FEASIBILITY REPORT

DAR ES SALAAM / LINDI COASTAL TRUNK ROAD PROJECT TANZANIA

VOL. I

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

JULY 1971

FEASIBILITY REPORT

DAR ES SALAAM / LINDI
COASTAL LINK ROAD PROJECT
TANZANIA

Vol. I

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

JULY 1971

Preface

The Goverhment of Japan, in compliance with the request of the Government of the Republic of Tanzania for a feasibility survey in relation to the Dar es Salaam/ Lindi Coastal Link Road Project, entrusted the Overseas Technical Cooperation Agency with the execution of the survey.

The Overseas Technical Cooperation Agency organized a survey team consisting of nine experts, headed by Mr. Takehide Kurita, Director of Planning and Research Department, Japan Highway Public Corporation, and sent it to Tanzania over a period of 40 days from October to November 1970.

The south region of Tanzania remains backward in economic development and is under constant threat of instability of people's livelihood due to disruption of road traffic during the rainy season. The recent survey, therefore was to provide a feasibility study on the construction of all-weather road aimed at overcoming such a difficulty in communication from technical and economical points of view.

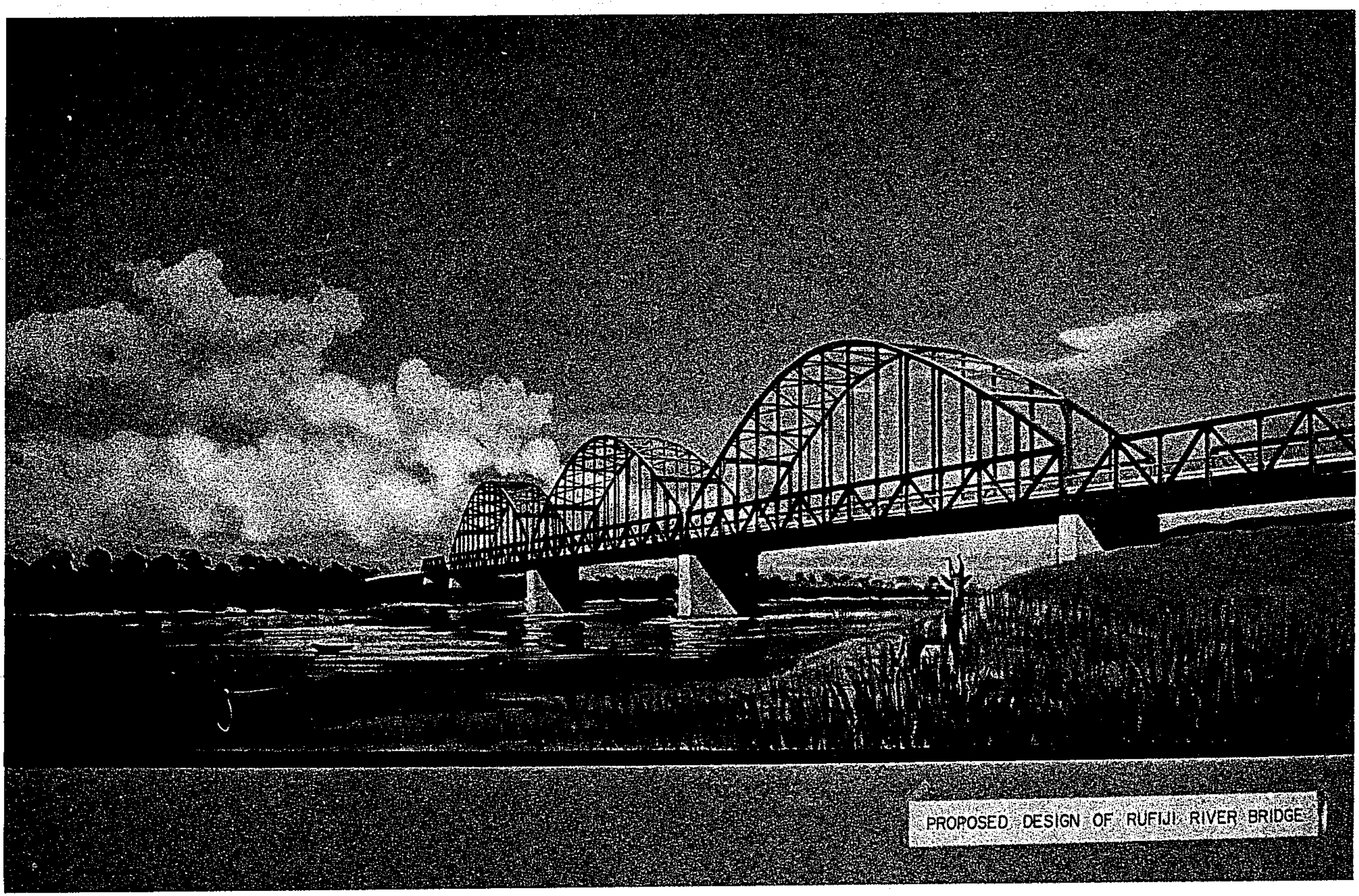
Thanks to the immeasurable support and cooperation of officials of the Tanzanian Government, the survey was carried out smoothly and the report of survey is now ready for presentation.

It is strongly hoped that the report will contribute to the development of south region of Tanzania and at the same time help promote friendly relations between the Republic of Tanzania and Japan.

June 1971

K. Tatsuke

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency



PROPOSED DESIGN OF RUFIJI RIVER BRIDGE

CONTENTS

SUMMARY AND RECOMMENDATIONS

The south coast of Tanzania covered by the present survey has the Rufiji River, the greatest in the country, besides several medium and small rivers generally flowing from west to east into the Indian Ocean and the existing road running from north to south in the area is cut to pieces here and there by these rivers. In the rainy season every year, the rivers, being not regulated as yet, flood over wide area for a long time and the interruption of traffic caused by it continues for from two to as long as six months, with the districts surrounding Mtwara in the southern coast area isolated as if they form a foreign country.

One of the most urgent need of the road administration in the United Republic of Tanzania who has well developed road networks in its northern and western parts is to construct an all-weather road linking Dar es Salaam, the capital of the country, with the southern coast area having a population of about 10% of the total and to prevent the area from being isolated in the rainy season so as to meet the long-cherished desire of the inhabitants.

At the request of the Government of Tanzania, the Japanese Survey Team made field surveys of the existing road running along the coastline, for about fourty days, on the policy to utilize it as far as possible and has prepared this report after having finished analysis and examination of various data and works on designing and cost estimation in the home country.

In this chapter, brief explanations of the field surveys and the works done in Japan are given and extract of the report is summarized in order to facilitate the understanding of the report; with investigations and surveying needed to be made prior to actual construction, and recommendations on concrete measures for the execution of works enumerated orderly.

Summary

Field Survey

1. Reconnaissance covering all sections of the three routes proposed by the Government of Tanzania.

Route 1: Kibiti - Utete - Nyamwage - Mohoro - Nangurukuru— Lindi

Route 2: Kibiti - Ndundu - Nyamwage - Mohoro - Nangurukuru - Lindi

Route 3: Kibiti - Utete - Njinjo - Mbata - Kiranjerange - Lindi

2. Soil survey and geological exploration made along the three routes and subsurface exploration of the foundation of the Rufifi River.

The Material Laboratory of the Government of Tanzania was requested to made the routine test of most of the samples collected by the survey team, while the samples of laterite and black cotton soil were brought to Japan as typical soils for test and research.

3. Reconnaissance and investigation of flood-marks in the drainage basins of Rufifi, Matandu, Mavuji and Mbwemkuru Rivers.

4. Data necessary for designing of road and planning of bridge construction were collected by a land levelling carried out in the drainage basins of Rufifi, Matandu, Mavuji and Mbwemkuru Rivers and other sections inundated during the rainy season, chiefly along Route 2. Also, a sounding was made in Rufiji River.

5. Collection of, and discussion on various data

a. Data of economic investigation including those of traffic census
b. Hydrological data
c. Data of soils and geology
d. Design standards of road and bridge
e. Data for cost estimation

Works carried out in Japan

1. Hydrological analysis was made to estimate the planned high water discharge of each river to find required cross-sectional area, and based on which the length of each bridge and viaducts for flood relief opening and the height of access roads were determined.

2. Necessary supplementary tests were made on the typical soil samples brought to Japan. Results of tests conducted by the material laboralory were arranged and included in the report.

3. Based on a comprehensive comparison of the results of hydrological analysis and estimations of construction costs for three routes, it was finally decided to select Route 2 as the most advantageous one.

4. The preliminary design of road and the plans of bridge construction were prepared and the estimation of construction costs made for Route 2 with two lanes provided over its all length.

5. Economic effects were examined and Benefit/Cost ratio estimated on the assumption that the works will be executed simultaneously on two lanes over the entire section of Route 2.

Extract of the Report

1. Estimated Traffic Volume

Estimated traffic volumes for the year when the road is expected to open for traffic and the year when the refundment of construction costs completes have been obtained by the Gravity Model method based on the O.D. survey data collected by the Government of Tanzania. In estimating them, growth in the number of registered vehicles, variations in the percentage distribution of vehicle types, increase of population and induced effects from the new construction of road were properly taken into consideration.

Table 1. Estimated Traffic Volume (vehicles/day)

Sections / Year		Dar es Salaam - Ndundu	Ndundu - Nanguru-kuru	Nanguru-kuru - Lindi	Lindi - Mtwara
When engineered gravel road is scheduled to open for traffic	1977	265	180	169	250
When paved road is scheduled to open for traffic	1979	342	286	269	300
When redemption of costs for engineered gravel road completes	2006	446	987	973	1492
When redemption of costs for paved road completes	2008	1771	1413	413	1656

2. Hydrological Analysis

Planned high water discharge, length of main bridge over the main stream and that of viaducts for flood relief opening obtained for each river from the hydrological analysis are as shown in Table 2. The clearance beneath the bridge beam provided for unusual flood is 1.5 meters for every bridge.

Table 2. Planned High Water Discharge and Bridge Over Main Stream and Viaduct

Name of River	Rufiji R.	Matandu R.	Mavuji R.	Mbwemkuru R.
Planned high water discharge (m^3/sec)	6700	2000	1000	2000
Length of main bridge (m)	330	80 + 120	50	80
Length of viaduct (m)	5000	1500	350	950

3. Soils and Geology

Cohesive soil with high plasticity such as black cotton soil will cause construction troubles. According to the results of shallow soil exploration conducted along the existing road between Kibiti and Lindi, about fifty kilometers representing one sixth of the total length are covered with black cotton soil. Besides this, there are about fifty kilometers of sections covered with cohesive soil of which plasticity index PI exceeding 20.

It is not advisable to use black cotton soil as an embankment material because its strength decreases substantially when it absorbs water, though it does not constitute any trouble in dry condition. Black cotton soil deposited on the low land is also not suitable as foundation of embankment and it should be removed to waste as its layer does not seem so deep.

Other types of soil in general, except cohesive soil with high plasticity can be safely used for earthwork material without any special treatment. Laterite of good quality distributed widely can be used as subgrade material. It is believed that this laterite will be an adequate material of subbase course if properly stabilized with asphalt emulsion or portland cement.

At some places along the route, outcrops of rock such as crystalized limestone are seen which can be used as an aggregate of concrete or pavement; however, it is needed further to make full-scale investigation of aggregates.

According to the preliminary subsurface exploration of the foundation of Rufiji River, a supporting layer with large N value has been found at the depth of from eleven to thirteen meters beneath the ground surface, and this assures that there will be no serious trouble as to the foundations of bridge if proper measure is taken to prevent them from scouring. It is also supposed that shallow pile foundations will suffice for viaducts for flood relief opening.

4. Selection of Route

Based on the results of examinations made for the three routes covered by the present survey, as to

a. how and where Rufiji River is to be crossed ?
b. which route is most inexpensive in terms of construction cost ?
c. which route is shortest in terms of length of the road ?
d. which route is most advantageous in terms of distribution of population along the route and economic effects ?

it has been finally determined to select Route 2 as the most advantageous one. The comparison of direct construction cost and length of road between three routes are shown in Table 3.

Table 3 Comparison between Three Routes

Name of Route	Route 1	Route 2	Route 3
Direct construction cost (shs)	223,870,000	192,630,000	266,060,000
Length of road (km)	348.5	319.5	378.9

5. Road Design

A preliminary design has been made for Route 2 with two lanes and pavement provided for the entire section. In this, the design standards of the Government of Tanzania were applied, of which chief standards are as follows:

Design speed		80 km/hr
Steepest longitudinal gradient	flat	5%
	hilly	6%
	mountainous	8%
Road width	overall width	9.6 - 8.4 m
	carriageway	6.0 m
	shoulder	1.8 - 1.2 m

Since the assumption is to make the utmost use of the existing road, the improvements of horizontal and longitudinal alignment are to be limited to local sections as far as possible. The improvement of alignment is to be carried out only for section that is extremely inadequate for the comfortable driving of vehicles; section which, being located at comparatively low elevation, seems to suffer severe influence from flood in the rainy season; and section that is detouring unnecessarily. The planning of earthwork has been made within the limit of minimum necessity for the economy of construction cost, while, on the other hand, a best possible consideration has been given to the planning of drainage in order to secure all-weather road.

It has been planned that any portion of the embankment section passing on area which is anticipated to be inundated with flood water for a long time in the rainy season is protected by stone or concrete block pitching in order to prevent its slopes from scouring and erosion and other portion of embankment section is provided with sodding or grass protection.

In order to make more detailed design of the road, it needs to carry out aerial photographic surveying of the entire route and local topographic survey and levelling.

6. Plan for Bridge Construction

The plan for construction of bridges has been formed on the same assumption as the road, that is for Route 2 with two lanes provided over the entire length. The standards of design are as follows

Specifications of design	British Standard
Effective width	7.0 m

Standardized designs have been applied to the designings of the main bridge and viaduct for flood relief opening as far as possible in order to reduce the costs of material, manufacture, transportation and erection of bridge as well as to take into consideration the easiness of rebuilding of bridge in case of destruction under disasters.

As for substructure, pile foundations are adopted to use H-section steel piles which are economical in transportation and driving costs for all bridges except the main bridge over Rufiji River to be provided with well or open caisson foundations.

It is naturally expected that some changes will be needed in the design as for penetration of foundation on others as a result of further detailed subsurface exploration of foundation ground. However, it may be believed that any major changes will not be made in the designs of superstructures including the spacing arrangement of spans, except the bridge over Mbwemkuru River which has large velocity and deep water depth, particularly in flood time, with its channel of stream curving sharply.

Table 4. Main Bridge and Viaduct

Name of river		Main bridge over main stream		Standard girder bridge for viaduct section	
		Spacing of spans	Length (m)	Spacing of spans	Length (m)
Rufiji R.		Langer truss 84m x 3	252	20m x 250	5000
		Pony truss 40m x 2	80		
Matandu R.	Main	Pony truss 40m x 2		20m x 446	920
	Branch	Pony truss 40m x 1	40	20m x 0	600
Mavuji R.		Pony truss 40m x 1	40	20m x 18	360
Mbwemkuru R.		Pony truss 40m x 2	80	20m x 48	960
Other small bridges		-	-	20m, 15m, 10m	1300
Sub-total		Langer truss	252	20m x 392	7840
		Pony truss	320	20m, 15m, 10m	1300
Total		Truss bridge	572	Standard girder bridge	9140

7. Costs and Period of Construction

The costs and period of construction for Route 2 are estimated as follows.

Total construction costs	approx. 261,447,000 shs.
Total construction costs excluding pavement cost (but including pavement cost down to 3 km south of Ndundu)	approx. 197,077,000 shs.
Total construction costs of Rufiji bridge and approach road	approx. 67,142,000 shs.
Total construction period	about 8 years
Survey period (aerial photogrammetry, ground survey, detailed design)	about 2 years
Work period (execution by stages for entire section)	about 6 years

8. Economic Effects

Quantitative benefits have been calculated by an ordinary technique used internationally, for the economic effects resulting from the linking of Dar es Salaam with Mtwara by an all-weather road. The basic conditions in this calculation are;

a. to complete by 1973 all investigations and design works needed to be done prior to the start of main construction works;

b. to complete all construction works by 1977, or within four years, in the case of engineered gravel road, and by 1979, or within six years, in the case of paved road, on the basis of simultaneous execution of works on the entire section; and

c. to set the redemption period at thirty years.

The benefits to be resulting from the all-weather road between Dar es Salaam and Mtwara include;

a. travel benefit - economy in travel costs derived from the improvement of earth road into engineered gravel or paved road;

b. time benefits including,

- those for passengers and vehicles due to conversion from Rufiji ferry to Rufiji bridge;

- those for passengers and cargoes converting from shipping service to road in the rainy season;

- those for vehicles due to the improvement of road;

- those for cargoes due to the improvement of road in the dry season; and

c. economy in charges

- for passengers converting from shipping service to road in the rainy season;

- for passengers and vehicles due to conversion from ferry to bridge;

and the greatest benefit among them is the travel benefits.

The estimated Benefit/Cost Ratios are as shown in Table 1-5. With interest rate of 10% applied, the Benefit/Cost Ratio for paved road is B/C = 1.30 and that for engineered gravel road is B/C = 1.02.

Table 5. Benefit/Cost Ratio (in shs.)

Engineered gravel road	Symbol	Interest rate = 2%	Interest rate = 6%	Interest rate = 10%
Cumulative gross benefits from the year (1977) of opening for traffic to the year (2006) of complete redemption	B	837,379,200	458,231,400	281,700,000
Total construction costs plus cumulative maintenance and repair costs up to the year (2006) of complete redemption	C	243,700,000	255,959,000	276,857,000
Benefit/Cost Ratio	B/C	3.44	1.79	1.02

Paved road	Symbol	Interest rate = 2%	Interest rate = 6%	Interest rate = 10%
Cumulative gross benefits from the year (1979) of opening for traffic to the year(2008) of complete redemption	B	1,505,998,100	829,447,500	513,478,200
Total construction costs plus cumulative maintenance and repair costs up to the year(2009) of complete redemption	C	314,965,000	349,701,000	396,243,000
Benefit/Cost Ratio	B/C	4.78	2.37	1.30

As seen from the above, it is presumed that the project is adequately profitable even in terms of economic effects alone expected to be directly derived from the all-weather road between Dar es Salaam and Mtwara and, besides them, there are various indirect effects beyond measure such as improvement in income and cultural levels, promotion of general development, stabilization of the public feeling and improvement in inhabitants' welfare resulting along with relieving of the southern coast area from fear of isolation.

Recommendations

Various Works necessary before the Start of Construction

It needs to carry out the operations including investigation, survey and design work shown below in respect of Route 2 selected finally.

1. Aerial photographic survey is to be made over the entire section of the route with an object to prepare drawings on scale of 1/2500 - 1/5000.

2. Further detailed soil survey and testing are to be carried out along the route based on the preliminary design of the road.

3. Borrow-pits and quarries near the road are to be investigated in more detail (as to quality, quantity and transportation distance).

4. Exploration of deep foundation is to be conducted in relation to the four principal rivers of Rufiji, Matandu, Mavudji and Mbwemkuru. Detailed ground survey and levelling is to be made successively in the starting order of works.

5. Detailed design of road and superstructures and substructures of bridges are to be prepared on the basis of the results of above exploration and survey.

Since it is impossible for the survey team to carry out all these operations by visiting the field two or three times for short period, an all-out cooperation by the Government of Tanzania through the Material Laboratory is desired, in particular, for items referred to in paragraphs 2 and 3 above. As it is expected that the completion of the operations will take about two years, they should be undertaken as soon as possible, to assure so as not to delay the start of execution of works.

Exectuion of Works

In setting the schedule for construction, the first priority should be given to the building of bridge over Rufiji River which constitutes the greatest cause for interruption of traffic in the rainy season. It is expected that most part of the trouble due to such interrupted traffic for a long time will be eliminated after the completion of main bridge and viaducts over the river and embankment of approach roads. If the works are advanced toward the south following the completion of the Rufiji section, it will facilitate the transportation of construction equipment and materials. It is also possible that, apart from the aerial photogrammetry, the works on investigation, surveying and designing referred to above can be proceeded by stages so as to be always ahead of the schedule for construction.

Route 2 is divided into four working sections as below for the convenience of the design of road, while the execution of works is not necessarily required to comply with such division but the works may be executed adapting to a financial programme.

1.	Kibiti-Ndundu-Nyamwage (including Rufiji bridge)	48.5 km
2.	Nyamwage-Mohro-Nangurukuru	103.5 km
3.	Nangurukuru-Kiranjerange	87.5 km
4.	Kiranjerange-Lindi	80.0 km
	Total	319.5 km

It will be a wise policy as an original step to adopt engineered gravel surface which enables to reduce the initial investment and secure adequate economic benefits as well, as the pavement cost accounts for about 32% of the total construction costs for the total length of 319.5 km from Kibiti to Lindi.

Where the works are executed by working sections properly set up,the works on bridges and viaducts should be planned to undertake in advance of those on roads, and thus this will serve to reduce the construction period as well as to decrease any influence of rainfall upon the schedule.

The total construction period is about four years for engineered gravel road or about six years for paved road; however this period is estimated on the basis of of provision of ample funds.

Fig. 1. shows the yearly construction costs of some motorways now in use in Japan for reference as an example of yearly fund programme in the case of a large scale construction. As they are eight-year fund programmes for the motorways with four lanes divided and fully access controlled, they are not suggestive in respect of amount of funds but should give some information to obtain yearly percent ratios of investment.

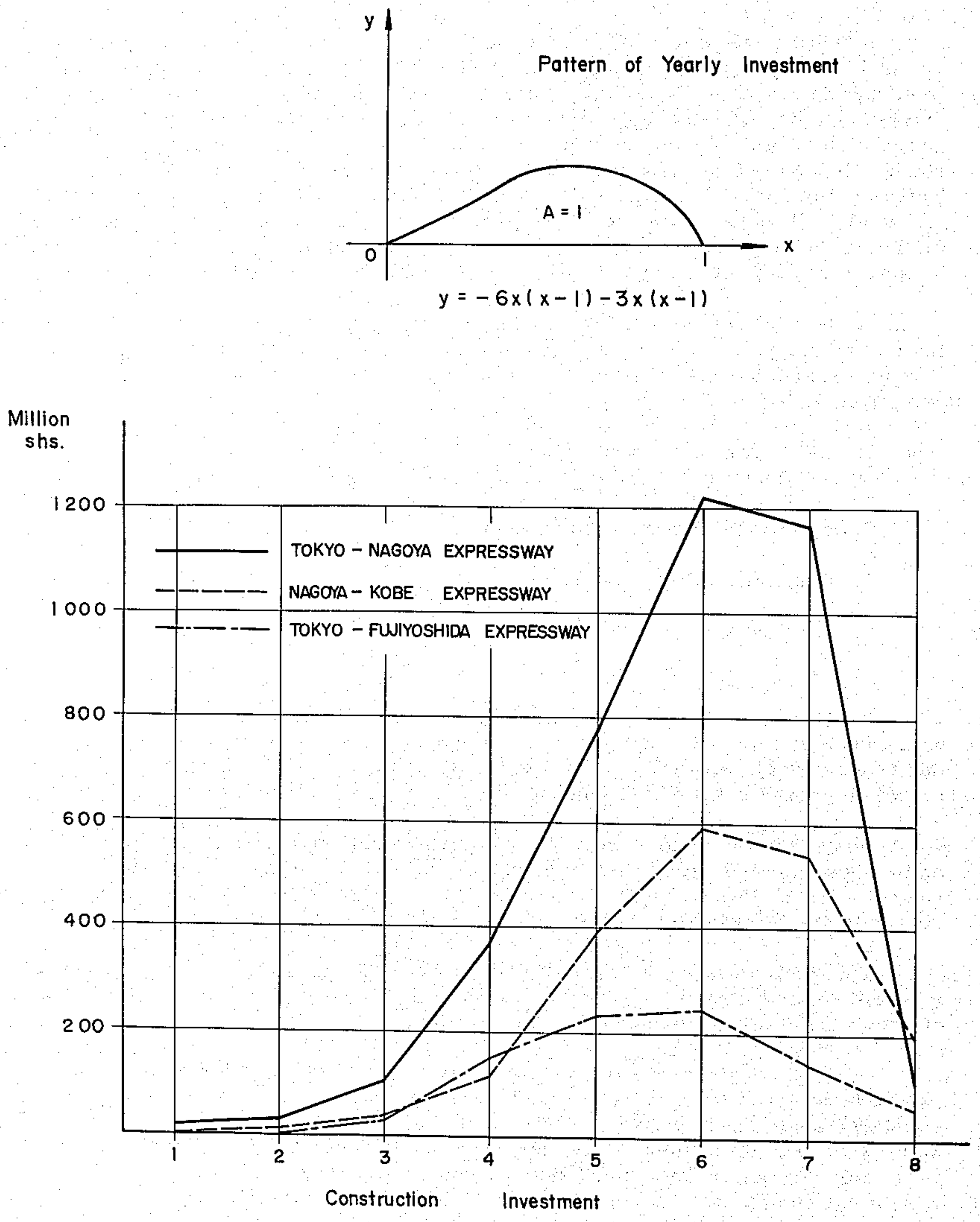


Fig.—1 Example of Yearly Investment for Expressway Construction in Japan

Acknowledgements

The successful completion of the field survey for the Dar es Salaam/ Lindi Coastal Link Road Project owes much to the kind cooperation of the Ministry of Communications, Transport and Labor, the Government of the Republic of Tanzania. We are particularly grateful to Mr. Kadoma, Principal Secretary, Mr. H. Singh, Chief Engineer and Mr. Singh Channe, Director, Roads & Aerodromes Division of the same ministry for valuable assistance. Thanks are also due to Mr. Kirti S. Joshi, Asst. Executive Engineer, Mr. G. Gulamali, Technical Assistant, Messrs. Msangi, Mosha and Harahala, technicians at the Material Laboratory, for constant help by accompanying the team during the entire period of field survey.

Acknowledgement must also be made to officials of the Treasury, National Water Resources Council, Water Development and Irrigation Division as well as the Ministry of Communications, Transport and Labour for valuable advices and information and to those who provided the team with every convenience for this survey by mentioning their names below.

Ministry of Finance	
Mr. C. D. Msuya	Principal Secretary
Mr. F. A. Byabato	Deputy Secretary
Mr. Chahali	Assistant Secretary
Ministry of Communications, Transport and Labour	
Dr. H. L. Uppal	Chief, Material Laboratory
Mr. D. V. Sikka	Soil Analyst, "
Mr. Msangi	Material Laboratory
Mr. Mosha	"
Mr. Halahala	"
Mr. Lloyo R. Mcginnis	Planning Section
Mr. R. Kramer	Executive Engineer, R. E. Coast
Mr. K. Ramadhani	Officer in Charge of Utete Rufiji
Mr. J. Z. Kagali	Officer in Charge of Kilwa Masoko
Mr. Said	Officer in Charge of Lindi
National Water Resources Council	
Mr. Hiroshi Hori	Planning Director
Mr. Junji Inoue	Senior Irrigation and Drainage Engineer Planning Division
Mr. Masao Yoshida	Senior Agricultural Economist, Planning Div.
Mr. Hideo Yasui	Senior Hydrologist and Planning Engineer, Planning Division
Mr. Akihiko Togo	Hydrologist, Planning Division
Ministry of Agriculture, Food and Cooperatives	
Mr. Hagen	Senior Hydrologist, Water Development and Irrigation Division -UBUNGO
Mr. Wingard	Hydrologist, "
East African Meteorological Department	
Dr. H.T. Möth	

CHAPTER 1

I N T R O D U C T I O N

CHAPTER 1 INTRODUCTION

1-1 Purpose of Survey

The Dar es Salaam/Lindi Link Road has a total length of approximately 480 km, originating in the capital city of Dar es Salaam and reaching Lindi City in the south via coastal area where the population density is relatively high.

However, the flooding of several rivers including the River Rutigi during the rainy season disrupts road traffic for about half a year annually and completely isolates the south region with about 10% of the total population of Tanzania.

Although there is a plan to construct a new road in the mountain area where the menace of flooding is much less in an attempt to overcome this difficulty, the recent survey was aimed for the road construction project which envisages the use of the existing coastal road to the best advantage.

1-2 Scope of Survey

In order to obtain a general prospect for the feasibility of the road construction project, the field survey was carried out by placing emphasis on the selection of the most economical route and on the constructions over the River Rutigi and other rivers and road construction on the economy and the people's livelihood in the area. After returning to Japan, the team made a series of analysis and study on the results of the survey and exerted utmost efforts to estimate the future traffic volume and the benefit to be derived from the road and for the study to estimate the run-off water of the River Rutigi. On the technical aspect, the future land surveying and soil survey of the site will provide basic informations for more accurate design of the bridges, and large scale aerial maps on a reduced scale will provide substantial information required for detailed design of the road. The report, therefore, is aimed at obtaining the maximum accuracy from the results of this reconnaissance survey.

1-3 Composition of Survey Team

Members of Japanese Survey Team for the Dar es Salaam/Lindi Coastal Link Road Project.

KURITA, takehide	Chief of the Team	Director, Planning Division, Japan Highway Public Corporation
TERASHI, hideo	Bridge Hydraulics	Director, Construction Division, Kansai Branch Office, Water Resources Development Public Corporation
SUMITOMO, eikichi	Road Planning	Chief Engineer, National Expressway Division Road Bureau, Ministry of Construction
SUGITA, yoshiaki	Road Planning	Vice Director, Planning Division, Japan Highway Public Corporation
NAGASHIMA, kunimura	Road Design and Survey	Director, Mitsui Consultants Co.
MORI, hiroshi	Geotechnology and Construction Materials	President, Japan Overseas Consultants Co.
NISHINO, mitsuo	Bridge Design	Director, Japan Overseas Consultants Co.
ASAHI, akira	Economy	Engineer, Japan Overseas Consultants Co.
TOKUMARU, masaya	Coordination	Engineer, Development Survey Division, Overseas Technical Cooperation Agency

Resident Japanese specialists on road construction who joined the field survey team.

SUGIURA, hideo	Ministry of Communications, Transport & Labour, Roads and Aerodrome Division
SUMIYOSHI, yukihiko	"

Liaison Officer from the Tanzanian Government who joined the survey team in the field survey

Mr. Kirti S. Joshi	Ministry of Communications, Transport & Labour,
Mr. G. Gulamali	" "

Three technicians from Material Laboratory

1-4 Outline of Field Survey

1-4 -1 Survey Schedule

In the recent survey the team was divided into the following two groups for reasons of camping facilities and the survey was conducted for each proposed route.

(A group)

Road Planning	Takehide KURITA Eikichi SUMITOMO	Members of Survey Team
Bridge Planning	Mitsuo NISHINO	
Soils & Geology	One member	

Resident Japanese Executive Engineer: Hideo SUGIURA

Liaison officer from the Tanzanian Government: Mr. Gulamali

(B group) Kunimura NAGASHIMA

Toppgraphic Survey	Masaya TOKUMARU Akira ASAHI	Members of Survey Team
Soils & Geology	Hiroshi MORI	
Flood Marks Survey	Hideo TERASHI	

Resident Japanese Executive Engineer: Yukihiko SUMIYOSHI

Liaison officer from the Tanzanian Government: Mr. Joshi

Technicians from the Material Laboratory: Mr. Msangi, Mr. Harahala, Mr. Moshi

The survey was carried out in two stages. In the first stage an over-all site reconnaissance was made (From October 15th to October 17th) and in the second stage a detailed field survey was conducted (From October 22nd to November 17th). The survey schedule is shown in the table below:

Base Camp	A Group	B Group
Kilwa Masoko	Oct. 22nd Oct. 30th	Nov. 1st Nov. 7th
Kibiti	Oct. 31st Nov. 7th	Oct. 22nd Oct. 31st

1-4-2 Outline of Individual Surveys

(A) Route survey

A route survey, which is necessary for working out plans for road improvement, bridge improvement and construction of bridges, was conducted mainly along Route 1 (Kibiti Utete Nyam Wage) and Route 2 (Kibiti Ndundu Nyam Wage Moharo Kilwa Lindi).

For Route 3 (Utete Njinjo Mbate Mtandawla Makangaga), only a rough site reconnaissance was conducted.

(B) Soils and Gel

(1) Foundation of exploration at the proposed site of Rufiji River crossing

Sampling by means of mechanical boring and measurement of bearing capacity of the foundation ground in terms of the standard penetration value were conducted in Utete and Ndunde where the ferry service is being provided. Both the boring and the penetration test were conducted on the left bank of Rufiji River. Samples taken were sent to the Material Laboratory of the Tanzanian Government for analysis and tests.

(2) Soil and geological survey along the route

Representative soil samples were taken at intervals of 5 to 10 m along Route 1 and Route 2 and the samples were sent to the Material Laboratory of the Tanzanian Government for consistency test. The soil samples totaled 72. Of these samples, 11 typical samples were also to be given compaction test and CRB test. Representative samples of laterite and black cotton soils were brought back to Japan for necessary supplemental tests. Only 6 samples were taken on Route 3 for consistency test.

(C) Topographic survey

A longitudinal topographic survey was conducted in the vicinity of major rivers such as Rufiji, Matandu, Mavudyi and Mbemkura and a lateral topographic survey was conducted at the control points.

The maximum high water levels were recorded on the profiles in joint work for flood marks survey mentioned in paragraph (d) in order to obtain basic information necessary for bridge and road embankment plans.

(D) Flood marks survey

The flood marks survey was conducted mainly in the basin of th Rufiji River. The scale and scope of the floods in the past were confirmed and the information necessary for the main bridge plan, flood water relief opening plan and slope protection of road embankment were obtained. During the flood marks survey, person-to-person interview with local residents was also utilized for gathering information.

CHAPTER 2

GENERAL DESCRIPTION OF THE PROJECT

CHAPTER 2. GENERAL DESCRIPTION OF THE PROJECT

2-1 Background of the Project

The area where the Dar es Salaam/Lindi Coastal Link Road runs through is situated in the southeastern part of Tanzania. It lies long from north to south extending over about 470 km along the coast of the Indian Ocean from Dar es Salaam, the capital of the country, to Mtwara with the width covering about 100 km toward the inland from the coast.

The project has a direct effect on Mtwara Region which alone has reached a population of 1,033,000 (1967) and if the environs of that region is included, their total population will be equal to 10% of that of Tanzania. The area to be served by the projected road is characterized by the fact that there are Kilwa which is famous for its old ruin and Selous Game Reserve, one of the largest game reserves in East Africa, including the principal cities such as Mtwara and Lindi.

The big rivers which travers west to east this long area extending from south to north constitute the serious obstacles to the land traffic to connect this area to Dar es Salaam, the capital of the country. These rivers include the Rufiji River, the largest in Tanzania, and the Matandu, Mavudji and Mbemkuru Rivers of which whole downstream basins are flooded in the rainy season paralyzing land traffic for a long time.

In particular, as shown in Table 2-1, it becomes impossible for motor vehicles to cross the Rufiji River for 3-6 months every year.

Therefore, the inhabitants in the area are seized with a feeling of isolation during the rainy season and it is strongly disired to build a perfect all-weather road in view of the administration, transportation, communication, culture, welfare and development of industry.

The investigations concerning these matters carried out so far are as follows:

1) Battelle Feasibility Report, 1964
2) Volkert Reconnaissance Study, 1965
3) TAMS Feasibility Report, 1969

The present survey has been made to locate a route along the existing road around which the population concentrates especially. As shown in Fig. 2-1, there are 6 trunk roads in Tanzania and the projected Coastal Link Road is to complete the missing part of Eastern Trunk Road. Table 2-2 shows the breakdown of roads in Tanzania by classes and by types of pavement.

Tab. 2-1 Records of Suspension of Ndundu and Utete Ferries Due to Flood

Year	Ndundu Ferry			Utete Ferry		
	Date of suspension	Date of open	Days of service suspended	Date of suspension	Date of open	Days of service suspended
1965	28/ 3/65	20/ 8/65	145	28/ 3/65	24/ 7/65	118
	4/ 8/65	0/ 9/65	5			
1966	19/ 4/66	20/ 6/66	62	23/ 4/66	18/ 6/66	56
1967	10/ 4/67	4/ 7/67	85	19/ 4/67	10/ 6/67	52
1968	4/ 4/68	10/ 7/68	97	20/ 4/68	14/ 7/68	85
1969	8/12/68	14/ 1/69	37	6/12/68	3/ 1/69	28
	10/ 2/69	12/ 8/69	185	10/ 2/69	17/ 6/69	129

Note: Average days of ferry service suspended
- 110 days (for 1965 - 1969)

source: Office of R. E. Coast

Tab. 2-2 Tanzania Roads - Classification, July, 1970

(in km)

	Trunk roads	Territorial main roads	Local main roads	Total
Bitumen	1397	293	544	2234
Engineered Gravel	317	488	308	1113
Earth	3703	678	9153	13634
Total	5417	1439	10005	16881

2-2 Administrative Division

As to the administration, Tanzania is divided into nineteen regions which are subdivided into sixty-two districts in all.

The projected road passes through Kisarame and Rufiji Districts of Coast Region and Kilwa, Lindi and Mtwara Districts of Mtwara Region; other districts adjoining to them are Morogoro, Nachingwea, Masasi and Newala Districts.

2-3 Population

The population of Tanzania has increased steadily year by year showing the the total growth rate of 35.1% for 10 years from 1957 to 1967; an average of annual growth rate for 1948 - 1957 was 1.8% and 3.1% for 1957-1967.

Table 2-3 Population of Mainland Tanzania

Item	Population (x 10^3)			Increase in population (x 10^3)		Annual growth rate (x 10^3)		Density (persons/ km^2)	Area (km^2)
Year	1948	1957	1967	1948 57	1957 67	1948 57	1957 67	1967	1967
Mainland Tanzania	7,500	8,800	11,900	1,300	3,100	1.8	3.1	13.4	918,182

Source: Regional Economic Atlas Mainland Tanzania, Research Paper No. 1, Bureau of Resource Assessment and Land Use Planning

Table 2-4 Population and Population Density by Regions

Regions (including towns)	Population (x 10^3)	Percentage of the total (%)	Density (persons/ km^2)	Regions (including towns)	Population (x 10^3)	Percentage of the total (%)	Density (persons/ km^2)
Arusha	602	5.1	7.3	Mtwara	1,033	8.7	12.5
Coast	781	6.6	23.1	Mwanza	1,058	8.9	53.7
Dodoma	708	6.0	17.1	Ruvuma	393	3.3	6.4
Iringa	684	5.8	12.1	Shinyango	888	7.5	17.5
Kigoma	471	4.0	12.6	Singida	455	3.8	9.2
Kilimanjaro	651	5.5	49.3	Tabara	552	4.7	4.5
Mara	536	4.5	24.6	Tanga	769	6.5	28.7
Mheya	956	8.0	11.4	West Lake	658	5.5	22.9
Morogaro	683	5.8	9.3	Total	11,877	100	

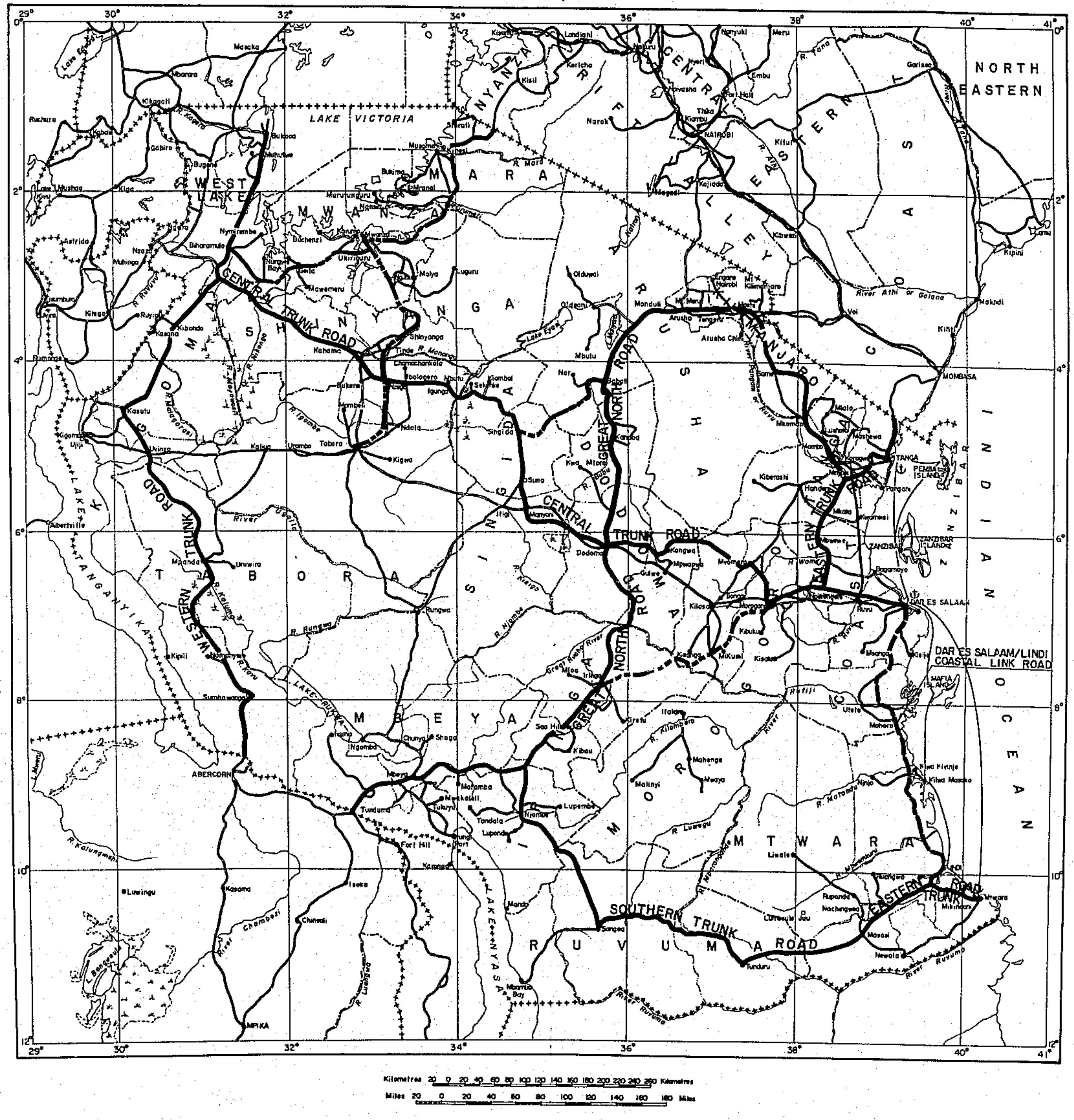
Source: Regional Economic Atlas, Mainland Tanzania, Research Paper No. 1, Bureau of Resource Assessment and Land Use Planning

Table 2-5 Population of the Area to be Affected by the Projected Road

Towns, districts or regions	Population (persons)			Increase in population		Annual growth rate (%)		Density (persons/ km^2)	Area (km^2)
	1948	1957	1967	1948-57	1957-67	1948-57	1957-67	1967	
Bagamoyo	77,700	88,800	116,300	9,100	27,500	1.2	2.8	11.8	9,840
Dar es Salaam Town	69,200	128,700	272,500	59,500	143,300	7.1	7.8	3,507.4	80
Mzizima	38,500	38,300	75,300	-200	37,000	0.0	7.1	108.7	780
Kisarawe	150,300	150,100	179,000	-200	28,900	0.0	1.8	19.2	9,320
Mafia	12,200	12,200	16,700	0	4,500	0.0	3.2	32.3	520
Fufiji	105,300	118,900	121,400	13,600	2,500	1.4	0.2	9.1	13,200
Coast Region	455,200	537,000	781,200	81,800	244,200	1.8	4.1	23.1	33,750
Kilwa	96,900	88,600	98,900	-8,300	10,300	-0.9	1.1	7.1	13,980
Lindi	178,700	178,200	237,200	-500	59,000	0.0	2.9	25.1	9,320
Masasi	122,600	150,900	213,600	28,300	62,700	2.3	3.5	23.9	8,810
Mtwara	88,700	96,000	134,700	7,300	38,700	0.9	3.4	35.8	3,880
Nachingwea	39,200	56,200	80,600	17,000	24,400	4.1	3.7	1.9	42,730
Newala	154,300	177,400	267,900	23,100	90,500	1.6	4.2	66.7	4,140
Mtwara Region	680,400	747,300	1,032,900	66,900	285,600	1.0	3.3	12.5	82,860

Source: District Data, 1967, Ministry of Economic Affairs and Development Planning

FIG. 2-1
TANZANIA
TRUNK AND TERRITORIAL
MAIN ROADS
1967



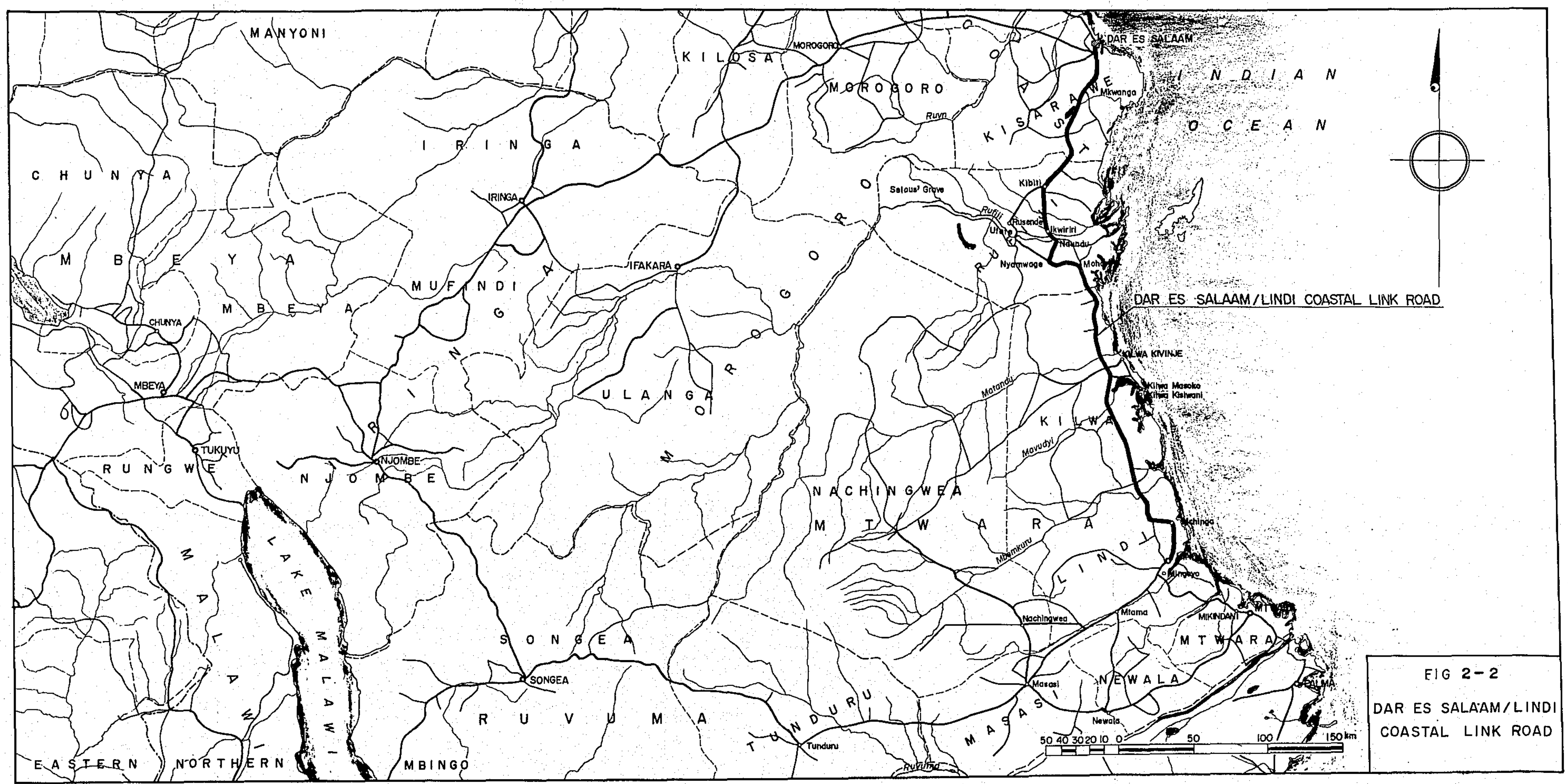


FIG 2-2

DAR ES SALAAM/LINDI COASTAL LINK ROAD

REGIONS & DISTRICTS 1967

ARUSHA
Arusha
Masai
Mbulu

COAST
Mzizima
Bagamoyo
Kisarawe
Mafia
Rufiji

DODOMA
Dodoma
Kondoa
Mpwapwa

IRINGA
Iringa
Mufindi
Njombe

KIGOMA
Kasulu
Kibondo
Kigoma

KILIMANJARO
Kilimanjaro
Pare

MARA
Musoma
N. Mara

MBEYA
Chunya
Mbeya
Mbozi
Sumbawanga
Rungwe

MOROGORO
Kilosa
Morogoro
Ulanga

MTWARA
Kilwa
Lindi
Masasi
Mtwara
Nachingwea
Newala

MWANZA
Geita
Kwimba
Mwanza
Ukerewe

RUVUMA
Mbinga
Songea
Tunduru

SHINYANGA
Kahama
Maswa
Shinyanga

TABORA
Mpanda
Nzega
Tabora

SINGIDA
Iramba
Manyoni
Singida

TANGA
Handeni
Korogwe
Lushoto
Pangani
Tanga

WEST LAKE
Biharamulo
Bukoba
Karagwe
Ngara

ZANZIBAR
PEMBA

FIG. 2-3 POLITICAL SUBDIVISIONS

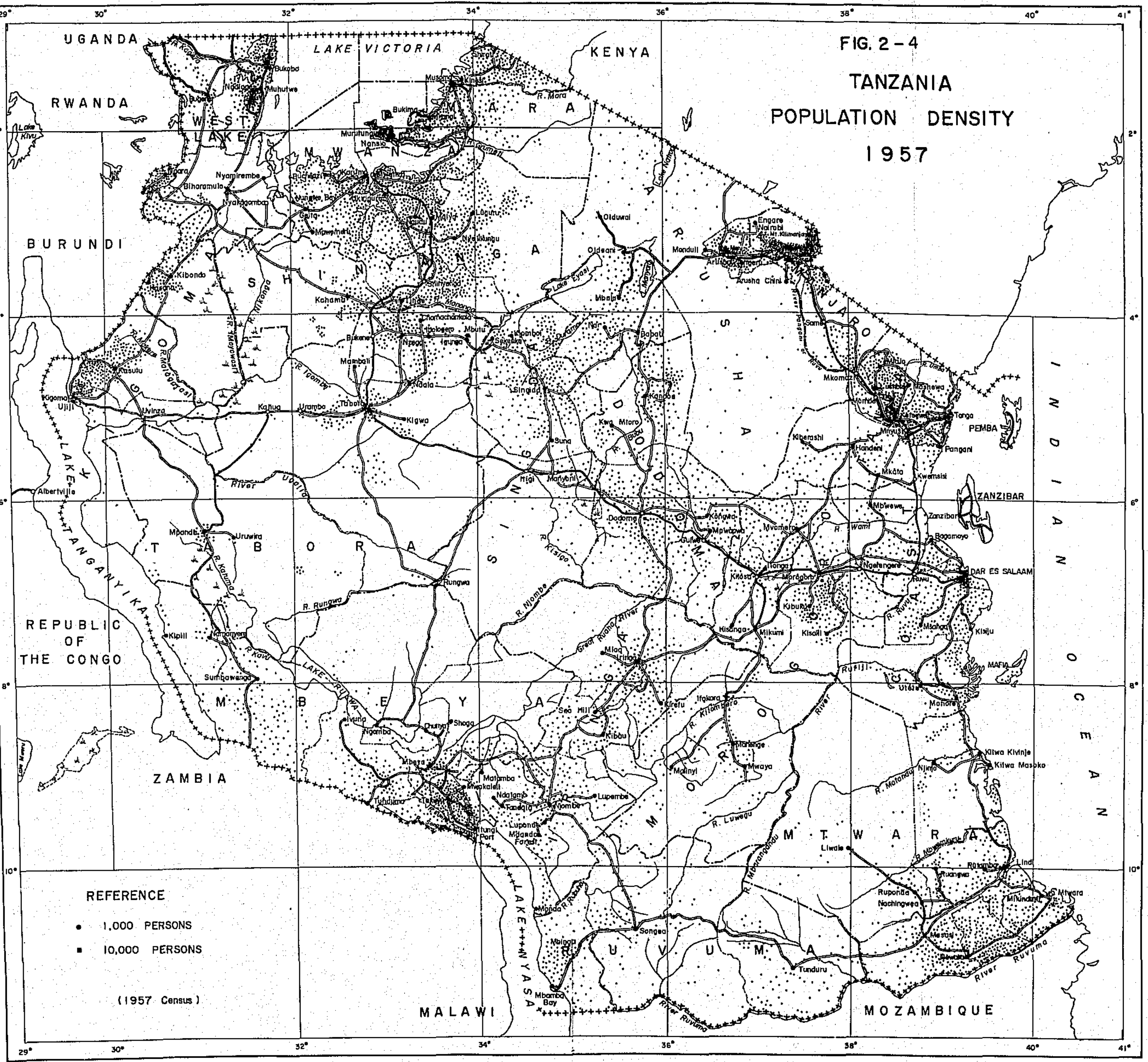


FIG. 2-4
TANZANIA
POPULATION DENSITY
1957

The increase in population can be attributed to the decrease in death rate especially in that of infants, and the improvement of census technique. In the area along the projected road, Dar es Salaam and the southern part have had a comparatively large increase in population and, in particular, the growth in population of Dar es Salaam was so remarkable that it indicated an annual rate of 7.8% for 1957-1967, showing a tendency of population concentrating into cities. On the other hand, the growth rates of population in Refiji and Kilwa Districts has been decreased due to the incomplete road network, undeveloped communication facilities and lack of staple industries.

The population of Mtwara Region was 1,033,000 in 1967, accounting for nearly 8.7% of the country's population and the growth rate is 38.2%, a little more than country's average growth rate of 35.1%.

The population density in Mtwara Region is 12.5 persons per km^2 which is a little less than the national average density of 13.4 persons per km^2; while in the limited small area of Mtwara and Newara Districts density indicates a very high point as shown in Table 2-5. The low population density of Nachingwea District due to the lack of sufficient settlement conditions constitutes a cause for decreasing the average density in Mtwara Region.

The growth rate of population in the production area of sisal hemp near Lindi is stagnated under the influence of decrease in production due to the increasing import of synthetic fibre.

2-4 Agriculture

Agriculture is a very important factor which supports the economy of Tanzania and its importance may be understood by the fact that nearly 96% of the population depend their living on the agricultural activities directly or indirectly by securing their self-sufficiencies or source of revenues. Although the proportion of agriculture in the total domestic production has tended downward after 1963 when it reached its peak of 61% as shown in Table 2-6, it still accounted for 50% of total production in 1968.

Tab. 2-6 Agricultural Production as Percentage in Total Domestic Production

Year	1963	1964	1965	1966	1967	1968
%	61	57	54	53	52	50

Source: Central Statistics Bureau

The population engaging in agriculture represented 38% of the total working population (in 1966) and in the area of Coast Region and Mtwara Region both of which are to be affected by the projected road agricultural population is accounted for 3.8% and 3.7%, respectively, of the total population engaging in agriculture in 1966.

The export especially of cashewnuts, cassava, sisal, sesame and timber provides an indicator which affect the level of economic activities, revenues and, though indirectly, traffic volume of the Mtwara area in future.

Table 2-7 Agricultural Production in the Area to be Influenced by Coastal Link Road (1966-1967)

Crop \ District	Bagamoyo				Kisarawe				Mafia			
	1966 tons	1967 tons	1967 000Shs.	% of Region	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1967 tons	1967 000 Shs.	% of Region
Cotton Lint	500	500	1,400		200	0	0					
Sisal	3,000	2,700	2,400		4,000	3,700	3,300					
Cashew	3,100	5,000	3,900		12,000	11,000	8,600		1,200	900	700	
Copra	600	700	600		2,700	2,200	1,900		2,900	1,900	1,600	
Coir	0	0	0									
Kapok		0	0						300	500	400	
Jaggery		3,000	3,800									
Total Export Crops	7,200	11,900	12,100	33.2	18,900	16,900	13,800	37.9	4,400	3,300	2,700	7.4
Maize	100	100	0			100	0		0	0	0	
Banana	200	500	100		100	200	0		0	0	0	
Cassava	100	500	100		1,500	2,500	500					
Bean & Pulses	0	100	0		100	100	0		0	0	0	
Paddy	500	500	200		100	100	0		0	0	0	
Oil Seed	300	200	200		200	200	200					
Millet & Sorghum		100	0									
Groundnuts												
Vegetables					200	200	100			0	0	
Onion												
Sweet Potatoes	100	100	0		100	0	0		0	100	0	
Irish Potatoes									100	200	100	
Citrus Fruits	300	400	100		500	500	200		0	0	0	
Coconut	100	200	300									
Total all crops	8,900	14,600	13,100	31.4	21,700	20,800	14,800	35.7	4,500	3,600	2,800	0.7

Crop \ District	Mzizima				Rufiji			
	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1967 000 Shs.	1967 000 Shs.	% of Region
Cotton Lint	100	0	0		400	300	900	
Sisal	1,200	1,600	1,400		1,400	1,200	1,100	
Cashew	4,100	3,500	2,700		3,000	1,100	900	
Copra	100	0	0		2,100	900	800	
Coir								
Kapok								
Jaggery								
Total Export Crops	5,500	5,100	4,100	11.3	6,900	3,500	3,700	10.2
Maize					400			
Banana	0	0	0		0	100	0	
Cassava	100	200			100	200	100	
Bean & Pulses					400			
Paddy	100	400	200		4,500	3,000	1,300	
Oil Seed	100	100	100		500	500	400	
Millet & Sorghum					100			
Groundnuts								
Vegetables	100	700	300					
Onion					0	0	0	
Sweet Potatoes	100	200			0			
Irish Potatoes								
Citrus Fruits	0	0	0		1,000	900	300	
Coconut								
Total all crops	6,000	6,700	4,700	11.3	13,900	8,200	5,800	13.9

Crop \ District	Coast - Region					Kilwa			
	1966 tons	1966 000 Shs.	1967 tons	1967 000 Shs.	Present of Tanzania	1966 tons	1967 tons	1967 000 Shs.	% of Region
Cotton Lint	1,200	3,500	800	2,300	1.2	0	0	0	
Sisal	9,600	8,600	9,200	8,200	4.2				
Cashew	23,400	18,300	21,500	16,800	25.3	2,700	3,000	2,300	
Copra	8,400	6,900	5,700	4,900	55.2	300	200	100	
Coir	0	0	0	0	0				
Kapok	300	300	500	400	57.0				
Jaggery	0	0	3,000	3,800	41.7				
Total Export Crops	42,900	37,600	40,700	36,400	3.9	3,000	3,200	2,400	4.4
Maize	500	100	200	0	0.1				
Banana	300	100	800	100	0.6	0			
Cassava	1,800	400	3,400	700	2.7				
Bean & Pulses	500	200	200	0	0.1		0	0	
Paddy	5,200	2,400	4,000	1,700	11.8	300	100	0	
Oil Seed	1,100	1,000	1,000	900	3.9				
Millet & Sorghum	100	0	100	0	0.3	0			
Groundnuts						1,100	1,000	900	
Vegetables	300	200	900	400	6.0				
Onion	0	0	0	0	0.0				
Sweet Potatoes	300	0	400	0	0.8	0	0	0	
Irish Potatoes	100	0	200	100	2.3				
Citrus Fruits	1,800	600	1,800	600	8.1	200	200	0	
Coconut	100	100	200	300	13.2				
Total all crops	55,000	42,700	53,900	41,200	3.7	4,600	4,500	3,300	4.7

Crop \ District	Lindi				Masasi				Mtwara			
	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1967 tons	1967 000 Shs.	% of Region
Cotton Lint												
Sisal	7,700	5,400	4,900						3,200	2,200	2,200	
Cashew	9,400	12,000	9,400		7,500	10,000	7,800		6,900	8,000	6,100	
Copra	300	400	300						0	0	0	
Coir												
Kapok												
Jaggery												
Total Export Crops	17,400	17,800	14,600	26.9	7,500	10,000	7,800	14.4	10,100	10,200	8,300	15.3
Maize	100	100	0							100	0	
Banana					0	100	0		200	200	0	
Cassava	500	1,000	200		1,100	2,000	400		3,500	3,000	600	
Bean & Pulses	200	400	200			300	100		0	0	0	
Paddy		100	100			0	0			100	0	
Oil Seed	2,200	2,300	2,000		300	400	400		100	200	100	
Millet & Sorghum	700	1,000	300		200	300	100		100	100	0	
Groundnuts		100	0		1,400	2,500	2,200					
Vegetables					100	100	0		100	100	0	
Onion	0	0	0		0	0	0					
Sweet Potatoes					0	0	0		0	0	0	
Irish Potatoes												
Citrus Fruits					600	800	300		4,000	8,000	2,400	
Coconut												
Total all crops	21,100	22,800	17,400	24.9	11,200	16,500	11,300	16.3	18,100	22,000	11,400	16.3

Crop \ District	Nachingwea				Newala				Mtwara - Region				
	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1967 tons	1967 000 Shs.	% of Region	1966 tons	1966 000 Shs.	1967 tons	1967 000 Shs.	% of Tanzania
Cotton Lint									0	0	0	0	0.0
Sisal									10,900	9,800	7,600	7,100	3.4
Cashew	2,000	3,000	2,300		21,500	24,000	18,800		50,000	39,100	60,000	46,700	70.6
Copra									600	500	600	400	6.7
Coir													
Kapok													
Jaggery													
Total Export Crops	2,000	3,000	2,300	4.2	21,500	24,000	18,800	34.6	61,500	49,400	68,200	54,200	5.9
Maize						100	0		100	0	300	0	0.2
Banana	100	100	0		100	100	0		400	0	500	0	0.3
Cassava					17,500	13,500	2,900		22,600	4,800	19,500	4,100	15.7
Bean & Pulses						100	100		200	200	800	400	2.7
Paddy						0	0		300	100	300	100	0.9
Oil Seed	1,100	1,500	1,300		200	100	100		3,900	3,400	4,500	3,900	16.1
Millet & Sorghum	100	100	0						1,100	300	1,500	400	4.0
Groundnuts	0	500	400		0	100	0		2,500	2,300	4,200	3,500	41.0
Vegetables	0	0	0		0	0	0		200	100	200	0	1.6
Onion	100	0	0						100	100	0	0	0.5
Sweet Potatoes	0	0	0						0	0	0	0	0
Irish Potatoes													
Citrus Fruits	200	100	0		300	300	100		5,300	1,600	9,400	2,800	40.7
Coconut													
Total all crops	3,600	5,300	4,000	5.7	39,600	38,300	22,000	31.5	98,200	62,300	109,400	69,400	6.2

The principal agricultural food products of Mtwara Region are paddy, proso millet, maize, soya bean, sugar-cane, agoundnuts and cassava while products for export include cashewnuts, sisal, sesame, soya bean, copra, tabacco, and coffee. In particular, the yearly growth rates of cashewnuts both in volume of production and amount of export revenue are remarkable.

In 1967, the volume of cashewnut produced in the coastal area represented nearly 96% of the total production in the country, comparising 21,500 tons (or 25.3%) raised in Coast Region and 60,000 tons (or 70.6%) raised in Mtwara Region.

Since the cashewnuts produced in Newara, Lindi and Masasi Districts constituting the most important crop for export of Mtwara Region are collected from November to February to export them from the port of Mtwara, traffic on roads connecting to Mtwara from Masasi via Mingoyo and from Newara increases heavily during the above period.

The second important crop for export is cassavas which are produced in Newara, Mtwara and Masasi Districts. Newara is an important production area and raised over 75% of the total amount exported from Mtwara Region in 1966. As for the amount of cassava production along the Coastal Lindi Road, 3,400 tons were produced in Coast Region and 19,500 tons produced in Mtwara Region in 1967.

As cassavas are planted in the beginning of a year and cropped from August to November of the next year, the peak of their transportation volume continues from September to November. Their production tends to hit the ceiling due to a fall in their price and much increase in production amount cannot be expected in view of the future market condition. Cassavas are exported mainly to Hamburg and Bremen where they are processed into starch.

Sisal is produced in the large plantations of Lindi and Mtwara Districts and in Kisarawe Bagamoyo and Rufiji Districts as well; however, its output is decreasing due to a fall in its international price caused by the development of synthetic fibre and the appearance of competing production countries such as Brazil.

Tab. 2-8 Production of Sisal in the Area to be Influenced by Coastal Link Road

Region	Year (annual average)	Production (ton)	Increase or decrease - Ratio of production to that of the preceding year (%)
Coast	1962-64	11,500	
	1965	9,400	-18.3
	1966	9,600	+ 2.1
	1967	9,200	- 4.2
	(annual average)		
Mtwara	1962-64	12,300	
	1965	11,600	- 5.7
	1966	10,900	- 6.0
	1967	7,600	-30.3

Source: District Data, 1967

The Kikwetu plantation located to the north of the town of Lindi has begun to replace the existing crops with cashewnut on the half of its cropping area of 35,000 acres.

A small scale cultivation of sisal which is essentially a plantation crop has resulted in failure on account of deterioration in quality and rise in price.

The development plan of Vjamma Village on the left bank of the Rufiji River contemplates to form a cropping area of 81,519 acres by 1974.

Table 2-9 Development Plan of Ujamma Village

Kind of crop \ Year	Planned cropping area (acre) 1970/71	71/72	72/73	73/74
Paddy	6,757	8,040	9,681	12,992
Cashew	n d	9,764	16,109	44,995
Coconuts	1,835	3,582	5,738	n d
Sesame	9,164	n d	n d	n d
Groundnuts	1,713	n d	n d	n d
Total	22,542	34,938	53,582	81,519

Source: Ministry of Regional Administration and Rural Development

In the Second Five-Year Plan, the priorities of agricultural productions to be developed in the respective District of Coast and Mtwara Regions are designated as shown in Table 2-10.

Table 2-10 Priorities Designated for the Development of Agricultural Products

Order	Kisarawe	Mzizima	Rufiji	Kilwa/Lindi/ Mtwara	Masasi	Nawara	Nachingwea
1	Cashewnuts	Coconuts	Paddy	Cashewnuts	Cashewnuts	Cashewnuts	Cashewnuts
2	Coconuts	Vegetables	Cashewnuts	Paddy	Oil seeds	Paddy	Oil seeds/pulses
3	Paddy	Cashewnuts	Cotton	Oil seeds/ pulses	Paddy	Oil seeds /Pulses	Paddy
4	Sesame	Cassava	Coconuts	Coconuts	Citrus fruits	Citrus fruits	Citrus fruits
5	Bananas	Paddy	Cassava	Maize/ Cassava	Maize/ Cassava	Maize/ Cassava	Maize/Sorghum/ Cassava
6	Cassava	Onions	Sesame	Citrus fruits	Coconuts	Coconuts	Coconuts
7	Vegetables	Citrus fruit	Bananas	Vegetables	Vegetables	Vegetables	Vegetables
8	Fruit	Bananas	Vegetables	Onions	Onions	Onions	Onions
9	Onions	Sweet potatoes	Fruit	Oil palm	Oil palm	Oil palm	Oil palm
10	Cotton	Sesame	Maize	Bananas	Bananas	Bananas	Bananas

Source: Tanzania Second Five-Year Plan for Economic and Social Development, Volume III, Regional Perspectives

Kisarame, Mzizima and Rufiji District are liable to be influenced by Dar es Salaam as they are located near to it, and have a considerable possibility for the development in future. The staple crops in the coastal belt zone include cashewnuts, coconuts and paddy; vegetables and fruits, in particular, hold a major importance in the suburban of Dar es Salaam.

The staple products in Rufiji District are paddy and cotton and it is intended to increase the cropping area especially of paddy to enhance its production. The outside area of Rufiji valley is a most suitable land for a increasing output program of cashewnut and coconut.

Cotton seems to continue to be an important cash crop in the inland part of Bagamoyo and a certain part of Kisarame where are most suitable for the increased production project of sesame.

2-5 Forestry

Tanzania has naturally many kinds of useful forest resources and its wooded region occupies an area of 442,300 km^2 representing about a half of the area of Tanzania Mainland(887,000 km^2). It is considered that much contribution is made to the development of industries by the remarkable growth of timber production from the natural forest and from the plantation being enhanced by afforestation programme. Table 2-11 shows the division of forest area.

Tab. 2-11 Division of Forest Land (Figures are rounded)

Ownership	km^2	As percentage in the area of Tanzania Mainland	As percentage in the forest land
Tanzania Mainland	887,000	100	-
Forest Land	442,300	50	100
* Permanent State	112,100	13	25
Permanent Local Authority Forest Reserves	16,700	2	4
Private Forests	600	-	-
Unreserved woods on Public Lands	312,900	35	71

* Of which 300 km^2 are plantations

Source: Forest Sub-division, 1970.

The following Table 2-12 shows the sub-division of the forest area shown in Table 2-11.

Tab. 2-12 Subdivision of the Forest Area

Division \ Unit	Unreserved		Reserved		Total	
	km^2	%	km^2	%	km^2	%
Closed forests	3,550	1	7,750	2	13,300	3
Woodlands	261,400	59	114,400	26	375,800	85
Mangrove	-	-	800	-	800	-
Open areas and Grass lands	48,550	11	3,550	1	52,100	12
Plantations	-	-	300	-	300	-
Total	313,500	71	128,800	29	442,300	100

Source: Forest Sub-division, 1970

In recent years, the production of timbers has been increasing steadily and 4,542,000 $ft.^3$ of logs were cut down in 1969. The demand for timbers for paper pulp has shown a phenomenal growth and in 1968 it increased to nearly 3.2 times of that for 1963 both in terms of volume and money, respectively reaching 20,196 tons and 45,824,000 shillings.

The demand for veneers and planking in 1968 also increased to 21,841,000 $ft.^2$ or nearly 3.3 times of 6,545,000 $ft.^2$ for 1963. The demand for wood for fuel during 1970-71 is estimated at 360-400 million $ft.^3$.

In Tanzania, the exact amount of consumption of timbers cannot be taken because much of cutting is done without any formal permission; however, the estimated production of softwood for 1968-69 was 2,855,000 $ft.^3$.

In 1968-69, the hardwood plantation growing eucalyptus was 63.5 km^2 with another 20.4 km^2 growing hardwood not yet matured, and the plantation growing wood for fuel was 43.1 km^2.

In Tanzania the forest resources are provided from the following four sources.

1. The Mountain forests distributed over rainy regions of higher elevation indicate high yield rate per unit area. Although these forest areas do not cover so large space they play an important role for forestry and river conservancies constituting an effective source of timbers supply for domestic consumption and export. The chief kinds of trees are podo, camphor, ceder, loliondo, mtambara and pillarwood.

2. Woodlands which are seen at the foots of hills and along the seaside in savanna zone are the predominant forest type in Tanzania. The chief kinds of trees are moule, arican, mahogany, those growing on seaside and hills such as muhuhu and backwood, as well as muninga, mtundu and abzelia.

3. Mangroves are seen along the seacoast, especially the estuaries and they are principally utilized in logs for building in local districts.

4. Although, at present, the plantations cover only small space of afforested land they will become main producing centers of timbers for industrial use in future. The kinds of trees planted are mainly softwood such as pine and cypress, which are grown together with teak and mvule in some districts. The condition of plantations is very favorable for producing softwood and the production system is starting to cope with the rapid growth of planted trees.

Mtwara area along the projected road was the chief producing center of hardwood in the past. However, as the reserves near to it were entirely cut down the reforestation has been started to grow softwood although these materials are used limitedly for buildings in the local districts or for fuels.

Export timbers are divided into two major kinds of alzelia pterocupus (or known as mninga in the local districts) and darbergia. Most of mninga which is a hardwood is exported to Japan.

Black mninga is used as the material of carvings which are a folk craft of Mtwara, constituting an important industry of the village.

The Forest Division operates a development zone of softwood at Rondo in Lindi District. Forest of coconut and bushes spreads over the seacoast area; forest of baobab and thicket of assorted trees are distributed over the hills in Ruvema Region, highlands in Mtwara Region and the western part of the country.

The efficient development of forest resources at present is prevented by the each of sufficient infrastructure to expand and develop timber market.

The forest reserve in Coast Region of which about one fifth is covered with mangrove includes its most important Bana softwood plantation of Bagamoyo.

2-6 Transportation Facilities

2-6-1 Movement of Passengers

At present, the movement of people between Dar es Salaam and Mtwara area in the southern part are attained by various sytems including bus service or private car driving on the coastal road during the dry season; aircraft though very expensive; and irregular service of "Jamhuri".

During the dry season, bus service is operated daily between Dar es Salaam and Mtwara through the coastal road by the Tanganyika Transport Company. The total number of passengers carried in both directions is about 1,000 per month and one trip takes about 12 hours.

Air service is operated daily between Dar es Salaam and Mtwara and 2～5 flights per week are provided between the capital and the three airports at Kilwa, Lindi and Nachingwea.

The East African Airways reported the number of air passengers (in both directions) for 1968 as follows:

Table 2-13 Air Passengers (1968)

D.S.M.	- Mtwara	5,225	persons
	- Lindi	4,959	"
	- Kilwa	701	"
	- Mafia	2,769	"
	- Zanzibar	29,506	"
	- Tanga	8,916	"

Source: East African Airways

The number of air passengers between Dar es Salaam and Mtwara reaches 1,078 persons in monthly average during the rainy season (from December to June), which is comparable with 668 persons in monthly average during the dry season, and this clear increase seems to be due to the transfer of passengers from the coastal road on which traffic is interrupted during the rainy season. In the rainy season, the indispensable vehicular traffic between the above two points uses detour route running as long as 1,600 km from Mtwara via Songea, Iringa and Morogoro to reach Dar es Salaam.

No particular pattern is found as to the passengers using "Jamhuri" to travel between Dar es Salaam and the southern part. This steamer service is operated regularly with two return trips per month during a certain period, while during other period, it is used only for local transportation between Zanzibar and Pemba and the mainland.

Passenger fares between Dar es Salaam and Mtwara by modes of transportation are shown in Table 2-14.

Table 2-14 Passenger Fares by Modes of Transportation

Modes of transportation	Class	Fare (in sh.)	Comparison with bus fare	Remarks
Bus	1	50	1.4	
	3	35	1	
Airways		270	7.7	
		213	6.1	Discounted fare of return ticket available for six days
Steamer	1	315	9.0	
	2	190	5.4	
	3	64	1.8	
Railway*	1	86	2.5	* Although there is no railway operated actually between these points, railway fares corresponding to the same distance are shown for comparison.
	2	57	1.6	
	3	17	0.5	

Source: Coastal Shipping Service, Dar es Salaam - Mtwara, A Feasibility Report by Bjorn Foss and Otto Chr. Hirth

2-6-2 Flow of Cargoes

Based on the study made by TAMS in 1968, the total volume of cargoes transported between Dar es Salaam and Mtwara in 1967 was estimated, though on an uncertain assumption, as follows:

Table 2-15 Flow of Cargoes between D. S. M and Southern Part (1967)

Modes of transportation	Section		Cargoes trans-ported (in ton)	(%)
	D.S.M.	Kilwa	2,219	3.1
Shipping service	"	Lindi	22,846	31.7
	"	Mtwara	37,725	52.3
	Sub-total		62,790	87.1
Road			9,000	12.5
Airways			288	0.4
	Total		72,078	100

Source: TAMS

In addition to the above, there are other flows of cargoes between three areas of Kilwa, Lindi and Mtwara and between Mafia Island and Dar es Salaam. According to certain data, the volume of seaforne cargoes between three ports (Kilma, Lindi and Mtwara) of the southern part was 3,702 tons in 1967. Thus the total volume of cargoes transported between the areas benefited from the coastal shipping service is about to reach 80,000 tons per year.

Based on a detail analysis of the coastal shipping between Dar es Salaam and the three port in the southern part, a change in the shipping pattern is expected according to factors such as interrelation of north and south-bound transactions, seasonal fluctuations, cargo composition and distribution of transport ships (coasters, schooners and dhows).

Of the transactions between Dar es Salaam and Mtwara 92% are south-bound cargoes and only 8% are north-bound cargoes. Of those shipped from Lindi 89% are south-bound and 11% are north-bound.

These facts means that only a small portion of available transportation capacity is utilized between Dar es Salaam and the southern part due to unbalanced volume of cargoes between both directions, resulting in comparatively high transportation cost.

Of the total south-bound cargoes shipped from Dar es Salaam 40% (20,000 tons) are cement and bulk oil. About half of the cargoes other than the above is foodstuff such as flour, sugar, rice, brans, milk and meats, including about 2,000 tons of various factory products such as beer and soft drink.

Most of the north-bound cargoes is empty bottles, drums and agri-cultural products.

The study about situation in the coastal transaction of only one year for 1967 showed a comparatively wide dispersion of the volumes by months in the south-bound cargoes. Most of this dispersion is due to the irregular transportation of cement and bulk oil.

The monthly volume of cargoes by shipping service is attaining a level of about 2, 500 tons except December and January when it increases to a level of 5, 000 tons.

It is estimated that 9, 000 tons of cargoes are transported between Dar es Salaam and Mtwara area on road. This transportation is made during the dry season continuing four or five months from June or July when the crossings over Rufiji River and other medium and small rivers are possible.

The outline of cargo movement is grasped based on the data of O.D. survey carried out by COMWORKS at the census point on the coastal road taking three days in the period of September, 1968 - January, 1969. Table 2-16 shows the principal movements of cargoes by articles.

It is supposed that the building materials transported to Dar es Salaam from the local districts are timbers and logs and those transported to the local districts from Dar es Salaam are sawed lumbers and plywoods. Also it is understood that how much agricultural products from the surrounding districts are being collected to Dar es Salaam, a consumer city with a population of 272, 500 (1967).

Table 2-16 Flow of Cargoes on the Coastal Road (in tons/day)

Articles	Origin	Destination	Cargoes (tons/day)	Date of data collected
Building materials	D. S. M.	Kisarawe	4	Nov. 1969
	"	Rufiji	7	"
	"	Lindi	1.7	"
	Kisarawe	D. S. M.	18	"
	Rufiji	"	57	"
	Kilwa	"	2.3	"
Sub-total			90.0	
Agricultural products	D. S. M.	Rufiji	2.3	"
	Kisarawe	D. S. M.	55	"
	Rufiji	D. S. M.	18.3	"
	Kilwa	D. S. M.	2.3	"
Sub-total			77.9	
Miscellaneous	D. S. M.	Kisarawe	2.3	"
	"	Rufiji	15.3	"
	"	Kilwa	2.3	"
	"	Lindi	5.3	"
	"	Mtwara	14.7	"
	Kisarawe	D. S. M.	4.7	"
	Rufiji	"	2.0	"
Sub-total			46.6	
Factory products	D. S. M.	Rufiji	9.3	"
	Mtwara	D. S. M.	2.3	"
Sub-total			11.6	
Fuel, Oil and Petrol	D. S. M.	Rufiji	2	"
	"	Mtwara	2.7	"
Sub-total			4.7	
Fishes	D. S. M.	Lindi	1.7	"
	Tanga	Lindi	2	"
Sub-total			3.7	
Cotton	Rufiji	D. S. M.	3.3	Jan. 1969
Sub-total			3.3	
Sisal	Kisarawe	D. S. M.	2.3	Nov. 1969
	Rufiji	D. S. M.	2.7	"
Sub-total			5.0	
Total			242.8	

Source: Data of O. D. Survey by COMWORKS

Note: The total volume of cargoes flowed in 3 days was divided by 3 to calculate the volume per day.

2-6-3 Construction in the Area to be Affected by the Coastal Road

i) Tan Zam Highway

Tan Zam Highway is a grand international road with a length of 940 km (583 miles) running from Dar es Salaam to Tunduma on the border of Zambia and its total construction cost is 494, 775, 000 shillings. It is so great project that other road programmes are as if eclipsed by it. The design speeds are 120 km/hr in flat section, 80 km/hr - 96 km/hr in flat-to-hilly section and 64 km/hr on hilly section

The whole length is divided into four sections and the construction works are under way on each section with the assistances of the World Bank, United States and Sweden.

Table 2-17 Construction of Tan Zam Highway (As of August, 1970)

Construction section	Length (in km)	Construction period	Cost expended (in sh.)	Total cost (in sh.)
1) Tunduma Iyayi	235	Nov., 1966 Oct., 1970	66, 571, 000	136, 181, 000
2) Iyayi Mahenge	270	Nov., 1966 Dec., 1971	60, 729, 000	113, 507, 000
3) Mahenge	230	Apr., 1969 Sept., 1971	43, 748, 000	126, 307, 000
4) Morogoro	181	June, 1968 July, 1973	3, 035, 000	98, 780, 000
5) By Passes at D.S.M. and Morogoro	24	July, 1970 July, 1973	-	20, 000, 000
Total	940		174, 083, 000	494, 775, 000

ii) Tanzania/Zambia Railway

The construction of the railway with a length of 1, 900 km connecting Dar es Salaam to Kapiri Mposhi of Zambia has the object to provide Zambia who has no seaport with the port facilities at Dar es Salaam of Tanzania now on good terms with Zambia. Zambia needs the railway to use Dar es Salaam as its international trade port for exporting its copper ore and to promote the agricultural development in its southern part as well.

Investigation and surveying as the first stage has been completed already with the assistance of People's Republic of China.

Designing as the second stage has been also completed and construction work as the third stage started.

The total construction cost is about 2, 903 million shillings of which about 103. 7 million shillings are covered by the goods imported from People's Republic of China.

CHAPTER 3

ESTIMATE OF THE TRAFFIC VOLUME

CHAPTER 3. ESTIMATE OF THE TRAFFIC VOLUME

3-1 Traffic Volume at Present

Data for the present traffic volume on the coastal road running from Dar es Salaam to Mtwara include OD distribution obtained from the survey made at Mkuwanga, Ikiwiriri and Nangurukuru by COMWORKS from 1968 to 1970 and as to Mtwara Region O.D. Research made by United Research Incorporated and COMWORKS, but in these data the year and month of survey were not same for different census points.

These data show that the present traffic volume of the Dar es Salaam - Kibiti section is 181 vehicles/day and that of Lindi-Mtwara section is 145 vehicles/day, indicating larger traffic volume than other sections where it is as small as 19 vehicles/day - 39 vehicles/day.

The traffic pattern in Tanzania is apt to be influenced by the factor such as seasonal fluctuations rather than yearly trends, because the natural condition in climate is characterized by rainy and dry seasons. For the present project, Rufiji River is giving the most serious problem of floods from November to May in the rainy season during which any traffic is almost paralyzed. The records of ferry service operated on Rufiji River indicate some cross-river traffic; however, even if it is possible to cross the River, other medium rivers including Matandu, Mavuji and Mbwemkuru as well as tens of small rivers make it impossible to travel between Dar es Salaam and Mtwara on surface in the rainy season. Therefore, any traffic crossing Rufiji River in the rainy season is supposed to be internal traffic within Rufiji District.

The transportation pattern of agriculutral products in each area is characterized by the distribution pattern of agricultural products corresponding to the climatic variances in the country and by the differences in the kind of crops harvested.

3-2 Growth in Vehicle Registration

As shown in Fig. 3-2, the number of vehicles registered has gone on increasing year by year. Its annual growth rate of 10.8% from 1960-62 to 1969 exceeded the growth rate of 3.1% for population in 10 years from 1957 to 1967 by as much as 7.7% and this fact means that the rate of registered vehicles per population is increasing yearly.

Referring to the types of vehicles, the agricultural and construction vehicles such as tractors, trailers and crane trucks showed a remarkable growth rate

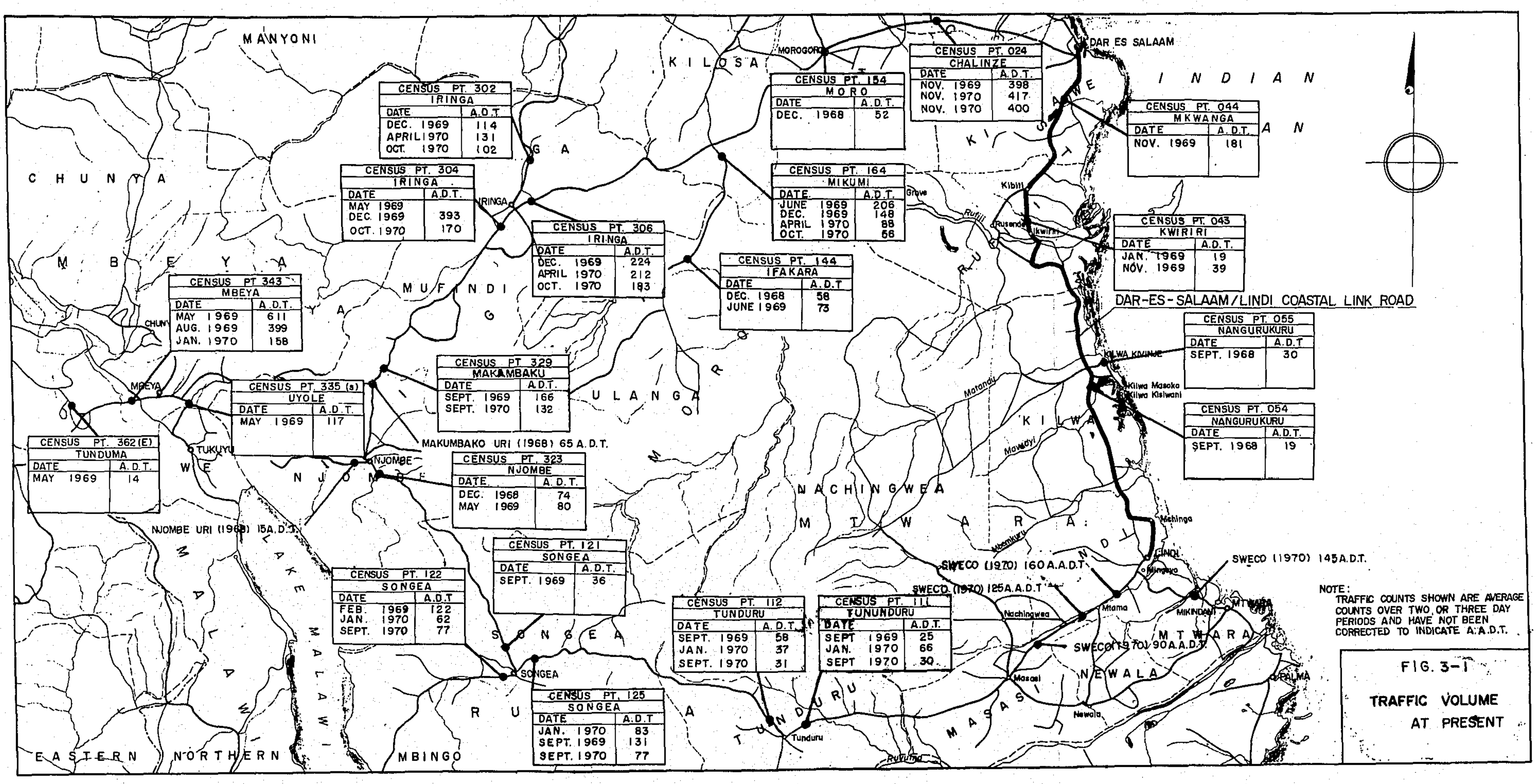
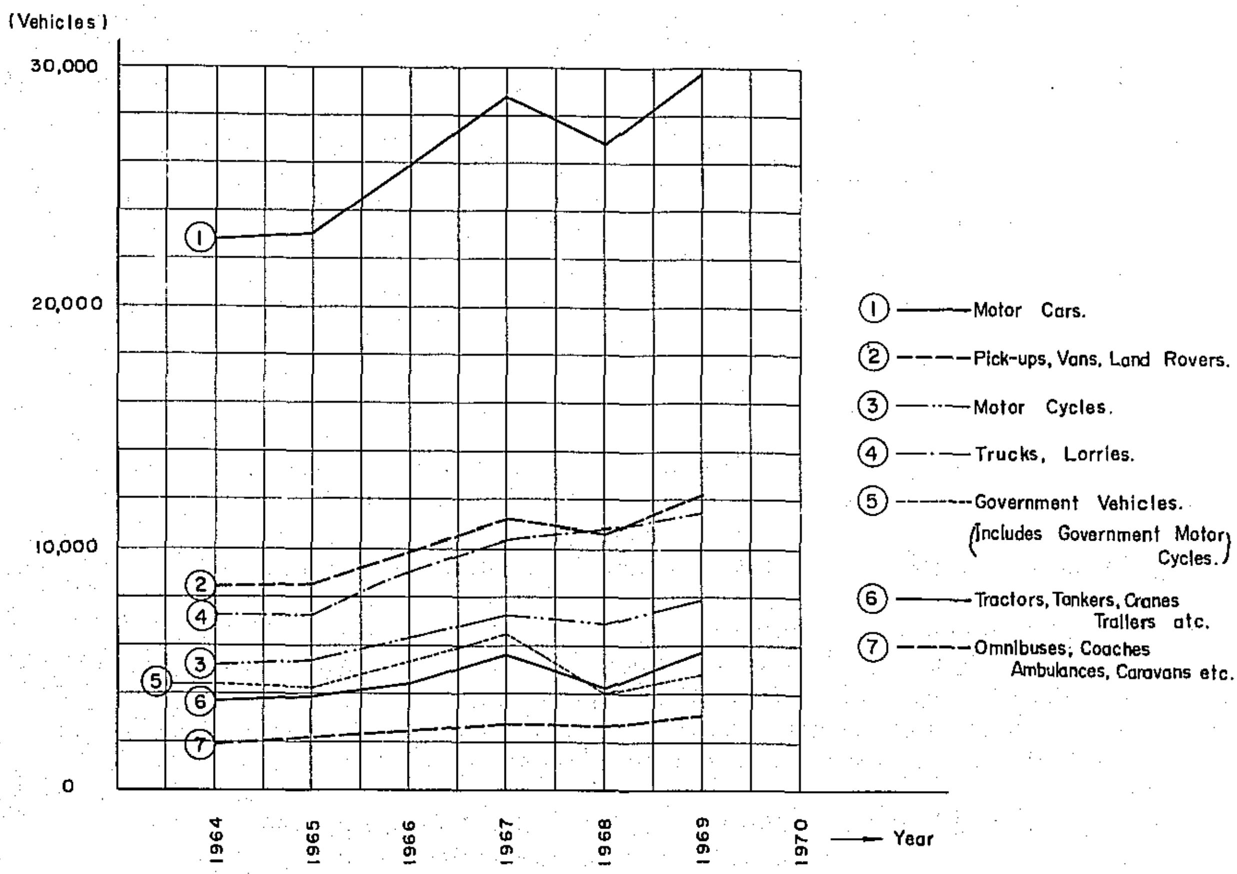


FIG. 3-1

TRAFFIC VOLUME AT PRESENT

Fig 3-2 MOTOR VEHICLES-TOTAL LICENSED (1964~1969)



Growth Rate (%)	①	②	③	④	⑤	⑥	⑦	Total
1968/1969	+11.1	+14.6	+14.8	+7.7	+21.7	+35.3	+18.0 (%)	+14.0 %
1960~62/1969	+7.9	+10.7	+9.2	+9.2	+5.7	+21.1	+7.4	+10.8 %

Source ; The Economic Survey and ANNUAL PLAN 1970~71.

reaching 21.1% annually from 1960-62 to 1969. This shows that great efforts have been exerted for the agricultural development and various construction works in Tanzania.

Table 3-1 Growth in Vehicle Registrations (1960 - 1969)

Types / Year	Passenger car	Pickup, Van, Land rover	Motorcycle	Truck, Lorry	Govern't-owned vehicle (including motorcycle)	Taactor, Trailer, Crane truck, Tank lorry	Large-size bus Ambulance-car, etc.	Total
1960 62	17,461	7,771	4,302	6,206	3,303	1,520	1,896	42,459
1964	22,854	8,454	5,221	7.301	4,391	3,712	1,978	53,911
1965	22,985	8,557	5,415	7,215	4,238	3,859	2,153	54,422
1966	25,877	9,884	6,449	9,004	5,320	4,439	2,472	63,445
1967	28,748	11,213	7,292	10,461	6,534	5,644	2,761	72,653
1968	26,809	10,648	6,959	10,750	4,003	4,274	2,650	66,093
1969	29,784	12,205	7,989	11,578	4,872	5,781	3,126	75,335
1969/1968 Percentage fluctuation %	+11.1	+14.6	+14.8	+7.7	+21.7	+35.3	+18.0	+14.0
(1960-62)/69 % Annual growth rate	+7.9	+10.7	+9.2	+9.2	+5.7	+21.1	+7.4	+10.8

Source: The Economic Survey and Annual Plan, 1970-71

The various types of vehicles shown in Table 3-1 are classified into four categories of passenger cars, lorries, vans and busses as shown in Table 3-2.

In this arrangement the following modifications were introduced.

1) Motorcycles were omitted.
2) In addition to pickups, land rovers and vans, government-owned vehicles were classified into "Vans".
3) In addition to trucks and lorries, tractors, trailors, crane trucks and tank lorries were classified into "Lorries".

Table 3-2 Number of Registered Vehicles by Types 1964-1969 (in vehicles)

Types / Year	Passenger cars	Lorries	Vans	Busses	Total
1964	22,854	11,013	12,845	1,978	48,690
1965	22,985	11,074	12,795	2,153	49,007
1966	25,877	13,443	15,204	2,472	56,996
1967	28,748	16,105	17,747	2,761	65,361
1968	26,809	15,024	14,651	2,650	59,134
1969	29,784	17,359	17,077	3,126	67,346

Source: The Economic Survey and Annual Plan, 1970-71

3-3 Make-up of Types of Vehicles Operating in the Coastal Area

The composition of vehicle types may be gotten readily if the number of registered vehicles by Districts is available. For the lack of such data, although any deduction of the compostion of vehicle types in this way will involve some problems, such data as considered to have relations to the coastal road between Dar es Salaam and Mtwara were selected from the OD data collected in the coastal area by COMWORKS and U.R.I. to calculate the average number of registered vehicles for 1967 and 1968. According to result, passenger cars represented 11.4%, lorries 45.0%, vans 29.3% and busses 14.3%.

As shown in Table 3-3, the make-up of vehicle types for the whole country indicates that passenger cars account for nearly half or 46%, by far exceeding 11.4% of the coastal area. The reasons for this seem to be that though the passenger cars have a tendency to concentrate in the cities, e.g. Dar es Salaam, the urban traffic cannot be grasped by the present OD survey and that passenger cars is replaced with lorries and vans in the rural traffic because of poor road conditions and unsuitableness of passenger cars to long distance travels.

Table 3-3 Composition of Vehicle Types in the Whole Country (%)

Types / Year	Passenger cars	Lorries	Vans	Busses	Total
1960~62	46	20	29	5	100
1964	47	23	26	4	"
1965	47	23	26	4	"
1966	45	24	27	4	"
1967	44	25	27	4	"
1968	45	25	25	5	"
1969	44	26	25	5	"
Average	45.4	23.7	26.4	4.5	100

Source: The Economic Survey and Annual Plan, 1970-71

Note: i) Motorcycles are omitted.
ii) In addition to pickups, land rovers and vans, government-owned vehicles are classified into "Vans".
iii) In addition to trucks and lorries, tractors, trailers and crane trucks are classified into "Lorries".

3-4 Utete and Ndundu Ferries

At present, ferryboats are being operated on Rufiji River at Utete and Ndundu from July to November in the dry season. The ferryboat has a capacity for loading three passenger cars, or one bus and two passenger cars providing shuttle service towed by a motorboat of about five meters in length.

The traffic volume crossing Rufiji River by ferryboats shown in Table 3-4 was calculated from the ferry charges, i.e. 5 shillings per vehicle and 5 cents per passenger. The number of vehicles and that of passengers were reckoned from the collected charges by months.

The traffic volume crossed Rufiji River by ferry as calculated in the above method is shown in Table 3-4.

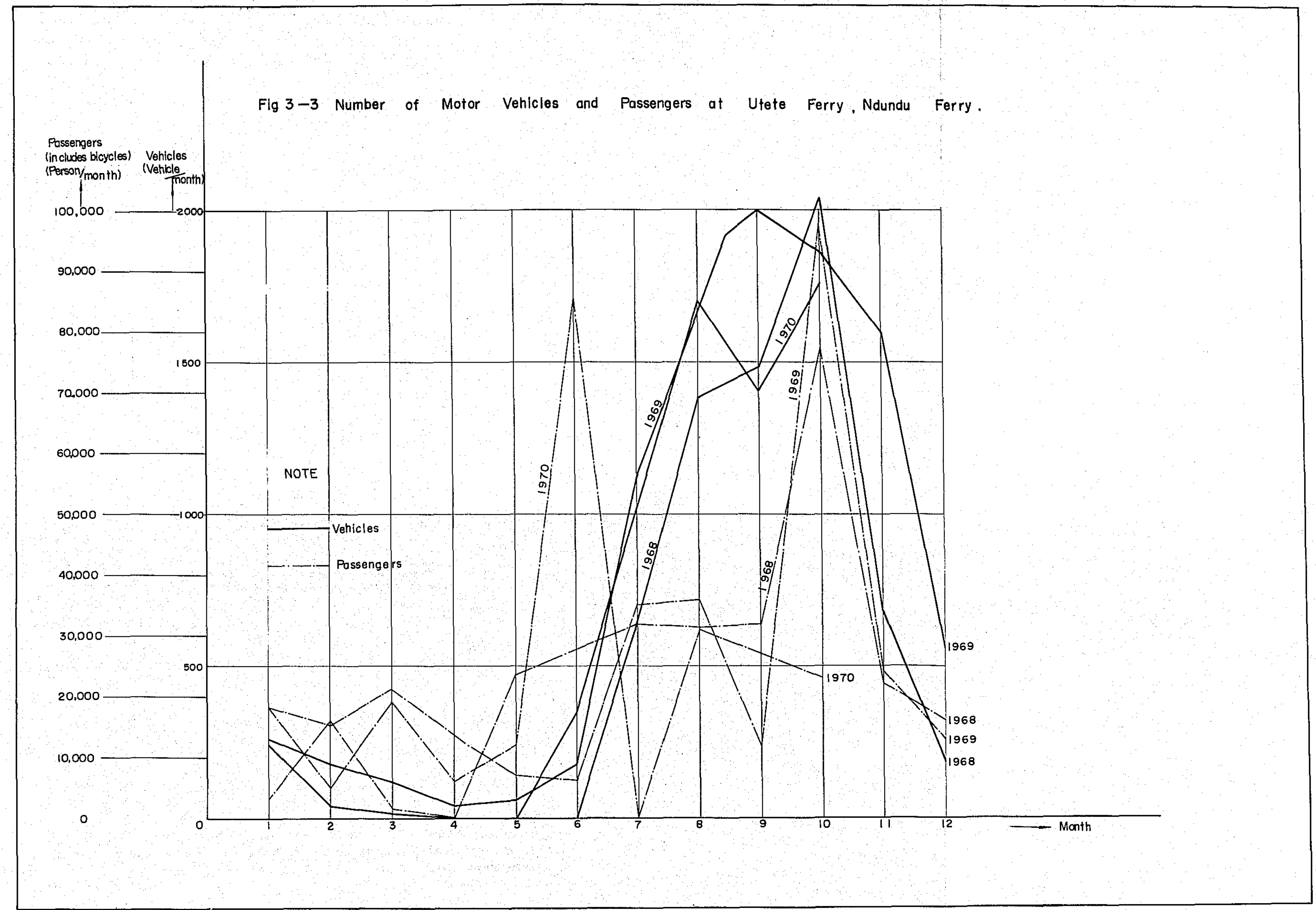


Fig 3—3 Number of Motor Vehicles and Passengers at Utete Ferry, Ndundu Ferry.
Passengers (includes bicycles) (Person/month)
Vehicles (Vehicle/month)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
2000
1500
1000
500
0
NOTE
Vehicles
Passengers
1970
1969
1968
1 2 3 4 5 6 7 8 9 10 11 12
Month

Table 3-4 Ferry Service Crossing the River at Utete and Ndundu

Year	Month	Vehicles		Passengers	
		units/day	units/day	persons/day	persons/day
1968	1	-	-	1,500	50
	2	-	-	16,200	540
	3	-	-	3,400	113
	4	- No datum available -			
	5	-	-	23,500	783
	6	-	-	27,900	930
	7	640	21	32,000	1,067
	8	1,380	46	31,400	1,047
	9	1,480	49	31,900	1,063
	10	2,040	68	77,250	2,575
	11	680	23	22,300	743
	12	180	6	16,000	533
1969	1	260	9	18,100	603
	2	80	3	20,000	667
	3	120	4	21,300	710
	4	40	1	13,700	457
	5	60	2	7,000	233
	6	180	6	6,000	200
	7	1,120	37	35,000	1,167
	8	1,920	64	36,000	1,200
	9	2,000	67	24,000	800
	10	1,860	62	95,000	3,167 (meeting of TANU etc.)
	11	1,600	53	24,000	800
	12	560	19	13,000	433
1970	1	240	8	18,000	600
	2	40	1	10,000	33
	3	15	1	19,000	633
	4	-	-	6,000	200
	5	-	-	12,000	400
	6	345	12	85,000	2,833
	7	- No datum available -			
	8	1,700	57	31,000	1,033
	9	1,400	47	27,000	900
	10	1,760	59	23,000	767

Note: Daily traffic volume (vehicles/day) and daily number of passengers (persons/day) were converted from monthly traffic volume (vehicles/month) and monthly number of passengers (persons/month) by dividing them by 30, with any fraction rounded.

Source: Office of R. E. Coast

3-5 Estimate of Future Traffic Volume

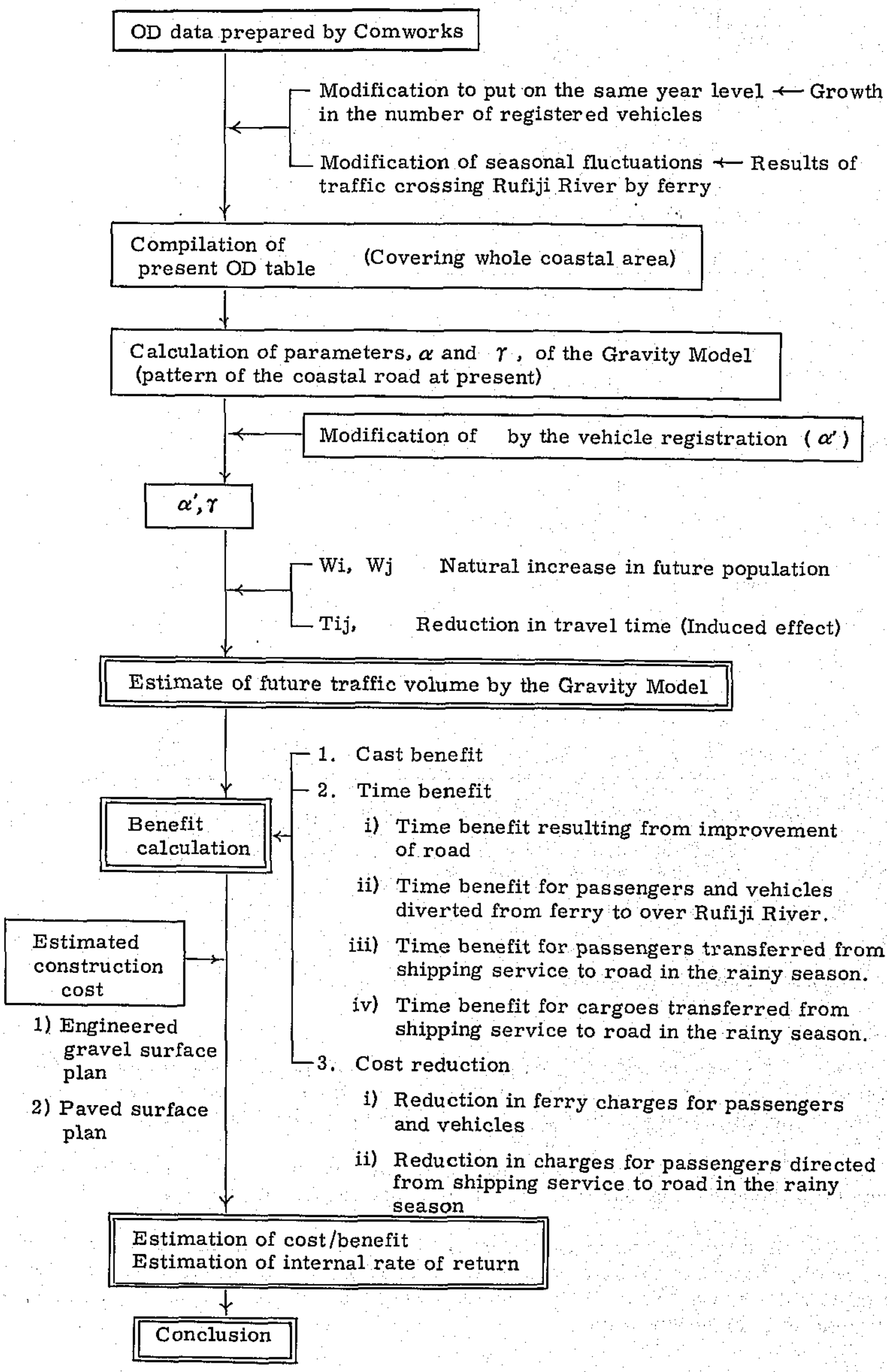
3-5-1 Outline

The area along the coastal road between Dares Salaam and Mtwara was divided into zones and traffic volume for each pair of zones was calculated based on the OD survey data for 1968-1970 prepared by COMWORKS.

The traffic volume passing the coastal road was subjected to some correction considering the seasonal fluctuations at Rufiji Ferries.

Since the years and months in which the surveys were made are divergent as a whole, the data whose survey dates differing over than one year were modified so as to unify them on the 1969 year, utilizing the growth in number of registered vehicles as correction factor.

Fig. 3-4 Flow of Traffic Forecast and Economic valuation



Based on the traffic volumes for pairs of zones for 1969 calculated in this way, the parameters, α and r, of the Gravity model to be applied to the coastal area are computed using the total population as economic indicator. Then, natural increase in the future population of each district is estimated based on the annual growth rate of population in the past, and the future traffic volume in the coastal area is estimated by the Gravity Model method with reduction in travel time, tij, taken as an induced effect after the coastal road has been opened to service.

Fig. 3-4 shows a flow chart of analyses and estimates starting from original data and ending in the economic evaluation.

3-5-2 Year for the Estimate of Traffic Volume

Traffic Volumes on the planned road are estimated respectively for the year when the road is opened to traffic and the year when the reimbursement completed, based on the two plans improving the existing road into engineered gravel and into bituminous paved road.

1) Simultaneous execution of work on the all section (engineered gravel road plan).

The section to the point of 3 km to the south of Rufiji River crossing will be perfectly paved, with the remainder being engineered gravel road.

It is assumed that -

Period required for investigation and designing	2 years
Period required for construction work	4 years
Total	6 years

If the investigation and designing are started in 1971 the road will be opened to traffic in 1977. If planned reimbursement period of construction costs is set at thirty years the reimbursement will be completed in 2006.

2) Simultaneous execution of work on the all section (bitumen road plan)

It is assumed that -

Period required for investigation and designing	2 years
Period required for construction work	6 years
Total	8 years

If investigation and designing are started in 1971 the road will be opened to traffic in 1979. If planned reimbursement period is set at thirty years the reimbursement will be completed in 2008.

The future traffic volumes are estimated for the above four years, i.e., 1977, 2006, 1979 and 2008.

FIG. 3-5 ZONING

3-5-3 Zoning

The influence area of the coastal road is divided into zones according to the administrative division, i.e., District.

Table 3-5 Designation of Zones

Zone No.	Districts
03	D.S.M. Mzizima, Kisarawe
04	Rufiji
05	Kilwa
06	Lindi
07	Nachingwea
08	Mtwara
09	Newara
10	Masasi
11	Tunduru

3-5-4 Compilation of Present OD Table

The data shown in Table 3-6 were used as the basis for compiling the present OD table. The present traffic volume acquired from these data is shown in Table 3-7.

Table 3-6 COMWORKS Traffic Census Origin and Destination Survey Data

Date	Census PT.	Location		
01/69	043	Kieiti	Kilwa Rd.	(Ikwifìfi)
11/69	043		"	"
11/69	044	Lar	Kibiti Rd.	(Mkwanga)
09/68	054			(Nangurukuru)
09/68	055			(")

Source: Planning Unit, COMWORKS

Table 3-7 Traffic Volume in the Coastal Area, as of September, 1969 (in vehicles/day)

Zone		Traffic volume (vehicles/day)
Kisarawe	Rufiji	74
"	Kilwa	8
"	Nachingwea	0
"	Lindi	6
"	Mtwara	10
"	Newara - Masasi	1
"	Tunduru	1

Note: i) It was assumed that the number of originating trip end and that of arriving trip end in each zone are equal.

ii) Monthly fluctuations of observed figures in OD survey was modified by the results of traffic crossing Rufiji River by ferry.

iii) Differences in observation years in OD survey were modified by the yearly variations in number of registered vehicles in the country.

3-5-5 Calculation of Gravity Model Method

$$Xij = \alpha \, Wi \cdot Wj \cdot Tij^{-\gamma} \quad \ldots\ldots\ldots\ldots \quad 3.1)$$

wherein; Xij . . . traffic volume between zone i and zone j,

Wi, Wj . . . total population of zone i and zone j,

Tij . . . travel time between zone i and zone j,

α, β . . . parameters

3-5-6 Calculation of Parameters α, γ

3-5-6-1 Estimate of Total Population

The population of each zone for 1969 obtained from the population statistics data of the country as of August, 1967, and the past annual growth rate from 1957 to 1967 is shown in Table 3-8.

Table 3-8 Total Population of Coastal Area (in persons)

Zone No.	Name of zones	Annual growth rate (%) of population (1957-1967)	1967	1969
03 = 031	O.S.M. city	7.8	272,500	313,400
+032	Kisarawe	1.8	179,000	185,400
+033	Mzizima	7.0	75,300	33,800
04	Rufiji	0.2	121,400	121,900
05	Kilwa	1.1	98,900	101,100
06	Lindi	2.9	237,200	251,000
07	Nachigwea	3.7	80,600	86,600
08	Mtwara	3.4	134,700	143,900
09 + 10	Newara	4.2	267,700	290,400
	Masasi	3.5	213,600	228,600
11	Tunduru	3.3	97,000	103,400

Source: District Data, 1967 (Ministry of Economic Affairs and Development Planning, Dar es Salaam, 1968)

3-5-6-2 Calculation of Travel Time tij

Although the travel speed of vehicle varies according to its type and the conditions of road (surface condition, horizontal and vertical alignment) it was assumed based on the condition of road surface, that average speeds are 50 miles/hr (80.5 km/hr) on paved road, 40 miles/hr (64.4 km/hr) on engineered gravel road and 30 miles/hr (48.3 km/hr) on earth road, without classifying them by types of vehicles.

Travel times tij obtained from the distance and average running speed between zones are as shown in Table 3-9.

Table 3-9 Travel Times between Zones (in hr.)

Destination \ Origin	03=031 032 033	04	05	06	07	08	09+10	11
03=031 032 033		3.4	5.8	9.3	11.6	10.6	11.7	15.5
04	3.4		3.1	6.6	8.6	7.9	9.1	12.9
05	5.8	3.1		3.5	5.8	4.8	6.9	9.8
06	9.3	6.6	3.5		2.3	1.3	2.4	6.2
07	11.6	8.6	5.8	2.3		3.0	2.4	5.0
08	10.6	7.9	4.8	1.3	3.0		2.7	7.0
09+10	11.7	9.1	6.9	2.4	2.4	2.7		5.5
11	15.5	12.9	9.8	6.2	5.0	7.0	5.5	

Note: i) Distances between zones were obtained from Road Map of East Africa and classification of R oads, COMWORKS (Ministrial Circular No. 1, 1969)

ii) Traffic crossing Rufiji River was added with 40 minutes 0.7 hours.

The parameters α and r were calculated by the least square method on the basis of total population Wi, Wj and travel time tij obtained in relation to the coastal road as desicribed above; they are shown in the followint table.

Table 3-10 α and r

Coastal road - 8 zones	α	r	R
1969	4.80×10^{-9}	2.15	0.894

R .... Coefficient of correlation

3-5-7 Modification of α by the Number of Registered Vehicles per Capita

As the growth rate of population in the past is 3.1% in annual average and the growth rate in number of registered vehicles per capita, although varying by types, is 10.8% per year exceeding the former by as much as 7.7%, the latter should be increasing annually.

It does not seem proper to estimate the future traffic volume based only on the natural increase of population, because the factor such as growth in the future traffic volume brought about by the increase in the number of registered vehicles is required to be taken into consideration.

So, for the modification of α, a formula to find annual variation in the number of registered vehicles per capita is obtained for each type applying the least square method to the data of such per capita number.

Table 3-11 No. of Registered Vehicles per Capita by Types, 1964 - 1969 (vehicles/persons)

Types / Year	Car	Lorry	Van	Bus	All types
1964	0.00201	0.00097	0.00113	0.00017	0.00428
1965	0.00197	0.00095	0.00110	0.00018	0.00420
1966	0.00217	0.00113	0.00127	0.00021	0.00478
1967	0.00235	0.00132	0.00145	0.00023	0.00535
1968	0.00214	0.00120	0.00117	0.00021	0.00472
1969	0.00233	0.00136	0.00133	0.00024	0.00526

Source: 1) 1967 Population Census, Central Statistical Bureau
2) The Economic Survey and Annual Plan, 1970 - 71

Formula to find annual variation in the number of registered vehicles per capita:

$$Y = a + bx \quad \ldots \quad 3.2)$$

wherein; Y . . . per capita No. of registered vehicles (vehicles/person),

x . . . year 1964 x = 0
1965 x = 1
1966 x = 2

i) Passenger car: $Y = 0.00200 + 0.0000654\,x$ . . . . 3.3)

ii) Lorry: $Y = 0.000945 + 0.0000834\,x$ . . . . 3.4)

iii) Van: $Y = 0.001144 + 0.0000397\,x$ . . . . 3.5)

iv) Bus: $Y = 0.000168 + 0.0000174\,x$ . . . . 3.6)

The registered vehicles per capita for the years of opening of road to traffic and those of completion of reimbursement shown as relative ratios against those of 1969, obtained from the above formulas 3.3), 3.4), 3.5) and 3.6) are shown in Table 3-12.

Table 3-12 No. of Registered Vehicles per Capita shown as Relative Ratios

Year \ Type	Car	Lorry	Van	Bus
1977/1969	1.223	1.493	1.248	1.625
1979/1969	1.279	1.610	1.291	1.680
2006/1969	2.039	3.272	2.113	3.780
2008/1969	2.086	3.382	2.134	3.680

3-5-8 Estimate of Future Percentage Distribution of Types in Total Registered Vehicles

Percentage distribution of types in the total number of registered vehicles in future was obtained from the general formula of registered vehicles number expressed by the least square method applied to the annual variations in the number of registered vehicles of such types as shown in Table 3-2. The general formulas used are as follows.

1) Passenger car: $Yi = 22,676 + 1400\ Xi$ . . . . 3.7)
2) Lorry: $Yi = 10,700 + 1321\ Xi$ . . . . 3.8)
3) Van: $Yi = 12,963 + 836\ Xi$ . . . . 3.9)
4) Bus: $Yi = 1986 + 215\ Xi$ . . . . 3.10)

wherein; 1964 $Xi = 0$
1965 $Xi = 1$
. .
. .

The numbers of registered vehicles of respective types corresponding to the years when the road is opened to traffic and when the reimbursement is completed are shown in Table 3-13.

Table 3-13 Number of Registered Vehicles by Types (in vehicles)

Year \ Types	Passenger cars	Lorries	Vans	Busses	Total
1969	29,784	17,359	17,077	3,126	67,346
1977	40,876	27,873	23,831	4,781	97,361
1979	43,676	30,515	25,503	5,211	104,905
2006	81,476	66,182	48,075	11,016	206,749
2008	84,276	68,824	49,747	11,446	214,293

If passenger car, lorry, van and bus expressed as percentages to the total number of registered vehicles in future are designated respectively as P_1, P_2, P_3, and P_4, these P_1, P_2, P_3 and P_4 are formulated by 3.11), 3.12), 3.13) and 3.14) respectively, as follows:

$$P_1 = \frac{P_{OO} \times \frac{N_{OF}}{N_{O9}}}{P_{OO} \times \frac{N_{OF}}{N_{O9}} + P_{LO} \times \frac{N_{LF}}{N_{L9}} + P_{VO} \times \frac{N_{VF}}{N_{V9}} + P_{BO} \times \frac{N_{BF}}{N_{B9}}} \qquad 3.11$$

$$P_2 = \frac{P_{LO} \times \frac{N_{LF}}{N_{L9}}}{P_{OO} \times \frac{N_{OF}}{N_{O9}} + P_{LO} \times \frac{N_{LF}}{N_{L9}} + P_{VO} \times \frac{N_{VF}}{N_{V9}} + P_{BO} \times \frac{N_{BF}}{N_{B9}}} \qquad 3.12$$

$$P_3 = \frac{P_{VO} \times \frac{N_{VF}}{N_{V9}}}{P_{OO} \times \frac{N_{OF}}{N_{O9}} + P_{LO} \times \frac{N_{LF}}{N_{L9}} + P_{VO} \times \frac{N_{VF}}{N_{V9}} + P_{BO} \times \frac{N_{BF}}{N_{B9}}} \qquad 3.13$$

$$P_4 = \frac{P_{BO} \times \frac{N_{BF}}{N_{B9}}}{P_{OO} \times \frac{N_{OF}}{N_{O9}} + P_{LO} \times \frac{N_{LF}}{N_{L9}} + P_{VO} \frac{N_{VF}}{N_{V9}} + P_{BO} \times \frac{N_{BF}}{N_{B9}}} \qquad 3.14$$

wherein: P_{OO}, P_{LO}, P_{VO}, P_{BO} ..... Passenger car, lorry, van and bus expressed as percentages to the total No. of registered vehicles in the coastal area, computed on the basis of OD survey data of COMWORKS;

N_{O9}, N_{L9}, N_{V9}, N_{B9} ..... Number of registered passenger cars, lorries, vans and busses of the whole country, in 1969;

N_{OF}, N_{LF}, N_{VF}, N_{BF} ..... Number of registered passenger cars, lorries, vans and busses of the whole country, in future;

Percentage distribution of types in the total number of registered vehicles computed with the formulas 3.11), 3.12), 3.13) and 3.14) is as shown in Table 3-14.

Table 3-14 Percentage Distribution of Types in the Total Number of Registered Vehicles (%)

Types / Year	Passenger car	Lorries	Vans	Busses	Total
1977	10.4	48.0	27.1	14.5	100
1979	10.2	48.4	26.8	14.6	100
2006	9.3	51.2	24.5	15.0	100
2008	9.3	51.2	24.5	15.0	100

3-5-9 Calculation of α'

The parameter α of the gravity model formula is substituted with α' of the following formula in future.

$$\alpha' = (P_1 a_1 + P_2 a_2 + P_3 a_3 + P_4 a_4) \quad \ldots\ldots\ldots \quad 3.15)$$

wherein;

P_1, P_2, P_3, P_4 . . . passenger car, lorry, van and bus expressed as percentage to the total number of registered vehicles;

a_1, a_2, a_3, a_4 . . . ratios of per capita nos. of passenger cars, lorries, vans and busses to those of 1969 put as 1;

α . . . . parameter obtained by the gravity model on the basis of OD survey data (planning Unit, COMWORKS) of the coastal area;

α' . . . . parameter in future with growth in number of registered vehicles taken into consideration

Table 3-15 α' as Modified α

Year	1977	1979	2006	2008
α'	$6,805 \times 10^{-9}$	$7,205 \times 10^{-9}$	$14,131 \times 10^{-9}$	$14,402 \times 10^{-9}$

3-5-10 Future Population of Each District for the Estimate of Future Traffic Volume

See Table 3-16.

Table 3-16 Future Population of Each District for the Estimate of Future Traffic Volume (in persons)

Zone no.		031	032	033	03 = 031 + 032 + 033	04	05	06	07	08	09	10	11
Districts		D.S.L.	Mzizima	Kisarawe		Rufiji	Kilwa	Lindi	Nachi-gwea	Mtwara	Newara	Masasi	Tunduru
Annual growth rate of population (%)	1948 - 57	7.1	0.0	0.0		1.4	-0.9	0.0	4.1	0.9	1.6	2.3	0.7
	1957 - 67	7.8	7.0	1.8		0.2	1.1	2.9	3.7	3.4	4.2	3.5	3.3
Total Population	1967	272,500	75,300	179,000	526,800	121,400	98,900	237,200	80,600	134,700	267,900	213,600	97,000
	1977	485,100	128,000	211,200	824,300	164,800	109,800	306,000	110,400	180,500	380,400	286,400	129,000
	1979	527,600	138,600	217,700	883,900	165,300	112,000	319,800	116,400	189,700	402,900	303,300	135,400
	2006	1,101,400	280,900	304,700	1,687,000	171,900	141,300	505,500	196,900	313,300	706,700	505,200	221,800
	2008	1,144,000	291,400	311,100	1,746,500	172,400	743,500	519,200	202,900	322,500	729,200	520,100	228,200

Notes: 1) The population of 1967 was obtained from "District Data, 1967", Ministry of Economic Affairs and Development Planning.

2) The populations of 1977, 1979, 2006 and 2008, respectively, was calculated on the basis of annual growth rate of population from 1957 to 1967 and the population of 1967.

3) The population of 04, Rufiji District was computed by adding 41,000 persons to the figure estimated by the annual growth rate in the past, to take into consideration the fact that this District has closer relations with Dar es Salaam than other Districts and the effect of expected increase in agricultural production due to the development plan of Vjamaa Village in Rufiji.

3-5-11 Estimate of Future Traffic Volume

Tables 3-17 ～ 3-21 show traffic volume between zones and those on the link road computed by the gravity model based on the parameter α' (α modified by the per capita No. of registered vehicles), the future population Wi, Wj of each District (Table 3-16) and travel time tij between zones obtained by the calculations described above.

Table 3-17 OD Table - 1977 (in vehicles/day)

Zone No.	03=031+032+033	04	05	06	07	08	09	10	11
03=031 +032 +033									
04	154								
05	30	35							
06	29	14	27						
97	5	2	3	38					
08	11	5	7	214	13				
09	18	7	9	121	43	55			
10	14	5	7	110	217	33	312		
11	3	1	1	5	3	2	9	13	

Table 3-18 OD Table - 2006 (in vehicles/day)

Zone no.	03=031+032 +033	04	05	06	07	08	09	10	11
03=031 +032 +033									
04	683								
05	162	97							
06	202	51	119						
07	42	8	13	235					
08	85	18	34	1273	82				
09	143	27	42	769	299	370			
10	107	21	33	662	1406	211	2110		
11	21	3	4	31	19	15	57	80	

Table 3-19 OD Table - 1979 (in vehicles/day)

Zone No.	03=031+032+033	04	05	06	07	08	09	10	11
03=031 +032 +033									
04	175								
05	43	65							
06	45	24	53						
07	8	3	4	45					
08	18	8	11	249	14				
09	27	10	12	141	52	65			
10	22	8	10	128	255	39	369		
11	4	1	1	6	4	3	10	15	

Table 3-20 OD Table-2008 (in vehicles/day)

Zone No.	03=031+032+033	04	05	06	07	08	09	10	11
03=031 +032 +033									
04	723								
05	216	172							
06	287	82	218						
07	57	12	17	253					
08	120	28	47	1372	89				
09	194	38	57	830	324	400			
10	145	30	45	714	1520	228	2284		
11	27	4	5	33	21	16	61	87	

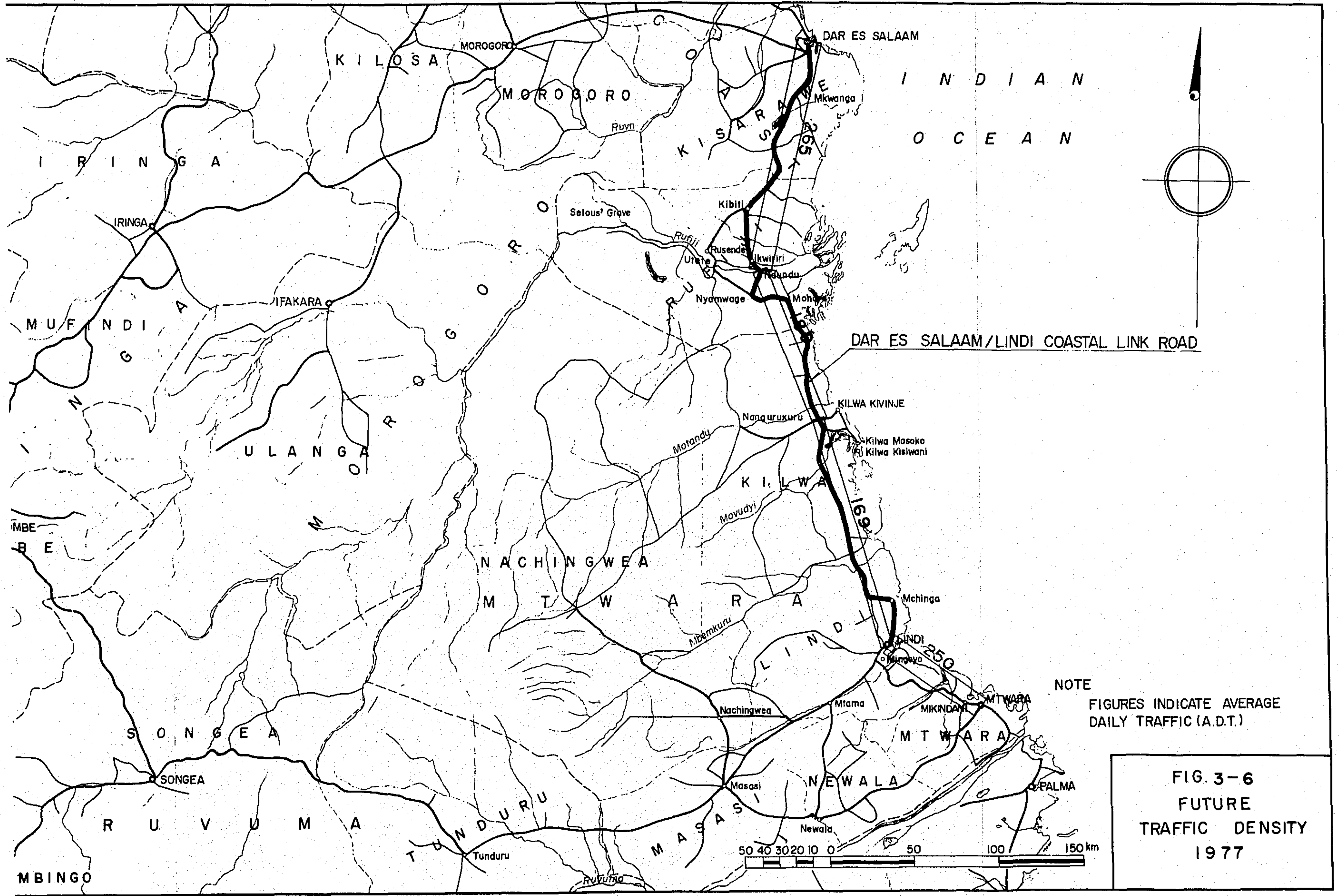


FIG. 3-6
FUTURE
TRAFFIC DENSITY
1977

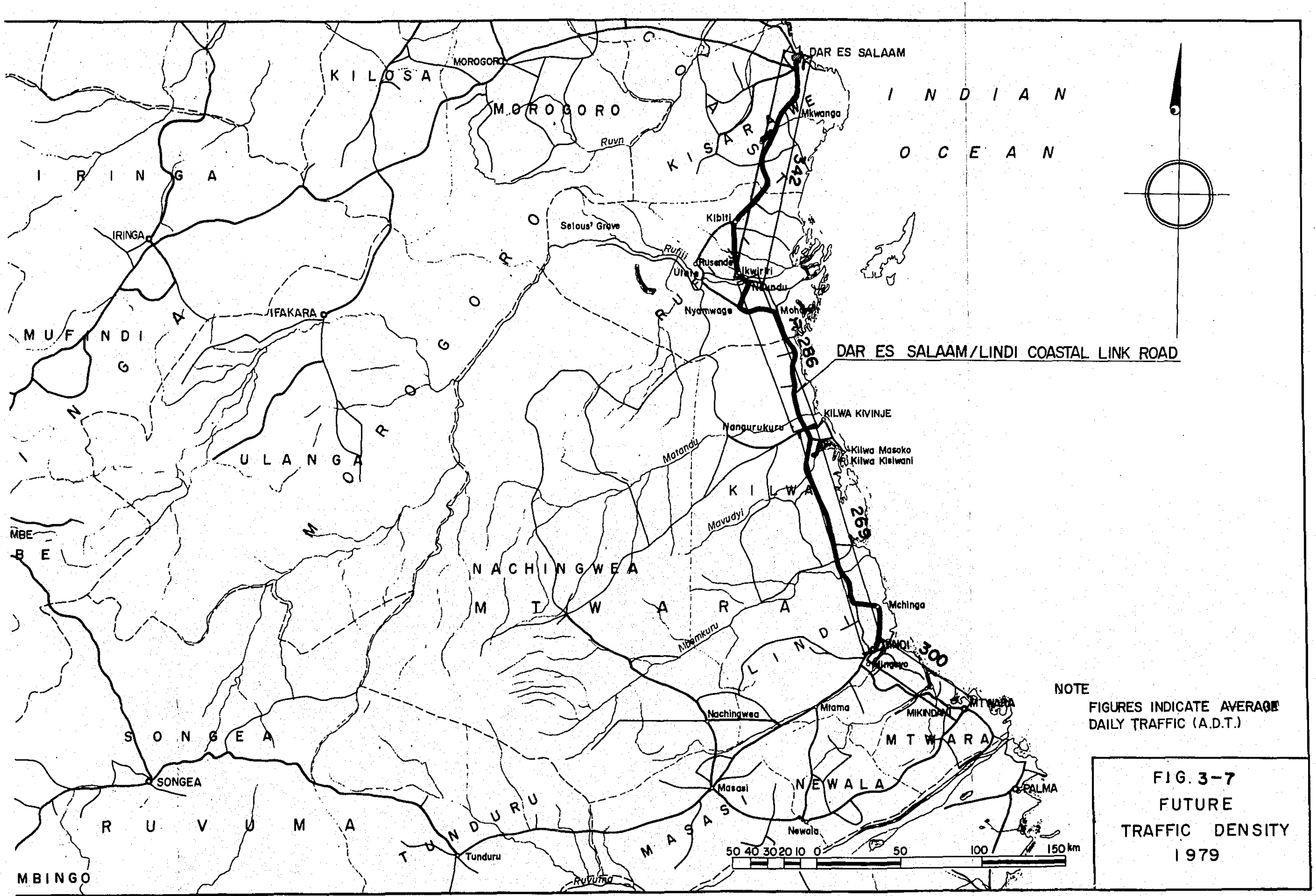


FIG. 3-7
FUTURE
TRAFFIC DENSITY
1979

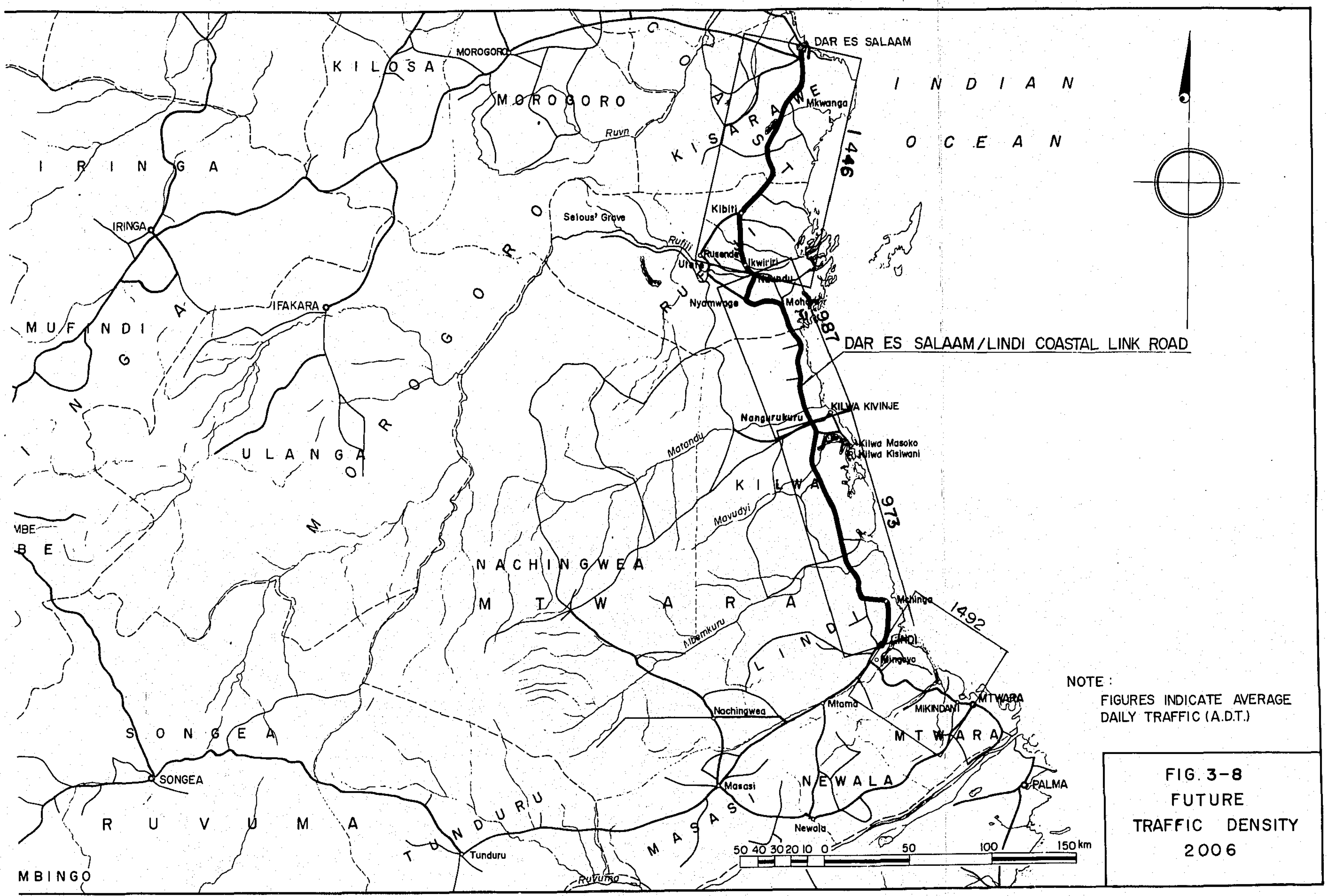


FIG. 3-8
FUTURE
TRAFFIC DENSITY
2006

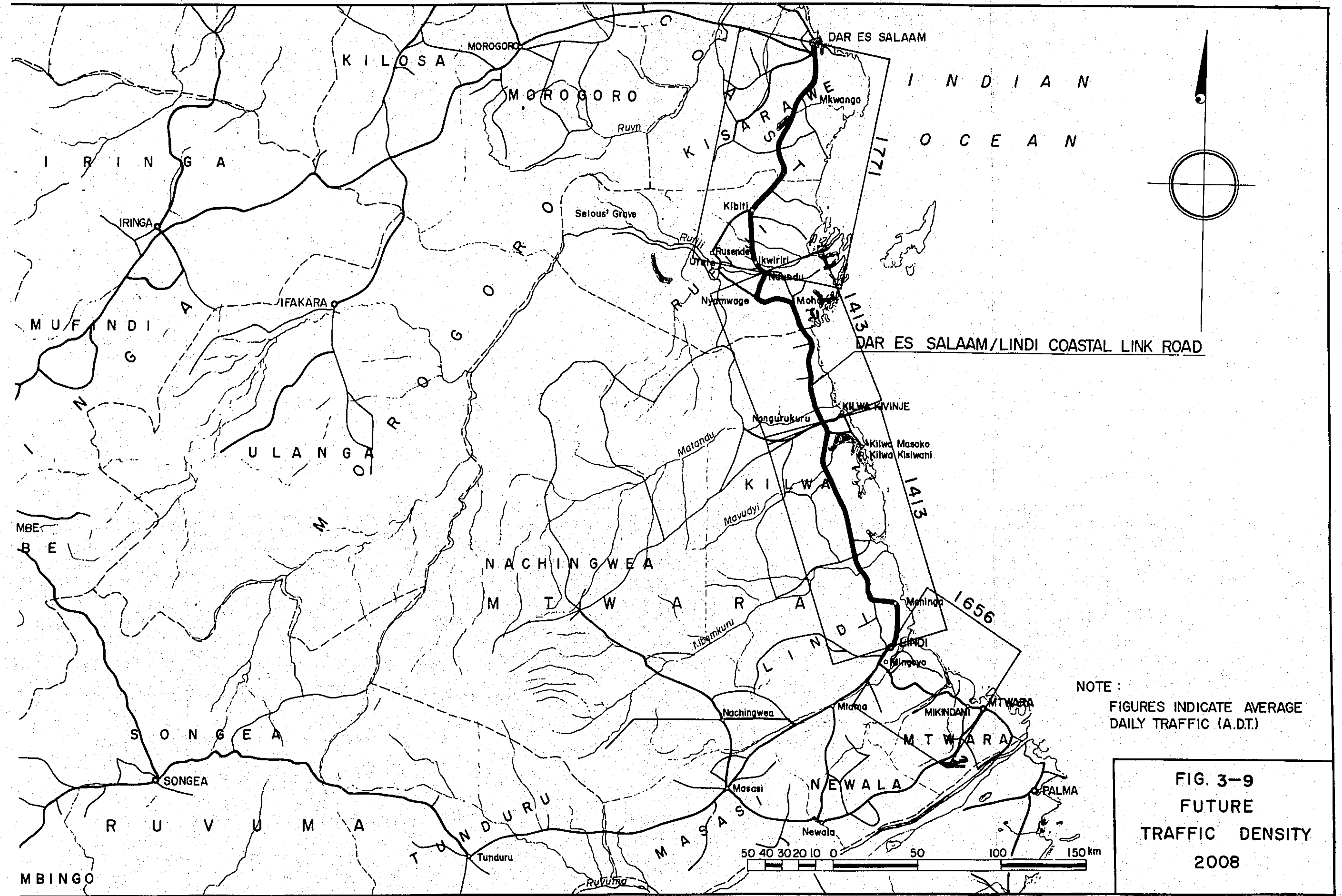


FIG. 3-9
FUTURE
TRAFFIC DENSITY
2008

Table 3-21 Future Traffic Volume (vehicles/day)

	Section \ Year	Simultaneous execution of work on the all section (Engineered gravel road plan)		Simultaneous execution of work on the all section (Bitumen road plan)	
		Year when opened for traffic	Year when payout of cost completed	Year when opened for traffic	Year when payout of cost completed
		1977	2006	1979	2008
1	Dar es Salaam Ndundu	265	1446	342	1771
2	Ndundu Nangurukur Nangurukuru	180	987	286	1413
3	Nangurukuru Lindi	169	973	269	1413
4	Lindi Mtwara	250	1492	300	1656

Note: Planned Reimbursement Period ..... 30 years

3-6 Estimate of Passengers Crossing the River at Utete and Ndundu Ferries

The following calculation was made to estimate the number of passengers utilizing the ferry to cross Fufiji River in future in the case where no bridge is built.

Actual results of ferry utilization in respective years do not indicate any definite characteristics of the annual variations. So, the monthly average of ferry passengers during the peak months of August, September and October from 1968 to 1970 was calculated, to which the growth in population of the influenced area of the coastal road was applied as a indicator of the growth in ferry passengers in the future.

Table 3-22 Number of Passengers Using Ferry Service at Ndundu and Utete (in persons/month)

Year \ Month	August	September	October
1968	31,400	31,900	77,250
1969	36,000	12,000	95,000
1070	31,000	27,000	23,000

The average number of ferry passengers in three months of August, September and October is;

$$364,550 \div 9 \text{ months} = 40,505 \text{ persons/month.}$$

If it is assumed that 80% of these passengers cross the river at Ndundu, they will be;

$$40,505 \text{ persons/month} \times 0.8 \div 30 = 1,080 \text{ persons/day}$$

The future population in the influenced area of the coastal road (Dar es Salaam, Mzizima, Kisarawe, Rufiji, Kilwa, Lindi, Nachingwea, Mtwara, Masasi, Newara and Tunduru) is estimated applying the annual growth rate from 1957 to 1967 in each district. (Totaling populations of zones 03 to 11 for each year as shown in Table 3-16.

Table 3-23 Population of Area Influenced by Coastal Road (in persons)

Year	Total population	Ratio to 1968
1969	1,911,500	1.00
1977	2,493,600	1.30
1979	2,628,700	1.38
2006	4,449,600	2.32
2008	4,584,500	2.40

Next procedure is to estimate the number of vehicles using ferry service on the basis of the data given in Table 3-4, in the same manner as for the ferry passengers.

Table 3-24 Number of Vehicles using Ferry at Ndundu and Utete (in vehicles/month)

Year \ Month	August	September	October
1968	1380	1480	2040
1969	1920	2000	1860
1970	1700	1400	1760

The average number of vehicles using ferry in three months of August, September, and October is;

$$15,540 \div 9 \text{ months} = 1,727 \text{ vehicles/month}$$

If it is assumed that 80% of them cross the river at Ndundu, they will be;

$$1,727 \text{ vehicles/month} \times 0.8 \div 30 = 46 \text{ vehicles/day}$$

The percentage distribution of vehicle types on the coastal road is 11.4% of passenger cars, 45% of lorries, 29.3% of vans and 14.3% of busses, and if it is assumed that each type of cars, lorries and vans carries 2 passengers and each of busses 40 passengers, the future number of pedestrian passengers crossing the river is calculated as follows:

$$1,080 \text{ persons/day} - \{46 \times 2 \times (0.114 + 0.45 + 0.293) + 46 \times 0.14 \times 40\}$$
$$= 738 \text{ persons/day}$$

1977 .... 738 persons/day × 1.30 = 959 persons/day

1979 .... 738 " × 1.38 = 1,018 "

2006 .... 738 " × 2.32 = 1,712 "

2008 .... 738 " × 2.40 = 1,771 "

CHAPTER 4

SYSTEM DESIGN

CHAPTER 4. HYDROLOGY

4-1 Rainfall Characteristics of Southern Tanzania

Rainfall condition in Tanzania may be classified into two distinctive types. In the northern coastal district, north of Dar es Salaam and at the northern plateau area, the rainy season occurs twice a year; namely, from October to December, and from March to May. In the central plateau region which comprises the greater portion of Tanzania and all over the south, the rainy season occurs only once a year - viz. from December to April. Above all, the heaviest rainfall occurs, in the northern region, from March to May; and in the south, from January to March. However, the average annual rainfall is small, and for more than three-quarters of the area of this country, the annual rainfall is less than 1,000 mm. In the southern part of Tanzania, where Dar es Salaam - Lindi Road runs, there are several large rivers, namely, Rufiji River, etc., which cross the highway and run into the Indian Ocean. Among the water basin of Rufiji River, the annual rainfall over the Great Ruaha River Basin is comparatively small ranging around 400 to 600 mm, but over the Kilombero River Basin, the rainfall is comparatively large amounting as much as to 1,000 to 2,000 mm.

Also in the water basins of Matandu River, Mavuji River, Mbwemkuru River, and others, the average annual rainfall measures around 800 to 1,000 mm. The annual rainfalls recorded at various stations located in respective river basins are as shown in Table 4-1. And the amount of rainfall during the rainy season (from November to May) are as shown in Table 4-2.

Table 4-1 Annual Rainfall Quantity Recorded at Rainfall Observation Stations for Each River's Drainage Basin

Drainage Basin			Observation Station	Annual Rainfall Quantity (mm)							
				1962	1963	1964	1965	1966	1967	1968	1969
Rufiji River	Great Ruaha R.	Kisigo R.	Ilangali	391.9	712.8	655.9	-	502.7	-	691.7	425.4
		Little Ruaha R.	Nduli	780.5	620.7	494.7	723.6	524.6	1,088.6	733.2	-
			Iringa	-	-	596.7	822.3	932.5	-	-	488.7
		Great Ruaha R.	Kisanga	-	-	1,526.2	1,069.4	1,168.0	982.6	-	746.5
	Kilombero R.		Ifakara	1,177.0	1,664.1	1,307.8	1,552.6	1,372.7	2,415.6	2,264.0	1,473.0
			Lupembe	-	2,520.0	1,456.2	1,702.2	-	2,225.8	1,853.6	1,764.0
	Rufiji R.		Utete	713.5	1,247.1	-	572.8	-	991.2	984.0	617.0
Matandu R.			Kilwa Kivinje	-	1,495.5	1,032.2	-	-	-	-	1,121.0
Mavuji R.			Kilwa Masoko	934.2	1,645.7	-	968.7	707.5	1,201.9	-	934.8
Mbwemkuru R.			Mkoe	-	1,191.6	867.9	1,171.1	603.4	1,040.6	648.4	-

Table 4-2 Rainfall Quantity During the Rainy Season

Drainage Basin			Observation Station	Rainfall Quantity (mm) - November/May						
				62 / 63	63 / 64	64 / 65	65 / 66	66 / 67	67 / 68	68 / 69
Rufiji River	Great Ruaha R.	Kisigo R.	Ilangali	567.3	860.3	-	-	658.5	-	437.2
		Little Ruaha R.	Nduli	593.4	702.9	482.6	563.5	890.3	1,023.4	-
			Iringa	-	-	673.6	640.4	1,204.8	-	-
		Great Ruaha R.	Kisanga	-	1,681.4	891.5	1,045.8	-	-	964.0
	Kilombero R.		Ifakara	1,381.3	1,487.2	1,348.8	1,464.0	1,532.8	2,540.0	1,673.0
			Lupembe	-	2,030.9	1,191.8	-	-	2,079.8	1,850.6
	Rufiji R.		Utete	994.6	-	-	-	-	914.9	900.3
Matandu R.			Kilwa Kivinje	-	1,368.2	-	-	-	-	550.2
Mavuji R.			Kilwa Masoko	1,206.7	-	-	887.3	793.4	1,188.0	970.0
Mbwemkuru R.			Mkoe	-	1,071.0	791.2	838.3	609.7	963.0	626.2

4-2 Status of Various Rivers from Dar es Salaam to Lindi

The rivers in the southern part of Tanzania are all unimproved ones. Compared with the enormous size of water basin, the river channels are quite narrow with noticeable meandering alignment. Therefore, the flood water overflows beyond the side banks, and the inundation lasts as long as half a year during rainy season.

The highway between Dar es Salaam and Lindi crosses these rivers. Rufiji River crossing is maintained by ferryboat operations at Ndundu and at Utete about 30 km upstream of Ndundu except heavy rainy season, but in other rivers such as Matandu, Mavudji, and Mbwemkuru, the existing road comes doen close to the river bed and crosses over the water channel by means of temporary fill or timber bridge. Such being the case, it can be easily understood that all traffic along the coastal link road is suspended during the flood season.

4-3 Investigation of Rufiji River

4-3-1 Existing Condition of Points of Crossing

The highway between Dar es Salaam and Lindi forks into two directions at Kibiti approximately 130 km south of Dar es Salaam, and one route runs along the coastal line, crosses Rufiji at Ndundu and reaches Nyamwage. The other route crosses Rufiji at Utete which is located upstream about 30 km from Ndundu and joins the route which goes through Ndundu and then turns south. The route via Utete would have to cross Rufiji River between Rusende located at the left bank of Rufiji River and Utete on the right bank. But the center of main stream of Rufiji River near Utete seems to have been shifting from time to time, since old days. According to the map in the museum at Bagamoyo, made about in the year 1912, Rufiji River is divided into two channels at this point. The one is near the present channel, close to Utete, and the other is the channel close to Rusende.

Also, according to an aerophotograph made in the year 1952, the present channel seems to have shifted about 1 km from where it was in 1912. Thus, the river channel cannot be considered stabilized. In the route via Ndundu, at the river crossing, the flood water overflow extends over the considerable width of about 12 km, but the center of main stream does not seem to have shifted since the old days. Slightly upstream of the crossing point, however, there exists an extremely large bend, and at the time of the flood in 1963, the flood stream dashed straight across this bend and washed away the embankment at various points, immediately after completion of the embankment in 1962. In comparing the two crossings, taking into consideration the bridge construction, it is felt certain that Ndundu area where the river channel is comparatively stabilized is far more advantageous than through Rusende-Utete route of which main stream has greater possibility for future shifting.

4-3-2 Scale of Floods

Traditionally told, there seems to have occurred fairly large scale floods, but ever since the survey at Stiegler's Gorge was started in 1954, and according to the data taken since, the maximum flood flow quantity ever observed was 7,100 m^3/sec. of April 24, 1956, and the next largest was 6,636 m^3/sec. recorded on January 20, 1962.

According to our recent flood mark survey, however, it has been confirmed that between Utete and Ndundu, the flood water level was highest for the flood of

1968, and the flood of 1962 was second to that of 1968. The maximum flood water flow recorded at Stiegler's Gorge was 5,750 $m^3/sec.$ on April 26, 1968. Although the magnitude was not very great, the flow quantity during March and April was comparatively large, and the duration of inundation was long resulting in a large scale ponding of the flood water. The catchment area at Stiegler's Gorge is 61,106 sq. miles (158,000 sq. km). According to FAO Report of "Envelope Curve of Extreme Floods for East and Central Africa", the maximum flood water quantity for the river having the catchment area of 61,106 sq. miles is approximately 390,000 cusecs (11,000 m^3/sec).

The formula for the maximum water flow quantity is:

$$Q_{max} = 3A^{0.71}$$

Q_{max} = Max. flood water flow ($m^3/sec.$)

A = Catchment area (km^2)

Using the formula, Q_{max} for the catchment area of 158,000 sq. km. is determined as 14,700 $m^3/sec.$.

Therefore, Rufiji River at Stiegler's Gorge has a possibility of causing the maximum flood flow of 11,000 to 15,000 $m^3/sec.$ The maximum flood water discharge for 15 years from 1955 to 1969 is as shown in Table 4-3, and basing on these data, the probable flood water discharge in various return periods is calculated as shown in Table 4-4.

Table 4-3 Maximum Flood Water Discharge at Stiegler's Gorge during Each Flood Year

Flood Year	Date of Flood	Maximum Discharge ($m^3/sec.$)
1954 / 55	8 May 1955	2,200
55 / 56	24 Apr. 1956	7,100
56 / 57	18 Apr. 1957	3,000
57 / 58	2 May 1958	3,400
58 / 59	9 Mar. 1959	1,700
59 / 60	6 Apr. 1960	5,440
60 / 61	24 Apr. 1961	1,765
61 / 62	20 Jan. 1962	6,635
62 / 63	14 Apr. 1963	5,660
63 / 64	24 Mar. 1964	5,711
64 / 65	15 Apr. 1965	3,720
65 / 66	3 Apr. 1966	3,013
66 / 67	16 Apr. 1967	3,100
67 / 68	26 Apr. 1968	5,750
68 / 69	2 May 1969	2,570

Table 4-4 Probable Flood Water Discharge at Stiegler's Gorge

Probable once in the following year	Flood Water Discharge (m^3/sec)	
	Iwai Formula	Gumbel Formula
500	14,368	13,759
400	13,882	13,382
300	13,322	12,894
200	12,446	12,208
100	11,056	11,032
80	10,620	10,652
60	10,063	10,162
50	9,713	9,851
40	9,290	9,470
30	8,752	8,976
25	8,411	8,662
20	7,999	8,276
15	7,471	7,775
10	6,731	7,059
5	5,462	5,791

At Ndundu, one of the crossing points of Rufiji River, the water level and flow quantity have not been observed nor recorded, but at Utete (1K4) about 30 km upstream of Ndundu, the water level observation records have been prepared and filed.

According to our recent flood mark survey near Ndundu, the flood mark of 1968 corresponds to Elev. 16.71m above the sea level on the left bank and 16.79 m on the right. Also, on the left side bank, below Ikwiriri Village, the mark was at 16.80 m, and the maximum water level can be deemed as being 16.80 m. The maximum flood water level at Utete (1K4) on March 31, 1968, was 18.97 ft. As the zero point of water gauge at 1Kr being 56.21 ft, the maximum flood water level would become 75.18 ft (22.91 m). Hence, the difference of water level at Utete and at Ndundu becomes 6.11 m. The distance between Utete and Ndundu along the river, measured by the map 1/50,000, is about 34 km at normal water time, but during the flood time, it is judged to become as short as 31 km. Accordingly, the surface slope of the flood water is considered to have been approximately 1/5,100 in 1968. Judging from the fact that the water surface slope measured on October 26, 1970, was 1/6,200, it seems reasonable that the surface slope at the time of flood is assumed as 1/5,100.

4-3-3 Planned High Water Discharge

In planning the highway between Dar es Salaam - Lindi, one of the important problems is how to estimate the high water level and high water discharge in planning the roadway and bridges.

In Rufiji River, the construction of dams at Stiegler's Gorge and Mtera is planned for irrigation and electric power generating purposes. It may be possible to take into consideration the function of these dams in controlling flood water discharge. However, it seems to take a considerably long time until the completion of the dams which are expected to help flood control. It seems reasonable to determine the high water discharge for only normal floods and to depend upon the function of proposed dams in the case of unusual floods which require surplus flood control.

As shown on Table 4-4, the high water discharge at Stiegler's Gorge probable once in every 15 years is approximately 7,500 m^3/sec. And this figure is quite close to the actual high water discharge of 7,100 m^3/sec. measured in 1956. Therefore it seems quite appropriate to select the return period of 15 years and to assume the planned high water discharge of 7,500 m^3/sec. at Stiegler's Gorge.

As there are no water discharge observation data available at Ndundu area which is located about 140 km downstream from Stiegler's Gorge, there is no other means but to assume the estimated high water discharge at Ndundu by calculating from that at Stiegler's Gorge.

Rufiji River, after passing Stiegler's Gorge, runs through an open plain where the flood water starts to overflow. During the flood of 1968, near Ndundu, the flood water extended as wide as 12 km and according to our flood mark survey, the depth of the flood water measured inside Ndundu Village was from 0.5 m to 1.0 m and in the low area, as deep as 2 - 3 m. Consequently, the water discharge of 7,500 m^3/sec. at Stiegler's Gorge will be reduced somewhat until it reaches Ndundu. Due to the absence of any sufficient data, it is difficult to say exactly, but it can be safely concluded that there exists approximately 10% reduction in the water discharge between Stiegler's Gorge and Ndundu.

Also, concerning the remaining area of water basin from Stiegler's Gorge to Ndundu, considering the arrival time in which the flood water travels, the discharge quantity is estimated less than that of the main stream. Therefore, it will not affect the maximum high water discharge of the main stream.

Thus, the estimated high water discharge at Stiegler's Gorge of 7,500 m^3/sec. will be reduced by about 10% at Ndundu and will become 6,700 m^3/sec. This value is decided as the planned high water discharge at Ndundu. This value is very close to that of the actual maximum discharge measured at Stiegler's Gorge during the flood of 1962.

4-3-4 Viaduct for Flood Relief Opening and Required Length

Considering the estimated high water level at Ndundu area, and the actual flood record in 1968, and setting this level at Elv. 16.80 m, about 2,960 m^3/sec. is assumed for the flow capacity of existing river channel as shown in Table 4-5.

Table 4-5 Flow Capacity of Existing River Channel

Classification	A	n	R	V	Q
Low Waterway	1,301	0.03	9.10	2.03	2,640
Flood Waterway	353	0.035	3.42	0.91	320
Total:	1,654				2,960

Where: I = Surface slope, 1/5,100

A: Cross Sectional Area (m^2)

n: Coefficient of Roughness

R: Hydraulic Mean Depth (m)

V: Average Flow Velocity (m/sec)

Q: Discharge (m^3/sec)

After all, the water carrying capacity of the existing river channel will not reach even a half of the estimated high water discharge of 6,700 m^3/sec. Thus, it is quite difficult to insure the necessary cross sectional area only by the existing river channel. Moreover, considering the flood condition extending over some 10 km, it is concluded that it is quite necessary that viaducts for flood relief opening must be properly provided. The highway embankment which was completed in 1962 was collapsed in several places during the flood season of 1963 and the embankment is left without restoration. It will be most effective to plan to construct viaducts for flood relief opening, selecting the places where the embankments were damaged. Instead of providing a number of short viaducts scattered over a long distance, it will be more desirable to plan to construct a few but substantial length of viaducts. The necessary viaduct length is as summarized in Table 4-6. It is assumed that the average water depth is 1.7 m; surface slope I = 1/5,100; coefficient of roughness n = 0.045.

Table 4-6 Required Total Length of Viaduct for Flood Relief Opening

Planned High Water Discharge (m^3/sec)	6,700
Flow Capacity of River Channel (m^3/sec)	2,960
Required Flow Capacity (Deduction) (m^3/sec)	3,740
Average Flow Velocity (m/sec)	0.44
Required Cross-Sectional Area (m^3)	8,500
Required Total Length of Viaduct for Flood Relief Opening(m)	5,000

The area in which the embankment was washed away by the flood of 1963 can be summarized in about 2,350 m section on the left bank and two sections of 700 m and 300 m on the right bank. The construction of viaducts 5000 m long in total seattered over such sections will be sufficient for the planned high water discharge of 6,700 m^3/sec.

4-3-5 Investigation Against Unusual Flood Condition

In future, it may become possible to depend upon the flood control effect of the proposed dams in the upstream in the event unusual floods probable once in extremely long return period should occur. However, for the time being, some reduction of the safety factor must be taken into account against unusual flood condition. The rise of flood water level is estimated as follows for unusual flood of 11,000 m^3/sec. and 9,700 m^3/sec. at Stiegler's Gorge which corresponds to the flood probable once in every 100 years and 50 years, respectively.

The rise of flood water level at Ndundu crossing is determined about 0.7 m and 0.5 m for the unusual flood of 9,900 m^3/sec. (90% of 11,000 m^3/sec) probable once in every 100 years and 8,700 m^3/sec (90% of 9,700 m^3/sec) probable once in every 50 years, respectively.

Therefore, when a marginal clearance of 1.5 m is assumed under the lowest superstructure and above the usual flood level, the Rufiji Bridge can stand against unusual flood conditions.

4-4 Investigation of Other Streams

4-4-1 Scale of Flood

As the necessary hydrological information concerning Matandu River, Mavuji River and Mbwemkuru River are not available, it is quite difficult to predict the scale of flood for each river. However, making use of the envelope curve in the FAO report, the formula of the maximum discharge, and the discharge data at Stiegler's Gorge, it is possible to determine the maximum discharge of these rivers for the flood of 1968 based on the well-known Rufiji data, the results of which are as shown in Table 4-7. Here the critical points other than along the Rufiji River mean the locations where the highway from Dar es Salaam to Lindi crosses the rivers. As the result of our investigation at site, it is found that during the last few years, the maximum flood was that of 1968.

Table 4-7 Maximum Flood Water Discharge at Critical Points

Name of River			Rufiji R.	Matandu R.	Mavuji R.	Mbwemkuru R.
Critical Point			Stiegler's Gorge	Matandu	Kizinbani	Kitumbini
Area of Basin A		km^2	158,000	15,210	3,030	16,460
(1)	Q_1	ft^3/sec	390,000	160,000	70,000	170,000
		m^3/sec	11,000	4,530	1,980	4,810
	q_1		0.070	0.298	0.654	0.292
(2)	Q_2	m^3/sec	14,700	2,800	890	2,960
	q_2		0.093	0.183	0.293	0.179
Max. Discharge of the Flood of 1968		m^3/sec	5,750	-	-	-
Q_{1968}/Q_1			0.52	-	-	-
$0.52\ Q_1$		m^3/sec		2,360	1,030	2,500

where: (1) represents value obtained from the FAO Report, "Envelope Curve of Extreme Floods for East and Central Africa"

(2) is obtained from: $Q = 3A^{0.71}$

$Q_{1,\ 2}$ = Maximum Flood Water Discharge (m^3/sec)

$q_{1,\ 2}$ = Coefficient of Discharge ($m^3/sec/km^2$)

As shown in Table 4-7, the maximum flood discharge of 5,750 m^3/sec at Stiegler's Gorge at the time of 1968 corresponds to about 52% of the maximum discharge of 11,000 m^3/sec obtained from the Envelope Curve of the FAO Report. Multiplying the coefficient of 52% by the maximum discharge of the rivers of Matandu, Mavudji and Mbwemkuru at the time of 1968 obtained from the Envelope Curve of the FAO Report, the maximum flood discharge can be determined, as shown in Table 4-7, for Matandu River, 2,360 m^3/sec., Mavuji River, 1,030 m^3/sec., and for Mbwemkuru River, 2,500 m^3/sec.

4-4-2 Planned High Water Discharge

It is possible to guess the highest water level of the flood of 1968 from our flood mark survey, but as it is quite difficult to obtain the data relative to the longitudinal direction of the rivers, surface slope of the flood water is not easily determinate. The waterway channel slope of Matandu River is, as far as the 1/50,000 map shows, quite gentle. Here, it is assumed that the surface slope is 1/5,000, and the flood mark of 1968 is the highest water level. The discharge is calculated, based on such assumption, as 430 m^3/sec, remarkably different from the expected value. Even if the surface slope is assumed as 1/1,000, the discharge will not reach 1,000 m^3/sec. Therefore, it might be concluded that no big flood occurred in the Matandu River in 1968. The planned highest discharge for Matandu River, judging from its water basin area, will be assumed as 2,000 m^3/sec. As the maximum flood water level of 1968 does not seem appropriate for the planned high water level, 15.80 m which is 1.0 m higher than the flood level of 1968 is assumed and the surface slope of 1/2,000 is also assumed.

When such assumption is applied, the flow capacity of 2,674 m^3/sec. is obtained on the basis of the existing cross-sectional area of the river bed. In this case, as it is anticipated that the flood water will overflow over the left bank of Matandu River and the left branch stream, the cross-sectional area of Matandu River should include such areas also.

Judging from 1/50,000 map, the river bed slope of Mavuji River seems to be about 1/500. The river area is extremely small, and at the time of the flood, it seems to overflow quickly and rush downstream. It is quite difficult to guess the exact surface slope without any data, however when the surface alope of 1/1,000 is assumed, the maximum discharge of 1968 is determined as shown in Table 4-8. In this case, the value of the maximum discharge is approximately the same as that is figured in 4-4-1. Hence, it is assumed to take the planned high water level of 1968 flood at the proposed river crossing, as 34.60 m, and the surface slope as: I = 1/1,000, and the planned high water discharge as 1,000 m^3/sec. The river bed slope of Mbwemkuru River, judging from 1/50,000 map, is approximately 1/1,000. Calculating the maximum discharge of 1968 based on the surface slope of 1/1,000, the result is as shown in Table 4-8. In this case, the discharge is less than that is figured in 4-4-1, but the planned high water discharge at the river crossing point is assumed the same as that of Matandu River, 2,000 m^3/sec., the planned high water level is assumed the same as the maximum flood level of 1968, 27.0 m, and the surface slope, I = 1/1,000.

Table 4-8 Flow Capacity with the Existing Cross-Section of River

Name of River	I	Classification	A	n	R	v	Q
Matandu R.	1/2,000	Main Stream	237	0.03	2.85	1.49	353
		Inundated Area	2,822	0.045	1.47	0.64	1,806
		Branch Stream	339	0.03	2.92	1.52	515
		Total:	3,398				2,674
Mavuji R.	1/1,000	Main Stream	110	0.03	4.34	2.80	308
		Left Bank Inundated Area	272	0.045	1.47	0.91	247
		Right Bank Inundated Area	432	0.045	1.92	1.09	467
		Total	814				1,024
Mbwemkuru R.	1/1,000	Main Stream	411	0.03	5.25	3.16	1,299
		Inundated Area(1)	984	0.045	1.42	0.89	876
		Inundated Area(2)	134	0.045	0.37	0036	48
		Total:	1,529				2,223

I: Surface Slope
A: Cross-Sectional Area (m^2)
n: Coefficient of Roughness
R: Hydraulic mean depth (m)
v: Average Stream Velocity (m/sec)
Q: Discharge (m^3/sec)

4-4-3 Required Total Length of Viaduct for Flod Relief Opening

The total length of bridge accross the river channel, according to the result of field survey, is as follows:

Matandu River . . . . Main stream, 80 m; branch stream, 120 m
Mavuji River . . . . 50 m
Mbwemkuru River . . . . 80 m

The flow capacity through the bridge is, respectively, Matandu River 868 m^3/sec., Mavuji River 392 m^3/sec., Mbwemkuru River 1,299 m^3/sec., and the necessary length of viaduct for flood relief opening is as summarized in Table 4-9.

Table 4-9 Required Total Length of Viaduct for Flood Relief Opening

Name of River	Matandu R.	Mavuji R.	Mbwemkuru R.
Planned High Water Discharge(m^3/sec)	2,000	1,000	2,000
Flow Capacity of Channel (m^3/sec)	868	392	1,299
Required Flow Capacity (m^3/sec) (Deduction)	1,132	608	701
Average Flow Velocity (m^3/sec)	0.64	1.01	0.83
Required Cross Sectional Area(m2)	1,770	602	845
Average Water Depth (m)	1.47	1.90	1.06
Required Total Length of Viaduct for Flood Relief Opening (m)	1,204	317	797

Therefore, considering the topography of the work site, necessary lengths of viaduct for flood relief opening are dicided as follows:

Matandu River . . . . 1,500 m
Mavuji River . . . . 350 m
Mbwemkuru River . . . . . . 950 m

4-4-4 Examination into Unusual Flood

The bridge length and total length of viaducts for flood relief opening for Matandu and two other rivers as described in 4-4-3. When the rise of the water level in case of unusual flood is taken into consideration, the result will be as follows:

In the case of the maximum flood water discharge of Matandu River at 4,530 m^3/sec . . . . approx. 0.9 m

In the case of the maximum flood water discharge of Mavuji River at 1,980 m^3/sec . . . . approx. 1.0 m

In the case of the maximum flood water discharge of Mbwemkuru River at 4, 810 m^3/sec . . . . approx. 1.15 m

The foregoing rise of the water level is calculated on the basis of surface slopes shown in Table 4-8. Therefore, if a marginal clearance of 1.5 m under the superstructure and above the usual flood level is secured, all bridges and viaducts will stand against unusual flood condition.

4-5 Supplement

Flood discharge system along the river basins seems quite compicated as there are various forestry areas, plains, or swampy and marsh lands within the catchment area of these rivers. It was inevitable to provide various assumptions in planning the countermeasures for flood, because the information necessary to solve such problem were insufficient.

Concerning Rufiji River, it seems that all sorts of investigations have been made due to necessity for various purposes. For other streams, however, there is nothing of the informations with respect to the water discharge even at location where it seems comparatively easy to obtain the discharge data like Stiegler's Gorge in Rufiji River. Also, as there is no detailed topographical survey result available at or in the neighborhood of the proposed river crossing the map of 1/50,000 was fully utilized except some areas where the rough field survey was made during our stay. Therefore, it is recommended to carry out more detailed field survey and to collect more informations before commencing the actual construction activity, in order to ensure sufficient accuracy for the flood flow analysis which is quite important for the proposed highway planning.

CHAPTER 5

SOIL SURVEY

CHAPTER 5 SOIL SURVEY

5-1 Soil Survey along the Existing Road

5-1-1 Introduction

A soil survey was carried out along the existing road from Kibiti to Lindi. The distribution of soil was identified by observing soils exposed on the ground surface, side wall of water wells, or along the surface of excavation.

Samples of soil were taken by either hand auger or hand shovel in every 5 km interval. As some soil was very hard in dry condition, hand augering was often limited to 50 cm to 1 m in depth. It is considered recommendable to make deeper test holes by a machine auger.

In the following articles in this chapter, the soil conditions observed by survey are described. The number of stations in the following articles coincides the distance from the north end of the route at Kibiti. For example ST 10 means the place which is 10 km south to the Kibiti terminal.

Typical samples obtained by augering were placed in plastic bags and sent to the government laboratory in Dar es Salaam.

Some samples of soil were put into tins for testing of compacted materials.

5-1-2 The Area from Kibiti to Ndundu

ST. 5

The hill within about 2 miles south from ST. 5 consists of lateritic sandy soils. A sample was taken at the depth of 1 m. A sample for compaction test was also taken here. The lateritic sand here, well-graded and containing some binder, seems to be usable as subgrade or sub-base material after it is properly compacted.

ST. 10

The hill beyond 2 miles from ST. 5 is covered with light brown sand. The soil profile appears to consist of:

0 - 25 cm light brown sand
25 - 60 cm loose fine gray sand
60 - 85 cm brown fine sand

Hand auger could not drill any more depth as fine sand caved in the drill hole. The soil here consisting of fine uniform sand seems not very stable. It also becomes dusty when it is dried up.

The area covered with fine sand terminates at several hundred meters south of ST. 10 and then laterite comes out again. This laterite area is short. The road descends to a low land covered with sand at the distance about 2 miles south of ST. 10.

ST. 15

The low land extending to 2 miles north of ST. 30 is covered with brown sandy soil. The area a little higher than the flood level is generally utilized as orchard. The soil profile at ST. 15 is:

0 - 30 cm brown silty sand
30 - 90 cm slightly silty brown sand, well graded
90 -190 cm brown sandy clay, plastic clay containing coarse sand

The ground water table is supposed to be about 1.90 m below ground surface as the clay there is saturated.

ST. 25

The land is depressed in the vicinity of ST. 25 and road crosses a river by Tingatinga bridge.

The soil profile near Tingatinga bridge is:

0 - 100 cm dark brown coarse sand

White sand came out at 1 m, but the drill hole could not be advanced under the ground water table at 1 m below the ground surface.

The foundation condition for this bridge appears not so serious, but an extended study of subsurface by means of deep borings is recommended.

ST. 30

From about 2 miles north of ST. 30 the ground surface is covered with black cotton clay. Hand augering was made in the vicinity of Ikwiriri Village. A hole was drilled in a cultivated land at about 30 m from the embankment which was not destroyed by flood. The soil profile obtained:

0 - 60 cm black cotton
60 - 100 cm brown sandy clay
100 - 200 cm brown silty fine sand

ST. 35

The drill hole was located near the collapsed embankment. The ground surface is covered with deposits of balck cotton clay.

0 - 50 cm black cotton
50 - 200 cm brown sand or silty coarse sand
G.W.L. - 200 cm

As seen in ST. 30 and ST. 35, the alluvial sandy soil in the flood plain may be used as embankment material after stripping off the black cotton having the thickness of about 50 cm which, however, should not be used for embankment. It is also recommended to remove black cotton below the embankment. Black cotton is very hard when it is dried, but becomes muddy when it is saturated. It may also expand after absorbing water and reduces its shear strength considerably.

The subsurface after removing black cotton is supposed to possess ample bearing capacity for embankment not higher than 5 m, but a thorough analysis on the stability and settlement of the embankment should be carried out by means of sufficiently deep borings and soil testing.

The slope protection and seepage problems in the embankment should be carefully studied, because sliding failure in the upstream surface and the failure due to piping action in the down stream surface appears to be a possibility.

Foundations of short span bridges and other structures in the flood plain is likely to have no serious problems. Spread foundations on the sandy soil or short piles driven into sand will be enough to support small bridges provided the foundation is embeded deep enough against scouring. However, deeper sounding of subsurface is recommended in order to secure the safety of those structures.

5-1-3 The Area from Ndundu to Nyam Wage Junction

ST. 40

Some black cotton soil was observed on the right side bank of Rufiji River, but at ST. 40 in the flood plain of Rufiji River is covered with well-graded brown sand. We could drill only 50 cm by a hand auger since the brown sand was very dense. The soil here is a slightly silty brown sand, not very different from the sand in the left side of Rufiji River.

Black cotton covers the ground surface in the area starting from 2 miles south of ST. 40. From this area to Nyam Wage Junction through ST. 45 is covered with balck cotton, which is a very sticky pure clay. We could not dig deeper than 1.10 m as black cotton was very hard in the dry season.

5-1-4 The Area from Kibiti through Utete to Nyam Wage Junction

ST. 10 U

The hill from Kibiti to ST. 5 + 1 km consists of lateritic red sand, then from ST. 5 U + 1 km to ST. 10 U + 1 km the ground is covered with brown sand. From ST. 10 U + 1 km to ST. 10 U + 4 km lateritic red sand is dis distributed. The weathered surface of lateritic sand changes its color to yellow or brown.

ST. 15 U

There is a borrow pit for the surface course of roads in the vicinity of ST. 10 U + 4 km. Two tin samples were taken for compaction test. The lateritic red sand is spread on the surface of road in alluvial plain where the ground surface is covered with either fine sand or balck cotton. The lateritic red sand is considered a suitable material as subgrade, as it has high shear strength and good drainage.

ST. 20 U

Beyond ST. 10 U + 4 km to ST. 20 U, the ground surface is covered with brown sand. Hand augering was done at ST. 20 U.

0 - 1.60 m brown sand
1.60 - 2.00 m white or light brown sand
G.W.L. = -2.00 m

Between ST. 15 U and ST. 20 U, there is a depression made by scouring of flood flow. The soil there is mixed deposits of sand and black cotton.

ST. 25 U

At about 25 U + 3 km where the road crosses river by a small wooden bridge, hand augering was carried out. The soil there was brown silty sand from the ground surface to the depth of 1.90 m. The soil within the depth of 1.90 m was almost uniform but becomes slightly more sandy with depth.

ST. 30 U

The ground surface is covered with brown silty sand or sandy silt, up to ST. 25 U + 4 km, from which the road goes down to flood deposits. At ST. 30 U the soil near the ground surface was brown fine clayey sand which was too hard for a hand auger to drill.

ST/ 35 U

Similar to ST. 30 U, brown sandy clay was exposed, but too hard to drill. A sample was taken at the depth of 50 cm.

ST. 40 U

Passing ST. 35 U the road soon crosses a swampy area. Looking at the side wall of a well dug manually, it was found that the soil here consisted of brown fine sand uniformly to the depth of 1.5 m.

Beyond ST. 40 U the road goes through paddy fields on the left side bank of Rufiji River. In this area, black cotton clay was deposited having a thickness of 60 cm to 100 cm. The coil near Rufiji River was brown silty sand in which black cotton was contained as clay lenses.

ST. 45 U

The right side of Rufiji River at Utete is elevated several meters higher than the river bed. Number of blocks of gabbro were observed near the Utete ferry. They may be a source of crushed stone if the amount of them are found sufficient.

Around a hot spring in the vicinity of Utete Village, volcanic tuff was exposed on the ground surface. It may also be used for aggregates.

ST. 50 U

At ST. 45 U + 2.5 km, the road crosses a swamp by a wooden bridge. The soil there is mainly white sand, not soft and compressible soil, though the ground surface is covered with black cotton.

Around ST. 50 U a soft and compressible soil is deposited in a valley formed by erosion of flood flow.

0 - 30 cm brown silty sand
30 - 200 cm blue sandy clay

A thorough investigation by deep borings will be required if a bridge is planned in this area.

ST. 55 U

From ST. 50 U to ST. 65 U the soil is generally brown clayey sand or sandy clay. The soil is well cemented with clay and very hard in the dry season. We could not drill through this hard soil by a hand auger. The clayey sand there is washed out in several portions and filled with recent flood deposits. In those portions the ground surface is covered with black cotton.

In the vicinity of ST. 55 U, there was a well dug by hand. Looking at the wall of the well, it was noticed that the soil here was light brown sandwitched with clay lenses having a thickness of 20 to 30 cm.

ST. 60 U

In the vicinity of ST. 60 U there were corrugated pipe conduits destroyed by flood flow. Observing the side wall of a well dug by hand near the conduit, it was noticed that brown silty sand continued uniformity down to the depth of 3 m from the ground surface.

ST. 65 U

Although hand augering could not be carried out here because of high dry strength of the soil, it was identified along the surface of cutting that the soil here consists of brown sandy clay.

ST. 70 U

The area around ST. 70 U is covered with black cotton as hard as soft rock in dry season. Some shells like snails scattered on the surface of recent flood deposits.

ST. 75 U

The surface 20 cm is covered with black cotton, underlain by brown silty sand which is well compacted. A sample was taken at the depth of 40 cm as we could drill 50 cm only.

5-1-5 The Area from Nyam Wage to Mohoro

ST. 50

The ground from Nyam Wage Junction to ST. 50 is covered with loose brown sand uniform to the depth of 2.00 m. The ground water table appears to lie at the depth of 2.00 m as sand in this depth is almost saturated.

ST. 55

The same sand as ST. 50. Sand here is dense and dry. We could drill only 50 cm by hand auger.

ST. 60

A cut surface along the road reveals that the soil here was brown fine sand. The sand is very fine like ash.

ST. 65

The same as ST. 60. Dried-up sand, very fine and dusty. Hand augering revealed that the soil down to 2 m deep was a very fine brown sand, almost uniform. The zone of fine sand terminates at ST. 65 + 3 km, then the road runs through a grass-covered land mantled with sandy clay as far as Mohoro.

ST. 70

Hand augering was done in Mohoro village.

0 - 40 cm brown sandy clay
40 - 50 cm brown fine sand very dense.

5-1-6 The Area from Mohoro to Kilwa Junction

ST. 75 and ST. 80

From Mohoro to ST. 80, the road runs on a flood plain covered with dark brown sandy clay. The road surface is slippery and unstable. Therefore, it is considered recommendable to relocate the route to higher elevation or to replace subgrade soil with sandy materials. Brown sandy clay covering this area was too hard to drill by a hand auger. Soil exploration by a machine auger is required.

ST. 85

From ST. 80 to ST. 95, the road crosses two different types of soil; the alluvial deposits consisting mainly of brown silty fine sand, and recent flood deposits mainly of black cotton clay or brown sandy clay. The surface of alluvial deposits is usually elevated above the recent flood deposits by about 5 m.

A sample representing typical properties of the alluvial sand was obtained at ST. 85.

0 - 60 cm brown silty fine sand

ST. 90 + 1 km

A typical soil profile of recent flood deposits was obtained from hand augering at ST. 90 + 1 km.

0 - 20 cm black cotton
20 - 50 cm brown clayey sand
50 - 180 cm gray clayey sand

Although the depth of exploration was limited, it is found that the soil is generally sandy even in recent flood deposits. The black cotton clay washed out of the original earth mantle covers only 20 cm near the ground surface. A tin sample of black cotton was collected here.

ST. 95

The recent flood deposits terminates at ST. 95 - 1 km, then the ground is covered with brown silty sand as far as ST. 100 - 1 km.

ST. 100

From ST. 100 - 1 km soil changes to brown sandy clay, dried up and very hard.

ST. 105 and ST. 110

From ST. 105 to ST. 110, the ground is covered with brown silty sand, but the soil from ST. 105 + 2 km to ST. 105 + 3 km is considered to be recent flood deposits. A sample of brown fine sand was taken from the ground surface as hand auger could not be used.

ST. 115 and ST. 120

The soil from ST. 115 to ST. 120 is brown fine sand in general. But the area from 115 to 1 km north to ST. 115 consists of recent flood deposits with black cotton near the ground surface. In this area drainage being poor, it will be hard to maintain the road passable in the rainy season.

A sample was taken at the depth of 60 cm of ST. 120. The soil here was brown fine sand from the ground surface to the depth of 70 cm.

ST. 125

From ST. 120 to 125 the soil consisting of brown fine sand contributes to maintain good surface conditions of the road. But the road crosses several small rivers most of which are dried up. Along those rivers highly plastic clay was observed. At about 500 m north to ST. 125, a sample was taken at the depth of 30 cm. By hand augering we could drill 60 cm and identified that soil here was brown highly plastic clay.

ST. 130

From ST. 130 to ST. 135, the road runs in undulated topographic conditions of hills and erosion valleys. The hills are generally covered with brown fine sand but there are some portions covered by plastic clay or black cotton. Especially clay is predominant at the edge of hills. For instance the hill at about 3 km north to ST. 130 was covered with black cotton. The hill around ST. 130 is composed with dark brown sandy clay containing black cotton but road surface is rather stable as the soil is fairly sandy.

ST. 135

The hills around ST. 135 and from ST. 135 to Matandu River are identified as elevated terrace deposits transported and laid by Matandu River. Hills are generally covered with brown silty sand but some of the hills are covered with plastic clay. A considerable amount of round gravels or boulders are exposed on some of the hills. From ST. 135 to 135 + 2 km, the road runs on the hill consisting of sandy soil mostly, but black cotton and terrace gravels are distributed locally. Beyond ST. 135 + 2 km, soil is generally clayey soil containing rolling stones or boulders.

At 1.5 km north to ST. 140, a belt zone of about 300 m wide in which terrace gravels are concentrated is located. The gravels are originated from hard sand stone or chart, and considered suitable for aggregate.

ST. 140

After the belt of terrace gravel, hills are mostly covered with brown sandy soil. However the hills are divided by several erosion valleys where black cotton and plastic clay are contained. A sample was taken at ST. 140 by a hand auger.

0 - 150 cm brown silty fine sand

ST. 145 - 2 km (Matandu River)

On the right bank of Matandu River, a sample was taken by a hand auger.

0 - 150 cm dark brown highly plastic clay
150 - 180 cm brown sandy clay

We could not drill deeper than 180 cm, because ground water came out. A thorough investigation of soil by means of deep borings is required for the design of bridge foundations.

On the left side of the river considerable amount of brown fine sand is deposited. Although it is a uniform fine sand, it may be used as a material to replaces black cotton or plastic clay, A tin sample was taken here for compaction test.

ST. 150

Beyond Matandu River, the road again goes up to hills which are considered to be covered with residual soil on bed rock. According to the rolling stones on the road side, the bed rock will be mostly igneous rock such as tuff rhyolite or quartzite. More detailed geological survey is required in order to clarify the origin and distribution of soil in this area.

At about 2 km north of ST. 150 the road crosses a valley where a sample of dark brown clay was taken at the depth of 30 cm.

The residual soils on the hills from ST. 150 to Kilwa Junction (Nangurukuru) are mostly brown clayey soils. The hills are gently undulated. At about 3 km north to Kilwa Junction, black cotton clay containing no rolling stone was encountered.

5-1-7 The Area from Kilwa Junction to Lindi

This area was mainly surveyed by Mr. Sugita. Subsequently the description of this article was made in accordance with the observation of Mr. Sugita. Some additional informations obtained by the writer through his brief review of the site were also included. Following the information of Mr. Sugita, the survey record in this article was described starting from Lindi and ending at Kilwa Junction.

A bag sample and a tin sample of laterite was taken near Lindi Airport. The lateritic soil terminates at ST. 300, then silty sand mixed with gravel is distributed. A bag sample was taken at a gravel pit.

At ST. 295, laterite comes out again. A bag sample of laterite was taken at ST. 290 + 3 k at the depth of 30 cm. Laterite terminates at ST. 290, and thereafter silty soil covers the distance of about 2 km.

Beyond there, outcrops of hard rock supposed to be limestone comes out. The rock is hard but numerous small cavities by erosion are developed resulting in an appearance like honecomb. The outcrops of the hard rock are exposed mainly around ST. 288 and ST. 282. From 288 to 281, the ground is covered with sand decomposed from the hard rock. From ST. 281 near Mbyni, soil becomes yellow laterite. It terminates at ST. 277, and then changes to organic dark brown clay. A bag sample was taken at ST. 272.4 where the clay continued to the depth of 1 m.

From ST. 269, the ground is covered with brown fine silty sand. The yellow laterite comes out again at ST. 262. A bag sample was taken at ST. 260.8. The yellow laterite continues up to ST. 252, then it changes to red lateritic sand. A bag sample and a tin sample were taken at ST. 250.6.

From there soil changes to black cotton, after crossing Mbwemkuru River, up to ST. 245.2. After ST. 245.2 to 241, soil becomes laterite having color of reddish yellow. From ST. 241 to 234, black cotton in high land is distributed. After ST. 234, soil becomes brown silt containing gravel after ST. 223 where a bag sample was taken. This cohesive soil continues up to ST. 212.

Rock is exposed on the road surface. It was hard to identify the rock as it was seriously weathered, but a variety of igneous rock such as quartzite, tuff and rubber rock seems to distribute around this area. There was a gravel pit at ST. 209.5 where a bag sample containing gravels, about 10 cm in diameter, was obtained. The ground is covered by silt up to ST. 208. Rock is again exposed at ST. 208.

From ST. 208 to ST. 206, the ground is also covered mainly with silt except rock outcrops exposed around ST. 208. A sample of silt was taken at ST. 207.6 at the depth of 1 m. Soil changes to laterite at ST. 206 and continues to ST. 205 from where soil becomes dark brown clay. It continues to ST. 201, and then changes to brown silt up to ST. 200, where a bag sample was taken.

From ST. 200 to 195, soil becomes yellow silt. Rock is exposed around ST. 195, and then the ground is again covered with yellow silt. A bag sample was taken at the depth of 3 m around ST. 189. There was a gravel pit at the road side at ST. 188, where a sample containing fine gravel with sand was obtained.

Soil becomes black cotton from ST. 185. A bag sample and a tin sample were taken at ST. 184.9. The black cotton continues to ST. 175. There was a gravel pit taking gravel below black cotton. A bag sample and tin sample were taken there. At ST. 175 soil changes to silt. There was a gravel pit at ST. 170.2 where gravel mixed with yellowish white sand was produced. A bag sample was taken there. Another bag sample was taken at ST. 165 from the depth of 70 cm.

5-2 Soil Exploration along Rufiji River

5-2-1 Introduction

The most serious problems of foundations are expected in the area where the route crosses Rufiji River and a flood plain along the both sides of Rufiji River.

The river bank of Rufiji River at Ndundu crossing is generally covered with brown fine sand. The flood plain is covered with black cotton clay on the surface, but 50 to 60 cm below the ground surface brown sand was encountered when we drilled a hand auger hole. Therefore the area around Ndundu crossing is supposed to consist of sandy deposits.

An alternative route crossing Rufiji River at Utete is to be studied. The geological conditions of the area around Utete crossing is not very different from the area around Ndundu crossing although some swampy deposits were observed on the right side of flood plain along the route crossing Rufiji River at Utete.

In the area near Utete, Rufiji River has changed its main stream channel, and left a number of swamps after it changed its stream channel. Those residual swamps are generally filled with loose sandy soil or soft clay.

Because of the limited time available for the soil exploration, thorough exploration of soil needed for the design of foundations has to be undertaken by a survey party in the future. In this study, it was intended to obtain a general view of soils in this area. For this purpose one drill hole in each crossing of Ndundu and Utete was planned to be put down to the depth of about 20 m by means of a TONE boring machine. TONE boring machine was abandoned in the midway and instead DANDO machine was employed. The depth of boring was then reduced to 15 m as the capacity of DANDO machine was limited. TONE boring machine could not work well because of mechanical reason. But it will work well if it is repaired and sufficient necessary tools and accessories are provided. The lack of bentonite near the site also made the use of a rotary drill rig very difficult.

Within 15 m below the ground surface soil strata having high bearing capacity was found at both Ndundu and Utete sites. Hence the purpose of this exploration was satisfied, but a more detailed soil exploration is required before finalizing the type of foundations.

5-2-2 Results of Boring

Depth (in m)	Soil Type	N-value
0 - 0.6	brown fine sand	
0.6 - 1.60	brown coarse sand	11
1.60 - 4.00	brown coarse sand containing thin lenses of gray silt	

4.00 - 5.00	brown silty sand	12
5.00 - 5.60	"	14
5.60 - 7.70	"	
7.70 - 9.60	blue clayey sand	26
9.60 - 11.80	"	27
11.80 - 12.20	brown coarse sand	50
12.20 - 12.30	blue hard pan	

According to the above data, it was identified that the soil was generally sandy, but the soil from the ground surface to the depth of about 5 m is loose and unstable.

Below the depth of 5 m the soil becomes dense and stable. Brown coarse sand below the depth of 11.80 m and blue hard pan beneath the coarse sand are considered suitable as bearing strata of bridge foundations.

Although more drill holes are required to determine the type of foundations, as a preliminary plan, foundations penetrated to the depth of 13 m will be supported safely by blue hard pan. In order to avoid damage of foundations by scouring, well or open caisson type foundations are considered recommendable.

Another drill hole was drilled on the left side of Rufiji River at Utete Ferry. This boring revealed that the soil profile there was not very different from the one at Ndundu. The summarized data at Utete Ferry are as follows:

Utete Ferry

Depth	N value
1.7 m	9
3.	10
4.5	12
6.0) 7.5)	No SPT available because of sand heaving
9	N = 14
11.4	N = 34
12.0	N = 44
13.5	N = 39

Samples

5' - 6"	brown coarse sand
10' - 0"	brown coarse sand
15' - 0"	brown coarse sand
30' - 0"	brown coarse sand
38' - 0"	dense brown clayey sand
40' - 0"	dense gray brown clayey sand
45' - 0"	brown hard pan (tuff-like, weathered)

5-3 Soil Testing

5-3-1 Identification and Classification of Soil Samples

As described in 5-1, soil samples were taken in above 5 km intervals, put into plastic bags, sealed and sent to the Material Laboratory of the

Tanzanian Government. Table 5-1, the samples taken from the existing Kibiti-Ndundu-Kilwa-Lindi road and sent to the laboratory are listed. The samples from the alternative route are also included in this figure adding "U" to the station number such as 20U. In the column of Station Number (T) means the station where a tin sample was taken, and (B & T) means both bag and tin samples were taken.

Identification tests for 56 bag samples and 10 tin samples were carried out and the results of testing were summarized by Tanzanian Government Officials in the APPENDIX of this report.

Combining those test data with the record of the field survey, it was attempted to clarify the distribution of soil along the existing Kibiti-Lindi Road.

The ground consists of different soil strata, but considering the influence to the stability of the proposed road, the type of soil predominant within 1 m of depth was taken as a representative soil type. The soil surveyed during the dry season was sometimes too hard to drill by a hand auger, and often samples could be obtained from depths of less than 1 m. Sometimes samples were obtained from near the ground surface, and had to be considered to represent the soil at a certain location. Such a tentative identification should be corrected or modified after deeper borings are drilled by a machine auger.

The distribution of soils along the existing road is summarized in Table 5-2. Reviewing data in APPENDIX, the soil representative of each location (Station No.) was classified by the Unified Classification and AASHO Classification. In the right two columns in Table 5-2 the symbols of classification by Unified Classification and AASHO Classification are tabulated.

Table 5-2 indicates that the majority of soil is sandy soil good for subgrade of road. It is recommended, however, that the soils classified as A-3 or A-4 by AASHO Classification be provided with good drainage when utilized in earthworks. The area covered with black cotton clay or other cohesive soils belonging to CL and CH of Unified Classification or A-7 of AASHO Classification should be replaced with sand, or covered with sandy fill of sufficient thickness. According to the data in Table 5-2, the total distance of area where such improvement of soil is required is about 108 km including 3 km in the alternative route.

5-3-2 Study on Lateritic Sand

Two samples of lateritic sand and a sample of black cotton clay were taken in tin cans on the right side of Rufiji River along the route via Utete. The samples were shipped to Tokyo and tested in the laboratory of Soil and Foundation Consultants Co. (Kisojiban Consultants, K.K.). The test results for both lateritic sand and black cotton clay are tabulated in Table 5-3 for the routine testing and Table 5-4 for the special one, respectively.

The lateritic sand tested is a medium grained sand, as shown in Fig. 5-2, which contains 27 per cent of silt and clay and exhibits some plasticity. It is classified as SC and A-2-6 in terms of the Unified and the AASHO Classifications, respectively. It is possible, therefore, that this s soil may be used as subgrade material if proper compaction and drainage are provided.

The water content of the samples was approximately 2 per cent at the time when they arrived at our laboratory. Fig. 5-4-2 shows the results of a compaction test performed in accordance with our standard, the first method of JIS A 1210, which gives the optimum water content of 11.1% and the maximum dry sensity of 1.97 grams per cubic centimeter. The method of the test is equivalent to that of a standard Proctor test and consists of the following:

Inside diameter of the mould	10 cm
Number of layers	3
Number of blows per layer	25
Weight of the rammer	2.5 kg
Height of fall of the rammer	30 cm
Compactive effort	5.6 cm/kg/cm^3

Fig. 5-5 shows the results of CBR tests performed in accordance with JIS A 1211. Compaction required during CBR tests is performed as specified in our Asphalt Pavement Manual and is equivalent to that in a modified Proctor test, consisting of the following:

Inside diameter of the mould	15 cm
Number of layers	3
Number of blows per layer	92
Weight of the rammer	4.5 kg
Height of fall of the rammer	45 cm
Compactive effort	26.5 cm-kg/cm^3

Practically no swell was recorded during soaking of specimens. On the right-hand side of Fig. 5-5, a plot of soaked CBR values versus dry density is shown for specimens compacted at the optimum water content and in 3 layers with the varying number of blows per layer of 17, 42 and 92. For instance, this relationship indicates a design CBR value of 44% for the soil compacted to a density more than the 95% modified Proctor maximum dry density.

This soil gives such a sharp compaction curve a careful control of in-place water content would be required; otherwise, the specified compaction may not be attained.

In order to obtain the information regarding cement stabilization, the sand was mixed with 5% of portland cement, and tested for the compaction and strength characteristics. A compaction test run in accord with JIS A 1210 (the first method) gives the results similar to those of untreated lateritic sand, as shown in Fig. 5-8-1.

After the sand was mixed with 3, 5, 7 and 9% of cement, specimens were compacted at the water content of 11.3% which was the optimum in the previous test. Immediately after compaction the specimens were extracted out of moulds. From each specimen were prepared four cylindrical specimens, 85 mm in diameter and 88 mm in height, which were then coated with wax to protect them from drying. They were cured in a constant-humidity room. One of the four was taken out of the room after seven-day curing and tested for the unconfined compression strength. The other three were taken out after the top and bottom surface. After soaking, the wax was removed also from their side and they were tested for the unconfined compressive strength. The test results are shown in Fig. 5-8-2 indicating the following:

i) unsoaked specimens with cement content of 3 to 9% possess unconfined compressive strengths of 24 to 41 kg/cm^2, respectively.

ii) soaked specimens, similarly, possess unconfined compressive strengths increasing from 14 to 24 kg/cm^2.

iii) for a range of cement contents from 3 to 9%, the unconfined compressive strength of soaked specimens is 60 to 74% of that of unsoaked ones.

It was found that soaked specimens with the cement content of 9% showed an unusually low average value of the unconfined compressive strength. It is considered, however, due probably to hair cracks developed in the specimens in the process of prepairing them. Therefore, the dotted line in the figure is considered to give correct values.

5-3-3 Study on Black Cotton Clay

The soil sample contained 95 per cent of fine materils, or 42 per cent of silt and 53 per cent of clay as seen in the gradation curve in Fig. 5-2. Atterberg limits indicate that the soil is a highly plastic clay. The ignition loss measured for this sample was 9.95%. The water content of the sample when it was brought to the laboratory was 30.6%. The result of a compaction test by the first method of JIS A 1210 for the air-dried sample of black cotton is illustrated in Fig. 5-4-2.

The sample of black cotton was compacted at various water content to be trimmed into specimens having diameter of 60 mm and height of 20 mm and they were placed in oedometer and the change of volume due to swelling was measured when the specimen was soaked in water. The results of the test are illustrated in Fig. 5- 7 togethter with the results of a compaction test.

It was noticed that the per cent swell during soaking in 10,000 minutes was 4.2% at the optimum water content. H. B. Seed proposed a formula to calculate the swelling potential, S, of soil as follows:

$$S = (K) \left(\frac{P.I.}{C-5}\right)^{2.44} (C)^{3.44}$$

where K = experimental constant = 3.6×10^{-5}
P.I. = plasticity index = 39
C = per cent finer than 0.002^{mm} = 42.2

Substituting the above values,

$$S = (3.6 \times 10^{-5}) \left(\frac{39}{42.4 - 5}\right)^{2.44} (42.4)^{3.44} = 13.2\%$$

Consequently the characteristics of swelling of the black cotton clay tested was identified not serious.

A triaxial compression test and an unconfined compression test was carried out for the compacted black cotton clay. The results of the triaxial compression test are given by Mohr's Circles in Fig. 5-9-1 through Fig. 5-9-8.

The values of the angle of internal friction and cohesion obtained by those triaxial tests are plotted against water content as shown in Fig. 5-6.

The values of the angle of internal friction and cohesion obtained by those triaxial tests are plotted against water content as shown in Fig. 5-6. This figure indicates that the angle of internal friction shows no remarkable difference between unsoaked and soaked specimens, but cohesion decreases considerably after soaking. The results of the unconfined compression test also indicates that the unconfined compressive strength of a soaked sample is about one half of the strength of an unsoaked sample.

CONTENTS OF FIGURES

Table 5-1 List of Samples

Station No.	Depth	Soil Type
5 (B & T)	1.5	laterite
10	0.5	grey sand
15	1.0	sandy clay
25	0.9	dark brown sand
	1.5	white sand
30	0.9	sandy clay
35	0.5	black cotton
35	0.7	brown sand
40 (B & T)	0.5	sandy clay
45	0.5	black cotton
50	0.5	sand
50	1.9	brown sand
10 U	G S	lateritic sand
20 U	0.6	brown sand
20 U	1.7	sand
25 U	0.6	sand
25 U	1.8	sand
30 U	0.6	sandy clay
35 U	0.5	sandy clay
45 U	G S	Sand
50 U	0.5	sandy clay
50 U	0.7	black cotton
50 U	2.0	sandy clay
55	0.5	brown sand
55	1.2	brown sand
60	0.6	brown sand
65	0.6	brown sand
65	1.8	brown sandy silt
70	0.3	brown sand
75	0.4	silty sand
80	G S	brown sandy clay
85	0.5	brown silty sand
90 + 1 km(T)	G S	black cotton
90 + 1 km	0.4	clayey sand

90 + 1 km	1.0	clayey sand
100	G S	sandy silt
100 + 2 km	G S	brown sand
110	G S	brown silty sand
115	G S	dark brown silt
120	0.6	fine sand
125	0.3	brown clay
135	G S	silty sand
140	0.5	sand
145	0.3	clayey sand
145 + 2 km(T)	G S	silty sand
145 + 2 km	0.3	sandy silt
150	G S	black cotton
165	0.7	silty sand
170	0.5	clayey sand
176 (T)	0.7	clayey sand
185 (T)	0.4	clayey sand
188	0.4	silty sand
189	3.0	clay
200	1.5	silty sand
208	1.0	sand
210	0.3	sand
223	1.0	black cotton
248 (T)	0.5	black cotton
251	1.0	black cotton
252 (T)	0.7	laterite
261 (T)	0.4	laterite
272	1.0	organic clayey sand
293	0.3	laterite
296	0.5	sandy clay
302 (2 miles East) (T)	G S	silty clay

Table 5-2 Distribution of Soils Along the Existing Road

Station No.	Distance (km)	Soil Type	Unified Classification	AASHO Classification
0 - 8	8	laterite	SC	A-2-7
8 - 11	3	brown sand	SP	A-1-b
11 - 13	2	laterite	SC	A-2-7
13 - 27	14	brown sand	SP-SM or SC	A-1-b A-2-6
27 - 40	13	black cotton (50 to 60 cm thick)	CL	A-7-6
40 - 43	3	clayey sand	SC	A-2-6
43 - 48	5	black cotton	CH	A-7-6
			(Alternative Route via Utete)	
0 - 6	6	laterite	SM	A-1-6
6 - 11	5	brown sand	SP	A-1-6
11 - 14	3	laterite	SM	A-1-b
14 - 20	6	brown sand	SP	A-3
20 - 29	9	silty sand or sa sandy clay	SP-SM	A-3
29 - 35	6	clayey sand	SC	A-2-6
35 - 40	5	fine sand	-	---
40 - 43	3	black cotton	CH	A-7-6
43 - 65	22	brown clayey sand	SC	A-2-6 or A-2-7
---	---	---	---	---
48 - 50	2	brown sand	SM	---
50 - 68	8	fine sand	SM	---
68 - 80	12	brown sandy clay	SM-SC	A-4
80 - 94	14	clayey sand	SP-SM	A-3
94 - 99	5	silty sand	SP-SC	A-2-6
99 - 105	6	sandy clay	SC	A-4
105 - 110	5	silty sand	SM	---
110 - 120	10	silty sand	SM	
120 - 130	10	fine sand or brown clay	SM CL	A-7-6

130 - 135	5	silty sand or black cotton	SM	
135 - 143	8	silty sand with gravel	SP-SM	A-3
143 - 152	9	residual clay or black cotton	CH	A-7-6
152 - 175	23	silt with gravel	GC	A-2-7
175 - 185	10	black cotton	CH	A-7-6
185 - 201	15	yellow clay with rock	CH and SM-SC	A-7-6 A-4
201 - 205	4	dark brown clay	--	---
205 - 206	1	laterite	--	---
206 - 212	6	silt with rock	SM-SC	A-6
212 - 234	22	silt with gravel	CL	A-7-6
234 - 241	7	black cotton	CL	A-7-6
241 - 245	4	weathered laterite	--	---
245 - 251	6	black cotton	SC	A-7-6
251 - 252	1	lateritic sand	SM	---
252 - 262	10	yellow laterite	--	---
262 - 269	7	fine silty sand		
269 - 277	8	organic clay	CL	A-7-6
277 - 281	4	yellow laterite	--	---
281 - 288	7	sand; rock	--	---
288 - 290	2	silt	--	---
290 - 295	5	laterite	GC	A-6
295 - 300	5	silty sand	(CL)	(A-6)
300 - 310	10	laterite	SC	A-2-4

Table 5-3 Summary of Routine Soil Testing

Sample			Black Cotton Clay	Lateritic Sand
Water Content *1 (%)			30.6	2.06
Specific Gravity of Soil Particles			2.61	2.63
Grading Analysis	Gravel (%)		0	0
	Sand (%)		5	73
	Silt (%)		42	7
	Clay (%)		53	20
	D_{60} *2 (mm)		0.074	0.39
	D_{30} *3 (mm)		Smaller than 0.001 mm	0.105
	D_{10} *4 (mm)		Ditto	Smaller than 0.001 mm
Consistency	Liquid Limit (%)		66	25
	Plastic Limit (%)		27	13
	Plasticity Index		39	12
Ignition Loss (%)			9.95	
Classification	Unified Classification		CH	SC
	AASHO Classification		A-7-6	A-2-6
Compaction Test *5	Optimum Moisture Content (%)		25.5	11.1
	Max. Dry Density (g/cm^3)		1.461	1.971
CBR Test *6	Optimum Moisture Content (%)			8.80
	Max. Dry Density (g/cm^3)			2.098
	17 Blows for Each Layer *7	Dry Density (g/cm^3)		1.875
		Soaked CBR (%)		16.5
	42 Blows for Each Layer	Dry Density (g/cm^3)		2.007
		Soaked CBR (%)		46.0
	92 Blows for Each Layer	Dry Density (g/cm^3)		2.070
		Soaked CBR (%)		56.2
	CBR Corresponding to 95 Max. Density (%)			44.5

Notes: *1 The water content at the time when the samples reached our laboratory

*2 The grain size corresponding to 50% on the grain size distribution curve

*3 " 30% "

*4 " 10% "

*5 This test was conducted in accord with the first method of JIS (Japan Industrial Standard) A 1210.

*6 The Compaction Test was run in accord with JIS A 1211.

*7 The specimen for CBR tests was compacted in three layers as specified in Japan Asphalt Pavement Manual.

Table 5-4 Summary of Special Soil Testing

Sample			Black Cotton Clay		Lateritic Sand	
Unconfined Compression Test and Triaxial Compression Test *1	Condition on Soaking		Unsoaked	Soaked		
	Water Content at which the Sample was compacted 18.6 (%)	Unconfined Compressive Strength qu (kg/cm²)	1.63	0.48		
	Ditto 24.6 (%)	Ditto qu (kg/cm²)	2.57	1.20		
	Ditto 29.3 (%)	Ditto qu (kg/cm²)	1.36	0.78		
	Ditto 35.0 (%)	Ditto qu (kg/cm²)	0.82	0.57		
	Approximate Water Content at which the Sample was compacted 20 (%)	ϕ *2	29°30'	4°00'		
		C *3 (kg/cm²)	0.47	0.16		
	Ditto 25 (%)	ϕ	19°30'	18°30'		
		C (kg/cm²)	0.90	0.10		
	Ditto 30 (%)	ϕ	6°30'	8°30'		
		C (kg/cm²)	0.61	0.33		
	Ditto 35 (%)	ϕ	3°30'	1°30'		
		C (kg/cm²)	0.35	0.29		
Swelling Test	Amount and Ratio of Swell		Amount (mm)	Ratio*4 (%)		
	Water Content at which the Sample was compacted 21.6 (%)		0.308	1.54		
	Ditto 24.8 (%)		0.876	4.38		
	Ditto 25.9 (%)		0.790	3.95		
	Ditto 29.2 (%)		0.218	1.09		
	Swelling Potential *5 (%)		13.2			
Cement Stabilizing Test	Compaction Test *6 for Soil Cement having the Cement Content of 5%	Optimum Moisture Content (%)			11.3	
		Max. Dry Density (g/cm³)			1.959	
	Average Unconfined Compressive Strength	Condition on Soaking			Unsoaked	Soaked
		Cement Content of 3% qu (kg/cm²)			24.0	14.3
		Ditto 5% qu (kg/cm²)			26.8	19.8
		Ditto 7% qu (kg/cm²)			29.3	21.8
		Ditto 9% qu (kg/cm²)			41.2	20.3

Notes: *1 The triaxial test was run in the undrained condition.

*2 The angle of internal friction

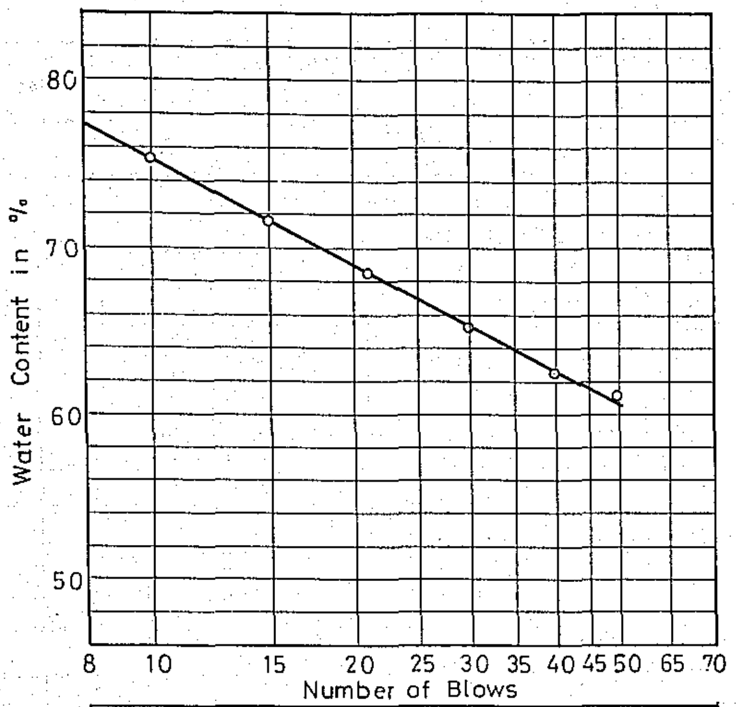
*3 The cohesion

*4 The ratio of swell is the amount of swell divided by the initial thickness of the specimen, 20 mm.

*5 The percentage swell of laterally confined sample on soaking under 1 psi surcharge after being compacted to maximum density at optimum moisture content in the standard AASHO method

*6 For each cement content, 1 specimen was cured for 7 days in a humid room in unsoaked condition and 3 specimens were cured for 6 days in the same manner and soaked for 1 day before the unconfined compression test.

FIG. 5-1 LIQUID LIMIT, PLASTIC LIMIT TEST RESULT



Sample No. Black Cotton Clay

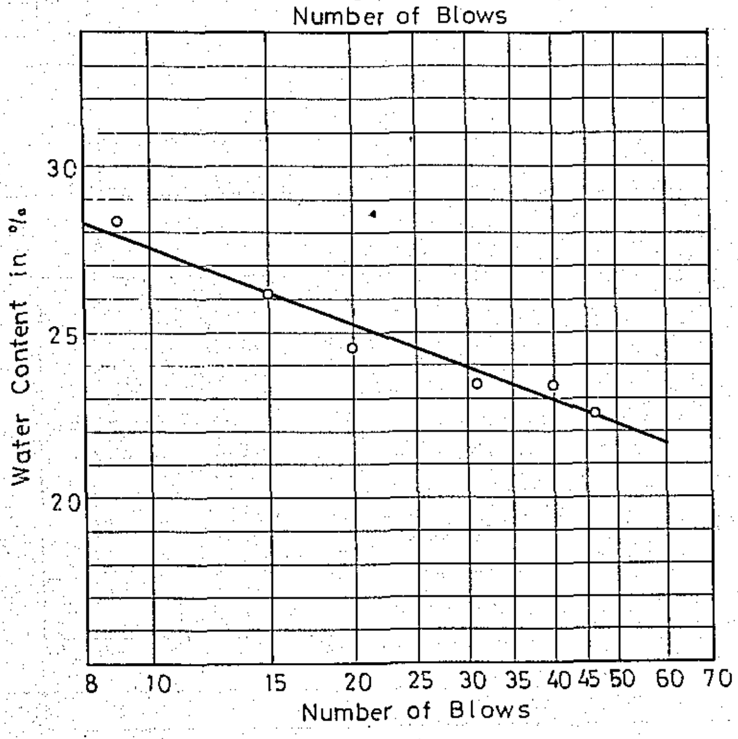
Liquid Limit L.L. = 66 %

Plastic Limit P.L. = 27 %

Plasticity Index P.I.= 39

Flow Index = ____

Remarks



Sample No. Lateritic Sand

Liquid Limit L.L. = 25 %

Plastic Limit P.L. = 13 %

Plasticity Index P.I.= 12

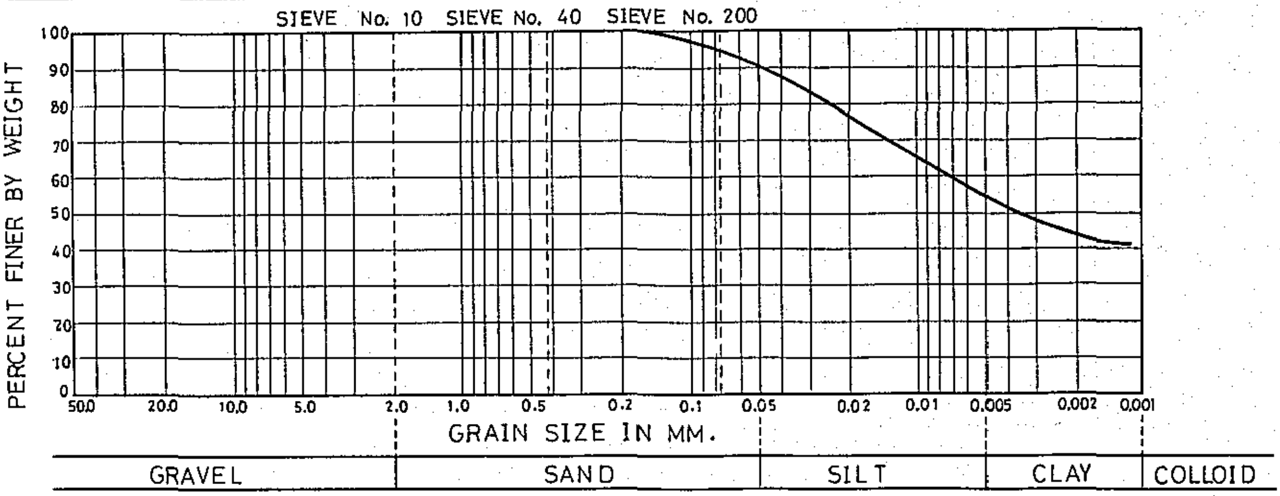
Flow Index = ____

Remarks

FIG. 5-2 RESULTS OF GRADING ANALYSIS

NO. OF SAMPLE	SAMPLING DEPTH (m)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	COLLOID (%)	DIA. AT 60 % (mm)	DIA. AT 10 % (mm)	UNIFORMITY COEFFICIENT	PERCENT FINER THAN NO. 200 SIEVE	REMARKS
Black Cotton Clay		0	5	42	53		0.0074	<0.001	—	95	

GRAIN SIZE DISTRIBUTION CURVES



NO. OF SAMPLE	SAMPLING DEPTH (m)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	COLLOID (%)	DIA. AT 60 % (mm)	DIA. AT 10 % (mm)	UNIFORMITY COEFFICIENT	PERCENT FINER THAN NO. 200 SIEVE	REMARKS
Lateritic Sand		0	73	7	20		0.39	<0.001	—	28	

GRAIN SIZE DISTRIBUTION CURVES

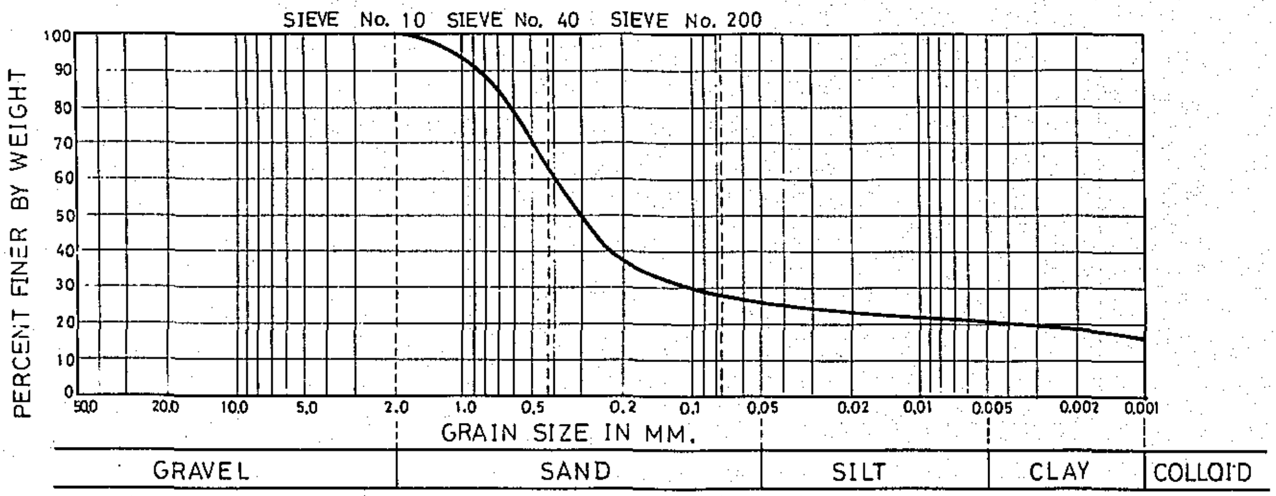
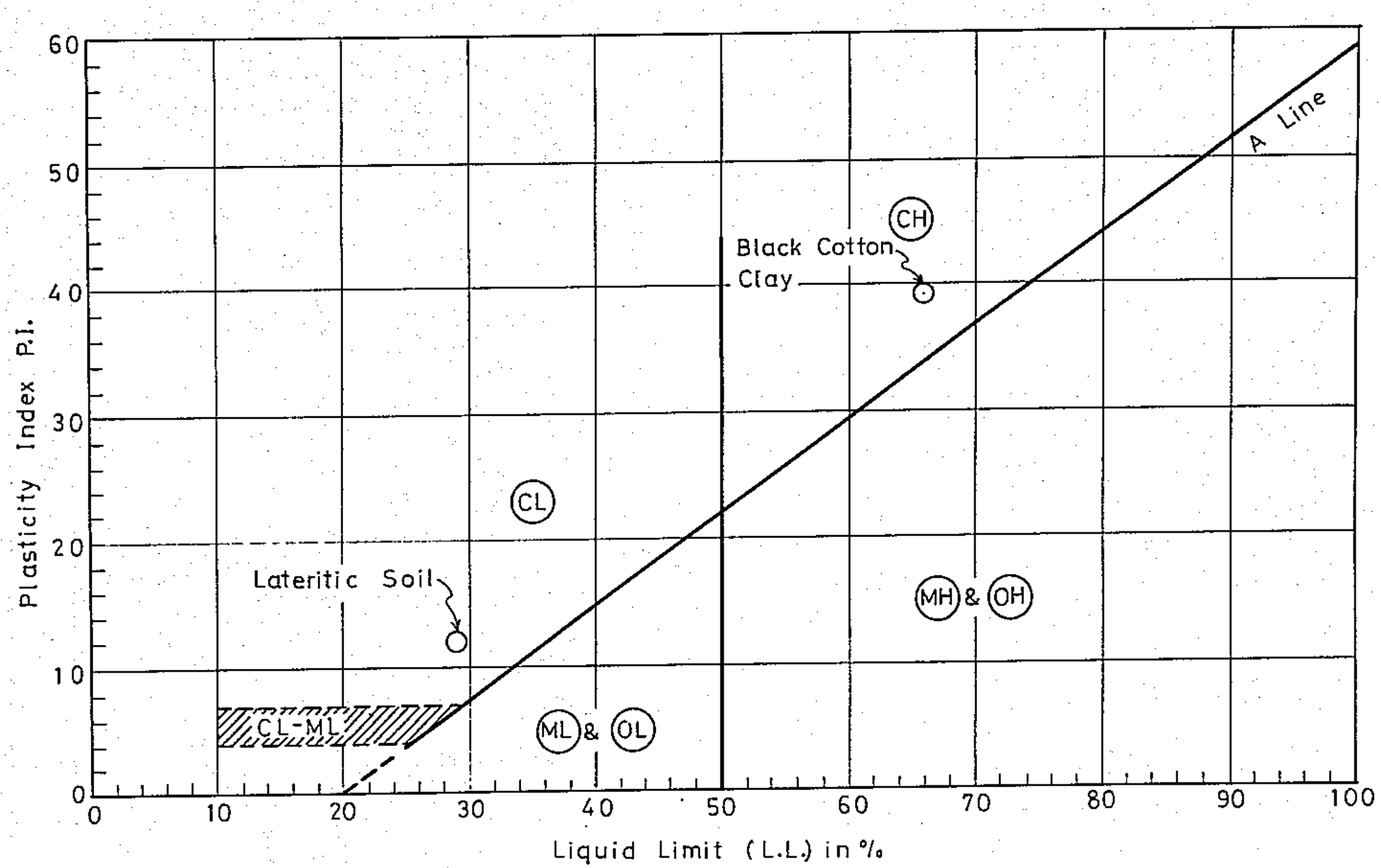


FIG. 5-3 CLASSIFCATION BY PLASTICITY CHART



ML: Inorganic silt with some plasticity, Very fine sand, Rock flour, Silty or Clayey fine sand and Clayey silt.

CL: Clay containing gravels with low or middle plasticity, Sandy clay and Silty clay.

OL: Organic silt with low plasticity and Organic silty clay.

MH: Inorganic silt with middle or high plasticity, Micaceous or Diatomaceous fine sandy soil and Silty soil.

CH: Inorganic caly with high plasticity.

OH: Organic clay with middle or high plasticity and Organic silt.

FIG. 5-4-1 RESULT OF COMPACTION TEST FOR LATERITIC SAND

Notes: The test was conducted in accordance with the 1st method of JIS A 1210.

Inside dia of mald	10cm	Weight of rammer	2.5kg
Number of layers	3	Drop height of rammer	30cm
Blows per layer	25	Compqctive effort	5.6 cm·kg/cm^3

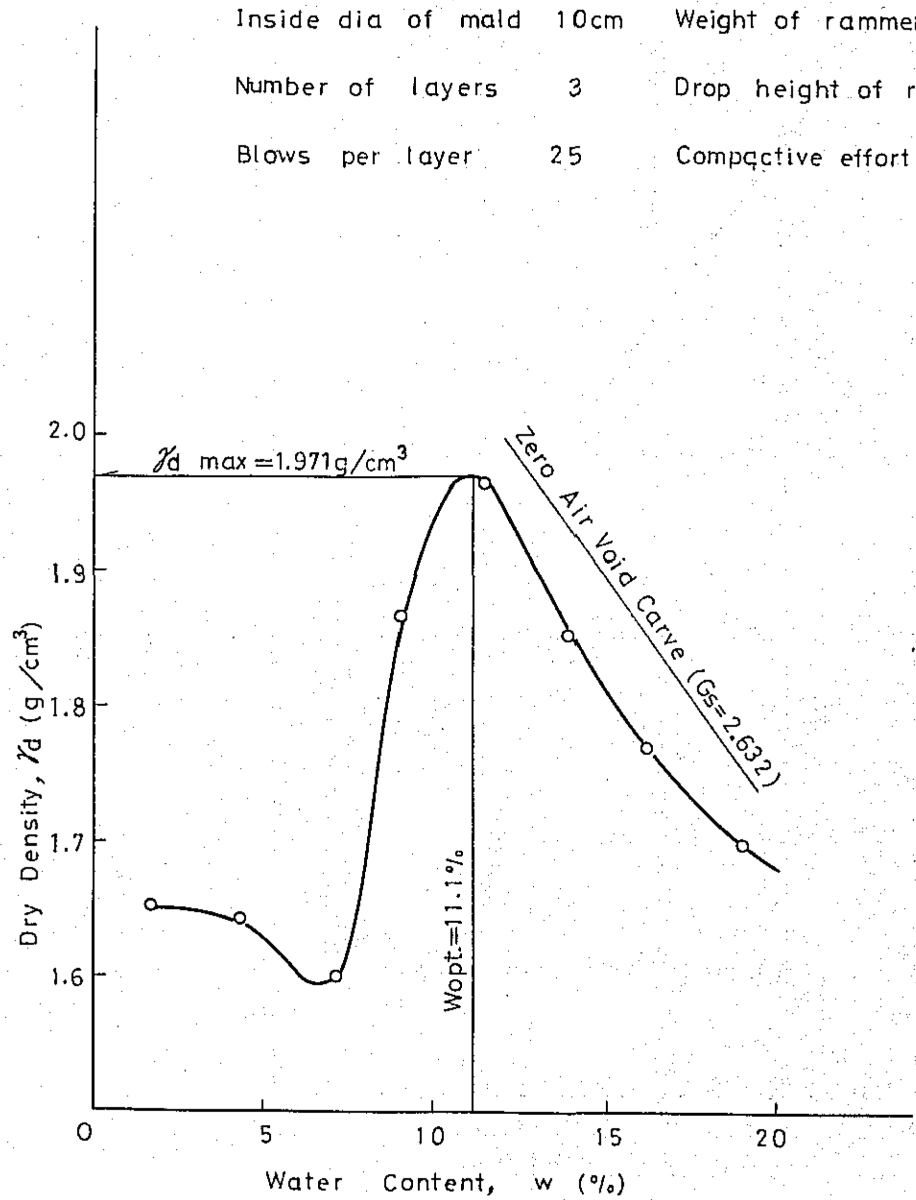


FIG. 5-4-2 RESULT OF COMPACTION TEST FOR BLACK COTTON CLAY

Note: The test was conducted in accordance with the 1st method of JIS A 1210

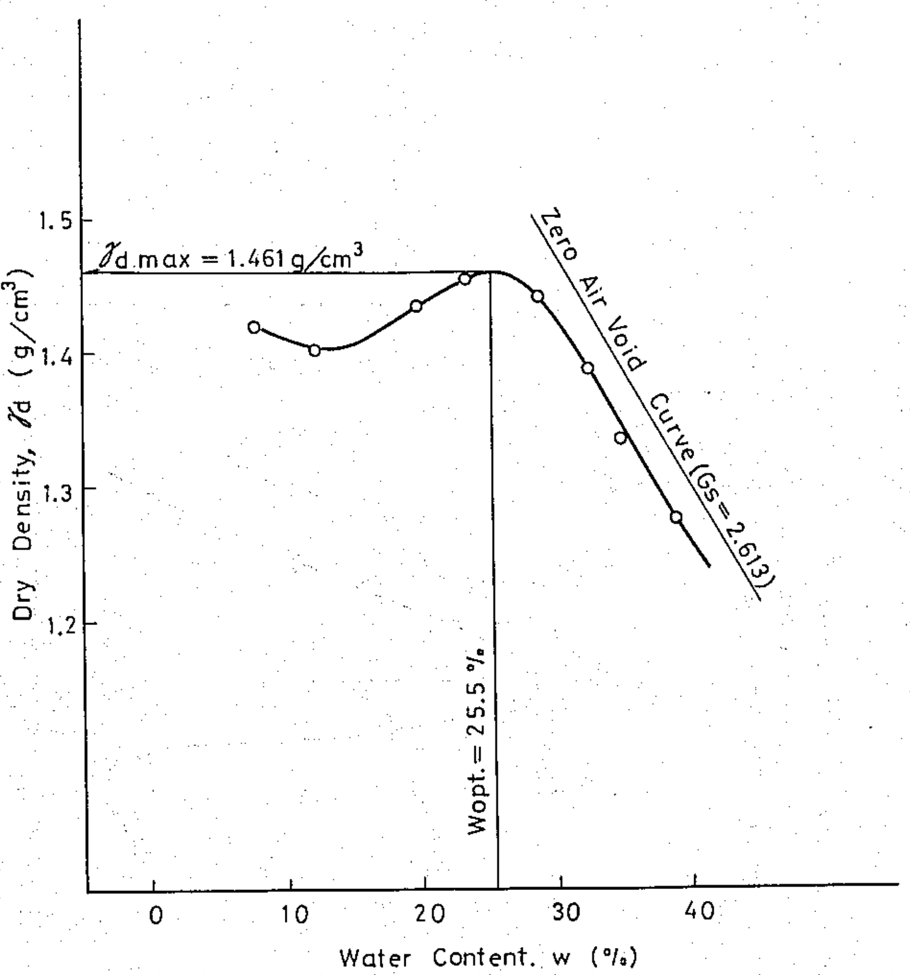
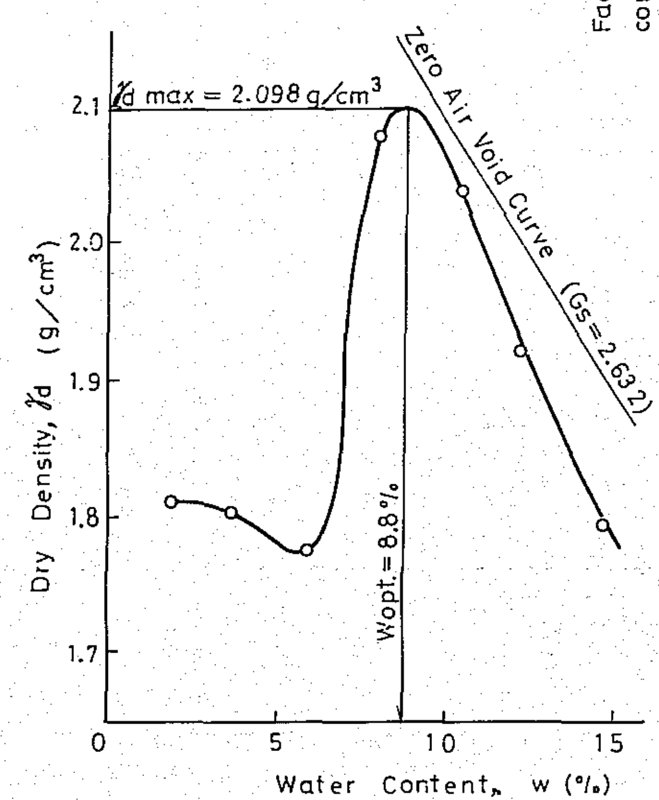


FIG. 5-5 RESULT OF CBR TEST FOR DISTURBED SAMPLE OF LATERITIC SAND

Notes: Both compaction and CBR tests were conducted in accordance with Japanese Code for Asphalt Pavement.

Factor relating with compaction test.

Inside dia of mold	15cm	Weight of rammer	4.5 kg
Number of layers	3	Drop height of rammer	45 cm
Blows per layer	92	Compactive effort	26.5 cm kg/cm^3



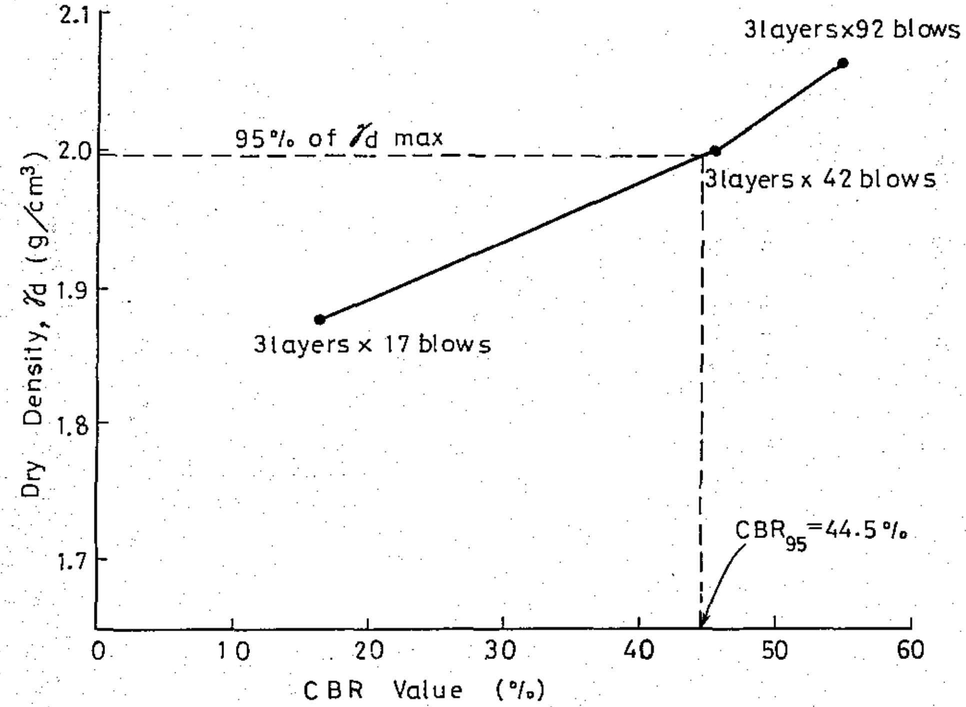
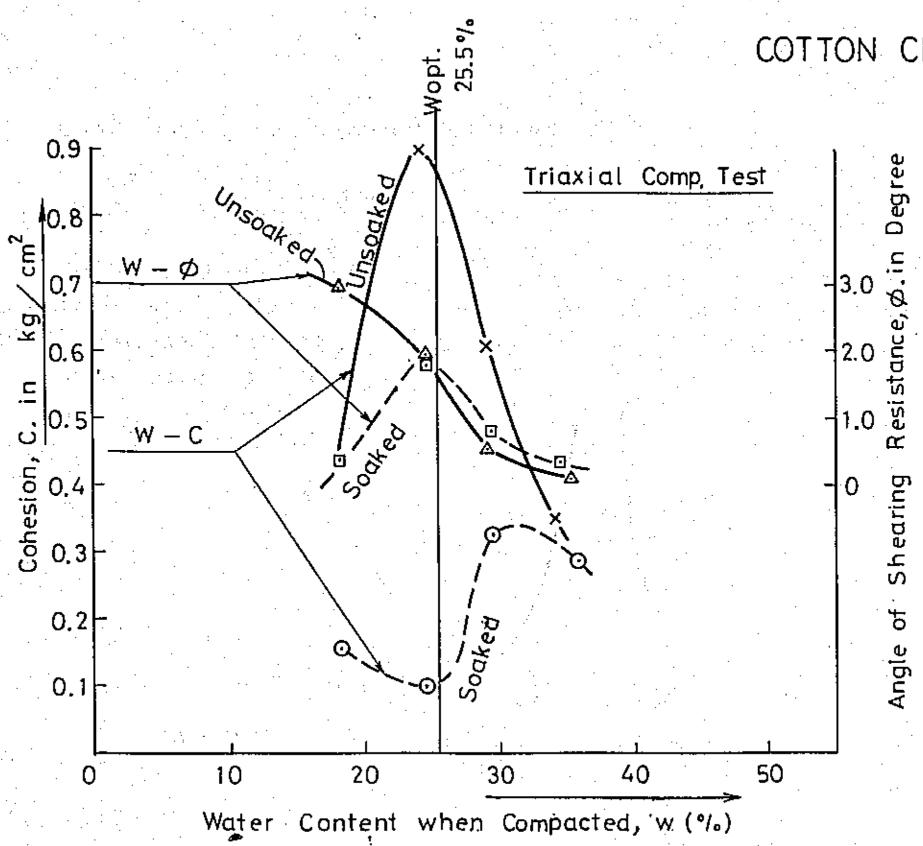


FIG. 5-6 RESULTS OF UNCONFINED AND TRIAXIAL COMPRESSION TESTS FOR COMPACTED BLACK COTTON CLAY



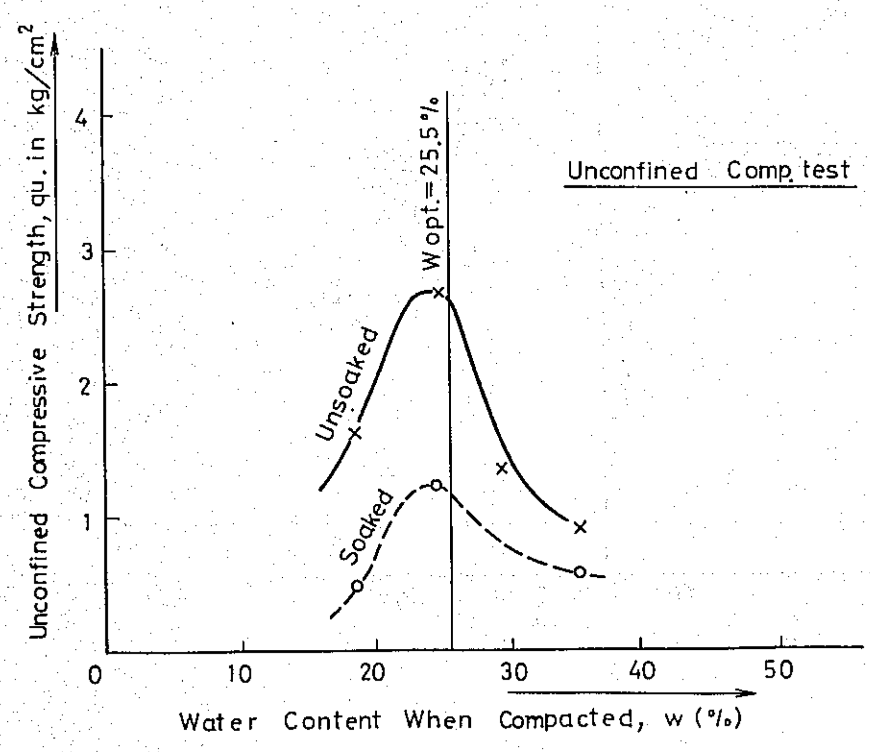
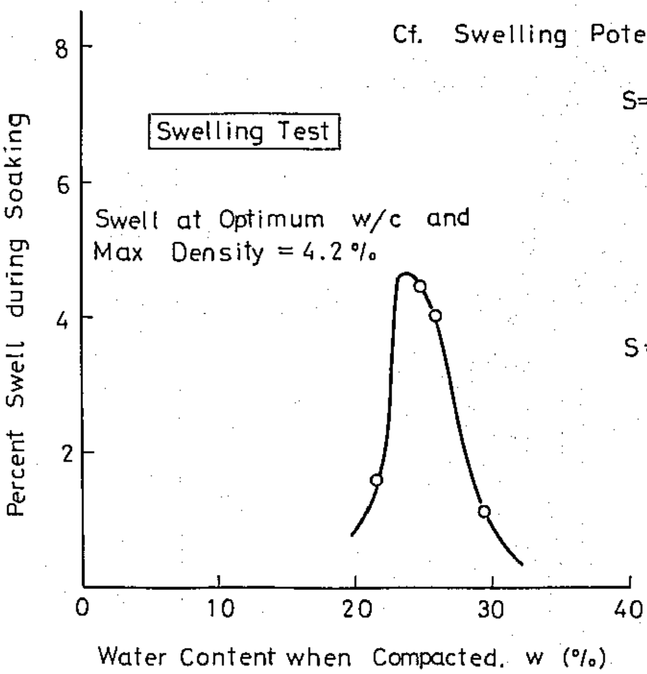


FIG. 5-7 SWELLING TEST FOR BLACK COTTON CLAY



Cf. Swelling Potential, S, by Pref. Seed

$$S = (K)\cdot\left(\frac{PI}{C-5}\right)^{2.44}\ (C)^{3.44}$$

K : Experimental Constant 3.6×10^{-5}

PI: Plastic Index of the sample=39

C : Percent Finer than 0.002mm of the Sample=42.2

$$S = (3.6\times10^{-5})\cdot\left(\frac{39}{42.2-5}\right)^{2.44}\cdot(42.2)^{3.44}$$

$$= 13.2\ (\%)$$

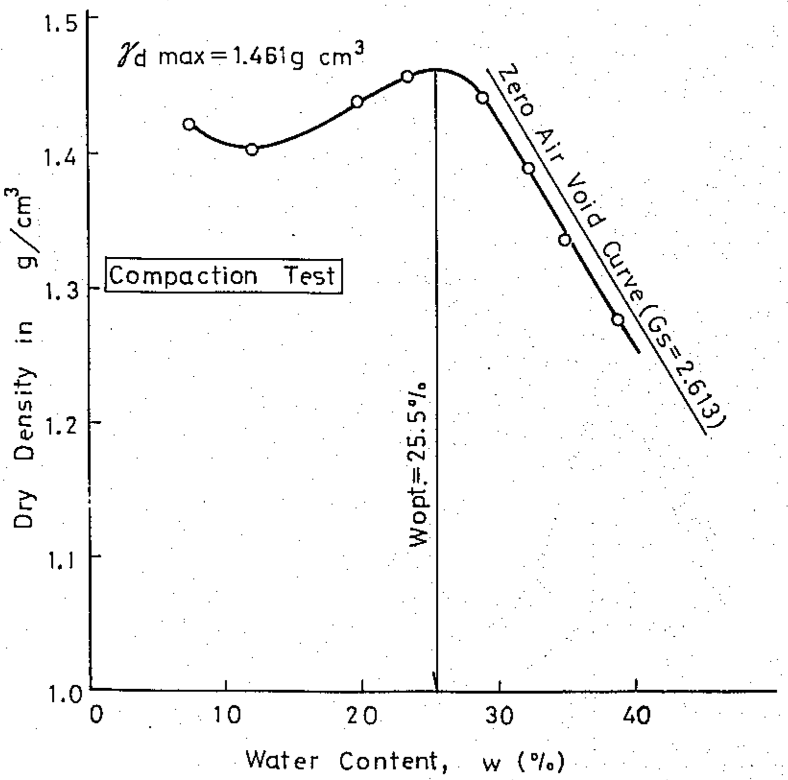


FIG. 5-8-1 RESULTS OF COMPACTION TEST FOR THE MIXTURE OF LATERITIC SAND AND CEMENT

Notes : 1. The mixture having the cement content of 5% was comacted in accordance with the 1st method of JIS A 1210

2. ——•—— shows the result of the mixture

------ shows the result of the original lateritic sand

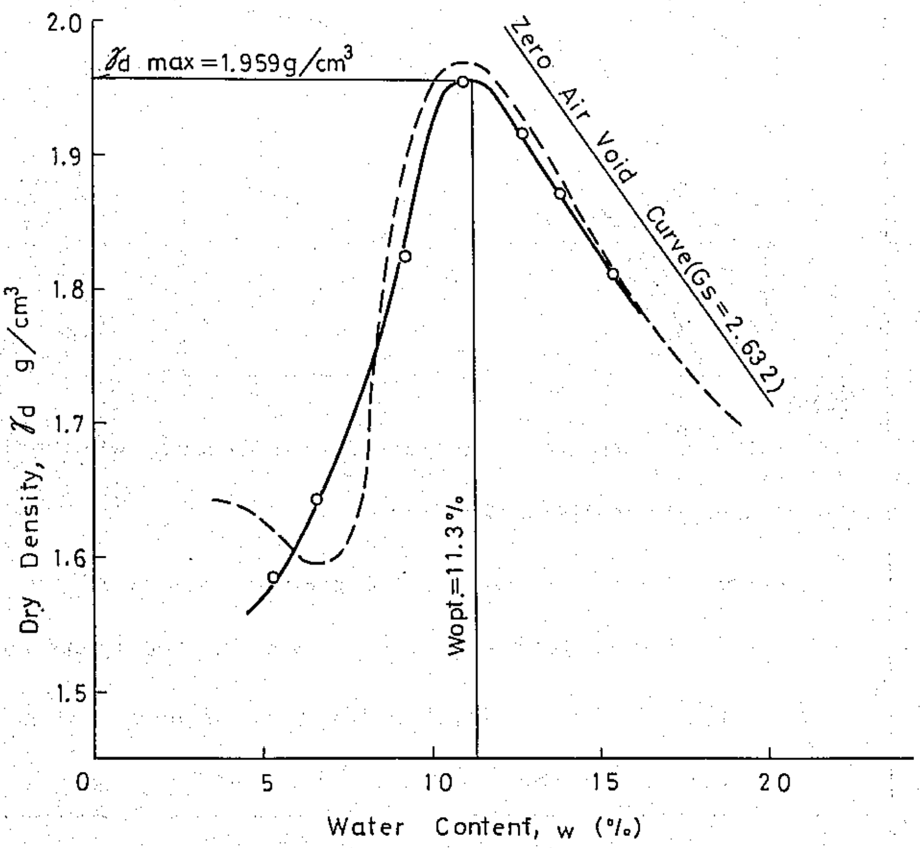


FIG. 5-8-2 RESULTS OF UNCONFINED COMPRESSION TESTS FOR LATERITIC SAND STABILIZED WITH CEMENT

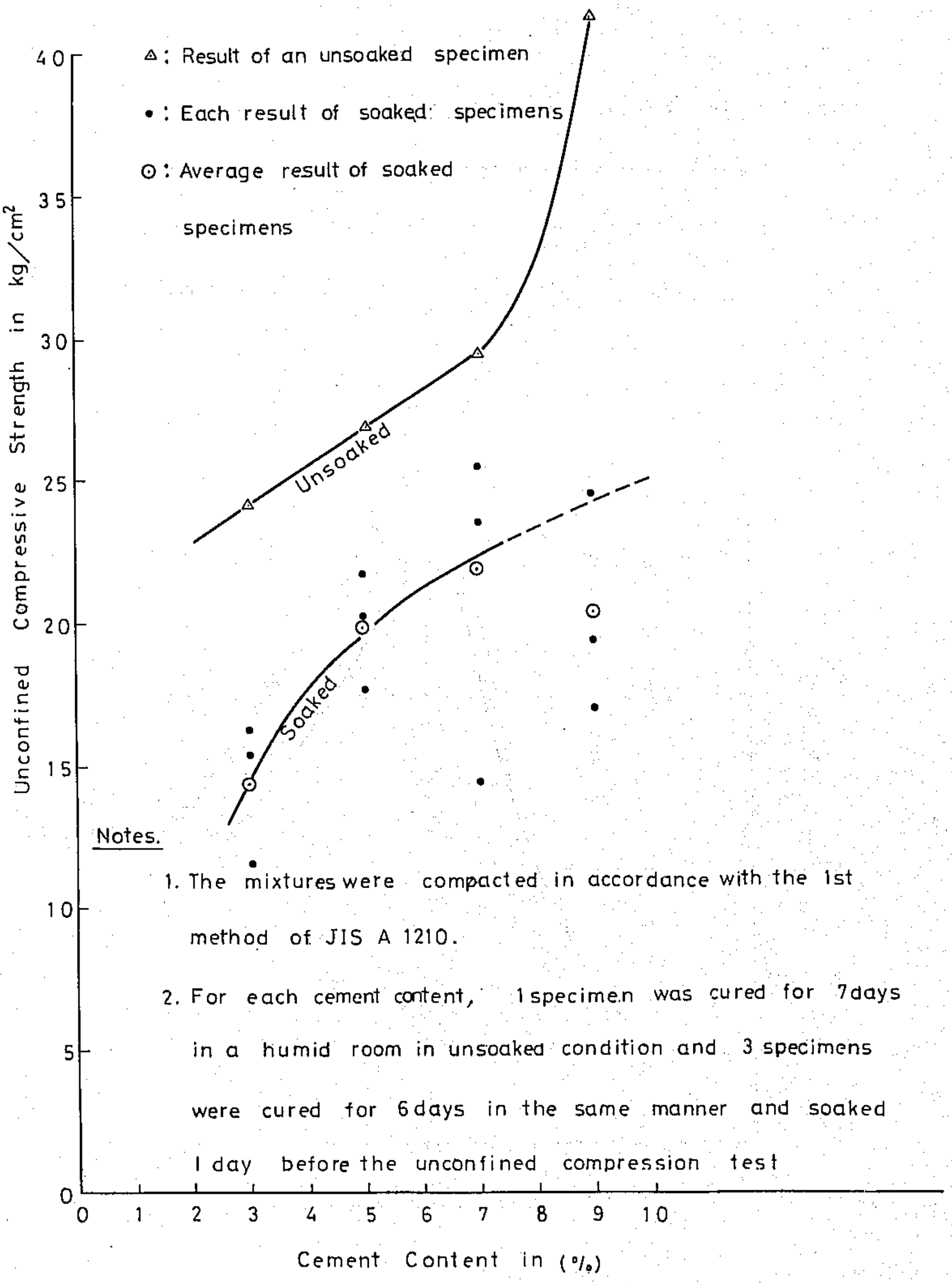


FIG. 5-9-1 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Unsoaked Water Content of 18.6% in Compaction

Condition of Drainage: Undrained.

Angle of Internal Friction: 29°30′

Cohesion: 0.47 kg/cm²

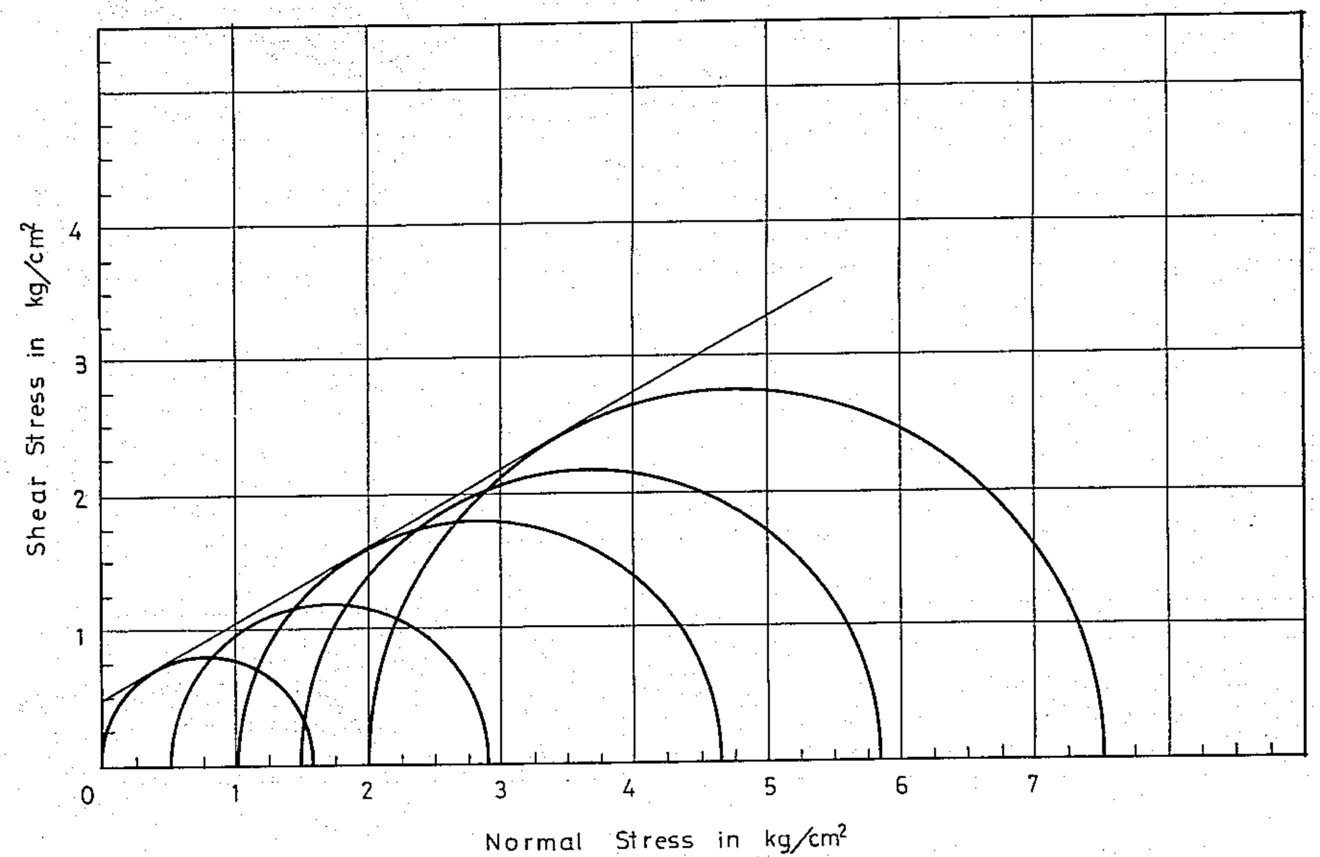


FIG. 5-9-2 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No: Compacted Black Cotton Clay

Condition of Sample: Unsoaked

Water Content of 18.6% in Compaction

Condition of Drainage: Undrained

Angle of Internal Friction: 19° 30'

Cohesion: 0.90 kg/cm^2

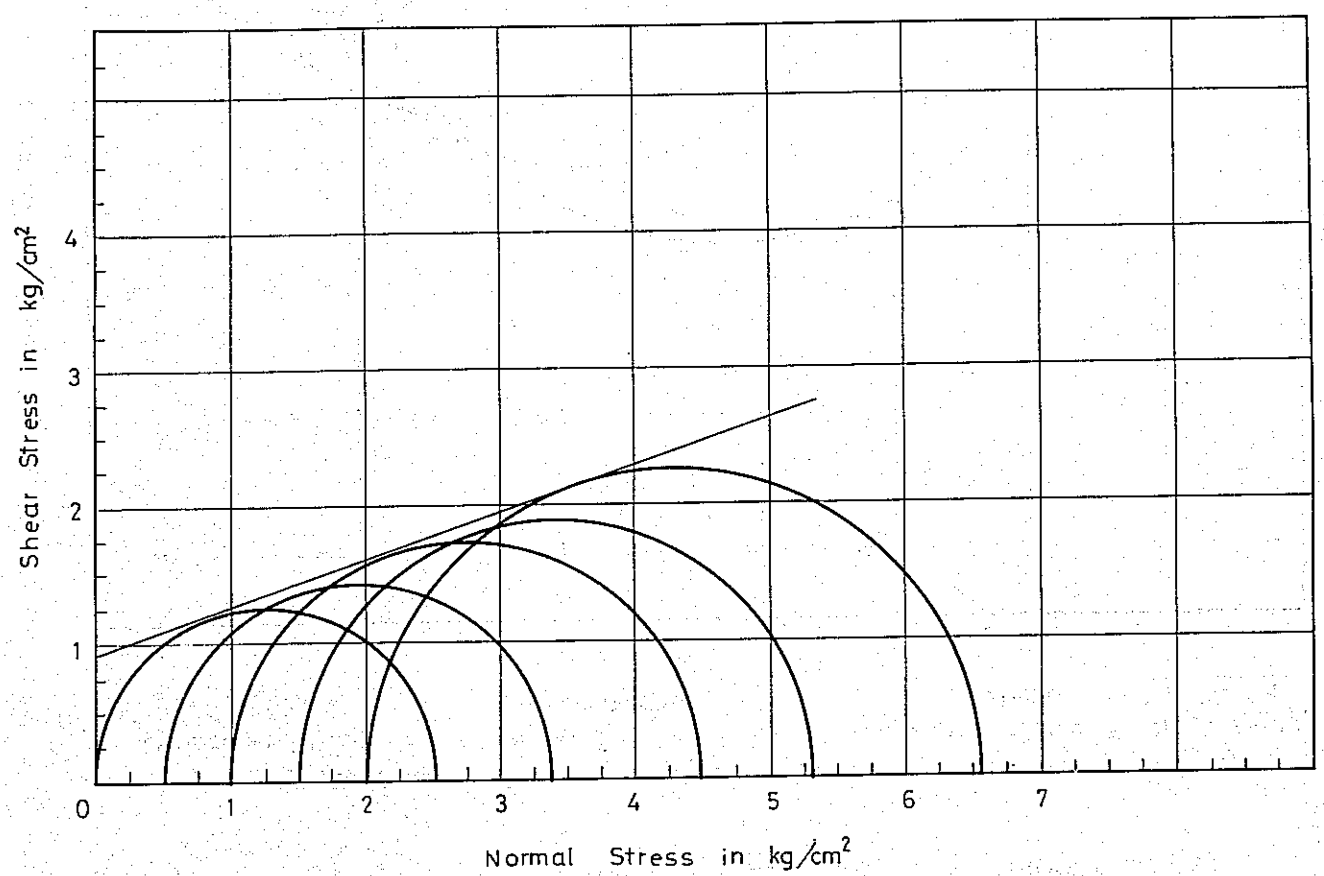


FIG. 5-9-3

TRIAXIAL COMPRESSION TEST (Moh'r s circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Unsoaked Water Content of 29.0% in Compation

Condition of Drainage: Undrained

Angle of Internal Friction: 6° 30′

Cohesion: 0.61 kg/cm²

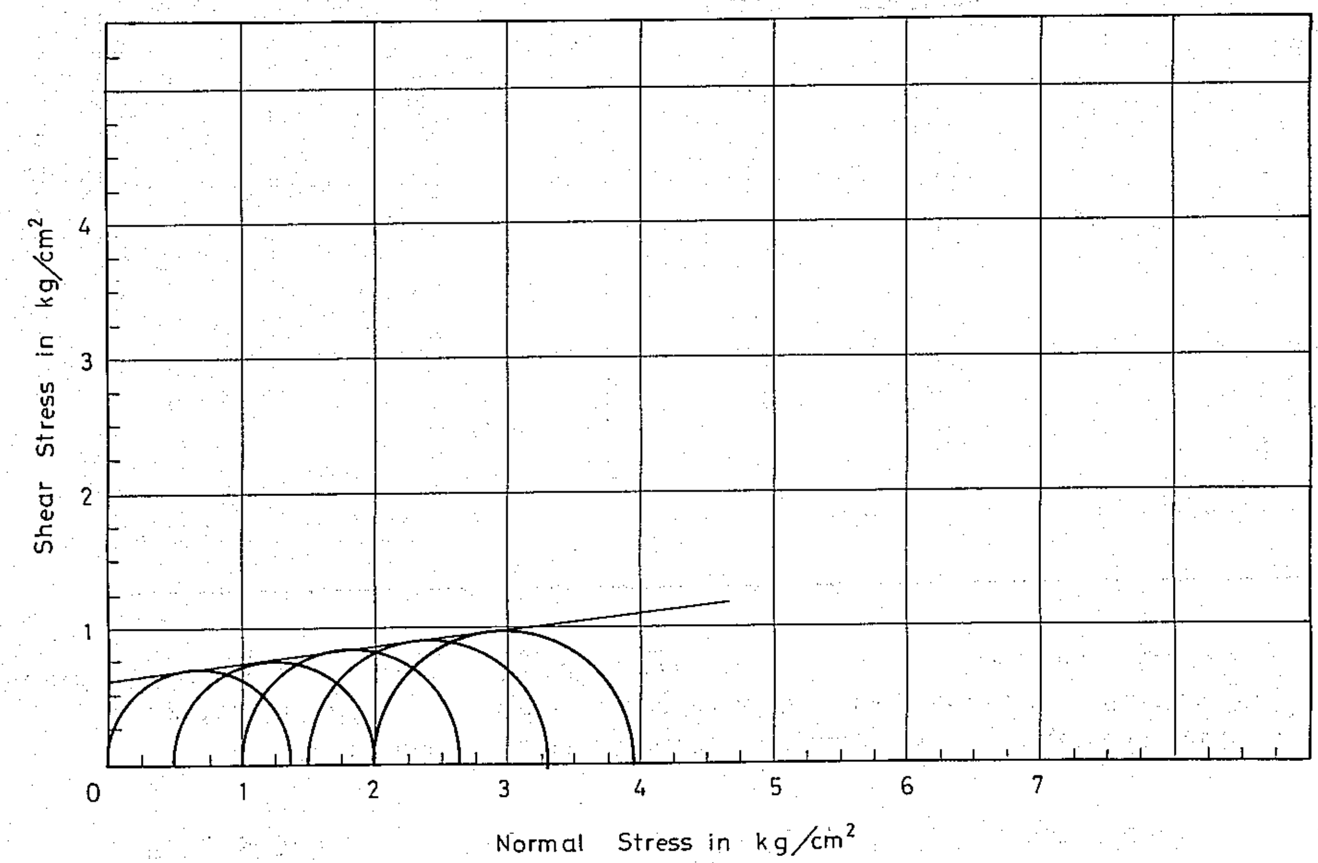


FIG. 5-9-4 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Unsoaked Water Content of 34.2% in Compaction

Condition of Drainage: Undrained

Angle of Internal Friction: 3°30′

Cohesion: 0.35 kg/cm²

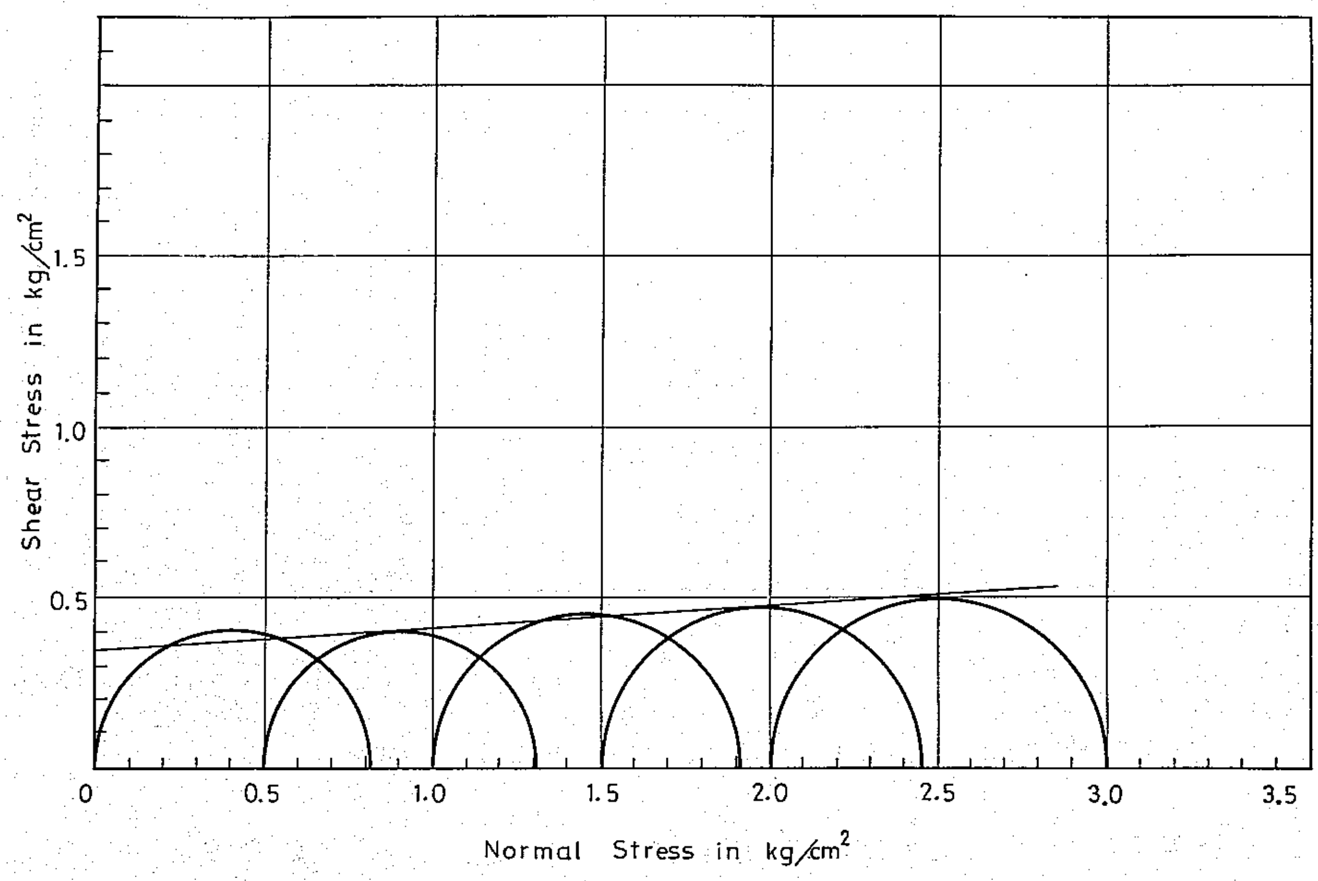


FIG. 5-9-5 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Soaked
Water Content of 18.6% in Compaction

Condition of Drainage: Undrained
Angle of Internale Friction: 4°00'
Cohesion: 0.16 kg/cm²

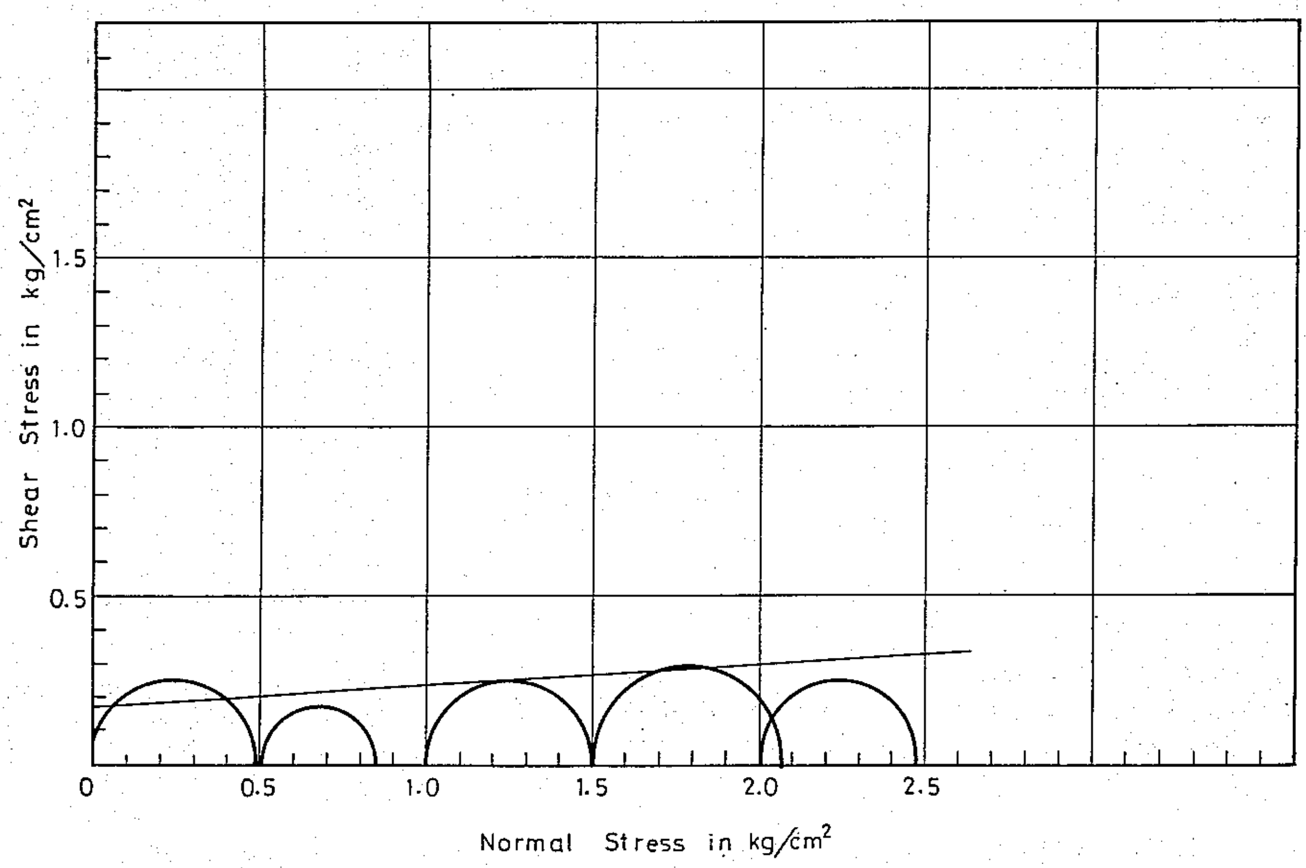


FIG. 5-9-6 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Soaked Water Content of 24.8% in Compaction

Condition of Drainage: Undrained

Angle of Internal Friction: 18°30′

Cohesion: 0.10 kg/cm²

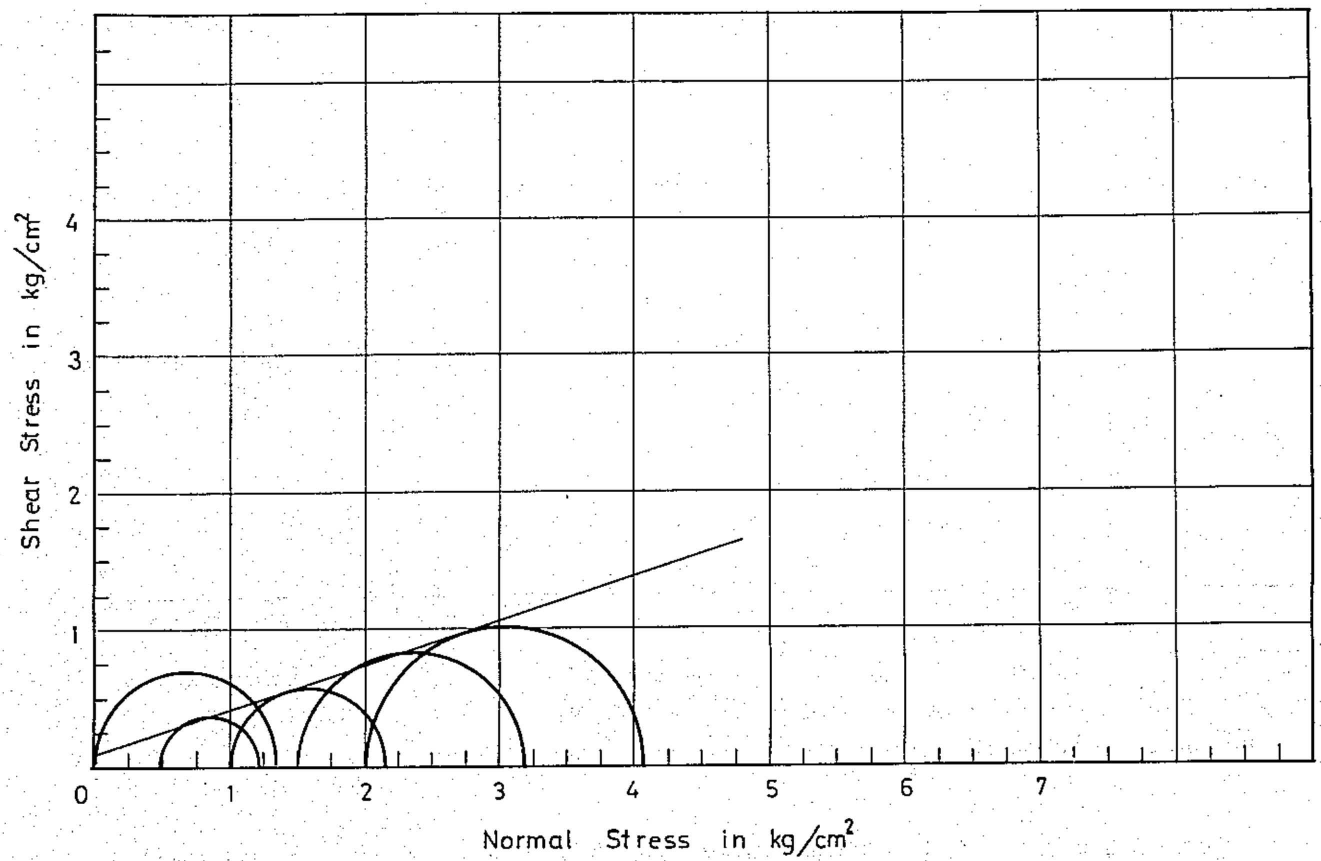


FIG. 5-9-7 TRIAXIAL COMPRESSION TEST (Mohr's circle)

Sample No.: Compacted Black Cotton Clay

Condition of Sample: Soaked

Water Content of 29.5% in Compaction

Condition of Drainage: Undrained

Angle of Internal Friction: 8°30′

Cohesion: 0.33 kg/cm²

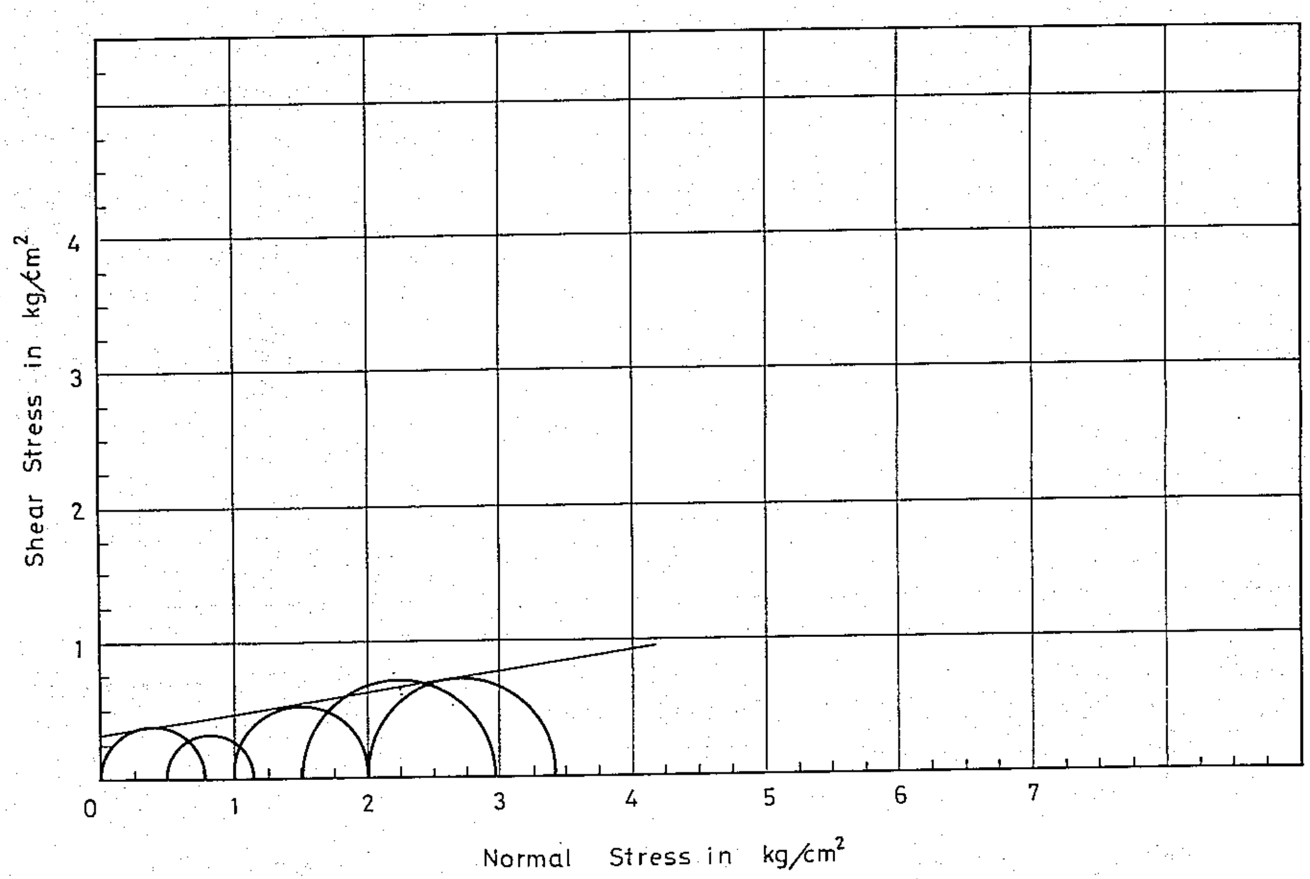


FIG. 5-9-8 TRIAXIAL COMPRESSION TEST (Mohr's circle)

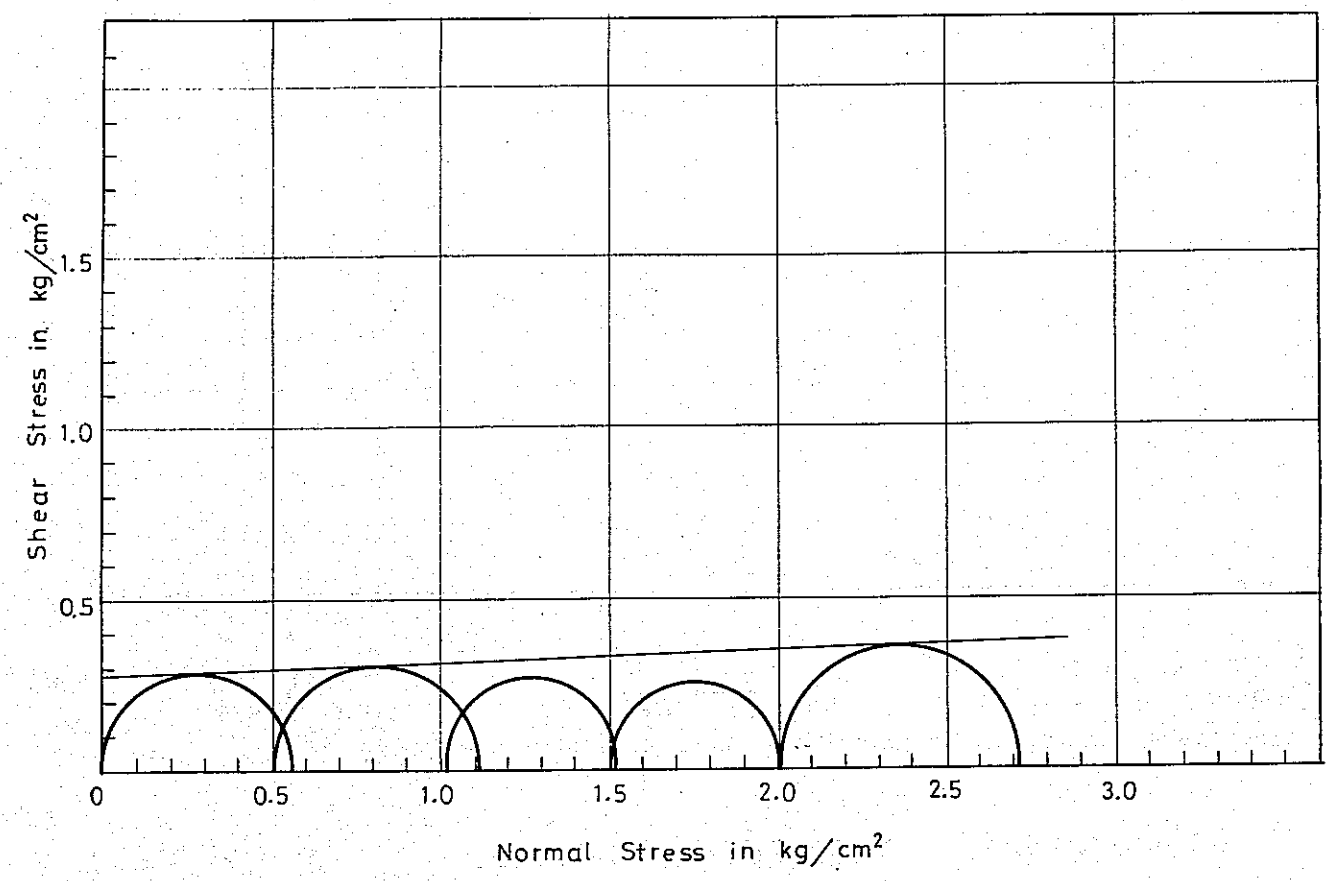
Sample No.: Compacted Black Cotton Clay

Condition of Sample: soaked Water Content of 35.7% in Compaction

Condition of Drainage: Undrained

Angle of Internal Friction: 1° 30'

Cohesion: 0.29 kg/cm²



APPENDIX

RESULTS OF SOIL TESTING UNDERTAKEN BY TANZANIAN GOVERNMENT OFFICIALS

I

PROJECT:- KIBITI - LINDI ROAD

Laboratory No.		7438	7439	7440	7441	7742	7743	7444	7445
Station No. Ks.		5	10	15	25	25	30	35	35
Depth in Metrs		1.5	0.5	1.0	1.5	0.9	0.9	0.7	0.5
Soil Type		Literite	Grey Sand	Sandy Clay	White Sand	Dark Brown Sand	Sandy Clay	Brown Clay	Black Cotton
SIEVE ANALYSIS									
Percentage Passing	3/16"								
B. S. Sieve No.	7	100	100	100	100	100		100	
	14	99	98	98	99	99		99	
	25	77	68	84	69	70	100	89	100
	36	62	45	70	47	47	98	74	99
	52	49	37	56	35	34	95	47	97
	72	39	16	40	23	17	90	18	92
	100	34	10	33	14	10	69	8	82
	200	30	7	24	8	5	28	3	72
ATTERBERG LIMITS									
Liquid Limit		41		34	-	-	29		41
Plastic Limit		17	NP	13	NP	NP	19	NP	15
Plasticity Index		24	-	21	-	-	10	-	26
Field Moisture Content %		10.0	2.4	13.2	13.0	6.2	14.6	4.1	29.8
Loss in Ignition %		-	-	-	-	-	-	-	10.6

I

PROJECT:- KIBITI - LINDI ROAD

Laboratory No.		7446	7447	7448	7449	7450	7451	7452	7453	7454
Station No. Km		40	45	30 U	50 U	50 U	50 U	75	55	35 U
Depth in Metre		0.5	0.5	0.6	0.5	2.0	0.7	0.4	1.2	0.5
Soil Type		Sandy Clay	Black Cotton	Sandy Clay	Sandy Clay	Sandy Clay	Black Cotton	Silty Sand	Brown Sand	Sandy Clay
SIEVE ANALYSIS										
Percentage Psssing	3/16"			100		100				
B. S. Sieve No.	7	100		99	100	97			100	100
	14	99	100	94	98	87		100	98	98
	25	91	97	68	80	62	100	96	77	68
	36	78	93	51	67	45	99	89	45	45
	52	60	88	33	60	32	98	76	20	26
	72	48	86	28	41	25	97	63	11	16
	100	39	83	23	34	21	96	44	5	9
	200	27	77	20	28	19	93	20	2	4
ATTERBERG LIMITS										
Liquid Limit		31	74	37	37	64	52	-	-	30
Plastic Limit		17	24	16	16	27	23	NP	NP	16
Plasticity Index		14	50	21	21	37	29	-	-	14
Field Moisture Content %		9.2	28.3	13.5	16.1	17.1	28.0	6.5	5.1	9.9
Loss in Ignition %		-	8.5		-	-	9.3	-	-	-

PROJECT:- KIBITI - LINDI ROAD

		7671	7672	7673	7674	7675	7676	7677	7678	7679	7680	7681	7682
Laboratory No.		7671	7672	7673	7674	7675	7676	7677	7678	7679	7680	7681	7682
Sample No. Km		165.0	170.2	176.0	185.0	187.8	189.0	199.8	207.6	209.6	223.0	247.6	250.8
Depth in Metre		0.7	0.5	0.7	0.4	0.4	3.0	1.5	1.0	0.3	1.0	0.5	1.0
Soil Type											Black Cotton	Black Cotton	Black Cotton
SIEVE ANALYSIS													
Percentage Passing	3/4"		100	100									
	3/8"		98	84						100			
	3/16"		74	69		100				91			
B. S. Sieve No.	7		47	60		48				76			
	14		35	55		29	100		100	68	100		100
	25		32	52		23	99	100	96	63	99	100	99
	36	100	31	51		22	99	99	93	61	98	99	98
	52	94	29	50	100	22	98	96	87	58	97	98	56
	72	83	28	48	99	20	98	92	72	56	96	98	93
	100	53	27	44	99	19	97	75	41	53	95	96	86
	200	30	26	34	98	16	97	37	19	48	91	75	43
ATTERBERG LIMITS													
Liquid Limit		26	58	37	66	34	52	20		35	43	42	51
Plastic Limit		18	29	15	26	18	23	15	NP	18	18	18	15
Plasticity Index		8	29	22	40	16	39	5		17	25	24	36
Field Moisture Content %		4.8	4.7	4.4	18.0	2.5	15.3	4.7	2.1	6.9	11.8	14.9	15.8
Loss in Ignition %		8.0									5.7		6.2
B. B. COMPACTION													
Maximum Dry Density lbs/cu.ft.				115.0	87.5	-	-	-	-	-	-	97.0	-
Optimum Moisture Content %		-	-	10.7	27.0	-	-	-	-	-	-	19.0	-
CALIFORNIA BEARING RATIO													
At Proctor with 60 lbs/sq. in minimum surcharge													
Unsoaked		-	-	14	13	-	-	-	-	-	-	9	-
After 24 hours soaking		-	-	1	0	-	-	-	-	-	-	0	-
Moulding Moisture Content %		-	-	10.7	28.4	-	-	-	-	-	-	19.9	-
Moulding Dry Density lbs/cu.ft.		-	-	116.7	86.8	-	-	-	-	-	-	96.2	
Moisture Content % after 24 hours Soaking		-	-	12.9	35.3	-	-	-	-	-	-	25	-

II

PROJECT:- KIBITI - LINDI ROAD

		7683	7684	7685	7686	7687	7688	7689	7690	7691
Laboratory No.		7683	7684	7685	7686	7687	7688	7689	7690	7691
Sample No. Km		251.8	260.8	272.4	292.8	296.2	302.0	22	23	24
Depth in Metre		0.65	0.4	1.0	0.3	0.5	East	7	0.3	River
Soil Type		Red Laterite	Laterite	Organic Soil	Red Laterite	GP	2 miles	Silty Clay	Gravel Pit	Mavudji Grey Clay
SIEVE ANALYSIS										
Percentage Passing	3/4"						100		100	
	3/8"						91		64	
	3/16"			100	100		78	100	39	
B.S. Sieve No.	7			96	63		69	91	28	
	14	100		90	57	100	61	89	25	
	25	96	100	83	53	98	53	87	23	100
	36	95	98	81	51	97	49	84	22	99
	52	89	87	76	49	94	43	83	22	98
	72	85	68	73	47	91	39	80	21	98
	100	78	42	69	45	85	32	78	21	97
	200	70	22	67	41	76	24	34	19	84
ATTERBERG LIMITS										
Liquid Limits		38		49	32	33	22	38	40	53
Plastic Limits		19	NP	17	13	13	14	15	16	19
Plasticity Index		19		32	19	20	8	23	24	34
Field Moisture Content %		7.3	2.6	19.3	14.5	6.7	3.1	12.4	8.5	21.7
Loss in Ignition %										
B. B. COMPACTION										
Maximum Dry Density lbs/cu.ft.		121.5	117.0	-	-	-	123.0			
Optimum Moisture Content %		12.0	9.5				10.4			
CALIFORNIA BEARING RATIO										
At Proctor with 60 lbs/sq. in minimum surcharge										
Unsoaked		11	9	-	-	-	10			
After 24 hours soaking		0.3	0	-	-	-	9			
Moulding Moisture Content %		11.4	9.2	-	-	-	9.5			
Moulding Dry Density lbs/cu.ft.		122.7	116.7	-	-	-	124.0			
Moisture Content % after 24 hours Soaking		13.7	11.7	-	-	-	12.2			

III Batch

PROJECT:- KIBITI - LINDI ROAD

Laboratory No.		7692	7693	7694	7695	7696	7697	7698	7699
Station No.		10 U	20 U	20 U	25 U	25 U	45 Km	50	50
Depth		GS	60 Cm	1.7 m	60 Cm	1.8 m	GS	50 Cm	1.9 m
Type of Soil		Laterite Soil Sand	Brown						Brown Sand
SIEVE ANALYSIS									
Percentage Passing	3/16"								
B.S. Sieve No.	7	100	100	100	100	100			
	14	99	98	99	98	98	-	100	100
	25	77	78	76	76	76	-	90	89
	36	47	61	51	56	56	100	75	70
	52	31	41	21	40	38	99	50	46
	72	24	21	13	25	23	92	40	36
	100	17	10	5	21	15	74	27	22
	200	13	3	2	14	8	29	13	5
ATTERBERG LIMITS:									
Liquid Limit									
PlasticiLimit		NP	NP	NP	NP	NP	NP	NP	NP
Plasticity Index									
Field Moisture Content %		2.5	2.4	11.9	6.0	7.5	3.5	11.4	17.4
Laboratory No.		7708	7709	7710	7711	7712	7713	7714	7715
Station No.		90 + 1Km	100	100 + 2K	110	115	120	225	135
Depth		1.0M	GS		GS	GS	60 Cm	30 Cm	GS
Type of Soil		Clayey Sand	Sandy Silt	Brown Sand	Brown Silt Sand	Dark Brown Silt	Kikanda Fine Sand	Brown Clay	Silty Sand
SIEVE ANALYSIS:									
Percentage Passing	3/16"								
B.S. Sieve No.	7	100							
	14	96	100	100	100	100	100	100	100
	25	85	97	98	97	97	94	97	96
	36	64	95	96	91	89	82	96	86
	52	38	90	91	76	76	57	91	63
	72	21	81	83	68	71	46	83	56
	100	14	71	73	53	47	33	72	46
	200	8	43	48	30	22	17	63	32
ATTERBERG LIMITS:									
Liquid Limit		24	19					45	
Plastic Limit		12	17	NP	NP	NP	NP	12	NP
Plasticity Index		12	2					33	
Field Moisture Content %		12.3	2.4	4.7	2.7	1.8	1.2	16.4	1.0

III Batch

PROJECT: KIBITI - LINDI ROAD

Laboratory No.		7700	7701	7702	7703	7704	7705	7706	7707
Station No.		55	60	65	65	70	80	85	90 + 1Km
Depth		50 Cm	60 Cm	60 Cm	1.8 m	30 Cm	GS	50 Cm	40 Cm
Type of Soil		Brown Sand	Brown Sand	Brown Sand	Brown Sandy Silt	Brown	Brown Sandy Clay	Brown Silty Sand	Clayey Sand
SIEVE ANALYSIS:									
Percentage Passing	3/16"					100			
B.S. Sieve No.	7					99			100
	14	100	100	100	100	87	100	100	96
	25	92	93	91	91	87	97	98	77
	36	79	81	79	77	67	91	96	56
	52	54	65	57	67	45	82	88	34
	72	44	51	48	47	39	71	82	18
	100	34	42	40	37	28	60	69	12
	200	24	28	22	20	16	40	31	8
ATTERBERG LIMITS:									
Liquid Limit							20		
Plastic Limit		NP	NP	NP	NP	NP	14	NP	NP
Plasticity Index							6		
Field Moisture Content		4.2	2.1	3.6	1.7	5.3	3.7	4.6	7.4
Laboratory No.		7716	7717	7718	7719	7720	7721	7722	
Station No.		140	145	145 + 2Km	150	25	26	27	
Depth		50 Cm	30 Cm	30 Cm					
Type of Soil					Black Cotton Clay	Top Soil	Brown Sand	Sand Silt	
SIEVE ANALYSIS:									
Percentage Passing	3/16"								
B.S. Sieve No.	7	100					100	100	
	14	97				100	99	98	
	25	76				98	80	80	
	36	60	100		100	94	57	63	
	52	37	97	100	99	89	36	42	
	72	29	90	99	99	84	23	36	
	100	17	62	96	98	81	15	29	
	200	5	21	72	96	66	8	23	
ATTERBERG LIMITS:									
Liquid Limit			40		67	27			
Plastic Limit		NP	10	NP	18	12	NP	NP	
Plasticity Index			30		49	15			
Field Moisture Content %		1.9	26.6	20.0	8.5	4.8	3.1	1.6	

PROJECT: KIBITI - LINDI ROAD

Laboratory No.	7723	7724	7725	7726
Station No. Km.	5	40	90 + 1 Km	145 + 2 Km
Type of Material	Laterite	Silty Sand	Black Cotton	Silty Sand
Depth	60 Cm	GS	GS	GS
B.S. COMPACTION TEST:				
Maximum Dry Density lbs/cu. ft.	120.0	121.0	92.0	113.0
Optimum Moisture Content %	11.0	10.5	23.0	13.5
CALIFORNIA BEARING RATIO:				
At Proctor with 60 lbs/sq. minimum Surcharge				
Unsoaked	16	21	13	48
After 24 hours Soaking	3	10	1	7
Moulding Moisture Content %	10.3	10.0	24.9	13.1
Moulding Dry Density lbs/cu. ft.	120.6	121.2	91.3	113.1
Moisture Content % after 24 hrs soaking	11.9	10.9	29.2	14.6

Remarks: - Only four samples were received, as against five mentioned in the letter.

PROJECT: NDUNDU FERRY

Laboratory No.		7751	7752	7753	7754	7755	7756	7757	7758
Bore Hole No.									
Depth in M.		1.6	5.0	5.6	8.0	11.8	12.2	32'	37'
Soil Type		Brown Silty Sand	Brown Silty Sand	Brown Silty Sand	Blue Clayey Sand	Sand Silt	Sand Silt	Coarse Sandy Clay	Blue Hard Pan
SIEVE ANALYSIS:									
Percentage Passing	3/16"			100	100	100	100		100
B. S. Sieve No.	7	100	100	99	99	99	97	100	98
	14	92	97	92	94	90	87	97	89
	25	53	86	62	73	49	59	67	65
	36	32	67	41	56	32	46	47	51
	52	20	43	16	33	24	34	30	35
	72	15	33	8	25	19	24	25	30
	100	11	29	4	19	16	18	20	23
	200	7	18	2	14	14	12	14	18
ATTERBERG LIMITS:									
Liquid Limit									
Plastic Limit		NP	NP	NP	PL	NP	NP	PL	PL
Plascticity Index									
Field Moisture Content		16.2	24.2	15.3	1.6	12.7	12.2	15.2	13.6

NP = PL = The sample is plastic but insufficient sample for test.

Remarks: 1. The depth of samples as given in the table is as per the depth given on the sample bag.
2. The number of samples actually delivered was eight as against 6, mentioned in the forwarding letter.

BATCH IV

PROJECT: UTETE FERRY (BORRHOLE NO. 1)

Laboratory No.		7759	7760	7761	7762	7763	7764	7765
Depth		5'6"	10'0"	15'0"	30'0"	38'0"	40'0"	45'0"
Type of Soil		Brown Sand	Brown Sand	Brown Sand	Brown Sand	Brown Sand	Sandy Clay	Brown Hard Pan
MECHANICAL ANALYSIS:								
Percentage Passing	3/16"							100
B. S. Sieve No.	7	100	100	100	100	100	100	97
	14	98	99	99	98	95	98	93
	25	83	83	88	86	70	80	90
	36	58	56	64	70	53	65	77
	52	40	16	26	38	29	42	55
	72	31	8	16	24	22	33	46
	100	25	4	6	11	16	22	38
	200	23	2	2	5	12	14	33
ATTERBERG LIMITS:								
Liquid Limit								48
Plastic Limit		NP	NP	NP	NP	NP	NP	13
Plasticity Index								35
Field Moisture Content %		14.5	19.6	18.3	21.1	13.7	16.7	16.4

CHAPTR 6
SELECTION OF ROUTE

CHAPTER 6. SELECTION OF ROUTE

Feasibility survey has been conducted for each of the following three routes selected for coastal road from Dar es Salaam to Lindi: Of this section of the project, from Dar es Salaam to Kibiti 140 km long, two lane paved highway has already been completed, and the remaining section from Kibiti to Lindi has been investigated.

6-1 Route Length and Principala Towns and Villages Along the Routes

Route 1 (Total length 348.5 km)
Kibiti - Utete - Nyam Wage - Nangurukuru - Kiranjerange - Lindi

Route 2 (Total length 319.5 km)
Kibiti - Ndundu - Nayam Wage - Nangurukuru - Kiranjerange - Lindi

Route 3 (Total length 378.9 km)
Kibiti - Utete - Njinjo - Mbata - Kiranjerange - Lindi

Feeder Road (Total length 75.0 km)
Mbata - Nangurukuru - Kilwa Kivinje - Kilwa Masoko

6-2 Outline of Selected Routes

Along the present coastal highways, the traffic is usually interrupted each year for two to six months, the main cause being the submersion of the roadway, during the rainy season by the flooding and inundation of Rufiji River and various other smaller streams. The period during which the ferry boat service was interrupted in these several years, is as shown in Table 6-1.

As one of the solutions to avoid such traffic interruption during rainy season, there has been a plan considered to shift the highway towards the inland and mountainous area where little effect of flood is expected, and some investigations have been carried out, but our recent survey is concentrated on the three routes along the coastal line in order to make maximum use of existing highways which are located in the densely populated area along the coastal line. The proposed routes, three in total, are as shown in the attached map of 1/50,000 scale, laying stress on improving the existing road, especially for the sections of low and marsh land where ponding of flood water is anticipated, or for the sections where numerous bridge structures are required. Improvement of such sections is planned chiefly based on the relocation of the routes from both economical and technical viewpoints. Thus, the highway planning, aiming at the improvement of the existing coastal highway, will be strongly affected by the rivers and streams, but on the other hand, the section to be newly constructed is comparatively shorter than that of the mountainous route, and the benefits which the populace along the route will receive are extremely great, and further, even if the work must be carried out section by section in stage construction due to the financial circumstances, the existing route can be tentatively used provided that most important traffic obstacles are eliminated one after another, and the efficiency of the investment will be increased by such arrangements.

Fig. 6-1 LOCATION PLAN S = 1 : 2,000,000

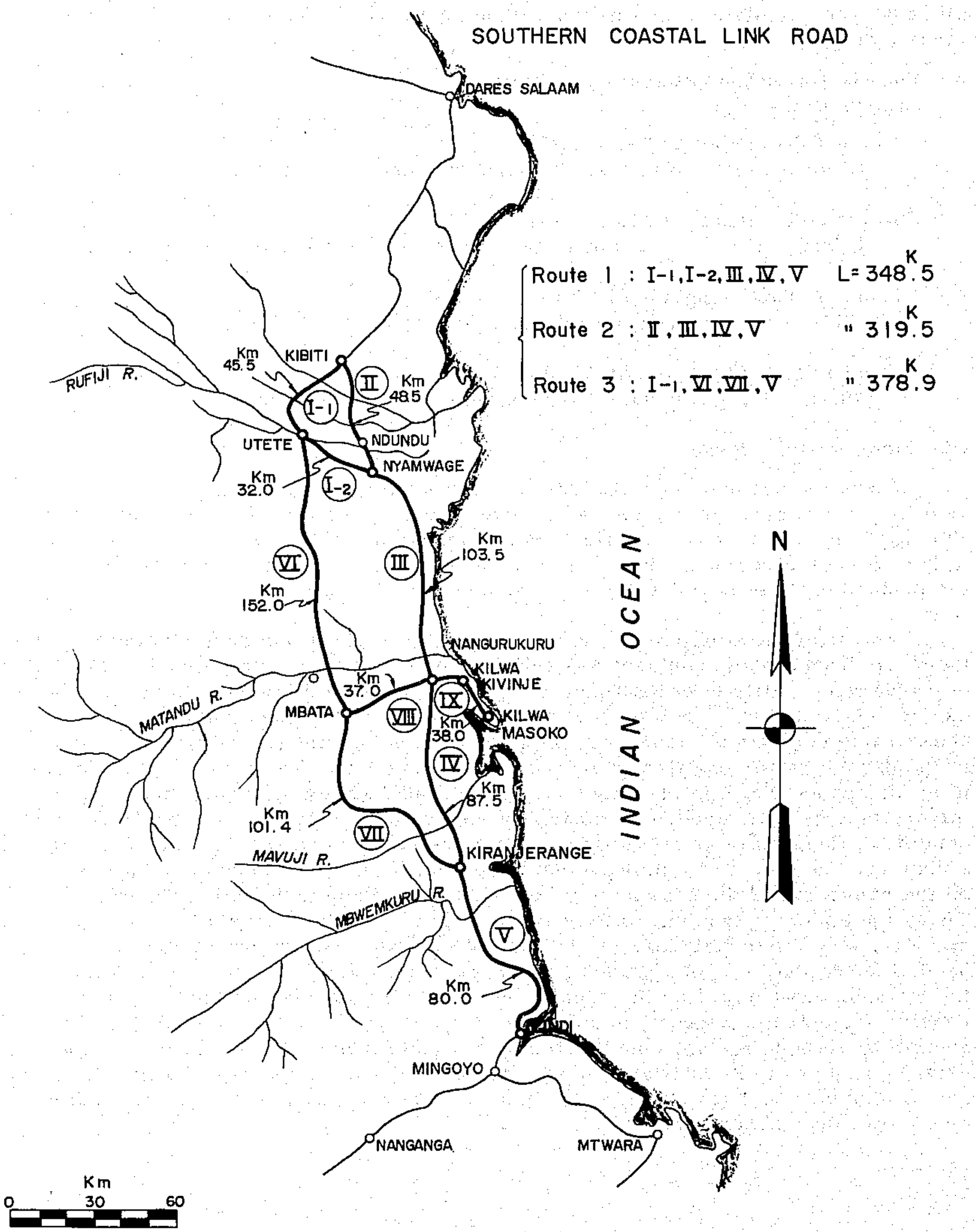


Table 6-1 Numbef of Days of Rufiji Ferry Interruption

Year	Ndundu Ferry			Utete Ferry		
	Period	Cause	No. of Days	Period	Cause	No. of Days
1965	3.28 - 8.20	Flood	179	3.28 - 7.24	Flood	152
	9. 4 - 9. 9	Flood	6			
		Total	185		Total	152
1966	4.19 - 6.20	Flood	63	4.23 - 6.18	Flood	57
		Total	63		Total	57
1967	4.10 - 7.44	Flood	86	4.19 - 6.10	Flood	53
		Total	86		Total	53
1968	4. 4 - 7.10	Flood	98	4.20 - 7.14	Flood	86
	10. 3 - 10.10	Ferry out of order	8	12. 6 - 12.31	Flood	26
	12. 8 - 12.31	Flood	24			
		Total	130		Total	112
1969	1. 1 - 1.14	Ferry out of order	14	1. 1 - 1. 3	Flood	3
	2. 1 - 8.12	Flood	184	2.10 - 6.17	Flood	128
		Total	198		Total	131

6-2-1 Route 1 (Utete Route)

Route 1, Kibiti - Rusende - Utete - Nyam Wage, total length of 77.5 km joins Route 2 at Nyam Wage. Between Kibiti to Utete, the roadway width is more than 6 m, and from Kibiti for the distance of 15 km, the soil of the hilly part 100 m to 240 m high above the sea level, is mainly composed of laterite, and the road surface is well maintained. There are two or three sections where the longitudinal gradient is about 10 to 11% in the hilly section, however, they can be easily modified to the longitudinal gradient of less than 5% by constructing less than 2 m embankment. Ruhoi Bridge, at Sta. 17.5, and timber bridges at Sta. 29, and at Sta. 36, at the time of flood, will be submerged under the flood water and will be washed away. Therefore, the formation height will have to be raised by 2 m to 3 m. The soil south of Ruhoi is black cotton soil, and the existing ground is low. In the section between Ruhoi and Kusende, the embankment more than 1 ~ 2 m high should be constructed.

It is very difficult to select the crossing point over the Rufiji River, between Rusende and Utete. Around the year of 1910, the present Rusende and Rufiji Revers seem to have run very close to each other and the two streams might have run as a single main stream, and also according to the record of 1952, the main channel is shifted about 800 m north from the present position. In order to cross over a constantly shifting river channel, the long span bridge of 2,000 m in total length and viaducts fro flood relief opening as long as 2,000 m will be necessary. Also, there are difficult technical problems in relation with the type and depth of foundation structure to prevent possible scouring caused by the constantly shifting channel. The road from Utete to Nyam Wage runs on a comparatively high ground and will not be flooded by Rufiji River flood, but the road crosses branch streams at 8 points. The existing corrugated metal pipes are set too low, and the cross-sectional area of the pipes is insufficient. Therefore, at the time of flood of the branch streams, the road and the surrounding area will be inundated even for a short period. To solve such trouble, it will be sufficient to construct small bridges of 20 - 30 m spans and 3 - 5 m culverts accross each branch stream and also to raise the existing embankment by about 1 m.

6-2-2 Route 2 (Ndundu Route)

Route 2, Kibiti - Ndundu - Nyam Wage, total length of 48.5 km is shorter by 29 km, compared with the Route 1. The longitudinal gradient is less than 8% and the roadway width is more than 6 m. The road conditions including longitudinal and horizontal alignments are far better than these of Route 1.

The soil of hilly section is mainly laterite and the roadway surface is we well maintained. The Ruhoi River located between Kibiti and Ikwiriri will require 100 m long bridge and also will need fills of 1.0 m high on both sides of the river about 20 km in total length.

From south of Ikwiriri to Station 40, the road was built in 1961 but the dykes were washed away in many places by the flood of 1962. The highest flood level in the past occurred in 1968, and the highest water level as high as 16.79 m has been confirmed by our recent flood mark survey. Therefore, it seems necessary to raise the embankment height up to more than 2 m and the embankment slopes must be protected from a long period submersion under flood water by stone on block pitching work.

At the crossing point of Rufiji River where the ferry boat service is in operation, the river channel is stable for many years, and it is far superior to Utete of Route 1. At Ndundu crossing, the main bridge of 332 m and viaducts of 5,000 m long will be necessary. But towards upstream from Ndundu, the main stream is considerably crooked. On account of the insufficient cross sectional area of existing main channel, the flood water will flow over the corner bank, and will cause the washing away of dykes as in the case of the flood of 1962. In order to insure the required cross sectional area of the flow, some investigation was made with the idea of altering a portion of the channel of the main stream and widening the flood waterway, and erecting the main bridge having the total length of 650 m and also building viaducts on both right and left banks, having the total length of 3,400 m. However, in such plan, about 1,800,000 cu m of soil excavation works are required, and the effect of partial channel alteration will be far less than expected unless the river improvement work on both up and down stream of the crossing point is followed in a considerably long distance. Further from the viewpoint of construction cost, such plan will not be more economical because the saving of bridge cost will be offset by an enormous earthwork cost. As stated previously, final decision is made on the plans of constructing 332 m bridge over the main stream and viaducts of total length of 5,000 m, of which 4,000 m on the left bank and 1,000 m on the right bank, without considerable excavation. From this point to Nyam Wage, the highway improvement work has already been completed.

6-2-3 Section of the Road Commonly Used by Route 1 & 2 (Nyam Wage - Lindi)

Between Nyam Wage - Nangurukuru - Kiranjerange - Lindi, the same road is commonly utilized by both Route 1 and 2, the total length being 271.0 km. The road between Nyam Wage - Mohoro - Miteja of 76 km lies on the alluvial deposit and the type of soil is basically black cotton soil. The road-surface is lower than the natural ground level by 20 - 30 cm and drainage condition being poor, therefore, this section will require a fill of about 1 m in height.

Around Mohoro, the ground elevation (above sea level) is less than 15 m and the record shows that the existing road was submerged in flood water by about 1 m, by the flooding of Mohoro River in 1968. Therefore, in order to avoid the low land between Stations 65 - 74, it will be desirable to relocate the proposed route towards the mountain side. Also between Stations 97 - 100 in Somanga district, as the horizontal alignment is not good, it is recommended to correct and relocate the route towards the mountain side.

Between Miteja - Nangurukuru for the distance of 34 km, the route is on a high ground, having the elevation 30 - 50 m and seems to be in good condition as the basement soil is gravelly. However, in this section, there are Matandu River and 12 other small to medium size streams to cross, and especially the flooding of Matandu River is the big traffic hazards. Horizontal and longitudinal alignment in this section is extremely poor because of so many crossings over the rivers.

The length of bridges in this section should be decided based on the cross sectional area for flow capacity in relation with the precipitation and catchment area. It will be also necessary to determine the bridge span and the clearance that will conform to the longitudinal alignment of the approach road.

In the Nangurukuru area, between Stations 150 - 153, the alignment is altered in order to improve unnecessary detour.

Between Nangurukuru to Mitole for the distance of 56 km, there are 13 streams other than Mavuji River, and longitudinal slope of the road is extremely steep near the crossing points. In this section from Stations 183 to 195, and from 199 to 210, the existing route crosses over Mavuji River at several points, and the number of structures required will be considerably many. It will be far advantageous to relocate the route to the area where such crossing will be minimized. The soil on the hilly area is basically laterite, and the roadway surface is in good condition. But at the time of rain, there are mamy sections where the roadway itself becomes the river channel. On the other hand, in flat terrain, streams of rainwater run accross the road in many places and run towards the coast. Extreme care should be exercised in planning the roadway height and drainage plan. The existing road between Mitole and Kiranjerange, for the distance of 30 km, utilizes the ridge of the hilly country, having the elevation of 150 - 160 m, and the soil type, horizontal and longitudinal alignment are all satisfactory, and if the surface drain is skillfully arranged, the existing road can be used as the subbase of the proposed road.

Of the 79.5 km between Kiranjerange and Lindi, the road, south of Mbwemkuru River up to Ngambe for the stretch of 22 km, goes accross the hilly area which is full of ups and downs, and the longitudinal alignment is quite unsatisfactory. It is required to improve the alignment by executing about 2 m cut and fill earthwork operations and by adjusting bridge elevation.

For the distance of 30 km between Mchinga and Lindi, the road passes through farm lands of sisal hemp on the coastal laterite terrace, and the alignment and the roadway surface are both very well maintained. But between Stations 286 and 290 where the road climbs up to the terrace from Mchinga, both the alignment and the slope are not good, and also the road bed will be eroded by the river directly below the terrace. It is desirable to relocate the road towards the higher side.

Besides, in Likonga area at Station 295, Mitonga area at Station 302, and Mibania area at Station 307, it is necessary to partially correct the alignment as the alignment and the slope are unsatisfactory.

6-2-4 Route 3

This route is the one that branches off at Utete from Route 1, and runs away from the coastal line towards inland for the distance of 40 - 50 km, going through mountainous area and going through Njinjo and Mbata, and joins again at Kiranjerange with Route 1, and finally reaches Lindi.

The road between Utete and Njinjo for a distance of 125 km,is only about 3.5 m in width and the surface condition is bad. Especially, from Utete for the distance of 35 km, the roadway surface is lower than the existing natural ground level, and hence, it becomes the stream bed and the road surface is dug very deeply during rainy seasons.

This route makes a large detour travel around the foot of Mt. Nanganguti, and goes by way of Kwambe. In comparison with Route 1, and 2, the total distance of this route is considerably longer. As this route runs along hillside in a long distance, the necessity for bridges and other structures will be comparatively few, but as the streams including Matandu River are presumed to have large flow velocity and water depth, detailed survey and investigation will be necessary before making the actual plans and designs. Also, in the area of Kwambe near Station 70, where the road runs close to and parallel to the river, there is some danger of the road being washed away by the flooded stream. It will be necessary to relocate the route towards the mountain side.

From here to Njinjo, the terrain is flat, and the road from Njinjo to Mbata for the distance of 27 km, has been improved and is in good condition.

The road from Mbata to Kiranjerange for the distance of 98 km is narrow and the bridge at Mavuji has fallen and the traffic is being interrupted. As there are many small streams running in random directions, and the road is in ruinous condition, many structures will be necessary along the road in this section.

6-2-5 Feeder Road

As Route 3 passes through the mountainous area where few people inhabited, it is quite important to improve the existing feeder road between Mbata - Nangurukuru - Kilwa Masoko, in order to effectuate the economical function of Route 3. The approximate cost for the construction and improvement of the feeder road is estimated for reference.

As the road from Mbata to Nangurukuru, as a whole, runs along the ridge of the hilly area, there are few rivers that cross the road, and the construction of new structures will be restricted to a minimum. For the section having steep longitudinal grade, in the absence of the roadside drainage ditches, full consideration shall be taken in the drainage plan as there are many sections where the roadway will become stream channel during rainy seasons.

6-3 Approximate Construction Cost of Each Route

The direct construction cost for the foregoing three comparative routes is as shown in Table 6-2. For Route 1, the cost is 223,870,000 Shs, and for Route 2, 192,630,000 Shs, and for Route 3, the cost will be 266,060,000 Shs, and Route 2 is the most economical one. Route 3 will become quite effective by connecting a paved feeder road from Mbata to Nangurukuru, but in this case, the cost will become more expensive.

The direct construction costs of each route classified by section, and construction items are as shown in Table 6-2, and the detailed construction cost classified by section and construction terms is as shown in Table 6-3.

Table 6-2 Direct Construction Cost of Each Route

(Unit = Shs)

Name of Route	Name of Section	Direct Construction Cost	
Route 1	I - 1	79,473,560	
	I - 2	13,784,580	
	III	53,396,060	
	IV	36,638,600	
	V	40,575,560	
	Total	223,868,360	≒ 223,870,000
Route 2	II	62,022,220	
	III	53,396,060	
	IV	36,638,600	
	V	40,575,560	
	Total	192,632,440	≒ 192,630,000
Route 3	I - 1	79,473,560	
	V	40,575,560	
	VI	88,972,020	
	VII	57,038,980	
	Total	266,061,120	≒ 266,060,000
Feeder Road	VIII	15,980,340	
	IX	15,384,920	
	Total	31,365,260	≒ 31,370,000

Table 6-3 Detailed Construction Cost, Classified by Section and Construction Items (Part 1)

(Unit = Shs)

Section		Clearing, Grubbing, & Cutting Down Trees			Earthwork			Slope Protection Work			Stone Block Pitching Work			Pavement Work			Drainage Work & Others			Sub Total
Sec-tion	Length	KM	Unit Cost	Amount	M^3	Unit Cost	Amount	KM	Unit Cost	Amount	KM	Unit Cost	Amount	KM	Unit Cost	Amount	KM	Unit Cost	Amount	
I-1	45.5	-			1,158,500	6	6,951,000	40.36	6,000	242,160	1.84	100,000	184,000	40.36	200,000	8,072,000	40.36	40,000	1,614,400	17,063,560
I-2	32.0	-			816,800	"	4,900,800	31.93	"	191,580	0.09	"	9,000	31.93	"	6,386,000	31.93	"	1,277,200	12,764,580
	77.5	-			1,975,300	"	11,851,800	72.29	"	433,740	1.93	"	193,000	72.29	"	14,458,000	72.29	"	2,891,600	29,828,140
II	48.5	-		-	685,000	6	4,110,000	43.07	6,000	258,420	2.61	100,000	261,000	43.07	200,000	8,614,000	43.07	40,000	1,722,800	14,966,220
III	103.5	13.0	8,000	104,000	1,508,600	"	9,051,600	101.51	"	609,060	2.04	"	204,000	101.51	"	20,302,000	101.51	"	4,060,400	34,331,060
IV	87.5	27.2	"	217,600	1,343,200	"	8,059,200	86.80	"	520,800	0.14	"	14,000	86.80	"	17,360,000	86.80	"	3,472,000	29,643,600
V	80.0	8.5	"	68,000	1,320,300	"	7,921,800	78.56	"	471,360	0.30	"	30,000	78.56	"	15,712,000	78.56	"	3,142,400	27,345,560
	319.5	48.7	"	389,600	4,857,100	6	29,142,600	309.94	"	1,859,640	5.09	"	509,000	309.94	"	61,988,000	309.94	"	12,397,600	106,286,440
VI	152.0	38.3	8,000	306,400	5,526,400	6	33,158,400	150.07	6,000	900,420	0.55	100,000	55,000	150.07	200,000	30,014,000	150.07	40,000	6,002,800	70,437,020
VII	101.4	34.7	"	277,600	4,758,300	"	28,549,800	101.23	"	607,380	0.10	"	10,000	101.23	"	20,246,000	101.23	"	4,049,200	53,739 980
	253.4	73.0	"	584,000	10,284,700	"	61,708,200	251.30	"	1,507,800	0.65	"	65,000	251.30	"	50,260,000	251.30	"	10,052,000	124,177,000
VIII	37.0	10.5	8,000	84,000	1,027,800	6	6,166,800	36.99	6,000	221,940	-			36.99	200,000	7,398,000	36.99	40,000	1,479,600	15,350,340
IX	38.0	5.0	"	40,000	736,100	"	4,416,600	37.92	"	227,520	-			37.92	"	7,584,000	37.92	"	1,516,800	13,784,920
	75.0	15.5	"	124,000	1,763,900	"	10,583,400	74.91	"	449,460	-			74.91	"	14,982,000	74.91	"	2,996,400	29,135,260

Table 6-3 Detailed Construction Cost, Classified by Section and Construction Items (Part 2)

(Unit = Shs)

Section		Corrugated Metal Pipe			Culvert Work			Bridge Construction Work								Sub Total	Total
								Medium to Small Bridges			Long Span Bridges			Total			
Section	Length	No.	Unit Cost	Amount	No.	Unit Cost	Amount	M	Unit Cost	Amount	M	Unit Cost	Amount	M	Amount		
I-1	45.5	34	5,000	170,000	2	60,000	120,000	3,140	8,000	25,120,000	2,000	18,000	36,000,000	5,140	61,120,000	61,410,000	79,473,560
I-2	32.0	32	"	160,000	5	"	300,000	70	"	560,000	-	-	-	70	560,000	1,020,000	13,784,580
	77.5	66		330,000	7	"	420,000	3,210		25,680,000	2,000		36,000,000	5,210	61,680,000	62,430,000	92,258,140
II	48.5	44	5,000	220,000	1	60,000	60,000	5,100	8,000	40,800,000	332	18,000	5,976,000	5,432	46,776,000	47,056,000	62,022,220
III	103.5	85	"	425,000	12	"	720,000	1,790	"	14,320,000	200	"	3,600,000	1,990	17,920,000	19,065,000	53,396,060
IV	87.5	31	"	155,000	14	"	840,000	660	"	5,280,000	40	"	720,000	700	6,000,000	6,995,000	36,638,600
V	80.0	30	"	150,000	12	"	720,000	1,365	"	10,920,000	80	"	1,440,000	1,445	12,360,000	13,230,000	40,575,560
	319.5	190		950,000	39	"	2,340,000	8,915		71,320,000	652		11,736,000	9,567	83,056,000	86,346,000	192,632,440
VI	152.0	79	5,000	395,000	11	60,000	660,000	1,735	8,000	13,880,000	200	18,000	3,600,000	1,935	17,480,000	18,535,000	88,972,020
VII	101.4	56	"	280,000	16	"	960,000	100	"	800,000	70	"	1,260,000	170	2,060,000	3,300,000	57,039,980
	253.4	135		675,000	27	"	1,620,000	1,835		14,680,000	270		4,860,000	2,105	19,540,000	21,835,000	146,012,000
VIII	37.0	18	5,000	90,000	7	60,000	420,000	15	8,000	120,000	-			15	120,000	630,000	15,980,340
IX	38.0	12	"	60,000	15	"	900,000	80	"	640,000	-			80	640,000	1,600,000	15,384,920
	75.0	30		150,000	22	"	1,320,000	95		760,000	-			95	760,000	2,230,000	31,365,260

6-4 Decision of Route

The existing condition of the road, technical problems of construction, and the direct construction cost have been examined for the three comparative routes along the coast line. The final decision of the route to be adopted should be made after reviewing the means of crossing Rufiji River, construction cost of the road and small to medium bridges south of Rufiji River, and the economical effect of the newly constructed route.

6-4-1 Method of Crossing Rufiji (Comparing Route 1 with Route 2)

Rufiji River is an unimproved one, and the condition of the stream is quite unstable, and during each rainy season the river channel has changed frequently. Two crossing points, one at Utete on Route 1, and the other at Ndundu on Route 2 are compared. At the Nudundu crossing, the river has been quite stable for the past several decades, the bridge length can be shorter as there is little difficult technical problem, this route constitutes the shortest route between Kibiti to Lindi, and also the cost of construction is comparatively less than that of Route 1. Thus, Route 2 is superior to Route 1.

6-4-2 Comparison of Route 2 with Route 3

1) As Route 3 is on the mountain side, both horizontal and longitudinal alingment being steep, it is more difficult to insure smooth and comfortable driving of vehicles compared to Route 2.

2) The total length of Route 3 is approximately 60 kmllonger, and hence, the construction cost becomes approximately 38% higher when compared with Route 2.

3) Along Route 2, where a comparatively dense population is seen the traffic of commodities is noticeable, but along Route 3, with thin population, the effect of road is much lower, and the effect on the economic development is rather low.

4) For Route 3, the problem lies in the crossing of Rufiji at Utete. We may consider the combination of Route 2 and Route 3 connecting Nyam Wage with Tawi, but this route does not seem advantageous, as the population along the route is small, and also the total length of the road will be long.

On account of the foregoing points, Route 2 is much advantageous, and we should adopt Route 2 as the final route along the coastal line.

CHAPTER 7

ROAD DESIGN

CHAPTER 7. ROAD DESIGN

7-1 Design Standards

The preliminary design has been made in accordance with the Typical Road Cross Sections for Bitumen Roads", Standards set forth by the Ministry of Communications, Transport and Labor, of the United Republic of Tanzania. We have also utilized, as the reference data, AASHO and Road Design Standards of Japan, which have been adopted in the design.

Table 7-1 Design Criteria

General Criteria	Level to Rolling	Hilly	Mountainous
Design Speed (km/h)	80	80	
Minimum Radius of Curvature (m)	610	305	122
Maximum Gradient (%)	5	6	8
Maximum Length of Grade at Maximum Gradient (m)	370	270	170
Stopping Sight Distance (m)	115		
Passing Sight Distance (m)	600		
Roadway			
Road Width (m)	9.6	9.6 - 8.4	
Travelway Width (m)	6	6	
Verge (m)	1.8	1.8 - 1.2	
Design Live Loading	H20-S16	(AASHO)	

7-2 Horizontal Alignment

It is found out in Chapter 6 that Route 2 is the most superior among the three routes along the coastal line compared from the standpoints of engineering, construction economics and traffic economics. The horizontal alignment of the route is investigated and discussed as follows.

(1) Route 2 is designed to run alongside the existing road as long as possible, and as a general rule, especially where the horizontal alignment is poor, some local improvement is considered in conformity with the design standards. To run the road alongside the existing road is the most advantageous means as the total length of route is the shortest, many houses are built along the existing road, hence the degree of the use of the road will be greater. Maximum use of the existing road will be also effective, in case it becomes necessary to perform the improvement work by stages, because of the financial conditions.

(2) In the vicinity of Mohoro where the existing road is passing through lowland where the elevation (above sea level) of the existing road is less than 15 m, the roadway surface will be flooded over in each flood time, and the traffic is interrupted. The route is relocated towards the mountain side in order to raise the road grade line in this section.

(3) In the vicinity of Kizimbani and Mitole, between Stations 183-195 and 199-210, where the route crossed Mavuji River at several places, the route is relocated towards the mountain side in order to lessen the number of structures.

(4) In Somanga area between Stations 97-100, Mchinga area between Stations 286-290, and Nangurukuru area between Stations 150-153, where the alignment is extremely bad, or the existing road is making an unnecessary detour, the horizontal alignment is corrected and improved. The same improvement is applied to other three sections also.

7-3 Longitudinal Alignment

As the existing road does not have permanent bridges and other structures over the rivers and streams and other waterways for the entire length of the route. Except ferry operation across Rufiji River, people and vehicles have no other means but to come down to the river beds to cross the rivers. And naturally the road grade before and after the river bed makes steep gradient as much as 10% - 18%, and this fact is making a big hazard to the general traffic.

Such tendency is particularly noticeable in the mountain area, and where the river crossing is to be made, it is necessary to construct bridges and culverts, etc., and perform earthwork before and after the crossing point by correcting the formation height by means of earth fill so that the longitudinal alignment may be modified to a grade of 8% or less.

7-3-1 Reserve Clearance under Bridge Girder

In case of construction of bridges over the streams other than Rufiji River, in the flat land, it is planned that the flood discharge, hydrologically calculated based on the 15-year probability as described in Chapter 4, may flow through under the bridge girders with the reserve clearance of 1.5 m from the planned high water level. By taking the reserve clearance of 1.5 m, any unusual flood water discharge, or 100-year probability flood water may safely flow through the river channel cross-section according to the theoretical calculations. The road before and after these bridges will be submerged under the flood water for a depth of 1 - 2 m for a long time. On either side of the bridges and viaducts, the height of embankment for the approach road must be over 2m to allow the road road stand any ordinary flood.

7-3-2 Grade Line Within Villages

The existing villages are located in comparatively high places to escape from flood water. In case the road is constructed through these villages, the grade line of the road should be kept within 1 m for both cuts and fills so that the populace along the route may make the full use of the road.

7-4 Cross-Section of the Road

For the cross-section of the road, four (4) types of the standard typical cross-section are shown in Dwg. No. 1. Two-lane highway having the roadway width of 6 m and the shoulder width of 1.8 m (1.2 m for cuts of depth of 3 m and over) is designed with cross fall slope of 2% for the travelled way and 3% for the shoulder and the excavated slope of 1:1, and embankment slope of 1:2.

The travelled way is designed with the surface course of 5 cm base of 10 cm, and sub-base of 10 cm in thickness, thus making the 3-layer pavement.

Type B_1:

This is the standard for an embankment less than 2 m in height, and the embankment material will not depend upon borrow, as a general rule. It is planned, however, to excavate ditches parallel to and on both sides of the road and the excavated material from such ditches will be used for the embankment material.

For the purpose of protecting the road bed, drainage ditches will be dug 2 m away from the toe of the slope.

Type B_2:

As the approach embankments before and after Rufiji River Bridge will be submerged in the flood water for a long time during rainy season. Slope protection work by stone block pitching, and also concrete block pitching work is planned to prevent erosion or scouring.

Type C_1:

This is the typical cross-section for the shallow cut. The shoulder width is set as 1.8 m, and the side ditches to have the shape of V and to be covered with soil cement.

Type C_2:

In deep cut sections where the run-off discharge is great and the speed of drainage flow is swift, U shaped side ditch with cast-in-place concrete is designed. And, in order to reduce cut volume, narrower shoulder width of 1.2 m is adopted.

Cross sectional width of bridges is designed by two-lane roadway having the shoulder width of 50 cm on both sides, making the total width, 7.0 m.

7-5 Planning of Earthwork

The condition of all-weather road should be that, throughout the year, the roadway surface will not be submerged under the flood water, and also, that the roadway surface is smooth and constantly well maintained for comfortable driving.

The existing Kibiti - Lindi Road runs on the existing natural ground line. Therefore, the road becomes in some cases a river bed and during the rainy season, the road becomes the river channel, thus causing traffic stoppage.

In our design, at river crossings, we have established the planned height of the flood water level high enough, so that the planned flood water discharge may safely flow down. As for the road surface, we have figured on constructing an embankment at least 1 m heigher than the existing ground line, so that the roadway surface will be completely protected from the surrounding streams. In cut sections, it is designed to install side ditches for perfect drainage.

The soil along the road is sandy soil or laterite, and makes a good quality subgrade material. Therefore, it is possible to utilize the excavated soil from the drainage ditches on both sides of the road, to the construction of embankment rather economically.

In the mountainous area, it is possible to adjust the longitudinal grade line to balance the cut and fill volume locally or to waste the surplus cut volume in adjacent areas.

As the right-of-way of the road is national land, and as there is no complicated restrictions, it is desirable to keep the side slope of earthwork as gentle as possible, but as the standard cross-section shows, 1:1 slope for cut sections and 1:2 slope for embankment sections are considered sufficient to maintain the slope. The slope is usually designed by means of sodding or grass protection, and for the section particularly liable to suffer inundation, will depend on stone block pitching and concrete block pitching.

The quantity of earthwork for Route 2 as per the foregoing, will be approximately 4,900,000 m^3.

For earthwork machinery, it is considered to be most economical and efficient to use the combination of Bulldozers, Carryall-Scrapers, Motor Scrapers, Tired Rollers, Motor Graders, Shovels and Dump Trucks.

7-6 Planning of Drainage

In the construction of the proposed road, the drainage facilities are extremely important for the durability and utility of the road. The drainage ditches and side ditches in the longitudinal direction are as explained in the foregoing; for the rivers, waterways, and for the swampy region, the drainage facilities across the road are planned to use corrugated pipes of 1 m diameter, box culverts of 3 m, 5 m and spans, and bridges of 10 m, 15 m to 30 m with standard beems.

Besides the foregoing, for the extremely long span bridge, such as for Rufiji River, we will explain in Chapter 8, but in any case, at the time of preparing the final design in the future, we will have to conduct more detailed jobsite survey and exploration, to check again the crossing point, the planned flood water discharge, cross-sectional area of the flow, and the planned high water level, etc.

CHAPTER 8

B R I D G E S

CHAPTER 8. BRIDGES

8-1 Introduction

Obviously the most important problem in the Dar Es Salaam - Lindi Coastal Link Road Project is the technical and economic planning of the bridges across Rufiji, Matandu,Mavudyi and Mbwemkuru Rivers and other minor rivers.

On the basis of the results of our 40-day investigation, the most fundamental and important points concerning the bridge project will be described in the following.

8-2 Description of the Rivers

According to our observations along the major rivers it may be generally stated that the cross-sectional areas of the main streams become smaller downstream. For example, the width of Rufiji River which was estimated about 700 m at Utete decreased to 240 m at Nudundu downstream. The width of Matandu River in the upstream near Njinjo is about 140 m, but in the downstream where Route 1 crosses the river it becomes as narrow as 60 to 70 m. Also, in Mavudyi River, the cross-sectional area of the stream is obviously large near Mtandawara (where the newly constructed bridge has fallen recently) south of Njinjo, because the depth is extremely large although the width is small, compared to those downstream. The above-mentioned characteristics may be attributed to hydrological, geological, and other reasons. As we go downstream along the rivers, the main streams become narrower, but the flood plains become wider. Consequently, the type and length of the bridges across the flood plain form a very important factor in the planning of the proposed bridges.

8-3 Basic Considerations for the Bridge Project

On the basis of the above considerations, we have paid careful attention to the design of the bridges across the flood plains, and placed emphasis on the following items:

a. The bridges across the flood plains do not generally require long spans, because short spans can provide adequate openings for flood water although the velocity of flow water may be great at some limited sections.

b. Because the total length of the bridges across the flood plains is extremely long, an important economic advantage would be gained by using standardized bridge sections of an equal length, in terms of materials, manufacturing, transportation, and erection costs.

c. If financial condition would permit, the standardization of bridge design would yield another advantage in storing spare sections for emergency needs in maintenance and repair, or for new routes.

d. According to the soil explorations the pile foundation will be feasible any where along the proposed route. Steel H-piles which presumably are more economical to haul and drive are preferred to steel pipe piles for the bridge foundations.

On the basis of the above considerations, the bridges over the flood plains are to be built of standard sections consisting of steel H girders and of corrugated steel deck plates covered with concrete slab and pavement.

The spans across the main streams are to be of a truss type of slender members, for economy of transportation.

The span lengths of the bridges across the main streams of Rufiji River and other major rivers are to be determined in such a way that common designs may be used as often as possible. The outline of the proposed bridges planned according to the above considerations will be described in the following.

8-4 Description of Major Bridges

8-4-1 Bridge Across Rufiji River

8-4-1-1 General

The bank-to-bank width of Rufiji River where Route 2 crosses it was measured to be approximately 240 m, and the highest water level was estimated at +16.8 m above the sea level according to the field investigation. The width of the river water was approximately 140 m, and the maximum depth of the water was approximately 10 m during our survey. According to the results of the hydrological surveys, the required length of the bridge across the main stream is 630 m, and that of the bridge for flood relief is approximately 3,500 m. In this case, however, the high portions of the river bed in the main stream must be excavated 3 m deep and about 400 m wide, requiring considerable time and cost. On the other hand, if the main span is built over the existing river width of 240 m, the bridge across the flood plain must be increased by 1,500 m in length, resulting in a total length of 5,000 m of viaducts. As the two schemes require approximately the same total cost, we prefer the latter to the former which requires enormous excavation work.

8-4-1-2 Bridge Design

(A) Bridge across the main stream

The bridge across the 240 m wide main stream will consist of three 84 m span Langer Trusses on open caisson foundations with the embedment depth of 15 m. On each end of the main spans, one 40 m approach span of pony truss is planned respectively, in order to assure safety across the badly eroded river banks. The span length of the pony trusses was determined from an aesthetic consideration in such a way that their main trusses will have the same height as the stiffening truss members of the Langer bridge.

(B) Bridge for flood relief

The bridge across the flood plain on the Kibiti side will consist of two-hundred 20 m spans of the standard design (total 4,000 m), and that on the Nudundu side will consist of 35 standard spans (700 m), and of 15 spans (300 m), including 550 m long embankment between these two bridge sections. The bridge across the flood plain will be built on the foundation of steel H-piles of 10 m long.

8-4-2 Bridge Across Matandu River

8-4-2-1 General

It was confirmed during our investigation that the main stream of Matandu River and its tributary to the north form a 2,000 m wide flood plain in the rainy season. The required lengths of the bridges across the main stream and the tributary will be 90 m and 120 m, respectively, and the bridge for flood relief will be 1,500 m long according to the hydrological investigation.

8-4-2-2 Bridge Design

(A) Bridges across the main stream and tributary

The 40 m span pony trusses of the same design as used for the approach spans for Rufiji River, will be adopted, i.e., two spans across the main stream and three spans across tributary. The substructure and the foundation for the bridges will also be the same as those for the approach spans for Rufiji River, except for a slight difference in the pier dimensions.

(B) Bridge for flood relief

The bridge across the flood plains will consist of forty-six 20 m spans of the standard design (920 m) adjacent to the bridge across the main stream, and of thirty standard spans (600 m) adjacent to the bridge across the tributary. There will be a 390 m long embankment between the bridges. The foundations for the bridges will be of steel H-piles with an embedment depth of 10 m.

8-4-3 Bridge Across Mavudyi River

8-4-3-1 General

The flood plain of Mavudyi River extends 160 m on the left bank and 300 m on the right bank of the main stream of a normal width of 40 m. The required length of the bridge for flood relief will be approximately 350 m.

8-4-3-2 Bridge Design

The bridge will consist of one 40 m pony truss across the main stream, eight 20 m spans (160 m) across the flood plain on the left bank where the slope of the ground is relatively steep, and ten 20 m (200 m) spans across the flood plain on the right bank.

8-4-4 Bridge Across Mbwemkuru River

8-4-4-1 General

The flood plain of Mbwemkuru River develops mostly on the right bank of the main stream. The total flood width of the river in the rainy season becomes approximately 1,700 m. An 80 m bridge across the main stream and 950 m bridges across the flood plain are planned to flow such flood water.

8-4-4-2 Bridge Design

(A) Bridge across the main stream

The bridge across the main stream will consist of two 40 m pony trusses. The mid-stream pier will require sufficient embedment depth, because both depth of water and flow velocity are great during a flood and the river is swerving sharply at the crossing point. Depending on the results of detailed field investigations in future, a single span bridge may possibly prove advantageous from the technical and economical viewpoints.

(B) Bridge for flood relief

The bridge across the flood plain on the right bank will consist of thirty-five 20 m spans (700 m) of the standard design adjacent to the main bridge a 60 m long embankment, and thirteen 20 m spans (260 m) arranged in this order.

8-4-5 Other Medium Size Bridges

In addition to the above-mentioned major bridges across Rufiji, Matandu, Mavudyi and Mbwemkuru Rivers, four medium size bridges will be required in the neighbourhood of Rufiji River as shown in the following list. The design for these bridges will be readily arranged and prepared by combining the standard spans and the foundation piles, because no serious problems are anticipated concerning the water depth, flow velocity, and stream bed.

		K.P. Km	Route	Total length of bridge, (m)
1.	Ruhoi River	17.5	Route 2	80.5
2.		17.5	Utete (Route 1)	340.5
3.		28.7	Utete (Route 1)	320.5
4.		47.8	Utete-Nyam Wage (Route 1)	120.5

8-4-6 Small Bridges

Several tens of smaller bridges ranging from 10 m to 60 m long for a total length of 1,300 m will be required. These bridges may be designed by combining standard types of 10 m, 15 m, and 20 m spans, although the actual lengths must be determined on the basis of data from on-site surveys at the proposed crossing points.

8-5 Design Criteria

The basic design criteria for the bridges proposed in this project are summarized as follows:

1. The design specifications should be based on the latest British Standards. When considering live loads, however, 80% of the knife edge load may be employed in the design.

2. The effective width of the bridges should be 7.0 m (2 lanes).

3. The clearance above the planned high water level should be 1.5 m.

4. Steel materials are to be specified by the Japanese Industrial Standards.

CHAPTER 9

COST OF CONSTRUCTION

CHAPTER 9. COST OF CONSTRUCTION

9-1 Total Project Cost

The plans for the construction of the route along the coast from Kibiti to Lindi will be affected by the weather peculiar to East Africa. Therefore, the construction work will be hampered or suspended often by the heavy rain in the rainy season and the fierce heat during the dry season, and the work schedule for the construction plan must be set up taking into full consideration of such regional and meteorological conditions. It is considered that it will require 6 years for the direct construction work now under contemplation, but prior to starting construction, we should resort to aerial survey, work-site land survey, and the detailed design, etc. in more detail. And for these, it is considered that it will require about 2 years. The work schedule is as shown in Diagram 9-1. The total construction cost for Route 2 is as shown in Table 9-1, the approximate cost being 261,447,000 Shs, of which the portion to be borne by the foreign funds is 176,834,700 Shs, and by the local funds, 84,612,300 Shs.

The unit prices for various work items are determined in reference with the actual unit prices for the construction works undertaken recently in Tanzania, as shown in Table 9-4.

Diagram 9-1 - Work Schedule

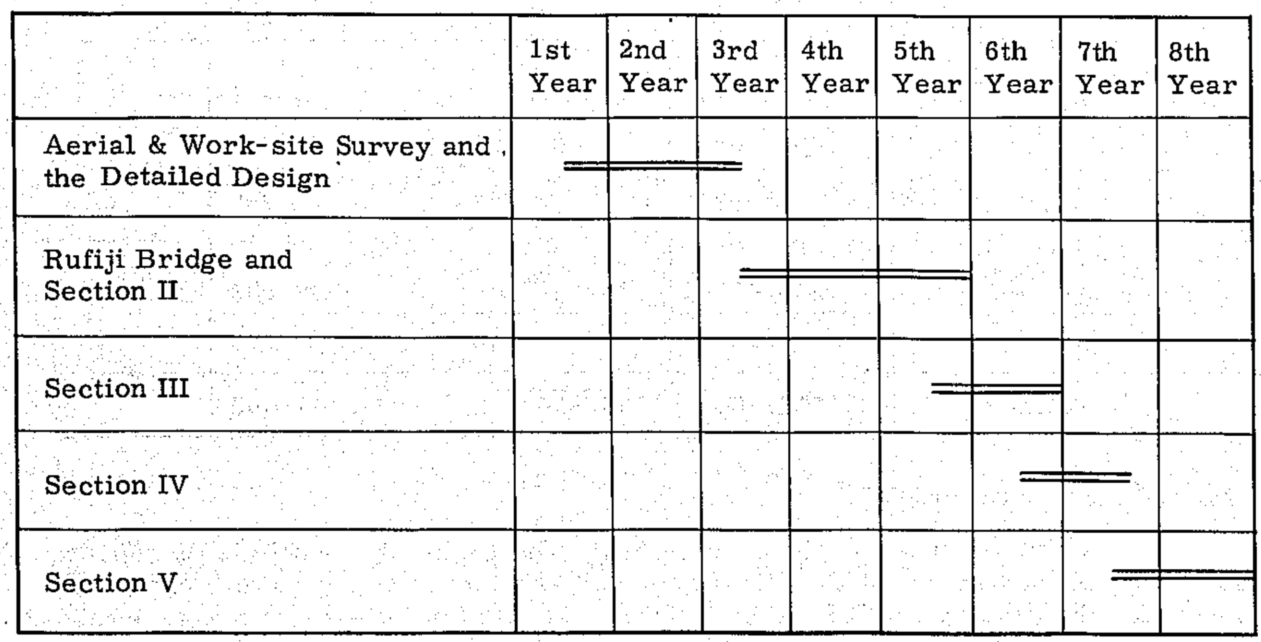


Table 9-1 Total Project Cost

Kibiti - Lindi Coastal Link Road (Route 2)

(Unit = Shs)

	Item	Local	Foreign	Total	Remarks
A	Direct Construction Cost	57,789,000	134,841,000	192,630,000	
	%	30	70	100	
B	Contingency	11,557,800	26,968,200	38,526,000	A x 20%
	%	30	70	100	
C	Sub Total	69,346,800	161,809,200	231,156,000	A + B
	%	30	70	100	
D	Tax	8,090,500	8,090,500	16,181,000	C x 7%
	%	50	50	100	
E	Detailed Survey & Design	3,467,500	3,467,500	6,935,000	C x 3%
	%	50	50	100	
F	Field Control & Work-Site Administration	3,467,500	3,467,500	6,935,000	C x 3%
	%	50	50	100	
G	Right of Way & Compensation	240,000	0	240,000	
	%	100	0	100	
	Total	84,612,300	176,834,700	261,447,000	

9-2 Order of Work Performance

Along the existing road connecting Kibiti and Lindi, the traffic is disrupted for 2 to 6 months every year by the flood, and this fact is acting as an important brake for the development of southern Tanzania, and the losses that are affecting the politics and the economy are extremely great. Therefore, it is the nation-wide prayer as well as the hopes and prayer of the populace along the projected route that the road may be converted into an all-weather road, as fast as possible. In order to attain this end, it is desirable to start the work all at once throughout the entire route, and complete the whole work in the shortest possible period, but when considering some restrictions to the available funds, we should fully consider the investment efficiency and investigate the priority schedule of work performance. In the projected route, the greatest traffic obstruction is the crossing of Rufiji River. During dry season, the ferry boat service maintains pedestrian and vehicular traffic, but there will be a limit to the capacity of traffic, and once in case of flood, the ferry service is interrupted for a long period of time.

Besides, Matandu River, Mbwemkuru River and other small to medium rivers are causing traffic hindrance, but as the flooded period is shorter, the degree of damage is far less in comparison with that for Rufiji River. As explained in the foregoing, the construction of Rufiji River Bridge and viaducts before and after Rufiji and to keep the approach road in good condition on either side of the River crossing, deserves the first priority in the order of work. By the construction of Rufiji River Bridge, the transportation of the construction equipmant and material to the south becomes easier, and the construction work will be expedited, and at the same time the trouble of traffic interruption each year for a considerable length of time will be solved. The cost for the construction of 12 km of road, including that for Rufiji River Bridge, is approximately 67,142,000 Shs, as shown in Table 9-3, of which 45,413,800 Shs will be borne by foreign funds, and 21,728,200 Shs by local funds.

Concerning the Sections other than Rufiji Bridge Section, we have to consult the financial status, and to push the work in the order of Sections III, IV and V towards south, which is considered most efficient. Matandu Bridge and Mbwemkuru Bridge will require many more days to complete, and it will be much more desirable to start the bridge work earlier to cath up the general roadway construction.

Table 9-2 Construction Cost

Rufiji River and Approach Road (Sta 28 + 0 - 40 + 0)

Unit = Shs.

	Item	Local	Foreign	Total	Remarks
A	Direct Construction Cost	14,841,000	34,629 000	49,470,000	
	%	30	70	100	
B	Contingency	2,968,200	6,925,800	9,894,000	A x 20%
	%	30	70	100	
C	Sub Total	17,809,200	41,554,800	59,364,000	A + B
	%	30	70	100	
D	Tax	2,078,000	2,078,000	4,156,000	C x 7%
	%	50	50	100	
E	Detailed Survey & Design	890,500	890,500	1,781,000	C x 3%
	%	50	50	100	
F	Field Control & Work-Site Administration	890,500	890,500	1,781,000	C x 3%
	%	50	50	100	
G	Right of Way & Compensation	60,000	0	60,000	
	%	100	0	100	
	Total	21,728,200	45,413,800	67,142,000	

Table 9-3 Direct Construction Cost

Rufiji River and Approach Road (Sta 28 + 0 - 40 +0)

(Unit = Shs)

Item		Quantity	Unit Cost	Amount	Remarks
Earthwork		238,000 (m³)	6	1,428,000	468,000 -230,000
Relocation & Excavation of the River Bed					
Slope Protection Work		405 (km)	6,000	24,300	
Stone Block Pitching Work		2.61 (km)	100,000	261,000	
Pavement Work		6.66 (km)	200,000	1,332,000	
Drainage Work, & Others		6.66 (km)	40,000	266,400	
Laying of Corrugated pipes		9 (pcs)	5,000	45,000	
Culvert Work		1 (pc)	60,000	60,000	
Bridge Work	Medium to Small Bridges	5,010 (m)	8,000	40,080,000	
	Long Span Bridges	332	18,000	5,976,000	
Total:		5,342 (m)	-	46,056,000	
Direct Construction Cost:				49,472,000 ≒ 49,470,000	

Table 9-4 Summary of Unit Construction Costs

Item	Recent Design	Dar es Salaam - Kibiti	Tan-Zam Highway	Tondma - Iyayi	Enex	TAMS
Earthwork	6.0 Shs/m³	6.0 Shs/m³ Started in 1966. Total Length, 129 km. Newly Constructed Road. Contracted Unit Cost.	5.72 Shs/m³ Started, 1969 Paid Unit Cost.	6.6 Shs/m³ Sept. 1970 Paid Unit Cost.	7.0 Shs/m³ Newly Constructed Road in Smatra Estimated Unit Cost. 1970	5.2 Shs/m³
Pavement Work	200,000 Shs/km	154,000 Shs/km Standard Unit Cost at Mtwara. Surface Course of Asphaltic Concrete Pavement, 4 cm. Cement Treated Base, 15 cm.	182,000 Shs/km	206,000 Shs/km	188,000 Shs/km Surface Course of Asphaltic Concrete Pavement, 6 cm. Cement Treated Base, 38 cm.	80,000 Shs/km 2 Seal Coats over the Base Course of 15 cm.
Bridge Construction Work:						
Small & Medium Size Bridges	1,150 Shs/m²	960 Shs/m²			1,120 Shs/m²	
Long Span Bridges	2,570 Shs/m²				1,280 Shs/m²	2,800 Shs/m²

CHAPTER 10

EVALUATION OF THE PROJECT

CHAPTER 10. EVALUATION OF THE PROJECT

10-1 Outline

In this chapter, benefits of the project are estimated for the opening years of 1977 (engineered gravel road plan) and 1979 (bitumen road plan), determined from consideration about the investigation, designing and plan for execution of works, and for the years of 2006 (engineered gravel road plan) and 2008 (bitumen road plan) when the redemption of cost is completed. On the assumption that the yearly changes in benefits will take a straight variations, the benefits are totalled for thirty years of the planned redemption period.

10-2 Travel Benefit

Saving cost in travelling was calculated for the both cases where the earth road is improved to engineered gravel road and where it is improved to paved road, based on the future traffic volume (see Table 3-21) and unit travel cost.

10-2-1 Unit Travel Cost

Unit travel cost is a unit cost estimated by the Weille method on the basis of the data analyzed by United Research Incorporated taking into consideration the unit cost and areal factor in Tanzania

Table 10-1 Unit Travel Cost (in cents/vehicle-km)

		Surface of road	Passenger car	Pickup	7-ton truck	Bus carrying 50 passengers
	Flat Hilly	Paved road	28.46	31.04	41.52	58.93
	Flat Hilly	Engineered gravel road	36.09	40.05	61.69	88.40
	Flat Hilly	Earth road	49.60	57.87	100.60	137.65
	Hilly Mountaineous	Paved road	29.76	33.05	45.72	65.29
	Hilly Mountaineous	Engineered gravel road	37.81	43.08	68.19	95.94
	Hilly Mountaineous	Earth road	52.06	62.15	111.74	148.18
Unit benefit	Flat Hilly	Earth road → Engineered gravel road	13.51	17.82	38.91	49.25
Unit benefit	Flat Hilly	Earth road → Paved road	21.14	26.83	59.08	78.72
Unit benefit	Hilly Mountaineous	Earth road → Engineered gravel road	15.25	19.07	43.55	52.24
Unit benefit	Hilly Mountaineous	Earth road → Paved road	23.3	29.10	66.02	82.89

Source: The Economic Feasibility of Improving Two Roads in the Mtwara Region of Tanzania (September, 1968)

10-3 Time Benefit

10-3-1 Time Benefit with Transferred Transportation from Rufiji Ferry

1) Vehicles

Table 2-1, the records of suspension of Ndundu and Utete ferries due to flood show that the average days of service suspension for five years from 1965 to 1969 are 110 days. If it is assumed that the ferry takes 40 minutes (= 0.67 hours) to cross Rufiji River, then, one year being 365 days, the time benefit B_T (Vehicle) received by vehicles annually is expressed by the following formula.

$$B_T(\text{vehicle}) = 0.67 \times V(\text{Rufiji}) \times (P V + P V + P V + P V) \times (365-110) \quad \ldots\ldots 10.1$$

Wherein;

V(Rufiji) . . future traffic volume crossing the river (vehicles/day);

P_1, P_2, P_3, P_4 . . . . . passenger car, lorry, van and bus expressed by percentages to the total number of registered vehicles;

V_1, V_2, V_3, V_4 . . . . . unit time values (shillings/vehicles-time) of passenger car, lorry, van and bus, respectively.

2) Passengers

If it is assumed that the time needed for pedestrian to cross the bridge over Rufiji River is 10 minutes, relative saving in time for a passenger after the completion of the bridge is:

40 - 10 = 3 minutes = 0.5 hours

The annual time benefit for passengers B_T (passenger) is expressed as follows:

$$B_T(\text{passenger}) = 0.50 \times P(\text{Rufiji}) \times U(\text{Passenger}) \times 365 \quad \ldots\ldots 10.2)$$

Whereas

P(Rufiji) .... number of passengers crossing the river on foot (persons/day);

V(Passenger) .. unit time value of passenger

In the above formula 365 days are adopted considering that the passengers utilize canoe or others to cross the river in the rainy season, although the actual days are (365-110) = 255 days.

10-3-2 Time Benefit for Passengers Transferred from Shipping Service to Road in the Rainy Season

The time benefit of this category is estimated for 110 average suspension days of Rufiji Ferry services, assuming that the number of passengers using shipping service during the rainy season correspond to that of long-distance passengers travelling by vehicles between Dar es Salaam and Kilwa, Lindi and Mtwara in the southern part and that these long-distance passengers will use the projected coastal road.

First, the estimate is made of the future traffic volume between Dar es Salaam and Kilwa, Lindi and Mtwara in the southern part.

In this estimate, it is assumed that the traffice from Dar es Salaam to Nachingwea, Newara, Masasi and Tunduru, respectively, are made via the port of Lindi or Mtwara in proportion to the traffic volumes between the respective zones (Nachingwea, Newara, Masasi and Tunduru) and the ports (Lindi and Mtwara).

Based on the obtained traffic volume between Dar es Salaam and the three port (Kilwa, Lindi and Mtwara) in the south, the number of passengers (persons/day) N passenger travelling between these points is expressed by the following formula 10.3) on the assumption that each of passenger car lorry and van carries two passengers per vehicle and each bus carries forty passengers per vehicle.

N passenger = {traffic volume (vehicles/day) between DSM ~ Kilwa, Lindi, Mtwara} × {Percentage of the total number of registered vehicles represented by passenger car, lorry and van × 2 persons + such percentage represented by bus × 40 persons} . . . . 10.3)

The time benefit B_T (passenger) for passengers who will be transferred to road from shipping service in the rainy season is obtained from the following formula.

$$B'T(\text{passenger}) = N\ \text{passenger}\left[\frac{V1}{V}\{T_1(\text{ship}) - T_1(\text{vehicle})\} + \frac{V2}{V}\{T_2(\text{ship}) - T_2(\text{vehicle})\} + \frac{V3}{V}\{T_3\ \text{ship}) - T_3(\text{vehicle})\}\right] \times \{(P_1 \times V_1 + P_2 \times V_2 + P_3 \times V_3) \div 2^{\text{persons}} + P_4 \times V_4 \div 40^{\text{persons}}\} \times 110\ \text{days} \quad \ldots\ 10.4)$$

Wherein;

N passenger . . . . no. of passengers (persons/day) travelling between DSM and Kilwa, Lindi and Mtwara, obtained from the formula 10.3);

V . . . . future traffic volume (vehicles/day) between DSM and Kilwa, Lindi and Mtwara;

V_1, V_2, V_3 . . . . traffic volumes between DSM and Kilwa, DSM and Lindi, respectively, and DSM and Mtwara;

T_1(ship), T_2(ship), T_3(ship) . . . . . travel time (hours) by shipping service between DSM and Kilwa, DSM and Lindi; and DSM and Mtwara

T_1 (vehicle), T_2(vehicle), T_3(vehicle) ... travel times (hours) by vehicle respectively between DSM and Kilwa, DSM and Lindi, and DSM and Mtwara;

P_1, P_2, P_3, P ... passenger car, lorry, van and bus expressed respectively as percentages to the total number of registered vehicles;

V_1, V_2, V_3, V_4 ... unit time values (sh/vehicle-hour) of passenger car, lorry, van and bus, respectively;

10-3-3 Time Benefit for Cargoes Transferred from Shipping Service to Road, in the Rainy Season

A general formula to estimate time benefit for cargoes B'T(cargo) is as follows:

$$B'_T(cargo) = \Big[\{T1(ship) - T'(vehicle)\} \times V1 + \{T2(ship) - T2(vehicle)\} \times V2 + \{T3\ (ship) - T3\ (vehicle)\} \times V3\Big] \times (P2V2 + P3V3) \times 110\ days \qquad 10.5)$$

For explanation of symbols used in the formula, see that of formula 10.4) above.

10-3-4 Time Benefit for Cargoes in the Dry Season,Resulting from the Improvement of Road

Time benefit B'_T(czrgo) for cargoes in the dry season, resulting from the improvement of road is estimated by the following general formula.

$$B_T(cargo) = \Big[\{T'1(vehicle) - T''1\ (vehicle)\ \times V1 + \{T2'(vehicle) - T2''(vehicle)\} \times V2 + \{T3'(vehicle) - T3''(vehicle)\} \times V3\Big] \times (P = V2 + P3V3) \times 255\ days \qquad 10.6)$$

Wherein;

T1'(vehicle, T2'(vehicle), T3'(vehicle) .... travel time (hours) between DSM and Kilwa, DSM and Lindi, and DSM and Mtwara respectively, in case existing road is used;

T1''(vehicle), T2''(vehicle), T3''(vehicle) ..... travel times (hours) between DSM and Kilwa, DSM and Lindi, and DSM and Mtwara respectively, in case engineered gravel or paved road is used.

For other symbols, they are the same as those used in the formula 10.4).

10-3-5 Time Benefit for Vehicles resulting from the Improvement of Road

The time benefits resulting from the reduction in travel time after the road has been improved are estimated for two types of traffic, one influenced by Rufiji ferry and the other not influenced.

The general formulas to estimate those time benefits are as follows:

10-3-5-1 Traffic Influenced by the Rufiji Ferry Service

$$B_T'(\text{vehicle}) = (T1 \times L1 + T2 \times L2 + T3 \times L3)\ (P1V1 + P2V2 + P3V3 + P4V4) \times (365 - 110)\text{days} \quad \ldots\ldots\ldots\ldots \quad 10.7)$$

Wherein;

L1, L2, L3 ..... traffic volume (vehicles/day) between Dar es Salaam and Kilwa, Lindi and Mtwara in the south passing through Link 1, 2 and 3, respectively;

T1, T2, T3 ..... saving (hours) in travel times from the improvement of road on Link 1, 2 and 3, respectively

For other symbols, see the formula 10.4).

10-3-5-2 Traffic Receiving no Effect From the Rufiji Ferry Service

$$B_T(\text{vehicle}) = \{T1(L1' - L1) + T2(L2' - L2) + T3\ (L3' - L3)\} \times \{P1V1 + P2V2 + P3V3 + P4V4\} \times 365 \text{ days} \quad \ldots \quad 10.8)$$

Wherein;

L1', L2', L3' . . . . traffic volumes respectively passing through Link 1, 2 and 3.

For other symbols, see the formula 10.7). above.

10-4 Economy in Charges

10-4-1 Saving in Charges for Passengers Transferred from Shipping Service to Road, in the Rainy Season

$$C(\text{passenger sea}) = N\text{-passenger} \times \left(\frac{V1}{V} \times C1 + \frac{V2}{V} \times C2 + \frac{V3}{V} \times C3\right) \times 110 \text{ days} \quad \ldots\ldots\ldots \quad 10.9)$$

Wherein;

C(passenger:sea) ..... saving in charges for passengers transferred from shipping service to road in the rainy season;

C1, C2, C3 .... differences (shillings) in charges between road and shipping service respectively between DSM and Kilwa, DSM and Lindi, as well as DSM and Mtwara.

For other symbols, see the formula 10.4).

10-4-2 Saving in charges of Rufiji Ferry for Passengers

$$C(\text{passenger:Rufiji}) = P(\text{Rufiji}) \times 0.05 \times 365 \quad \ldots\ldots\ldots\ldots \quad 10.10)$$

Wherein;

C(passenger:Rufiji) ..... saving in charge (shillings) to be collected from passengers utilizing the Rufiji ferry.

10 4-3 Saving in Charges of Rufiji Ferry for Vehicles

$$C(\text{vehicle:Rufiji}) = V(\text{Rufiji}) \times 5.0 \times 255 \quad \ldots\ldots\ldots\ldots \quad 10.11)$$

Wherein;

C(vehicle:Rufiji) .... saving in charge (shillings) to be collected from vehicles utilizing the Rufiji ferry;

V(Rufiji) .... future traffic volume (vehicles/day) crossing the river.

10-5 Unit Time Value

As it is deemed that unit time values indicate relative differences between countries in accordance with economic conditions of each country, the unit time value for Tanzania is calculated from the unit value given by Winfrey in Highway Engineering Handbook (Kenneth B. Woods, Editor-in-chief) multiplying it by the per capita income rate of Tanzania to U.S.A.

The unit time values indicated in Highway Engineering Handbook are as follows:

Passenger cars	1.35 U.S.$/vehicle.hour
Light commercial vehicles	1.80 "
Single-unit trucks	2.10 "

The unit time values for Tanzania are calculated assuming light commercial vehicles as vans and single-unit trucks as lorries.

$$C(\text{Tanzania}) = C(\text{U.S.A}) \times \frac{I(\text{Tan}(1960))}{I(\text{U.S.A}(1960))} \times \frac{I(\text{Tan}(1967))}{I(\text{Tan}(1960))}$$

$$= C(\text{U.S.A}) \times \frac{I(\text{Tan}(1967))}{I(\text{U.S.A}(1960))} \quad \ldots\ldots \quad 10.12)$$

Wherein;

C(Tanzania) .... unit time value(shillings/vehicle-hour) for Tanzania;

C(U.S.A) .... unit time value (U.S.$/vehicle-hour) for U.S.A;

I(Tan(1960)), I(Tan(1967)) .... per capita income of Tanzania respectively for 1960 and 1967;

I(U.S.A.(1960)). . . . . per capita income of U.S.A. for 1960

The unit time values calculated by types of vehicles applying the formula 7.12) are as follows:

Passenger cars	. . . .	0.28 shillings/vehicle. hour
Lorries	. . . .	0.44 shillings/vehicle. hour
Vans	. . . .	0.37 shillings/vehicle. hour

The unit time value of busses is calculated multiplying the unit time value of passenger car for Tanzania by the ratio of unit time value of bus to that of passenger car for Japan. This procedure of calculation is as follows:

$$\text{Busses} \ldots \; 0.28 \times \frac{0.69(\text{shillings}/\text{vehicle. hour})}{0.16(\text{shillings}/\text{vehicle. hour})}$$
$$= 1.24\ (\text{shillings}/\text{vehicle. hour})$$

10-6 Travel Time by Shipping Service

DSM ~ Kilwa	24.9 hours
DSM ~ Lindi	32.5 hours
DSM ~ Mtwara	42.0 hours

Note: To calculate the travel times between DSM and Kilwa and between DSM and Lindi, the travel time between DSM and Mtwara was diminished taking into consideration the distance and the hours necessary for loading, unloading and for crews.

Source: Coastal Shipping Service, Dar es Salaam Mtwara; a Feasibility Report by Bjrn Foss and Otto Chr. Hiorth.

10-7 Passenger Fare

As shown in Table 2-4, the difference in fares for shipping and bus passengers travelling between Dar es Salaam and Mtwara is 64 - 35 = 29 shillings.

Bus	35 shillings
Steamer (3rd class)	64 shillings

10-8 Estimate of Benefits

The benefits described in the former paragraphs from 10-2 to 10-4 are extracted in Table 10-2.

The benefits B for the planned redemption period are calculated (for the engineered gravel road plan and the bitumen road plan respectively) with the interest rates r of 2%, 6% and 10% on the assumption that the benefit Bi will make a straight fluctuation in accordance with the yearly variation.

$$B = \sum_{i=o}^{29} \frac{Bi}{(1+r)^i} \quad \ldots\ldots\ldots\ldots \quad 10.13)$$

10-8-1 Benefits

1) Engineered gravel road plan

Year of opening to traffic 1977
Last year of planned reimbursement period 2006

Benefits for 1977 Bo = 11, 164, 300 shillings
Benefits for 2006 B29 = 67, 920, 100 shillings

∴ Bi = 11, 164 + 1, 957, 097i 10. 14)

With r = 2% applied;

$$B = \sum_{i=0}^{29} \frac{11,164,300 + 1,957,097i}{(1 + 0.02)^i} = 837,379,200 \quad . . . \quad 10.15)$$

With r = 6% applied;

$$B = \sum_{i=0}^{29} \frac{11,164,300 + 1,957,099i}{(1 + 0.06)^i} = 458,231,400 \quad . . \quad 10.16)$$

With r = 10% applied:

$$B = \sum_{i=0}^{29} \frac{11,164,300 + 1,957,097i}{(1 + 0.10)^i} = 281,700,000 \quad . . \quad 10.17)$$

2) Bitumen road plan

Year of opening to traffic 1979
Last year of planned redemption period 2008

Benefits for 1979: Bo = 21, 853, 400 shillings
Benefits for 2008: B29 = 119, 975, 300 shillings

∴ Bi = 21, 853, 400 + 3, 383, 514i 19. 18)

With r = 2% applied;

$$B = \sum_{i=0}^{29} \frac{21,853,400 + 3,383,514i}{(1 + 0.02)^i} = 1,505,998,100 \quad . . \quad 19.19)$$

With r = 6% applied;

$$B = \sum_{i=0}^{29} \frac{21,853,400 + 3,383,514i}{(1 + 0.06)^i} = 829,447,500 \quad . . \quad 19.20)$$

With r = 10% applied;

$$B = \sum_{i=0}^{29} \frac{21,853,400 + 3,383,514i}{(1 + 0.10)^i} = 513,478,200 \quad . . \quad 19.21)$$

Table 10-2 Benefits by Years (shillings/year)

Benefits \ Year			Simultaneous execution of works on the whole section (Engineered gravel road plan)		Simultaneous execution of works on the whole section (Bitumen road plan)		Remarks
			Year of opening to traffic	Last year of redemption	Year of opening to traffic	Last year of redemption	
			1977	2006	1979	2008	
Travel benefit			7,939,900	45,596,900	16,949,100	89,001,200	
Time benefit	Rufiji ferries	Vehicle	19,800	109,800	28,000	143,600	Average time needed to cross the river by Rufiji ferry ... 40 m. Reduction in travel time by bridging the river .. 40-10=30 m.
Time benefit	Rufiji ferries	Passenger	29,800	56,200	31,600	58,200	
Time benefit	Time benefit for passengers transferred from shipping service to road in the rainy season.		416,300	3,065,600	648,100	4,337,800	
Time benefit	Time benefit for cargoes transferred from shipping service to road in the rainy season		98,600	700,100	153,300	991,100	
Time benefit	Time benefit for cargoes due to improvement of road, in the dry season		14,400	103,400	31,100	203,300	
Time benefit	Time benefit for vehicles which receives influence from the operation of *Rufiji ferries*		23,800	170,800	52,600	343,600	
Time benefit	Time benefit for vehicles which does receive influence from the operation of Rufiji ferries		33,300	137,700	72,700	276,400	
Economy in charges	Economy in charges for passengers transferred from shipping service to road, in the rainy season		2,286,600	16,396,700	3,467,900	22,558,000	
Economy in charges	Rufiji ferries	Vehicle	284,300	1,551,700	400,400	2,029,800	Rufiji ferry charges 5 shillings/vehicle (as of Nov. 1970)
Economy in charges	Rufiji ferries	Passenger	17,500	31,200	18,600	32,300	Rufiji ferry fare: 5¢/person (as of Nov. 1970)
Total			11,164,300	67,920,100	21,853,400	119,975,300	

10-8-2 Costs

1) Construction costs

i) Engineered gravel road plan (provided that the section from Kibiti to 3 km point to the south of Ndundu is to be paved)

A.	Direct construction cost	145,160,000 shillings
B.	Contingency (A × 20%)	29,032,000
C.	Sub-total (A + B)	174,192,000
D.	Surveying and designing cost	5,225,800
E.	Construction supervising cost (C × 3%) . .	5,225,800
F.	Tax (C × 7%)	12,193,400
G.	Compensation expense	240,000
	Total	197,077,000 shillings

Bridge over Rufiji River (cost for paving approaches excluded.) — 65,388,000 shillings

ii) Bitumen road plan

Total cost . . . . 261,447,000 shillings

Construction cost for bridge over Rufiji River . . . . 67,142,000 shillings

Construction cost for all bridges on Route 2 (Rufiji River bridge included) . . . 112,684,000 shillings

The costs are estimated on the assumption that the total construction costs will be invested within the scheduled period between surveys designing and start of construction works (1971 to 1977 for the engineered gravel road plan and 1971 to 1979 for the bitumen road plan) considering the rate of interest.

$$C = Cc + \sum_{i=0}^{29} \frac{Mi}{(1+r)^i} \quad \ldots\ldots\ldots\ldots\ldots \quad 10.22)$$

Wherein;

Cc . . . total construction cost;
Mi . . . maintenance cost for i year;
r . . . rate of interest

2) Maintenance costs

i) Engineered gravel road plan

Maintenance cost of improved road . . . .

3000 shillings /year x 48.3 km = 144,900 shillings /year
3410 shillings /year x 281.7 km = 960,600 shillings /year

Repainting expense of bridges . . . . .

2,187,552 shillings ÷ 5 year = 437,510 shillings /year

Total 1,427,510 shillings /year

ii) Bitumen road plan

3000 shillings /km-year × 330.0km = 990,000 shillings /year

Repainting of bridges:

2,187,552÷5 year = 437,510 shillings /year

Total 1,427,510 shillings /year

3) Estimate of total cost with interest taken into consideration

The total costs (construction cost + maintenance cost) estimated by the formula 20.22) with the rate of interest taken into consideration are as follows:

i) Engineered gravel road plan

For r= 2%:

Cr = 2 = 243,700,000 shillings

For r= 6%:

Cr = 6 = 255,959,000 shillings

For r= 10%:

Cr = 10 = 276,857,000 shillings

Fig 10-1 Simultaneous Execution of Works of the All Section (Engineered gravel road plan)

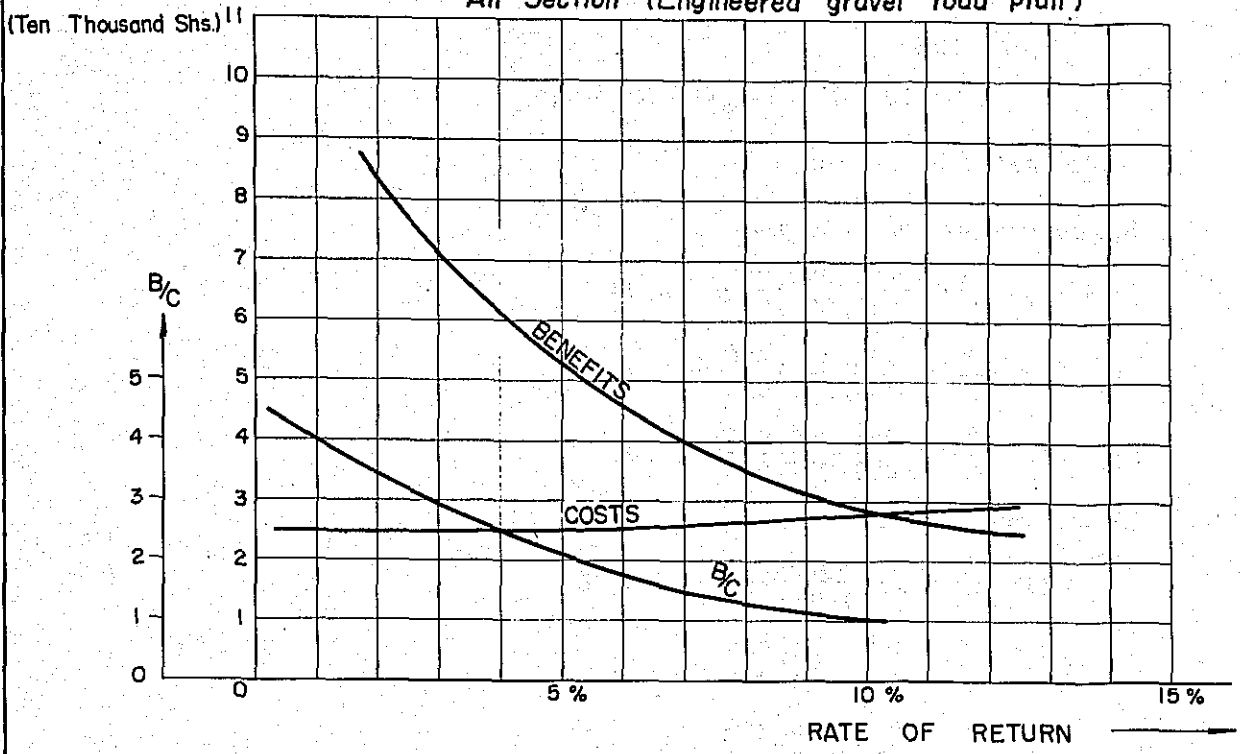
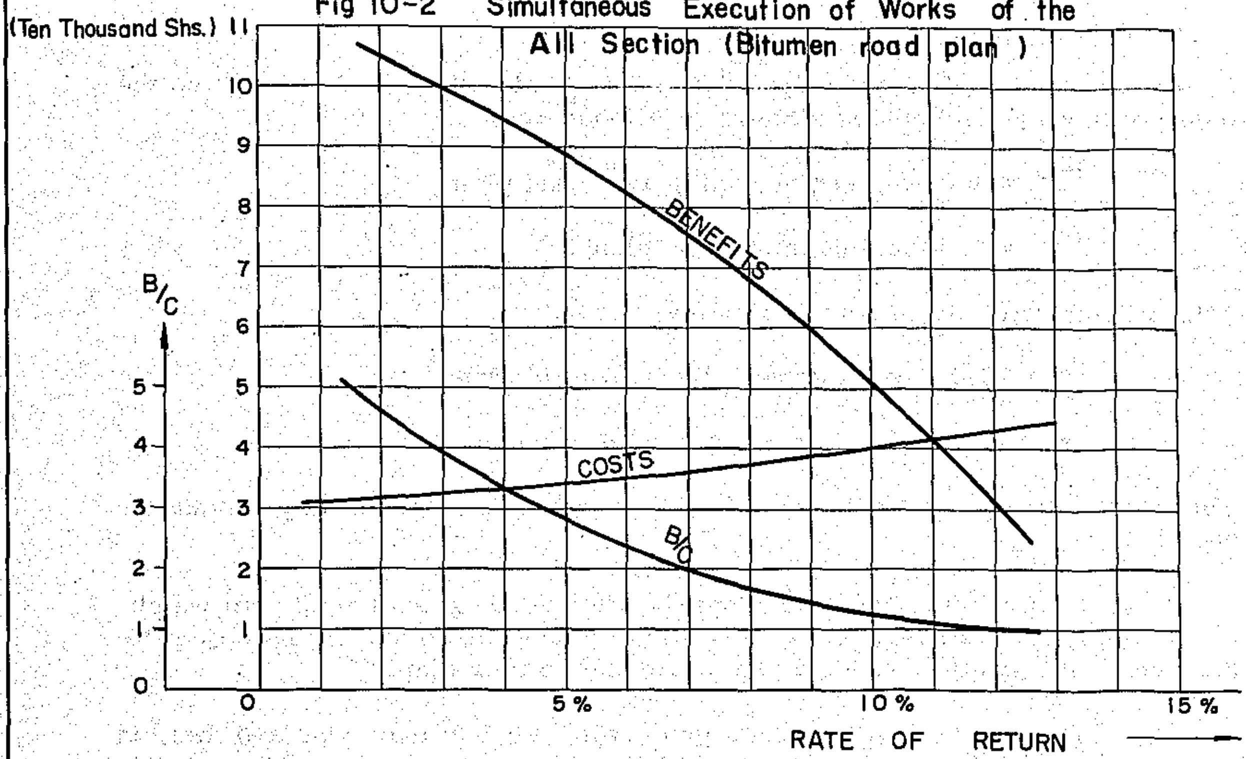


Fig 10-2 Simultaneous Execution of Works of the All Section (Bitumen road plan)



ii) Bitumen road plan

For r = 2%

Cr = 2 = 314,965,000 shillings

For r = 6%

Cr = 6 = 349,701,000 shillings

For r = 10%

Cr = 10 = 396,243,000 shillings

10-8-3 Benefit/Cost Ratio

1) Engineered gravel road plan

$$(r = 2\%) \quad \frac{B}{C} = \frac{837,379,200}{243,700,000} = 3.44$$

$$(r = 6\%) \quad \frac{B}{C} = \frac{458,231,400}{255,959,000} = 1.79$$

$$(r = 10\%) \quad \frac{B}{C} = \frac{281,700,000}{276,857,000} = 1.02$$

2) Bitumen road plan

$$(r = 2\%) \quad \frac{B}{C} = \frac{1,505,998,100}{314,965,000} = 4.78$$

$$(r = 6\%) \quad \frac{B}{C} = \frac{829,447,500}{349,701,000} = 2.37$$

$$(r = 10\%) \quad \frac{B}{C} = \frac{513,478,200}{396,243,000} = 1.30$$

10-8-4 Conclusion

The benefit/cost ratios $^{B}/C$ worked out with 10% of interest on the basis of surveys and analysis above mentioned are:

$^{B}/C$ = 1.02 for engineered gravel road plan;

$^{B}/C$ = 1.30 for bitumen raod plan;

with the internal rate of return r' being:

r' = 10.2% for engineered gravel road plan;

r = 11.0% for bitumen road plan.

Therefore, it may be concluded that this project has economically adequate possibility.

It is recommended to adopt the engineered gravel road plan which needs smaller initial investment than the bitumen road plan, as the object to provide an all weather road can be attained by either plan.

This project will be quite promising because it is expected that, in addition to the direct economic effects, the opening of road to traffic will have various indirect effect including improvement in income and cultural levels of the districts, promotion of overall development, securing of popular sentiment and public welfare for the inhabitants resulting from the integration of Dar es Salaam with the southern part.

FEASIBILITY REPORT DAR ES SALAAM/LINDI COASTAL LINK ROAD PROJECT TANZANIA Vol. I