THE REPUBLIC OF LIBERIA

FEASIBILITY STUDY

ON THE

GBARNGA - MENDIKOMA HIGHWAY PROJECT

(PROGRESS REPORT)

SEPTEMBER, 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

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September 3, 1979

Honourable Gabriel J. Tucker
Minister of Public Works
Ministry of Public Works
Monrovia, Liberia

Re: Progress Report of the
Feasibility Study on the
Gbarnga-Mendikoma Highway
Project

Dear Sir:

We are pleased to submit herewith thirty five (35) copies of the progress report on the captioned project in compliance with the Scope of Work agreed between the Japanese Government and the Liberian Government.

The progress report incorporates the findings and the preliminary results of the field survey and study conducted from the late June to the end of August. Although the survey period was in the heavy rain season, all of the field works were executed on schedule, thanks to the best arrangement and heartfelt cooperation provided to us by the Ministry of Public Works and other Ministries concerned. Particularly, continuous assistance had been provided by the counterpart persons and surveyors as well as drivers assigned from Ministry of Public Works for the accomplishment of the field works.

Upon our return to Japan, we will start detailed study and analysis, the results of which will be compiled into a Draft Final Report at the end of November 1979. Final Feasibility Study Report will be completed at the end of January, 1980 incorporating all the comments on the Draft Report from your Government, which will be submitted in early February.

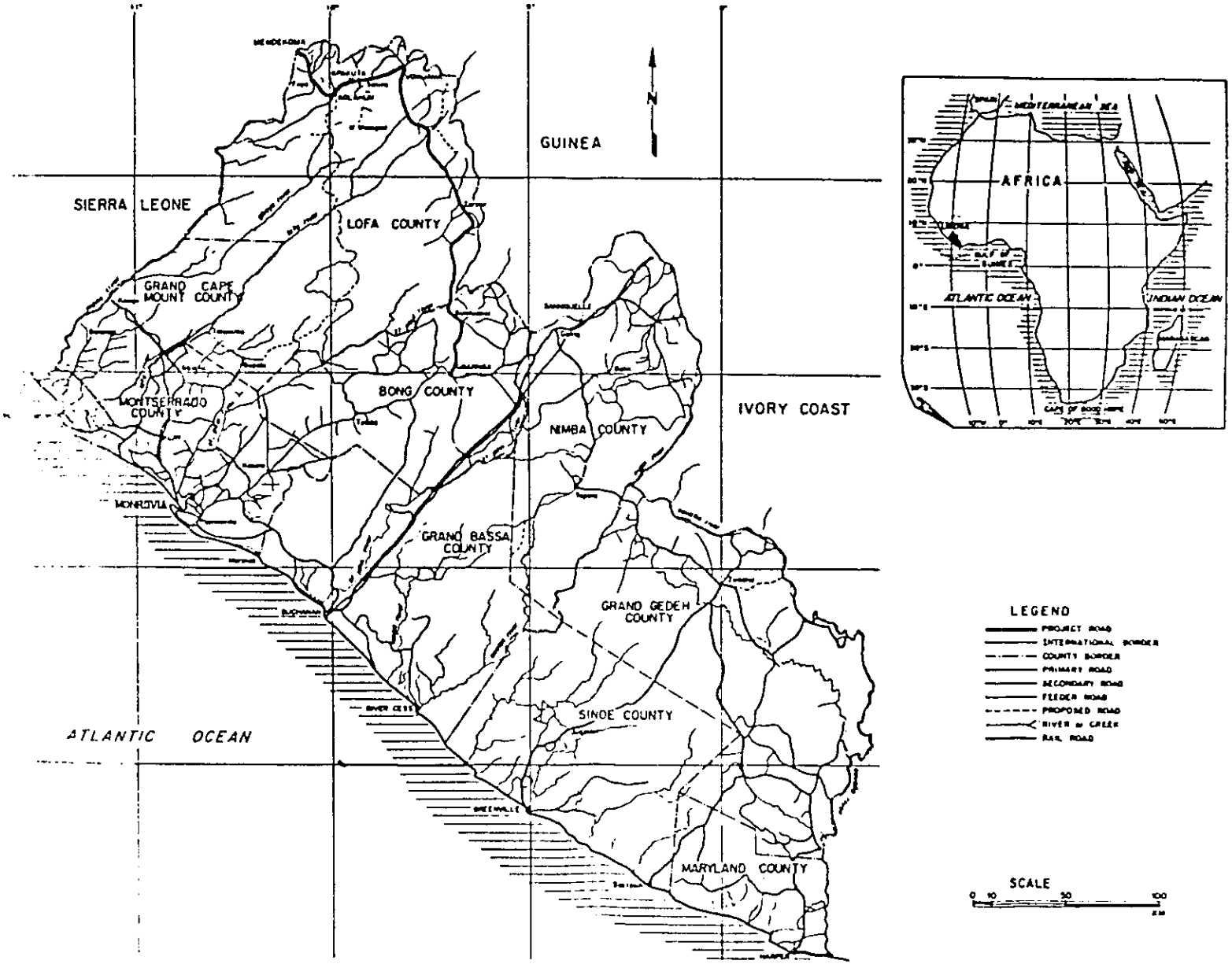
Finally, thanking you again for your kind assistance and hoping that the project can be materialized very soon.

Very truly yours,

J. Kawakami

T. Kawakami
TEAM LEADER
JICA SURVEY TEAM

LOCATION MAP



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. INTRODUCTION

1.1 Project Background

The Government of Liberia is following a policy to expand the base for the country's economic development, now dependent largely on the mining sector, to agriculture. Under this strategy, it is placing considerable emphasis on the improvement of transport facilities. During the Five Year Development Plan period (1976-1980) US$141 million or almost 40% of the total investment was allocated for improvement of the road network. The objectives of the Plan for the road sector are 1) to improve road maintenance, 2) to upgrade key primary roads and extend the secondary road system to agricultural development areas, and 3) to provide most urgent feeder roads to support rural development.

Included in the plan are Totota - Ganta Road, Ganta - Saniquellie and Ganta - Tapita Roads, Paynesville - Totota Road, Paynesville - Robertsfield Road and Tubman Bridge - Bomi Hills Road for the primary road, and Monrovia By-Pass, and New Mesurado Bridge (Gabriel J. Tucker Bridge) and U. N. Drive for urban roads improvement, most of which are under construction or under preparation.

Improvement of rural roads or feeder roads has been much more facilitated for promoting regional economic development particularly agricultural development. Most significant performance are Lofa County Feeder Roads and Upper Bong County Feeder Roads now partly under construction both of which constitute an integral part of the regional agricultural development projects (Lofa County Agricultural Development Project and Upper Bong County Agriculture Development Project) and are expected to contribute to the regional development considerably.

The Gbarnga - Mendikoma Road is a primary road connecting the capital of Bong County with Mendikoma, a border town between Liberia and Sierra Leone. The road passes through the highest agricultural potential area, Upper Bong and Upper Lofa, in the country and acts not only as a national trunk line in the north-west but also as a main agricultural transport road integrating all the feeder roads in the region.

In view of the importance of the road for the regional development, the project was identified earlier and the feasibility study was originally included in the Fourth Highway Project financed by the World Bank in 1978. From June 1978, pre-feasibility study had been commenced by the Ministry of Public Works. During the study, traffic survey including traffic counts and O-D survey, and economic survey was conducted.

In parallel to the pre-feasibility study, a preliminary engineering study on the project road (excluding Kpakutua - Mendikoma section) was made by JICA in 1978 as a part of the infrastructure study for the development of the Wologisi Mine under the technical assistance of the Japanese Government. In the study, preliminary cost estimate for the road improvement was conducted as well as economic impacts study. The results of the preliminary study indicate that the improvement on the road is marginally feasible. After this survey, the Liberian Government decided to request further technical assistance on the road improvement extending from Gbarnga to Kolahun to the Japanese Government.

In response to the request, the Japanese Government accepted to conduct a feasibility study of the said project and despatched a preliminary survey mission in

February, 1979 for working out details of the study. A draft scope of work together with tentative work schedule was formulated in the bilateral discussion in which the road to be studied was recommended to extend to Mendikoma.

On the basis of the results of the discussion, JICA organized a survey team, headed by Mr. T. Kawakami, a senior highway engineer of Nippon Koei Co., Ltd., and despatched the survey team to Liberia together with a Chairman of the Advisory Committee, Mr. M. Tokumaru. from June 25, 1978. The scope of work agreed between both Governments are presented below.

I. Preliminary Study
- Review of available data and reports
- Preparation of Inception Report

II. Field Survey and Study
- Socio-economic and transport economic survey
- Traffic Survey
- Engineering Survey
- Confirmation of design standard
- Preparation of alternative plans
- Study on traffic generating sources
- Preliminary traffic forecast
- Preparation of Progress Report

III. Detailed Study and Analysis
- Refinement of traffic forecast
- Preliminary design of road and structures

- Construction plan and construction scheduling
- Estimate of construction quantity and cost estimate
- Estimate of benefits
- Economic analysis
- Preparation of Draft Final Report
- Preparation of Final Report

1.2 Progress of Field Works

After arriving in Monrovia on June 27, 1979, we held meeting with the Ministry of Public Works' staffs from June 27 to June 28 in which the contents of Inception Report were discussed together with survey schedule. On June 28, another meetings were held with the Ministry of Planning and Economic Affairs, and the Ministry of Finance for explanation of the objectives and contents of our survey. From June 29 up to July 1st all the staffs of the survey team and the counterpart staffs assigned by the Ministry of Public Works went to the project site for understanding present condition, and collecting preliminary information and data. After the short field reconnaissance the survey team came back to Monrovia and the preparation work for the field survey was commenced from July 2nd for each different group. Brief explanation of the major field works undertaken by JICA Survey Team from July 2nd to September 5th is presented below.

1.2.1 Traffic Survey

(1) Preparation of the Traffic Survey

Before starting the traffic survey, traffic survey team consisting of Mr. H. Kojima, a Traffic Engineer, Mr. A. Morikawa, a Transport Planner and Mr. T. Tai, a Project Economist, together with Dr. J. Ansah, Mr. J. Walace and Mr. J. Moise from the Ministry of Public Works checked the procedures and results of the previous survey conducted on the project road in June 1978. Discussions were held during the first week of July concerning zoning and methods of the survey between JICA traffic team and Ministry of Public Works' staffs in order to make survey mor

comparable to the previous one. On the basis of the discussions, method of the traffic survey was finally determined including survey points, survey period, traffic counting hours and survey forms.

All the necessary arrangement for the field survey such as employment of enumerators, preparation of the accommodations and vehicle arrangement was made by Ministry of Public Works. Eight enumerators were selected from the Ministry of Public Works together with one supervisor for the survey, all of whom were under the responsibility of the traffic team.

(2) Traffic Count and O-D Survey

The traffic team went to the project site on July 7 and completed field preparation including recruitment of 16 assistant enumerators until July 8. The traffic survey started from 7:00 (seven o'clock) in the morning on July 9, and ended at 7:00 (seven o'clock) in the afternoon on July 15. Items of the traffic survey are briefly presented below (details of the procedure of the survey are shown in Chapter IV together with the preliminary results).

Classified Vehicle Count (12 hours from 7:00pm to 7:00pm)

Period = July 9 to July 15, 1979
Counting Point = All stations (8)

Classified Vehicle Count (24 hours from 7:00am to 7:00pm)

Date = July 10, 1979
Counting Point = One Station (at Voinjama)

O-D Survey

Date = July 12, 1979
Survey Point = Five Stations

The survey sheets filled up by enumerators were collected every day and checked by the traffic team. During the traffic survey, the traffic team investigated traffic situation not only on the project road but also on the related feeder roads in the influence area. Particularly, the feeder roads connecting agricultural potential areas around Zorzor, Voinjama, Kolahun and Foya were investigated carefully in due consideration of future traffic generation.

(3) Compilation of the Results

After finishing the traffic survey, the traffic team came back to Monrovia on July 17. Classified vehicle count sheets and O-D survey sheets were checked during the third week of July. Compilation of the survey sheets was carried out from the fourth week to first week of August. Preliminary results of the survey were compiled into O-D matrix and average daily traffic for each different type of vehicle was calculated.

(4) Preliminary Forecast of Traffic

On the basis of the calculated ADT, traffic forecast was made preliminarily taking into account population growth, economic growth and the regional agricultural development. The results of the preliminary forecast are presented in Chapter IV.

1.2.2 Socio-Economic and Transport Economy Survey

(1) Field Survey

From early July, Project Economist joined the traffic survey and investigated the land use along the project road. In order to make familiarize the socio-economic condition in the influence area, the areas along the secondary and

feeder roads connecting the project road were investigated intensively. In parallel to the field investigation, economic and transport economic data in the influence area were collected in the following offices.

i) Lofa County Superintendent Office
   - Socio-Economic data in Lofa

ii) LCADP
   - Agricultural production data and future plan

iii) Lofa County Police Office
   - Accident records by type of vehicle

iv) LPMC
   - Production records of each crops and cultivated area

v) Regional Office of Ministry of Agriculture

vi) BCADP
   - Agricultural production data

vii) ALTCO
   - Forestry production data

(2) Data Collection in Monrovia

After comming back to Monrovia on July 17, data collection was commenced regarding socio-economy, agricultural economy and transport economy in the following Ministries or Agencies concerned.

i) Ministry of Public Works
   - Vehicle Operation cost
   - Economic costing

ii) Ministry of Agriculture (MOA)
- Agricultural production
- LCADP data
- BCADP data

iii) Ministry of Planning & Economic Affairs
- Socio-economic indicators
- Agricultural census, 1971
- Economic development plan

iv) Forestry Development Authority (FDA)
- Forestry production data with area
- Transport cost

v) Liberian Produce Marketing Corp. (LPMC)
- Production record of cash crops with area
- Marketing

vi) Liberian Rubber Development Unit (LRDU)
- Rubber production record with cultivated area
- Marketing and trasport mode

vii) Mano River Union
- Land use and soil data

viii) Ministry of Finance (MOF)
- Vehicle registration record
- Tax and duties

ix) Ministry of Commerce, Industry & Trasportation
- Gas consumption record

x) Air Liberia
- Passenger record for local transport

xi) Transport Companies and Car Dealers
- VOC data

(3) Data Compilation and Study

In parallel to the data collection in these offices, data compilation was made to estimate present agricultural production in the influence area including cash crops, rubber and forestry. For the estimate of future traffic the trend of the agricultural production was studied together with that of mining sector and general economic growth.

Study on vehicle operation cost was also made by collecting additional data and information including Ministry of Public Works estimates.

1.2.3 Engineering Survey

During the first week of July, necessary preparatory works were conducted for the engineering survey. Discussions were made concerning contents of the survey works and the schedule between JICA Survey Team consisting of Mr. T. Kawakami (Team Leader), Mr. Y. Okano (Highway Engineer), Mr. T. Inoue (Pavement Engineer), Mr. F. Ide (Soil Mechanical Engineer) and Mr. T. Saito (Survey Supervisor), and counterpart staffs from Ministry of Public Works, Mr. L. Togba, Mr. W. Renner, Mr. S. Sarwah, and Mr. S. Hallowanger.

After the preparation, engineering survey team moved to Gbarnga in July 7, where necessary numbers of laborers were recruited and started the field survey works.

Major items for the engineering survey are:

1) Road inventory survey and route selection survey
2) Topographic survey
3) Soil sampling and soil material test at laboratory
4) Road surface investigation and materials survey
5) Design standard and cost data collection

(1) Road Inventory Survey and Route Selection Survey

The inventory survey and route selection survey were conducted all over the project road by the Highway Engineer with an assistant surveyor from the second week of July up to late August. The items surveyed for the road inventory were road distance, topography along the road, road structures, horizontal and vertical alignment and road surface. Besides, additional dimension survey was carried out on five bridges located in Voinjama - Mendikoma section. (Other bridges located in Gbarnga - Voinjama were already investigated in the previous survey.[1/])

Before starting the survey, study on the proposed route was made using the available photo-mosaic scaled at 1 to 10,000. The route selection survey was conducted to check and confirm the preliminary proposed route. During the survey, survey points for cross section of the road were identified with the interval of 50m-400m.

All the results of the inventory survey were compiled into the inventory table as presented in Appendix 5.

1/ = JICA Survey on the infrastructure for the Wologisi Iron Ore Development.

(2) Topographic Survey

The topographic survey was carried out by one levelling team and one cross section team with three assistant surveyors from the Ministry of Public Works from the second week of July until late August.

Logitudinal profile survey was conducted by using a Level and a Transit survey equipment. Horizontal distance and relative height were measured all over the project road. During the survey, the cross section survey points selected by the route selection survey were checked and connected to the longitudinal survey points.

Available bench marks were investigated at Gbarnga junction, Voinjama junction and Johnny Town, which will be related to the survey points in the further study.

Total survey distance was 275 km and divided as follows:

Gbarnga	-	Zorzor	101.4 km
Zorzor	-	Voinjama	94.1 km
Voinjama	-	Mendikoma	79.5 km

Cross section survey was conducted by simple cross section survey method using poles and tape on all the survey points, which were selected necessary for estimating the expected earth work volume. Total survey points were 1,899 with the following distribution.

Road Section	Nos. of Survey Section
Gbarnga - Zorzor	647 Sections
Zorzor - Voinjama	674 Sections
Voinjama- Mendikoma	578 Sections

During the survey, the length of the road width components such as lane, side ditch and shoulder were checked together with their gradients. For the road sections where major realignment will be required, additional section of 50 - 300m was surveyed.

(3) Soil Sampling and Soil Test

Soil mechanical survey was conducted by the Soil Mechanical Engineer. Soil sampling work was commenced from the middle of July after the general reconnaissance and completed in late July. During the field survey, soil samples were taken from the shoulders or the lower portion of the cutting slopes on 30 points along the existing road throughout Gbarnga to Mendikoma.

All the soil samples collected were brought to Monrovia in late July. The soil tests were conducted using the Soil Laboratory of the Ministry of Public Works under the cooperation of the laboratory staffs. The items for the soil test were:

1) moisture content,
2) grain size,
3) liquid limit,
4) plastic limit,
5) CBR test,
6) compaction, and
7) natural density.

All the tests were completed by late August, the results of which are presented in Chapter V.

4) Road Surface Investigation and Materials Survey

Road surface investigation and test were carried out by the road surface survey team consisting of the Team Leader, a Pavement Engineer, a Soil Mechanical Engineer and a laboratory expert from Ministry of Public Works during the last week of the field works. The road surface test was made to determine the pavement design, which includes field CBR test, deflection test. Numbers of the survey points and the results were presented in Chapter V.

The borrow pit of selected laterite was investigated all over the project road during the inventory survey by the Highway Engineer. The investigation for quarry site was conducted throughout the project road by the Pavement Engineer assisted by an expatriate quarry engineer. Reconnaissance survey was made to confirm the availability on the proposed quarry site within the area of 1.5 km from the project road. Rock samples were taken from the sites and rock test were conducted in the laboratory. Location of the identified quarry site was marked on the map together with rough estimate of the available volume.

(5) Design Standard and Cost Data Collection

Design standards were collected in Monrovia both for the project road when constructed, and for the primary roads. With respect to the design standard to be applied for the project road, discussions were made between JICA Survey Team and the Ministry of Public Works' staff at the first meeting in late June. At the meeting, Ministry of Works recommended the design speed of 72 - 80 km/hr (45-50 mile/hr) for the project road.

Data for construction cost and maintenance cost were collected in Monrovia and Lofa County, which include the recent contract documents for the Totota-Ganta Highway Improvement Project, recent price of construction machineries and materials, and recent maintenance study reports.

In addition, meteorological and hydrological data concerning the influence area and the project road were collected.

II GENERAL BACKGROUND OF THE COUNTRY

2.1 Geography

Liberia consists of a narrow coastal plain with extensive swamps, tidal lagoons and creeks, a central plateau and a mountaineous area along the country border with Guinea. Total area is about 111,400 km^2. The population of the country is estimated at 1.71 million in 1978 with an average annual growth rate of 3.3%. The average population density is estimated at 15 persons per km^2. The population is unevenly distributed; over 60% occupy about 30% of the land area in the central and southwest regions. Nearly 30% of the population live in urban areas which registered high annual growth rate of 7.9%. The population shift from rural areas to urban areas is evident.

Gross Domestic Product (GDP) in real terms (1971 constant price) is estimated at US$431 million in 1977. From 1964 to 1974 the economy grew at an annual average rate of 5.7%, but stagnated thereafter with an average annual rate of growth 0.5%. The average growth rate of the economy for the whole period of 1964 - 1977 is estimat at around 4.2% per year. Per capita GDP increased in real terms at 2.4% per year over the period of 1964 - 1974 and stagnated after 1974, which is estimated at about US$300 in 1977.

The economy of Liberia is a dualistic one where production and consumption patterns differ considerably between the monetary and traditional sectors. The monetary economy generates almost 80% of GDP, while 60%

of the total population still live in the traditional economy producing residual 20% of GDP. The economy is dominated by the mining sector in which iron ore mining is by far the largest activity with the total production value of US$105 million in 1978. The sector's contribution to GDP and export value were around 30% and 56% respectively in 1978. The iron ore mining is operated by three foreign mining companies.

Agriculture is the second largest sector in the economy contributing 25% of GDP and 40% of export earnings. Total production value from the agriculture sector was US$114 million in 1978. Commercial operations of modern agriculture are dominated by foreign-owned rubber plantation and logging companies. Rubber is the largest single commodity, which produces about 40% of all agricultural exports and employs a third of the country's labor force. Forestry products are the second important activity in the agriculture sector by contributing to 10% of the national export value in 1978.

The production of other sectors than mining and agriculture is quite limited; manufacturing and energy sector produced US$59 million and construction sector raised US$50 million in 1978 contributing less than 10% of GDP in total.

Total export value was US$486 million in 1978. Exports of goods increased at a relatively high growth rate of 14% per annum during 1970 - 1974 period, while it slowed down thereafter with around 5% of the annual growth rate. The export of the country depends on production of the primary goods, in which particularly iron ore and rubber are the most important contributing

about 70% of the total export. Total import value in 1978 was US$480 million. During the past eight years (1970-1978), import of goods increased continuously with a higher rate of 16% per year. Raw materials including crude oil accounts for more than 50% of the total import, while investment goods for about 23%, and consumption goods including food about 27%. Rice, an important staple food in the country, is still insufficient and about 60,000 tons were imported in 1977. The country's external account on trade balance had shown a relatively large surplus until 1976, but it turned to deficit or marginal surplus since then due to the stagnated export growth against continuous high growth of imports.

2.2 Present Transport System

Transportation demands in Liberia are met by a combination of road network, coastal shipping, air transport, and, on a limited scale, inland waterways. In addition, railway transportation is available in the country, which is run by the mining companies mainly for iron ore transport.

2.2.1 Road Network and Road Transport

(1) Road Network

Liberia's road network totals 6,075 miles (9,775 km), which includes 1,202 miles (1,934 km) of primary roads, 3,387 miles (5,450 km) of secondary roads and 1,486 miles (2,391 km) of private roads.

There are three main trunk of primary roads starting from Monrovia within the national road network. The first trunk line runs northeast direction through relatively populated areas of Montserrado and Bong counties up to Yekepa, Nimba County, a border town with Guinea, with junctions at Gbarnga and Ganta. Total length of the road is 211 miles (338 km). The Gbarnga Junction continues in a northern direction to Voinjama and, then turns to west up to Mendikoma, while the Ganta Junction continues in southeast direction, passes through Tapeta and Zwedru and arrives at Harper, Maryland County, a major population and economic center near the Ivory Coast border. These trunk lines are mostly unpaved except Monrovia - Gbarnga (Gbarnga-Ganta section is now being paved).

The second trunk line runs in the northwest direction through Bomi Hills up to the Mano River on the Sierra Leone border, with a junction at Klay. Total length of

this road is 87 miles (139 km), half of which is now being paved from Monrovia to Bomi Hills. The road runs alongside the joint LMC-NIOC ore concession railway line. From Klay, the road takes west direction and reaches Bo, a border town with Sierra Leone, where a road and bridge are under construction to link both countries. From the Medina junction on the Klay-Bo road, a new road runs through the coastal area and reaches Robertsport, a promising port with a potential resort near Lake Piso. The third trunk line is a 94 miles (150 km) paved road that runs through Robertsfield and Harbel to Buchanan, capital city of Grand Bassa County.

In spite of the impressive increase in road mileage since late 1960's, Liberia still has one of the lowest road density in West Africa. The road density per km^2 in the country is only 0.106 km/km^2, which is relatively low compared with that of 0.27km/km^2 in Sierra Leone. The road density per 1,000 population is only 4.2 km considerably lower than that of 33 km in Sierra Leone and 38 km in Cameroon.

Besides the quantitative shortage, the roads in Liberia are still in shortage in quality. Even for the primary roads only about 20% is paved and the residuals are laterite roads. Although the laterite roads are classified into all weather road, passage on most of them is difficult during the wet season. A particular deficiency exists with regard to the secondary and feeder roads including private roads. Most of the feeder roads were built by forestry and rubber concessionaires as short term, low-standard haul roads and many are merely earth trucks without sufficient drainage.

To improve the above situation, the Liberian Government is emphasizing their improvement through strengthend regular maintenance work and new investment not only for the primary roads but also for secondary and feeder roads. Typical feeder road improvement projects now conducted are in Upper Lofa County and Upper Bong County both for facilitating rural development through agricultural production expansion.

The Highway Network in Liberia
(Miles)

R o a d s	1971	1974	1977	1978
I. Public Roads				
1. Primary Roads				
Paved	203	208	230	253
Laterite (all weather)	941 (1,144)	968 (1,176)	946 (1,176)	949 (1,202)
2. Secondary & Feeder Rds.				
Laterite (all weather	487	707	823	973
Earth(Dry weather)	1,270 (1,757)	1,265 (1,972)	1,432 (2,255)	2,414 (3,387)
Sub-total I	2,901	3,148	3,431	4,589
II.Private Roads				
Paved	86	86	90	98
Laterite & Earth	1,184	1,308	1,359	1,382
Sub-Total II	1,270	1,394	1,444	1,486
Grand Total	4,170	4,542	4,875	6,075

Source: Ministry of Public Works, Planning & Programming Div.

Road Transport

The growth and composition of the vehicle fleet can be traced by the available data on vehicle registration as summarized below:

Vehicle Registration

Year	Passenger Cars	Taxis	Trucks[1/]	Buses	Total
1970	9,377	4,735	5,234	3,864	23,210
71	8,996	4,103	5,454	2,521	21,074
72	10,607	3,384	4,730	2,575	21,295
73	10,769	3,507	5,384	3,135	22,795
74	9,875	4,576	5,841	1,800	22,092
75	10,375	2,421	5,466	2,497	20,759
76	11,800	1,967	4,770	2,600	21,134
77	11,234	2,981	5,621	N/A	19,836
78	10,659	3,046	6,427	1,049	21,181

1/ = Including Pick-ups

Source: Ministry of Finance, and Ministry of Commerce, Industry and Transportation.

During a decade up to 1970, vehicle registration had been increased at an annual rate of 11%, but vehicles going out of use were not automatically deregistered. Since 1970, vehicles no longer use have been removed from the register. The inconsistency in the table can be explained by this change of procedure.

Another available data indicating the trend of road transport is fuel consumption, the data shows only a slow growth in traffic.

Consumption of Petroleum Products
(1,000 US Gallons)

Year	Gasoline	Kerosene	Gas-Oil
1969	15,519	3,171	23,139
70	N/A	N/A	N/A
71	19,987	3,695	51,181
72	16,098	3,144	48,688
73	21,374	3,823	58,046
74	18,891	3,616	61,614
75	21,078	3,139	54,676
76	23,708	3,251	48,140
77	-	-	-
78	-	-	-

N/A = Not available
Source = Ministry of Finance

2.2.2 Other Transport Mode

(1) Railways

The railways are an another important transport mode in Liberia, which, owned and operated by mining concessions, are used mainly for iron ore transportation. Around 20 million tons of iron ore were carried by the railways in 1978. Beside the iron ore, general cargo and passenger were transported by the railways; the Liberian American Mining Company (LAMCO) line carries some 100,000 tons of general cargo annually including about 10,000 tons of rubber and 6,000 tons of logs and sawn timber, and about 150 passengers daily.

(2) Ports

There exist four seaports in Liberia, which includes two deep-water ports at Monrovia and Buchanan and shallow-water ports at Greenville and Harper. About 85% of foreign trade goods or about 20 million tons annually are handled by Monrovia and Buchanan, while about 300,000 tons of goods are handled by Greenville and Harper. All ports are managed fairly efficiently by the National Port Authority (NPA) except Buchanan which is managed by LAMCO.

Capacity is adequate at all ports, but expansion of facilities and a new port will be required for the planned mining and forestry development. The studies are now being carried out including a new port construction at Robertsport.

(3) Air Transport

There is one international airport at Robertsfield in Liberia, which is now served by Air Liberia and twelve international airlines. Both international passenger traffic and air cargo increased about 8% per year during the past 5 years up to 1976. Besides the international airport, 14 airfields are served by scheduled flights for domestic passenger and cargo. Domestic air transport still acts as an important role in the local transportation particularly, for access to remote parts of the country. Domestic air traffic increased rapidly with an average annual growth rate of 28% during 1973-1978.

Port Traffic By Ports
(1,000 Tons)

Port	1975	1976	1977	1978
Monrovia	11,082	11,713	8,795	8,936
Greenville	153	254	216	244
Harper	35	57	45	60
Buchanan	8,957	9,526	8,542	11,012
T o t a l	20,227	21,550	17,598	20,252

Source = Economic Survey of Liberia, 1978

Domestic Air Traffic

I t e m	1976	1977	1978
Number of passenger disembarking	14,372	15,774	23,660
Embarking	14,399	15,839	23,759

Source = Ministry of Commerce, Industry & Transportation.

III. THE INFLUENCE AREA

3.1 Project Location and Influence Area

The Gbarnga-Mendikoma road is located in the north-western part of the country and runs through Upper Bong County and Upper Lofa County. The road consitutes a part of the national primary road that links Monrovia with north-western areas of the nation up to the border country, Sierra Leone.

The influence area of the project road is divided into internal influence area and external influence area. The internal influence area, which is the study area through which project road passes, is divided into 13 small zones on the basis of the administrative units of clans. The external influence area is the area outside the internal influence area and divided into relatively larger 12 zones. The zonal system established for the study is summarized in Fig. 3.1 and Table 3.1 together with the link and node system. Important cities and towns are selected as the nodes for the zones. (It is noted that the word "the influence area" tc be used means only the internal influence area hereafter).

Fig. 3.1 ZONAL SYSTEM

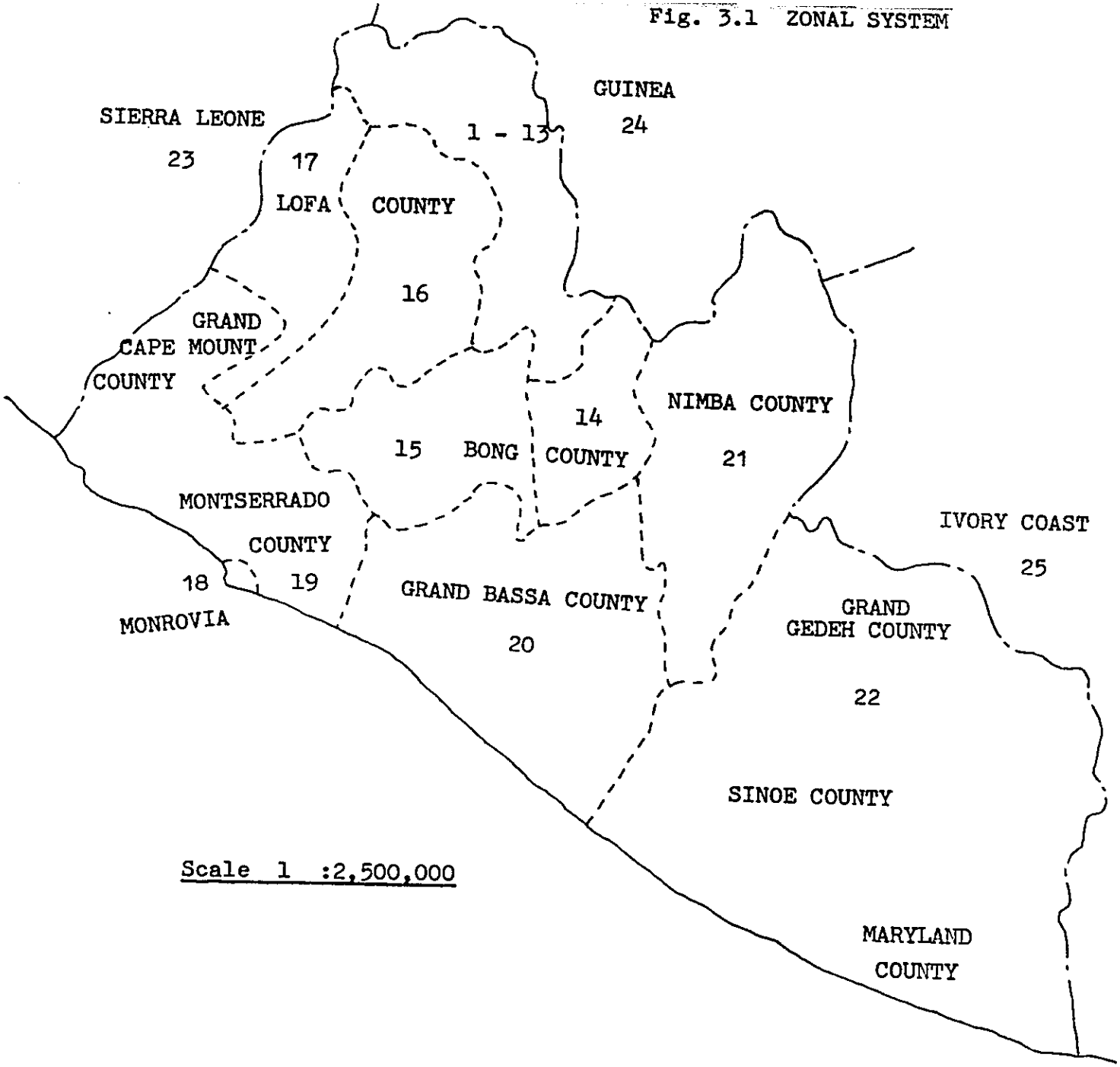


Table 3.1 Zonal Division

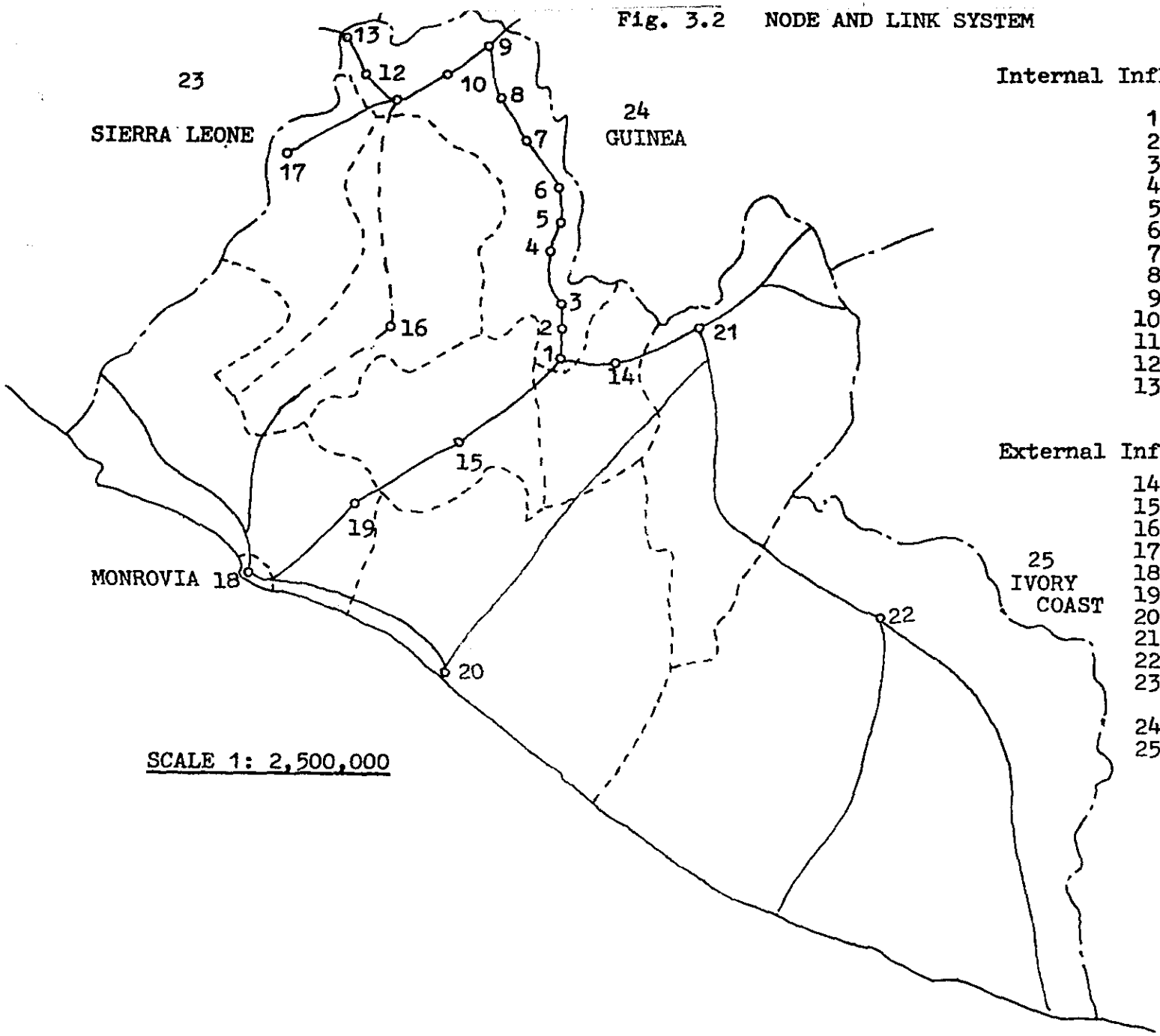
Z o n e	C l a n	District	County
	Internal Influence A r e a		
1	Jorquellie	Gbarnga	Bong
2	Jorpool	"	"
	Kporyorquellie	"	"
3	Zota	"	"
	Kpaquellie	"	"
	Wruhan	Panta	"
4	Gbarlin	Zorzor	Lofa
5	Palama	"	"
6	Gizima	"	"
	Vavala	"	"
7	Ziama	"	"
8	Bondi	Voinjama	"
	Wy-Wome Gomai	"	"
9	Upper Worker	"	"
	Wy-Wome Gamai	"	"
10	Lower Worker (LISCO Camp)	"	"
11	Wulukoha	Kolahun	"
	Tahamba	"	"
12	Rankolle	"	"
	Wuam	"	"
13	Tangai	"	"
	External Influence A r e a		
14	Bellequellie	Gbarnga	Bong
	Gbarnshy	"	"
	Shean-Sue	"	"
	Panta	"	"
	Waytua	"	"
	Wolota	"	"
	-	Kokoya	"
15	Kpatawee	Gbarnga	"
	Suakoko	"	"
	Zeansue	"	"
	Garyea	"	"
	Yaidawon	"	"
	-	Sanoyea	"
	-	Salala	"
16	Lucasu	Kolahun	Lofa
	Yarweyahun	"	"
	Buluyema	Zorzor	"
	-	Belle	"
	-	Gbokomu	"
	-	Bopolu	"

.../2 ...

Table 3.1 Zonal Division

Zone	Clan	District	County
	External Influence Area (Continued).../2		
17	Hassala	Kolahun	Lofa
	Tangai	"	"
	-	Guma	"
	-	Gbama	"
18	-	"	Monrovia
19			Grand Cape Mount
	-	-	Montserrado
20	-	-	Grand Bassa
21	-	-	Nimba
22	-	-	Grand Gedeh
		-	Sinoe
	-	-	Maryland
23	-	-	Sierra Leone
24	-	-	Guinea
25	-	-	Ivory Coast

Fig. 3.2 NODE AND LINK SYSTEM



Internal Influence Area

1. Gbarnga
2. Wenshu
3. Belefuanai
4. Golu
5. Salayea
6. Zorzor
7. Konia
8. Jayama
9. Voinjama
10. Kpakuta
11. Kolahun
12. Foya
13. Mendikoma

External Influence Area

14. Palala
15. Totota
16. Belle Yalla
17. Vahun
18. Monrovia
19. Kakata
20. Buchanan
21. Ganta
22. Zwedru
23. Sierra Leone
24. Guinea
25. Ivory Coast

3.2 Population

Two population censuses are available concerning the size and distribution of the population in Liberia. The first census was conducted in 1962, the results of which were summarized in accordance with three territorial divisions, while the second census, or the latest one, was carried out in 1974, which was compiled in accordance with newly established 14 political sub-divisions of the country.

Total population of the internal influence area was 104,500 in 1962 and increased up to 154,600 in 1974. Although there is inconsistency in the compilation of the two population census including revisions of area size, the results are considered to be used as an indicative one when compared. Assuming that the population in the internal influence area grew at 3.3% per annum, the same rate of growth during 1962 - 1974, the total population is estimated to attain 180,000 in 1979.

In the internal influence area, population growth is different between two counties, Bong and Lofa. Population included in Zone-1 to Zone-3, or in Bong County increased relatively high rate of 5.3% per year during 1962 - 1974, while that of Lofa County, Zone-4 to Zone-13 grew at lower rate of 2.8% per year. This difference indicates some relationship between the regional development and the transportation or easy accessbility.

The population in the external influence area also increas at the same rate of 3.3% during 1962 - 1974, which is identical to the growth of national population. Monrovia City showed the very high rate of growth in the population, which was estimated at 8.0% per year affected by the immigration from the rural areas.

Projection of future population in the influence area will be made in detail, taking into account the expected regional development potential including agricultural development and mining in the further study at home. In this report, the population in all the influence area is assumed to increase at around 3.5% per year during the next decade, slightly higher than the past trend, only for preliminary traffic forecast.

Table 3.2 Population Growth by Zone

Zone No.	1962 '000	1974 '000	Average Annual Growth Rate(%) 1962-1974
1	5.0	10.7	6.5
2	5.2	8.5	4.2
3	10.3	18.7	5.1
4	2.2	5.1	7.3
5	3.3	3.6	0.7
6	15.6	24.1	3.7
7	6.3	11.3	5.0
8	6.3	10.3	4.2
9	12.3	19.2	3.8
10	4.4	6.1	2.8
11	12.3	14.2	1.2
12	18.6	20.1	0.6
13	2.7	2.7	0
	Internal	Influence Area	
	104.5	154.6	3.3
14	40.5	51.1	2.0
15	96.1	105.3	0.8
16	34.1	37.6	0.8
17	23.9	26.4	0.8
18	81.2	204.2	8.0
19	169.0	292.4	4.7
20	128.3	151.1	1.4
21	160.3	249.7	3.8
22	178.5	231.0	2.2
	External	Influence Area	
	911.9	1,348.8	3.3
Liberia Total	1,016.4	1,503.4	3.3

3.3 Land Use

The influence area covers most of the Upper Lofa County and part of the Upper Bong County with a total area of 790,000 ha (or 7,900 km^2). The land use is classified by natural forest area, secondary forest[1/] and food crops area, tree crop and rubber plantation area and other areas[2/].

The natural forest is mainly located in Upper Lofa County along the road from Salaye up to the Lofa River. Most of the other areas than the natural forest, are used for shifting cultivation of food crops with the interval of 5-10 years. Rubber is planted mostly in upper Bong and southern part of Upper Lofa. The intensity of the land use in the influence area is relatively high compared with other parts of the counties and other regions. Particularly, in such highly populated area as Zorzor, Voinjama, Kolahun and Foya agricultural production is conducted with intensive land use. Indicative land use figures are presented below.

Land Use in the Influence Area

Item	Area (ha)	%
Natural Forest[3/]	241,000	30.5
Secondary Forest and Food Crops	494,200	60.6
Tree Crop and Rubber	15,300	1.9
Others	39.500	5.0
Total	790,000	-

1/ Used mainly for shifting cultivation.

2/ Other areas included roads, rivers and residential areas and be assumed at 5% of the total area.

3/ Includes concession area and unprotected forestry.

3.4 Agriculture

Agriculture is the most important economic sector in the influence area in which about 74% of the total population is working. The agricultural activity is characterized by the following three different types of farming system.

(1) Concession farms and plantation
(2) Liberian commercial farms and plantation
(3) Traditional farms

The concession farms are large, mainly foreign owned enterprises and are operated on land leased from the Government. In the influence area only logging companies are operating under this system.

Liberian commercial farms are primarily engaged in rubber production, but also include significant acreage of cocoa,coffee, oil palm and vegetables, and some poultry and livestock breeding. The size of the farms ranges from 2 ha to 500 ha.

Traditional farms are, in general small less than 5 ha and are cultivated by thousands of small-holders. Most of the food crops such as rice, cassava and a part of those cash crops like coffee, cocoa and oil palm in the influence area are produced by these farms.

The Lofa County and Bong County, where the project road is located, are well endowed with agricultural products in Liberia, producing about 40-60% of rice, coffee, cocoa and palm kernels in the nation. There are still enough agricultural potential lands available in these counties, which are now under shifting cultivation or forestry. For the exploitation of these agricultural potential, the Liberian Government has embarked on

integrated rural development projects both in upper Lofa County and Upper Bong County since 1976. Both projects aim to increase the agricultural production and welfare of small Liberian farmers through providing new agricultural technology together with supplying physical and institutional infrastructures including feeder roads development, cooperative and credit, and health program. By these projects significant impacts are expected to be given not only to the agricultural and regional development in the area, but also to the regional traffic.

Upper Lofa County Agricultural Development Project (LCADP)

The LCADP is located in Upper Lofa County with the total area of 3,300 km^2, all of which is included in the influence area of the Gbarnga-Mendikoma Road. About 14,000 farm families (or 71,000 of farming people) live in the LCADP area. The LCADP agricultural service package consists of improved cultivation methods, farm inputs, farm credit, agricultural cooperatives, marketing, banking and health monitoring. To support the agricultural development, th LCADP also includes road improvement, which consists:

a) upgrading and maintenance of the primary road, linking Foya to Zorzor and 500 km of existing feeder roads, and

b) construction of 100 km of new feeder roads.

The project was commenced in 1976 and part of these roads improvement works are now under way by the Ministry of Public Works. The LCADP aims to increase agricultural products through improving the existing cultivation and development of the non-cultivating area, and focuses its development on upland rice, swamp rice, coffee and cocoa.

The expected annual incremental agricultural productions in the LCADP area are 10,900 tons of rice, 2,500 tons of coffee and 1,800 tons of cocoa. All the products of the coffee and cocoa are purchased by LPMC through respective cooperatives established in the districts, and brough to Monrovia for exports. Although a part of rice is consumed by the farmers, the residuals are purchased by LPMC through the cooperatives and be brought to local markets and other regions including Monrovia.

Upper Bong County Agricultural Development Project (BCADP)

Following the successful commencement of the LCADP, BCADP started in 1978, jointly financed by IDA/USAID. The BCADP has a total area of 6,500 km^2 with a population of about 19,000 farm families (or 98,000 farming population). A part of the BCADP area, about a quarter of the total area, is included in the influence area of our project road, which consists of Gbarnga and Panta Districts. Agricultural package to be provided by the BCADP are almost same as that of the LCADP which includes both farming technics and institutional ones. The feeder roads improvement are also included in the BCADP, which are:

a) new construction of 170 km farm to market roads,

b) improvement in the existing 130 km of farm to market roads, and

c) maintenance of about 540 km of the feeder roads.

The BCADP also emphasizes the development of such food crops and tree crops as rice, coffee and cocoa. Annual incremental agricultural productions to be expected in the whole BCADP area will be 8,740 tons of rice, 3,000 tons of cocoa and 1,500 tons of coffee at the full

development stage. All the products of cocoa and coffee are purchased by LPMC mainly through local traders since cooperatives are not well established and not functioning as a buying agent, and brought to Monrovia. Rice is mostly consumed locally, but residuals are brought to local market and other regions through local traders.

3.4.1 Food Crops and Tree Crops Production

(1) Present Production

As mentioned above, the influence area of the Gbarnga-Mendikoma road includes all the LCADP area and a part of the BCADP area. Therefore, present production of major crops in the influence area included in the two project areas is firstly estimated on the basis of their current production estimate refering to LPMC purchased volume of the products. Then, those products in the influence area outside the two projects are estimated in due consideration of the farming population, their average holdings and cropping pattern. The estimated products in the influence area are 32,250 tons of rice, 1,800 tons of coffee, 1,500 tons of cocoa and 3,500 tons of oil palm (fresh fruits bunch), which are summarized in the following table together with their cultivated areas.

Current Crop Production in the Influence Area

Crops	Area (ha)	Products (Tons)
Upland Rice	29,900	27,440
Swamp Rice	3,700	4,810
(Sub-Total	(33,600)	(32,250)
Coffee	6,500	1,800
Cocoa	5,400	1,500
Oil Palm	700	3,500 1/

1/ = Fresh fruits bunch.

Source: LCADP, BCADP, LPMC (Voinjama) MOA

(2) Surplus Production

Surplus production of the major crops in the influnece area is estimated on the following assumptions:

1. Per-capita consumption of rice is 100 kg. in the area.
2. All the products of coffee and cocoa are sold to the market.
3. Per-capita consumption of red oil is 13 kg. and all palm kernels is sold to the market.
4. Other food crops such as cassava, corn, and sugar cane are mostly consumed by farmers themselves and the marketed volume is negligible.

Crop	Marketable Surplus (Tons)
Rice	2,250
(Clean Rice)	(1,350)
Coffee	1,800
Cocoa	1,500
Palm Kernel	900
T o t a l	6,450

(3) Future Production Estimate

Future production estimate of the major crops in the influence area is preliminarily made mainly on the basis of the forecasted yield increase and expansion of newly cultivated land prepared by LCADP and BCADP and their current progress. At the full development stage (around 1987-1988) of the both project, total crop production in the influence area will be as follows:

Rice	52,000	Tons (Paddy)
Coffee	4,000	"
Cocoa	3,000	"
Oil Palm	17,000	"(Fresh Fruit Bunch

Although this is only a preliminary one and detailed calculation of the production forecast will be made in the next stage, these figures can show the expected tendency in the production. From this production estimate, the expected marketable surplus is calculated assuming that the population increase in the influence area will be around 3-4% per year. Based on these figures, the expected growth rate of the marketable surplus is estimated at 9-12% for the next ten years.

3.4.2 Rubber

In the influence area, rubber is planted mostly along the Gbarnga - Zorzor section. Total area of the rubber farms is estimated at around 2,650 ha. on the basis of the previous study[1/] and the recent information from Liberian Rubber Development Unit (LRDU). All the rubber farms are owned by Liberian, which are Liberian commercial farms or traditional farms, and are in general, small in the scale. (Only two farms are operating with more than 200 ha.)

Since there is no continous production records of the farms, annual production of rubber in the influence area is estimated on the basis of the information from farmer's interview and LRDU with the following assumptions:

1/ = Feasibility Study of the Liberian-owned Rubber Industry, 1975.

1) About 30%[1/] of the rubber farms is now under tapping.

2) Yields[2/] are 0.8t/ha and 0.3t/ha for plantation farm and small holder farm, respectively.

The estimated current annual production of rubber is around 370 tons in the influence area.

Most of the products are sold to the Liberian Processing Corporation at Gbarnga in the form of specification and non-specification coagulum. Larger farms like the TolbertFarm sell their products to the Firestone in the form of latex.

In order to strengthen the Liberian-owned rubber industry, a rubber development project is being implemented under IBRD finance. Included in the project are Marshall and Bomi Territories, Montserrado, Grand Bassa, Bong and Nimba Counties. The rubber project plans to improve the income and welfare of small and medium farmers, and increase exports through replanting of 16,000 ha of old rubber and rehabilitation of 9,500 ha of matured untapped rubber. About two thirds of the rubber farms within the influence area are included in the IBRD project.

Estimate of future production is rather difficult since rubber production is quite sensitive to the international price changes. However, for the calculation of future traffic rubber production estimate in the future is roughly made in due consideration of the IBRD project with the following assumptions:

1) The present area of the rubber farms will not change in the future.

1/ = Agricultural Census, 1971

2/ = Specification or non-specification coagulum.

2) About 13% of the existing farm will be replanted during next 5 years.

The estimated annual production is around 1,000 tons of coagulum at the full development stage. Annual increase rate of the rubber production will be around 6%.

3.5 Forestry

As discussed in Chapter II, the role of forestry and forestry industries in the national economy has been increasing very rapidly since late 1960's. During 1970-1978, total products of forestry increased at an annual average rate of 17.0%, and attained 774,600 m^3 in 1978. Total forest area in Liberia is around 25,000 km^2 which includes 16,000 km^2 of the national forest area and 9,000 km^2 of unprotected forest area, and 33 foreign-owned concessions are operating with forest products utilization contracts.

In the influence area of the Gbarnga - Mendikoma road, two national forest, namely North Lorma National Forest (between Zorzor and Voinjama section) and Lorma National Forest (between Gbarnga and Zorzor) exist along the road. Total forestry area of the influence area is around 2,400 km^2. Three logging companies, ALTCO, DLC and VLC acquired concessions, out of which only two, ALTCO and VLC, are operating at present.

	ALTCO (Associated Liberian Timber Corp.	VLC (Varjam Logging Corporation)
Date of Establishment	1975	1974
Date of Operation	1976	1975
Concession (ha)	71,200	76,900
Processing Facilities	One Sawmill	-
Current Annual Production(1978) (m^3)	14,413	344

Source = Forestry Development Authority

Total forestry production in the influence area is around 15,000 m^3, which includes 9,000 m^3 of sawn timber processed at ALTCO sawmill in Luyema, Lofa County, and 6,000 m^3 of logs. Most of the logs and timber produced in the influence area are being carried by road to Tropai, Nimba County through the project road, and are brought to Buchanan using LAMCO line. Only the produced timber is transported to Monrovia by road, which are being used for local consumption. Production trend of the forestry products by the two concessions in the influence area is presented below.

(m^3)

Year	ALTCO	VLC	Total
1975	-	-	-
76	4,813	N/A	4,813
77	12,606	574	13,176
78	14,413	344	14,757

According to the information gained from interviews with the logging company (ALTCO) and the data of the national forestry inventory[1/], the most important timber areas are located in the southeast region of the country and available forest in the northwest region (the influence area is located) is poor in good species for export and quantities of logs with exploitable diameter. Furthermore, topographical condition is not so attractive with rough terrain and major portion of the forestry lies in far away from the existing highways.

Production prospect in future would not be so bright, if the environmental aspects mentioned above will not be changed. However, the following factors shall be taken into account for the estimate of future forestry production under with - the - road - project condition.

1) Project road will reduce transport cost considerably, which will make it feasible to exploit relatively uneconomic forestry at present.

2) Development of the Wologisi mine increase demand of local consumption.

3) Belle-Yella-Kolahun road now under detailed design, will facilitate the forestry development by shortening, the access in the influence area.

1/ = National Forestry Inventory in Liberia, 1968

Although detailed calculation for the future production of the forestry will be made in the study at home in due consideration of the above factors and also world market situation, the production for local consumption is expected to grow at comparatively high rate with the road improvement project. But the products for export will grow slowly or stagnate. This expectation of future production is already traced by the current production trend in the influence area that the share of the local timber increased rapidly from 10% in 1976 to 70% in 1978 and the production for export stagnated.

3.6 Mining

In the influence area, there exists a potential iron ore, the Wologisi Iron ore, the feasibility study for which is now underway. According to the plan about 4 million tons of iron ore will be produced at the first stage and later increased to 7 million tons. The development of the iron ore is expected to give substantial impacts both on regional economy and national economy in view of its dominant share in GDP. Impacts on employment cannot be neglected i.e. around 2,500 local people and 1,500 expatriates are to be involved during the peak construction period.

Traffic on the project road is also considered to be affected by the iron ore development from the stage of construction. Even the transportation of the exploited iron ore be carried by another mode like pipe line or another route, regional development induced by the iron ore exploitation will affect the traffic in the influence area. The detailed study will be made

in the next study stage at home fully taking into account the results of the feasibility study for the Wologisi development.

IV. TRAFFIC SURVEY AND PRELIMINARY ANALYSIS

4.1 General

Before starting traffic survey on the project road, review on the available data and information concerning the traffic was made. Particularly, recent traffic survey records conducted by Ministry of Public Works in June, 1978 were checked in detail together with the survey methods including zoning system and investigation period.

The purpose of the traffic survey is to quantify and classify present vehicle movements on the roads under study. For this object, classified vehicle counts, and origin and destination surveys were conducted at different stations under the schedule and procedures presented in Fig. 4.1 and Table 4.1

The location of the station is listed below.

Station 1:	Gbarnga	(about 100 m from the intersection toward Voinjama)
Station 2:	Belefuanai	(about 300 m after Belefuanai toward Zorzor
Station 3:	Zorzor	(1 km before Zorzor from Belefuanai)
Station 4:	Voinjama	(Immigration gate before Voinjama)
Station 5:	Voinjama	(300 m after Voinjama toward Kolahun)
Station 6:	Kolahun	(500 m before Kolahun from Voinjama)
Station 7:	Kolahun	(200 m after Kolahun toward Mendikoma)
Station 8:	Mendikoma	(100 m before Immigration gate).

Fig. 4.1 LOCATION OF TRAFFIC SURVEY STATION

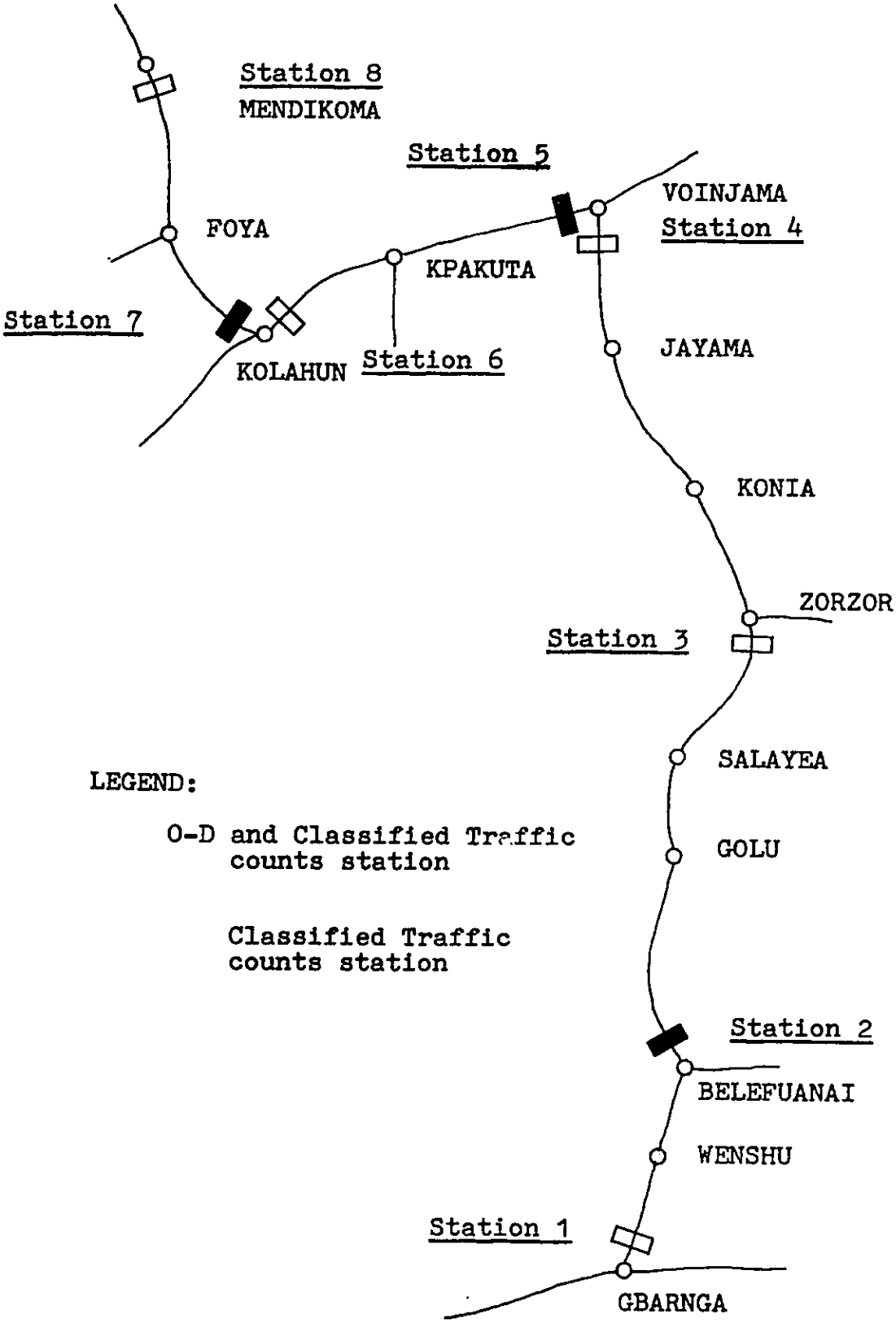


Table 4.1 Traffic Survey Schedule

Station No. and Location	J U L Y (7:00 A.M. TO 7:00 P. M.)						
	9 MON	10 TUE	11 WED	12 THU	13 FRI	14 SAT	15 SUN
Station 1 Gbarnga	TC	TC	TC	OD	TC	TC	TC
Station 2 Belefuanai	TC	TC	TC	TC	TC	TC	TC
Station 3 Zorzor	TC	TC	TC	OD	TC	TC	TC
Station 4 Voinjama 1	TC	TC*	TC	OD	TC	TC	TC
Station 5 Voinjama 2	TC	TC	TC	TC	TC	TC	TC
Station 6 Kolahun 1	TC	TC	TC	OD	TC	TC	TC
Station 7 Kolahun 2	TC	TC	TC	TC	TC	TC	TC
Station 8 Mendikoma	TC	TC	TC	OD	TC	TC	TC

TC = Classified Traffic Counts

OD = Origin and Destination Survey

* = 24 Hours Classified Traffic Counts

Discussions were held between JICA Survey Team and the staff of Planning and Programming Division, Ministry of Public Works regarding the above. The selection of the location of the survey stations and the survey items on O-D were made to trace most of the zone to zone movement both within the internal influence area and between the internal and the external. Period of the survey was determined to be seven days for grasping the weekly fluctuation of the traffic. Although the survey time was already in wet season, the rain was not so heavy with only short time shower and the survey was conducted under relatively fine weather condition.

4.2 Traffic Count

Classified traffic counts were carried out on 8 stations for one week starting from July 9 as 12 hours counts from 7:00 a.m. to 7:00 p.m. In the survey the present traffic was classified into 7 types of vehicle i.e., car, taxi, pick-up and bus for passenger traffic and light truck, heavy truck and trailer for freight traffic. The results of the classified traffic counts are summarized in the following table and actual counts records from 7:00 a.m. to 7:00 p.m. by station, by day and by direction are presented in Appendix.

Result of Classified Traffic Counts
(From 7:00 a.m. to 7:00 p.m.)

Station	Car	Taxi	Pick-up	Truck	Total
1. Gbarnga	42	26	163	36	268
2. Belefuanai	32	14	82	19	146
3. Zorzor	27	23	98	31	179
4. Voinjama 1	59	77	249	80	465
5. Voinjama 2	76	29	209	46	360
6. Kolahun 1	48	59	229	42	378
7. Kolahun 2	33	43	223	25	324
8. Mendikoma	14	37	114	17	182

The traffic volumes exclude the number of vehicles travelling short distance (less than a mile). 24 hours classified traffic counts were also carried out on station No.4 to expand the 12 hours counts to 24 hours traffic by type of vehicle.

The claculated expansion factor is presented in the following table. Since the 24 hours count covers only one day, the results of the previous survey conducted by Ministry of Public Works in 1978 were used to supplement our results.

Finally, the expansion factor is estimated by calculating the average of the present survey data and the previous ones which are summarized in the table below.

Expansion Factor for ADT

Survey	P-Car	Taxi	Pick-up	Truck
1979 Survey	1.13	1.12	1.19	1.25
1978 Pre-F/s[1/]	1.39	1.28	1.26	1.44
Average	1.26	1.20	1.23	1.35

1/ = The expansion factors of pre-feasibility study were calculated by making average of each station excluding some extraordinary ones.

The estimated expansion factor that the day-time traffic from 7:00 a.m. to 7:00 p.m. is around 80 - 83% for passenger car, taxi and pick-up, and relatively lower of 74% for truck.

The average daily traffic volumes (ADT) by type of vehicle, by station are estimated by applying these expansion factors as shown in the following table.

Estimated Daily Traffic Volumes

Station	Car	Taxi	Pick-up	Truck	Total
1. Gbarnga	53	31	200	49	333
2. Belefuanai	40	17	101	26	184
3. Zorzor	34	28	121	42	225
4. Voinjama 1	74	92	306	108	580
5. Voinjama 2	96	35	257	62	450
6. Kolahun 1	60	71	282	57	470
7. Kolahun 2	42	52	274	34	402
8. Mendikoma	18	44	140	23	225

Note: Subject to minor change after the detailed analysis at home.

During the survey period, very few mini-buses were identified on the project road. Since they have almost the same axle loads identical physical characteristics and then use is incidental to the use of pick-up, the mini-bus is classified in the group of pick-up.

Since there exists no appropriate data or information regarding seasonal fluctuation of the traffic, no adjustment was made on the estimated ADT. In the stage of the detailed study at home, all the relevant information including seasonal valuation of agricultural products and gas consumption will be checked, the results of which are to be taken into account for the final estimate.

4.3 Origin and Destination Survey

Main objectives of the origin and destination survey are to collect data on:

1) Traffic pattern by O-D pairs and vehicle type
2) Traffic pattern by O-D pairs and type of goods carried.
3) Traffic characteristic such as type of fuel, purpose of trip and occupancy.

4.2.1 Survey Procedure and Data Compilation

Five stations were selected out of eight stations, where the O-D survey was carried out in the procedure as presented in Table 4.1. Only motor vehicles were stopped and the drivers interviewed by means of the questionnaire. The sample size of the O-D survey was 100% at all stations over the 12 hours (7:00 a.m - 7:00 p.m.) survey.

In order to avoid duplication in the preparation of O-D matrix the vehicles once stopped for interview were not stopped again at the following stations. The collected data were processed and compiled into the following matrices for trips between zones of origin and zones of destination.

1) Matrix for the number of trips with car.
2) Matrix for the number of trips with taxi.
3) Matrix for the number of trips with pick-up.
4) Matrix for the number of trips with trucks.

Since the O-D survey covers only one day records from 7:00 a.m. to 7:00 p.m., the O-D matrices thus compiled were modified by applying weekly variation factors and the expansion factors for ADT. The weekly variation

Table 4.2 - Origin-Destination Matrix

O \ D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
1		10	11	1		11	4		24		6	2	1		1			2								73
2	22														1			1								24
3	16														3			2	1							22
4						1																				1
5	3					16	1		1									1								22
6	5			1	6				56		7	3						9	1							88
7	5								10						1			1								17
8									84									2								86
9	29				3	62	3	57		114	51	38					5	41	2	4	1					410
10									137		90	4					3									234
11	2					4			52	88		156	6				7	13					2			330
12	2								33	8	93		28					13					64			241
13											3	22						5								30
14																										0
15	1	1	3				1																			6
16																										0
17									5	3	8							2								18
18		1	1		2	11	4		35		16	12	1										2			85
19			2			3			4			1														10
20												1														1
21							1		1																	2
22																										0
23	1								1		12	67						2	1							84
24																										0
25																										0
Total	86	12	17	2	11	108	14	57	443	213	286	306	36	0	6	0	15	94	5	4	1	0	68	0	0	1,784

factors to be applied for the adjustment of the matrices were calculated by making averages on those of the all stations, as presented below.

Weekly Variation

Station	Car	Taxi	Pick-up	Truck
1. Gbarnga	1.11	1.24	1.20	0.52
2. Belefuanai	1.68	1.17	0.92	1.00
3. Zorzor	0.93	1.21	0.87	0.46
4. Voinjama 1	0.87	3.85	1.15	1.23
5. Voinjama 2	0.96	0.76	0.98	1.07
6. Kolahun 1	1.09	1.97	0.97	0.93
7. Kolahun 2	0.84	1.03	0.09	0.81
8. Mendikoma	2.80	0.84	1.41	1.00
Average	1.29	1.51	1.07	0.88

$$\text{Weekly Variation Rate} = \frac{\text{Average traffic volume for 7 days (12 hours)}}{\text{Traffic volume on O-D survey time (12 hours).}}$$

The estimated total O-D matrix is summarized in Table 4.2 and O-D matrices for different type of cars are presented in Appendix.

In the detailed study at home the estimated O-D matrices will be checked again taking into account the estimated food crops productions, rubber and forestry products, and production of other economic sectors. Traffic forecast in the future will be carried out on the basis of the refined O-D matrices.

4.4 Traffic Characteristics

Although in-depth study and analysis concerning traffic characteristics will be made in the study at home, preliminary results are summarized from the O-D survey sheet.

(1) Cargo Carried by Truck

The type of cargo carried by truck and trailer is presented in the following Table. High percentage of empty truck is a significant characteristic of the road transport. This preliminary results are partly used for the future traffic estimate in this report.

Type of Cargo Carried by Truck

Type of Goods Carried	% of Freight
1. Empty	53%
2. Fuel	6 %
3. Logs	2 %
4. Sawn Timber	2 %
5. Rubber	1 %
6. Agricultural Crop & Products	14 %
7. Consumer Goods	11 %
8. Construction Materials	8 %
9. Mix	3 %
T o t a l	100%

(2) Average Number of Persons Per Vehicle

Average number of persons per vehicle is calculated for each station by type of vehicle as summarized in the following table. The estimated occupancy rates for cars ranged from 2.3 to 4.0 with an overall average of 3.2, while the occupancy rates for taxis is slightly higher

ranging from 5.3 to 6.3 with an average of 5.9. The occupancy rate for pick-ups is very high with an average of 10.6 and that for trucks is 4.7.

Average Number of Persons per Vehicle

Station	Cars	Taxis	Pick-ups	Trucks
1. Gbarnga	3.4	6.0	11.4	2.8
3 Zorzor	4.0	5.8	10.4	3.8
4. Voinjama 1	3.4	5.3	11.0	6.5
6. Kolahun 1	2.8	6.3	8.8	6.1
8. Mendikoma	2.3	5.9	11.6	4.3
Total	15.9	29.3	53.2	23.5
Average	3.2	5.9	10.6	4.7

4.5 Preliminary Traffic Projection

4.5.1 Existing Traffic by Section

On the basis of the O-D matrices adjusted by ADT, present traffic volume on each homogeneous road section is calculated. For the calculation, all the short distance traffic and the traffic within the same zone are excluded.

The estimated traffic volume for representative, five sections is presented in the following table. (Detailed calculation of the present traffic on each homogeneous road section will be made in the further study at home).

Present Traffic[1/] by Road Section

Road Section	Vehicle Type				
	Car	Taxi	Pick-Up	Truck	Total
1. Gbarnga-Wenshu	50	30	200	50	330
2. Salayea-Zorzor	30	30	120	40	220
3. Jayama-Voinjama	70	90	310	110	580
4. Kpakuta-Kolahun	60	70	280	60	470
5. Foya-Mendikoma	20	40	140	20	220

4.5.2 Preliminary Projection

Preliminary projection of the future traffic on the project road is made on the following assumptions:

1) Growth rate of regional product in real terms is about 4.5-6.5% per annum.
2) Per-capita income growth is 2.0-3.0% per annum in the influence area.
3) Population increase per year in the influence area is 3.0-3.5% slightly higher than the previous record (3.3% during 1962-1974).

1/ Figures are rounded.

4) Income elasticity of traffic demand is 1.5 .
5) Selection of transport mode will follow the present pattern.

(1) Passenger Traffic

Projection of passenger traffic in the future is made on the basis of the projected population growth and per-capita income growth with income elasticity. For the projection, it is assumed that the present pattern of the traffic will not change and passenger traffic includes car, taxi and pick-up. The estimated traffic in the future on the representative sections is presented in Table 4.3.

(2) Cargo Traffic

Projection of the cargo traffic on the projected road is made on the basis of the forecasted production growth rates for different commodity groups and the present cargo composition assuming that traffic pattern follows the present pattern. For the preliminary projection, the effect of the Wologisi mine on the traffic is not taken into account, which will be studied in detail during the detailed study and analysis at home.

Projected cargo traffic together with the passenger traffic on the representative sections is presented in the following table.

Table 4.3 Future Normal Traffic by Road Section

Road Section	Vehicle Type	1979	1985	2000
1. Gbarnga - Wenshu	Car	50	80	200
	Taxi	30	50	120
	Pick-up	200	320	820
	Truck	50	80	170
	Total	330	530	1,310
2. Salayea - Zorzor	Car	30	50	120
	Taxi	30	50	120
	Pick-up	120	190	490
	Truck	40	60	130
	Total	220	350	860
3. Jayama - Voinjama	Car	70	110	290
	Taxi	90	140	370
	Pick-up	310	490	1,270
	Truck	110	170	370
	Total	580	910	2,300
4. Kpakuta - Kolahun	Car	60	100	250
	Taxi	70	110	290
	Pick-up	280	440	1,150
	Truck	60	90	200
	Total	470	740	1,890
5. Foya - Mendikoma	Car	20	30	80
	Taxi	40	60	160
	Pick-up	140	220	570
	Truck	20	30	70
	Total	220	340	880

4.5.3 Generated Traffic and Diverted Traffic

The traffic in the future estimated in the preceding section is the normal traffic or the expected traffic on the project road under the condition that no improvement will be made during the study period but with necessary maintenance works to keep the road in the present condition.

Besides the above, development of some traffic or generated traffic is expected by the improvement of the existing road. The generated traffic caused by considerable reduction in vehicle operation cost will be studied in detail both for passenger traffic and cargo traffic in the study and analysis at home.

Diverted traffic will also be studied in the next stage, fully taking into account the possible diversion from local air transport and the Belle Yella-Kolahun road to be constructed or diversion from the project road to the Belle Yella-Kolahun road.

V. ENGINEERING SURVEY

5.1 Present Road Condition

5.1.1 General Concept

The first section, Gbarnga-St. Paul River of the project road was constructed in 1954, the second section, St. Paul River-Foya was completed in 1958, and the section of Foya-Mendikoma is considered to be completed thereafter. Since then, the laterite pavement has been well maintained by Bong and Lofa Counties maintenance offices.

According to the existing drawings designed by Liberian Government's engineers, the road was designed to have the pavement width of 6.0 m (20 ft.), maximum gradient of 10% and design speed of about 50 km/hr. The running times from Gbarnga to Mendikoma with a length of 275 km are about six(6) to eight(8) hours.

Special characteristic of the project road is the laterite soil, a typical soil found in tropical areas. From the engineering survey, the laterite soil of the project road is understood as follows:

1) Generally, the laterite soil is very hard in dry season and fairly stable even in wet season.

2) Trafficability of the laterite road is influenced mainly by the character of other contained soils such as clay, silt, sand and gravel.

General findings on the laterite road condition during the engineering survey are briefly summarized hereunder.

Gbarnga-St. Paul Bridge

Before heavy rainy season, the road surface condition was fairly good, but during the heavy rainy season many pot holes were shaped caused by rain water on all of this sections and the surface of the shoulder became very slippery.

St. Paul Bridge-Zorzor

In the whole section from Gbarnga to Mendikoma, this section is most stable and reliable section in terms of the road surface condition, because the gravel laterite is well spread.

Zorzor-Voinjama

In addition to the poor alignment, many streches are covered by the clay laterite in this section, which makes the trafficability not sufficient after continuous rainy days. On the other hand, drivers and users suffered from uncomfortable shock by bumpy surface during dry season and even in the wet season if good day continues. Only Lofa River - Voinjama strech is maintained comparatively stable.

Voinjama-Kolahun-Mendikoma

The section from Voinjama to Kolahun is comparatively good, but in the next section from Kolahun to Foya, the laterite contains much clay soils and many pot holes are found on the road surface caused by rain water, but still maintain its traficability. The last section from Foya to Mendikoma is narrow in road width but fairly maintained in the road surface.

While, the peak of wet season is the latter part of August and the annual mean precipitation is around 2000 mm in the project road area.

The rainfall is characterized by its locality, or the rainfalls on the very limited areas of the road stretch. Even in the mid wet season, fine days continue for a few days that is an another characteristic of the rainfall in the project road area.

5.1.2 Horizontal and Vertical Alignments

Horizontal and vertical alignments were investigated by the inventory survey and the route selection survey, and the logitudinal profile survey. Results of these surveys were summarized in the inventory sheet presented in Appendix.

According to the results, improvement in the vertical alignment is considered to be more urgently required than that in the horizontal. Number of the road section with the gradient of more than 5% is 238 on the project road. About 41 sections of the road are of the steep gradients with more than 9%. Number of the road section with steep gradients is summarized as follows:

Road	5% < G < 7%	7% < G < 9%	9% < G
Gbarnga - Zorzor	61	24	14
Zorzor - Voinjama	45	20	15
Voinjama - Mendikoma	29	18	12
Total	135	62	41

Furthermore, deformation of the vertical alignment was identified during the field survey both for the cutting section and the embankment section. Caused by heavy rain and the maintenance work on the road, the road surface has been continously lowered which attain about 40 cm from the original height at the maximum.

Compared with the vertical alignment, the horizontal alignment is relatively fair. But there still exist about 194 places with steep curvature of less than 250m on all the road stretch. Around 33 road sections are with steep curvature of less than 150m. Number of the places with relatively steep curvature on the project road is summarized in the following table.

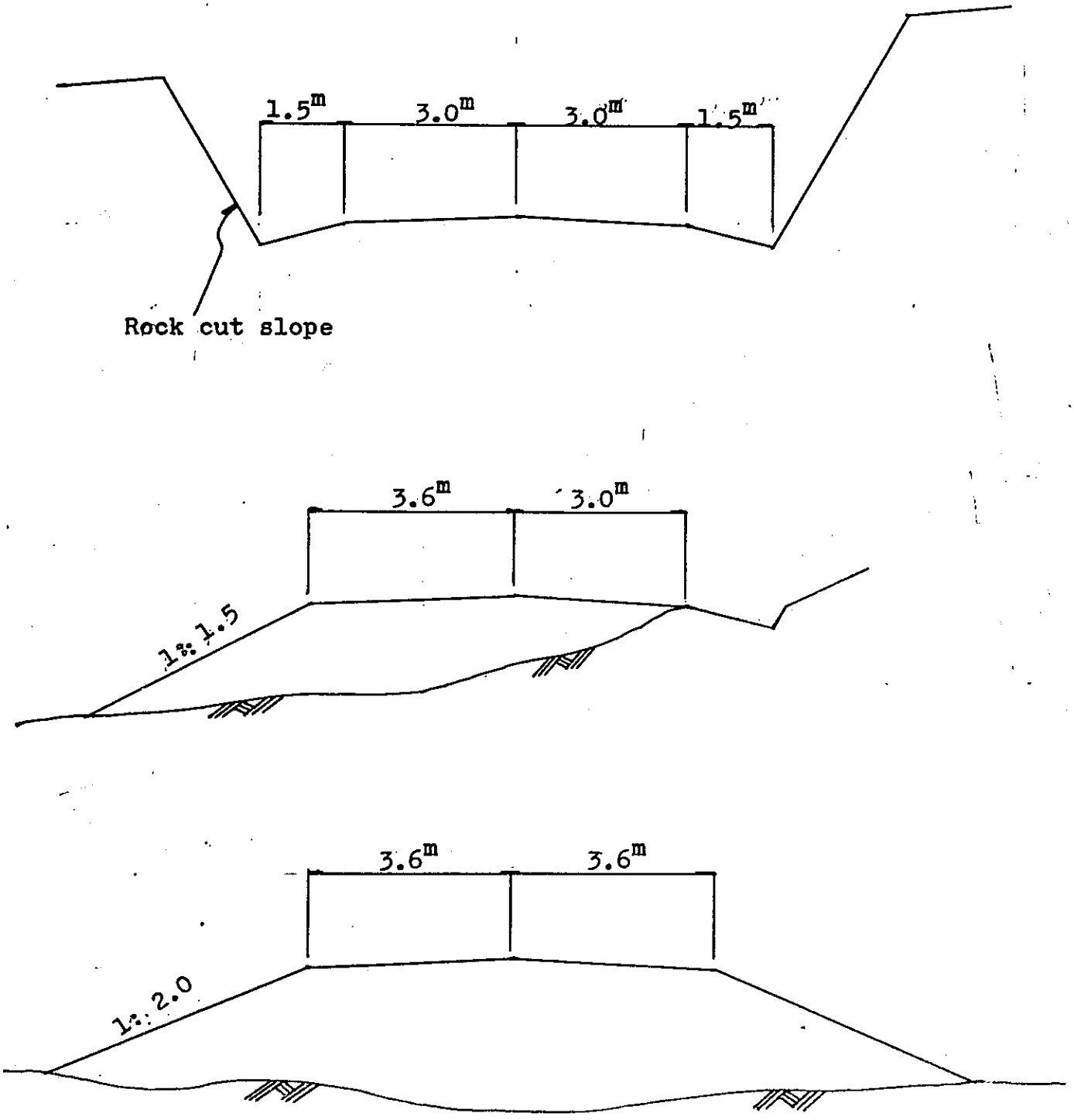
Road	R < 150	150 < R < 250	250 < R < 400
Gbarnga - Zorzor	7	52	88
Zorzor - Voinjama	22	70	67
Voinjama - Mendikoma	4	39	41
Total	33	161	196

There exist 29 bridges on the project road, of which six(6) are large bridge with the length of more than 45m. Almost all the bridges on the project road are generally in good condition and no replacement is considered to be required. However, study is to be made on the improvement in the maintenance work.

5.1.3 Cross Sections

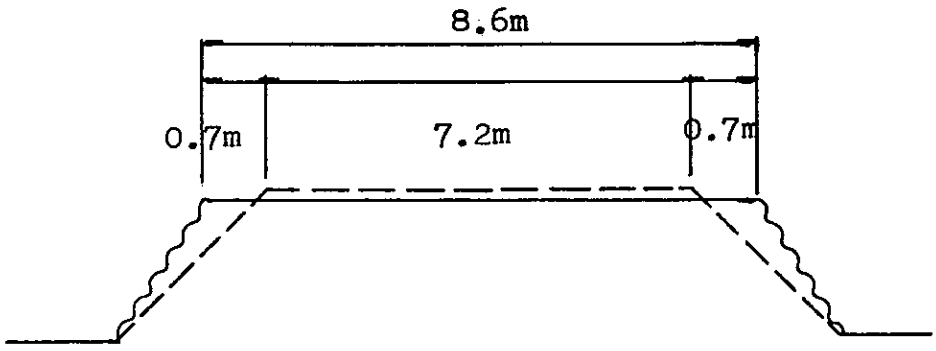
On the basis of the cross section survey, typical cross sections were pictured as presented in Fig.5.1. The effective carriage way of the road from Gbarnga to Kolahun is 7-12m in width. The carriage way width is, in general, relatively wider on the embankment portion but become narrower on the cutting section. From Kolahun the carriage way become narrower, particularly on the section between Foya and Mendikoma with the effective width of 5.5 - 6.5m.

Fig. 5.1 TYPICAL CROSS SECTION



As indicated above, most predominant feature of the embankment portion is enlarged carriage way width all over the project road as shown below.

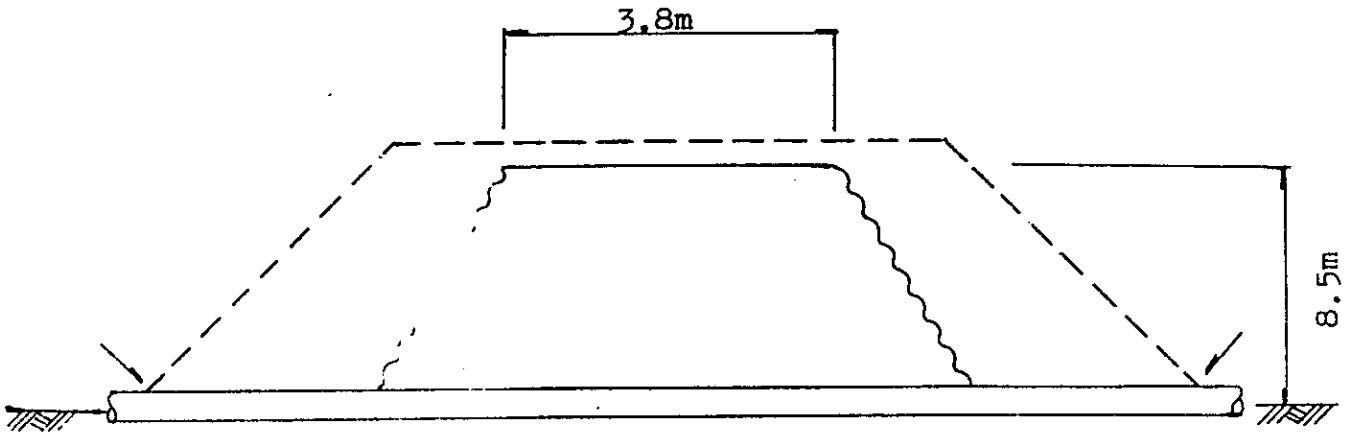
Widened Embankment Section



The embankment was originally constructed under the design with sufficient safety slope. Since then, the road width has been widened by about 1.4m and the slope of the embankment has become steeper caused by the regular maintenance works of the road surface.

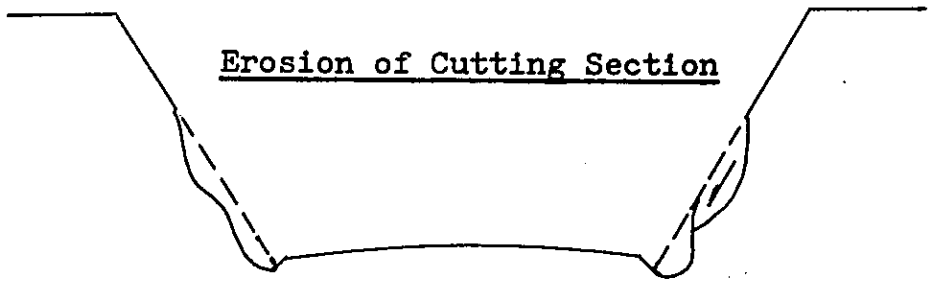
Erosion of the embankment was found on the limited section. Particularly, the high embankment section near St. Paul River Bridge was extremely eroded mainly by heavy rain and the road carriage way width shrank to about 3.8m, sufficient width for only one lane, as illustrated below.

Narrowed Embankment Section



The fact that the embankment has been eroded seriously was identified by the existing trace of the original embankment edge put on the culvert. For the preparation of the improvement plan, this kind of characteristics is to be fully taken into account.

On many portion of the cutting section, erosion of the cutting slope was found as illustrated below.



Erosion of Cutting Section

This was caused by the erosion of the side ditch. Identified number of those erosions on the cutting slope are 73 on all the project road with the following distribution.

Gbarnga	- Zorzor	6	Places
Zorzor	- Voinjama	31	"
Voinjama	- Mendikoma	36	"

For the improvement, the cutting section is to be widened by bench cut shape with about 0.7m wide step on the foot of slope.

5.1.4 Drainage Structures

Gbarnga-Zorzor

There are twelve(12) existing bridges from Gbarnga to Zorzor. Two(2) bridges (Mem Creek and St. Paul River) are of steel structure, and other 10 bridges are of concrete structure. There are no problems for the bridges

from the structural and hydraulic view points except that the slab surface concrete maintenance is required for the first bridge located at 11.0 km from Gbarnga.

Box and pipe culverts were checked and surveyed to analize the function which are fairly well maintained.

Zorzor-Voinjama

There are twelve(12) bridges of concrete structures from Zorzor to Voinjama. Five(5) of them are longer than 45m; the longest one is the Lofa River Bridge with 93.2m long, the second is the Loma River Bridge with 68.4m long; and Weaher River bridges are of 49.95m, 49.10m, and 47.6m long. All of the bridges are judged to have enough clearance from the field survey.

Several curverts were found on this section most of which are located under the exising ground level, but maintain drainage function fairly. To strengthen the drainage function, additional structures for inlet and outlet are to be considered for the improvement plan.

Voinjama-Mendikoma

In Voinjama-Mendikoma section, there exist five(5) bridges. The largest bridge is located near Mendikoma with 44.5m in length. The structural condition of these bridges are good.

Besides, boxes and pipe culverts are found, which are well maintained and kept their function good.

5.2 Soil Materials and Pavement Survey

5.2.1 Soil Material Survey and Test

As explained in the preceding chapter, soil samples were taken from thirty (30) points along the existing road. Number of the sampling points was determined in the manner that at least one soil sample could be picked up from the road stretch of about 8 km.

Soil samples taken from those survey points were brought to the Soil Laboratory of Ministry of Public Works, where soil tests were made for eight test items. All the tests were carried out in accordance with the AASHTO standard except CBR test for subgrade, which was tested according to the JIS-A1211[1/], a modified or simplified method of the AASHTO CBR test. For the material of the CBR tests for base course, the sample G-3 in Gbarnga area was mixed with the sample V-9 in Mendikoma area.

The list of the soil samples and laboratory tests is presented in Table 5.1 and the results of the test were shown in Table 5.2. Detailed analysis of the test results will be made in the further study at home.

5.2.2 Road Surface Test

In order to select the most optimum pavement design, the road surface test was conducted in the field. The test items and the survey points were as presented below.

1)	Field CBR test	16 Points
2)	Road surface deflection test	16 Points
3)	Sounding test	16 Points

1/: Japan Industrial Standard

For the test items 1) and 2), a heavy truck fully loaded with laterite soil which was checked to be 5.2 ton and 6.0 kg/cm^2 air pressure of tire was used as the test load. The field CBR test was conducted in accordance with AASHTO standard, while the deflection test was carried out by using the Benkolman Beam.

The sounding test was conducted by using a special equipment designed by the Road Research Laboratory of the Ministry of Construction, Japan.

The results of the field road surface test are listed in Table 5.3. The recorded CBR value shows a high value ranging from 15.4 to 108.0 with an approximate average of 47.0, which seems very high value if considered that the test was carried out in the heavy rainy season. The maximum deflections of the road surface recorded were less than 2.5mm in Gbarnga-Voinjama section, and less than 4.5mm in Voinjama-Mendikoma section.

The results of these tests will be checked together with the results of the boring survey conducted by the Ministry of Public Works in December, 1978, and used for the analysis of the pavement design for the project road.

Table 5.1 Soil Samples and Laboratory Test

		A	B	C	D	E	F	G	H	I
Gbarnga-Zorzor	1	T	NT	T	T	-	-	-	T	-
	2	T	T	NT	NT	T	NT	NT	T	5.6
	3	T	T	T	T	-	N*	-	T	"
	4	T	T	T	T	T	-	-	T	"
	5	T	T	T	T	-	-	-	T	"
	6	T	T	T	T	T	-	T	T	"
	7	T	T	T	T	-	-	-	T	"
	8	T	T	T	T	T	-	-	T	"
	9	T	T	T	T	-	-	-	T	"
	10	T	T	T	T	T	NT	NT	T	"
	11	T	T	T	T	-	-	-	T	"
Zorzor-Voinjama	1	T	T	T	T	T	NT	NT	T	-
	2	T	T	T	T	-	-	-	T	5.8
	3	T	T	T	T	T	NT	T	T	"
	4	T	T	NT	NT	-	-	-	T	"
	5	T	T	T	T	T	-	-	T	"
	6	T	T	T	T	-	-	-	T	"
	7	T	T	T	T	T	-	NT	T	"
	8	T	T	T	T	-	NT	-	T	"
	9	T	T	T	T	T	-	-	T	"
	10	T	NT	T	T	T	NT	T	T	"
Voinjama-Mendikoma	1	T	T	T	T	-	NT	-	T	-
	2	T	T	T	T	T	-	T	T	5.4
	3	T	NT	T	T	-	-	-	T	"
	4	T	T	T	T	-	-	-	T	"
	5	T	T	T	T	T	-	NT	T	"
	6	T	T	T	T	-	NT	-	T	"
	7	T	T	T	T	T	-	-	T	"
	8	T	T	T	T	T	-	NT	T	"
	9	T	T	T	T	-	NT	-	-	"

LEGEND

A: A: Moisture Centent
B: Grainsize Analysis
C: Liquid Limit
D: Plastic Limit
E: C.B.R. Test for Subgrade Material
F: C.B.R. Test for Basecaurse Material
G: Compaction
H: Natural Density
I: Interval (miles)
T: Tested
N.T: Not Tested
*: Mixed and tested or as one material

TABLE 5.2(1) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality Gbarnga - Zorzor

Sample No.			G-1	G-2	G-3	G-4	G-5
Sample Depth		(m)	0.5	1.0	1.0	0.5	0.5
Gradation	Gravel	(%)	-	65.1	26.8	4.6	18.5
	Sand	(%)	-	19.8	35.8	37.5	39.9
	Silt	(%)	-	15.1	37.4	57.9	41.6
	Clay	(%)	-	"	"	"	"
	Max Diameter	(mm)	-	25.4	25.4	9.5	19.1
	Coefficient of Uniformity	(Uc)	-	-	-	-	-
	Coefficient of Curvature	(Uc)	-	-	-	-	-
Consistency	Liquid Limit w_L	(%)	43.7	-	49.3	26.8	54.0
	Plastic Limit	Wp(%)	35.8	-	33.4	24.2	22.8
	Plasticity Index	IP	7.9	-	15.9	2.6	31.2
	Japanese United Soil Classification		-	-	-	-	-
Natural State	Natural Moisture Content	wn(%)	24.3	13.9	19.0	19.5	22.3
	Wet Density γ_t	(g/cm^3)	1.778	1.825	2.129	2.015	1.915
	Dry Density γ_d	(g/cm^3)	1.4	1.6	1.8	1.7	1.6
Compaction	Test Condition (AASHTO) T180		-	-	-	-	-
	Optimum Moisture Content w_{opt}	(%)	-	-	-	-	-
	Maximum Dry Density $\gamma_{d\,max}$	(g/cm^3)	-	-	-	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material	(%)	-	9.1	-	8.1	-
	C. B.R. Test for Base-Course Material	(%)	-	-	-	-	-

TABLE 5.2(2) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality Gbarnga - Zorzor

				G-6	G-7	G-8	G-9	G-10
Sample No.								
Sample Depth			(m)	1.0	1.5	2.0	4.0	1.0
Gradation	Gravel		(%)	37.3	38.1	34.9	1.1	1.4
	Sand		(%)	23.6	34.6	38.9	59.9	59.9
	Silt		(%)	39.1	27.3	26.2	39.0	38.7
	Clay		(%)	"	"	"	"	"
	Max Diameter		(mm)	19.1	19.1	25.4	4.76	4.76
	Coefficient of Uniformity		(Uc)	-	-	-	-	-
	Coefficient of Curvature		(Uc)	-	-	-	-	-
Consistency	Liquid Limit	w_L	(%)	36.4	37.8	42.2	35.6	32.5
	Plastic Limit		Wp(%)	23.6	22.3	18.1	21.8	20.8
	Plasticity Index		IP	12.8	15.5	24.1	13.8	11.7
	Japanese United Soil Classification			-	-	-	-	-
Natural State	Natural Moisture Content		(%)	25.1	13.2	13.3	27.7	20.5
	Wet Density	γ_t	(g/cm^3)	1.884	2.050	1.897	1.836	1.859
	Dry Density	γ_d	(g/cm^3)	1.5	1.8	1.7	1.4	1.5
Compaction	Test Condition (AASHTO) T180			C	-	-	-	-
	Optimum Moisture Content	w_{opt}	(%)	13.8	-	-	-	-
	Maximum Dry Density	$\gamma_{d\,max}$	(g/cm^3)	1.92	-	-	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material		(%)	19.0	-	20.7	-	[illegible]
	C. B.R. Test for Base-Course Material		(%)	-	-	-	-	-

TABLE 5.2 (3) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality	Gbarnga - Zorzor					
Sample No.			G-11	-	G-3 &V-9	
Sample Depth		(m)	2.0			
Gradation	Gravel	(%)	22.5		47.5	
	Sand	(%)	45.7		25.4	
	Silt	(%)	31.2		27.1	
	Clay	(%)	"		"	
	Max Diameter	(mm)	19.1		19.1	
	Coefficient of Uniformity	(Uc)	-		-	
	Coefficient of Curvature	(Uc)	-		-	
Consistency	Liquid Limit w_L	(%)	37.5		42.1	
	Plastic Limit	Wp(%)	26.9		29.7	
	Plasticity Index	IP	10.6		12.4	
	Japanese United Soil Classification		-		-	
Natural State	Natural Moisture Content	(%)	24.8		-	
	Wet Density γ_t	(g/cm^3)	1.694		-	
	Dry Density γ_d	(g/cm^3)	1.4		-	
Compaction	Test Condition (AASHTO) T180		-		-	
	Optimum Moisture Content w_{opt}	(%)	-		16.2	
	Maximum Dry Density $\gamma_{d\,max}$	(g/cm^3)	-		1.89	
C.B.R. Test	C.B.R. Test for Subgrade Material	(%)	-		-	
	C. B.R. Test for Base-Course Material	(%)	-		$\frac{65}{10}$	

TABLE 5.2 (4) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality	Voinjama-Mendek ma

	Sample No.			V-1	V-2	V-3	V-4	V-5
	Sample Depth		(m)	0	1.0	3.0	0.5	2.0
Gradation	Gravel		(%)	57.0	0.4	-	16.3	2.9
	Sand		(%)	19.6	5 .1	-	40.9	67.7
	Silt		(%)	23.4	41.5	-	42.9	29.4
	Clay		(%)	"	"	"	"	"
	Max Diameter		(mm)	25.4	4.76	-	9.5	9.5
	Coefficient of Uniformity		(Uc)	-	-	-	-	-
	Coefficient of Curvature		(Uc)	-	-	-	-	-
Consistency	Liquid Limit	w_L	(%)	52.8	3 .8	-	42.4	38.6
	Plastic Limit		Wp(%)	23.5	21.9	-	28.2	22.0
	Plasticity Index		IP	29.3	16.9	-	14.2	16.6
	Japanese United Soil Classification			-	-	-	-	-
Natural State	Natural Moisture Content		(%)	14.9	17.5	26.1	20.0	24.2
	Wet Density	γt	(g/cm^3)	2.095	1.933	1.752	1.891	1.926
	Dry Density	γd	(g/cm^3)	1.8	1.7	1.4	1.6	1.6
Compaction	Test Condition (AASHTO) T180			-	C	-	-	-
	Optimum Moisture Content	w_{opt}	(%)	-	14.0	-	-	-
	Maximum Dry Density	γd_{max}	(g/cm^3)	-	1.86	-	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material		(%)	-	5.8	-	-	6.6
	C. B.R. Test for Base-Course Material		(%)	-	-	-	-	-

TABLE 5.2 (5) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality	Voinjama-Mendekoma

				V-6	V-7	V-8	V-9	V-9"
Sample No.								
Sample Depth			(m)	0	2.0	1.2	0	0.5
Gradation	Gravel		(%)	41.9	2.4	13.0	52.1	-
	Sand		(%)	28.2	34.5	55.3	16.6	-
	Silt		(%)	29.9	63.1	31.7	31.5	-
	Clay		(%)	"	"	"	"	-
	Max Diameter		(mm)	19.1	4.76	19.1	25.4	-
	Coefficient of Uniformity		(Uc)	-	-	-	-	-
	Coefficient of Curvature		(Uc)	-	-		-	-
Consistency	Liquid Limit	w_L	(%)	56.2	51.6	38.9	36.8	-
	Plastic Limit		Wp(%)	29.2	44.5	25.5	26.7	-
	Plasticity Index		IP	27.0	7.1	13.4	10.1	-
	Japanese United Soil Classification			-	-	-	-	-
Natural State	Natural Moisture Content	w_n	(%)	17.7	33.5	16.1	22.6	35.2
	Wet Density	γ_t	(g/cm^3)	2.014	1.848	2.103	2.211	1.870
	Dry Density	γ_d	(g/cm^3)	1.7	1.4	1.8	1.8	1.4
Compaction	Test Condition (AASHTO) T180			-	-	-	-	-
	Optimum Moisture Content	w_{opt}	(%)	-	-	-	-	-
	Maximum Dry Density	$\gamma_{d\,max}$	(g/cm^3)	-	-	-	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material		(%)		4.6	13.2	-	-
	C. B.R. Test for Base-Course Material		(%)	-	-	-	-	-

TABLE 5.2 (6) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality Zorzor - Voinjama

Sample No.			Z-1	Z-2	Z-3	Z-4	Z-5
Sample Depth		(m)	2.0	3.5	0.5	3.0	0.5
Gradation	Gravel	(%)	24.6	19.2	3.4	17.0	8.4
	Sand	(%)	32.2	36.8	60.3	36.8	41.4
	Silt	(%)	43.2	44.0	36.3	46.2	50.2
	Clay	(%)	"	"	"	"	"
	Max Diameter	(mm)	19.1	12.7	9.5	12.7	4.76
	Coefficient of Uniformity	(Uc)	-	-	-	-	-
	Coefficient of Curvature	(Uc)	-	-	-	-	-
Consistency	Liquid Limit W_L	(%)	51.1	46.4	26.8	-	47.1
	Plastic Limit	Wp(%)	34.5	27.1	16.4	-	31.0
	Plasticity Index	IP	16.6	19.3	10.4	-	16.1
	Japanese United Soil Classification		-	-	-	-	-
Natural State	Natural Moisture Content	(%)	22.7	20.2	12.9	20.8	21.6
	Wet Density γ_t	(g/cm^3)	1.983	2.002	2.019	2.015	2.004
	Dry Density γ_d	(g/cm^3)	1.6	1.7	1.8	1.7	1.7
Compaction	Test Condition (AASHTO) T180		-	-	C	-	-
	Optimum Moisture Content W_{omc}	(%)	-	-	10.6	-	-
	Maximum Dry Density $\gamma_{d\,max}$	(g/cm^3)	-	-	2.00	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material	(%)	17.4	-	15.7	-	6.6
	C. B.R. Test for Base-Course Material	(%)	-	-	-	-	-

TABLE 5.2 (7) SUMMARY OF SOIL LABORATORY TEST

Name of Survey & Locality Zorzor - Voinjama

				Z-6	Z-7	Z-8	Z-9	Z-10
Sample No.								
Sample Depth			(m)	0.6	0.8	1.5	1.0	2.0
Gradation	Gravel		(%)	21.6	13.1	4.9	16.5	-
	Sand		(%)	44.0	32.2	73.3	35.1	-
	Silt		(%)	34.4	54.7	21.9	48.4	-
	Clay		(%)	"	"	"	"	-
	Max Diameter		(mm)	25.4	25.4	9.5	19.1	-
	Coefficient of Uniformity		(Uc)	-	-	-	-	-
	Coefficient of Curvature		(Uc)	-	-	-	-	-
Consistency	Liquid Limit	w_L	(%)	56.6	37.2	55.4	38.4	-
	Plastic Limit		Wp(%)	31.3	27.0	30.8	24.1	-
	Plasticity Index		IP	25.3	10.2	24.6	14.3	-
	Japanese United Soil Classification			-	-	-	-	-
Natural State	Natural Moisture Content		(%)	16.7	21.9	26.7	17.8	21.9
	Wet Density	γ_t	(g/cm^3)	2.017	2.006	1.848	2.057	1.955
	Dry Density	γ_d	(g/cm^3)	1.7	1.7	1.5	1.8	1.6
Compaction	Test Condition (AASHTO) T180			-	-	-	-	-
	Optimum Moisture Content	w_{opt}	(%)	-	-	-	-	-
	Maximum Dry Density	$\gamma_{d\,max}$	(g/cm^3)	-	-	-	-	-
C.B.R. Test	C.B.R. Test for Subgrade Material		(%)	-	8.3	-	8.3	6.6
	C. B.R. Test for Base-Course Material		(%)	-	-	-	-	-

Table 5.3(1) Summary of Road Surface Test (In the Field)

Gbarnga-Zorzor

Sample No.			No.51		No.148		No.266		No.389		No.516					
Sample Depth (m)			0		0		0		0		0					
C.B.R. Test	Natural Moisture Content (%)		10.7		15.0		10.6		6.1		8.9					
	Field C.B.R. (%)		46.4		30.7		46.7		42.4		38.0					
Benkelman Bean Test	Initial Dial Reading (mm)		2.3	2.5	2.2	2.0	1.0	1.4	0.7	0.2	3.1	2.5				
	Final Dial Reading (mm)		0.6	0.9	1.2	1.0	0.7	1.4	0.7	0.2	2.6	1.8				
	Total Rebound Deflection (mm)		0.7	1.6	1.0	1.0	0.3	0	0	0	0.5	1.4				
Sounding Test	N-Value Per 10 CM Depth From Surface	Lane	150		104		58		58		75					
		Shoulder	36		25		17		29		30					

Table 5.3(2) Summary of Road Surface Test (In the Field)

Zorzor-Voinjama

	Sample No.		No.08		No.129		No.260		No.398		No.549		No.594	
	Sample Depth (m)		0 Surface		0 Surface		0 Surface		0 Surface		0 Surface		0 Surface	
C.B.R. Test	Natural Moisture Content (%)		8.9		3.3		6.2		11.1		10.1		9.4	
	Field C.B.R. (%)		74.6		94.9		108.0		42.3		34.3		16.1	
Benkelman Bean Test	Initial Dial Reading (mm)		2.4	2.3	1.7	0.8	2.2	2.5	3.7	2.5	1.1	1.7	0.6	1.0
	Final Dial Reading (mm)		2.4	2.0	1.3	0.8	1.5	2.4	2.2	1.0	0.6	0.7	0.2	1.0
	Total Rebound Deflection (mm)		0	0.3	0.2	0	0.7	0.1	1.5	1.5	0.5	1.0	0.4	0.1
Sounding Test	N-Value Per 10 CM Depth From Surface	Lane	167	125	98		136		125		-		250	
		Shoulder	12		23		125		29		28		-	

Table 5.3(3) Summary of Road Surface Test (In the Field)

Voinjama-Mendekoma

Sample No.			No.95		No.300		No.397		No.464		No.505					
Sample Depth		(m)	0		0		0		0		0					
C.B.R. Test	Natural Moisture Content	(%)	8.0		8.3		18.0		8.4		11.8					
	Field C.B.R.	(%)	38.9		39.4		15.4		35.8		49.6					
Benkelman Bean Test	Initial Dial Reading	(mm)	3.5	3.6	2.4	4.2	3.8	4.3	3.8	3.4	2.6	2.3				
	Final Dial Reading	(mm)	3.1	2.7	2.4	4.2	1.6	2.3	2.2	2.1	1.8	1.7				
	Total Rebound Deflection	(mm)	0.4	0.9	0	0	2.2	2.0	1.6	1.4	0.8	0.6				
Sounding Test	N-Value Per 10 CM Depth From Surface	Lane	208		139		91		127		91					
		Shoulder	-		-		-		78		45					

5.2.3 Borrow Pit and Quarry

Borrow pit for selected laterite was investigated along the existing road. The preliminary results of the investigation are presented below.

Gbarnga-St. Paul River: within 5 km along the road, good selected laterite was found in many portions.

St. Paul River-Zozor: poor along the road.

Zorzor Town Area : around Zorzor town good materials were found only in limited 5 km area.

Konia-Lofa River: poor along the road.

Lofa-Voinjama : poor, but found in limited portion.

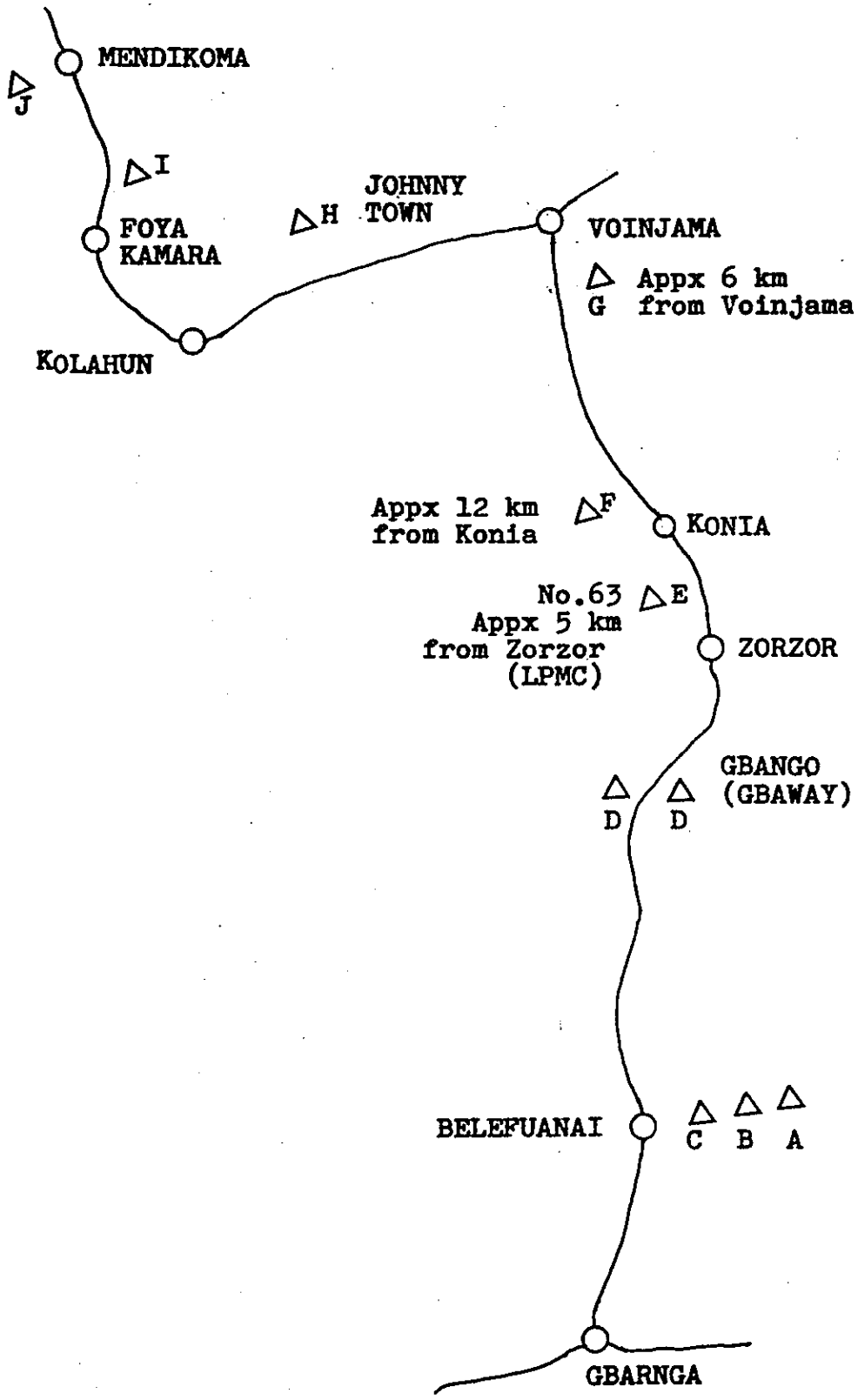
Voinjama-Kolahun: poor along the road but rich along feeder road within 5 km from the junction to main road.

Kolahun-Mendikoma: Almost same as the Voinjama-Kolahun section, and good laterite found near by Mendigisua but not includes course agregate.

The investigation of coarse aggregate for asphalt mixture was conducted and 10 quarry sites were identified. Location of the quarry sites is presented in Fig. 5.2 and the present condition of the sites is briefly explained in Appendix together with the estimated reserve volume.

Through the reconnaissance survey on the quarry sites it was found that all samples obtained posses similar characteristics. Most of them belong to igeous group characterized by the presence of quartz and feldspar, and

Fig. 5.2 - LOCATION MAP FOR QUARRY SITES



classified as granite or syenite. All the proposed sites have no problem for the right of way and the access road to the sites can be constructed economically.

Rock tests on the quarry material taken from the proposed sites were carried out by the Ministry of Public Works Laboratory in late August. Only two items of the rock tests i.e., specific gravity and its moisture content were made and other test items like abrasion test was excluded, since it was judged that the quality of the rocks is quite suitable for the material of asphaltic mixture through the test exploration. The results of specific gravity tests showed the values of 2.64 and 2.66 and the moisture contents were 0.41% and 0.92%.

5.3 Design Standard

The original design standard of the project road was firstly studied refering to the available drawings obtained from Ministry of Public Works. The applied design standard is considered to be as follows:

Design Speed	50 cm/hr.
Minimum curvature	80m
Maximum gradient	10%
Minimum sight distance	55m
Road width	6.0m
Bridge design load	HT-20
Pavement structure	Laterite pavement max. 30cm thick.

Then, the Liberian design standard of the primary road - A paved class was reviewed for checking its applicability to the project road.

The design standard is:

Design speed	72 km/hr
Minimum curvature	360m
Maximum gradient	7.0%
Minimum sight distance	90m
Road width	7.8m
Bridge design load	HT-20
Pavement structure	bituminous 3.75cm-7.5cm pavement on 40cm-45cm laterite base.

Although the final design standard to be applied is determined by the economic analysis on the alternative plans, the formulation of alternative design standards is to be made on the following basic understandings.

1) Design speed applied for the Liberian primary road is 72-80 km/hr (45-50 mile/hr).
2) Through the engineering survey, it is identified that some limited section of the road(ex. Konia-Lofa River) has insufficient terrain for application of the above design speed economically.
3) Even if the topographical condition not guarantees desired design standard on some section (ex. radius is smaller than 360m), necessary consideration is to be made for safely such as providing enough sight distance through widening or bench-cut of the cutting slope.
4) The existing laterite soil on the project road stretch is quite suitable for the pavement materials under the condition that drainage is properly made. Pavement design is to be made fully taking into account the characteristic of the laterite soil.

VI. ALTERNATIVE PLANS FOR IMPROVEMENT

6.1 Plans Formulation

As mentioned in the preceding chapters present condition of the project road including its alignment and pavement is not sufficient to sustain the socio-economic activities in the region. Major problems that the road users and non-road users are facing in the region are summarized as follows:

1) High vehicle operation cost including high gas consumption and necessity of frequent maintenance and discomfort mainly caused by laterite surface and poor alignment.

2) Traffic stops or delays during wet season particularly on the low-lying zones even under relatively well maintained condition.

3) Accidents or danger of accident caused by poor alignment with short sight distance.

4) Sand and dust caused by the traffic on the laterite road not only in the dry season but also in the wet season if good weather continues for a few days.

Under these conditions, alternative improvement plans are formulated from three(3) points of views i.e. geometric design, pavement structure and traffic volume.

For considering the alternatives in terms of geometric design, complete realignment plan is excluded and the alternative plans are considered on the basis of the design speeds.

1) 80 km/hr, partly with 60 km/hr.
2) 80 km/hr for the whole road sections, partial realignment in hilly area is required.

For the alternative of the pavement structures, the following three types are considered in due considerations of the soil condition, and the expected traffic in the future.

1) Asphalt surface treatment
2) Asphalt penetration macadam
3) Asphalt concrete

By combining two geometric standards with three types of pavement, six alternative plans for the improvement are formulated as follows:

	Design Speed	Pavement Structure
Alternative I	80 km/hr partly 60 km/hr	Asphalt surface treatment
Alternative II	80 km/hr partly 60 km/hr	Asphalt penetration macadam
Alternative III	80 km/hr partly 60 km/hr	Asphalt concrete
Alternative IV	80 km/hr	Asphalt surface treatment
Alternative V	80 km/r	Asphalt penetration macadam
Alternative VI	80 km/hr	Asphalt concrete

6.2 Preliminary Assessment of the Alternative Plans

Selection of the most optimum plan for each homogeneous section of the project road will be made by the economic analysis on the basis of the estimated project cost and benefit in the further study at home. In this report, only a preliminary assessment is made mainly focussing on the projected traffic in the future.

Although the projected traffic is not detailed one, it indicates future tendency of the traffic within some range of error. The project road is roughly divided into the following three categories in accordance with the preliminary traffic forecast.

I) Projected ADT in 1985 is more than 700
II) Projected ADT in 1985 is between 500-700
III) Projected ADT in 1985 is less than 500

Included in I) are Joyama-Voinjama section and Voinjama-Kolahun section while Gbarnga-Wenshu section is included in II) and Foya-Mendikoma section is included in III).

In view of the relation between the traffic and the pavement structure, the road section under I) can be designed as asphalt concrete or at least asphalt penetration macadam, the road sections under II) and III) be paved by asphalt penetration macadam or only asphalt surface treatment depending on the traffic.

These comparative studies will be made in detail not only from the economic point of view but also from the technical point of view that includes axle load analysis in the farther study at home.

VII. FURTHER STUDIES AND SCHEDULE

7.1 Further Study and Analysis

Immediately after comming back to Japan, detailed study and analysis for the feasibility study will be commenced. Most optimum improvement plan for the Gbarnga-Mendikoma road will be determined through the economic evaluation on the basis of the projected traffic in the future, expected benefit and project costs with its maintenance costs. Study items and the methods for the further study at home are briefly described hereunder.

7.1.1 Study on Traffic Generating Sources

Traffic generating sources will be studied in detail, particularly emphasizing on the agricultural development which is the most important aspect for the future regional development. Production estimate of the agricultural goods both for present and future already prepared in the field survey and study stage will be refined for each crop taking into account the productivity increase and labor force increase together with the development in the institutional infrastructures.

More detailed study and analysis on the population will be made in the next stage, including the estimate of population growth in each zone on the basis of the expected regional development and the past trend. Immigration from other region to the influence area caused by the agricultural development will also be considered.

Besides agricultural study, the development of the Wologisi iron ore will be studied in detail. At present, another transport system is considered for the iron ore

development, but the regional development facilitated by the exploitation will affect the traffic on the project road.

Study on the development of the capital Monrovia and south-eastern part of Sierra Leone, which are the important zone outside the influence area in terms of traffic, will be made in due consideration of the future traffic growth.

7.1.2 Refinement of Traffic Projection

On the basis of the study on traffic generating sources, the projected traffic made in the field work will be refined further by using the computer model. In the detailed study and analysis, generated traffic and diverted traffic will also be estimated. The generated traffic is expected both for passenger traffic and cargo traffic, mainly caused by the reduction in vehicle operation cost on the project road. For the estimate of generated traffic on cargo, attention will be paid to the transport of the forestry products and agricultural crops.

Possibility of traffic diversion from local air transport to the project road will be studied as well as possible diversion from the project road to the Belle Yella - Kolahun road.

7.1.3 Preliminary Design

Preliminary design will be conducted on the basis of the findings from the engineering survey including topographic survey, and the results of the soil and materials survey and projected traffic. Two different

design speeds, 80km/hr all through the road and 80 km/hr with partial 60 km/hr, will be considered for preparation of the horizontal and vertical alignment plan. In the pavement design, three different pavements discussed in preceeding chapter will be incorporated. All the pavement designs prepared for three alternatives will be studied carefully and comparative analysis be made.

The results of the design will be drawn on plans and profiles at the scale of 1/20,000 (H) and 1/1,000 (L). Computer program for automatic design will be fully utilized for the design works.

During the field survey, it is identified that there is no bridge to be replaced or to be newly constructed on the project road. Therefore, only appropriate maintenance work will be considered for those bridges.

7.1.4 Construction Plan and Cost Estimate

Construction method will be studied on the assumption that the construction work will be carried out under contract base, in due consideration of local conditions including natural condition and availability of construction materials. Following to this, construction schedule will be established.

Based on the preliminary design and construction plan, construction work quantities will be calculated for the alternative plans. Our computer program will be used, also in this calculation. Construction costs of the road improvement for the alternative plans will thus be estimated by using the work quantities and unit construction cost data which were collected and reviewed during the field work. Maintenance costs will be estimated for different improvements levels of the alternative plans.

Besides the financial costs of the project, economic costs will also be estimated for the economic evaluation. Collected data concerning tax and duties to be imposed on construction machineries and materials will be utilised as well as shadow wage rate for the economic costing. Price contingency included in the financial costs will be excluded to estimate the economic costs.

7.1.5 Benefit Estimation

Quantifiable benefits to be estimated are:

1) Reduced vehicle operation cost
2) Time saving benefit
3) Reduced discomfort and strain
4) Reduced road maintenance costs
5) Reduced traffic accident.

For determining the optimum estimate method of the vehicle operation cost, comparative analysis will be made between the conventional method and TRRL[1]/IBRD method. Estimated figures by Planning and Programming Division, Ministry of Public Works will fully be taken into account for the final estimate.

Time saving benefit will be estimated only for passenger traffic on the basis of the estimated per-capita income and time to be saved.

Reduced comfort and strain for people living along the road will be estimated by means of the alternative cost for stopping dust.

1/ = Transport and Road Research Laboratory, Growthorne, Berkshire.

Reduced road maintenance costs and reduced traffic accidents will be evaluated on the basis of the collected data refering to similar experiences in the country.

These benefits will be estimated by using computer program for each of the alternative plans, which will be compared with corresponding costs for the economic analysis.

7.1.6 Economic Evaluation

On the estimated costs and benefits, most optimum development plan will be selected for each of the homogeneous section of the project road by calculating IRR and B/C ratio. Sensitivity analysis for the optimum plan will be carried out to test the impact of changes in various decisive factors such as construction cost and traffic growth.

Besides, intangible economic benefits and social impact comming from the project implementation will be evaluated, which will be incorporated in the overall project evaluation.

7.2 Schedule of The Study

Further studies will be commenced from early September, immediately after the Survey Team comes back to Japan and continue up to the end of November. All the results of the study and analysis will be compiled into a Draft Final Report, which will be submitted to the Liberian Government in early December. Discussion will be held concerning the Draft Report between the Liberian Government and Japanese Government after submitting the report.

The Final Report will be prepared incorporating all the comments and the results of the discussion in January, 1980 and be submitted to the Liberian Government in early February, next year.

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