 177)	1,543.6 (202)	1,654.0 (217)	1,809.8 (237)	2,055.3 (269)	2,039.1 (267)
KENYA	2,474.7 (100)	2,783.8 (112)	2,979.0 (120)	3,208.8 (130)	3,573.7 (144)	3,887.9 (155)	3,982.3 (161)	4,338.1 (175)	3,717.3 (191)	4,691.0 (190)
Annual	Growth Ra	ate: Coasta	l — Beach	1972 - 1976 - (1970 -	- 1981 - 1981 - 1980)	11.5% 8.5% (14.8%)			·	
		KENY	Α	1972 -	- 1981	7.4%				

1976 - 1981

(1970 - 1980)

Table 2–5	HOTEL I	BEDS	OCCUPANCY	AΤ	COASTAL - BEAG	)H	AR	EA
						111	nit•	1000 Red-nights)

5.6%

( 9.5%)

- 2.9 -

# 2.4 TRAFFIC PROJECTION

#### 2.4.1 General

It is assumed that service at the Kilifi creck crossing should not be allowed to deteriorate in the future. The following components must hence be taken into account in the traffic forecast.

- a) Normal traffic growth, i.e. the growth when the ferry service retained and regularly expanded to maintain the present level of service.
- b) Induced traffic due to the construction of a bridge. The traffic forecast in this study is mainly based on the results of traffic survey and analysis of past trend from the traffic census data.

#### 2.4.2 Normal Traffic

A guture traffic volume is forecasted on the basis of the present O-D table which is conducted by an O-D survey. A formulation for the future traffic volume estimation is as follows.

a) For work, Business and Personel trip and others.

$$nTk = \frac{8}{\sum_{i=1}^{\infty} nG_i^k} = \frac{8}{\sum_{i=1}^{\infty} (s_i G_i^k \times \frac{nP_i}{s_i P_i})}$$

nTk ; Traffic volume in total zone in year (n)

- $nG_i^k$ ; Traffic volume in (i) zone in year (n)
- $_{83}$  G<sub>i</sub><sup>k</sup>; Traffic volume in (i) zone in year 1983

nPi ; Number of population on (i) zone in year (n)

b) For home bound trip

$$nTk = \sum_{i=1}^{8} nG_i^k = \sum_{i=1}^{8} \cdot \sum_{j=1}^{8} nOD_{ij}^k$$

 $nOD_{ii}^{k}$ ; Traffic volume from (i) zone to (j) zone in year (n)

c) For tourist traffic

$$nTk = {}_{83}Tk x \frac{nH}{{}_{83}H} = {}_{83}Tk x (1 + r)^{n-1983}$$

- nH ; Number of hotel bed night in year (n)
- r
- ; Average growth rate of the hotel bed night in year 1976--1981

d) Future traffic volume

$$nTT = \sum_{k=1}^{8} \cdot nTk$$

nTT ; Total traffic volume in year (n)

nTk ; Total traffic volume of (i) purpose in year (n)

# 2.4.3 Induced Traffic

Construction of a bridge could be expected to induce some extra traffic across the Kilifi creek, in addition to the traffic which would have used the ferries anyway. However, it is difficult to make any firm estimates of such induced traffic volume.

In this forecast, it is assumed that the induced traffic would account for 30% of the normal traffic in the first year of the operation of the bridge. This estimate is based on the notable variation of traffic volume before and after the construction of the New Mtwapa bridge.

#### 2.4.4 Future Traffic Volume

The results of forecast of the future traffic volume are shown in Table 2–6 and Table 2–7. The number of the total vehicles in above mentioned Table is including normal and induced traffic volume and these numbers are illustrated in Fig. 2–6. Annual growth rates are 5.1 percent, 5.3 percent and 5.2 percent during the periods of 1983 to 1990, 1990 to 2000 and 2000 to 2010 respectively.

Table 2-6 ESTIMATED FUTURE TRAFFIC VOLUME BY YEAR AND BY PURPOSE

(Vehicle/day)

		Total					
Year	Going to work	Business	Going Home	Tourism	Personal	Others	Vehicles
1983	156	665	46	94	11	11	983
	(15.9)	(67.7)	((4.7)	(9.6)	(1.1)	(1.1)	(100.0)
1990	279	1,194	82	216	22	21	1,814
	(15.4)	(65.8)	(4.5)	(11.9)	(1.2)	(1.1)	(100.0)
2000	448	1,901	122	489	39	38	3,037
	(14.8)	(62.6)	(4.0)	(16.1)	(1.3)	(1.2)	(100.0)
2010	700	2,930	178	1,105	64	62	5,038
	(13.9)	(58.2)	(3,5)	(21.9)	(1.3)	(1.2)	(100.0)

- 2.11 -

Table	27	ESTIMATED FUTURE TRAFFIC VOLUME
		BY YEAR AND BY VEHICULAR TYPE

Year	: <sup>1</sup>	Vehicle	Total	Total		
	Car Light	Medium	Heavy	Bus	Vehicles	P.C.U.
1983	589 (59.9)	201 (20.4)	93 (9.5)	100 (10.2)	/ 983 (100.0)	1,617
1990	1,108 (61.0)	361 (19.9)	166 (9.2)	179 ( 9.9)	1,814 (100.0)	2,949
2000	1,913 (63.0)	574 (18.9)	266 (8.8)	284 (9.4)	3,037 (100.0)	4,847
2010	3,303 (65.6)	887 (17.6)	410 ( 8.1)	438 (8.7)	5,038 (100.0)	7,831

ſV	'ehic	1e/	da	wì
۲.	cine	iv;	цa	ւյյ

Note: The following P.C.U. conversion factor is used:

Туре	Passenger Car Light Goods	Medium Goods	Heavy Goods	Buses
Conversion factor	Ĩ.0	2.5	3.5	2.0



Fig. 2-6 ESTIMATED FUTURE TRAFFIC VOLUME
# **3. CHARACTERISTICS OF THE STUDY AREA**

## 3.1 NATURAL CONDITION

#### 3.1.1 Temperature

The average monthly temperature in Kilifi is shown in Fig. 3-1.

#### 3.1.2 Rainfall

Annual rainfall in Mombasa is 1,163 mm (1931 - 1960). Histogram of the average monthly rainfall is shown in Fig. 3-2.

## 3.1.3 Wind

The seasonal wind blows in the south-west direction between April and October, and north-east between December and March. The former is generally stronger than the latter, but this seasonal wind is generally mild, i.e. the maximum instantaneous wind speed does not exceed 40 knots (= 20 m/sec).



Fig. 3–1 AVERAGE MONTHLY TEMPERATURE Fig. 3–2 AVERAGE MONTHLY RAINFALL

#### 3.1.4 Tide

(1) Tidal Range

According to the tide table of Kenya Ports Authority, the maximum tidal range in Kilindini (Mombasa) is 3.98 m, that is between + 3.93 m and -0.05 m.

## (2) Tidal Current

According to the chart of Kilifi creek (surveyed in 1880), the maximum tidal current velocity in the creek is 1.5 knots, that is 0.75 m/sec.

#### (3) Effect of Flood

At the up-stream of the Kilifi creek, several rivers, for example Rave and Ndzovuni, flow into the Kilifi creek. But as the basins of these rivers are rather small while the opening of the creek is comparatively wide, any extreme rise of water level at or after heavy rainfall does not appear. In fact the ground near the Kilifi creek on which the present MOTC Provincial Office building is standing, is only slightly higher than the normal hightide level but has never been submerged.

#### (4) Datum Line

The datum line of the survey of kenya is used for this study. This is the mean sea level of mombasa port and is 1.85 m above the admiral chart datum (Fig. 3-3).



Fig. 3-3 DATUM LINE OF THE STUDY

#### 3.1.5 Earthquake

There are some earthquakes data namely the Modified Mercalli Scale of 1931 (Wood and Neumann 1981), supplemented by Richter's version (1956) and the Code of Practice for the Design & Construction of Buildings & other Structures in relation to Earthquakes (1973).

According to the above mentioned reports, a total of five hundred (500) earthquakes with intensity high enough to effect to the people have occured between the year 1892 and 1969. These earthquakes occured mainly along the Rift Valley.

In the study area, some minor earthquakes have occured but they are very scanty. The effects to the bridge structure by earthquakes in the study area seem very unlikely.

## 3.2 FIELD SURVEY

#### 3.2.1 Conducted Survey

In order to study the physical conditions of the study area, the following surveys were conducted in June and July, 1983:

- a) Bathymetric survey
- b) Sub-surface investigation and
- c) Topographic survey

The above mentioned survey areas or survey points are illustrated in Fig. 3-4.



Fig. 3-4 SURVEY SITE LOCATION

-- 3.3 --

#### 3.3 SUBSURFACE INVESTIGATION

#### 3.3.1 General

In compliance with the proposed location of Kilifi Bridge, the subsurface investigation for the design of substructure foundations was performed along the centre line of the Kilifi Bridge between 16th June, 1983 and 15th August, 1983. In addition, the aggregate materials investigation for construction was performed in and around the Kilifi region.

Two onshore exploratory borings were sunk to 30 m deep at the expected two abutments on both the banks of Kilifi creek. Two offshore borings were sunk to 40 m and 50 m deep respectively from the bottom of creek near the proposed two locations of piers.

The representative soil samples were tested in the laboratory on physical and mechanical properties necessary for the analyses of the subsurface ground conditions.

The actual field work was carried out by Consolidated Marine Engineering Constractors Limited under our supervision. The laboratory soil and material tests were carried out by Central Testing Laboratories Limited under our direction.

#### 3.3.2 Outline of Physiography and Geology

Physiography and geology of the Kilifi region is outlined below for a better understanding of the subsurface ground conditions.

- (1) The coastal belt of the Kilifi area can be described as a series of four parallel zones. These four zones are the (I) Coastal Plain, which is typified by Pleistocene deposits, (II) Foot Plateau, which is practically coincidental with the Jurassic outcrop, (III) Coast Range, which comprise the Jibana and Simba hills, and (IV) Nyika, which embraces the ground covered by the Duruma Sandstone Series. All four zones, as shown in a Physiographical Map of Kilifi Mazeras Area, in Fig. 3–5 can be found in the Kilifi region.
- (2) The Kilifi area falls on the (I) Coastal Plain which varies from 2 to 5 miles (3 to 8 kms) in width and generally lies below 100 ft in elevation. Its seaward margin is composed of a Pleistocene coral reef and this is backed by a series of variable sands, also of Pleistocene age. Under natural conditions, the coastal plain supports thick bush, but throughout most of the Kilifi area the bush has been cleared and the ground is presently being cultivated for large sisal plantations, e.g. the Vipingo Estates and Kilifi Plantations.

The geology of the Kilifi-Mazeras area is shown in a Geological Map in Fig. 3-6.

(3) The rocks of the Kilifi-Mazeras area are of wholly sedimentary origin, and range in age from Triassic to Recent. Generally, these rock formations descend gradually seaward from west to east.

The general geologic structure of the coast follows a linear north-south pattern as shown in Fig. 3-6. Fluctuating sea levels over extended periods

- 3.4 --

have lead to the formation of narrow parallel bands of sands, clays, coral, coral limestone, shale, limestone, and sandstone. This can be clearly seen on the geological map. Kilifi is one of the few areas where the linear north-south structure is traversed and replaced by an east-west structure. The wide creek has cut through a whole range of coastal geology and soils perpendicular to the coastline.

(4) The site reconnaisance survey was made between 14th March and 24th March, 1983. The present physical geography of the major study area is sketched in Fig. 3–7 and based on outcrops, microclimate and microsoil variations, which account for changes in vegetation. A typical cross-section for the south side of the creek is shown in Fig. 3–8, this being not much different from the north side of the creek. However, it is observed that the dry slope for the northern side of the creek is steeper and less vegetation exists than on the southern side of the dry slope. From Fig. 3–8 it can be seen that there are coral limestone boulders and cobbles spreading along the foot of both dry slopes and consist mainly of coral limestone and marls. In some sections, coral covers the areas along the shoreline near the mangrove sand beach.

#### 3.3.3 Results of Subsurface Ground Conditions

Two offshore boreholes were drilled down to 40 and 50 m in depth respectively from the creek-bed near the expected two locations of piers by one Pilcon hydraulic rotary drill rig mounting aboard the 270-tonnage ship, Venture. Two onshore boreholes were sunk to 30 m deep by one Crealius D750 Drill rig at the expected two abutments on both the banks of Kilifi Creek. The results of subsurface ground conditions are shown in a Soil Profile along Kilifi Bridge in Fig. 3-9.

The stratigraphy of the subsurface is classified into 5 layers as shown in Fig. 3-9. Descriptions of each layer, i.e. type of soil, relative density, characteristics and geologic period are tabulated in Table 3-1. It is observed that each of the 5 layers is developed horizontally at the site. It is also found that no geological faults exist around the site. The laboratory soil and material tests were performed after British Standard. Grading mixture of each borehole is shown in Fig. 3-10.



Fig. 3-5 PHYSIOGRAPHICAL MAP OF KILIFI-MAZERAS AREA



## Fig. 3-6 GEOLOGICAL MAP

- 3.7 -







- 3,8 -



<u></u>	
0-1	i
b-TIM	
17 L	
	1
N	
D	Ø
	Ŷ
	<i>y</i>
· · · · · · · · · · · · · · · · · · ·	
	1
· · · · · · · · · · · · · · · · · · ·	
1. Support and the second sec second second sec	
	i
Description	
own loors silty and	
own loose sity sand,	
eyish black loose silty fine sand in the creek-bed,	
oral sand with pebbles consist of coral pieces,	
nca, accomposed coral imestone,	
white popul limetone	
atum are filled with gravelly sand, decomposed	
me sections, low recovery of coring.	
ty clay with occasionally coral pebbles	
20 ~ 50	
se $(N = 20 - greater than 50)$ vollowish to	
and, loosely consolidated sandstone some sections	
osely cemented, with calcium, guarts, biotite	

- 3.9 -.

Layer	Type of Soil	Description	Geologic	
			Epoch	Period
1	Silty Sand	Brown to reddish brown loose silty sand, N = $5 \sim 10$ Greyish brown to greyish black loose silty fine sand in the creek-bed, N = $3 \sim 10$	Recent	
2	Fine to Coarse Sand	Compact to dense coral sand with pebbles consist of coral pieces, quarts, biotite and mica, decomposed coral limestone, $N = 30 \sim 40$	(Recent) Pleistocene	Quaternary
3	Coral Limestone	Very hard yellowish white coral limestone, pores and some cracks which exist in the stratum are filled with gravelly sand, decomposed coral limestone in some sections, low recovery of coring.	Pleistocene	
4	Limy Silty Clay	Very stiff to hard silty clay with occasionally coral pebbles $\phi 10 \sim 40$ mm, N = $20 \sim 50$	Pleistocene	 
5	Weak Calcareous Sandstone	Compact to very dense (N = $20 \sim$ greater than 50) yellowish to greyish brown silty sand, loosely consolidated sandstone, some sections of this stratum are loosely cemented, with calcium, quarts, biotite and mica.	Pliocene	Tertiary





# Fig. 3-10 SUMMARIZED GRADING MIXTURE

- 3.10 -

÷.,

## 3.3.4 Some Comments on Coral Limestone and Weak Calcareous Sandstone

(1) Coral Limestone

From the engineering viewpoint, the marine coral limestones developed in the tropical region are distinguished from other rocks by two characteristics:

- a) Solubility in water that produces enlarged pores and cavities, and
- b) Blanketing by nonsoluble sediments or residual soils in the cavities. The tropical marine coral limestone is essentially a soil, rather than a rocklike material. The tropical marine coral limestone and decomposed coral limestone deposits are encountered between MSL + 16M and MSL + 2m in elevation. The coral limestone has a primary porosity solution as shown in Fig. 3-11 and Fig. 3-12 in its materials. It is observed that some secondary porosities as shown in Fig. 3-11 and Fig. 3-12 exist in the coral limestone layer according to the outcrops in the slope of cliff and the core samples obtained from borings.





Fig. 3–11 PRIMARY POROSITY SOLUTION ENLARGE-MENT



It is found that the young poorly consolidated coral limestones in the Kilifi area have a relatively high void ratio and exhibit a soft chalky fabric in some sections. It is believed that the strengths of the chalky phase range from 3,500 KN/M<sup>2</sup> to 3,000 KN/M<sup>2</sup> ( $350 \text{ t/m}^2 - 300 \text{ m} \text{ t/m}^2$ ). Therefore, it can be estimated that the whole coral limestone bearing capacity is 3,000 KN/M<sup>2</sup>, as a conservative value. It is recommended that plate loading tests on the proposed depth of abutments be carried out to ascertain the required bearing capacity for confirmation at the construction stage. When some sinkholes and/or some cracks are encountered in excavation at the proposed bottom of foundations, some minor modifications of footing widths/depths and/or concrete grouting shall be required at the construction stage. It is also recommended that some slope protection, i.e. concrete gridworks be placed in front of both the abutments.

(2) Weak Calcareous Sandstone

Loosely consolidated weak calcareous sandstone layer below coral limestones is developed predominantly in the Kilifi creek. Major characteristics of the weak calcareous sandstone are summarized below:

- a) Compact to very dense (N = 20 greater than 50)
- b) Some sections of this layer are loosely cemented with calcium, quarts, biotite and mica
- c) Grading mixture consists of fairly well graded silty fine to coarse sand with little coral and calcareous gravels.
- d) No boulders/cobbles exist in this layer

Based on the above characteristics, the following pile foundations for the proposed piers are considered below:

- i) Concrete pile and/or steel pipe pile
- ii) Cast-in place concrete pile

It is anticipated that driving concrete and/or steel piles in deep water are considered to be difficult to penetrate through to the required depth of around MSL - 40 m. Therefore, it is expected that cast-in-place concrete piles by using a reverse circulation drill is preferable than driving pile methods.

It is recommended that drilling bits, i.e. tricon bits and rock crushing bits be used in the drilling.

## 3.3.5 Aggregate Materials Investigation

Fine to coarse aggregate materials investigation for construction was carried out in and around the Kilifi region.

Potential sources of aggregate materials are summarized in Fig. 3-14.

Results of grading analysis for each aggregate material are shown in Fig. 3-13.

From the results of grading analysis, Tiboni sand is more suitable as the fine aggregate for concrete mixture than the Sabaki River sand. Available amount of Rare River sand is limited for the required amount in the project. Mkongani materials are also suitable for the borrow materials.







Fig. 3-14 LOCATION OF POTENTIAL SOURCES OF AGGREGATES



The existing B-8 road near the ferry terminal at Kilifi side. The width of the pavement is about 6.0 meters and a 1.5 meters soft shoulder is provided on both sides of the road.



## Photo 2

The existing B--8 road at the Manarani side. The horizontal alignment is almost in a straight line and the widths of the pavement and schoulders are 6.0 meters and 1.5 to 2.0 meters respectively.



General view of the Kilifi creek crossings. A view towards the Kilifi side.



# Photo 4

General view of the Kilifi creek crossing. This photograph is taken from the proposed bridge construction site in Kilifi to the Mnarani Club.

.



Main street of the Kilifi township. Both the commercial and residential areas are located along this road.



## Photo 6

The existing E921 road. The widths of the pavement and pedestrian way are about 6.0 meters and 1.5 meters respectively.



Residential areas in the Kilifi township. The proposed road is to avoid disrupting such established settlement.



## Photo 8

The town center at the Mnarani side. There are some residences in this area. The proposed road project is to preserve such areas.



The outskirts of the central area in the Mnarani side. The proposed road is located to pass into this area.



# Photo 10

The livestock farming area in the Mnarani side. A part of the proposed road will pass through this area.

# 3.4 DEVELOPMENT FEATURES OF STUDY AREA

#### 3.4.1 Existing Landuse Pattern

The study area consists of the Kilifi side and Mnarani side with the Kilifi creek inbetween. The population of Kilifi township and Mnarani is about 42,600 and 626 respectively (1979 population census). The commercial area is located along the D551 road and some parts of the E921 road. Along the seashore of the Kilifi creek, housing area and government utility are located on the Kilifi townside. Residential areas are located on both sides of the creek with their adjacent areas and the hinderland as open spaces left for crop and livestock farming. The existing situations of the study area are shown in the photo 1 to photo 10.

#### 3.4.2 Existing Road Condition

The B-8 road passes through the side of Kilifi township and the D551 and E921 roads pass through the Kilifi township. The number of lanes of the B-8, D551 and E921 roads are two (2) lanes and the width of the pavement of the above roads are 7.0 m, 6.0 m and 5.5 m respectively. The pavement condition is comparatively good but the boundary between the pavement and the shoulder is at a different level due to heavy rainfall and other reasons. In the night time, a driver can easily misjudge the difference in level. This is one of the causes of many traffic accidents.

### 3.4.3 Existing Institution

#### (1) Public Utilities

There are two (2) schools, one national hospital, two (2) mosques and one church in the Kilifi township. There are also two (2) hotels; one at Kilifi township and one on the Mnarani side.

(2) Electric Power Line

Two (2) electric power lines run across the Kilifi creek; one is 132,000 V (132 KV) and the other is 33,000 V (33 KV). From the discussions with the East African Power and Lighting Company, it was learnt that the shifting of these lines to other places would be very difficult. To shift the lines would necessitate a reconstruction of the tower, involving a new electric line planning. Therefore it will be necessary, when locating the route, to avoid these electric power lines.

(3) Telephone and Telegram Communications Line

One telephone line passes through the Kilifi creek and the post that supports this telephone line is made of wood. The telephone line is light compared with the electric line. Therefore it is comparatively easy to shift the telephone line to another place.

(4) Ferry

Two (2) ferry boats are operating at a 24 hours service on Kilifi creek with one (1) ferry boat as a standby. The capacity of the existing ferry boat is