AFRICAN DEVELOPMENT BANK

THE DEMOCRATIC REPUBLIC OF THE SUDAN

FEASIBILITY AND PRELIMINARY ENGINEERING STUDY OF ROAD PROJECT EL OBEID-UM RUABA THE SUDAN

INTERIM REPORT

OCTOBER, 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

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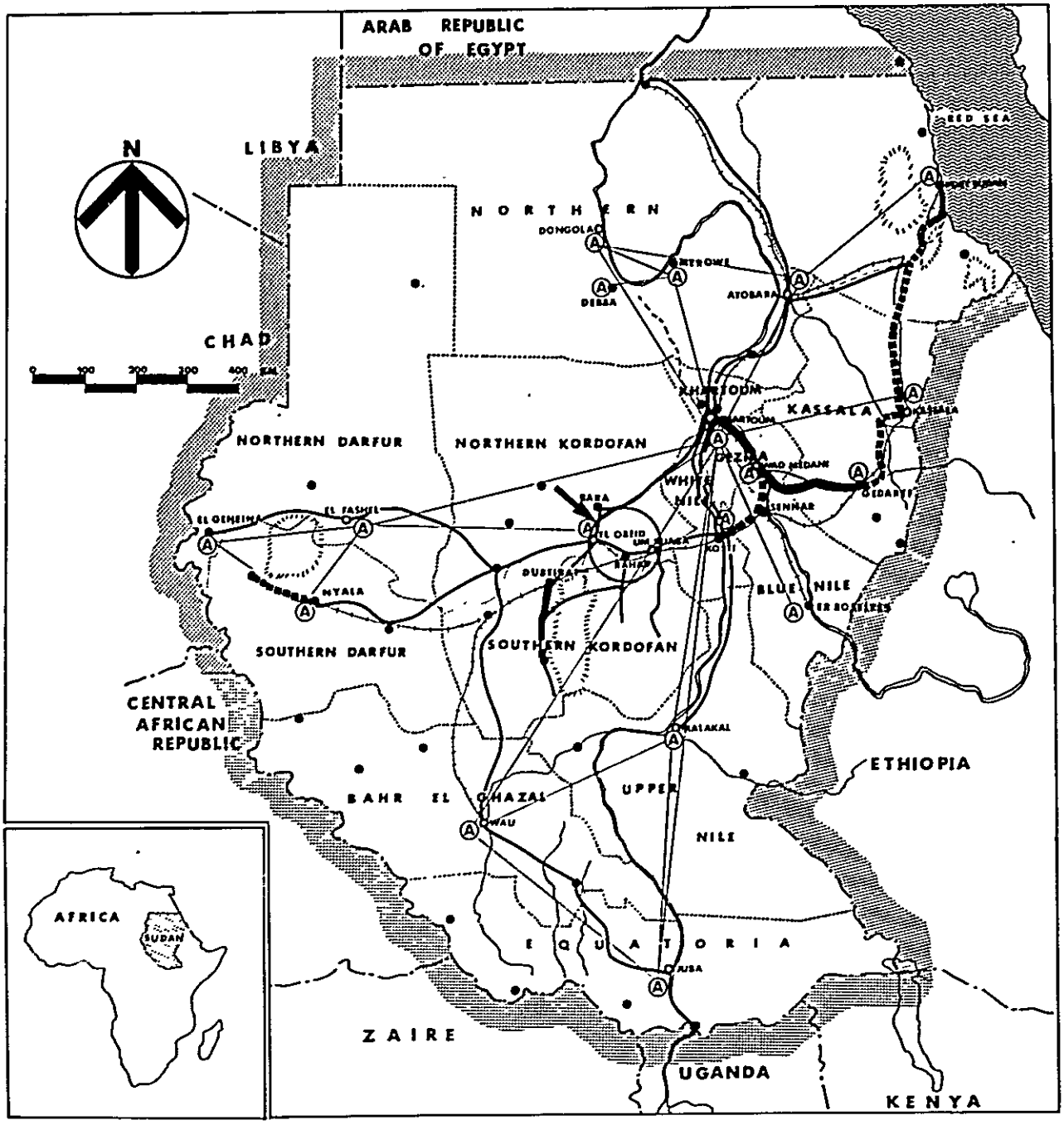
THE SUDAN



LEGEND

- PAVED ROADS
- UNDER CONSTRUCTING ROADS
- OTHER ROADS
- RAILWAYS
- AIRPORTS
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- PROJECT AREA

CHAPTER I

1.00 INTRODUCTION

1.01 Purpose

An inter-regional transport system in the Sudan has been developed in parallel to the River Nile which runs from south to north through the country. The next target of the development program will be to improve the transport lines crossing the vast country from Port Sudan to the west. There are several on-going studies and construction works of roads and railways under this program.

This study of the road project between El Obeid and Um Ruaba of 150 km. is a section of 1,800 km. crossing the country from the east at Port Sudan to the west at the border with Chad, El Geneina. The section is nominated as a part of the trans-African highway. The purpose of the study is to explore the economic feasibility of the construction plan together with preliminary engineering of the road. The best plan will be developed by assessing the economic impact of the alternatives on the road users and the regional economy.

1.02 Background

With the urgent necessity to improve the nation's transportation system, the Government of the Sudan requested technical cooperation regarding the feasibility and engineering study of this road project to the African Development Bank (A.D.B.) group and the Government of Japan in early 1976. The Government of Japan has already agreed to carry out technical cooperation in studying projects which are

included in the lending program of the Bank. The Sudan, A.D.B. and Japan agreed in November, 1976 that the Government of Japan will finance the study of the project under a technical cooperation program while A.D.B. keeps it in its pipeline of projects.

The study is being carried out by the Japanese International Cooperation Agency (J.I.C.A.), an official executive agency for overseas technical cooperation of Japan, which selected a study team of consultants in February, 1977. The team entered the Sudan in March, 1977. The field study had gone on up to mid-June, followed by home work scheduled to be completed in March, 1978. In September and October three Sudanese counterpart staffs were in Japan to work with the staffs of the study team. The interim report will be submitted in November to the Roads and Bridges Public Corporation of the Sudan (R.B.P.C.) and A.D.B. The comments and advice on the context of the interim report will be incorporated in the draft final report which will be submitted again by February, 1978.

J.I.C.A. has organized a supervisory committee of the study of the project. The committee members were selected from among officials in the Ministry of Construction of Japan. They give advice on the study at appropriate times, while attending meetings with the Sudan and A.D.B.

CHAPTER II

2.00 METHODOLOGY

2.01 The Study

There are two corridors in the project area; one is the northern corridor linking El Obeid and Um Ruaba directly, the other is the southern corridor. The latter is longer than the northern route and runs parallel to the railway passing through the populated areas including Rahad town. In the southern corridor six alternative routes are proposed for comparative study. They are proposed by considering the alignment of railways, the soil conditions, and the terrain. Accordingly, seven alternatives in total are studied under the same conditions.

The design standard applied in this study is a bituminous surfaced two lane road assumed to be overlayed with asphalt concrete in 1996 or 1997. In the case of the northern route, the construction of an access road to Rahad is included in the project. The access road is designed to be a one lane bituminous surfaced road. The economic cost for each of the seven alternatives is estimated. Benefits realized by these alternatives are estimated as well. The cost and benefits analyses are conducted to find the best alignment among the seven alternatives. The study up to this analysis is incorporated in this interim report of the project study.

The next stage of the study will be the reviewing of the cost and benefit estimates, and economic evaluation of alternatives such as pavement designs, by-passes and bridges. These minor alternatives

will be analyzed on the best route chosen through the first stage of study.

2.02 The Schedule and Methodology

The time table of the study is shown in TABLE II-1, and the system of the study is presented in the flow chart in FIG.II-1. The team were in the Sudan for approximately 100 days from mid-March, followed by office work in Japan. The study will be completed by March, 1978. The following is a general idea of the scope of the study:

a) A map at the scale of 1 : 250,000 and a photo mosaic of 1 : 48,000 taken in 1962 were supplied by the Sudanese Government. The team have used these data in the course of comparative study of the seven alternatives.

b) An aerial photo was taken on the southern corridor with a width of 5 km. A photo mosaic of 1 : 25,000 was produced by the film. When the best alignment is determined, a map of 1 : 5,000 covering the area with a width of 500 m for each side of this alignment is to be developed. This map will be used in the second stage of the study for reviewing the cost estimate and for the selection of design standards.

c) The field inventory studies include the findings on the conditions of the existing roads, such as slopes, surfaces in sections, the soil and the material. Tests on soils and materials were conducted in the laboratories of R.B.P.C. and the consultants. The

hydrological survey includes field observation, the collection of climatic data, and the analysis of these informations.

d) The information necessary for the estimate of the project cost was obtained in the project area and in Khartoum. They were incorporated in the priced bill of quantity for each of the seven alternatives.

e) A series of traffic studies was conducted in the project area and other areas. Statistical data were provided by various government sources and private organizations. Future traffic volume was then forecasted and transportation costs were estimated.

f) The rural and urban economies of the project area were studied in their existing status and their prospects for the future. The development potentiality is considered in the above estimate of the future traffic. The benefit streams were estimated for the project life period.

g) The result of the economic benefit cost analysis not only presents the best alignment among the seven alternatives, but also suggests that the project, because of the satisfactory benefit cost figures, should be included in the development investment programme and given high priority.

2.03 Members of Supervisory Committee and Study Team

2.03.1 Supervisory Committee

Chairman	Toshiyuki Ono:	Kanto Regional Bureau, MOC
Member of Committee	Mohei Miki:	Kanto Regional Bureau, MOC
"	Tokuhisa Kakuchi:	Bureau of Roads, MOC
"	Kaoru Ono:	Kanto Regional Bureau, MOC
"	Hiroshi Morimoto:	Bureau of Roads, MOC
"	Yasusuke Agata:	Kanto Regional Bureau, MOC
Coordinator	Hiroyoshi Kurihara:	Japan International Cooperation Agency

2.03.2 Study Team

Team Leader:	Noritomo Okuda
Acting Team Leader and Economist:	Teruhiko Horie
Highway Engineer Cost Estimator:	Kunio Taniguchi
Agronomist:	Masae Yamazaki
Highway & Bridge Engineer:	Harumi Nishikawa
Transport Economist:	Shizuo Iwata
Highway Engineer:	Takeshi Tomiyasu
Hydrologist:	Masataka Miyagawa
Traffic Engineer:	Kunio Ohashi
Geologist:	Ryuichi Ichihara
Surveyor:	Yoshiaki Otoku
Surveyor:	Mikio Kurita

FIG.II-1 FLOW CHART OF THE STUDY ON EL OBEID-UM RUABA ROAD PROJECT

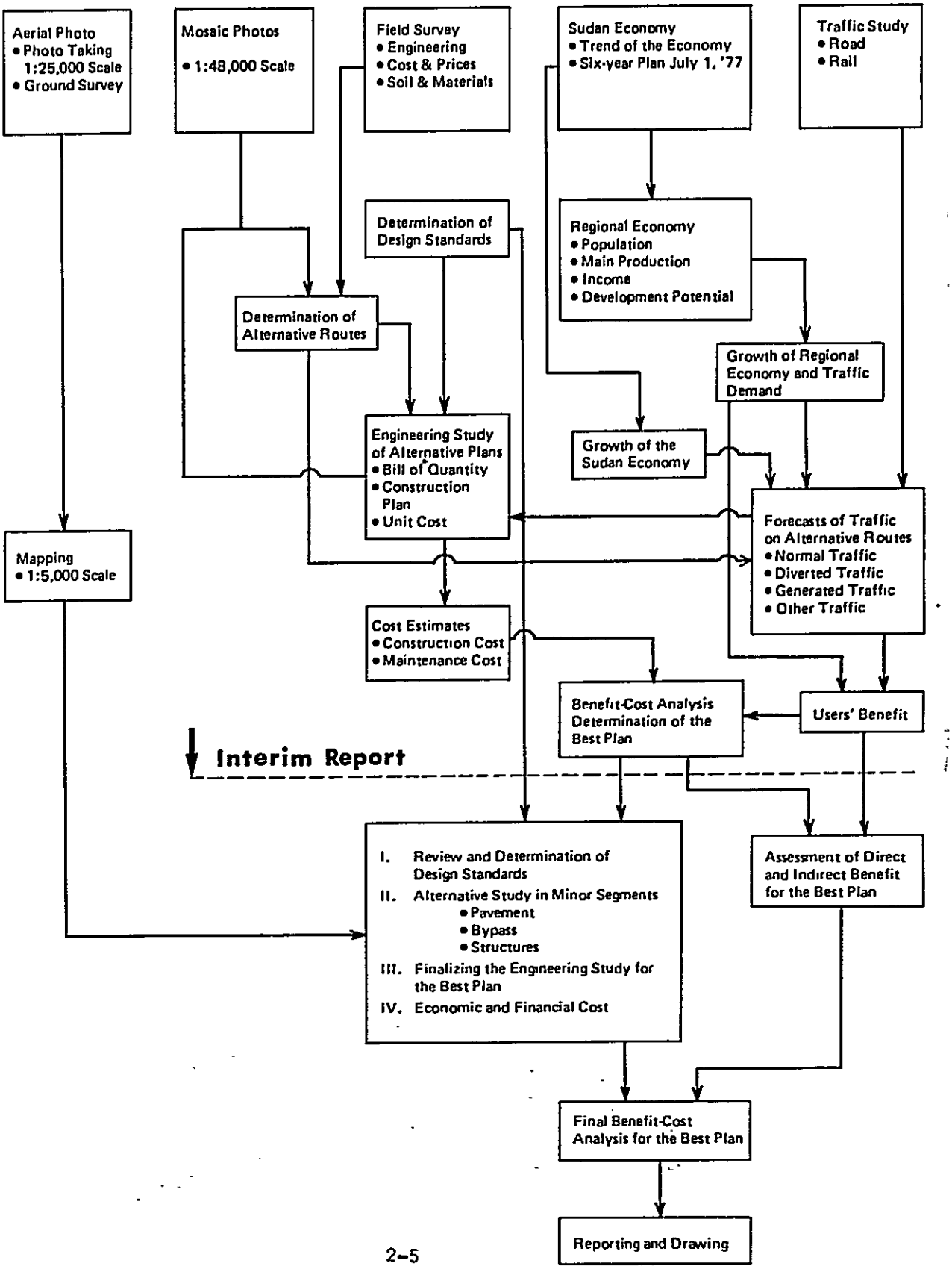

TABLE II-1 TIME TABLE OF THE STUDY

	1977 Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	1978 Jan.	Feb.	Mar.
1) Entering in and out of the Sudan													
2) Aerial photo taking													
3) Traffic Study													
4) Office work													
5) Cooperation of Counterpart staff in Japan													
6) Presentation of Interim-Report													
7) Continuation of the study													
8) Presentation of Final Draft Report													
9) Presentation of Final-Report													

CHAPTER III

3.00 THE SUDAN IN GENERAL

3.01 Geography

The Sudan is located in the north-eastern part of the Africa continent surrounded by Egypt, Ethiopia, Kenya, Uganda, Zaire, Central Africa, Chad and Libya. It has an area of 2.5 million sq. km, being the largest country in Africa. It lies in the area between 22°N and 4°N latitude, stretching 2,040 km from north to south and 1,600 km from east to west in maximum distance. It faces the Red Sea on the north-east with a coast line of 650 km. Port Sudan is the only sea port and thus handles all exports and imports of the Sudan.

The White Nile river originates in Uganda. The Blue Nile enters Sudan from Ethiopia and passes through the southern portion. Both Niles join in the center of the Sudan to form the Nile which continues north towards Egypt. Khartoum, the capital of the Sudan, is located at the confluence of the Blue and White Niles. The terrain is generally flat except for some highlands in the east, west and south. The Sahara Desert covers part of the country in the north. Rainfall is rare in this part of the country. Savanna lies in the middle of the country. Besides savanna, there are swamps, forests and jungles in the south.

The country has a typical tropical and continental climate. Hot and dry north winds cover the northern part of the country throughout the year. In the middle and southern part of the country, dry north winds and humid south winds alternate. The hottest season is from April to June, while November to January comprise the winter season.

Rainfall is rare in the northern part. More rainfall is registered in the central and especially in the southern part. Annual rainfall is 20 mm in the north and 1,500 mm in the south. The rainy season comes during the four months from June to September. Rainfall is heavy, sometimes with thunder. Sandy winds (haboob) occur frequently in the desert and savanna regions.

3.02 Population

A nationwide population census was carried out in 1955/56 and in 1973. Due to a shortage of information, there are different figures regarding the estimate of the nation's population. Those are two versions, one is by U.N. statistics and the other by the Sudanese Statistical Department. The over-all trends of population in the Sudan are noted in the following paragraphs.

According to U.N. statistics, the population was approximately 17.3 million in 1974 with an average growth rate of 2.6% per year during the past 8 years. The population of the country with the annual rate of increase since 1966 is shown in Annex III-1. It also shows changes of population in urban areas. It is observed that there has been a continuous increase of people living in urban areas. The rate of increase in urban population is estimated at 5.5% per year during the same period.

According to data published by the Statistical Department of the Sudan, the population in 1973 was 15.0 million, with an average annual increase rate of 2.2% during the past 17 years since 1956. Annex III-2 shows the population in the Sudan by province in 1955/56 and 1973.

The population density of the country was six persons per square kilometer in 1973.

The labour force (economically active population), defined as those who have a job and those who have the will to work in the age group over 15 years of age, is 8.4 million, comprising 55% of the people of that age group. The labour force is shown in Annex III-3, and indicates that 72% is occupied by the agriculture and livestock sector.

3.03 Economy

Persons engaged in agriculture occupy 3/4 of the labor force in the Sudan as shown in the Annex III-3. The majority are in a subsistence economy, marketing part of their product for cash income.

It is said that at present 15 million feddans of land are cultivated out of a total arable land area of 120 million feddans. It is expected that the Sudan will become a major crop producing and exporting country in the Arab world since the Government is enthusiastically planning to utilize uncultivated land with the cooperation of foreign countries.

Cotton, groundnuts, and gum arabic (Annex III-6) contribute to the economy of the Sudan by sharing more than 85% of total exports. Major export items and their values are presented in the Annex III-11. Dura and Dukhn are the main staples produced and consumed in the country. As shown in the Annex III-4 the output and producing area of cotton decreased by 20% and 40% respectively during 1973/74 - 1975/76.

Other crops had increased by 30%, on the whole, during the same period, as shown in the Annex III-5. Wheat, sugar, and some other corps are still imported. (Annex III-7)

The total population of livestock was approximately 40 million in 1973/74 as presented in the Annex III-8. The majority are raised by nomads who move continuously seeking fresh pastures. Part of the camel and goat population is exported to neighbouring countries from Port Sudan and Halfa. The export of cattle and sheep has been banned since the end of 1974 in order to maintain the supply of these animals in the local market to offset price rises. The most serious problem to be solved in the livestock sector is to keep and increase the area of pasture land in order to feed the huge population of livestock.

Some characteristics of the processing sector of the economy are that its raw materials are mostly agricultural products, that the government joins in investment both with domestic and foreign funds (examples: sugar, tannery, textiles), and that outputs are mostly insufficient to meet domestic demand (examples: cement, textiles, tobacco). Investment from abroad is encouraged by the Development and Promotion Act of Industrial Investment of 1972. The percentage share of the manufacturing sector in G.D.P. was around eight to nine percent from 1966/67 to 1975/76. (Annex III-9)

The inflow of foreign capital increased from £S20 million in 1971/72 to £S142 million in 1975/76, while the balance of payments has also grown in deficit from £S20 million to £S69 million during the same period. The balances are shown in Annex III-10.

Changes in G.D.P. in the past nine years are shown in Annex III-9. It is observed that there has been little change in the sectoral composition during these years. The drought of the early 1970's and the world inflation after the Arab-Israeli War of 1973 occurred during this period. G.D.P. at market price increased from £S533 million in 1966/67 to £S1,511 million in 1974/75. The latter is 2.8 times larger than the former and the average annual rate of increase is 13%. But, in terms of constant price, the G.D.P. increased by only 20%, at a rate of only 2% per year in these years. However, in terms of constant price the average rate of growth of G.D.P. from 1971/72 to 1974/75 was 4% per year, which would reach 5% or more if the period is extended to 1976/77. The Table of Annex III-9 shows that the percentage share of agriculture grew from 33% to 39% while the service industry share decreased from 29% to 23%.

3.04 Transportation

The Sudanese transport system consists of railways, roads, airlines and rivers. In addition, the traditional system of animal transport (camel and donkey) is commonly used by the people. The railways are the major carriers of export and import commodities, and of inter-regional passengers and commodities as well. The railways carried approximately 70% of the inter-regional flow of passengers and commodities in 1973 as shown by table in Annex III-13. The increase of services by other modes of transport is necessary for the growth of the economy. Accordingly, an improvement of the road network has been undertaken vigorously in the past several years.

Roads and Bridges Public Corporation (R.B.P.C.) is a unit of the central government, which administers planning, construction, and maintenance of the national road network. The government allocates some of its revenue for the expenditures of R.B.P.C. It has no revolving funds. The organization of R.B.P.C. at mid-1977 is shown in Annex III-14.

The Sudanese roads are divided, according to R.B.P.C. data, into paved roads of 875 km. (i.e., 5%) roads under construction of 900 km.(i.e., 5%), gravel roads of 6,000 km. (i.e., 30%), and earth and sandy roads of 14,000 km. (i.e., 60%). Earth and sandy roads are in poor condition. The roads network is shown in Annex III-15. Although R.B.P.C. is responsible for all national roads, actual maintenance is performed on paved roads only. Little maintenance is given to gravel and earth roads.

Passenger cars and small buses serve only in urban areas and on surfaced roads, since conditions of roads outside urban areas are so bad. Vehicles running on the roads in savanna and desert areas are mainly large and medium trucks, four wheel drive vehicles and buses, having larger wheels and higher power engines. Fine sand covering roads together with other negative conditions have resulted in high costs of road transport.

The ongoing improvement programme of the road network is presented in Annex III-16. The registered vehicles have increased from 50,000 in 1970 to 79,000 in 1975, with an annual average growth rate of 12%, while fuel consumption by vehicles has increased 4.5% per annum during the same period. These statistical data are shown in Annexes III-17 and 18.

Sudan Railways Corporation's Headquarters is located in Atbara, 330 km. north of Khartoum. The total length of track in operation is 4,800 km, all narrow gauge and single track. The section on which heavy traffic is concentrated is between Khartoum and Port Sudan through Atbara, a distance of 800 km., where rails of 90 lb/yard are installed. Other sections have rails of 75 or 50 lb/yard.

Tracks, workshops and rolling stock are generally obsolete although replacement of some of them has been undertaken. Their current performance cannot meet the transport demands of the country, often resulting in shortages of goods in the market place such as vehicle fuel, vehicle parts, cement, sugar, etc.

According to the Sudan Railways Report [1], the share of petroleum products amongest the commodities transported from Port Sudan to Khartoum is approximately 40%. Most of this will be diverted to pipeline transport which is scheduled to start operating in September, 1977. It is expected that the railways will utilize the facilities which will become available as a result of this diversion, for transporting other commodities or for allocating some rolling stock to other sections of the railways. Urgent investment projects are to construct a double track system between Port Sudan and Haiya and to replace much of the obsolete capital equipment.

There are 18 airports serving the domestic airlines among which Khartoum and Port Sudan airports are international airports and have

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Note 1) The Sudan Railways Corporation, Annual Report 1975/76.

facilities for night operation. The airports of Juba, and El Geneina are able to handle flights to and from neighboring countries. Flights between Khartoum and Port Sudan, Khartoum and El Obeid, and Khartoum and Juba are major domestic lines. Passengers on these lines in 1973 numbered 15,530, 17,138 and 9,826, respectively. The chart in Annex III-15 shows the airports and airlines.

Demand for air transport service has increased rapidly in recent years. Passengers carried by airlines totaled 100,000 in 1973. That is 4% of the total inter-city travellers in that year (Annex III-13). All domestic lines are operated by Sudan Airways Corporation. Boeing 737 and Fokker 27 are the plane models being used. They cannot serve the demand adequately because of obsolete airport facilities, mechanical troubles, and shortages in parts supply.

There are some additional points to mention concerning the Sudan transport system. a) Port Sudan is the only seaport serving all export and import by sea. Transport facilities to and from the port and berthing facilities are insufficient for the flow of goods. Congestion at pier and depot are quite common. b) River transport is prevalent on the Nile rivers. Major sections of this river transport are the Kosti-Malakal-Juba section on the White Nile river and the Karima-Dongola section on the Nile river. There are also ferry services crossing the rivers. c) Animal transport, mostly by camel and donkey are quite common in the country. Volume of such transport is hard to estimate. However, they play a very important role in regions where rail and vehicle transport are non-existant. It is presumed that some passengers prefer to use animal transport even in comparison with vehicle transport on a paved highway.

CHAPTER IV

4.00 THE ECONOMY IN THE PROJECT AREA

4.01 General Feature of The Zones of Influence

4.01.1 General

In this chapter, the zones of influence of the project will be shown followed by an estimate of population distribution, the economy in the project area, and prospects for the development of the regional economy. The existing status of transportation in the region is studied in chapter VI.

The project locates in the vicinity of El Obeid, a regional urban center in the western half of the Sudan. The city is the provincial capital of Northern Kordofan, situating 400 km. south west from the capital, Khartoum. With a population of 100,000, it is the third largest city and is the regional center of administration, economy and the hub of transportation. It is surrounded by vast flat savanna where people make their living by traditional farming.

The direct zones of influence of the project stretch towards the south-east covering the other towns of Rahad, Semeih, and Um Ruaba. Since the project area is close to the Nuba mountain area of Southern Kordofan Province, where cotton is produced predominantly, the southern part of the project zone also produces cotton. Most traffic between the north-eastern provinces such as Khartoum, Gezira, and the western provinces,

such as Southern Darfur and the western half of the Northern Kordofan Province, pass through El Obeid where vehicles refuel and load and unload commodities and travellers.

4.01.2 Zoning

Zones are determined in order to study the population, economy and traffic flow along the project road. The zones determined here are the same as the zones used in the traffic study of Chapter VI. The area of the project (direct influence zones) is delineated as 10 km. on both sides of the existing road between El Obeid and Um Ruaba. The center of each zone is set at the railway station or at a large populated village. Ten zones are fixed as shown in Table IV-1. The secondary influence zones are the areas outside the ten zones extending from Northern and Southern Kordofan to the whole country, as shown in FIG. IV-1. These indirect influence zones are 15 in number.

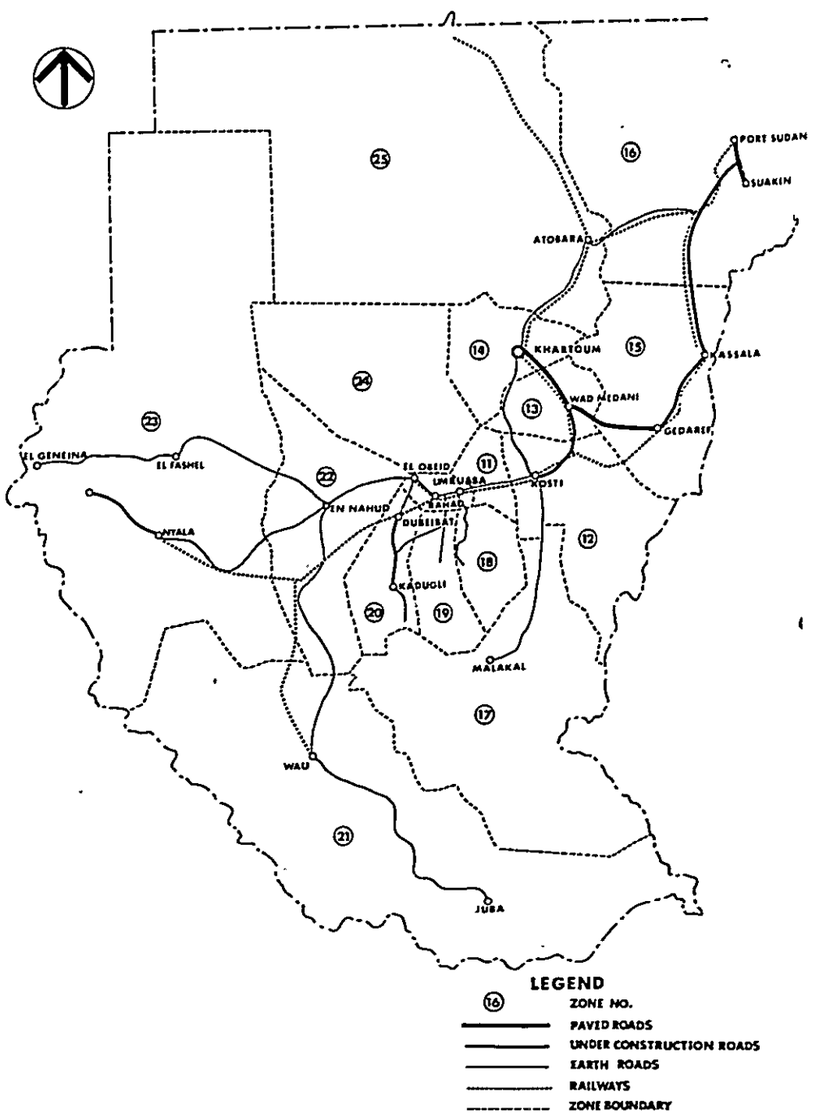
TABLE IV-1 DIRECT INFLUENCE ZONES

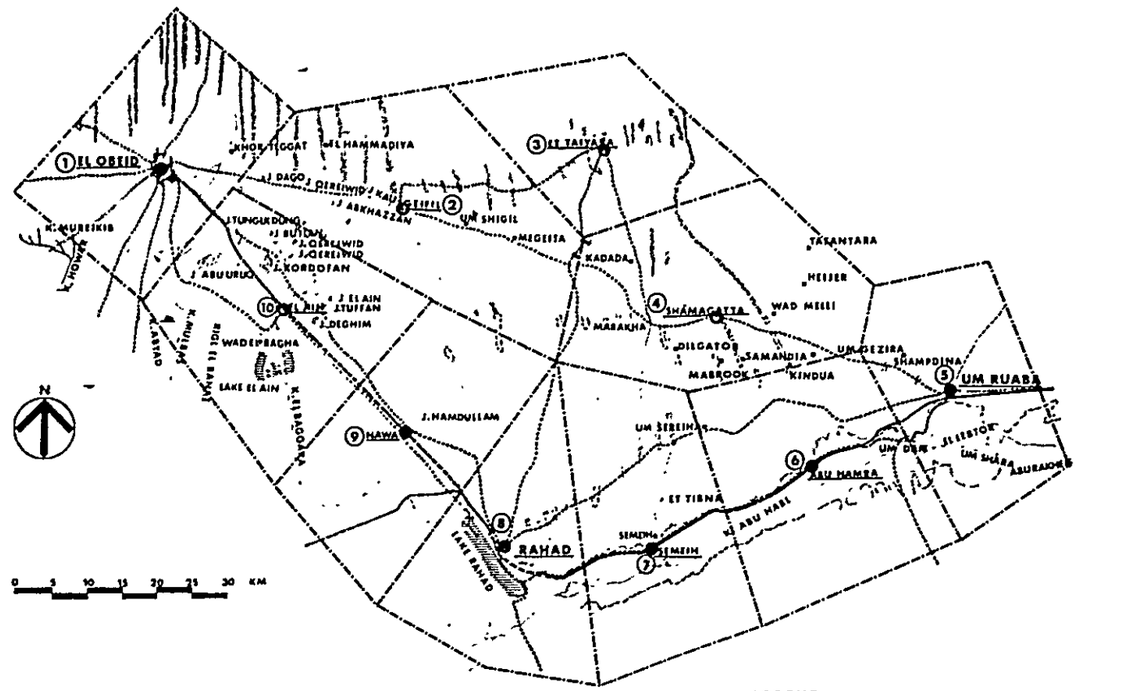
(Km^2)

No.	Name	Area	Urban or lake	Rural
1	El Obeid	675	20	655
2	Geifil	1,060		1,060
3	Et Taiyara	670		670
4	Shamagatta	920		920
5	Um Ruaba	770	2	768
6	Abu Hamra	870		870
7	Semeih	850		850
8	Rahad	700	3, Lake 31	666
9	Nawa	780		780
10	El Ain	850		850
	Total	8,145	56	8,089

FIG. IV-1

ZONE MAP AND ROAD NETWORK





NUMBER AND ZONE

1	EL OBEID	11	TENDELTI	21	WAU-JUBA
2	GEIFIL	12	KOSTI-SENNAR	22	EN NAHUD
3	ET TAIYARA	13	WAD MEDANI	23	NYALA
4	SHAMAGATTA	14	KHARTOUM	24	BARA
5	UM RUABA	15	KASSALA	25	ATBARA
6	ABU HAMRA	16	PORT SUDAN		
7	SEMEIH	17	MALACAL		
8	RAHAD	18	EL ABBASIYA		
9	NAWA	19	NUBA MOUNTAIN		
10	EL AIN	20	KADUGLI		

TABLE IV-2 POPULATION ESTIMATES IN NORTHERN KORDOFAN PROVINCE, 1977

	Settled Population		Nomad	Settled Population Total	Rural Population including Nomad	Total
	Urban (1)	Rural (2)	(3)	(1) + (2)	(2) + (3)	(1) + (2) + (3)
Northern Kordofan Province	198,406	903,083	213,916	1,101,489	1,166,999	1,365,405
Central District	105,738	97,792	5,149	203,530	102,941	208,679
Eastern District	40,097	291,451	21,365	331,548	312,816	352,913
Western District	38,953	307,034	9,822	345,987	316,856	355,809
Northern District	10,479	140,693	15,285	151,172	155,978	166,457
North-Western District	3,139	66,113	142,395	69,252	208,508	211,647
Free Lance	-	-	69,900	-	69,900	69,900

4.02 Population

4.02.1 Northern Kordofan Province

A national population census was carried out in the Sudan in 1955/56, a census of urban area in 1964/66, and a nationwide census in 1973. The results of the last census is not yet published. Population in these years is estimated by the Government and some U.N. offices, separately. The estimate of population by a U.N. office shows the growth rate in the past as a relatively high 3% p.a. It is considered that the average annual growth rate of the Sudan for the 18 years from 1955 to 1973 was 2.2% and that for Northern Kordofan Province, in the same period, 1.3%. The data provided by the Government and the provincial office are attached in Annexes IV-1, IV-2, IV-3. Based on these data and the information gathered at the project site, the populations of both Northern and Southern Kordofan in 1977 are estimated as presented in Annex VI-4.

Further, the district population for urban, rural, and nomads in 1977 is developed by using the above statistics. The result is presented in Table IV-2, in which the total inhabitants of the province number 1,365,000.

As shown in Table IV-2, the nomads in Northern Kordofan Province total 210,000 and together with those in Southern Kordofan Province they numbered 400,000 in 1977. While the source of Northern Kordofan Province says there were 286,644 nomads in the former Kordofan area in 1973, the preliminary

estimate [1] by the Department of Statistics in 1973 has a different figure of 406,274 for the same area. As this discrepancy indicates, it is difficult to determine the number of nomads since they move seasonally from one region to another.

4.02.2 The Estimate of Population in the Zones

The population for each of the ten zones is estimated in the following way: -- The number of villages are surveyed on the aerial photo at 1 : 48,000 (produced in 1962) and on the map at 1 : 250,000 (revised in 1975). The villages are divided into three groups according to the scale of the number of houses. Assuming each house has a family of five persons, the settled inhabitants in each village, and henceforth in the zone, are estimated. The result is shown in Table IV-3. The table also presents the population in urban areas, the number of farm households and those engaged in agriculture. The detail of the estimate of zonal population is attached in Annex IV-5.

4.03 Economy in the Zones

4.03.1 Urban Area

The delineated zones of influence of the project cover an area of 8,145 km^2 which is divided into urban areas of 25 km^2 (the three towns of El Obeid, Um Ruaba, and Rahad) and a rural area of 8,120 km^2.

Note 1) National Planning Commission, Economic Survey, 1974, Appendix Table 2-1.

TABLE IV-3 POPULATION IN THE ZONES OF INFLUENCE, 1977

Zone No.	Total	Urban	Rural Settled	Settled in Agriculture	Settled From-households
1	119,688	105,738	13,950	11,718	2,344
2	13,340	-	13,340	11,206	2,241
3	10,970	-	10,970	9,215	1,843
4	13,950	-	13,950	11,718	2,344
5	41,041	23,141	17,900	15,036	3,007
6	9,614	-	9,614	8,076	1,615
7	12,922	-	12,922	10,854	2,171
8	29,226	16,956	12,270	10,307	2,061
9	6,750	-	6,750	5,670	1,134
10	12,800	-	12,800	10,752	2,150
Total	270,301	145,835	124,466	104,552	20,910

There are more than 100,000 inhabitants in El Obeid, where the provincial headquarters and the branches of central government are located. There is a power plant operated by diesel fuel which provides electricity for the town. The town has developed a water supply network, although it suffers from chronic shortage of water. Social services are provided by such facilities as hospitals, medical doctors, primary and junior high schools, a senior high school with boarding facilities, crop and animal markets, fire stations, a court house, and a police force. The transport system and its uses are noted in Section 1, Chapter VI. There is an industrial area where the processing factories of edible oil of groundnuts and sesame, and the garages serving vehicles are located. There are small cottage industries such as tailors, shoesmiths, and furniture makers centered around several market squares in the town. Warehouses which store crops and others locate close to the truck terminal squares. The movement of goods in and out of the storehouses appears brisk.

There are several branches of banks including the Bank of Sudan. It is observed in the town that the supply of consumer's goods produced locally appear sufficient, while those imported to the market of retail shops and wholesalers appear insufficient. Many people gather at night in the markets for shopping, eating, and tea drinking.

Though the results of a survey on job opportunities for urban workers in 1973 are not yet released, it is considered

that the main sectors of employment are wholesale and retail shops, transport services including garages and gas-stands, public services and agriculture. Manufacturing is not developed yet and therefore, does not provide jobs for a large number of workers.

Um Ruaba is the center of the Eastern District with a population of 23,000. A characteristic point is that this town is the center of edible oil processing in the region. The number of factories are ten, larger than the five of El Obeid.

Rahad is the smallest town with a population of 17,000. An electricity system is not constructed yet. The railways split here, one going to El Obeid and the other to Nyala. An animal feeding yard was constructed several years ago to serve for the transport by rail of cattle from west to east. Unfortunately it has not been used. However, a study to utilize this facility for animal transport was started recently.

4.03.2 Rural Area

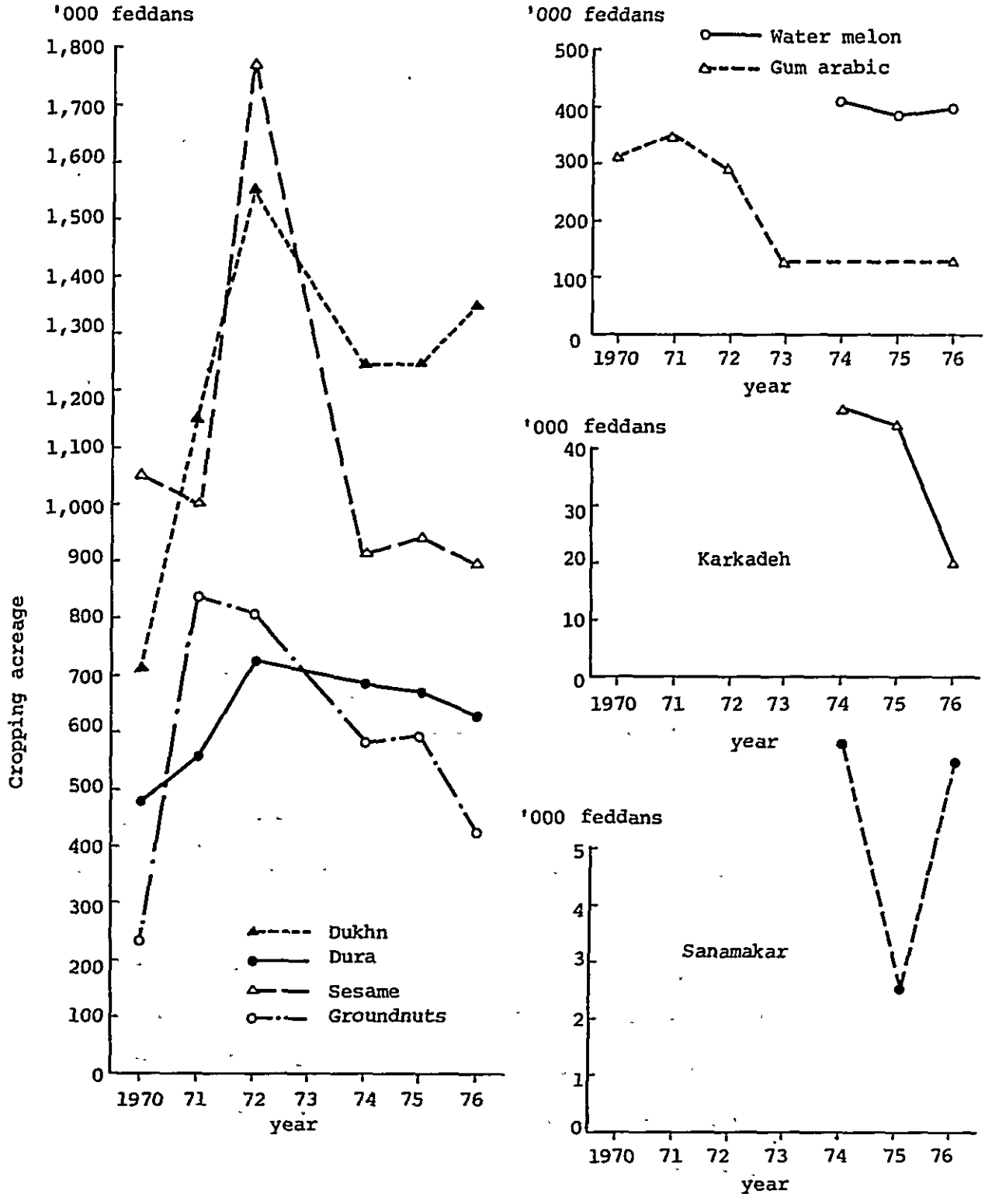
The rural area occupies 8,100 km^2 out of the total project area of 8,145 km^2. The farmers in the area lead simple, traditional lives. They live in huts of dry grass and dung. They consume most of the harvest by themselves but sell the remaining surplus to middlemen or carry it to market by donkeys or camels. Settled farmers keep animals for transportation and for their own milk and meat. Most animals sold in the markets are raised by nomads. It is said nearly 90% of the

animals in the province are owned by nomads.

The cultivated land including fallow areas of the province is estimated at 4.4 million fedans. The traditional rain-fed farming is predominantly practiced by farmers. The main cash crops are dura, sesame, groundnuts, watermelon seeds, and gum arabic from trees. Yearly output has not been stable. FIG. IV-2 and Annex IV-6 show the changes in the areas of crops and production since 1970. Production in recent years has been more stable than in the early 1970's. The main reason for the variation is that annual rainfall in the province is not constant, varying in a range of 200 to 400 mm, which barely satisfies the minimum volume necessary to raise these crops. A restraint on any increase in production is that water reservoirs and irrigation systems are not available yet so the farmers are unable to extend their area of cultivation into the uncultivated land nor are they able to increase the annual cultivation time span.

Table IV-4 shows the area of main crops and their products in Northern Kordofan Province and in the area of the project. Other noteworthy products in the Province are fire wood of 6,000 m^3, and charcoal of 12,100 tons. The project area also yields fire wood and charcoal from its savanna trees. Output is estimated at nearly 1/5 of that of the province. Both products are commonly used as fuel by the urban and rural populace.

FIG. IV-2 CULTIVATED AREAS BY TYPE OF MAIN PRODUCT IN NORTHERN KORDOFAN PROVINCE, 1970-'76



Sources : Produced by the data on Annex IV-6.

TABLE IV-4 MAIN AGRICULTURAL PRODUCTIONS IN NORTHERN KORDOFAN PROVINCE,1976

Items	Unit Yield Kg/f	Cultivated Area		Production	
		Direct Influence Zones '000 f,S	Northern Kordofan Province '000 f,S	Direct Influence Zones Tons	Northern Kordofan Province '000 Tons
Dukhn	120	174,000	1,300,000	20,904	156,000
Dura	150	88,440	660,000	13,266	99,000
Sesame	75	123,280	920,000	9,246	69,000
Groundnuts	350	71,020	530,000	24,857	185,500
Watermelon seeds	95	52,930	395,000	5,028	37,525
Karkadeh	12	4,958	37,000	59	444
Sanamakar	540	670	5,000	362	2,700
Gum Arabic	50	18,090	135,000	905	6,750
Total	1,392	533,388	3,982,000	74,627	556,919

Note: 1) The percent composite of farm households of the direct influence zones in the total of the province is applied to estimate the cultivated area in the direct influence zones.

One sector other than agriculture in the rural area of note is a ginnery of cotton near Semeih rail station in Zone 7. The cotton is cultivated by a corporation system covering a clay soil area of 7,200 feddans to the south east of Semeih railway station. Cultivation in this area is by the flooded farming method using the water of Abu Hable river in the rainy season. Each of 600 family keeps 12 feddans, 6 feddans for cotton and the rest for dura. Seed oil processing factories locate in the three towns of the project area. They buy sesame and groundnuts around the area and send oil and oilcake to Khartoum and elsewhere.

4.03.3 Livestock

Nomads own approximately 90% of the livestock in the province. The North-western district is said to contain the largest number of nomads and animals. They move northward in the rainy season and move deep into Southern Kordofan Province in the dry season seeking pasture lands. A nationwide livestock census was conducted in 1976. The results were partially published. The animals in the Central District and the Eastern District of the province are shown in Annex IV-7.

There are some animal markets in the urban areas. It is said that all animals brought to market are not always traded the same day. Often, when the quality of the livestock does not meet the buyers' requirements, the owners, mostly nomads, take the animals back to their fields and return them

to the market a few days later, or sell them to a slaughter house. Normal veterinary services, such as vaccinations, are given at the markets. Animals for slaughtering are priced by the market for slaughtering. Since animals slaughtered in the markets number less than total consumption in the region and there are few animals exported to other regions, it is surmised that many animals are slaughtered in the villages privately. Their number exceeds by far those slaughtered in markets. The registered trade of animals at the markets is shown in Annex IV-8.

4.04 Average Household Income

An estimate of the main cash crops and their cultivated land in each zone of the project area is shown in the table of Annex IV-9. Farmers market their surpluses immediately after the harvest, approximately 80% of them during the months from November to January.

The market prices in 1977 at El Obeid are shown in Annex IV-10. Market charges are levied on the traded crops and are usually paid by the buyers. Charges per 100 Quntar are £S0.20 in average; it is taken the charges are equal to 0.1% of the unit market price. The losses of crops, during transport by animals or transport by trucks, are deducted resulting in a net income of 90% of the market price for such rural produce.

The farmer doesn't own his land in one unit, rather it is quite common for a farmer to hold land in several parcels located close to his house or far away from the village. When they seed or harvest, they often live in temporary villages far away from their original village.

It is estimated that cash income per family in 1977 will total £S155 (US$380)(Annex IV-11). It thus comes to £S13 per month and £S30 (US$75) per person. On the other hand, in urban areas, the statistics on distribution and income of jobs are not available; only the following income level could be obtained for El Obeid.

Unskilled labor	£S 25 per month
Employed by service sector or factory worker	£S 35 per month
Driver and mechanic	£S 45 per month
Skilled worker	£S 55 per month
Junior office clerk	£S 50 per month
Senior office clerk	£S 80 per month

It can be seen by these figures that income level is higher in urban areas than that in rural areas. The higher level of income in urban areas is a contributing factor to immigration from rural to urban areas.

4.05 Future of the Regional Economy

4.05.1 Rural Economy

The climate in the project area, according to the climatologic classification of W.P. Koppen, is a desert or savanna climate with rainfall in the summer season. Annual rainfall ranges between 200 mm and 400 mm; however, it has registered a wide range of variation together with the volume per each rainfall. Evaporation ratio is 15 mm per day in average, decreasing to one-half in the rainy season. Humidity is 15% in the dry season and 50% in the rainy season. Temperatures average a maximum and minimum of 39°C and 24°C, respectively, in May and 31°C and 14°C, respectively, in January.

The range of changes in temperature is suitable for the growth of plants and livestock. Wind velocity, registering 3.5 m/sec. in average, is generally mild except for the strong wind (Haboob) during the dry season. However, the negative effect of the habbob on crops is lessened by the vegetation in the savanna.

The terrain is flat, having a range of gently sloping hills. The rivers (khors) contain no water during the dry season. Clay soil covers the southern part of the project area. The region is called "Vertisols". The clay soil shrinks in dry season, while swelling occurs in the rainy season. Fertility is high. There is a high density subbase stratum of which permeability is low. The clay soil area extends from the

southern part of Northern Kordofan Province to the Nuba mountain region in Southern Kordofan Province, where cotton is produced predominantly.

Most of the area, except the above clay soil area, is covered by a soil called "Qoz" which belongs to the Arenosols region. It is a stabilized mature sand soil covering the vast plain with uniform quality. Fertility is low. It becomes firm with the rain. Traditional rain-fed farming is quite common on this soil which produces dura, groundnuts, sesame, arabic gum and karkadeh. Land productivity is low compared to the average of the country. These relative figures are shown in Annex IV-12. Also, nomads move through the area grazing animals.

The problems to be encountered in the future regional economy are summarized as follows.

i. Water Resources, and Facilities to Use Them

As mentioned in other sections, rainfall is not sufficient, and it is irregular. The use of underground water should be developed further, together with the feasibility of constructing water reservoirs and an irrigation system. The shortage of water is the most serious problem to be solved in the course of agricultural development. It is a cause of decrease in productivity and a restraint on the expansion of cultivated land. Farmers concentrate traditional cultivation on land close to their villages. Although they practice land-shifting by burning plants

and fallowing, it is hard to maintain fertility under the existing conditions.

ii. Traditional Ownership

Land around the village is traditionally owned by small scale farmers. When a large scale, mechanized farming system is introduced, the existing land ownership should be reorganized.

iii. Shortage in Pasture Land

Keeping a large number of livestock, nomadic people move north in the rainy season and return south in the dry season. Along the way they sell some of their livestock at urban markets or to farmers in the villages. Quite similar to the case of farmers, nomads need enough pasture land to feed the animals which steadily increase in number. Some policies and programmes should be adopted to maintain the pasture for animals.

iv. Damage by Blight and Insects

Nematode is a cause of damage to vegetation often seen in the region. It is well known that this disease spreads easily on land where vegetables of the same kind are planted continuously, year after year. One method of extermination is the spraying of chemicals on the soil. However, over a vast plain like that of the project area, the only

practical way to get rid of nematode is to apply a sequence of burning, shifting and fallowing on a scheduled basis.

The diseases of livestock in the region are rinderpest, foot and mouth disease, and anthrax. Vaccination, routine observation by veterinary staff, and the establishment of animal check points are necessary to keep the livestock in a healthy condition. In both sectors of farming and livestock, the implementation of effective methods to prevent diseases is yet to be seen. They are just getting started on a modest scale.

v. Demonstration Farms

The El Obeid office of the Ministry of Agriculture has already located several demonstration plots through which they can offer guidance to farmers. The scale of these activities is small. The office in El Obeid has not yet fixed a plan to develope these demonstration plants into an efficient organization, because of a shortage of fund.

vi. Agricultural Development Projects

There is no practical development project for agriculture and livestock in the project area. Persons concerned in the Government and Province have several ideas of investment to promote the growth of the regional economy. These ideas require study and fund allocation.

Through these findings, it is concluded that the rural population in the area will grow slowly at a rate of less than 1% per annum and that the economy consisting of rain-fed farming and livestock production will grow steadily, similar to its past performance.

4.05.2 Urban Economy

As mentioned in 4.03., Chapter III major products of the urban manufacturing are the processing of the edible oil of crops grown in the rural area. If the primary product increases further, the output of these factories will increase simultaneously. This will invite new investment and cause a chain of multiplying effects in other sectors of the regional economy. However, it is likely that the rapid expansion of the primary product and new investment in the processing sector are premature as a realistic programme for the near future. It is also unlikely that there will be rapid development in any sector of the service industry. The urban economy in the region will continue to grow at about the same rate as in the past decade.

4.05.3 Development Benefits

By considering the economy at present and in future, development benefits and development traffic will be negligible in relation to the investment in the road project. It has been decided not to quantify the development benefits in the benefit-cost analysis.

CHAPTER V

5.00 INVENTORY OF THE EXISTING ROADS

5.01 *Road Condition Survey*

The project area of this survey is a semi-dry district that conforms to a tropical savannah climate. El Obeid is located 575 m. above sea level, Rahad, 496 m. and Um Ruaba 450 m. The land, as a whole, is gently rolling.

On the west side of the road connecting Rahad and El Taiyara, there are many rocky mountains such as J. Kordofan, 785 m. above sea level, and J. El Ain, 759 m. above sea level. These mountains are also the source of many streams in the area. The east side of the road is links land where dunes are observed every 1 - 2 km. running in a south-north direction and 15-30 m. in height. The west slope of the dune is steeper than that of the east slope. South of the railway, between Rahad and Um Ruaba, Abu Habl river runs from west to east.

There are two roads between El Obeid and Um Ruaba as shown in Annex V-1. One is the southward route running along the railroad via Rahad with a length of about 150 km. This road is utilized mainly during the dry season. The other is a nothward route, via Shamagatta, with a length of about 120 km. This road is utilized mainly during the rainy season.

These roads, except at the city zone, are so called multi-choice roads that are not maintained or repaired and drivers are forced to select better alignments.

As shown in Annex V-2, routes I, II and III are flat. However, in routes IV and V, gradients of more than 3% are observed at several places due to crossing sand dunes. (For fourther details of existing roads, refer to Annex V-3 and V-4)

5.01.1 Route I (El Obeid - Rahad L=75.2 km.)

Route I connects El Obeid and Rahad, running along the north-east side of the railroad, and has a total length of about 75 km. This route is divided into three sections for explanation purposes.

i. El Obeid - El Ain (L=27.3 km.)

The starting point is at a T-type intersection in front of the El Obeid railway station. From the starting point, a 6-meter width road runs 2.2 km. to the entrance of the airport. The road surface is penetration bituminous pavement and is bumpy. The road intersects with the railways 2.9 km. from the station. Guard rails are installed at the intersection only and no rail protection material is provided. Therefore, the crossing is suitable only for vehicles with high ground clearance.

The road runs parallel with the railway for 9.1 km. Drivers are driving at a speed of 40 - 80 km/hr. within a 200 m.-wide zone, selecting the most suitable course. There are no structures at waterway crossings and

during the dry season drivers cross the dry and sand-bottomed river by finding the most suitable point.

At a point 16 km. from the station, the road separates into northward and southward courses and goes around Kordofan Hill. The northward course is the main route for large vehicles, and ascends to the plateau of Kordofan with a 3% gradient. Between 18 km. and 20 km. from the station the road becomes sandy. Duruing the rainy season, the road becomes a waterway and deep ruts are formed.

On the southward route, there are many streams flowing down from Kordofan hills although the gradient is flat. Between 22 km. and 28 km. the route is crossed by many streams, one of which is El Baggara river, the largest stream in this project area.

ii. El Ain - Nawa (L=22.2 km.)

This road runs along the valley of J. El Ain. Big rocks are scattered on the surrounding slopes,and there is some danger from falling stones. From El Ain hills to Nawa, there is a gentle down slope. The width of the road is about 100 m. with several deep ruts. Drivers select better routes freely, avoiding the deep ruts formed during the rainy season. At the front of Nawa station, a river, K.Nawa, flows and in the dry season the river bottom becomes a road. The road surface is in very bad condition.

iii. Nawa - Rahad (L=25.7 km.)

At 63 km. from the starting point of El Obeid, the planned road joins a road which connects Rahad and Geifil. Starting at this junction, and continuing for 6 km., the road surface is very good. There is a gentle down slope which permits driving at 80 - 100 km./hr. After this, a good road continues in a fine sand zone to Rahad.

5.01.2 Route II (El Obeid - Rahad, L=75.8 km.)

i. El Obeid - El Ain (L=31.6 km.)

The starting point is the same as Route I, but branches off at the airport entrance on the paved road. About 5 km. after the branch-off, vehicles can run more than 60 km./hr. on the so-called multi-choice road. From 8 km. to 30 km. from the starting point, a 10 m. width earth road continues which has some indication of surface work by a grader. Maintenance and repair of this road is currently taken care of by the El Obeid Airport which uses it for transporting water from lake El Ain for an Airport expansion project.

Up to 15 km. from the starting point, the road runs in the middle of a wide ridge. This is the best section of road and is not interrupted by crossing waterways. There is an irish bridge for the crossing K. Mulbas at 15 km. from the starting point. This bridge has a width of 6.7 m. and a length of 33 m., and the road surface is concrete pavement.

The shoulder is protected by gabion. There is another route from El Obeid to the irish bridge at Mulbas river. It runs off at 3 km. point on the road from El Obeid to Kadigli and Dilingi, passes by a reservoir of Beinu and comes to the irish bridge. Although it is an earth road, vehicles can operate at a speed of 60 - 90 km./hr.

At 31 km. from the starting point, K. El Baggara flows. This waterway has no bridge. According to local drivers, they some times have to wait as long as 25 days before they can cross during the rainy season. In addition, short waits occur at other times in the rainy season.

ii. El. Ain - Rahad (L=44.2 km.)

This road runs parallel to the railway at its west side. The slope is gentle except for a sudden gradient change at the waterway crossing. There are two crossings with the railway at 65 km. and 75 km. from the starting point, but crossing is very difficult because no crossing facility is provided. On K. Nawa, 67.7 km. from the starting point, an irish bridge was built. However, at present, the concrete surface of the bridge is damaged and has not been repaired so vehicles are crossing on the fine sand river bed instead of on the bridge.

5.01.3 Route III (Rahad - Um Ruaba L=79.0 along the railways)

As this route runs across the K. Abu Habl flooding plain, it is

only available during the dry season. Where sand dunes exist, the gradient of the road increases to 2 - 3% and driving becomes very difficult due to loose sand. The flooding plain is a wide road, generally flat except for small deep tracks and cracks at the clay zone. The road intersects with the railways at two points near Abu Hamra and near Um Ruaba, on which no crossing structures are provided.

5.01.4 Route IV (Rahad - Um Ruaba L=72.5 km. mountain side)

On this route the road runs among sand dunes and is utilized during the rainy season. As the road crosses the sand dunes 20 - 30 m. height, sections of 3 - 5% gradient occur frequently. Moreover, on the sand dune, deep tracks with loose sand are developed which makes driving difficult during the dry season.

Several places, which may turn into ponds during the rainy season, were observed in the valley of the the sand dunes. The biggest pond is 18 km. from the starting point in Rahad. When necessary, vehicles are driven around the pond.

5.01.5 Route V (El Obeid - Um Ruaba, L=118.7 km. mountain side direct route)

As sand dunes occupy the major portion of this route, the road is mainly utilized during the rainy season and seldom utilized during the dry season.

In the suburbs of El Obeid, about a 2 km. length of subgrade road,

running northeast, has been constructed with up to 0.5 - 1.5 m. of embankment height.

In the vicinity of Um Ruaba, although horizontal alignment is established, there is no base course nor subgrade.

Betwen El Obeid and Geifil, the land lies flat, and the road surface is hard. Accordingly, driving is comparatively easy. Between Geifil and Um Ruaba, sand dunes similar to Route IV are formed regularly. Due to the steep gradient and loose surface, vehicles are running about 20 km./hr. in this area. Villages are scattered around the summit of some sand dunes, and the road passes near these villages.

5.01.6 Access Road (Rahad - El Taiyara L=40.9 km.)

This route is the shortest one between Rahad and Route V, but it is a multi choice road where vehicles are running on fine sand, following tracks. The gradient is gentle and Khor are not crossing. Thus, vehicles are able to drive at 30 - 40 km./hr. However, at 13 km. from the starting point in Rahad ponds form during the rainy season.

5.02 Topographic Survey

The Survey Department has supplied a photo mosaic with the scale of 1 : 48,000 covering the project area. By adjusting the scale to 1 : 50,000 the photo mosaic, together with a map of 1 : 250,000, are used for engineering work in the first stage of this study.

The study team has been given an airphoto of the southern route at a scale of 1 : 25,000 with a width of 5 km. A topographic map, at a scale of 1 : 5,000, is drawn for a width of 500 m. each side along the best alternative determined by the first stage of the study. The following ground surveys were conducted to supply necessary data for developing the map.

a) the installation of air signals

b) the identification of the three triangulation stations of the Survey Department

c) traversing and leveling

d) azimuth observation

e) names of towns, rivers, mountains, etc.

The map at a scale of 1 : 5,000 has a counter of 2.0 m. The map on which the designed alignment is drawn, will be attached to the final report.

5.03 Soil and Material Survey

5.03.1 Soil

i. General

The variety of soils in the project area is small and have five classifications as shown in the soil map (Annex V-5)

a. Dune sand

b. Cotton clay

c. Sandy silt

d. Silty clay

e. Clay

To investigate characteristics of soils as materials for subgrade and embankment, a laboratory test was performed. Samples of the soils were collected at 15 points, as shown on the soil map (Annex V-5), and 8 samples, representing the classification, were entrusted to R.B.P.C. Laboratory for testing in compliance with AASHTO standards.

a. Sieve Analysis (A.A.S.H.T.O. T-88)

b. Specific Gravity Test (A.A.S.H.T.O. T-100)

c. Compaction Test (A.A.S.H.T.O. T-99)

d. Atterberg Limit Test (A.A.S.H.T.O. T-90)

e. Shirinkage Limit Test (A.A.S.H.T.O. T-92)

f. C.B.R. Test (A.A.S.H.T.O. T-193)

The results of the test are shown in Annex V-6.

ii. Survey Results

a) Summary of Survey Results

a-1) As material for subgrade, dune sand and sandy silt are most suitable. Cotton clay, silty clay and clay are not so good.

a-2) As material for embankments, dune sand and sandy silt

for embankments, thorough precautions have to be taken during construction.

a-3) Since dune sand and sandy silt are erosive, clay and gravel are recommended for use on the slope covering the above materials.

b) Feature of Soils

b-1) Dune sand is fine sand of a red-brown colour, single grain, and is composed of crystalline rocks such as sand stone and granite which originate from Nubian [1] of the latter term of Diluvium.

Sand dunes are longitudinal dunes which run in an almost south-north direction and are fixed at present by iron oxide or plants. Dune sand belongs to A-3 of AASHTO classification and is suitable for subgrade and embankment material. However, lowering of shearing strength by compaction is feared. Also, due to easy erosion, slope protection becomes necessary.

b-2) Cotton clay is deep grey coloured alluvial clay accumulated on the flood plain of K. Abu Habl. Cotton clay has another name - dark cracking clay, because tortoise shell cracks occur in this layer during the dry season due to its shrinkage and swelling properties.

Note: 1) Name of stratum of mesozoic era and spreading in mid-north zone of Sudan.

Heavy specific gravity is a special feature of this clay, and organic compounds are partially involved. The high value of liquid limit and plasticity index are identified. By AASHTO classification, this clay is classified as A-6 or A-7 and unsuitable for materials of subgrade or embankment.

b-3) Clay is blue-grey coloured alluvial clay accumulated on the low ground between sand dunes. Its properties are about the same as cotton clay.

b-4) Sandy silt and silty clay are distributed along the existing routes of I, II, V and at a part of the access road. Sandy silt is red-brown or dark red-brown coloured aeolian soil and forms a thin cover over silty clay. Sandy silt contains 20 - 30% of fine grain with the diameter of less than 0.074 mm. This soil is classified as A-2-4 by AASHTO classification and is suitable for subgrade and embankment material. However, this soil erodes easily,and it is necessary to provide slope protection.

Silty clay is fine grain soil, brown or yellow-grey coloured, involving silt and clay for 40 - 50 %. Similar to the nature of cotton clay, the volume of this soil changes considerably. By AASHTO classification, this material belongs to A-6 class and is not recommended as subgrade or embankment material.

5.03.2 Bridge Foundation

Rivers in the project area are located at cotton clay or silty clay zones. Bridge construction is considered necessary at the following points. They are shown in Annex V-5.

1) 7.4 km. point from El Obeid
2) K. El Baggara
3) K. Nawa

At the above points, a seismic prospecting was performed to estimate the bearing capacity of the foundation.

The results of the seismic survey are shown in the Annex V-7. The ground, on which a bridge construction is planned, is compacted with silty clay and the assumed *N* value by seismic prospecting is 22 - 23. A converted value to allowable bearing capacity is 25 t/m^2, which is considered satisfactory for spread foundation. In addition, as silty clay has a low degree of saturation and is tightly compacted, there will be no settlement due to consolidation.

5.03.3 Materials

i. General

As shown in the location map of materials (Annex V-8), almost all of the construction materials are located in the north-west part of the project area.

To investigate the suitability of rocks and gravel, a survey was conducted to find 15 sample points. Samples selected from these points were entrusted to R.B.P.C. to perform the following laboratory test.

1. Specific Gravity Test (A.A.S.H.T.O. T-100)
2. Los Angeles Abrasion Test (A.A.S.H.T.O. T-91)
3. Absorption Test (A.A.S.H.T.O. T-1228)
4. C.B.R. Test (A.A.S.H.T.O. T-193)

In addition, as materials for base course are few at the sand dune zone, the following stabilization test was performed in the consultants' office.

a) Cement stabilization test

Compaction test (A.A.S.H.T.O. T-134)
Unconfined compression test (A.S.T.M. D-1633)
Wetting and drying test (A.A.S.H.T.O. T-135)

b) Lime stabilization test

Compaction test (A.A.S.H.T.O. T-134)
Unconfined compression test (A.S.T.M. D-1639)

c) Asphalt stabilization test

Hubbard-Field stability test (A.S.T.M. D-1138)
Marshall stability test (A.S.T.M. D-1639)

ii. Test Results

Test results are shown in Annex V-9 and summarized as follows:

a) Gravel deposits

Gravel deposits are scattered around rocky mountains in the form of pediment or fulviatile deposit and are generally suitable as sub base course material. A gravel deposit 10 km. from El Obeid has plenty of fine grain components and indicates low C.B.R. value. However, by mechanical stabilization, these gravels can be used as sub base course material.

There is a gravel pit at J. Abu Uruq which is used for the El Obeid Airport construction. Quartz gravel of good quality in deposit of more than 500,000 m^3, is available. They are suitable for a base course material by conducting a mechanical stabilization.

b) River bed deposits

Sand is deposited at river beds, near rocky mountains. Specifically, plenty of coarse sand is available from K. El Baggara. Grain forms of the sand are irregular and angular and, as clay and organic components are few, these sands are suitable as fine aggregate for concrete.

c) Rocky Mountains

Rocky mountains are formed with granite of plotonic rock, aplite of dyke rock, pegmatite and shist of metamorphic rock and generally suitable as aggregates for pavement and concrete, especially suitable are quartzite and fine grained acid rock. At J. Dago, hard quartzite gravel is available as good quality material for use in surface course and in concrete. J. Et Tibna, about 6.0 km. north of Semeih, produces good quality material. However, as the trigonometrical station of Survey Department is located there, no quarrying is allowed.

iii. Stabilization

As previously stated, there are little gravel deposits in the sand dune area. Stabilization test of dune sand was performed, and the test result is shown in Annex V-10. As dune sand is uniform fine sand, stabilization by asphalt or lime is not effective. In cement stablization, unconfined compaction strength indicated 25.4 kg/cm^2 by 10% cement addition. This proves cement stabilization is effective for dune sand.

5.03.4 Water for Construction

i. General

Underground water has two series, Um Ruaba series [1] and Nawa series [2], and is the major water supply source for the sand dune zone where no reservoirs exist. Reservoirs are located at the silty clay zone between El Obeid and Rahad, and at the cotton clay zone between Rahad and Um Ruaba. These reservoirs are utilized as water for living at El Obeid and Rahad and as water for irrigation at K. Abu Habl basin. Annext V-13 shows the location of reservoirs and underground wells.

Water required for construction work can be secured from reservoirs at El Ain and Rahad.

The El Ain reservoir is being expanded as written in Annex IV-14. Pondage will be 5,500,000 m^3 after completion. Rahad reservoir has abundant pondage of 56,000,000 m^3 and is being utilized for local inhabitants, cattle and irrigation, and there is still a sufficient amount for construction use.

Notes: 1) Name of stratum at tertiary or quaternary era.

2) Name of stratum at the paleozoic era.

5.04 Hydrological Survey

5.04.1 Climate at Project Area

The rainy season is between June and October in which annual rainfall is about 400 mm. (Ref. Annex V-14) The weather condition of El Obeid and of Kosti is shown as follows.

TABLE V-1 WEATHER IN EL OBEID AND KOSTI (1941-1971)

Location	Item	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
El Obeid	Rainfall(mm)	0	0	0	2	14	27	113	143	68	19	0	0
	Humidity (%)	16	13	11	12	19	29	47	56	42	23	17	16
	Direction of Wind	N	N	N	N	N	SSW	SSW	SSW	SW	N	N	N
	Temp(C°) Max.	38.6	40.7	42.9	43.0	44.3	42.3	40.0	37.7	39.0	29.7	38.4	37.6
	Temp(C°) Min.	6.4	4.4	9.0	13.0	17.2	17.1	17.3	17.5	17.1	14.5	9.2	5.8
Kosti	Rainfall(mm)	0	0	1	2	16	39	111	142	63	21	1	0
	Humidity (%)	23	18	14	13	21	32	46	57	67	31	23	24
	Direction of Wind	N	N	N	N	N	SSW	SSW	SSW	SSW	N	N	N
	Temp(C°) Max.	40.2	42.2	44.8	45.3	46.0	44.2	41.5	40.2	40.8	41.6	40.8	39.1
	Temp(C°) Min.	10.3	10.6	12.4	14.4	17.0	18.4	18.9	18.9	19.0	18.2	13.1	10.1

Source: Meterological Department, Sudan 1941-1977.

5.04.2 Probable Rainfall and Depth Duration Curve

i. Probable daily rainfall

Probable daily rainfall is calculated by the maximum value of the daily rainfall record for each year as shown in Annex V-15. Calculation followed the Gumbel method. The result of this calculation is shown below and by Annex V-16.

Probable Rainfall

Return Period	Maximum Rainfall (mm/day)
10 years	83.0
50 years	110.0

ii. Rainfall intensity formula

The intensity of rainfall is strong for short periods in a small hyetal region. A pattern of rainfall intensity is shown as follows:

Duration (Min.)	1,440	360	120	60	30
Accumulated percentage	100	95	90	86	80

Source: Meterological Department, Sudan, 1977

Based on this pattern, the intensity is determined by the following formula

$$r = \frac{a}{t + 7.0}$$

Probability per 10 years : $r = \frac{5,006}{t + 7.0}$

Probability per 50 years : $r = \frac{6,635}{t + 7.0}$

Where r = Rainfall intensity within minutes (mm)

t : Time of concentration (minutes)

$$t = \frac{L}{20.I^{0.6},60}$$

Where I = Water surface slope

L = Length (m) of water flow

5.04.3 Estimate of Discharge

Discharge of the river was calculated using the following rational formula.

$$Q = \frac{1}{3.6} .f.A.r.$$

Where Q : Discharge (m^3/s)

f : Run-off coefficient (0.15 - 0.25)

A : Catchment area km^2 (Ref. Annex V-17)

r : Rainfall intensity (mm/hr.)

Probability, 1/10, 1/50

Run-off coefficient f was assumed as follows;

(a) For up to 30 km. point from the starting point ((1) - (13)) f = 0.25

(b) For other rivers beyond the above area. f = 0.15

For some rivers on which the above formula is not applicable, discharges are estimated by a specific run-off curve. The

specific run-off curves, which are developed by this study, are shown by Annex V-18. The result is shown in Annex V-19.

CHAPTER VI

6.00 TRAFFIC STUDIES

6.01 Transport System in the Project Influence Area

6.01.1 General Description

The project influence area is served by rail, road and air which connect the area with the rest of the country, as is shown in FIG. VI-1 which illustrates an overall transport network. El Obeid is the center of transport as well as of socio-economic activities in the West Sudan and has been playing an important role in the region.

Railways link the project area with Khartoum and Port Sudan in the east, Dubeibat and Nyala in the west and other important regional centers in the south. An air route connects El Obeid and Khartoum. Major inter-regional roads linking the project area with other regions are:

to the north; El Obeid - Bara - Khartoum,

to the west; El Obeid - En Nahud - El Fashiel or Nyala,

to the east; El Obeid - Um Ruaba - Kosti - Khartoum,

to the south; El Obeid - Dillinge - Kadugli,
Um Ruaba - El Abbasiya and
Rahad/Semeih - Dillinge - Kadugli/Nuba Mountain

Among the roads listed above only two sections, namely Khartoum - Wad Medani and Dubeibat - Dillinge are paved while the others are earth roads. As many of these earth roads are merely ruts

and are not properly maintained, difficulties are often experienced in driving vehicles. During the rainy season traffic is even cut off in some sections.

6.01.2 Roads

The road network in the project area is basically composed of two trunk routes, the southern route along the railways linking El Obeid, Rahad and Um Ruaba and the northern route linking El Obeid and Um Ruaba directly, and the various feeder roads branching off from the trunk routes. Of the roads in the area only a part of urban streets and a road to the airport in El Obeid are paved.

Generally, the Southern route along the railways is utilized throughout the year except during rainy season when the sections of silty clay become so muddy due to heavy rain that traffic is greatly impeded and often stopped, particularly in the section between Um Ruaba and Semeih. Then, the northern route and/or other small tracks in the Qoz area, which are less affected by rainfall, are utilized. Existing conditions of the roads in the area are described in detail in Chapter V.

Given such road conditions, light vehicles, except those of four-wheel drive, can not pass on these roads. Trucks with loading capacities of 6 to 11 tons prevail in the inter-regional traffic. Donkeys and cammels are also popular traditional means of transportation for shorter distances.

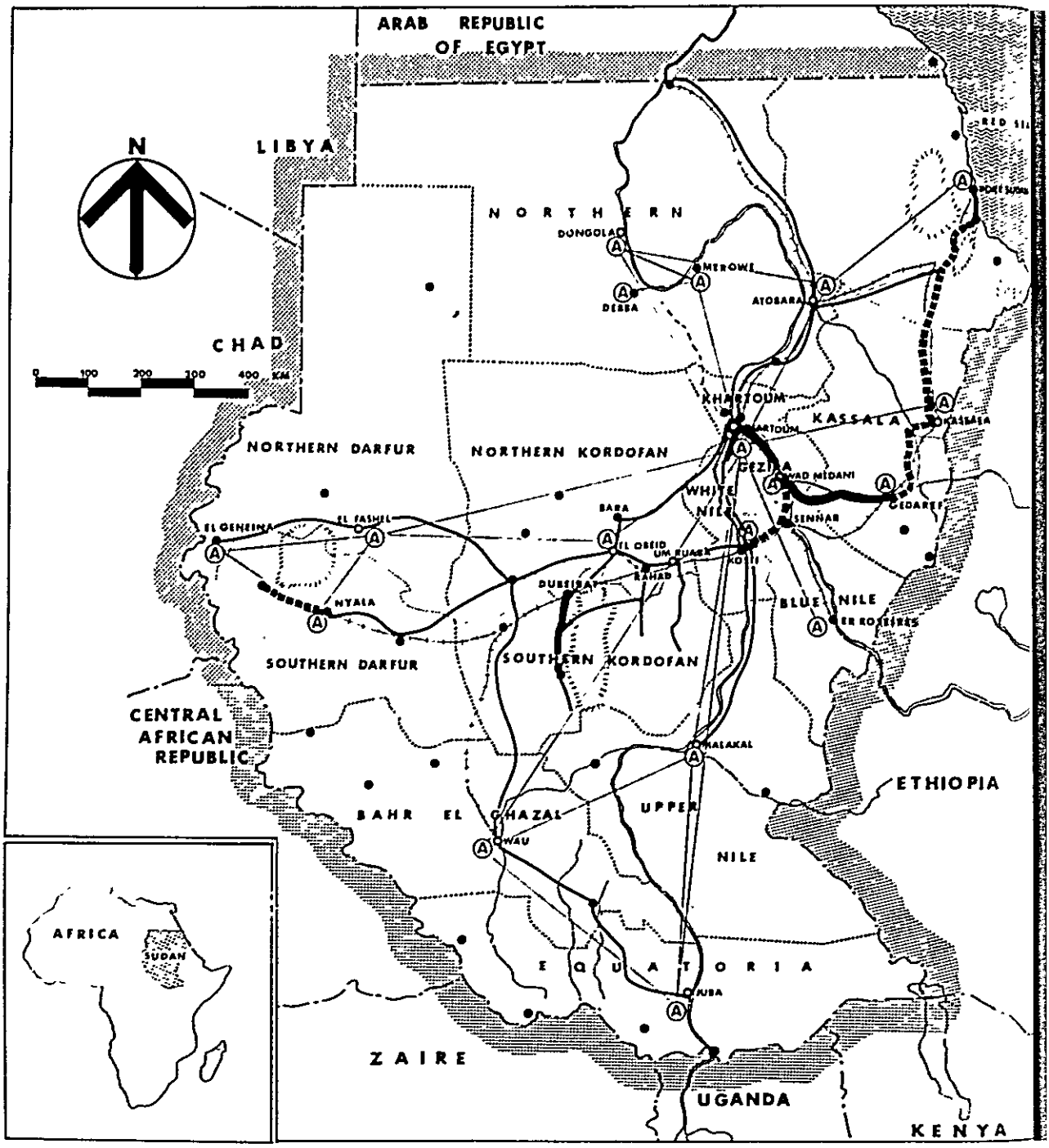
Inter-city bus services are available only between El Obeid and Rahad once daily. The buses are always fully occupied and can hardly meet demand. Most of the passengers, therefore, hitch rides on trucks together with goods. In El Obeid City taxies and buses serve relatively well, whilst only a small number of taxies is available in Um Ruaba and neither type of vehicle is available in other cities.

6.01.3 Railways

A trunk line linking El Obeid, Rahad, Um Ruaba and four other stations with Khartoum and another line branching off at Aradeib and leading to Nyala compose the railways network in the project area, are shown in FIG. VI-2.

The railways are single track of narrow guage with 75 lb. rails laid on laterite embankments. They are not efficiently operated due to obsolete facilities and equipment and poor maintenance. Although design speed is 60 km. per hour, trains are actually operated at 30 km. per hour for passenger trains and 25 km. per hour for freight trains. Nevertheless, the railway plays a very important role in transporting imports and exports, various consumer goods and passengers. It is reported that the El Obeid - Khartoum section, which passes several major cities like Kosti and Wad Medani, is ranked next to the Port Sudan - Khartoum section, the main artery of the country, in volume of traffic.

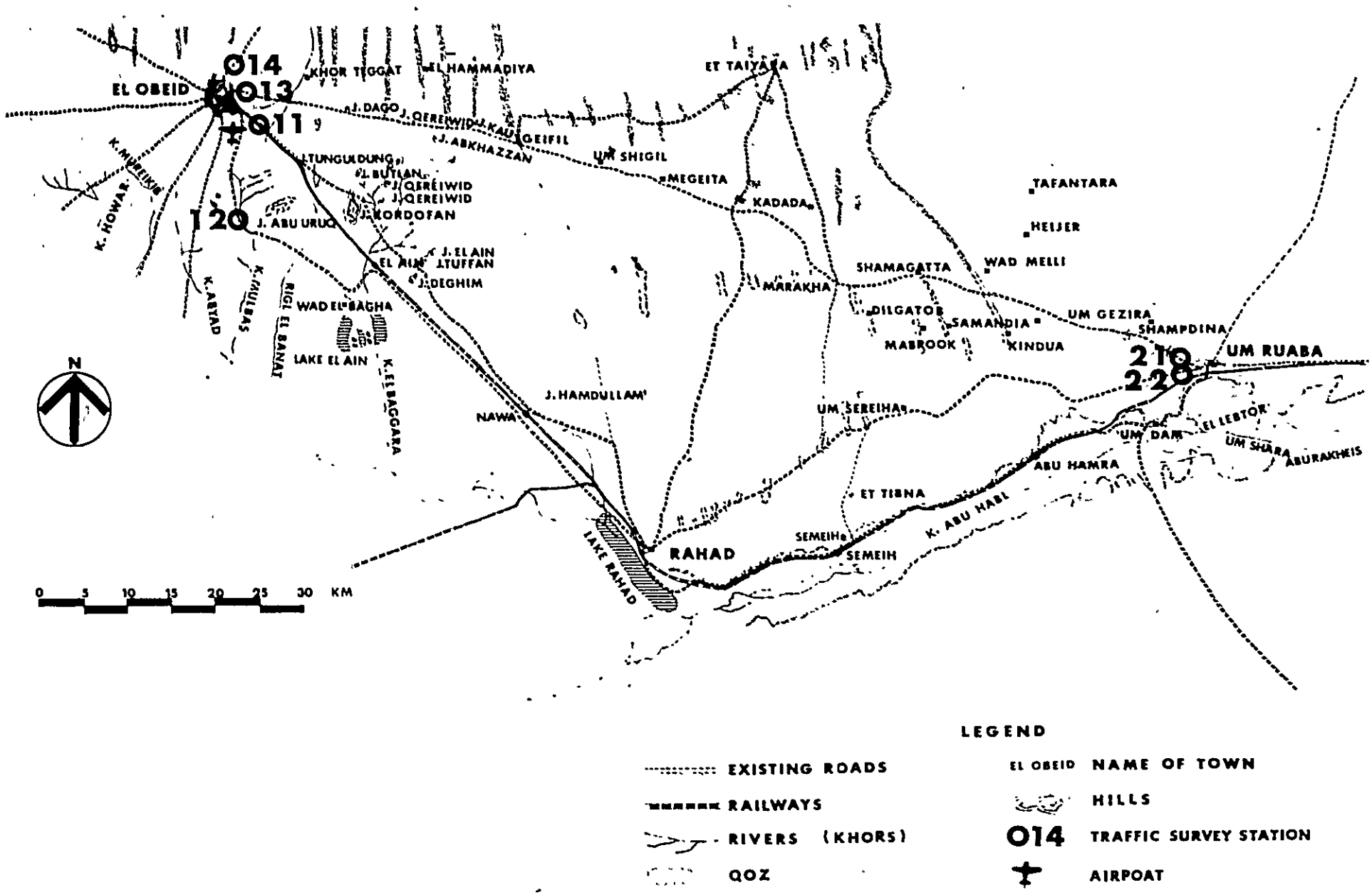
FIG.VI-1 TRANSPORTATION NETWORK, SUDAN



LEGEND

- PAVED ROADS
- UNDER CONSTRUCTING ROADS
- OTHER ROADS
- RAILWAYS
- AIRPORTS
- BOUNDARY
- PROVINCIAL BOUNDARY
- MOUNTAINS

FIG.VI-2 EXISTING TRANSPORTATION NETWORK IN THE PROJECT AREA



Between El Obeid and Khartoum a passenger train is operated daily in each direction of which express and ordinary trains run twice and five times a week, respectively. Daily service of passenger trains is also available between Nyala and Khartoum which passes Um Ruaba and Rahad in the area. Three express trains and four ordinary trains run each week. A passenger train is composed of five different classes of coaches, namely sleeper, 1st, 2nd, 3rd and 4th class.

Freight trains are operated three to five times a week in each direction both on the El Obeid - Khartoum line and the Khartoum - Nyala line. During the peak shipping period of agricultural products, frequencies of service double.

6.01.4 Airways

El Obeid airport contains two 45 meter-wide runways, one is 1,800 meters and the other 1,300 meters long. The 1,300 meter runway was seldom used and is now being reconstructed. The taxi way is 163 meters long and 23 meters wide. The runways and taxi way are paved with gravel. The air terminal, fire facilities, storage facilities, etc. are of old types and telecommunication facilities are inadequate. There are no night lighting facilities.

A regular flight is operated once daily between El Obeid and Khartoum. A Fokker 27 with 36 seats and a Boeing 737 with 101 seats are used, of which the latter is operated every Friday

and Saturday, a Boeing 737 between Khartoum and El Fasher and a Fokker 27 between Khartoum and Nyala via El Fasher are also operated by way of El Obeid. Although these flights are mostly fully occupied, delays and cancellations often occur.

6.02 Field Surveys

In order to study the traffic and its characteristics of freight and passengers the following field surveys were carried out.

6.02.1 Road Traffic Survey

i. Types of Surveys Conducted

Traffic count and road-side interviews including an origin and destination survey and other items on traffic characteristics were made. Survey sheets used for the surveys are contained in Annex VI-1 and VI-2.

ii. Period of Survey

As it is known that the traffic level in May corresponds to the yearly average, the dates of the surveys were chosen as follows.

El Obeid	May 9 - May 15	(7 days)
Um Ruaba	May 21 - May 25	(4 days)

iii. Survey Stations

Four stations in El Obeid and two stations in Um Ruaba were selected for the survey as shown in FIG. VI-2.

iv. Survey Method

Surveys were conducted for 24 consecutive hours. However, at the 1-4 Survey Station in El Obeid and 2-1 Um Ruaba where no traffic was recorded during night-time hours for the first two days, surveys from 19:00 to 7:00 hours were omitted. Two to five surveyors were assigned to each station according to their traffic volume. Vehicles passing the stations were stopped and interviewed.

v. Items of Survey

For the traffic count the number of vehicles was counted by vehicle type and by hour. Different survey items of (1) Time of day interviewed, (2) Vehicle type, (3) Maker of vehicle, (4) Years in service, (5) Origin of journey, (6) Destination of journey, (7) Travel time, (8) Capacity, (9) Number of passengers aboard, (10) Number of wheels, (11) Loading capacity, (12) Major type of commodities loaded, (13) Tonnage of loaded commodities, (14) Fuel used and (15) Estimated fuel consumption were asked during road-side interviews.

vi. Adjustment of the Number of Vehicles Surveyed

As it was observed, during the survey, that some vehicles did not stop at the stations (approximately 10% of the number of vehicles surveyed for each station) and some bypassed the stations (approximately 20 to 40% depending on the station), the number of vehicles actually surveyed was adjusted and enlarged to a realistic number in the course of data processing.

vii. Additional Survey

In order to survey traffic composition on paved roads in the Sudan, an additional 24 hour traffic-count was conducted at a place 10 kilometers from Khartoum to Wad Medani Road for two days, May 30 and May 31. The results are shown in Annex IX-1.

6.02.2 Railway Traffic Survey

i. Types of Surveys Conducted

Interviews for both origin and destination were carried out for passengers only. Freight traffic was surveyed at the head-quarters in Atbala, El Obeid and Um Ruaba stations of the Sudan railways either by statistics or interviews with relevant officials.

ii. O-D Survey for Railway Passengers

a) Survey Period: May 17 - May 21 (5 days)

b) Places of Survey: El Obeid and Um Ruaba Stations, coaches in operation.

c) Survey Method: 5 surveyors were assigned to interview the passengers, either waiting at the stations or travelling by train.

d) Interview Questions: Origin and destination of journey, size of group, class, trip purpose.

e) Trains Surveyed: All the trains passing either station during the survey. (7 trains)

iii. Railway Statistics Survey

Statistics of freight traffic handled at relevant stations and those of passenger ticket sales were surveyed. Data showing origin and destination of the traffic could not be obtained.

6.03 Results of Traffic Analysis

6.03.1 Zoning

The zones used for traffic analysis here are the same as those used in Chapter IV. In the field surveys,75 places for road vehicles and 56 places for railway passengers were recorded as origin or destination places. These places were integrated into 10 zones in the direct project influence area and 15 zones in the rest of the country. The major city or village of each zone was chosen as the zone center. FIG. VI-3 shows the results of zoning.

6.03.2 Road Traffic

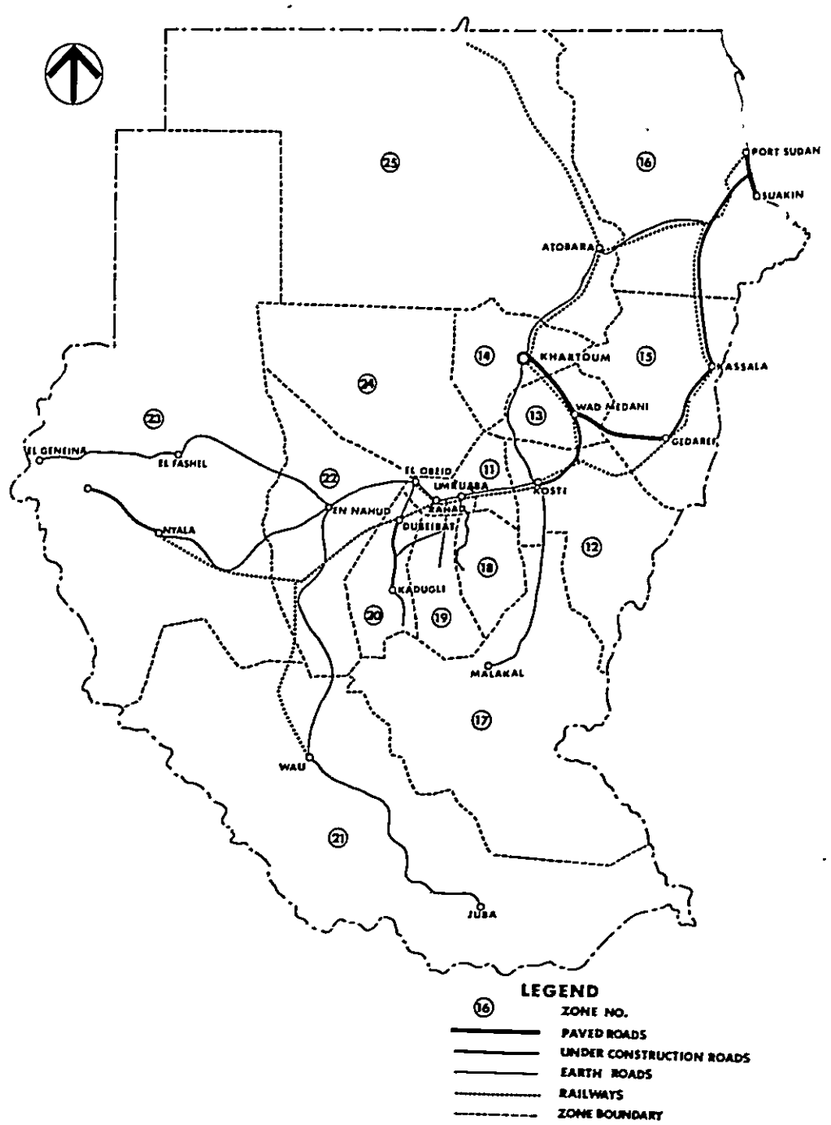
i. Traffic Volume on the Roads in the Project Area

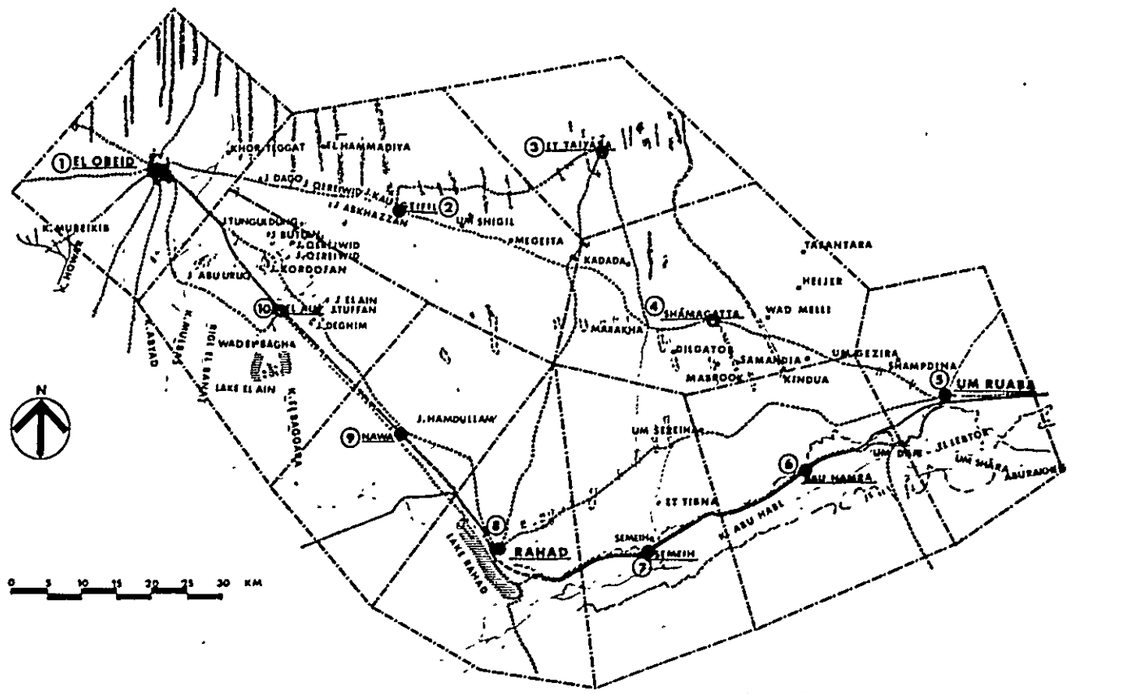
The average daily traffic at each survey station was estimated as shown in Table VI-1 for the 4 stations around El Obeid and the 2 stations around Um Ruaba. Details are shown in Annex VI-3 to VI-6. As it was considered that the traffic level in May shows an average of the year, judging from the commodity movement at El Obeid station and the El Obeid crop market which are shown in Annex VI-10 and VI-11, the average daily traffic of the survey period was regarded as the annual average daily traffic.

Due to the poor road conditions in the area,light vehicles are scarcely seen and trucks embrace the largest percentage

FIG.VI-3

ZONE MAP AND ROAD NETWORK





NUMBER AND ZONE

1	EL OBEID	11	TENDELTI	21	WAU-JUBA
2	GEIFIL	12	KOSTI-SENNAR	22	EN NAHUD
3	ET TAIYARA	13	WAD MEDANI	23	NYALA
4	SHAMAGATTA	14	KHARTOUM	24	BARA
5	UM RUABA	15	KASSALA	25	ATBARA
6	ABU HAMRA	16	PORT SUDAN		
7	SEMEIH	17	MALACAL		
8	RAHAD	18	EL ABBASIYA		
9	NAWA	19	NUBA MOUNTAIN		
10	EL AIN	20	KADUGLI		

TABLE VI-1 AVERAGE DAILY TRAFFIC, EL OBEID-UM RUABA ROAD

(May, 1977)

Area	EL OBEID								UM RUABA			
Survey Points[1]	11		12		13		14		21		22	
Vehicle Type	No.of Veh.	%	No.of Veh.	%	No.of Veh.	%	No.of Veh.	%	No.of Veh.	%	No.of Veh.	%
Van, Pick-up	1.0	1.8	4.5	10.0	1.1	3.3	8.8	30.9	4.8	12.6	0.9	0.8
Medium Truck	50.0	93.7	38.7	86.5	29.6	91.2	13.7	48.1	33.3	87.4	108.6	96.2
Heavy Truck	2.2	4.1	0.4	0.9	1.8	5.5	0.6	2.1	0.0	0.0	3.0	2.7
Bus	0.2	0.4	1.1	2.5	0.0	0.0	5.4	18.9	0.0	0.0	0.3	0.3
Total	54.0	100.0	44.7	100.0	32.5	100.0	28.5	100.0	38.1	100.0	112.8	100.0
Day Time (7:00-19:00)	42.6	78.9	30.9	69.1	22.9	70.5	25.5	89.5	38.1	100.0	62.7	55.6
Night Time (19:00-7:00)	11.4	21.1	13.8	30.9	9.6	29.5	3.0	10.5	0.0	0.0	50.1	44.4

Note; 1) Location of Survey Points are shown. in FIG. VI-2.

of the traffic, from 50 to 95% of the total traffic, at any station. Accordingly, light vehicles used are mainly four-wheel drive vans and pick-ups. Cars and taxis are seen only in the urban area.

Although it can not be decisively said about the daily variation of the traffic, there is tendency for traffic to lessen on Fridays compared to other days. Hourly distribution of the traffic, as summarized in Annex VI-7 and VI-8, indicates there is more traffic in the morning and evening hours, both in El Obeid and Um Ruaba. The peak hour is between 17:00 and 18:00 hours and the peak ratio is approximately 10%.

FIG. VI-4-1 shows the traffic in the area on major roads during the dry season and was worked out by estimating the course of the O-D traffic by survey station. The Um Ruaba-Rahad-El Obeid road is utilized most heavily, and the ADT is about 130.

During the rainy season (June to September), however, the above-mentioned road becomes muddy and the traffic is interrupted to a great extent for quite a long period. Many vehicles then divert to the tracks in the qoz area, particularly to the Um Ruaba-Shamagatta-El Obeid road. FIG. VI-4-2 shows the traffic movement pattern during the rainy season which was estimated based on the results of interviews with drivers, truckers, etc. during the field

FIG. VI-4-1 TRAFFIC FLOW ON ROADS IN DRY SEASON ' 1977 (VEHICLE PER DAY)

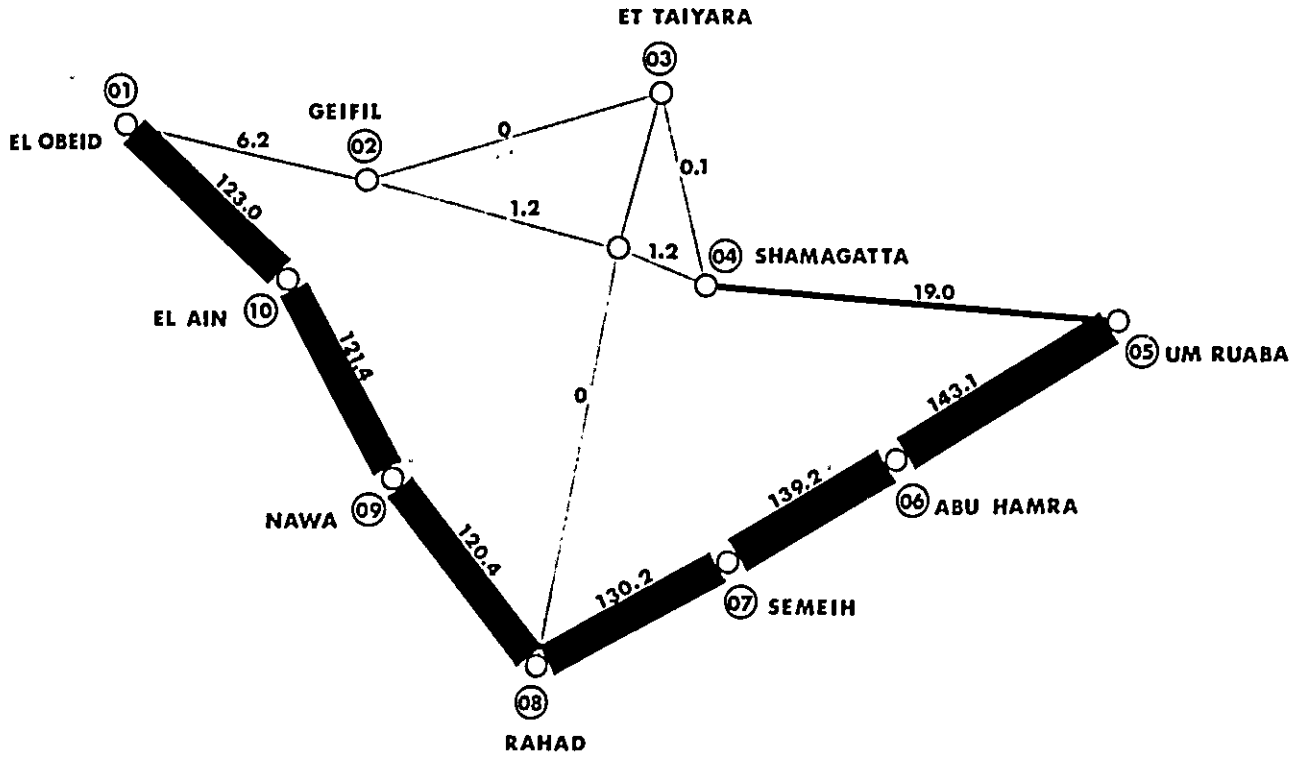
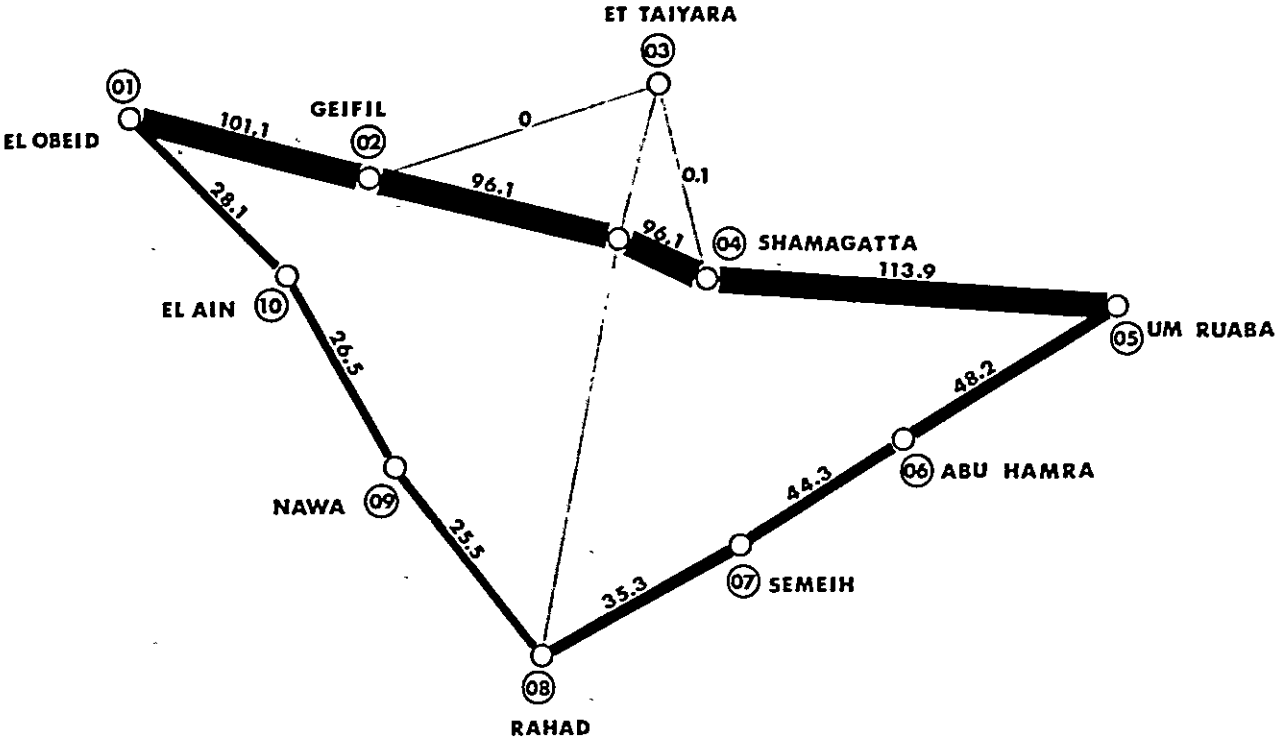


FIG. VI-4-2 TRAFFIC FLOW ON ROADS IN RAINY SEASON '1977 (VEHICLE PER DAY)



survey. The ADT of Um Ruaba-Rahad-El Obeid road decreases to 35, whilst the ADT of Um Ruaba-Shamagatta-El Obeid road increases to 100.

When rainfall is very heavy, traffic is stopped at many places along the river side, particularly between Um Ruaba and Semeih. Vehicles then either have to wait until the water runs off, or they have to run a long way round in the qoz area.

ii. Characteristics of Road Traffic

Characteristics of vehicles and road traffic are summarized as follows.

a) Medium size trucks with loading capacities of 5 to 8 tons are used predominately in the area in which 6-ton trucks amount to approximately 50% of the total number of vehicles. The Bedford 6-ton truck is the most popular. Most of the light vehicles are four-wheel drive, and the Fiat 11-ton truck is the most frequently used among heavy trucks, as is shown in Annex VI-12.

Table 6-8 in Annex VI-13 shows the distribution of the vehicle's years in service, indicating most of the vehicles are 1 to 4 year old. Average age of the medium size trucks is 3.6years.

b) As is shown in Table 6-9 of Annex VI-13 average loading capacity of van/pick-ups, medium size trucks and heavy trucks is 1.00, 6.10 and 13.10 tons, respectively.

c) Due to the lack of bus services in the area, passengers and freight are often carried together. As is shown in Table 6-10 of Annex VI-13, 78% of all vehicles carry both passenger and freight and empty vehicles total only 2%.

d) As shown in Table 6-11 of Annex VI-13, payloads are 0.11 tons of freight and 4.71 passengers for vans and pick-ups, 4.14 tons of freight and 9.44 passengers for medium size trucks and 7.19 tons of freight and 6.54 passengers for heavy trucks. Average loading ratios of medium size and heavy trucks are 78% and 70%, respectively.

iii. Vehicular O-D Traffic

Origins and destinations of vehicular traffic are shown in Table 6-12-1 to Table 6-12-5 of Annex VI-14. Table VI-2 summarizes the traffic distribution of all types of vehicles (van/pick-up, medium truck, heavy truck and bus) for 8 integrated zones.

The traffic can be divided into those which move

- within the project influence area . . .81.5 vehicles/day
- between the project influence area and other areas . . . . . .81.5 vehicles/day

and

- between the other areas . . . . . .33.4 vehicles/day (through traffic)

These indicate that the traffic which moves within the area is only 41% of the total. Thus, the project road is important in serving the inter-regional traffic as well as the project influence area.

Of the total traffic, 28% is traffic generating in El Obeid. Through traffic is 17% of the total. Major zone-pairs and the traffic volume are as follows.

El Obeid - Khartoum	40.3	vehicles/day
El Obeid - Rahad	22.3	"
Um Ruaba - Shamagatta	16.5	"
Nyala - Khartoum	15.6	"
El Obeid - Um Ruaba	14.9	"
El Obeid - Kosti/Sennar	14.1	"

TABLE VI-2 DISTRIBUTION OF ROAD TRAFFIC,[1] 1977

(vehicles/day)

O \ D	Zone No. in Original O-D Table	EL OBEID	UM RUABA	RAHAD	Rest of Project Area	KHAR-TOUM	PORT SUDAN	WEST SUDAN	Rest of SUDAN	TOTAL
EL OBEID	01	-	14.9	22.3	10.0	40.3	1.3	-	20.0	108.8
UM RUABA	05		-	11.1	23.2	-	-	1.0	9.0	59.2
RAHAD	08			-	0	3.0	0	0.7	3.9	41.0
Rest of Project Area	02,03,04,06 07,09,10				-	1.1	0.3	0	0.9	35.5
KHARTOUM	14					-	-	17.8	6.0	68.2
PORT SUDAN	16						-	0.3	-	1.9
WEST SUDAN	21,22,23,24							-	0.6	20.4
Rest of SUDAN	11,12,13,15,17 18,19,20,25								8.7	57.8
TOTAL										392.8

1) Figures are for all type of vehicles.

iv. Commodity Movement by Road

Movements of commodities are contained in the form of O-D table in Table 6-14-1 to Table 6-14-22 of Annex VI-16, according to the classification of the commodities shown in Annex VI-15. Table VI-3 summarizes the three major movements of commodities by type.

Agricultural products share as much as 58% of the total goods traffic, and manufactured foodstuffs, construction materials and manufactured consumer goods follow with 2.4%, 9% and 11%, respectively.

TABLE VI-3 COMMODITY MOVEMENT BY ROAD, MAY 1977

(tons/day)

O D / Commodity Group	Within Project Influence Area	Project Influence Area and Other Area	Between Other Areas	Total tons	Total %
10.Unprocessed Cereals	40.6	56.1	3.8	100.5	13.5
20.Other Unprocessed Agricultural Foodstuffs	18.1	17.5	22.3	57.9	7.8
30.Unprocessed Agricultural Cash Crops	41.9 (0.2)	94.1 (2.9)	17.2 (-)	153.2 (3.1)	20.6 (0.4)
31.Arabic Gum	9.3	29.8	3.3	42.4	5.7
32.Ground Nuts	0.4	0.6	1.6	2.6	0.4
33.Karkadie	-	0.4	-	0.4	0.1
34.Water Meron Seeds	-	9.5	7.9	17.4	2.3
35.Simsim	30.3	20.9	0.6	51.8	7.0
36.Umbas(Foodstuffs for Animals)	1.7	29.7	3.8	35.2	4.7
37.Cotton	-	0.3	-	0.3	0.0
40.Processed Cereal Products	3.3	2.4	0.4	6.1	0.8
50.Manufactured Foodstuffs	2.6	34.0	19.6	56.2	7.6
60.Processed Agricultural Cash Crop	40.1	39.5	35.9	115.5	15.5
70.Livestock and Products	0.7	7.7	4.4	12.8	1.7
80.Other Manufactured Consumer Goods	4.7	43.9	16.2	64.8	8.7
90.Forestry Products	10.8	5.3	6.2	22.3	3.0
100.Mining Products	-	-	-	-	-
110.Mineral Oil Products	4.0	9.1	4.6	17.7	2.4
120.Building and Construction Materials	30.3	36.2	13.1	79.6	10.7
130.Miscellaneous	13.7	17.7	3.0	34.4	4.6
140.Others	6.4	10.6	5.7	22.7	3.1
Total	217.2	374.1	152.4	743.7	100.0

1) Figures in parenthesis are the tonnage of other unprocessed agricultural cash crops.

TABLE VI-4 COMMODITY MOVEMENT BY ROAD, MAY 1977
(all types of commodities)

(tons/day)

O \ D	Zone No. in Original O-D Table	EL OBEID	UM RUABA	RAHAD	Rest of Project Area	KHAR-TOUM	PORT SUDAN	WEST SUDAN	Rest of SUDAN	TOTAL
EL OBEID	01	-	40.8	21.7	5.6	105.7	2.4	-	31.0	207.2
UM RUABA	05	15.0	-	9.1	26.6	-	-	1.2	3.7	55.6
RAHAD	08	36.5	26.5	-	-	2.8	-	-	13.4	79.2
Rest of Project Area	02,03,04,06 07,09,10	13.8	22,8	-	-	2.1	-	-	1.3	40.0
KHARTOUM	14	102.9	-	7.8	2.7	-	-	59.7	10.8	183.9
PORT SUDAN	16	7.8	-	-	1.2	-	-	1.9	-	10.9
WEST SUDAN	21,22,23,24	-	2.2	4.0	-	36.9	-	-	0.9	44.0
Rest of SUDAN	11,12,13,15,17 18,19,20,25	42.0	37.3	1.5	1.5	9.3	-	1.3	32.3	125.2
TOTAL		218.0	129.6	44.1	37.6	156.8	2.4	64.1	93.4	746.0

According to Table VI-4 showing the O-D movements of all types of goods, the traffic between El Obeid and Khartoum is the largest for each direction and shares 28% of the total traffic.

v. Passenger Movement by Road

The characteristics of passenger movements by road are summarized in Table VI-5 which was worked out from the detailed O-D table shown in Annex VI-17. The passenger traffic can also be divided into the three major movements as follows.

- within the project influence area . . . . 1,027 (118) * persons/day
- between the project influence area and other areas . . . . . 697 (667) persons/day
- between the other areas . . . . 374 (504) persons/day (through traffic)

* figures in parenthesis indicate passenger traffic by rail.

Although the general features of a modal-split are seen in that longer trips are made by rail, quite a large number of passengers still prefer travelling by uncomfortable truck, even for long distances. This is due to the fact that there are frequent delays in railway operation and that the potential demand of passenger movements are absolutely large. Accordingly, improvement in bus services, when the project road is constructed, will be a very important factor in meeting the demand adequately.

TABLE VI-5 PASSENGER MOVEMENT BY ROAD, 1977

(persons/day)

O \ D	Zone No. in Original O-D Table	EL OBEID	UM RUABA	RAHAD	Rest of Project Area	KHAR-TOUM	PORT SUDAN	WEST SUDAN	Rest of SUDAN	TOTAL
EL OBEID	01		127.7	197.8	89.7	299.4	7.5	-	179.2	901.3
UM RUABA	05			170.7	441.3	-	-	6.0	90.3	836.0
RAHAD	08				0	36.9	0	6.1	47.7	459.2
Rest of Project Area	02,03,04,06 07,09,10					18.8	1.2	0	4.2	555.2
KHARTOUM	14						-	142.1	99.0	596.2
PORT SUDAN	16							0.6	-	9.3
WEST SUDAN	21,22,23,24								4.0	158.8
Rest of SUDAN	11,12,13,15,17 18,19,20,25								127.8	680.0
TOTAL										4,196.0

6.03.3 Railway Traffic

i. Commodities Movement by Rail

Historical trends of the tonnage of railway commodities has generally shown a slight increase during the last 6 years as shown in Table VI-6 and FIG. VI-5. At the same time, however, the tonnage handled at the four stations has increased 14 percent between 1974/75 and 1975/76.

The received tonnage of commodities of 4 stations shares approximately 60 percent of the total tonnage in the area, and the increased rate of received tonnage is larger than that of the forwarded tonnage.

Table VI-7 shows that the major forwarded commodities are cash crops and oil cake, whilst received commodities are mainly grains, salt, sugar and cement. Eighty percent of the total transported tonnage is made up of cash crops, oil cake, sugar, salt, petroleum products and grains. Groundnuts are the largest single commodity transported.

Nearly 80 percent of the total tonnage of railway commodities is handled at El Obeid sation.

TABLE VI-6 RAILWAY FREIGHT HANDLED AT MAJOR STATIONS[1]

(tons/year)

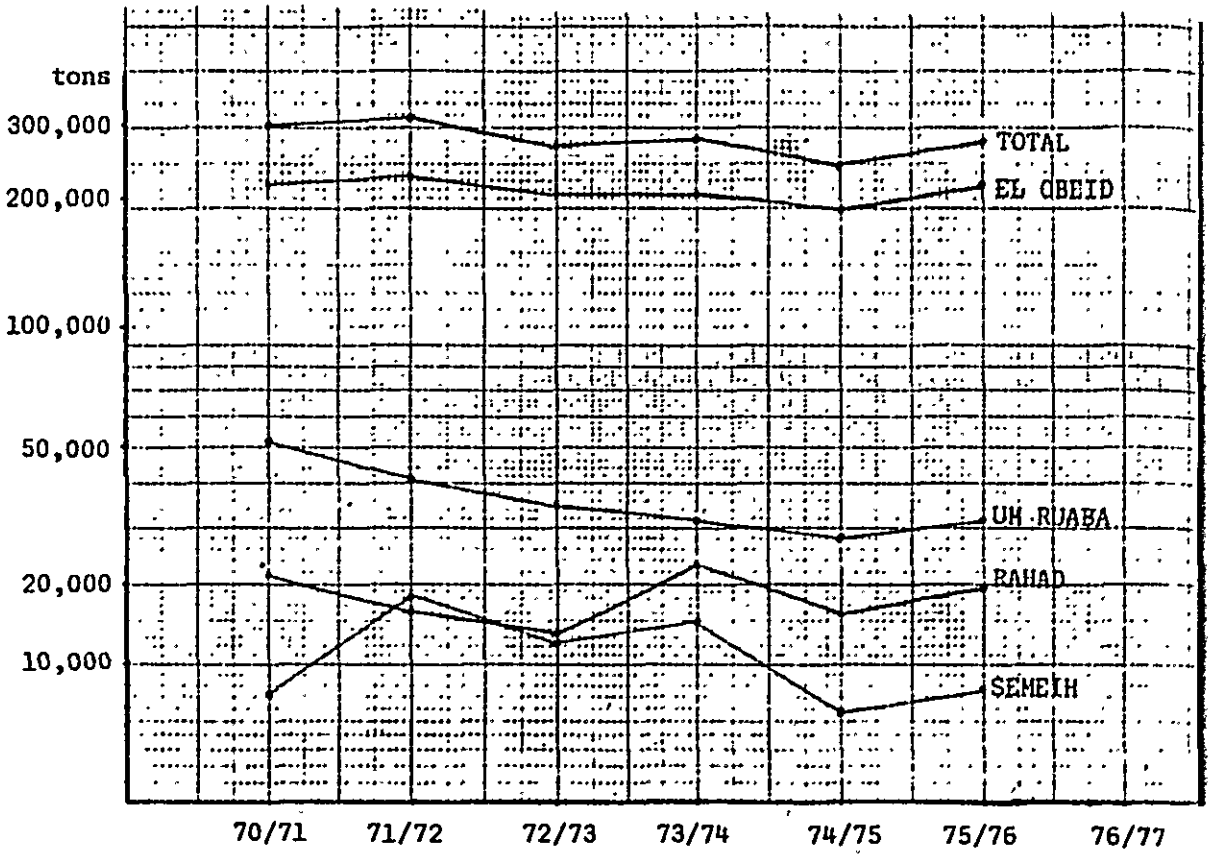
Station	Year	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77[2]
EL OBEID	Forwarded	76,575	77,207	94,089	68,673	91,308	66,859	76,226
	Received	139,171	148,973	110,056	135,104	98,040	147,283	167,917
	Total	215,746	226,180	204,145	203,777	189,348	214,142	244,143
RAHAD	Forwarded	13,132	9,576	6,701	13,534	7,392	11,598	13,223
	Received	8,329	6,602	6,708	9,784	8,568	7,906	9,014
	Total	21,461	16,178	13,409	23,318	15,960	19,504	22,237
SEMEIH	Forwarded	4,858	15,886	11,792	13,415	3,552	5,487	6,256
	Reveived	2,285	2,491	785	1,492	2,232	2,094	2,387
	Total	7,143	18,377	12,577	14,907	5,784	7,581	8,643
UM RUABA	Forwarded	31,056	20,099	20,613	17,059	16,596	22,621	25,790
	Received	21,276	21,097	14,328	14,574	11,480	8,877	10,121
	Total	52,332	41,196	34,941	31,633	28,076	31,498	35,911
TOTAL	Forwarded	125,621	122,768	133,195	112,681	118,848	106,565	121,495
	Received	171,061	179,163	131,877	160,954	120,320	166,160	189,439
	Total	296,682	301,931	265,072	173,635	239,168	272,725	310,934

SOURCE : Sudan Railways Corporation, 1977

NOTE 1) Tonnage excludes parcels and livestock.

2) Estimated

FIG. VI-5 RAILWAY FREIGHT HANDLED AT MAJOR STATIONS



SOURCE : Produced by Table VI-6

TABLE VI-7 ESTIMATE OF RAILWAY FREIGHT HANDLED AT MAJOR STATIONS BY TYPE OF GOODS (1976/77)

Item	EL OBEID			RAHAD			SEMEIH			UM RUABA			TOTAL		
	For-warded	Receiv-ed	Total	For-warded	Receiv-ed	Total	For-warded	Receiv-ed	Total	For-warded	Receiv-ed	Total	For-warded	Receiv-ed	Total
10.Whear, Dura	43	6,945	6,948	-	84	84	-	-	-	-	387	387	43	7,416	7,459
30.	57,772	-	57,772	10,181	-	10.181	6,193	-	6,193	11,658	-	11,658	85,804	-	85,804
31.Arabic Gum	6,325	-	6,325	446	-	446	-	-	-	300	-	300	7,071	-	7,071
32.Groundnuts	45,088	-	45,088	6,046	-	6,046	-	-	-	8,006	-	8,006	59,140	-	59,140
33.Karkadie	422	-	422	246	-	246	-	-	-	1,093	-	1,093	1,761	-	1,761
34.Water Melon Seeds	3,855	-	3,855	11	-	11	-	-	-	42	-	42	3,908	-	3,908
35.Sesame	2,082	-	2,082	3,425	-	3,425	-	-	-	2,217	-	2,217	7,724	-	7,724
36. -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37.Cotton/ Cottonseeds	-	-	-	7	-	7	6,193	-	6,193	-	-	-	6,200	-	6,200
40.Flour	-	18,088	18,088	-	1,666	1,666	-	-	-	-	2,020	2,020	-	21,774	21,774
60.Oil Cakes Sugar/Salt	14,600	63,703	78,303	2,778	3,703	6,481	-	338	338	12,842	2,468	15,310	30,220	70,212	100,432
70.Livestock[1]	(32,398)	(1,237)	(33,635)	(-)	(55)	(55)	(-)	(-)	(-)	(4,159)	(-)	(4,159)	(36,557)	(1,292)	(37,794)
110.Petroleum Products	-	28,751	28,751	-	2,559	2,559	-	1,863	1,863	-	3,559	3,559	-	36,732	36,732
120.Cement	-	8,451	8,451	-	101	101	-	67	67	-	169	169	-	8,788	8,788
Others	3,811	41,979	45,790	264	901	1,165	63	119	182		1,518	2,808	5,428	44,517	49,945
Total	76,226	167,917	244,143	13,223	9,014	22,237	6,256	2,387	8,643	25,790	10,121	35,911	121,495	189,439	310,934

SOURCE : Sudan Railways Corporation, 1977

NOTE : 1) Figures in Parenthesis indicate number of Livestock.

ii. Passenger Movement by Railways

Table VI-8 and FIG. VI-6 show declining tendencies of railway passenger volume between 1970/71 and 1974/75. After 1974/75, however, passenger traffic began to increase. It was observed during the survey that all the trains were fully occupied, and some passengers were even riding on the roofs of the train.

Table VI-10 shows the distribution pattern of the railway passengers whose trip length is much longer than that of road passengers. According to Table 6-18-2 in Annex VI-20, major O-D movements and the traffic volume of the railway passengers are as follows.

El Obeid - Khartoum	303.9 persons/day
Khartoum - Nyala	246.9 "
El Obeid - Kosti/Sennar	108.1 "
Wad Medani - Nyala	75.4 "
Rahad - Khartoum	72.4 "
El Obeid - Um Ruaba	59.6 "

There is a tendency that passengers are gradually coming to choose higher class coaches when travelling, as is shown in Table VI-9.

Annex VI-19 shows the historical trends of ticket sales of railway passengers at four stations: El Obeid, Rahad, Semeih and Um Ruaba.

TABLE VI-8 PASSENGER BOOKING AT FOUR STATIONS

(tickets)

Year / Station	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77[1)]
EL OBEID	94,959	95,142	109,248	90,345	84,309	92,474	100,466
RAHAD	51,298	48,130	44,807	35,703	28,343	31,224	33,922
SEMEIH	10,199	7,765	7,507	5,412	4,028	3,168	3,442
UM RUABA	56,266	53,831	48,137	36,844	30,770	33,327	36,207
TOTAL	212,722	204,868	209,699	168,304	147,450	160,193	174,037

Source; Sudan Railway, 1977

1) Estimated

FIG. VI-6 PASSENGER BOOKING AT FOUR STATIONS

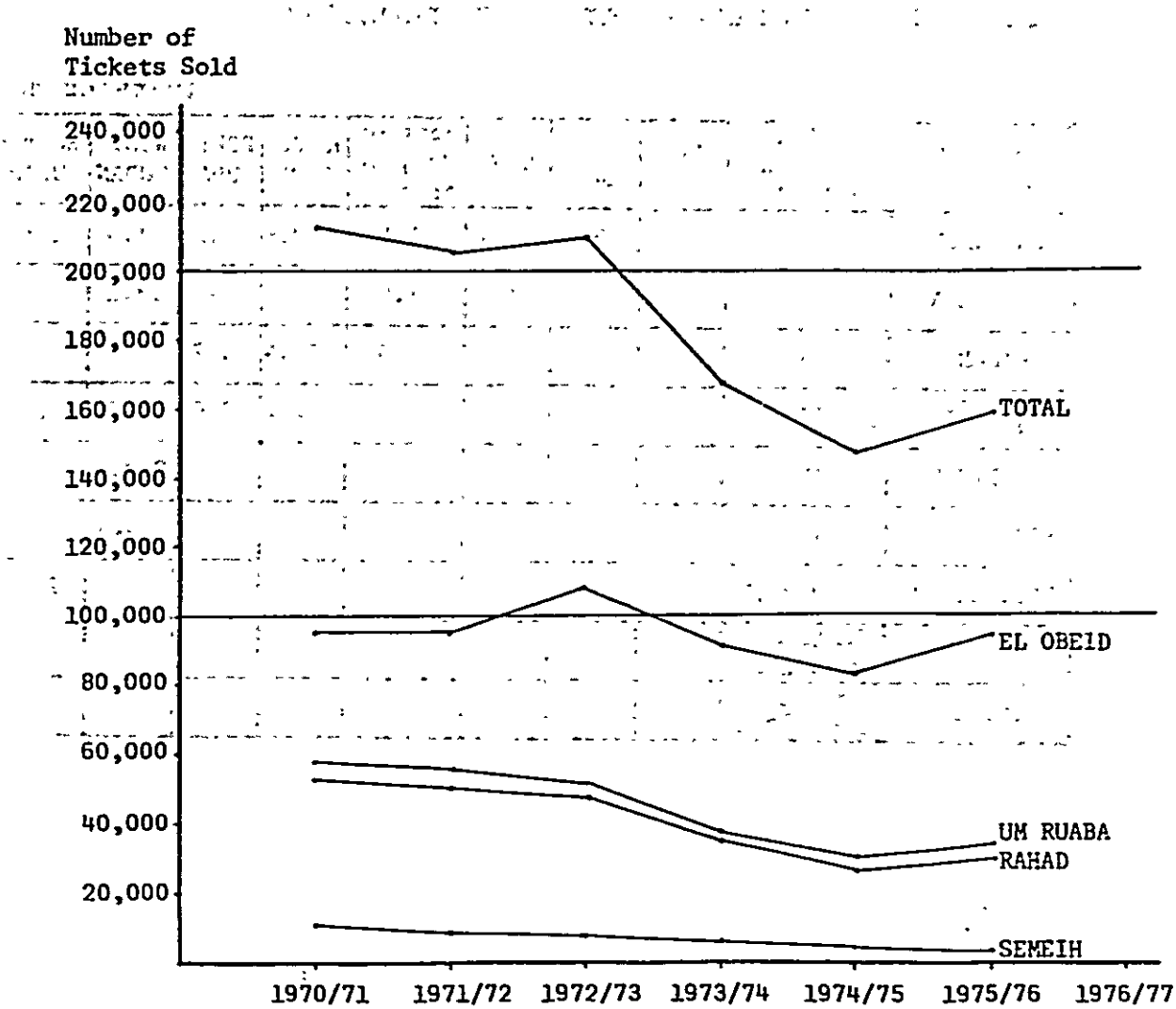


TABLE VI-9 PASSENGER BOOKING BY CLASS[1)]

(%)

	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76
1st Class	2.3	2.2	2.75	3.4	4.7	4.6
2nd Class	5.9	5.2	5.75	6.7	7.8	7.4
3rd Class	23.9	20.8	23.6	27.8	34.5	30.9
4th Class	67.9	71.8	67.9	62.1	53.0	57.1

1) Percentage is calculated based on total passenger booking at four stations in the project area.

TABLE VI-10 PASSENGER MOVEMENT BY RAIL, 1977

(persons/day)

O \ D	Zone No. in Original O-D Table	EL OBEID	UM RUABA	RAHAD	Rest of Project Area	KHAR-TOUM	PORT SUDAN	WEST SUDAN	Rest of SUDAN	TOT
EL OBEID	01		59.6	3.4	1.5	303.9	5.2	1.9	176.6	552
UM RUABA	05			51.1	1.9	-	-	13.2	-	125
RAHAD	08				0	72.4	0.7	-	70.1	197
Rest of Project Area	02,03,04,06 07,09,10					2.3	2.6	0	16.8	25
KHARTOUM	14						-	279.4	4.0	662
PORT SUDAN	16							3.6	0.7	12
WEST SUDAN	21,22,23,24								215.0	513
Rest of SUDAN	11,12,13,15,17 18,19,20,25								0.8	484
TOTAL										2,57

6.04 Transportation Cost

6.04.1 Vehicle Operating Cost

i. Field Survey on Vehicle Operating Cost

In order to estimate vehicle operating cost under various conditions for both existing and proposed roads, the following surveys were carried out during the field survey. The surveys mainly consist of,

a) interviews with dealers and operators of garages and trucking companies,

b) interviews with the drivers carried out during the O-D survey in the area,

c) analysis of the results derived from similar surveys, and

d) driving survey with four-wheel drive pick-up.

Considering the particular conditions of the roads in the area, the following surface types were chosen for the analysis.

a) paved

b) gravel

c) hard surface clay

d) loose sand

Regarding c) and d) above, the differences of vehicle operating costs in rainy season and in dry season were also studied.

ii. Characteristics of the Representative Vehicles

On the basis of the results of interviews with dealers and those of the traffic survey conducted in the area, the representative vehicles mainly being used at present and expected to be used in the future were selected as follows.

a) Car . . . . . Toyota Corolla 1200

b) Van/pick-up . . . . Toyota Pick-up (4 wheel drive)

c) Medium truck . . . . Bedford 6-ton

d) Heavy truck . . . . Fiat 682 11-ton

e) Bus . . . . . Bedford 6-ton (remodeled)

Cars are included in view of the forecast that they are expected to be used extensively after the improvement of the road, though, at present, cars are used almost exclusively in urban areas. Table VI-11 shows the characteristics of the representative vehicles.

TABLE VI-11 CHARACTERISTICS OF REPRESENTATIVE VEHICLES

Type of Vehicle	Car	Van, Pick-up	Medium Truck	Heavy Truck	Bus
Representative Vehicle	Toyota Corolla	Toyota Pick-up	Bedford	Fiat682	Bedford
Loading Capacity	4 pass.	10 pass. 1.5 tons	6 tons	11 tons	44 tons
Number of Axles	2	2	2	2	2
Number of Tyres	4	4	4	4	4
Fuel Used	Gasoline	Gasoline	Diesel	Diesel	Diesel
Maximum Cruising Speed	125(km/h)	110	90	90	90
Average Life (Years)	10	8	6	6	5

Source; Interviews with dealers.

iii. Estimates of Vehicle Operating Cost

Vehicle operating cost of each representative vehicle was estimated based on an analysis of factors such as

- depreciation and interest of vehicle,
- insurance,
- wages of drivers and assistants,
- licencing fees,
- fuel consumption,
- engine oil consumption,
- tyre wear,
- maintenance
- overhead.

Both economic and financial operating costs of vehicles were at first estimated for the four different surface types mentioned previously on flat roads in the dry season. Prices of 1977 were used in the analysis.

In adjusting the vehicle operating costs due to changes in road gradient, percentage change of fuel consumption was studied as described in Table 6-20-19 of Annex VI-21. Changes in surface conditions during the rainy season were also taken into consideration. Vehicle operating costs in the dry season were adjusted and enlarged according to information obtained from interviews made in the area. Tables VI-12 to VI-16 show the results of the analysis as described in detail in Annex VI-21.

6.04.2 Railway Operating Cost

Railway operating cost is described in Section 3 of Chapter IX, within the scope of estimating the diverted traffic and the benefits.

TABLE VI-12 OPERATING COST OF VEHICLES, CAR

(mm/km)

Cost Item \ Surface	Financial Cost				Economic Cost			
	Paved	Gravel	Hard Surface	Loose Sand	Paved	Gravel	Hard Surface	Loose Sand
Depreciation and Interest	28.90	36.13	48.17	-	14.12	17.75	23.67	-
Insurance Fees	7.37	9.22	12.29	-	6.27	7.83	10.45	-
Wages	-	-	-	-	-	-	-	-
License Fees	0.55	0.69	0.92	-	-	-	-	-
Fuel Consumption	8.10	10.12	12.14	-	4.22	5.28	6.34	-
Engine Oil Consumption	0.57	0.67	0.83	-	0.49	0.58	0.72	-
Tyre Wear	2.33	4.67	7.78	-	1.67	3.33	5.56	-
Maintenance Parts	4.62	5.68	15.98	-	2.27	2.79	7.85	
Maintenance Labour	0.30	0.40	0.80	-	0.30	0.40	0.80	-
Overhead	-	-	-	-	-	-	-	-
Total Cost on Flat (0-3%) Road	52.74	67.58	98.91	-	29.34	37.96	55.39	-
Savings	-	14.84	45.84	-	-	8.62	26.05	-
	-	-	31.33	-	-	-	17.43	-
Total Cost on 3-5% Road					29.76	38.49	56.02	-
Total Cost(Flat Road)					29.34	37.96	83.09	
Rainy Season(3-5%)					29.76	38.49	84.03	-

TABLE VI-13 OPERATING COST OF VEHICLES, VAN/PICK-UP

(mm/km)

Cost Item \ Surface	Financial Cost				Economic Cost			
	Paved	Gravel	Hard Surface	Loose Sand	Paved	Gravel	Hard Surface	Loose Sand
Depreciation and Interest	27.07	30.76	37.60	45.12	17.71	20.12	24.59	29.51
Insurance Fees	5.93	6.74	8.24	9.88	5.04	5.73	7.00	8.40
Wages	-	-	-	-	-	-	-	-
License Fees	0.38	0.44	0.53	0.64	-	-	-	-
Fuel Consumption	20.24	25.30	30.36	45.53	10.56	13.20	15.84	23.76
Engine Oil Consumption	0.72	0.83	0.98	1.29	0.63	0.72	0.85	1.12
Tyre Wear	5.71	11.11	20.00	16.67	4.00	7.78	14.00	11.67
Maintenance Parts	6.32	9.03	22.57	35.21	4.13	5.90	14.76	23.03
Maintenance Labour	0.36	0.52	1.04	1.44	0.36	0.52	1.04	1.44
Overhead	-	-	-	-	-	-	-	-
Total Cost on Flat (0-3%) Road	66.73	84.73	121.32	155.78	42.43	53.97	78.08	98.93
Savings	-	18.00	54.59	89.05	-	11.54	35.65	56.50
	-	-	36.59	71.05	-	-	24.11	44.96
Total Cost on 3-5% Road					44.96	57.14	81.88	104.63
Total Cost(Flat Road)					42.43	53.97	117.12	98.93
Rainy Season(3-5%)					44.96	57.14	122.82	104.63

TABLE VI-14 OPERATING COST OF VEHICLES, MEDIUM TRUCK

(mm/km)

Cost Item \ Surface	Financial Cost				Economic Cost			
	Paved	Gravel	Hard Surface	Loose Sand	Paved	Gravel	Hard Surface	Loose Sand
Depreciation and Interest	16.91	19.73	22.91	35.51	12.88	15.02	17.44	27.04
Insurance Fees	2.74	3.20	3.72	5.76	2.33	2.72	3.16	4.90
Wages	17.14	20.00	23.23	36.00	16.74	19.53	22.68	35.16
License Fees	0.40	0.47	0.54	0.84	-	-	-	-
Fuel Consumption	20.24	24.29	30.36	48.57	17.16	20.59	25.74	41.18
Engine Oil Consumption	0.94	1.06	1.26	1.63	0.82	0.92	1.10	1.42
Tyre Wear	11.88	23.24	44.57	38.20	7.87	15.41	29.53	25.31
Maintenance Parts	6.70	9.80	25.78	40.21	5.10	7.46	19.63	30.62
Maintenance Labour	1.20	1.96	3.92	5.48	1.20	1.96	3.92	5.48
Overhead	7.82	10.38	15.63	21.22	7.82	10.38	15.63	21.22
Total Cost on Flat (0-3%) Road	85.97	114.14	171.92	233.42	71.92	93.99	138.83	192.33
Savings	-	28.17	85.95	147.45	-	22.07	66.91	120.41
	-	-	57.78	119.28	-	-	44.84	98.34
Total Cost on 3-5% Road					79.30	102.84	149.90	210.04
Total Cost(Flat Road)					71.92	93.99	208.25	192.33
Rainy Season(3-5%)					79.30	102.84	224.85	210.04

TABLE VI-15 OPERATING COST OF VEHICLES, HEAVY TRUCK

(mm/km)

Cost Item \ Surface	Financial Cost				Economic Cost			
	Paved	Gravel	Hard Surface	Loose Sand	Paved	Gravel	Hard Surface	Loose Sand
Depreciation and Interest	38.93	46.11	53.09	83.43	25.96	30.74	35.39	55.62
Insurance Fees	7.69	9.11	10.49	16.48	6.54	7.74	8.91	14.01
Wages	16.00	18.95	21.82	34.29	15.63	18.51	21.31	33.49
License Fees	0.48	0.57	0.65	1.03	-	-	-	-
Fuel Consumption	24.29	31.57	38.86	72.86	20.59	26.77	32.94	61.77
Engine Oil Consumption	2.77	3.18	3.84	4.98	2.41	2.77	3.34	4.33
Tyre Wear	23.56	46.10	88.35	75.73	16.49	32.26	61.84	53.00
Maintenance Parts	15.26	22.89	59.77	92.84	10.17	15.26	39.85	61.89
Maintenance Labour	1.40	2.28	4.56	6.40	1.40	2.28	4.56	6.40
Overhead	13.04	18.08	28.14	38.80	13.04	18.08	28.14	38.80
Total Cost on Flat (0-3%) Road	143.42	198.84	309.57	426.84	112.23	154.41	236.28	329.31
Savings	-	55.42	166.15	283.42	-	42.18	124.05	217.08
	-	-	110.73	228.00	-	-	81.87	174.90
Total Cost on 3-5% Road					121.08	165.92	250.44	355.87
Total Cost(Flat Road)					112.23	154.41	354.42	329.31
Rainy Season(3-5%)					121.08	165.92	375.66	355.87

TABLE VI-16 OPERATING COST OF VEHICLES, BUS

(Rs/km)

Cost Item \ Surface	Financial Cost				Economic Cost			
	Paved	Gravel	Hard Surface	Loose Sand	Paved	Gravel	Hard Surface	Loose Sand
Depreciation and Interest	18.39	21.45	24.91	38.62	13.93	16.25	18.88	29.26
Insurance Fees	2.64	3.08	3.58	5.55	2.25	2.62	3.04	4.72
Wages	15.00	17.50	20.32	31.50	14.60	17.03	19.77	30.65
License Fees	0.33	0.39	0.45	0.70	-	-	-	-
Fuel Consumption	20.24	24.29	30.36	48.57	17.16	20.59	25.74	41.18
Engine Oil Consumption	0.94	1.06	1.26	1.63	0.82	0.92	1.10	1.42
Tyre Wear	11.88	23.25	44.57	38.20	7.87	15.41	29.53	25.31
Maintenance Parts	7.61	11.13	29.28	45.67	5.77	8.43	22.18	34.60
Maintenance Labour	1.20	1.96	3.92	5.48	1.20	1.96	3.92	5.48
Overhead	7.82	10.41	15.87	21.59	7.82	10.41	15.87	21.59
Total Cost on Flat (0-3%) Road	86.05	114.52	174.52	237.51	71.42	93.62	140.03	194.21
Savings	-	28.47	88.47	151.46	-	22.20	68.61	122.79
	-	-	60.00	122.99	-	-	46.41	100.59
Total Cost on 3-5% Road					78.80	102.47	151.10	211.92
Total Cost(Flat Road)					71.42	93.62	210.05	194.21
Rainy Season(3-5%)					78.80	102.47	226.65	211.92

CHAPTER VII

7.00 CONSTRUCTION PLAN

As already mentioned in CHAPTER I, Introduction, the objective of this study is to compare several alternative plans for routes to connect El Obeid and Um Ruaba. The individual plan of each alternative is explained in Section 2 of Chapter VII.

At the opening year of the project road (1983), there is no substantial variation in the basic volume of traffic, 180 vehicles per day, in Plan 1 through 7.

In addition, topographical conditions of the routes are planes or gently inclined hills. Therefore, in the comparison of alternative plans for determining the optimum route, the construction cost calculations of the road for each plan is based on the same standards and specifications. The construction cost calculated for each plan will be utilized in Section 1 of CHAPTER X, Cost and Benefits Analysis for evaluation in determining the optimum route.

When the optimum route is determined, further studies on bypasses, structures, and pavement designs on this route will be carried out in a later stage of this study. These data will be studied in the benefit cost analysis to finalize the best construction plan.

7.01 Design Standards

7.01.1 Geometric Design Standards

In the Sudan, the design standards of road construction are

based on AASHTO in most cases. The standards which are applied in this project are listed in Table VII-1 and FIG. VII-1. These standards are established in accordance with AASHTO with necessary adjustments. The basic concepts of the established standards are as follows.

i. Classification by Area

Rural area and urban area.

ii. Classification by Terrain

The terrains of the planned roads are classified as follows:

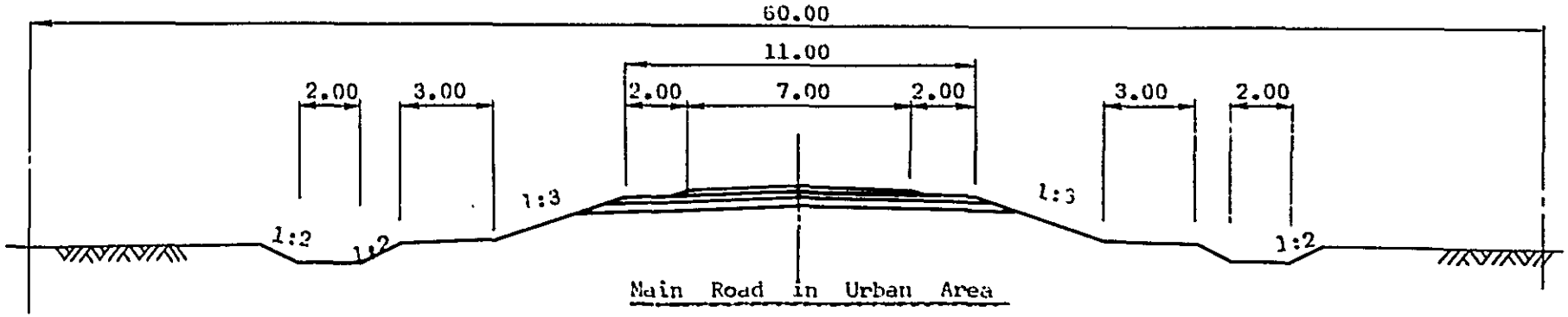
Classification by Terrain

Classification	Flat	Hilly	Mountainous
Gradient (%)	0 - 3	3 - 6	Over 6

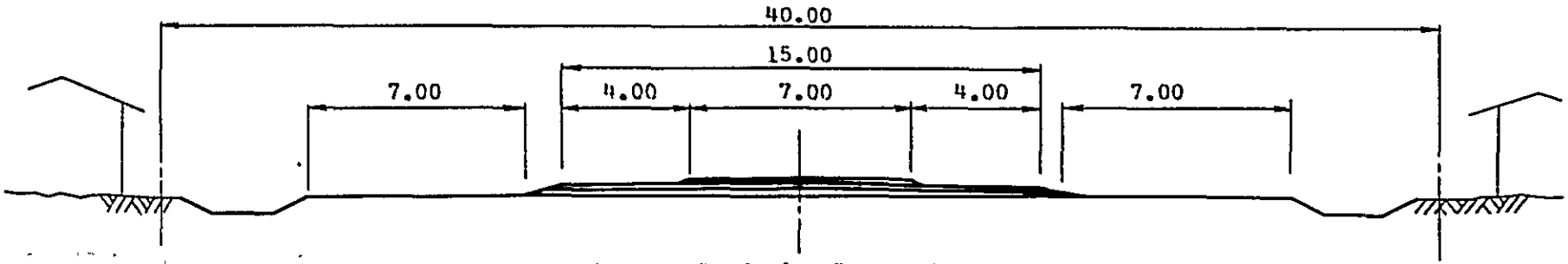
TABLE VII - 1 GEOMETRIC DESIGN CRITERIA

Area	Terrain	Type of Route	Design speed (km/h)	Width of Carriage way (m)	Shoulder Width (m)	Width of Animalpass (m)	Width of Side walk (m)	right of way width (m)
Rural	Flat	Main Road	100	2 x 3.5	2 x 2.0	2 x 7	-	80
	Hilly	Main Road	80	2 x 3.5	2 x 2.0	2 x 7	-	60
Urban	Flat	Main Road	60	2 x 3.5	2 x 4.0	2 x 7	-	40
Rural	Flat	Access Road	60	1 x 3.5	2 x 2.0	2 x 7	-	40

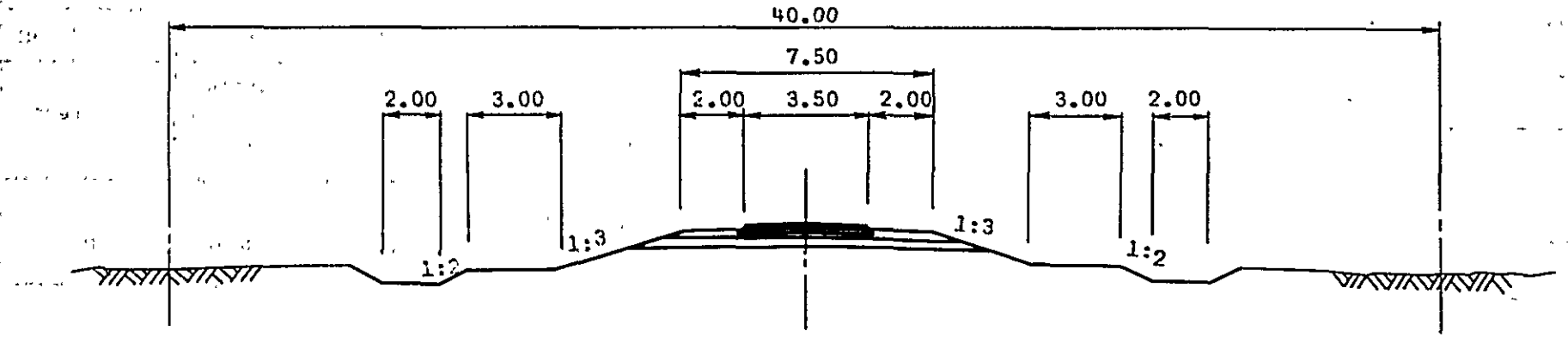
Main Road in Rural Area



Main Road in Urban Area



Access Road in Rural Area



iii. Design Speed

The planned area is generally flat terrain which enables high design speed in rural areas.

100 km/h . . . . . Flat terrain
80 km/h . . . . . Hilly terrain
60 km/h . . . . . Main roads in urban area and access roads

iv. Design Traffic Volume of The Project Road

a) Two-Lane Road

Assuming the level of service as "B" in "AASHTO Highway Capacity Manual 1965", the design traffic volumes of the project road are set as follows:

5,000 vehicles/day (passenger car equivalent)

b) One-Lane Road

The traffic volume of one-lane roads is set at 500 vehicles/day.

v. Carriageway Width

a) Two-Lane Road

The carriageway widths are determined as follows:

Design Speed (Km/h)	Vehicles per hour (Passenger car equivalent) 100 - 200	200 - 400
50	-	6.0 m
60	-	7.0 m
80	-	7.0 m
100	-	7.0 m

vi. Shoulder Width

a) Two-Lane Road

The shoulder width is determined at:

2.0 m is rural areas

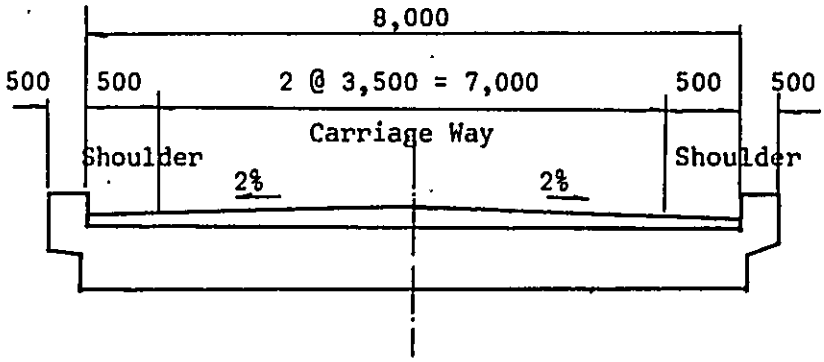
4.0 m in urban areas where slow moving traffic is expected

b) One-Lane Road

The shoulder width is determined to be 2.0 m, same as the two-lane road in rural area.

vii. Width of Bridge

The width of the bridge is illustrated as follows:



viii. Factors of Alignment

Clothoid is employed for transition curve. Other factors of alignment are determined as follows:

	Design Speed		
	60 km/h	80 km/h	100 km/h
Minimum Horizontal Curve Radius	130 m	230 m	380 m
Maximum Super-elevation	8 %	8 %	8 %
Maximum Gradient Plain	5 %	4 %	3 %
Maximum Gradient Hill	6 %	5 %	4 %
Minimum Vertical Curve Length	50 m	70 m	85 m
Composite Gradient	8 %	8 %	8 %
Minimum Passing Sight Distance	450 m	550 m	670 m

Note: For the maximum gradient, 2% can be added when necessary.

7.01.2 Structure

i. Loads

Designed vehicle load is quoted from AASHTO H-20, and impact load is taken into consideration. The effect of load by wind and earthquake is disregarded. The earth pressure is calculated by Rankine's formula.

ii. Strength of Materials

Classification	Strength of Concerete on 28 days	Application
Class A	210 kg/cm^2	Superstructure of Bridge
Class B	150 "	Other Structures
Class C	105 "	Leveling Concrete

Reinforcing Bar	Allowable Stress
Grade 40	1,400 kg/cm^2
Grade 60	1,700 "

7.02 Alignment Plan

7.02.1 Proposed Alternative Routes

Two routes are proposed between El Obeid and Rahad; A and B. Three routes are proposed between Rahad and Um Ruaba; C, D and E. A northern direct route F, is added for the study. They are indicated in FIG. VII-2.

i. Routes Between El Obeid and Rahad

a) Route A

This route runs along the east side of the railroad and connects El Obeid and Rahad, passing through the mountains of J. Kordofan and J. El Ain.

b) Route B

This route runs along the west side of the railroad and connects El Obeid and Rahad, passing through the reservoir of El Ain.

ii. Routes Between Rahad and Um Ruaba

a) Route C

This route runs along the existing road, which is used in the dry season, passing through cotton clay over the flood plain of K. Abuhabul.

b) Route D

This route runs along the northern hilly terrain of the railroad making a short detour from the flood plain of K. Abuhabul.

c) Route E

This route runs along the existing road used during the rainy season in the northern hilly terrain of sand dune.

iii. Northern Route

a) Route F

This route directly connects El Obeid and Um Ruaba and the access road is planned to connect Rahad to this route.

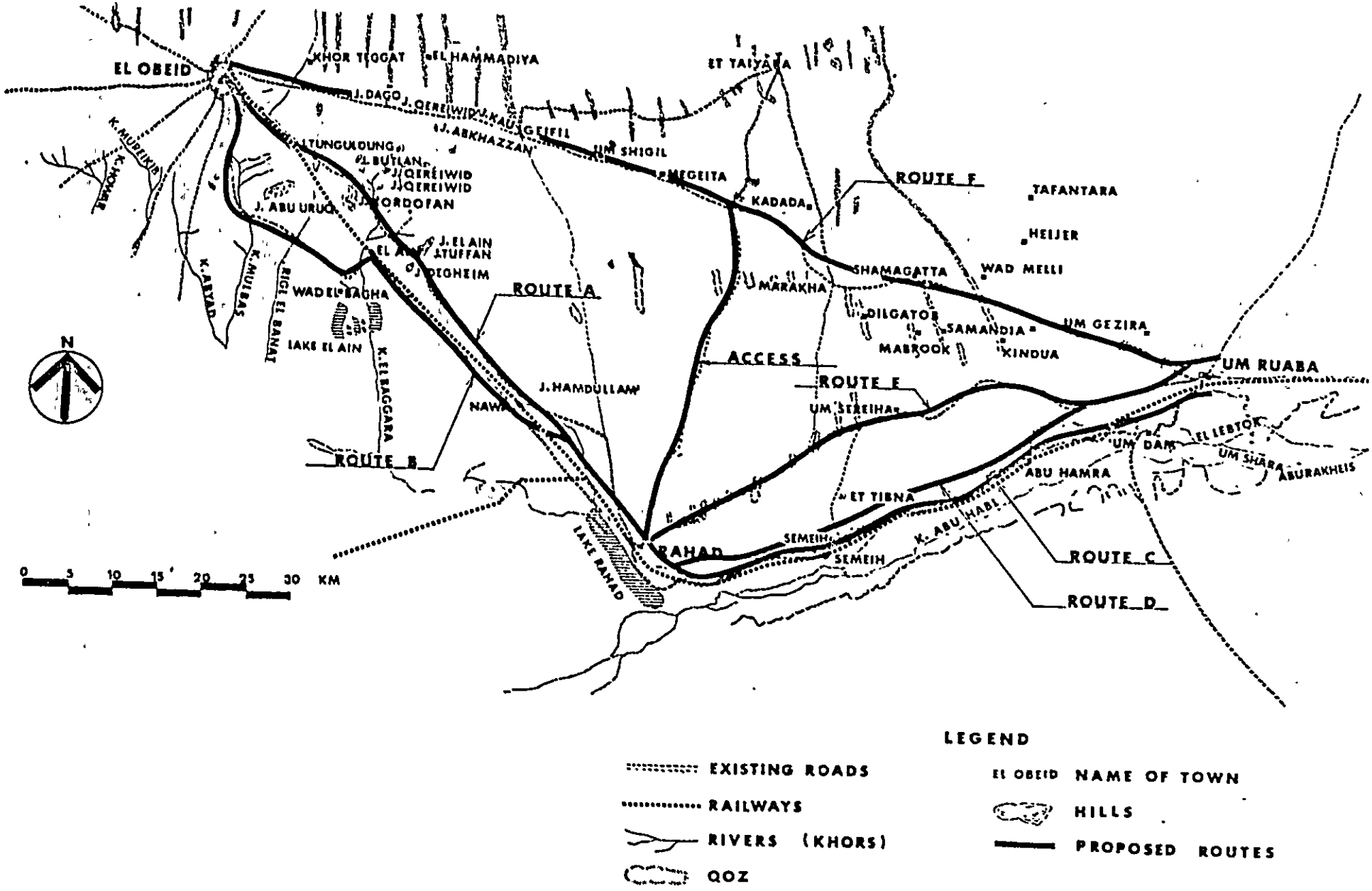
TABLE VII-2 TECHNICAL COMP ARISON OF ALTERNATIVE PLANS

Alternative Plan		1 (A+C)	2 (A+D)	3 (A+E)	4 (B+C)
Length		139.8 km	134.6 km	135.3 km	144.8 km
Alignment	Horizontal Curve Radius (R)	Two places where R is under 1,500 m	No place where R is under 1,500 m	No place where R is under 1,500 m	Five places where R is under 1,500
	Longitudinal Grade (L.G.)	Total length 0.95 km of which L.G. is steeper than 3%.	Total length 8.2 km of which L.G. is steeper than 3%.	Total length 29.15 km of which L.G. is steeper than 3%.	Zero km of which L.G. is steeper than 3%.
		Although the longitudinal grade is gentle, the horizontal alignment meanders considerably along K. ABUHABL.	Horizontal alignment is very good. Since the route runs across a sand dune area, L.G. is up and down in many places.	Same as PLAN 2	Since this route runs through flat terrain, vertical alignment is goo but horizontal alignment has many detours which increases total dist
Soil Conditions		Some countermeasures have to be considered for the cotton clay in the flood plain.	Although this route runs through a very limited part of the cotton clay scattered in the flood plain of K. ABUHABL, the soil condition of other areas is generally good.	Same as PLAN 2	The section of this route between RAHAD and UM RUABA runs through a cotton clay scattered area. The soil condition is very poor.
Material Conditions		Supply of base course materials and aggregates is available, since this route runs through J. KORDOFAN (gravel available), J. ELAIN and J. SEMEIH (quarry site).	Same as PLAN 1	Carrying-in of the base course materials to the section between RAHAD and UM RUABA is disadvanta-geous because of long transport distance.	Same as PLAN 1
Construction Difficul-ties		Easy to secure water for construction. Easy to carry-in equipment and mate-rials by using the railroad. Expensive for maintenance of slope protection in the flood plain in rainy season.	Easy to secure water for construc-tion. Easy to carry-in equipment and materials by using the railroad.	Disadvantageous in obtaining water for construction and in carrying-in equipment and materials.	Same as PLAN 1
Structures	Total Bridge Length	166 m	166 m	145 m	208 m
	Box Culvert	19 places	20 places	29 places	25 places
	Total Length of Pipe Culvert	1,356 m	696 m	372 m	1,284 m
	Cost for Structure	LS 525,000	LS 448,025	LS 428,175	LS 619,743
Pavement	Total Length of CBR 3%	39 km	3 km	2 km	39 km
		Since the section of roadbed of which CBR is 3%, is lengthy, the cost for displacement of subgrade increases.	Since the section of roadbed of which CBR is 3%, is short, the cost for displacement of subgrade is low.	Same as PLAN 2	Same as PLAN 1
Drainage		Consideration has to be paid for slope protection around K. BAGGARA and for the flood plain in K. ABUHABL.	No particular problem observed.	Same as PLAN 2	Same as PLAN 1

I-2 TECHNICAL COMP ARISON OF ALTERNATIVE PLANS

A+E)	4 (B+C)	5 (B+D)	6 (B+E)	7 (F+Access)
.3 km	144.8 km	139.6 km	140.3 km	155.5 km
is under 1,500 m	Five places where R is under 1,500 m	Three places where R is under 1,500 m	Three places where R is under 1,500 m	No place where R is under 1,500 m
6 km of which L.G. 3.	Zero km of which L.G. is steeper than 3%.	Total length 7.25 km of which L.G. is steeper than 3%.	Total length 28.2 km of which L.G. is steeper than 3%.	Total length 29.78 km of which L.G. is steeper than 3%.
	Since this route runs through flat terrain, vertical alignment is good, but horizontal alignment has many detours which increases total distance.	Since this route runs across a sand dune area, L.G. is up and down in many places.	Same as PLAN 5	Although the horizontal alignment is very good, L.G. is up and down in many places because this route runs through a sand dune area.
	The section of this route between RAHAD and UM RUABA runs through a cotton clay scattered area. The soil condition is very poor.	Same as PLAN 2	Same as PLAN 2	This route runs partly across a silty clay area, but most crossing areas are sand dune which is a good soil condition.
e base course section between A is disadvantalong transport	Same as PLAN 1	Same as PLAN 1	Same as PLAN 3	Problems exist in obtaining aggregates since no quarry site is available near the section between GEIFIL and UM RUABA.
n obtaining water and in carrying-in erials.	Same as PLAN 1	Same as PLAN 2	Same as PLAN 3	Difficult to obtain the water for construction. Difficult to get aggregates. No railroad available.
	208 m 25 places 1,284 m LS 619,743	208 m 26 places 624 m LS 542,610	187 m 35 places 300 m LS 522,760	42 m 40 places 348 m LS 296,070
	39 km Same as PLAN 1	3 km Same as PLAN 2	2 km Same as PLAN 2	3 km In the section between GEIFIL and UM RUABA, cement stabilized base course is to be used because of insufficient supply of aggregates.
	Same as PLAN 1	Same as PLAN 2	Same as PLAN 2	No particular problem observed.

Fig. VII-2 ALTERNATIVE PLAN



Seven alternative plans, which are the combinations of Routes A, B, C, D, E and F listed in the following table, are the objects of the first stage of this investigation.

Alternative Plans

Plan	El Obeid-Rahad		Rahad-Um Ruaba		Total Distance
1	(A)	68.0 km	(C)	71.8 km	139.8 km
2	(A)	68.0	(D)	66.6	134.6
3	(A)	68.0	(E)	67.3	135.3
4	(B)	73.0	(C)	71.8	144.8
5	(B)	73.0	(D)	66.6	140.3
6	(B)	73.0	(E)	67.3	139.6
7	(F)	114.7 + (Access)		40.8	155.5

7.02.2 Horizontal Alignment Plan

In selecting routes, planning will take the following factors into account:

i. The route will be planned to run along the existing road, as a rule for the purpose of utilizing the existing road for construction purposes, and also for serving residents in villages scattered along the existing road.

ii. The horizontal alignment will be planned by detouring such

places as flood plain, low land and mountainous terrain, trying to keep the total distance to a minimum.

iii. In selecting the river crossing points, the areas where the river course is stabilized will be selected and meanders and confluences will be avoided.

iv. The starting point of the projected south-bound route, is set at the end of a paved road which runs from El Obeid to the Airport. The 2.2 km. paved road, which runs from the T intersection in front of the El Obeid Station to the entrance of the airport, is excluded from this project. The terminal point of all planned routes is set at the center of the town of Um Ruaba.

7.02.3 Vertical Alignment Plan

The terrain of all alternative routes is predominately plain or gentle hilly terrain. In planning the vertical alignment, attention has been given to the following:

i. The maximum gradient is set at 5%. The minimum gradient at the place where the super elevation changes from plus to minus, is planned at 0.3% in order to maintain drainage from the slope.

ii. The height of embankment is planned as approximately 1 m. Where the route crosses over the flood plain of the river

or over low ground, the minimum height of embankment is set at 1.5 m.

iii. The vertical alignment at the river crossing section is planned by considering the past flood level plus 1 m. clearance under the girder.

7.02.4 Cross Section Plan and Drainage Plan

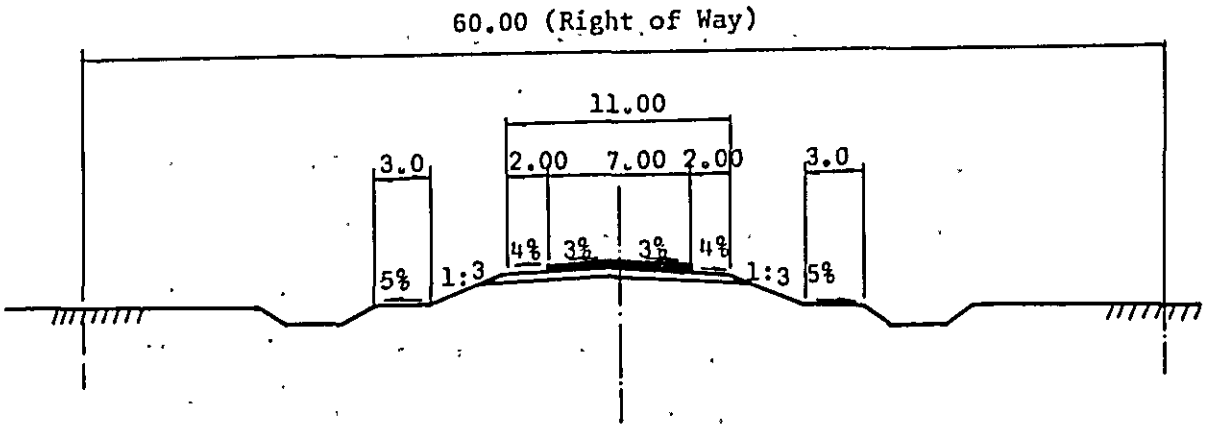
i. Cross Section Plan

As indicated in the following illustration, earth side ditches are provided at both sides of the road. As a principle, earth evacuated from ditches is used as the material for embankments in order to reduce construction costs. The width, about 7 m for the other side of the side ditch is for use as a construction road and animal path.

ii. Drainage Plan

Drainage from the road surface flows into side ditches and then flows along the road. The drained water is discharged into medium or small rivers or natural valleys wherever necessary. In sections where the water velocity is high and the discharge volume large in the earth side drainage ditch, stone pitchings are provided to protect the earth ditch from erosion.

The standard cross fall of the main road is 3% at the carriageway and 4% at the shoulder.



7.03 Design of Pavement Structure

7.03.1 General Description

The pavement structure has a close relationship between the subgrade supporting value and the number of passages of 8.2 ton equivalent single axle loads. Since the CBR Test is usually used for measuring subgrade supporting value, the same test has been conducted in this investigation. Design standard of the pavement section is based on "Interim Guide for Design of Pavement Structure", 1972, AASHTO.

7.03.2 Traffic Analysis and Design Axle Load

The results of the OD survey conducted in the field, indicated that the average daily traffic volume of the entire route is nearly the same as the traffic volume at the middle section of the route; that is, between RAHAD and SEMEIH. Therefore,

the pavement design is based on the traffic volume of the middle section as indicated in Table 7-1, Annex VII-1.

Both front and rear axles are counted as loading axles for trucks larger than medium trucks, and rear axles only are counted for small trucks. Since the single axle load of passenger cars is less than 1 ton, passenger cars are disregarded for purposes of pavement design. Axle loads by type of vehicle are calculated in FIG.7-1, Annex VII-3, and standard equivalent factors for various types of vehicles are calculated in FIG. 7-2, Annex VII-4.

The number of standard axles on one lane is the first year of operation (1983), the year that the number of axles reaches 700,000 total, and the total number of axles during the entire service period of this project is indicated as follows: a 10% increase in axle numbers, due to diverted and generated traffic, are included. (Refer to Table 7-2, Annex VII-2)

	Standard Axle Number
The first year after opening	24,057
Total number till the 13th year	678,931
Total number till the 20th year	1,507,643

7.03.3 Determination of Pavement Section

i. Structure Number

Structure number is determined according to the formula in the Interim Guide of AASHTO.

$$SN = a1\ D1 + a2\ D2 + a3\ D3$$

Note: a1, a2 and a3 denote layer coefficients, representative of surface, base and sub-base course, respectively.

D1, D2 and D3 denote actual thickness, in inches, of surface, base and sub-base course, respectively.

SN denotes structure number

Layer coefficients of the pavement materials are the values determined as in the following table. The regional factor (R) is set at 1.0 considering that the terrain of the project road is generally flat, annual rainfall is relatively light, damage caused by frost is not expected and the level of under-ground water is low.

Layer Coefficients of Pavement Composing Materials

Pavement Composing Materials	Layer Coefficient
Surface Course	
Hot Mixed Asphalt Mixture (Plant mix)	0.44
Penetration	0.24
Base Course	
Unscreened Crushed Stone	0.07
Crushed Stone (CBR = 80)	0.15
Cement Stabilization (Unconfined compression strength of one axle : 18 kg/cm^2)	0.15
Lime Stabilization	0.15 - 0.20
Sub-Base Course	
Crushed Stone with Sand	0.11
Sand and Sandy Soil	0.05 - 0.10

ii. Determination of Pavement Section

The surface course is to be constructed in two-stages. The first stage is the penetration (DBST) until the 13th year after opening, the year that accumulated equivalent axle numbers reach 700,000. The second stage is the overlay of 5 cm. thick asphalt concrete on the surface after the 13th year. Thickness of pavement for each CBR value is as follows:

Thickness of Each Layer of Pavement (After compaction)

(Unit: cm)

CBR Value	3%	5%	9%	Over 12%
Surface	DBST 3	3	3	3
Base Course	Gravel (CBR≧80) 15	15	15	15
Sub-base Course	Gravel (CBR≧30) 20	20	20	20
Sub-grade D4	Select (CBR≧20) 40	30	15	10
Total Thickness	78	68	53	48

7.04 Structures Design

Bridges, box culverts and pipe culverts are defined as the road structures. Selection of road structures is based on the data described below referring to relationship of the flood-passing capacity and the construction cost (refer to FIG. 7-3, Annex VII-6 and Table 7-3, Annex VII-5). This relationship is established by this study. The general shapes of road structures are illustrated in FIG. 7-4, Annex VII-7 through FIG. 7-6, Annex VII-9. The location of each road structure is noted in Table 7-4, Annex VII-10.

	Flood Passing Capacity
Bridge	Over 15 m^3/s
Box Culvert	4 - 15 m^3/s
Pipe Culvert	0 - 4 m^3/s

7.04.1 Design of Bridge

i. Substructure

a) Foundation

According to the results of the geological survey stated in Section 3, CHAPTER V, the bearing capacity of the ground under a depth of more than 2m. can be expected to be 25 ton/m^2; therefore, the foundation of structures is sufficient with the spread foundation. Since the soil is generally silty clay and the ground water level is very low, no settlement due to consolidation is expected.

b) Footing Depth

Footing depth is determined to be more than 1.0 m at abutments and more than 2.0 m. at piers for protecting from erosion by flood.

ii. Superstructure

As indicated in FIG.7-3, Annex VII-6, the construction cost of steel bridges is higher than that of reinforced concrete bridges; therefore, steel bridges are eliminated from the cost estimates. Since the river beds in the project area are shallow and the ground conditions for foundations are good, large foundation structures for piers are not required. This means that a bridge with short spans and many piers is more economical than a bridge on which spans are long with few piers. Accordingly, the construction of a slab bridge with the superstructure of precast reinforced concrete girders of 7 m. or 9 m. length is proposed in the plan.

7.04.2 Design of Box Culvert

Since the road is constructed with a low embankment height, the section of box culvert is designed with low height as indicated in FIG.7-5, Annex VII-8.

7.04.3 Design of Pipe Culvert

i. Size of Pipe

Hydrogic survey only covers the estimate of discharge of the main rivers. For the discharge of small streams, pipe culverts are proposed as a minor drainage system. One to three culverts are set each with 1 m. diameter precasted concrete pipe, crossing the proposed Road, FIG.7-6, Annex VII-9. For the access roads precasted concrete pipes with 0.60 m. diameter are planned for channelling the water.

ii. Corrugated Pipes

The comparison of the cost between pipe culvert and corrugated pipes discloses that corrugates are to be imported and that cost is higher for corrugates. The results is indicated by Table 7-5, Annex VII-11. The uses of corrugated pipes are not included in the cost estimate of the project.

CHAPTER VIII

8.00 CONSTRUCTION COST

8.01 Implementation Plan

The road construction plan takes into consideration the local weather conditions, such as fierce heat in the dry season and flooding in the rainy season. The key site bases are to be located at El Obeid, Ramad and Um Ruaba where living conditions are fairly good. The segment of construction work is planned as follows; El Obeid to Rahad and Rahad to Um Ruaba are to be divided into three sections each, the northern route between El Obeid and Um Ruaba is to be divided into four sections and the access road into two sections.

Construction time is estimated at three years starting in 1980 and ending in 1982. As the rainy season continues for as long as four months yearly, only preparatory work is scheduled to be performed during this period. Table VIII-1 shows a schedule of construction between El Obeid and Um Ruaba.

8.02 Preparations for Computing Construction Cost

i. Computing construction cost is based on the following conditions.

a) The currency unit is the Sudan Pound (LS)

b) The exchange rate is LS 1.00 to US$2.52.

c) Material and labor costs are to be based on those of July, 1977.

TABLE VIII-1 WORK SCHEDULE

Item \ Period / Month		1979		1980				1981				1982				1995		1996			
		7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	7-9	10-12	1-3	4-6	7-9	10-12
Preparation																					
Earthwork	Clearing																				
	Filling																				
	Cutting (1)																				
	Cutting (2)																				
Structures																					
Pavement	Subgrade																				
	Subbase																				
	Base																				
	Surface																				
Miscellaneous																					
Yearly Section				El Obeid -- Nawa				Nawa -- Semeih				Semeih -- Um Ruaba						El Obeid - Um Ruaba			

Remarks: 1. Cutting (1) is excavation of earth side ditch.

2. Cutting (2) is road excavation.

d) Construction costs are to be paid in foreign and local currencies

e) Classification of customs and taxes is to follow the Sudan procedure.

ii. Payment in foreign currency is as follows.

a) Prices of imported materials and machinery such as asphalt, steel products in CIF price, except round iron bars.

b) Foreign cost component which corresponds to the crude oil price of fuel.

c) Cost which corresponds to the foreign currency component of expenses by consultants and contractors.

iii. Payment in local currency is as follows.

a) Prices of local product materials such as cement, round bar, etc.

b) Import duties, local taxes, etc.

c) Labor costs and transportation costs

d) Costs which correspond to local currency expenses by consultants and contractors.

TABLE VIII-2 ECONOMIC UNIT COSTS OF CONSTRUCTION ITEMS

Item	Unit	Unit Cost (LS)
1. Earth work		
Clearing and Stripping	m^2	0.061
Cut to fill (compacted)	m^3	0.959
Preparation of Formation	m^2	0.155
Slope Protection, select fill	m^2	0.543
2. Pavement		
Subgrade, select (compacted)	m^3	1.855
Subbase, pit run (compacted) (including overhaul)	m^3	4.007
Base course, as above	m^3	4.210
Prime coat MC-70 1.5 Kg/m^2	m^2	0.203
Double bituminous Surface Treatment	m^2	0.654
Asphalt concrete, hot mix 5^{cm} Layer (asphalt 6%)	m^2	2.094
Shoulder treatment (compacted)	m^2	0.420
3) Structures		
Excavation	m^3	0.291
Concrete, plain	m^3	26.340
Concrete, reinforced	m^3	32.470

TABLE VIII-3 ECONOMIC COST OF THE PROJECT

(Unit: LS 000 in 1977 Price)

	Item	Plan Distance	1 139.8 km	2 134.6 km	3 135.3 km	4 144.8 km	5 139.6 km	6 140.3 km	7 [1] 155.5 km
1.	Construction Cost		7,912	7,595	8,668	8,102	7,786	8,859	10,909
2.	Preparation	4% of 1.	316	304	347	324	311	354	436
3.	Total		8,228	7,899	9,015	8,426	8,097	9,213	11,345
4.	Physical Contingency	10% of 3	823	790	902	843	810	921	1,135
5.	Supervision	5% of 3	411	395	451	421	405	460	567
6.	Total		9,462	9,084	10,368	9,690	9,312	10,594	13,047
7.	Compensation	2% of 3	165	158	180	169	162	184	227
8.	Detailed Design	6% of 3	494	474	541	506	486	553	681
9.	Grand Total		10,121	9,716	11,089	10,365	9,960	11,331	13,955
10.	Cost per km		72	72	82	71	71	80	90
	Cost by Year		1	2	3	4	5	6	7
	1978	(20% of 8.)	99	95	108	101	97	110	136
	1979	(80% of 8, 70% of 2)	616	592	675	629	604	688	850
	1980	(30% of 2.)	3,223	3,210	3,643	3,173	3,148	3,574	3,686
	1981		2,932	2,726	3,917	3,210	3,010	4,216	4,173
	1982		3,251	3,093	2,746	3,252	3,101	2,743	5,110

Note 1) The access road is 40.8 km, and the main route is 114.7 km.

TABLE VIII-4 CONSTRUCTION COST BY PLAN

(LS in 1977 Price)

Item \ Alternative Plan	1	2	3	4	5	6	7
	A + C	A + D	A + E	B + C	B + D	B + E	F + Access Road
Distance (km)	139,800 km	134,600 km	135,300 km	144,800 km	139,600 km	140,300 km	155,500 km
Clearing	248,600	231,300	230,700	254,400	237,100	236,500	259,500
Earthwork	848,100	1,075,400	1,767,900	820,100	1,047,400	1,739,900	2,840,900
Slope protection	314,800	231,000	272,200	290,800	207,000	203,200	321,400
Pavement	3,322,600	3,056,000	3,032,800	3,423,200	3,156,600	3,133,400	3,312,900
Bridge	179,000	179,000	152,600	222,300	222,300	195,900	44,400
Box culvert	74,700	77,900	118,500	103,140	106,340	146,940	138,000
Pipe culvert	113,000	58,000	31,600	107,900	52,900	26,500	31,100
Drainage work	42,000	118,300	193,800	33,500	109,800	185,300	324,800
Masonry work	109,200	15,700	12,500	122,400	28,900	25,700	27,300
Sub Total:	5,252,000	5,042,600	5,767,600	5,377,740	5,168,340	5,893,340	7,300,300
Overhead and Profit:	2,659,600	2,552,700	2,900,700	2,724,400	2,617,500	2,965,500	3,609,000
Total:	7,911,600	7,595,300	8,668,300	8,102,140	7,785,840	8,858,840	10,909,300

TABLE VIII-5 CONSTRUCTION COST BY ROUTE

(LS in 1977 Price)

Item \ Route	A	B	C	D	E	F	Access Road
Distance (km)	68.000km	73.000km	71.800km	66.600km	67.300km	114.700km	
Clearing	119,000	124,800	129,600	112,300	111,700	194,900	64,600
Earthwork	340,500	312,500	507,600	734,900	1,427,400	2,395,700	445,200
Slope portection	106,500	82,500	208,300	124,500	120,700	260,300	61,100
Pavement	1,338,300	1,438,900	1,984,300	1,717,700	1,694,500	2,826,500	486,400
Bridge	152,600	195,900	26,400	26,400	-	44,400	-
Box culvert	48,100	76,540	26,600	29,800	70,400	123,100	14,900
Pipe culvert	19,300	14,200	93,700	38,700	12,300	18,500	12,600
Drainage work	16,700	8,200	25,300	101,600	177,100	294,900	29,900
Masonry work	12,500	25,700	96,700	3,200	-	27,300	-
Sub Total	2,153,500	2,279,240	3,098,500	2,889,100	3,614,100	6,185,600	1,114,700
Overhead and profit	1,089,500	1,154,300	1,570,100	1,463,200	1,811,200	3,058,000	551,000
Total	3,243,000	3,433,540	4,668,600	4,352,300	5,425,300	9,243,600	1,665,700

8.03 Unit Costs of Construction Items

Unit costs of construction items are shown in Table VIII-2. As detailed in Annex VIII, the estimate includes costs for equipment, labour and materials.

8.04 Construction Cost

Construction costs for each alternative route are shown in Table VIII-3 and Table VIII-4. For each of the seven alternative plans, the economic cost was calculated. To the total of direct construction and preparatory work cost, which is 4% of the former, 10% for physical contigency, 5% for supervising, 2% for compensation and 6% for detailed design cost were added. Details of quantity, unit cost and the total cost of each classified work item are shown in Annex VIII-3. Table 8-2-2 in Annex VIII-2 shows the numbers of equipment used in each year of the construction period for alternative plan 2, as an example.

8.05 Maintenance and Repair Cost

For maintenance and repair, after completion of the road, the daily maintenance and periodic overlay costs are estimated as shown by the following tables of VIII-6 and VIII-7. The details of this estimate are presented in Annex VIII-4.

Table VIII-6 MAINTENANCE AND REPAIR COST (LS/KM)

Item	Cost	Remarks
GRAVEL ROAD		
Levelling	41.8	Every year
Repair of surface	73.0	"
Miscellaneous works	83.8	"
Management	79.4	"
Sub Total	378.0	"
Overlay	3,651.0	Every five(5) years
PENETRATION BITUMINOUS ASPHALT PAVEMENT		
Repair of surface	36.0	Every year
Miscellaneous works	84.0	"
Management	48.0	"
Sub Total	168.0	"
Overlay	3,612.0	Every seven(7) years
ASPHALT CONCRETE PAVEMENT		
Repair of surface	14.6	Every year
Miscellaneous works	83.8	"
Management	39.6	"
Sub Total	138.0	"
Overlay	14,658.0	Every ten(10) years

TABLE VIII-7 MAINTENANCE AND REPAIR COST (1983 - 2002)

a) Maintenance and Repair

(LS in 1977 Price)

	Plan / Year	1	2	3	4	5	6	7
1	1983	23,486	22,613	22,730	24,326	23,453	23,570	25,063
2	1984	"	"	"	"	"	"	"
3	1985	"	"	"	"	"	"	"
4	1986	"	"	"	"	"	"	"
5	1987	"	"	"	"	"	"	"
6	1988	"	"	"	"	"	"	"
7	1989	23,486	22,613	22,730	24,326	23,453	"	25,063
8	1990	528,444	508,788	511,434	547,344	527,688	530,334	513,044
9	1991	23,486	22,613	22,730	24,326	23,453	23,570	25,063
10	1992	"	"	"	"	"	"	"
11	1993	"	"	"	"	"	"	"
12	1994	"	"	"	"	"	"	"
13	1995	"	"	"	"	"	"	"
14	1996	23,486	22,613	22,730	24,326	23,453	23,570	25,063
15	1997	19,292	18,575	18,671	19,986	19,265	19,361	21,622
16	1998	"	"	"	"	"	"	89,513
17	1999	"	"	"	"	"	"	21,622
18	2000	"	"	"	"	"	"	"
19	2001	"	"	"	"	"	"	"
20	2002	19,292	18, 575	18,671	19,986	19,625	19,361	21,622
Total		949,514	914,207	918,950	983,474	948,167	952,910	1,033,486

b) Overlay

1996	2,040,188	1,972,967	1,983,227	2,122,478	2,046,257	2,056,517	1,681,273

CHAPTER IX

9.00 ECONOMIC BENEFITS

9.01 Traffic Forecast

9.01.1 Growth Rate

The growth of the Sudanese economy is evident in the changes of gross domestic product for the past several years. During the period of 1970 - 1975 the GDP increased 19% p.a. in terms of current prices, which in terms of constant price is 2% p.a. They are shown in Annex III-9. The changes in population in the same period were shown in Annex III-2, where the average growth rate was 2.2% p.a.

The increase in the number of licensed vehicles can be taken as statistical data reflecting the increase in road traffic. Annex III-17 and Table IX-1 show the increase in the number of vehicle registrations between 1970 and 1974. The vehicles operating on roads are less than the number of licensed vehicles because of the shortage of spare parts, mechanical troubles specifically caused by fine sandy dust, and the shortage of gasoline. Approximately 60% of the vehicles in the country are registered in Khartoum Province in which population, economic activities, and administrative and social activities are concentrated.

Main streets are surfaced in large urban areas so passenger cars and small truck can run effectively. One the other hand,

the roads are not surfaced nor maintained in rural areas where these small vehicles cannot run because of the loose sandy surface. Only high powered trucks and buses or four wheel drive vehicles can manage to run in rural areas. Therefore, it can hardly be considered that the increase in the number of registered vehicles reflects the growth of traffic on the entire road network. Under the circumstances it is better to note the changes in the consumption of vehicle fuels as an indicator of the trend in traffic growth on the roads of the country. The increase in fuel consumption on roads is shown in Table IX-1, where consumption increased 4.5% p.a. during 1970 to 1975.

If the changes in the fuel consumption, which is assumed to coincide with the changes of traffic volume on roads, is related to the changes in GDP, the relationship can be shown by the following formula.

$$\text{Elasticity of Traffic on Roads} = \frac{\text{Percentage change in fuel consumption, 1970-1975}}{\text{Percentage change in GDP at constant price, 1970-1975}}$$

$$2.25 = \frac{4.5\%}{2.0\%}$$

If we assume the Sudanese economy will grow 10-15% p.a. in current prices, that is 3% p.a. at constant price, the traffic on roads will grow 7% p.a. since

$$2.25 \times 3\% = 7\%$$

TABLE IX-1 GROWTH OF ECONOMY AND ROAD TRAFFIC

G.D.P. in current prices (ES Million)	647.0	685.8	752.1 (19% p.a.)	896.8	1246.2	1510.8
G.D.P. in 1970 price (ES Million)	647.0	638.0	636.3 (2.0% p.a.)	651.7	723.7	715.7
Number of Licenced Vehicles	49502	52800	59500 (12.4% p.a.)	62500	79100	
Gasoil and Benzine Consumption on Roads ('000 tons)	205	218	229 (4.5% p.a.)	234	238	256

Source: Annex III-9, -17 and -18.

If the economy grows more slowly at the rate of 2% p.a.,

$$2.25 \times 2\% = 5\%$$

There is no development project in other sectors of the zones of influence. It is too far from the Khartoum region to consider that economic growth in that region will involve the project area directly and immediately. Rather, it is considered that the average growth rate of 7% should be applied for the coming years up to the middle of the project life. The growth rate of 5% p.a. will be applied for the latter half of the project life, to be on the conservative side.

These figures of 7% and 5% for the normal traffic are also applied to the growth rate of diverted traffic and generated traffic as well.

9.01.2 Vehicle Composite

As shown in Table VI-1 the percentage composite of vehicles at the traffic counting stations in El Obeid are 83% for medium size trucks, 2.7% for large trucks, and 4.2% for buses. The remaining 10% is for small vehicles. In Um Ruaba, 94% are medium size trucks, 2%, large trucks, and 4%, other vehicles.

The road between Khartoum and Wad Medani is a representative paved highway in the Sudan. A traffic counting survey was conducted on this road in order to estimate vehicle composite on the project road. The study was carried out late in May, 1977.

The findings together with other traffic data of RBPC are presented in Annex IX-1. The percentage composite differs among these data, but it is evident that the percentage share of heavy trucks in the trucks larger than medium size category is relatively high, 10 to 27% compared to 2 to 3% on the existing roads of the project area.

It is quite likely that the percentage share of heavy trucks will increase if the project road is opened. It is assumed the percentage share of heavy trucks in the trucks larger than medium size trucks category will increase up to 27% in 1992, 10 years after the opening, and to 40% in 2002, the last year of the project life.

There are truck trailers running on the paved road of Khartoum and Wad Medani. It was decided that a truck trailer is equal to two heavy trucks in terms of loading capacity and equivalent standard axle load factor. No truck trailers appear in the types of vehicles in the project study.

9.02 Normal Traffic and Its Benefits

9.02.1 The Traffic Estimate on Alternative Alignments

The traffic on each alternative alignment is determined by estimating the tendency to increase of traffic on the existing road. The rate of growth is estimated in 9.01.1, Chapter IX. The traffic volumes forecasted for each alignment

by sections are shown in Figure IX-1. A breakdown into vehicle types is presented in the Annex IX-3.

Vehicle running costs on various road surfaces are studied in 6.04.1, Chapter VI. When the existing vehicles runs on a paved road, there will be savings on vehicle running costs because of better road conditions. The savings are taken as a primary benefit generated by the investment in the project. This normal benefit is calculated by a comparison of running costs on the existing road and on the proposed road between the origin and destination of the vehicles. The result of the estimate is shown in Table IX-2.

The comparative study of alternative alignments is aimed at finding the best alternative. The road conditions are set under the same standards temporarily for this purpose. When the best alignment is determined, another economic study will be performed to finalize the best construction plan on the selected alignment. In this stage, a series of benefits will be estimated again for the alternatives, such as pavement designs, bypasses at minor section, etc.

9.03 Diverted Traffic and Its Benefits

9.03.1 Passengers

It is expected that some rail passengers will divert to vehicle use when the road is constructed. The modal choice by passenger is determined by comparing the fare, travel time,

TABLE IX-2 EL OBEID- UmRUABA ROAD: BENEFITS OF NORMAL TRAFFIC

(£S '000 in 1977 Price)

No. of Plan / Km	Plan 1	2	3	4	5	6	7
(1977)							
1983	1,215	1,238	1,208	1,192	1,215	1,187	875
1992	2,604	2,652	2,586	2,556	2,604	2,542	2,065
2002	4,530	4,613	4,497	4,448	4,530	4,420	5,295
1983 - 2002 Discounted to the base year of 1978 1)	12,538	12,776	12,454	12,308	12,542	12,245	9,787

Note: 1) Discount rate in this table is 10% p.a.

regularity of service, and other content of services provided by buses and trains. When there are diverted passengers, the economic benefits are estimated by assessing the balance of transport costs of these passengers between the existing railways and the new buses on the project road.

The buses carrying the diverted passengers are estimated as shown in Table IX-3 and their economic benefits are noted in Table IX-4. In the course of the analysis it is assumed that the number of passengers on the railways in the project area will neither increase nor decrease till the year of the opening of the project road, since the occupancy rate of trains is nearly 100% and the passengers on railways have not increased in the past several years. After the opening of the road, the diverted passengers will grow at the same rate as the normal traffic. The details of the estimate are contained in Annex IX-2.

9.03.2 Cargoes

Similarly, the diversion of cargoes from rail to road is determined by the shipper, who evaluates the rate and other services between rail and truck transport. The economic benefit is the balance of the transport cost between the two modes: the cost by the existing railroad and that by heavy truck. The goods forwarded and received in the stations of the direct influence zones are shown in Table VI-7. Most of them are to and from Khartoum or Port Sudan.

The charges on the access transport and warehouse are added to the estimate of railways' tariff in major items subject for diversion. They are compared with the charges by truck operators. The charges by railways are less expensive. The economic costs of railway and truck transport were studied for major commodities. The cost is also less expensive for the railway services. It is determined by these studies that there will be no diversion to truck services. Annex IX-2 presents the details of this analysis.

However, considerable amount of goods are already carried by trucks for long distance running on roads in poor condition. These flows are shown by tables in Annex VI-16. If the paved road is constructed, the travelling time and damage to goods will be lessened, resulting in greater use of trucks rather than rail services. It means the shipper prefers to choose truck service rather than railway service despite paying higher charges. Although paying higher transport costs, he receives some benefits including savings in time.

It is difficult to evaluate savings in time and other benefits under the economic evaluation. These benefits should be included in social benefits or non-quantifiable benefits, rather than being converted into economic benefits by a questionable method. The diversion benefit of goods is not included in the stream of the economic benefits.

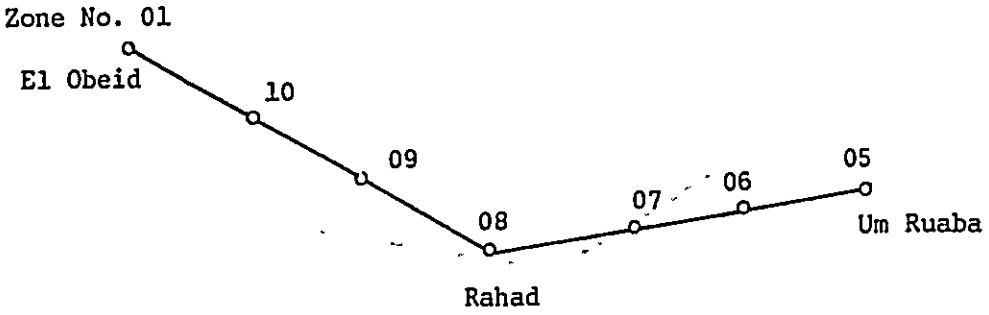
9.04 Generated Traffic and Its Benefits

When a road is constructed, traffic increases because of the better road surface. In the case of the project road, small vehicles now confined to El Obeid and other urban streets can run out easily to other neighboring zones on the new road. The generated traffic and its benefits are estimated as follows.

Generated Traffic:	the volume of the generated traffic on the project road is 10% of the normal traffic. In the first year of the road in use, it is 18 vehicles, comprising 9 passenger cars and 9 pick-up trucks. Fig. IX-1 shows the estimated volume.
Generated Benefit:	the benefit per vehicle is half of that of the normal benefit.
Growth Rate:	they will grow at the same rate as the normal traffic.

Fig. IX-1-1 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT

PLAN 1

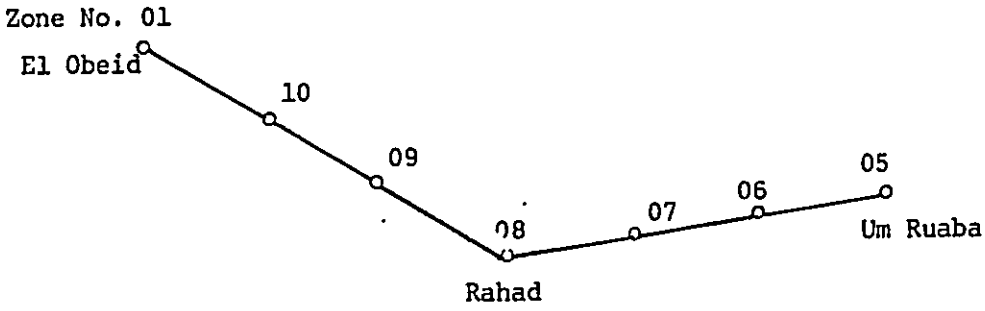


(Total Length 139.8 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Length (Km) / Traffic by year		23.5	23.5	21.0	23.0	26.0	22.8	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(129.8)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	184.6
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.8	210.6
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	354.1
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	401.9
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	569.7
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.6	674.1	647.6

Fig. IX-1-2 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT

PLAN 2

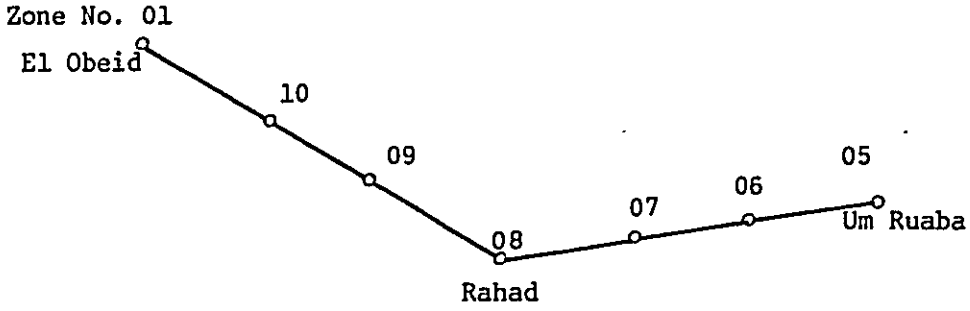


(Total Length 134.6 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Length (Km) / Traffic by year		23.5	23.5	21.0	20.0	25.0	21.6	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(129.6)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	184.3
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.8	210.3
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	353.5
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	401.3
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	568.9
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.6	674.1	646.8

Fig. IX-1-3 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT

PLAN 3

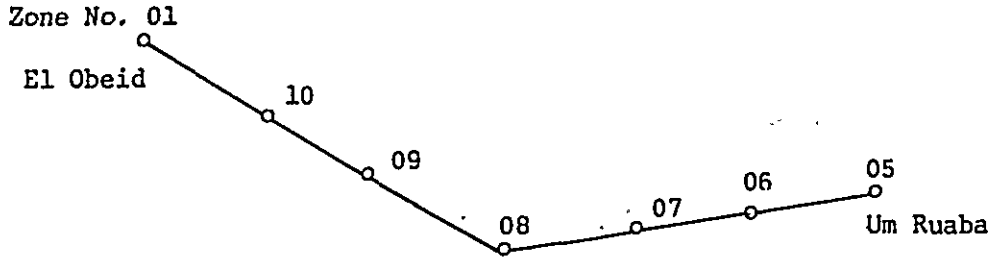


(Total Length 135.3 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Traffic by year \ Length (Km)		23.5	23.5	21.0	31.0	14.0	67.3	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(129.0)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	183.4
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.8	209.8
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	351.9
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	399.7
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	567.7
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.6	674.1	645.6

Fig. IX-1-4 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT

PLAN 4

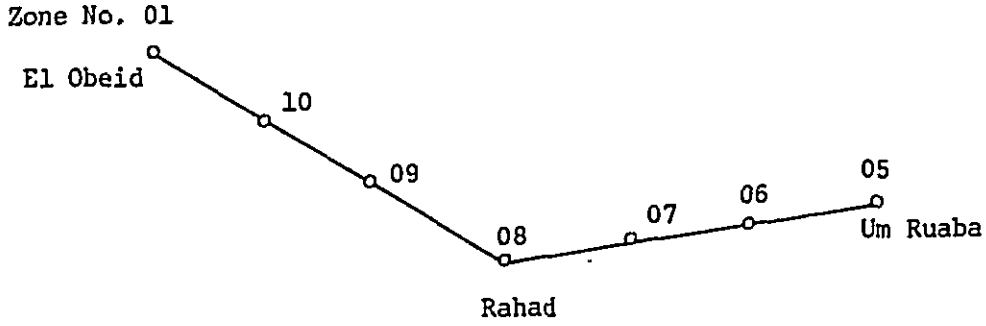


(Total Length 129.5 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Length (Km) / Traffic by year		26.0	21.0	26.0	23.0	26.0	22.8	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(129.5)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	184.2
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.1	210.2
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	353.4
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	401.2
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	568.8
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.0	674.1	646.7

Fig. IX-1-5 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT

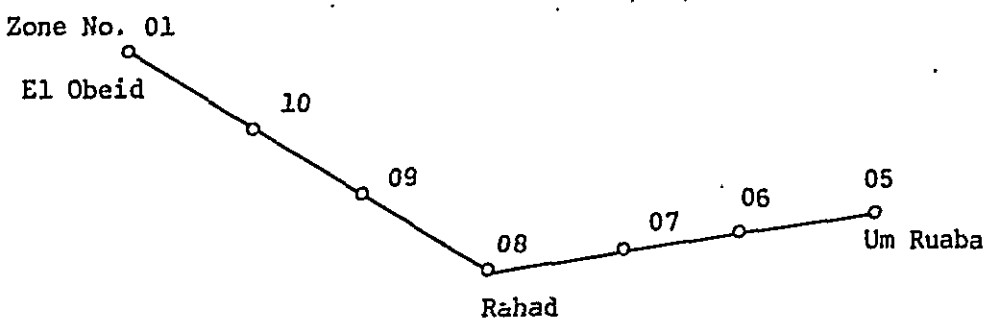
PLAN 5



(Total Length 139.6 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Length (Km) / Traffic by year		26.0	21.0	26.0	20.0	25.0	21.6	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(129.3)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	183.9
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.8	209.9
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	352.8
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	400.6
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	568.0
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.6	674.1	645.9

Fig. IX-1-6 EL OBEID-UM RUABA ROAD PLAN 6
TRAFFIC BY SECTION, ADT

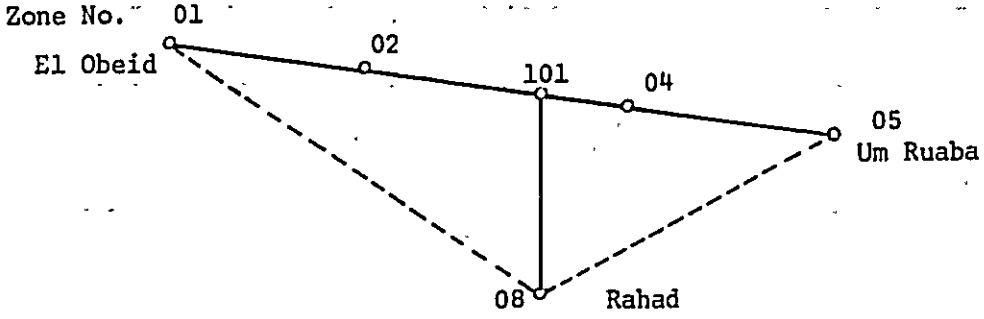


(Total Length 140.3 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Length (Km) / Traffic by year		26.0	21.0	26.0	31.0	14.0	22.3	
1977	Normal Traffic	(123.0)	(121.4)	(120.4)	(130.2)	(139.2)	(143.1)	(128.7)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	175.4	173.1	171.9	185.4	197.1	202.3	182.9
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18	18	18	18	18	18	18
	Total	200.9	198.6	197.4	211.9	223.6	228.8	208.9
1992	Normal Traffic	338.5	334.1	332.1	359.2	374.3	382.6	351.8
	Diverted Traffic	13.8	13.8	13.8	15.6	15.6	15.6	14.7
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	33.1	33.1
	Total	385.4	381.0	379.0	407.9	423.0	431.3	399.6
2002	Normal Traffic	550.0	543.1	540.3	584.2	600.3	594.8	566.9
	Diverted Traffic	22.5	22.5	22.5	25.4	25.4	25.4	24.0
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	53.9	53.9
	Total	626.4	619.5	616.7	663.5	679.6	674.1	644.8

Fig. IX-1-7 EL OBEID-UM RUABA ROAD
TRAFFIC BY SECTION, ADT

PLAN 7
(including Access)



(Total Length 155.5 Km)

Section		01-02	02-101	101-04	04-05	Average	101-07	Average
Length (Km) / Traffic by year		35.45	24.35	11.31	43.59	114.7	40.8	
1977	Normal Traffic	(126.6)	(121.6)	(129.9)	(147.7)	(133.9)	(58.9)	(114.2)
	Diverted Traffic							
	Generated Traffic							
	Total							
1983	Normal Traffic	180.1	173.3	184.2	208.6	189.9	83.3	161.9
	Diverted Traffic	7.5	7.5	8.5	8.5	8.0	1.2	6.2
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	6.0	14.9
	Total	205.0	198.8	210.7	235.1	215.9	90.5	183.0
1992	Normal Traffic	345.1	334.5	351.6	391.1	361.0	155.0	306.9
	Diverted Traffic	13.8	13.8	15.6	15.6	14.7	2.2	11.4
	Generated Traffic	33.1	33.1	33.1	33.1	33.1	11.0	27.3
	Total	392.0	381.4	400.3	439.8	408.8	168.2	345.6
2002	Normal Traffic	557.8	543.3	565.7	621.2	579.6	245.0	491.9
	Diverted Traffic	22.5	22.5	25.4	25.4	24.0	4.3	18.8
	Generated Traffic	53.9	53.9	53.9	53.9	53.9	17.9	44.5
	Total	634.2	619.7	645.0	700.5	657.5	267.2	555.2

TABLE IX-3 NUMBER OF BUSES FOR DIVERTED PASSENGERS PER DAY 1)

	EL Obeid	Rahad	Um Ruaba	Average per Km
(1977)	(7.5)	(8.5)		(8.0)
1983	7.5	8.5		8.0
1992	13.8	15.6		14.7
2002	22.5	25.4		24.0

Note: 1) Alternatives 1. - 7.

TABLE IX-4 ECONOMIC BENEFITS OF DIVERTED PASSENGERS

	£S in 1977 Price	£S Discounted to 1978 at 10% p.a.
(1977)	(108.138)	-
1983	108.138	67.157
1992	198.758	52.333
2002	323.578	32.843

Note: 1) Alternatives 1. - 6. The benefit for alternative 7. will be less by 1%.

CHAPTER X

10.00 COST-BENEFITS ANALYSES

The economic evaluation is carried out in order to find out the best route among the seven alternatives. The result is shown in Table X-1 which shows Plan 2 is the best route among the proposed seven alternatives. Plan 2 registers 1.727 as B/C ratio and £S5.9 million as the present worth, when a discount rate of 10% is applied. The economic rate of return is 17%. Table X-2 shows the streams of cost and benefit for the years in the project life period including the years of implementation.

Table X-3 shows the results of benefit-cost analysis under a more conservative assumption of a traffic growth rate of 5% p.a. constantly from 1977 up to the end of the project of 2,002. Again, Plan 2 is the best route among the seven alternatives.

The economic assessment of the postponement of the project is seen by Table X-4. If the project is deferred one year, two years, three years and so on, the net benefit (B-C) increases £S 5.9 million, 6.3 million, 6.6 million, etc. Net benefit (B-C) increases at a decreasing rate. Consequently the project will serve the country more when it is implemented earlier.

TABLE X-1 COST-BENEFITS ANALYSIS OF THE PROJECT [1)]

Alternative	1	2	3	4	5	6	7
Sections	A, C	A, D	A, E	B, C	B, D	B, E	F
Initial Economic Cost in £S Million	10.121	9.716	11.089	10.365	9.960	11.331	13.955
Benefits-Cost Ratio r=0.10	1.633	1.727	1.484	1.567	1.657	1.427	1.256
Present Worth r=0.10 (£S '000)	5,320	5,878	4,448	4,878	5,442	4,010	2,866
Economic Rate of Return	0.159	0.166	0.146	0.154	0.161	0.141	0.126

Note: 1) The growth rate of the traffic is assumed at 7% p.a. up to 1,992 and 5% p.a. for the period between 1,992 and 2,002. Due to the changes in the vehicle composition, the benefit increases yearly slightly higher than the above figures of traffic growth.

TABLE X-2 STREAMS OF COST AND BENEFIT : PLAN 2

(In ES '000)

CASE 2 DISCOUNT RATE = 0.100 B-C = 5878 B/C = 1.7267

ECON. RETURN = 0.166 B-C = -7 B/C = 0.9989

			C1	C2	CT	CTD	AGGR.	B1	B2	B3	BT	BTD	AGGR.
1978	0		95		95	95	95						
1979	1		592		592	508	603						
1980	2		3210		3210	2360	2963						
1981	3		2726		2726	1718	4681						
1982	4		3093		3093	1671	6352						
1983	5	1		23	23	11	6363	1227	116	24	1367	633	633
1984	6	2		23	23	9	6372	1318	124	26	1468	583	1216
1985	7	3		23	23	8	6380	1419	132	28	1579	538	1754
1986	8	4		23	23	7	6387	1532	142	30	1704	498	2252
1987	9	5		23	23	6	6393	1660	152	31	1843	461	2713
1988	10	6		23	23	5	6398	1805	162	34	2001	430	3143
1989	11	7		23	23	4	6402	1971	174	36	2181	401	3544
1990	12	8		509	509	80	6482	2160	186	38	2384	376	3920
1991	13	9		23	23	3	6485	2377	199	42	2618	354	4274
1992	14	10		23	23	3	6488	2631	213	45	2889	335	4609
1993	15	11		23	23	2	6490	2770	223	47	3040	302	4911
1994	16	12		23	23	2	6492	2920	235	49	3204	273	5184
1995	17	13		23	23	2	6494	3079	246	52	3377	247	5431
1996	18	14	1973	23	1996	125	6619	3250	259	54	3563	223	5654
1997	19	15		19	19	1	6620	3435	271	57	3763	202	5856
1998	20	16		19	19	1	6621	3632	285	59	3976	183	6039
1999	21	17		19	19	1	6622	3841	299	63	4203	166	6205
2000	22	18		19	19	1	6623	4069	314	66	4449	151	6356
2001	23	19		19	19	1	6624	4313	330	69	4712	137	6493
2002	24	20		19	19		6624	4576	347	73	4996	124	6617

TABLE X-3 COST-BENEFITS ANALYSIS OF THE PROJECT [1)]

Alternative	1	2	3	4	5	6	7
Sections	A, C	A, D	A, E	B, C	B, D	B, E	F
Initial Economic Cost in £S Million	10.121	9.716	11.089	10.365	9.960	11.331	13.955
Benefits-Cost Ratio r=0.10	1.302	1.377	1.183	1.249	1.321	1.138	1.001
Present Worth r=0.10 (£S '000)	2,541	3,051	1,685	2,147	2,663	1,300	16
Economic Rate of Return	0.132	0.139	0.120	0.127	0.134	0.115	0.110

Note: 1) The growth rate of the traffic is assumed at 5% p.a. for the whole period of 1977 to 2002.

TABLE X-4 POSTPONEMENT OF THE PROJECT : PLAN 2 [1)]

Year	B/C	B-C (In £S '000)	Increase in B-C (In £S '000)
Opening in 1983	1.727	5,878	-
Opening in 1984	1.851	6,254	376
Opening in 1985	1.982	6,563	309
Opening in 1986	2.122	6,820	257
Opening in 1987	2.270	7,017	197
Opening in 1988	2.427	7,164	147

Note: 1) The discount rate applied in this Table is 10% p.a. Other assumptions are the same as in Table X-1.