TABLE VII-1 ALTERNATIVE PLANS

Plan	El Obeid-Rahad	Rahad-Um Ruaba	Total Distance
1	(A) 68.0 km	(C) 71.8 km	139.8 km
2 [1)]	(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	139.6
6	(B) 73.0	(E) 67.3	140.3
7	(F) 114.7 + (Access) 40.8		155.5

Note: 1) The length is to be revised as in CHAPTER VIII.

7.02 Design of Alternative Routes

7.02.1 Design Standards

It is understood the AASHTO standards are generally applied to the road system of RBPC. For the selection of the best route among the alternatives, the design criteria applied, in the main, follow the AASHTO standards. Application of these criteria was discussed with RBPC when the study team was in the Sudan and at a meeting held to discuss the interim report.

i. Traffic Volumes

For all alternatives, the estimated traffic is shown in FIG. IX-1. ADT of the opening year in 1983 is approximately 220 vehicles and ADT in the last year of the project life in 2002 is approximately 660 vehicles. The maximum traffic

TABLE VII-2 TECHNICAL COMPARISON OF ALTERNATIVE ROUTES

Item / Route		Southern Routes			
		El Obeid — Rahad		Rahad — Um Ruaba	
		Route A	Route B	Route C	Route D
Alignments	Horizontal curve Radius (R)	No place 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 1,5
	Longitudinal Grade (L.G.)	Total Length 0.95 km of which L.G. is steeper than 3%.	No sections with L.G. steeper than 3%.	No sections with L.G. steeper than 3%.	Total length 7.25 km of which is steeper than 3%.
		Although the longitudinal grade is gentle, the horizontal alignment meanders along J. KORDOFAN.	Since this route runs through flat terrain, vertical alignment is good, but horizontal alignment has many detours which increases total distance.	Although the longitudinal grade is gentle, the horizontal alignment meanders considerably along K. ABU HABL.	Horizontal alignment is very Since the route runs across dune areas, there are many up down sections.
Soil Conditions		The soil condition is generally good.	Same as Route A	The section of this route between RAHAD and UM RUABA runs through a cotton clay area. The soil condition is very poor.	This route runs through a ve limited part of the cotton c area in the flood plain of K. ABU HABL. The soil condit of other areas are generally
Material Conditions		Transportation of base course materials and aggregates is relatively easy, since this route runs through J. KORDOFAN (gravel available), and J. EL AIN (quarry sites).	Same as Route A	Transportation of the base course materials to the section between RAHAD and UM RUABA are disadvantageous because of long transport distance.	Same as Route C
Construction Difficulties		Easy to secure water for construction. Easy to transport equipment and materials by railways if necessary.	Same as Route A	No work in the rainy season at the flood plain of K. ABU HABL. Easy to transport equipment and materials by railways if necessary.	Little influence of the flood the rainy season. Easy to tr port equipment and materials railways if necessary.
Structures	Bridges	10 places	12 places	3 places	3 places
	Box Culverts	10 places	16 places	9 places	10 places
	Pipe Culverts	11 places	10 places	51 places	26 places
Pavement		Surface DBST Base Course Gravel CBR $\geqq$ 80 Sub-base Course Gravel CBR $\geqq$ 30 Sub-grade Select CBR $\geqq$ 20	Same as Route A	Same as Route A	Same as Route A
Drainages		Consideration has to be paid for slope protection around K. BAGGARA.	Same as Route A	Consideration has to be paid for slope protection around K. ABU HABL.	No particular problem observed

TECHNICAL COMPARISON OF ALTERNATIVE ROUTES

	Southern Routes			Northern Direct Route
	Rahad —— Um Ruaba			El Obeid —— Um Ruaba
/	Route C	Route D	Route E	Route F + Access
under	Three 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.	One place where R is under 1,500 m.
eeper than	No sections with L.G. 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%.
rough flat ent is good, has many otal	Although the longitudinal grade is gentle, the horizontal alignment meanders considerably along K. ABU HABL.	Horizontal alignment is very good. Since the route runs across sand dune areas, there are many up and down sections.	Same as Route D	Although the horizontal alignment is very good, there are many up and down sections because this route runs through sand dune areas.
	The section of this route between RAHAD and UM RUABA runs through a cotton clay area. The soil condition is very poor.	This route runs through a very limited part of the cotton clay area in the flood plain of K. ABU HABL. The soil conditions of other areas are generally good.	The route runs through the sand dune areas. The soil condition is generally good.	This route runs partly across a silty clay area. In other areas of sand dunes, the soil condition is generally good.
	Transportation of the base course materials to the section between RAHAD and UM RUABA are disadvantageous because of long transport distance.	Same as Route C	Same as Route C	Problems exist in obtaining aggregates since no quarry site is available near the section between GEIFIL and UM RUABA.
	No work in the rainy season at the flood plain of K. ABU HABL. Easy to transport equipment and materials by railways if necessary.	Little influence of the flood in the rainy season. Easy to transport equipment and materials by railways if necessary.	Same as Route D	Difficult to obtain the water for construction. Difficult to get aggregates. Less convenient to use railway transportation.
	3 places 9 places 51 places	3 places 10 places 26 places	- 19 places 11 places	3 places 45 places 24 places
	Same as Route A	Same as Route A	Same as Route A	Same as Route A
	Consideration has to be paid for slope protection around K. ABU HABL.	No particular problem observed.	Same as Route D	Same as Route D

in 2002 is 740 vehicles for a section of Plan 7 and the minimum is 620 vehicles for a section in another plan.

These figures are examined by a design traffic volume indicated by Highway Capacity Manual, 1965. It indicates that a two-lane flat rural road has a capacity of 5,000 vehicles per day in terms of passenger car equivalency. If this is converted into a realistic number of vehicles considering the vehicle type composition, the proposed two lane paved road can be expected to have a reasonable capacity in serving the estimated traffic flow for the 20 years of the project life. The design capacity and the estimated traffic are shown below in terms of ADT, where the design traffic capacity is converted into the realistic number of vehicles.

	Design traffic capacity		Estimated Traffic in 2002	
	6m width	7m width	maximum	minimum
Flat	1,600	2,000	740	620
Hilly	800	1,000		

ii. Geometric Criteria

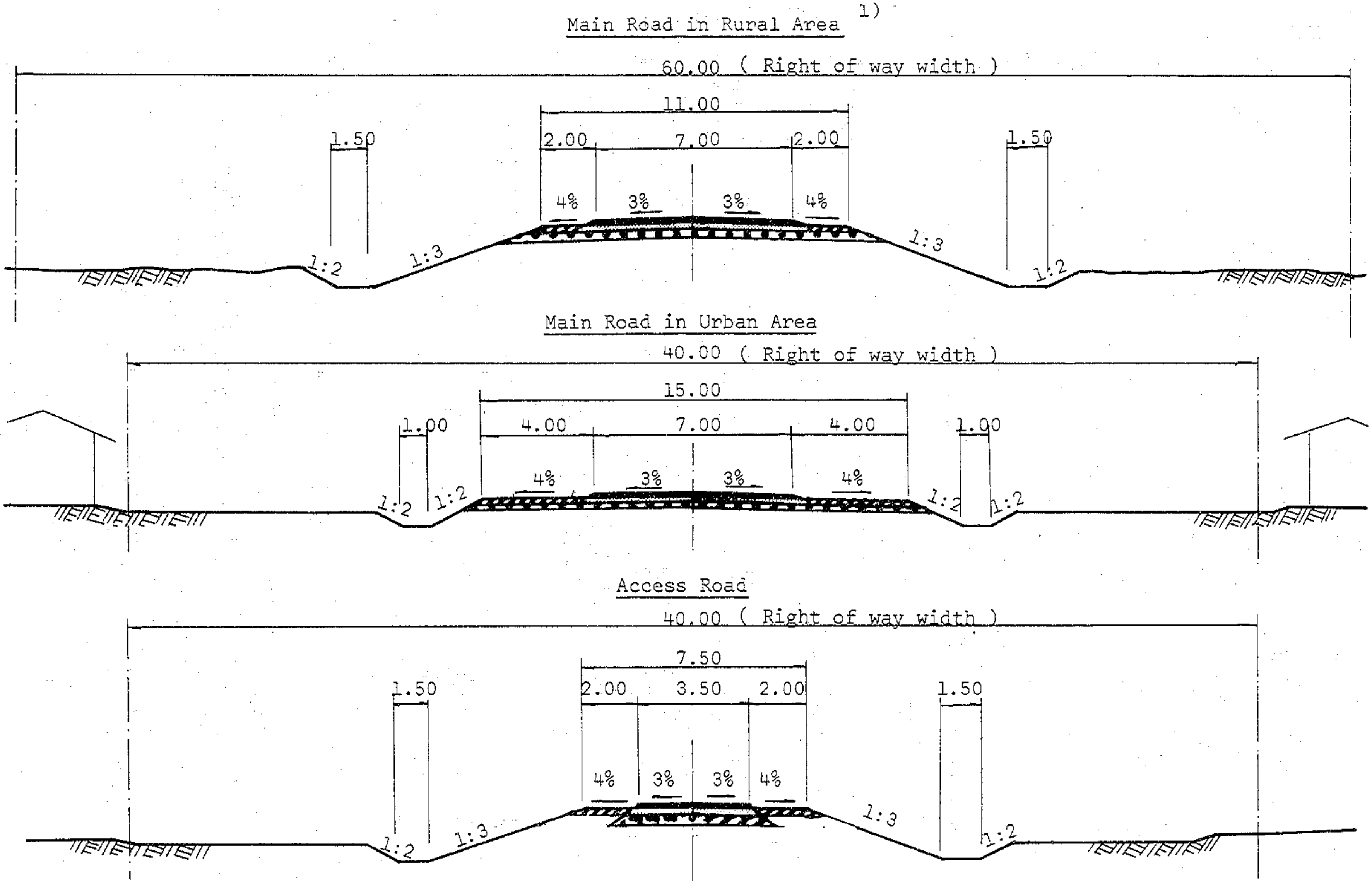
Geometric design criteria applied to all seven alternatives are shown in Table VII-3. Typical cross sections are shown in FIG. VII-2.

TABLE VII-3 GEOMETRIC DESIGN CRITERIA

Road	Area	Terrain	Design Speed (km/hr)	Width (m) Carriage-way	Width (m) Shoulder	Gradient Max. (%)	Max. Super-elevation (%)	Mini. Horiz. Curve Radius (m)	Mini. Vert. Curve Length (m)	Sight Distance (m)
Main Road										
	Rural	Flat [1)]	100	2 x 3.5	2 x 2.0	3	8	380	85	670
	Rural	Hilly [1)]	80	2 x 3.5	2 x 2.0	5	8	230	70	550
	Urban	Flat	60	2 x 3.5	2 x 4.0	5	8	130	50	430
Access Road										
	Rural	Flat	60	1 x 3.5	2 x 2.0	5	8	130	50	430

Note: 1) Flat terrain is defined as having a gradient of less than 3%. Hilly terrain is defined as having a gradient in the range of 3 to 6%.

FIG. VII-2 TYPICAL CROSS SECTIONS



Note: 1) Only for comparative study of the seven routes.

LEGEND: DBST or AC; BASE COURSE; SUBBASE COURSE; GRAVEL

iii. Structure Specifications

Designed vehicle load is quoted from H-20-44 of H Loading, Standard Specification for Highway Bridges, 1973 AASHTO, and impact load by vehicle is taken into consideration. Possibilities of load factors by wind and earthquake are disregarded. Earth pressure is calculated by the Rankine's formula. The allowable design strength of materials is based on Interim Specifications Bridges, 1974 AASHTO and is shown by the following table.

Classification	Allowable Stress in kg/cm^2	Application
Concrete A	110	Reinforced beam and slab
Concrete B	60	Reinforced wall and deck
Concrete C	40	Foundation, etc.
Reinforcing Bar Grade 40, 50	1,400	All structures

iv. Design Standards of Pavement Structures

In the first stage of the study to compare the alternative routes, the design of pavement structures is based on AASHTO Interim Guide for Design of Pavement Structures, 1972. It is to be noted that the design standards applied in the best route are reviewed in CHAPTER VIII.

7.02.2 Road Planning

i. Horizontal Alignment Plan

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

a. The new road will run along the existing road, as a rule, for the purpose of expediting construction works, and also to serve residents in villages scattered along the existing tracks.

b. The horizontal alignment will be planned to detour such places as flood plains, low ground and mountainous terrain, while keeping the total distance to a minimum.

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

d. The starting point of the projected south-bound route is set at the end of the 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 town centre of Um Ruaba only for the purpose of comparative study.

ii. Vertical Alignment Plan

The terrain of all routes is predominantly gently sloping. In planning the vertical alignment, attention has been given to the following:

a. The maximum gradient is set at 5%. The minimum radius of vertical curvature is designed at 3000 m.

b. The mean height of embankment is planned to be 1 m, generally. Where the road crosses over the flood plain of the river or over low ground, the minimum height of embankment is set at 1.5 m.

c. The vertical alignment at river crossings is planned to have 1 m clearance from the assumed high water level to the beam.

iii. Cross Sections and Drainage Plan

a. Cross Sections

Typical cross sections are shown in FIG. VII-2. They are applied only for the first stage study in comparing seven alternative route plans.

b. Drainage

As shown in FIG. VII-2, earth side ditches are provided at both sides of the carriageway. As a principle, earth evacuated from ditches will be used for embankments.

Drainage from the road surface flows into side ditches and then flows parallel to the road. The drained water is discharged into watercourses or natural valleys wherever necessary. In each side drainage ditch where the current velocity is high and the water discharge is large, stone pitching is provided to protect the earth ditch from erosion. The standard cross fall of the new road is 3% at the carriageway and 4% at the shoulder.

7.02.3 Design of Pavement Structure

Concerning the pavement structure, two factors should be studied; they are the subgrade supporting value and the number of repetitions of 8.2 tons equivalent standard axle loads. Since the CBR test is usually applied for measuring subgrade supporting value, the same test has been conducted in this investigation. The design standard of the pavement section is based on the "Interim Guide for Design of Pavement Structure", 1972, AASHTO.

i. Traffic Analysis and Design Axle Load

Daily traffic volume for each section is estimated as shown in FIG. IX-1. The differences in traffic volume among the sections are relatively small. The ADT in 1977 of the Abu Hamra - Um Ruaba section is 143, which is the maximum volume among the sections and 10% more than the average ADT (130) of the all sections. The ADT in 1977 of the Nawa - Rahad section is 120, which is the minimum and 8% less than the average value. Based on these figures, it was decided to take the traffic volume at the middle section of the route Rahad - Semeih as a representative figure because this volume is approximate to the average. The calculation is shown in Annex VII-1 and 2.

Both front and rear axles are counted as loading axles for trucks larger than medium size trucks, and rear axles only are counted for small trucks. For small size vehicles composed of small trucks and passenger cars, the equivalent factor of small trucks is used. Axle loads by type of vehicle are shown in FIG. 7-1, Annex VII-3, and standard equivalent factors for various types of vehicles were calculated by applying the figures shown in FIG. 7-2, Annex VII-4.

The accumulated number of repetition of standard axles on one lane of the road for a particular year is indicated as follows. Here, an additional 10% increase in axle numbers, due to diverted and generated traffic, is included. (ref. Table 7-2, Annex VII-2).

	Accumulated Standard Axle Number
The first year after opening (1983)	24,057
Total number until the 13th year	678,931
Total number until the 20th year	1,507,643

ii. Determination of Pavement Structure

a) Structural Number

A structural number is determined according to the formula in the Interim Guide of AASHTO. With the following coefficients the pavement thickness is designed as in Table VII-5.

$$SN = a1\ D1 + a2\ D2 + a3\ D3 + a4\ D4$$

Where: a1, a2, a3 and a4 denote layer coefficients, representative of surface, base, subbase and subgrade, respectively.

D1, D2, D3 and D4 denote actual thickness, in cm, of surface, base, subbase and subgrade, respectively.

SN denotes a structural number.

TABLE VII-4 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 $\geq$ 80)	0.15
Sub-base Course & Subgrade	
Crushed Stone with Sand	0.11
Sand and Sandy Soil	0.05 - 0.10

Layer coefficients of the pavement materials are the values determined as in the above Table VII-4. The regional factor (R) is set at 1.0 since the terrain of the project area is generally flat, annual rainfall is relatively light, frost is not expected and the level of ground water is low.

b) Determination of Pavement Section

It is proposed that the surface course be constructed in two-stages. The first stage is double bituminous surface treatment (DBST) maintained until the 13th year after opening, because the accumulated equivalent axle numbers reach 700,000 in this year. The second stage is an overlay of 5 cm thick asphalt concrete on the surface in the 13th year. Thickness of pavement for each CRB value is as noted in Table VII-5. Table VII-6 shows the length of the sections each having the CBR value of 3%, 5%, 9% and over 12%, respectively.

TABLE VII-5 THICKNESS OF EACH LAYER OF PAVEMENT 1)

(Unit: cm)

CBR Value			3%	5%	9%	Over 12%
Surface	: D1	DBST	3	3	3	3
Base Course 2)	: D2	Gravel (CBR≥80)	15	15	15	15
Sub-base Course 2)	: D3	Gravel (CBR≥30)	20	20	20	20
Sub-grade 2)	: D4	Select (CBR≥20)	40	30	15	10
Total Thickness :			78	68	53	48

Note: 1) These thicknesses are only for the comparative study of the seven alternatives. The pavement thickness is reduced for the designing of the optimum route as covered in CHAPTER VIII.

2) Degree of compaction is not less than 95%.

TABLE VII-6 ROADBED LENGTH

Upper value : km
(Lower value :(%))

Alternative	Route	C B R Value (%) 3	5	9	Over 12	Total
Plan 1	A + C	39.08 (28)	0.75 (1)	20.65 (15)	79.32 (56)	139.80 (100)
Plan 2	A + D	2.73 (2)	0 (0)	20.65 (15)	111.22 (83)	134.60 (100)
Plan 3	A + E	2.18 (2)	0	51.77 (38)	81.35 (60)	135.30 (100)
Plan 4	B + C	39.08 (27)	0.75 (1)	34.22 (23)	70.75 (49)	144.80 (100)
Plan 5	B + D	2.73 (2)	0	34.22 (24)	102.65 (74)	139.60 (100)
Plan 6	B + E	2.18 (2)	0	65.34 (46)	72.78 (52)	140.30 (100)
Plan 7	F + Access	3.00 (2)	0	8.09 (5)	144.41 (93)	155.50 (100)

7.02.4 Structure Design

i. Determination of Structure

The basis of design is referred in 7.02.1.iii in CHAPTER VII. Selection of road structure is based on the study of the data described below, referring to the relationship between the flood-passing capacity and construction cost (ref. FIG. 7-3, Annex VII-6 and Table 7-3, Annex VII-5). This relationship is established by this study. The general shapes of drainage structures are illustrated in FIG.7-4, Annex VII-7 through FIG.7-6, Annex VII-9. The location of each road structure is listed in Table 7-4, Annex VII-10. For the purpose of determining a structure requirement, the following standards are applied.

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

ii. Design of Bridge

a) Substructure

According to the results of the seismic prospecting stated in 5.03.3, CHAPTER V, the bearing capacity of the ground at a depth of more than 2 m can be expected to be more than 25 t/m^2; therefore, a spread foundation is most applicable for bridges. Since the soil is generally silty clay and the ground water level is very low, settlement due to consolidation will be negligible. Foundation depth is determined to be more than 2.0 m at abutments and piers for protection from flood erosion.

A comparison is made of the costs of substructures using brick, natural stone and reinforced concrete. As shown by Annex VII-11, the uses of brick and shaped stone are more expensive so the substructures are designed with reinforced concrete in a reversed T shape.

b) 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. "A beam and slab bridge" is compared with other types of bridge as shown by Annex VII-11. The former is less expensive. Construction of slab bridges with precast reinforced concrete beam of 7 m or 9 m in length are proposed in the plan.

iii. Design of Box Culvert

Since the formation at embankment sections of proposed roads is planned to be as low as possible, the box culvert sections are designed to be low in height as indicated in FIG. 7-5, Annex VII-8. Suitability of lesser openings by box culvert against a larger number of openings by pipe culvert is studied partly in 7.02.4, i. However, it should be noted that this problem is a matter to be further elaborated upon in the detailed engineering.

iv. Design of Pipe Culvert

a. Size of Pipe

Pipe culverts are proposed for minor drainage wherever deemed necessary. One to three pipe culverts are set with 1 m diameter precast concrete pipe, crossing the proposed road. They are shown in FIG.7-6, Annex VII-9. For the access roads precast concrete pipes of 0.60 m diameter are planned for channelling the drainage water.

b. Concrete Pipe and Corrugated Metal Pipe

The comparison of the cost between concrete pipe culverts and corrugated metal pipe culverts discloses that metal pipes must be imported and their construction cost is slightly higher, although metal pipes are easier to transport and to use in construction. The results are indicated in Table 7-5, Annex VII-12. The use of corrugated metal pipe is not included in the cost estimate of the project.

7.03 Construction and Maintenance Cost of Alternatives

7.03.1 Implementation Plan

The construction schedule takes into consideration the local climate conditions, such as fierce heat in the dry season and flooding in the rainy season. The construction base camps are to be located at El Obeid, Rahad and Um Ruaba where living conditions are fairly good. The sections of construction work are 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 annually, preparatory and minor works are scheduled during this period.

7.03.2 Preparations for Estimating Construction Cost

i. Construction cost estimates are based on the following items.

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

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

c) Mechanical equipment, material and labour costs will be based on prices as of July, 1977.

d) Construction costs will be paid in foreign and local currencies. The work will be carried out by contractors.

e) Classification of customs and taxes will follow the Sudanese procedure.

f) For purposes of economic comparison, the inflation factor will not be considered.

ii. Payment in foreign currency is as follows.

a) Imported materials and machinery such as asphalt, steel products in CIF price.

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

c) Costs which correspond to the foreign currency component of expenses by consultants and contractors.

iii. Payment in local currency is as follows.

a) Local product materials such as cement, round bars, etc.

b) Import duties, local taxes, etc., if not exempted.

c) Labour costs and transportation costs.

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

7.03.3 Unit Costs of Construction Items

Unit costs of construction items are shown in Table VII-7. As detailed in Annex VII-13, the estimate includes costs for equipment, labour and materials.

7.03.4 Construction Cost

Construction costs for each alternative route are shown in Tables VII-8 and VII-9. 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 contingency, 5% for supervision, 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 VII-14 and 15. Table 8-11 in Annex VIII-11 shows the quantity of equipment used in each year of the construction period for alternative plan 2, as an example.

TABLE VII-7 ECONOMIC UNIT COSTS OF CONSTRUCTION ITEMS [1]

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
Sub-base, 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 thickness (asphalt 6%)	m^2	2.094
Shoulder treatment (compacted)	m^2	0.420
3. Structures		
Excavation	m^3	0.291
Concrete C for foundation, etc.	m^3	22.380
Concrete B for reinforced wall and deck	m^3	26.340
Concrete A for reinforced beam and slab	m^3	32.470

Note: 1) Assuming the construction starts from the first section of El Obeid, and including overhead and profit surcharges.

TABLE VII-8 ECONOMIC COST OF THE PROJECT

(LS 000 in 1977 price)

	Item	Plan / Distance	1	2	3	4	5	6	7 [1)]
			139.8 km	134.6 km	135.3 km	144.8 km	139.6 km	140.3 km	155.5 km
1.	Construction Cost		7,912	7,595	8,668	8,102	7,786	8,859	10,909
2.	Preparation	(1) x 4%	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	(3) x 10%	823	790	902	843	810	921	1,135
5.	Supervision	(3) x 5%	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	(3) x 2%	165	158	180	169	162	184	227
8.	Detailed Design	(3) x 6%	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 (8) x 20%		99	95	108	101	97	110	136
	1979 (8) x 80%	(2) x 70%	616	592	675	629	604	688	850
	1980 (2) x 30%	(34%) of the remaining	3,223	3,210	3,643	3,173	3,148	3,574	3,686
	1981	(31%) - " -	2,932	2,726	3,917	3,210	3,010	4,216	4,173
	1982	(35%) - " -	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 road is 114.7 km.

TABLE VII-9 CONSTRUCTION COST BY PLAN

(LS in 1977 Price)

Alternative / Item / Plan	1 A + C	2 A + D	3 A + E	4 B + C	5 B + D	6 B + E	7 F + Access Road
Distance (km)	139.8	134.6	135.3	144.8	139.6	140.3	155.5
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
Cost per km	56,592	56,428	64,067	55,954	55,772	63,142	70,156

7.03.5 Maintenance and Repair Cost

For maintenance and repair after completion of the road, the annual maintenance and periodic overlay costs are estimated in Tables VII-10 and VII-11. The details of this estimate are presented in Annex VII-16.

TABLE VII-10 MAINTENANCE AND REPAIR COST

(LS/km)

Item	Cost	Remarks
DOUBLE BITUMINOUS SURFACE TREATMENT		
Repair of surface	36.0	Every year
Miscellaneous works	83.8	"
Management	48.0	"
Sub Total	167.8	"
Resurfacing	3,612.0	Every 7 years
ASPHALT CONCRETE SURFACING		
Repair of surface	14.6	Every year
Miscellaneous work	83.8	"
Management	39.6	"
Sub Total	138.0	"
Overlay	14,658.0	Every 10 years

As for the access road from Rahad to route F, the road is assumed to open as a one-lane paved road and to be widened into two lane paved road in 1990, in which the main route F is planned to be resurfaced simultaneously.

TABLE VII-11 MAINTENANCE AND REPAIR COST (1983 - 2002)

(LS in 1977 Price)

	Year	Plan -	1	2	3	4	5	6	7
a) Maintenance and Repair									
1.	1983		23,486	22,613	22,730	24,326	23,453	23,570	26,124
2.	1984		"	"	"	"	"	"	"
3.	1985		"	"	"	"	"	"	"
4.	1986		"	"	"	"	"	"	"
5.	1987		"	"	"	"	"	"	"
6.	1988		"	"	"	"	"	"	"
7.	1989		"	"	"	"	"	"	"
8.	1990	resurfacing	528,444	508,788	511,434	547,344	527,688	530,334	1,080,300
9.	1991		23,486	22,613	22,730	24,326	23,453	23,570	26,124
10.	1992		"	"	"	"	"	"	"
11.	1993		"	"	"	"	"	"	"
12.	1994		"	"	"	"	"	"	"
13.	1995		"	"	"	"	"	"	"
14.	1996		"	"	"	"	"	"	"
15.	1997		19,292	18,575	18,671	19,986	19,265	19,361	21,622
16.	1998		"	"	"	"	"	"	"
17.	1999		"	"	"	"	"	"	"
18.	2000		"	"	"	"	"	"	"
19.	2001		"	"	"	"	"	"	"
20.	2002		"	"	"	"	"	"	"
	TOTAL		949,514	914,207	918,950	983,474	948,167	952,910	1,549,644
b) Overlay with AC of 5 cm thickness									
	1996		2,049,188	1,972,967	1,983,227	2,122,478	2,046,257	2,056,517	2,279,319

CHAPTER VIII

Page

8.00 THE OPTIMUM ROUTE : ENGINEERING AND COST

8.01 Engineering on the Optimum Route

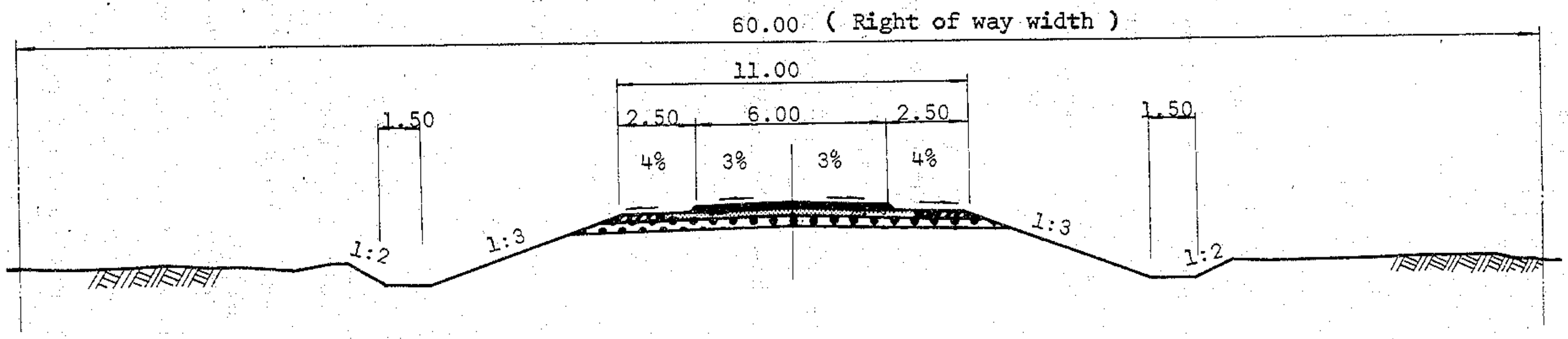
Seven alternative routes were proposed and assessed by benefit cost analysis to find the best route. The route A and D in the southern corridor, defined as plan 2, is chosen as the best route since it registered the highest figure in BC values. This course of the study is defined as the first stage and its engineering study is covered in CHAPTER VII.

Although the best route has been determined, there remain some sections and design standards to be examined further. They are the selection of an alignment among the alternatives for sections of the roads, the adoption of a staged construction plan, the design of pavement structure, and the selection of bridge type, etc. The subjects of this second stage study may be designated as minor alternatives. The engineered features of these alternatives and cost estimates are shown in this chapter. The best plan is determined by economic evaluation as covered in CHAPTER X.

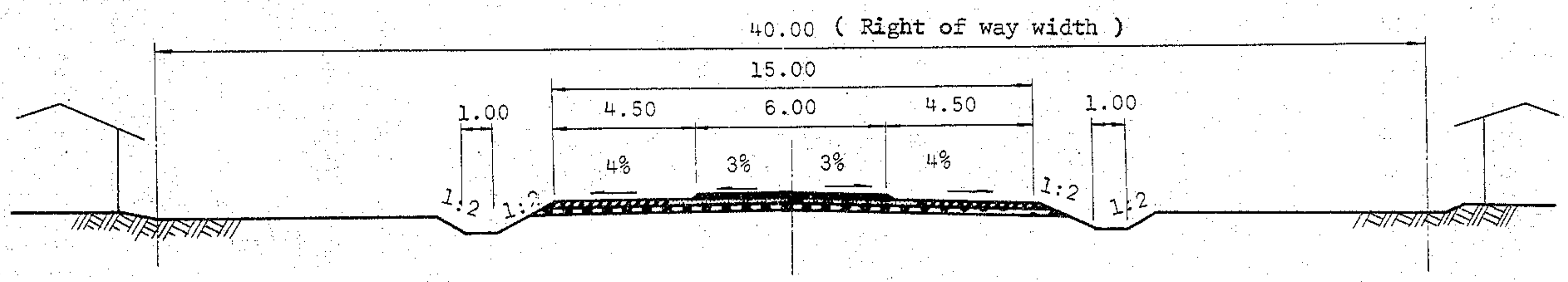
Typical cross sections and geometric design criteria are shown in FIG. VIII-1 and Table VIII-1. The shoulder with 4.5 m width having a slope of 4% is designed for the access roads to Rahad and Um Ruaba. This shoulder in urban area is designated for stopping and parking of vehicles and the use of bicycles, pedestrains and animal driven carts. Repair and maintenance cost of the shoulder, in the total of 2.5 km in length, is included in the annual maintenance cost from 1983 to 2002.

FIG. VIII-1 TYPICAL CROSS SECTIONS

Main Road



Access Road



LEGEND:

- DBST or AC
- BASE COURSE
- SUBBASE COURSE
- GRAVEL

TABLE VIII-1 GEOMETRIC DESIGN CRITERIA ON THE OPTIMUM ROUTE

( ) shows the figures adopted in the design.

Road	Area	Terrain	Design Speed (km/hr)	Width (m) [2)] Carriage-way	Width (m) [2)] Shoulder	Gradient Max. (%)	Max. Super-elevation (%)	Mini. Horiz. Curve Radius (m)	Mini. Vert. Curve Length (m)	Sight Distance (m)
Main Road										
	Rural	Flat [1)]	100	2 x 3.0	2 x 2.5	3 (2.600)	8	380 (1,000)	85 (100)	670
		Hilly [1)]	80	2 x 3.0	2 x 2.5	5 (4.670)	8	230 (3,000)	70 (100)	550
Access Road										
	Urban	Flat	60	2 x 3.0	2 x 4.5	5 (0.540)	8	130 (1,000)	50 (200)	430

Notes: 1) Flat terrain is defined as having a gradient of less than 3%. Hilly terrain is defined as having a gradient in the range of 3 to 6%.

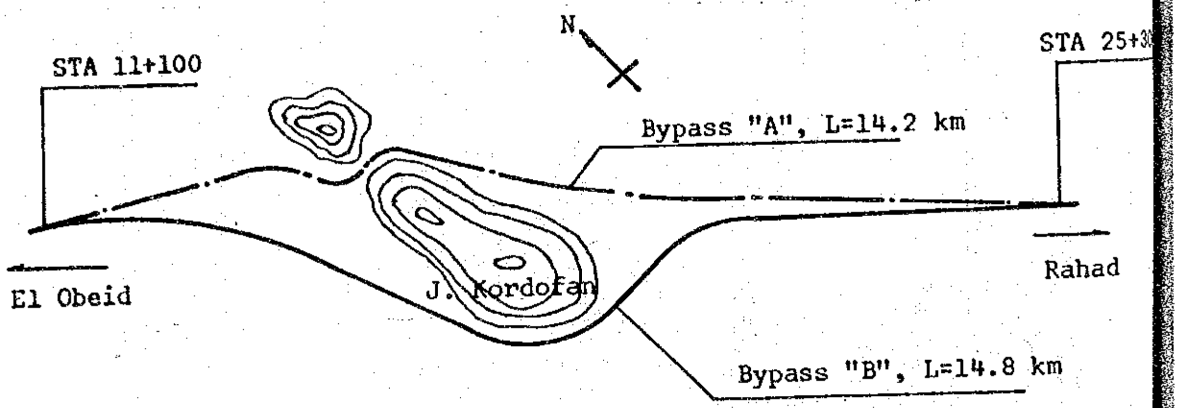
2) For the first stage of construction.

8.01.1 Bypasses

Minor alternative routes on the alignment are proposed for three sections, that is, around the Kordofan Hill area, near Rahad and the access to Um Ruaba.

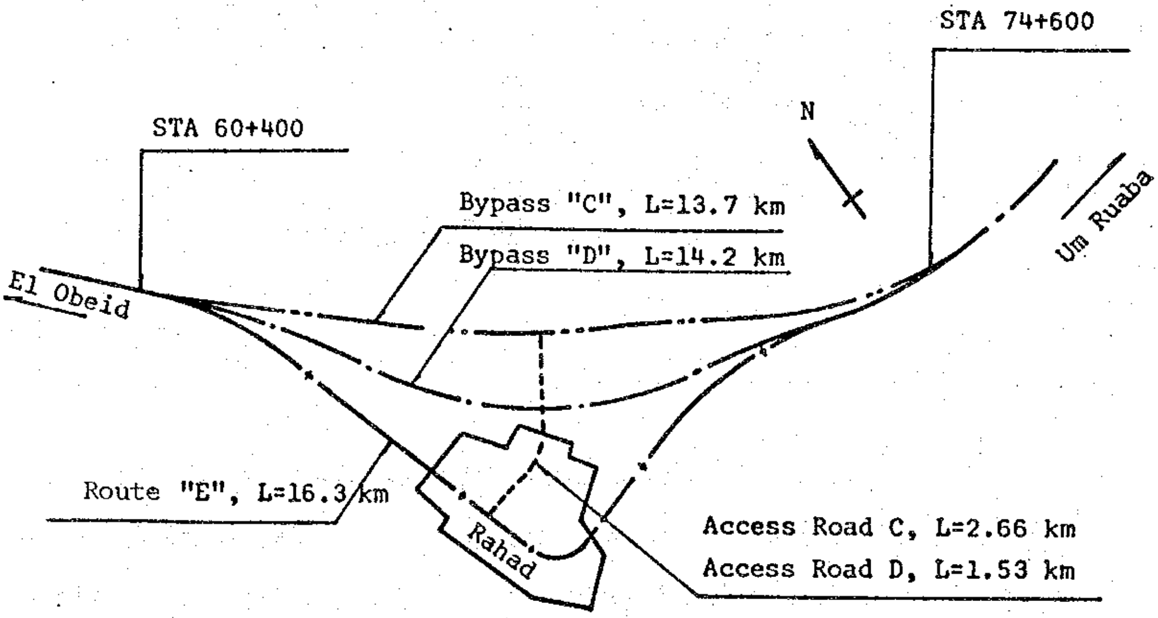
i. Kordofan Hill Area

Two alternative routes are the subject of this analysis: one is bypass "A" passing the northern side of the J. Kordofan with a gentle gradient passing over a hilly area, the other is located at the southern side of flat terrain. Design features and estimated costs of the two alternatives are shown in Annex VIII-1. As presented in 10.01, CHAPTER X, the cost is less for bypass A. Therefore, bypass A is incorporated in the best alignment.



ii. Rahad Bypasses

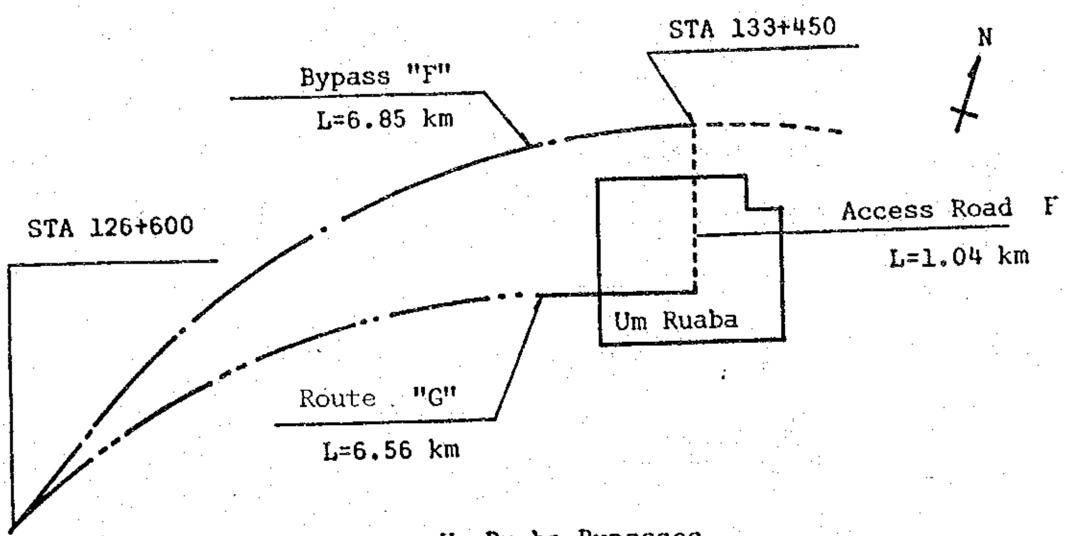
Three routes are proposed to determine an alignment around Rahad: the shortest northern route as bypass C, bypass D closer to the town, and route E passing through Rahad town. A two lane access road is necessary from the town centre to C and D, respectively. The engineered features and estimated costs are shown in Annex VIII-1. The economic evaluation is carried out as covered in CHAPTER X resulting in bypass D as the best alignment.



iii. Um Ruaba Bypass

Two alternative routes are proposed for the study in the Um Ruaba area: one is a bypass located at the northern side of the town, shown as bypass F on the next page, the other is a direct route through the town, shown as route G. An access two-lane paved road is connected to bypass

F. The eastward extension of the bypass F should be considered in the road project of Kosti-Um Ruaba. Engineered features and estimated costs are shown in Annex VIII-1. To avoid accidents in the urban area, as described in CHAPTER X, bypass F plan is recommended.



Um Ruaba Bypasses

8.01.2 Staged Construction

Estimated traffic volume is approximately 220 for ADT in 1983, the year of the opening, and 660 for ADT in 2002, the last year of the 20-year project life. Considering the traffic volume in the range of the above figures, the staged construction plans are studied for five different types as shown in Table VIII-2 and FIG. VIII-2. Although the pavement width of Sudanese trunk roads are set at 7 m, the selection of 7 m width surface in the first staged construction, or the second staged, depends on the results of technical and economic studies.

To find a year of the second staged construction, the accumulated number of repetition of equivalent standard axle load factor was considered, as calculated in 7.03, CHAPTER VII. For this comparative study a section of 20.1 km between Rahad and Semeih was selected, in which structures, geometric and soil conditions are considered typical of the whole.

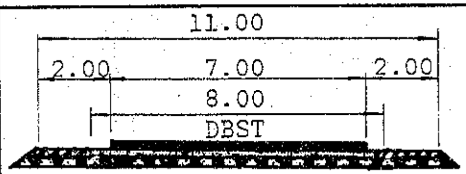
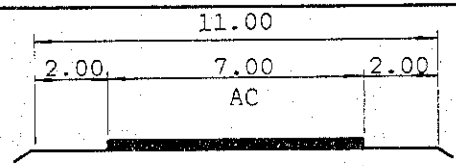
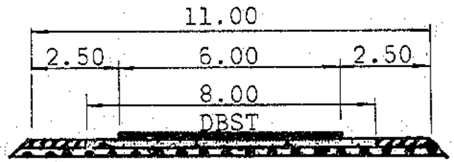
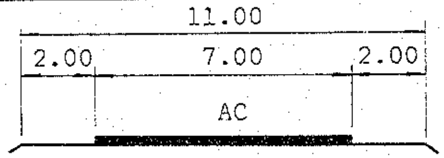
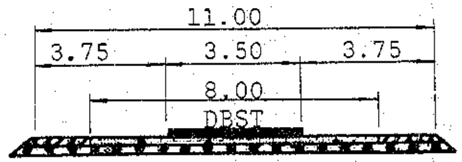
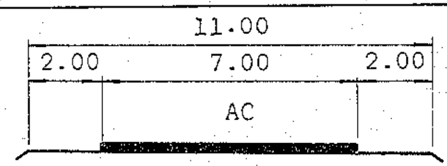
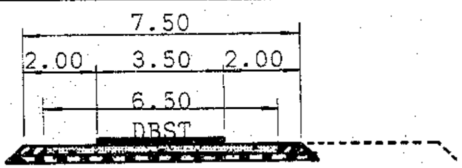
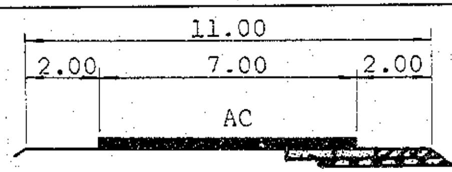
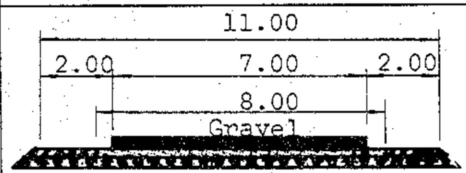
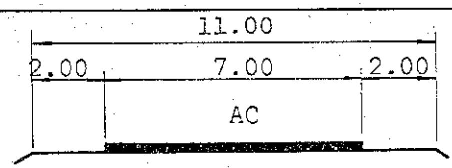
The influence of these different surfacings on vehicle operation and road maintenance costs are estimated and studied from the economic standpoint together with other relevant factors as covered in CHAPTER X. Type B, DBST pavement of 6 m width, is selected as the best type among the alternatives. FIG. VIII-2 shows the typical cross sections of the five types, Table VIII-2 presents the summary of these features, and Annex VIII-2 presents the estimated costs of them.

TABLE VIII-2 STAGED CONSTRUCTION PLANS

(m)

Item	Type A	Type B	Type C	Type D	Type E
1st Stage					
Roadway width	11.00	11.00	11.00	7.50	11.00
Base course width	8.00	8.00	8.00	6.50	8.00
Pavement width	7.00	6.00	3.50	3.50	7.00
Surface course	DBST	DBST	DBST	DBST	Gravel
2nd Stage					
Roadway width	11.00	11.00	11.00	11.00	11.00
Pavement width	7.00	7.00	7.00	7.00	7.00
Surface course	AC	AC	AC	AC	AC
Overlay	After 14 years	After 14 years	After 8 years	After 8 years	After 11 years

FIG. VIII-2 STAGED CONSTRUCTION PLANS

Classification	First Stage		Second Stage	
	Year	Cross Section	Year	Cross Section
Type A	1983		1996	
Type B	1983		1996	
Type C	1983		1990	
Type D	1983		1990	
Type E	1983		1993	

LEGEND: DBST or AC; BASE COURSE; SUBBASE COURSE; GRAVEL

8.01.3 Design of Pavement Structures

Three types of pavement design are studied: namely, pavement designs by standards of US AASHTO, UK Road Note 29 and 31, and UNESCO Low Cost Roads. A section of 20.1 km between Rahad and Semeih is taken as a comparison for purposes of cost estimation, and a CBR value of 9% is assumed for subgrade soil. The result is shown by the following Table VIII-3 together with a reference in Annex VIII-3. The pavement thickness designed by the standards of "Road Note 29 and 31" and "Low Cost Roads" are same. The pavement structure designed by AASHTO standard is thicker than the others and consequently more expensive. As shown by the result of an economic evaluation in CHPATER X, the pavement structure designed by Low Cost Roads (or by UK Road Note 29 and 31) is recommended for the engineering on the alignment selected as the optimum one.

8.01.4 Bridges

i. Normal bridges and submergible bridges

Two types of bridges are proposed for the study: normal bridges and submergible bridges(Irish bridges). Plans call for 13 bridges to be constructed on the best route between El Obeid and Um Ruaba, as listed in Annex VIII-4. Normal bridges with one to three spans of precast concrete are compared with alternative Irish bridges. Representative profiles are shown in Annex VIII-5, and the costs are shown in Annex VIII-6.

TABLE VIII-3 PAVEMENT STRUCTURE AND COST

Type	AASHTO (cm)	R.N. 31 and Low Cost Roads 1) (cm)	AASHTO (LS'000)	R.N. 31 and Low Cost Roads 1) (LS '000)
The 1st stage				
Double bituminous surface treatment	3	3		
Crushed rock and/or 2) gravel base CBR≥80	15	15		
Gravel subbase 2) CBR≥25	30	15		
Total	48	33	590	480
Cost/km	-	-	29.3/km	23.9/km
The 2nd stage				
Asphalt concrete surfacing	5	5	324	324
Crushed rock and/or 2) gravel base CBR≥80	15	15		
Gravel subbase 2) CBR≥25	30	15		
Total	50	35	324	324
Cost/km	-	-	16.1/km	16.1/km

Notes: 1) The standard is same for both "Road Note 29 and 31" and "Low Cost Roads".

2) Degree of compaction is not less than 95%.

Cost of construction, maintenance and vehicle operation are compared in CHAPTER X. The construction of normal bridges is recommended.

ii. Railway crossing

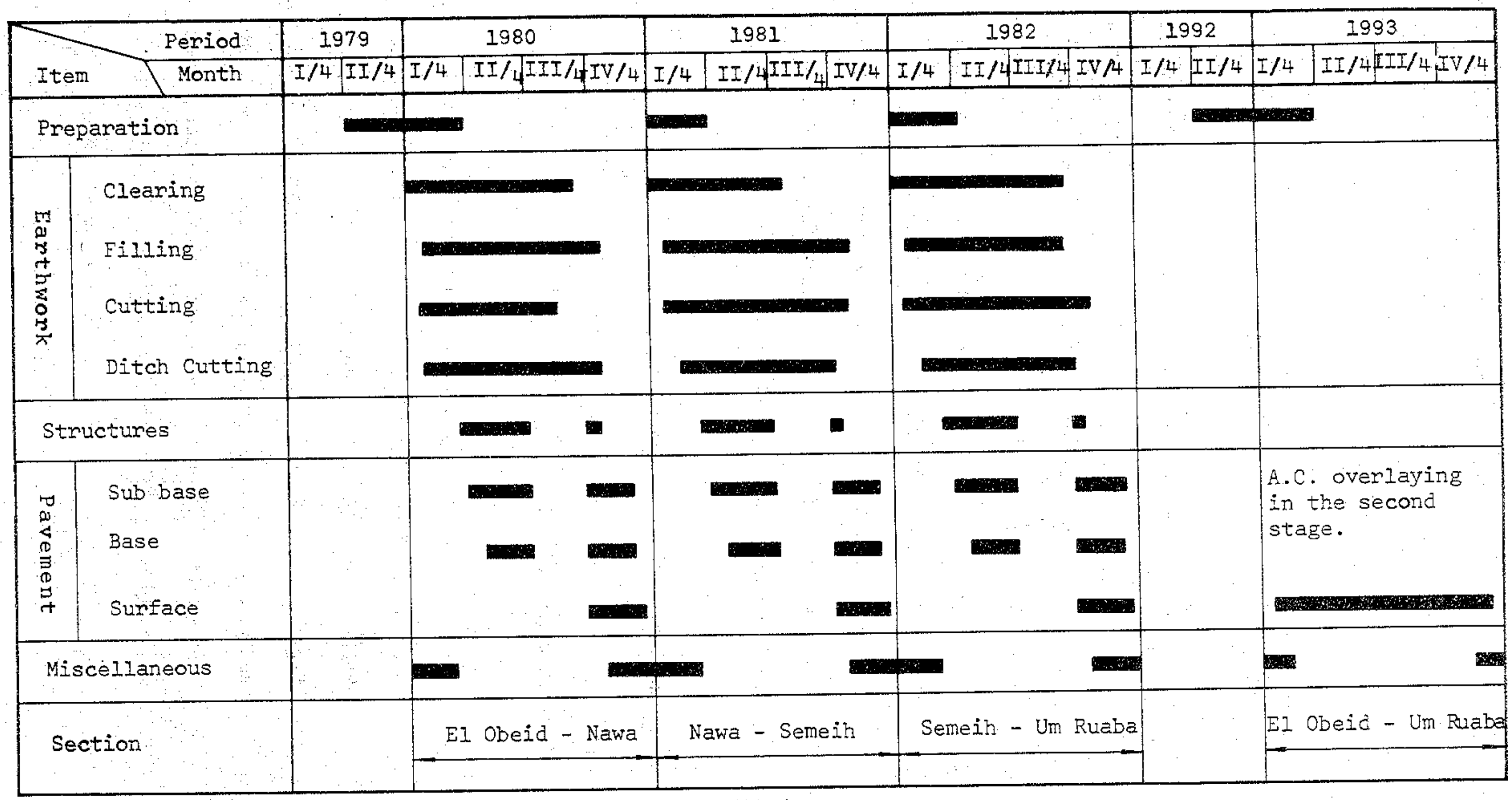
There are two proposed plans for a railway crossing, a level crossing and an overpass crossing. The crossing is planned at km 9.7 from El Obeid on the best route. The costs estimated for the two types of crossings show a cost of LS 134,000 for the overpass crossing, 23 times larger than the cost of the level crossing. Since train frequencies are about 4 to 6 times a day, the delay cost incurred by vehicles is negligible. Therefore, the level crossing is recommended as shown in "The Drawings".

8.02 Construction of the Optimum Plan

8.02.1 Work Programme

For construction work, the project road is divided into 6 sections: 3 sections for El Obeid - Rahad and 3 sections for Rahad - Um Ruaba. The construction is set to start at the first section from El Obeid, since aggregates, rocky hills, and water sources locate in the adjacent areas. When construction is completed, section by section, the new roads will serve for the transportation of materials to the construction site. FIG. VIII-3 shows the work schedule. Another plan to start construction from the Um Ruaba side is rejected

FIG. VIII-3 WORK SCHEDULE



Note: 1) Annual working days are estimated 260.

because the transportation cost of gravel and crushed stone would increase by 45%.

8.02.2 Construction Costs

The propositions for the cost estimate are the same as in the first stage study as presented in CHAPTER VII. Revisions in engineering criteria and unit costs were carried out when necessary in the course of the second stage of the study as described in this chapter. Bills of quantity are estimated by using the map at a scale of 1 : 5,000. The estimated quantities and costs including access roads to the towns of Rahad and Um Ruaba are shown in Table VIII-4. Table VIII-5 shows the total project cost, net of taxes and duties, resulting in LS 12,936,000 (approximately US$33 million) covering the costs of preparation, supervision, detailed engineering study (ref. Annex VIII-9) and contingencies. Annex VIII-7 shows bills of quantity and costs for each section. Annex VIII-8 presents the quantities of materials to be procured. Annex VIII-10 presents the output of the work items, and Annex VIII-11 the quantity of equipment used each year. Annex VIII-12 shows the acquisition cost of equipment and Annexes VIII-13 - 15 present examples of detailed cost components in work items.

8.02.3 Maintenance and Repair Costs

Costs of maintenance and repair for the new road are estimated with the revised quantity in the same way as in 7.03.5, CHAPTER VII. The cost per km is shown in Table VIII-6, and costs for the years up to 2002 are shown in Annex VIII-16.

TABLE VIII-4 CONSTRUCTION COST

Plan 2 (LS in 1977 Price)

Distance 136.02 km.

	Unit	Unit Cost Economic	Unit Cost Financial	Quantity	Cost Economic	Cost Financial
A. Earthworks and Pavement						
1. Clearing	m^2	0.042	0.046	4,758,960	200,900	219,300
2. Earthwork fill	m^3	0.649	0.788	1,610,520	1,044,900	1,269,400
3. Cutting	m^3	0.730	0.885	913,100	666,500	808,100
4. Ditch cutting	m^3	0.114	0.125	1,029,870	116,900	128,300
5. Preparation of formation	m^2	0.103	0.123	816,120	84,000	100,400
6. Slope protection	m^3	0.404	0.496	681,450	275,000	337,900
7. Subbase	m^3	3.639	4.812	243,770	887,000	1,172,900
8. Base	m^3	3.777	4.992	163,230	616,600	814,800
9. Prime coat	T	91.39	127.62	1,220	111,500	155,700
10. Surface (DBST)	m^2	0.605	0.810	816,120	493,400	661,300
11. Shoulder	m^3	2.191	2.869	71,940	157,600	206,400
Sub Total					4,654,300	5,874,500
B. Structures						
12. Bridge: 7.0 x 1	U	8,900	10,670	3	26,700	32,000
" 7.0 x 2	U	14,750	17,700	2	29,500	35,400
" 9.0 x 1	U	10,440	12,540	5	52,200	62,700
" 9.0 x 2	U	18,200	21,900	1	18,200	21,900
" 9.0 x 3	U	26,400	31,850	2	52,800	63,700
Sum				13	179,400	215,700
13. Box Culvert						
2.0 x 1.5 1 cell	U	2,990	3,610	11	32,900	39,700
" 2 cell	U	4,630	5,570	6	27,800	33,400
" 3 cell	U	6,200	7,450	2	12,400	14,900
Sum				19	73,100	88,000
14. Pipe: ϕ 1.0 x 1	U	1,134	1,336	39	44,200	52,100
" ϕ 1.0 x 2	U	1,980	2,340	5	9,900	11,700
" ϕ 1.0 x 3	U	2,730	3,230	3	8,200	9,700
Sum				47	62,300	73,500
15. Pipe ϕ 0.6	U	23.0	27.5	673	15,500	18,500
16. Masonry	m^2	0.911	1,006	52,890	48,200	53,200
Sub Total					378,500	448,900
TOTAL					5,032,800	6,323,400
Overhead & Profit 33%					1,897,200	2,086,600
TOTAL					6,930,000	8,410,000

TABLE VIII-5 APPROXIMATE PROJECT COST OF THE BEST PLAN

Plan 2

(LS '000)[2]

	Foreign A	Local B	Economic C (A + B)	Customs Taxes D	Financial E (C + D)
A. Implementation					
1. Construction Cost	4,175	2,755	6,930	1,480	8,410
2. Preparation (4%)	194	83	277	59	336
3. Sub-total (1 + 2)	4,369	2,838	7,207	1,539	8,746
4. Physical Contingency (10%)	505	216	721	154	875
5. Supervision (5%)	252	108	360	77	437
6. Sub-total (3+4+5)	5,126	3,162	8,288	1,770	10,058
7. Compensation (2%)		144	144	31	175
8. Sub-total	5,126	3,306	8,432	1,801	10,233
9. Price Contingency[3] 10% p.a. for 8.	2,464	1,589	4,053	865	4,918
10. Total	7,590	4,895	12,485	2,666	15,151
11. Cost per km	56	36	92	19	111
B. Detailed Engineering					
1. Detailed Engineering (5%) 1)	342	38	380	57	437
2. Price Contingency[3] 10% p.a.	64	7	71	11	82
3. Total	406	45	451	68	519
4. Cost per km	2	1	3	1	4
C. Total					
1. Costs	5,468	3,344	8,812	1,858	10,670
2. Price Contingency[3] 10% p.a.	2,528	1,596	4,124	876	5,000
3. Total	7,996	4,940	12,936	2,734	15,670
4. Cost per km	59	36	95	20	115

Notes: 1) Refer to Annex VIII-9.

2) Based on the prices of 1977.

(Cont'd note)

(Cont'd note)

Notes: 3) Yearly Expenditure Percentage and Inflation Factor

	Economic Cost (LS '000)		Ratio
1977			1.000
1978	B (1) x 20%	76	1.100
1979	A (2) x 70%, B (1) x 80%	498	1.210
1980	A (2) x 30%, Others in (A) x 29%	2,390	1.331
1981	Others in (A) x 29%	2,382	1.464
1982	Others in (A) x 42%	3,466	1.610
	Total	8,812	

TABLE VIII-6 MAINTENANCE AND REPAIR COST

(LS/km)

Surfacing	DBST	AC	
Repair of Surface	31.0	14.6	Every year
Miscellaneous Works	104.6	83.8	"
Management	45.0	32.0	"
Total	180	130.0	"
Resurfacing	3,100.0	14,658.0	7 or 10 years

One or two units of maintenance team as shown in Annex VII-16, should be organized when the project road is completed. It is suggested that the location of offices for supervising the construction work should be determined reminding a possibility of using the site afterwards for the office of maintenance team.

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. This is shown in Annex III-9. The changes in population in the same period are shown in Annex III-2. 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. It is considered in the Sudan that 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 petrol fuel. 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 trucks can run effectively. On the other hand, the roads are not surfaced nor maintained in rural areas so 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, the increase in the number of registered vehicles does not accurately reflect the growth of traffic on the entire road network. Consequently, it is better to note the changes in 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 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.

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

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

Assuming 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

$$2.25 \times 3\% \fallingdotseq 7\%$$

TABLE IX-1 GROWTH OF ECONOMY AND ROAD TRAFFIC

Year	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75
G.D.P. in current prices (LS Million)	19% p.a. (1969/70–1974/75)					
	647.0	685.8	752.1	896.8	1246.2	1510.8
G.D.P. in 1970 price (LS Million)	2.0% p.a. (1969/70–1974/75)					
	647.0	638.0	636.3	651.7	723.7	715.7
Number of Licenced Vehicles	12.4% p.a. (1969/70–1973/74)					
	49502	52800	59500	62500	79100	
Benzine and Gasoline Consumption on Roads ('000 tons)	4.5% p.a. (1969/70–1974/75)					
	205	218	229	234	238	256

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

If the economy grows more slowly at the rate of 2% p.a., traffic will increase -

$$2.25 \times 2\% \doteqdot 5\%$$

There are no development projects in other sectors of the influence zones. The project area 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 an average growth rate of 7% should be applied for the coming years up to the middle of the project life. A 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.

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 thus evident that the percentage share of heavy trucks will increase if the project road is opened. It is assumed the percentage share of heavy trucks among the trucks larger than medium size trucks 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 present paved road from Khartoum to Wad Medani. It is decided that a truck trailer is equivalent 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 study of future traffic.

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 of traffic to increase on the existing road. The traffic flows on the existing roads are shown in FIG. VI-4-1 and -2. The details of their origin and destination are presented in Annex VI-14. The growth rate is estimated in 9.01.1, in this chapter.

By applying the growth rate to the traffic on the existing roads, the traffic on the sections of each alternative route is forecasted. The traffic assignment for a new road is determined by comparing the vehicle operating cost between the origin and destination of vehicles running on the existing roads with those on a new proposed road. The traffic volumes forecasted for each alignment, by sections, are shown in FIG. IX-1. A breakdown into vehicle types is presented in Table IX-2 and Annex IX-3.

Vehicle running costs on various road surfaces are studied in 6.04.1, CHAPTER VI. When a vehicle runs on a paved road, there will be savings in vehicle running costs because of the 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 this estimate is shown in the tables of CHAPTER X.

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, 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, not of fares paid by them, 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 are assumed to grow at the same rate as the normal traffic. The details of the estimate are contained in Annex IX-2.

It is generally agreed that the savings in time of passengers can be evaluated as an economic benefit in the study of projects. In this road project it is expected that the newly constructed road will better serve the passengers by providing high speed vehicle transport and thus reduce travel time. However, care must be taken in determining to what extent and under what circumstances savings in time are economically valuable.
The regional per capita income is relatively low. Dual production prevails in agriculture: one for markets and the other for subsistence. It is observed in urban areas also that the economy and the lives of the people are not developed sufficiently to have a significant economic value for savings in time.

It is, therefore, decided that savings in time will not be included in the benefit cost analysis although a certain amount of time is saved by the new road. The savings in time may be considered as a social or non-quantified benefit of the project.

9.03.2 Cargoes

Similarly, the diversion of cargoes from railways to roads is determined by the shipper, who compares and evaluates the rates and other services between rail and truck transport. The economic benefit is the difference of the transport costs between the two modes: the cost by the existing railways and that by trucks. 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 for access transport and warehousing are added to the estimate of railway tariff for major items subject to diversion. They are compared with the charges by truck operators. The charges by railway are less expensive. The economic costs of railway and truck transport were studied for the same major commodities. The cost here is also less expensive by railway. Thus, 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 presently being carried by trucks for long distance hauls on poor conditioned roads. 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. Evidently, the shipper prefers to choose truck services rather than railway services, despite paying higher charges. Although paying higher transport costs, he receives some benefits, especially savings in time.

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

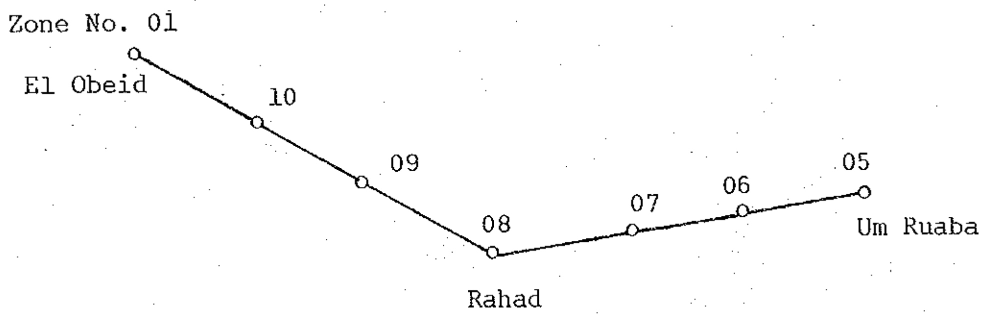
Growth Rate: They will grow at the same rate as that of the normal traffic.

9.05 Benefits on the Best Route

The benefits are estimated by dividing the road into 3 sections in accordance with the plan of construction. The first section will be opened for vehicles in 1981, the second in 1982, and the last and the all sections in 1983. Diverted and generated benefits are assumed to be generated after all the sections are opened for use. The streams of benefits are established under the same assumption as in 9.01 - 04, and are noted in tables in CHAPTER X and Annex X.

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

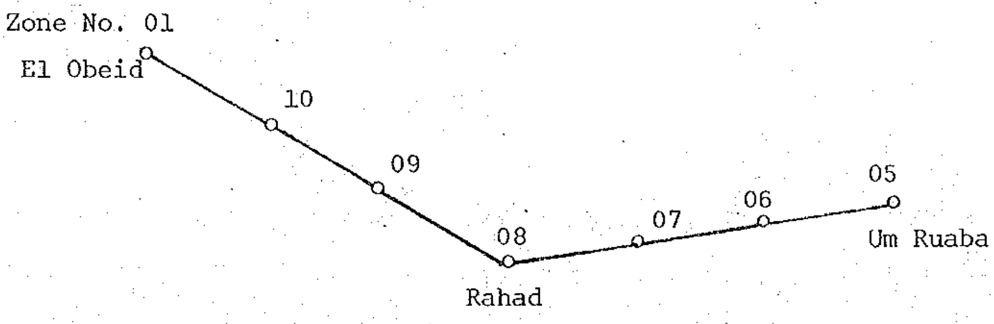
PLAN 1



(Total Length 139.8 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Traffic by year	Length (Km)	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	184.6	182.2	180.7	195.4	208.9	214.8	194.8
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	220.8
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	358.1
	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	386.3	381.8	379.1	407.9	432.8	443.5	405.9
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	583.3
	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	629.2	622.0	617.5	664.4	704.9	722.4	661.2

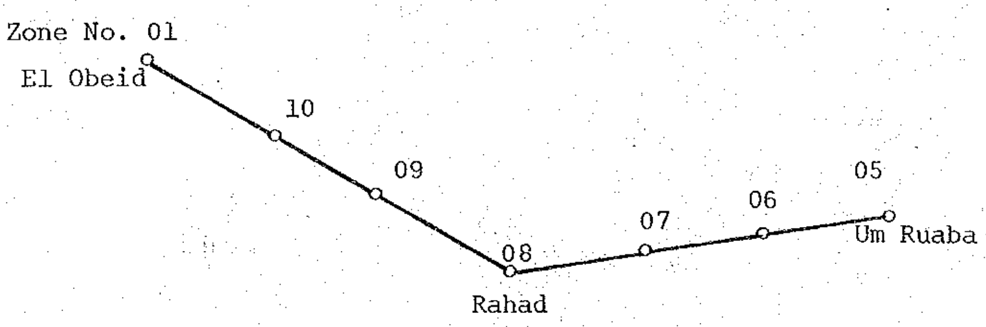
FIG. IX-1-2 EL OBEID-UM RUABA ROAD TRAFFIC BY SECTION, ADT PLAN 2



(Total Length 134.6 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Traffic by year	Length (Km)	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	184.6	182.2	180.7	195.4	208.9	214.8	194.5
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	220.5
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	357.6
	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	386.3	381.8	379.1	407.9	432.8	443.5	405.9
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	582.4
	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	629.2	622.0	617.5	664.4	704.9	722.4	660.3

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

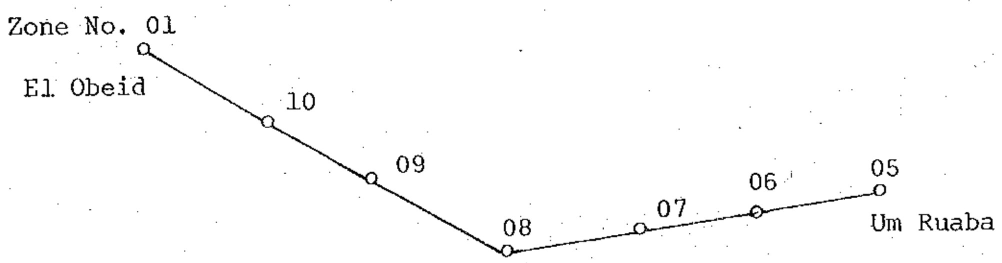


(Total Length 135.3 Km)

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	184.6	182.2	180.7	195.4	208.9	214.8	193.6
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	219.6
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	355.9
	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	386.3	381.8	379.1	407.9	432.8	443.5	403.7
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	579.7
	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	629.2	622.0	617.5	664.4	704.9	722.4	657.6

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

PLAN 4

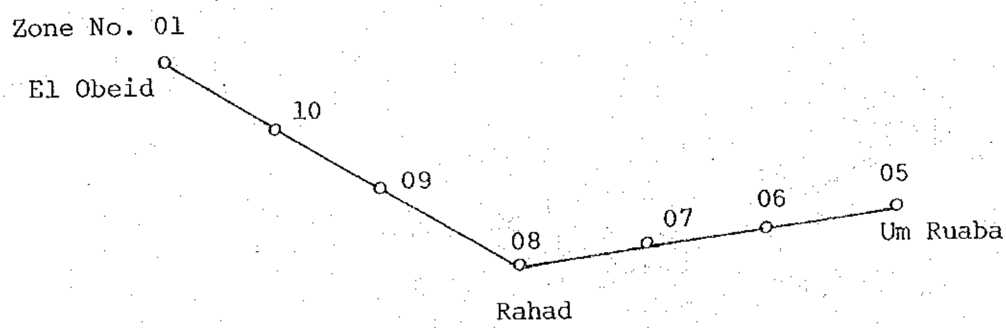


(Total Length 129.5 Km)

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	184.6	182.2	180.7	195.4	208.9	214.8	194.3
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	220.3
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	357.3
	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	386.3	381.8	379.1	407.9	432.8	443.5	405.1
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	582.0
	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	629.2	622.0	617.5	664.4	704.9	722.4	659.9

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

PLAN 5

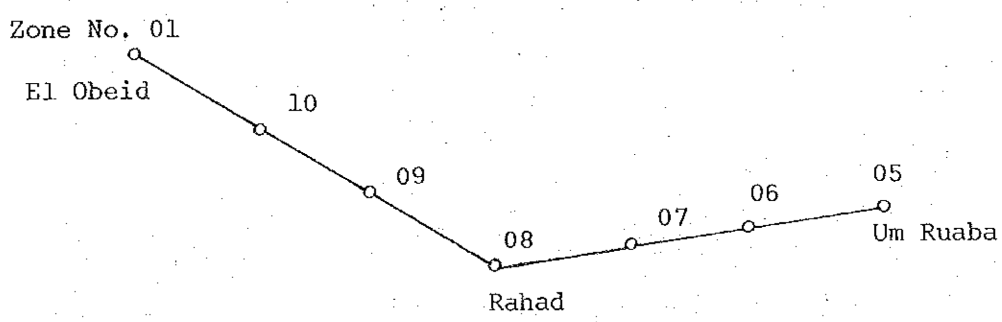


(Total Length 139.6 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Traffic by year / Length (Km)		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	184.6	182.2	180.7	195.4	208.9	214.8	194.0
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	220.0
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	356.7
	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	386.3	381.8	379.1	407.9	432.8	443.5	404.5
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	581.1
	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	629.2	622.0	617.5	664.4	704.9	722.4	659.0

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

PLAN 6

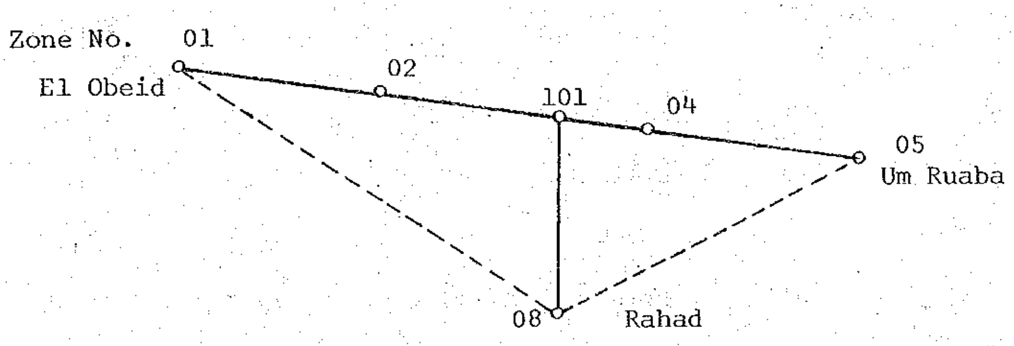


(Total Length 140.3 Km)

Section		01 - 10	10 - 09	09 - 08	08 - 07	07 - 06	06 - 05	Average
Traffic by year / Length (Km)		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	184.6	182.2	180.7	195.4	208.9	214.8	193.1
	Diverted Traffic	7.5	7.5	7.5	8.5	8.5	8.5	8.0
	Generated Traffic	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	Total	210.1	207.7	206.2	221.9	235.4	241.3	219.1
1992	Normal Traffic	339.4	334.9	332.2	359.2	384.1	394.8	355.1
	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	386.3	381.8	379.1	407.9	432.8	443.5	402.9
2002	Normal Traffic	552.8	545.6	541.1	585.1	625.6	643.1	578.4
	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	629.2	622.0	617.5	664.4	704.9	722.4	656.3

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	190.0	182.5	194.9	221.7	200.9	88.4	171.4
	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	215.5	208.0	221.4	248.2	226.9	95.6	192.5
1992	Normal Traffic	349.3	335.5	358.4	407.5	369.4	162.5	315.1
	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	396.2	382.4	407.1	456.2	417.2	175.7	353.8
2002	Normal Traffic	569.0	546.5	583.8	663.8	601.8	264.7	513.2
	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	645.4	622.9	663.1	743.1	679.7	286.9	576.5

TALBE IX-2 AVERAGE DAILY TRAFFIC BY VEHICLE TYPE [1)]

Year	Type of Vehicle				
	Small Vehicles	Medium Size Trucks	Large Trucks	Buses	Total
1983	25.5	165.2	20.4	9.4	220.5
1984	27.3	174.6	23.9	10.1	235.9
1985	29.2	184.5	28.0	10.8	252.5
1986	31.2	194.7	32.7	11.5	270.1
1987	33.4	205.0	38.3	12.3	289.0
1988	35.8	215.5	44.9	13.1	309.3
1989	38.3	225.9	52.6	14.1	330.9
1990	41.0	236.5	61.6	15.0	354.1
1991	43.8	246.9	72.1	16.1	378.9
1992	46.9	256.9	84.4	17.2	405.4
1993	49.2	266.2	92.2	18.1	425.7
1994	51.7	275.5	100.7	19.0	446.9
1995	54.3	285.2	109.9	19.9	469.3
1996	57.0	294.7	120.1	20.9	492.7
1997	59.9	304.5	131.1	21.9	517.4
1998	62.9	314.1	143.2	23.0	543.2
1999	66.0	323.8	156.4	24.2	570.4
2000	69.3	333.4	170.8	25.4	598.9
2001	72.8	342.9	186.5	26.7	628.9
2002	76.4	352.2	203.7	28.0	660.3

Note: 1) On the proposed alignment of Plan 2. The figures are weighted average vehicles per km of the road. Diverted and generated traffic are included.

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

	LS in 1977 Price	LS 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 plan 7 will be less by 1%.

9.06 Non-Quantified Benefits

9.06.1 Savings in Time

Savings in time of passengers and cargoes realized by an improvement in the road transport system have been mentioned in 9.02 and 9.03 of this chapter. Although they are not included in the quantified benefits in economic evaluation, they can be considered as substantial benefits in the economic, cultural, and social lives of the people.

9.06.2 Other Impacts

It is expected that the opening of the road will affect on-going economic activities, especially in making the rural economy much more market oriented. Some of the populace may have difficulty adjusting to the new economic system, but in the long run the road service will help to raise the living standards of the people.

9.06.3 Social Services

The new road will definitely assist in improving efficiency of administration since it will facilitate communications and movements among the offices of province, districts, and local municipalities. Visits to other communities will become easier. Education services can be extended to less populated, more remote areas. People will benefit medically by easier access to hospitals and clinics and by easier access by medical teams to local villages and towns.

CHAPTER X

10.00 BENEFIT COST ANALYSIS

10.01 Alternative Routes

The economic evaluation in the first stage study is carried out to find the best route among the seven alternatives. The implementation programme for the alternatives is as follows. Detailed engineering work together with the preparation of bidding documents will be performed in 1978-1979 followed by the construction to DBST surfaced road in 1980-1982.

The costs of yearly maintenance, periodic resurfacing, and AC overlay of the surface in terms of economic cost are other cost inputs for determining the benefit cost analysis. The new road is assumed to open in January, 1983, with a project life of twenty years. The residual value of the road at the end of the project life is not taken into consideration in this analysis. The benefits to normal, diverted and generated traffic are estimated for each alternative comparing "with improvements" to "without improvements". Development benefits are not included.

Traffic growth rate is assumed at 7% p.a. up to 1992 and 5% thereafter up to 2002. The result is shown in Table X-1 which indicates that Plan 2 is the best route among the seven alternatives. Plan 2 registers 1.727 as B/C ratio and LS 5.9 million as the present worth of B-C, when a discount rate of 10% is applied. The economic rate of return is 17%.

TABLE X-1 BENEFIT COST ANALYSIS OF THE PROJECT (Traffic Growth Rate at 7%-5%) 1)

Alternative	1	2	3	4	5	6	7
Sections	A + C	A + D	A + E	B + C	B + D	B + E	F+Access
Initial Economic Cost in LS Million	10.121	9.716	11.089	10.365	9.960	11.331	13.955
Benefit-Cost Ratio r=0.10	1.633	1.727	1.484	1.567	1.657	1.427	1.256
Present Worth r=0.10 (LS '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 traffic growth rate is assumed at 7% p.a. up to 1992 and 5% p.a. for the period between 1992 and 2002. Due to the changes in vehicle composition (toward an increasing percentage of heavy trucks), the benefit increases yearly are slightly higher than the above figures of traffic growth.

TABLE X-2 BENEFIT COST ANALYSIS OF THE PROJECT
(Traffic Growth Rate at 5%) 1)

Alternative	1	2	3	4	5	6	7
Sections	A + C	A + D	A + E	B + C	B + D	B + E	F+Access
Initial Economic Cost in LS Million	10.121	9.716	11.089	10.365	9.960	11.331	13.955
Benefit-Cost Ratio r=0.10	1.302	1.377	1.183	1.249	1.321	1.138	1.001
Present Worth r=0.10 (LS '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 traffic growth rate is assumed at 5% p.a. for the whole period from 1977 to 2002.

Table X-2 shows the results of benefit cost analysis under a more conservative assumption of a constant traffic growth rate of 5% p.a. from 1977 to the end of the project in 2002. Again, Plan 2 is the best route among the seven alternatives. BC figures for Plan 2 are 1.377 as a B/C ratio and LS 3.05 million as a present worth of B-C, by applying a discount rate of 10% p.a. The economic rate of return is 14%.

The economic assessment in the event of a postponement of the project is covered by Table X-3. If the project is deferred one year, two years, three years and so on, the net benefit (B-C) increases LS 5.9 million, 6.3 million, 6.6 million, etc. However, net benefit (B-C) increases at a decreasing rate. Consequently, the project becomes less economically feasible when deferred to later years. The road will serve the country better if implemented earlier.

TABLE X-3 POSTPONEMENT OF THE PROJECT : PLAN 2 [1)]

Year	B/C	B-C (in LS '000)	Increase in B-C (in LS '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.

10.02 The Best Route

In the second stage study, the following minor alternative plans were studied to determine the best construction plan. The engineered profiles and estimated construction cost for these minor alternatives are studied in CHAPTER VIII. The benefits or the savings corresponding to these plans are presented in CHAPTER X, applying the basic units determined in CHAPTERS VI and IX.

10.02.1 Minor Alternatives on the Best Route

i. Bypasses

a) J. Kordofan

Alternative routes are proposed for comparison around the J. Kordofan area: one passing the northern side (A) and the other passing the southern side (B). Construction, maintenance and vehicle operating costs of route A are estimated for 20 years in the project life. These figures, shown in Table 10-1, Annex X-1, are taken as a basis and the differences in the corresponding estimates of B are estimated as in Table 10-2, Annex X-1. Total transport cost is less for Plan A. Consequently, Plan A is recommended for incorporation into the best alignment plan.

b) Rahad

Three alternative alignments (C, D, E) are proposed for the Rahad town area. Plan E route runs through the town proper following the existing streets, plan D is a bypass nearby the town, and plan C is another bypass located to the north of plan D. The latter two plans include access roads to the town centre.

The engineered features and estimated costs are shown in 8.01.1, CHAPTER VIII. Plan E which passes through the town would increase the possibility of traffic accidents similar to the case of the Um Ruaba through route. Also, as shown in 8.01.1, CHAPTER VIII, the length of the section is longer compared to the other two, resulting in greater construction and vehicle operating costs. Therefore, plan E is not recommended. The differences of costs for construction, maintenance and vehicle operation are estimated as shown by the tables in Annex X-2. Bypass plan D is the least cost solution. It is recommended for the best construction plan.

c) Um Ruaba

A bypass to run on the northern side of Um Ruaba is proposed. Even if the whole section of the Um Ruaba bypass is constructed, the conventional BC analysis rules in favour of a direct through route rather than the longer bypass because the traffic, with less than 1,000 ADT for the whole project period, will not cause congestion in the town.

However, in addition to vehicles, animals and pedestrians are numerous in the town of Um Ruaba. Thus, the possibility of traffic accidents on a direct through-route are great. The probability of accidents, the vehicle noise and other nuisance factors are definitely greater for the direct through-route than for the bypass.

Although the above mentioned impacts on the inhabitants are not quantified in the BC analysis, it is assumed that "these unquantitied costs" over the 20 years of the project life will be larger than the increment of the construction cost (LS 112,000) of the bypass over that of the direct through route. Also, RBPC stands definitely in favour of constructing a bypass to detour the populated town. Consequently, the construction of a bypass is recommended in the Um Ruaba area.

ii. Staged Construction

Staged construction plans are proposed as described in 8.01.2, CHAPTER VIII. An economic evaluation of these plans was conducted and the details of the evaluation are shown in Annex X-3. The result favours the pavement of DBST for the 6 m width carriageway in the first stage of construction and an overlay of AC for the 7 m width in 1993. This is applied for the preliminary design of the project road.

iii. Pavement Structure

As described in 8.01.3, CHAPTER VIII, two kinds of pavement design are proposed, both being technically sound. The economic evaluation is carried out in a similar way to the other minor alternatives. A pavement structure based on AASHTO design standards is taken as a basic condition for estimating the streams of cost of construction, maintenance and overlaying for the project life of 20 years. The estimated cost is contained in Table 10-4-1 of Annex X-4. The balance between these figures and those of Low Cost Roads standards are estimated. They are discounted by compound interest rates of 10% and 16.6% and summed up in total as shown in Table 10-4-2, Annex X-4. The result shows the pavement structure as designed by the standards of Low Cost Roads or RRL Road Note 29 and 31 is less expensive than by AASHTO. The application of design standards by UNESCO's Low Cost Roads is, therefore, recommended for designing the project road.

iv. Normal Bridge and Irish Bridge

Comparative analysis was conducted respecting the construction of an Irish bridge (submergible bridge) instead of a normal bridge. As shown in Table 8-5, Annex VIII-6, the cost of the Irish bridge is less for construction but more for annual maintenance compared to that of normal bridge.

In the case of an Irish bridge the vehicle running cost increases in the rainy season because vehicles must stop and wait at the bridge site for the water to recede to a passable level. The stopping and waiting in terms of additional costs are estimated by the following assumptions.

1. 30 wait periods per rainy season

2. 5 hours wait each time

3. The number of vehicles is 30% of ADT.

4. The cost of waiting consists of additional wages of 5 hours for a driver and two assistants per vehicle plus the additional vehicle running cost per stop.

The normal bridges with the costs of investment, maintenance and vehicle running are taken as a base and the costs for Irish bridges are compared as shown in Tables 10-5-1 and 10-5-2 of Annex X-5. The result, which favours Irish bridges, is sensitive and reversible due to the changes in input factors as follows.

1. It is assumed one vehicle must stop at one river side for one rain. However, if it must stop twice or more, the vehicle operation cost will increase greatly.

2. Irish bridges, in cases of unexpected heavy rain, incur greater damage than normal ones, resulting in increases in maintenance cost.

3. The economic value of wages of drivers and assistants of vehicles might be assessed more conservatively in this BC analysis.

In addition, in the case of Irish bridges, passengers will be inconvenienced by long waiting periods. Therefore, despite higher initial investment costs, the normal type of bridge is recommended for the construction plan.

10.03 Conclusion

10.03.1 Benefit Cost Calculation

After the assessment of minor alternatives as noted in 10.02 above, the alignment of the best construction plan is determined.

The costs and benefits are also reviewed in order to finalize the economic evaluation. An evaluation for each section is shown in Annex X-6 indicating all sections are viable with rates of return of 13-19%.

The evaluation of the total sections results in a rate of return of 19% as shown in Table X-4 where a traffic growth rate of 7% p.a. is assumed for the years up to 1992 and 5% thereafter up to 2002. The rate of return is 16% assuming a growth rate of 5% p.a. for the years up to 2002, as shown by Table X-5.

10.03.2 Sensitivity Analysis

A sensitivity analysis is conducted to find the consequences of changes in cost factors on the BC figures. The result is shown in Annex X-7. It confirms that the project is economically feasible.

10.03.3 Conclusion

The project as presented by the preliminary engineering, is technically sound, and the benefit cost analysis shows the project is economically feasible. Therefore, it is recommended that the road construction plan be incorporated in, with high priority, the development programme of the Sudan and implemented as soon as possible.

TABLE X-4   BENEFIT COST STREAMS : ALL SECTIONS

DISCOUNT RATE = 0.100   B-C = 7058   B/C = 1.9293

ECON. RETURN = 0.191

			C1	C2	CT	CTD	AGGR.	B1	B2	B3	BT	BTD	AGGR.
1978	0		380		380	380	380						
1979	1		325		325	273	653						
1980	2		2351		2351	1658	2311						
1981	3		2345	9	2354	1394	3705	308			308	182	182
1982	4		3411	17	3428	1705	5410	704			704	350	532
1983	5	1		26	26	11	5421	1232	108	22	1362	569	1101
1984	6	2		26	26	9	5430	1323	116	24	1463	513	1614
1985	7	3		26	26	8	5438	1426	124	26	1576	464	2078
1986	8	4		26	26	6	5444	1539	132	28	1699	420	2498
1987	9	5		26	26	5	5449	1667	142	29	1838	382	2880
1988	10	6		168	168	29	5478	1814	152	31	1997	348	3228
1989	11	7		156	156	23	5501	1979	162	33	2174	319	3547
1990	12	8		178	178	22	5523	2171	174	36	2381	293	3840
1991	13	9	741	26	767	79	5602	2389	186	38	2613	270	4110
1992	14	10	677	24	701	61	5663	2644	199	41	2884	250	4360
1993	15	11	773	21	794	58	5721	2784	209	43	3036	221	4581
1994	16	12		19	19	1	5722	2934	219	45	3198	196	4777
1995	17	13		19	19	1	5723	3095	230	48	3373	173	4950
1996	18	14		19	19	1	5724	3266	242	50	3558	154	5104
1997	19	15		19	19	1	5725	3452	254	52	3758	136	5240
1998	20	16		19	19	1	5726	3649	266	55	3970	121	5361
1999	21	17		19	19		5726	3861	280	59	4200	107	5468
2000	22	18		19	19		5726	4090	294	61	4445	95	5563
2001	23	19		19	19		5726	4336	308	64	4708	85	5648
2002	24	20		19	19		5726	4599	324	67	4990	76	5724

Note: Traffic growth rates of 7% p.a. up to 1992 and 5% thereafter up to 2002.

TABLE X-5 BENEFIT COST STREAMS : ALL SECTIONS

DISCOUNT RATE = 0.100   B-C =   4186   B/C = 1,5512

ECON, RETURN = 0.160

			C1	C2	CT	CTD	AGGR,	B1	B2	B3	BT	BTD	AGGR,
1978	0		380		380	380	380						
1979	1		325		325	280	660						
1980	2		2351		2351	1746	2406						
1981	3		2345	9	2354	1507	3913	286			286	183	163
1982	4		3411	17	3428	1891	5804	639			639	353	536
1983	5	1		26	26	12	5816	1098	108	22	1228	584	1120
1984	6	2		26	26	11	5827	1157	114	24	1295	531	1651
1985	7	3		26	26	9	5836	1222	119	24	1365	482	2133
1986	8	4		26	26	8	5844	1296	125	26	1447	440	2573
1987	9	5		26	26	7	5851	1377	131	28	1536	403	2976
1988	10	6		168	168	38	5889	1469	138	29	1636	370	3346
1989	11	7		156	156	30	5919	1573	145	30	1748	341	3687
1990	12	8		178	178	30	5949	1692	152	31	1875	315	4002
1991	13	9	741	26	767	111	6060	1827	160	33	2020	292	4294
1992	14	10	677	24	701	87	6147	1985	168	35	2188	273	4567
1993	15	11	773	21	794	85	6232	2089	176	36	2301	247	4814
1994	16	12		19	19	2	6234	2202	185	38	2425	225	5039
1995	17	13		19	19	2	6236	2322	194	40	2556	204	5243
1996	18	14		19	19	1	6237	2449	204	42	2695	185	5428
1997	19	15		19	19	1	6238	2588	214	45	2847	169	5597
1998	20	16		19	19	1	6239	2736	225	47	3008	154	5751
1999	21	17		19	19	1	6240	2896	236	49	3181	140	5891
2000	22	18		19	19	1	6241	3066	248	52	3366	128	6019
2001	23	19		19	19	1	6242	3251	260	54	3565	117	6136
2002	24	20		19	19	1	6243	3448	273	57	3778	107	6243

Note: Traffic growth rate of 5% p.a. from 1977 up to the end of the project life.

CHAPTER XI

11.00 CONCLUSION

11.01 Studies in the Field and Home Office

In accordance with the terms of reference, prepared jointly by Roads and Bridges Public Corporation (RBPC) of the Sudan, African Development Bank (ADB) and Japan International Cooperation Agency (JICA), engineering and economic studies in the field were carried out from March to June, 1977. Studies in the Sudan covered the field of economies, traffic, inventories, soils and materials, surveying, cost information, etc.

The study team analysed the data collected after returning to the home office and has prepared an Interim Report in which Plan 2 was selected from other alternative plans after appraising engineering and economic studies. The first stage of the study, extending from the above inventory studies to the selection of the best route, was presented in the Interim Report. A meeting was held to discuss that report in mid-November at Khartoum with the attendance of RBPC, ADB and JICA members.

In general, the study presented in the Interim Report was accepted by RBPC and ADB, while some comments and advice were given to the study team. Revisions to the Interim Report were made and second stage studies were conducted and incorporated into the Draft Final Report. The optimum construction plan for the project road was proposed after studying minor alternatives on the best route such as plans for bypasses, staged construction, pavement structures, etc. The Draft Final Report was presented to the RBPC of the Sudan and the African Development Bank in February 1978, and this Final Report in March 1978.

11.02 Construction Plan

The optimum construction plan proposed after the economic evaluation is summarized as follows. Construction work is divided into three subsections El Obeid - Nawa, Nawa - Semeih and Semeih - Um Ruaba.

11.02.1 Proposed Road

		Section I	Section II	Section III	TOTAL
Length (km) :	Main Road	46.00	40.50	46.95	133.45
	Access Road	-	1.53	1.04	2.57

Route Location : Section I, following the existing route of the northern side of the railway.

Section II, following the existing route up to Rahad and running in sand dune areas.

Section III, passing through sand dune areas to the northern side of the railway. (detouring the flood plain of K. Abu Habl).

Design Speed : 100 km/hr for flat terrain and 80 km/hr for hilly terrain.

Alignment : Minimum horizontal curve R=1,000 m
Maximum longitudinal gradient 4.67%

Pavement :	DBST on 6 m carriageway
Bridge :	Reinforced concrete bridge.

11.02.2 Time Schedule

Construction Year :

1978 - 1979	Detailed design and contract award
1980	Construction work starts for Section I
1981	" " " Section II
1982	" " " Section III

Opening Year :

1981	Section I
1982	Section II
1983	All sections

11.03 Project Cost

11.03.1 Cost by Section

(US$ '000)[1)]
LS '000

	Foreign Component	Local Component	Total Economic Cost	Taxes & Customs	Total Financial Cost
Section I, El Obeid - Nawa (46.00 km)					
1. Cost	(3,745) 1,486	(2,416) 959	(6,161) 2,445	(1,315) 522	(7,476) 2,967
2. Price Contingency 2)	(1,802) 715	(1,162) 461	(2,964) 1,176	(633) 251	(3,597) 1,427
3. Total	(5,547) 2,201	(3,578) 1,420	(9,125) 3,621	(1,948) 773	(11,073) 4,394
4. Per km	(121) 48	(77) 31	(198) 78	(42) 17	(241) 95
Section II, Nawa - Semeih (42.03 km)					
1. Cost	(3,735) 1,482	(2,411) 957	(6,146) 2,439	(1,313) 521	(7,459) 2,960
2. Price Contingency 2)	(1,794) 712	(1,157) 459	(2,951) 1,171	(630) 250	(3,581) 1,421
3. Total	(5,529) 2,194	(3,568) 1,416	(9,097) 3,610	(1,943) 771	(11,040) 4,381
4. Per km	(132) 52	(85) 34	(217) 86	(46) 18	(263) 104
Section III, Semeih - Um Ruaba (47.99 km)					
1. Cost	(5,438) 2,158	(3,503) 1,390	(8,941) 3,548	(1,910) 758	(10,851) 4,306
2. Price Contingency 2)	(2,613) 1,037	(1,686) 669	(4,299) 1,706	(917) 364	(5,216) 2,070
3. Total	(8,051) 3,195	(5,189) 2,059	(13,240) 5,254	(2,827) 1,122	(16,067) 6,376
4. Per km	(168) 67	(108) 43	(276) 109	(59) 23	(335) 133

Notes: 1) Exchange rate LS 1.00 = US$2.52.

2) Inflation factor of 10% p.a. is assumed from 1977 to the year of expenditure by the programme.

11.03.2 Cost of Total Section

(US$ '000)[1]
LS '000

	Foreign Component	Local Component	Total Economic Cost	Taxes & Customs	Total Financial Cost
A. Implementation					
1. Cost	(12,918) 5,126	(8,331) 3,306	(21,249) 8,432	(4,538) 1,801	(25,787) 10,233
2. Price Contigency 2)	(6,209) 2,464	(4,004) 1,589	(10,213) 4,053	(2,180) 865	(12,393) 4,918
3. Total	(19,127) 7,590	(12,335) 4,895	(31,462) 12,485	(6,718) 2,666	(38,180) 15,151
4. Per km	(141) 56	(91) 36	(232) 92	(48) 19	(280) 111
B. Detailed Design					
1. Cost	(862) 342	(96) 38	(958) 380	(143) 57	(1,101) 437
2. Price Contigency 2)	(161) 64	(18) 7	(179) 71	(28) 11	(207) 82
3. Total	(1,023) 406	(114) 45	(1,137) 451	(171) 68	(1,308) 519
4. Per km	(5) 2	(3) 1	(8) 3	(2) 1	(10) 4
C. Total					
1. Cost	(13,779) 5,468	(8,427) 3,344	(22,206) 8,812	(4,682) 1,858	(26,888) 10,670
2. Price Contigency 2)	(6,371) 2,528	(4,022) 1,596	(10,393) 4,124	(2,207) 876	(12,600) 5,000
3. Total	(20,150) 7,996	(12,449) 4,940	(32,599) 12,936	(6,889) 2,734	(39,488) 15,670
4. Per km	(149) 59	(91) 36	(240) 95	(50) 20	(290) 115

Notes: 1) Exchange rate LS 1,000 = US$2.52.

2) Inflation factor of 10% p.a. is assumed from 1977 to the year of expenditure by the programme.

11.04 Economic Benefits and Evaluation

The traffic growth rate is estimated after studying changes in GDP, vehicle fuel consumption and other related factors. The average daily traffic (ADT), with the growth rate of 7% p.a., up to 1992 and afterwards 5% p.a., up to 2002, is estimated as follows (the total of normal, diverted and generated traffic).

	1983	1992	2002
ADT	220	405	660

Economic benefits are estimated to accrue in normal, diverted and generated traffic in the form of savings in transport cost. Development benefits are not considered in the benefit cost calculation. It is recognized that the road project will generate unquantified and social benefits for the region and the country. BC analyses result in the following figures, where a discount rate of 10% p.a. was applied for B/C and B-C.

	Assumed Growth Rate of Traffic	
	7%: ~1992 5%: ~2002	5%: ~2002
Section I		
Economic rate of return	16.3%	13.3%
Benefit cost ratio (B/C)	1.56	1.26
Present worth (B-C)	LS 1,392,000	LS 645,000
Section II		
Economic rate of return	19.4%	16.1%
Benefit cost ratio (B/C)	1.92	1.53
Present worth (B-C)	LS 2,057,000	LS 1,185,000

Section III

Economic rate of return	17.1%	13.9%
Benefit cost ratio (B/C)	1.68	1.33
Present worth (B-C)	LS 1,963,000	LS 949,000

All Sections

Economic rate of return	19.1%	16.0%
Benefit cost ratio (B/C)	1.93	1.55
Present worth (B-C)	LS 7,058,000	LS 4,186,000

The project, as presented by the preliminary engineering, is technically sound and economically feasible. It is recommended that the road construction plan be incorporated in, with high priority, the development programme of the Sudan and implemented as soon as possible.

BIBLIOGRAPHY

1. AASHTO, AASHTO Interim Guide for Design of Pavement Structures, 1972: 341 National Press Building, Washington, D.C. 20045, U.S.A.

2. AASHTO, A Policy on Geometric Design of Rural Highways, 1965, 444 North Capital Street, N.W., Suite 225 Washington, D.C. 20001

3. Awouda, H.M., Production and Supply of Gum Arabic 1970/71: Ministry of Agriculture, Food, and Natural Resources

4. Cherry T.T. and Waters K.H., Shear-wave recording using continuous signal methods, Part I - Early Development, Geophisics Vol. 33, No. 2 (U.S.A., 1968).

5. Customs Department, Customs Tariff, 1977.

6. Dept. of Economics and Social Affairs, Statistical Office, Demographic Year Book, 27th Issue, 1976, U.N., New York, N.Y., U.S.A.

7. Dept. of Statistics, National Income 1972/73 - 1974/75.

8. Dept. of Statistics, Population and Housing Survey, Urban Area, Kordofan Province, 1964/66.

9. Dept. of Statistics, Statistical Year Book, 1973.

10. De Weille, Jan. Quantification of Road User Savings: I.B.R.D., 1970, Washington, D.C., U.S.A.

11. Imai T. and Yoshimura M.: The Relation of Mechanical Properties of Soils to P and S wave Velocities, Geophisical Exploration, Vol. XXV, No. 6 (Tokyo, The Society of Exploration Geophisists of Japan, 1972).

12. Ministry of Agriculture, Food and Natural Resources, Current Agricultural Statistics CAS - Vol. 1, No. 2, June, 1976.

13. Ministry of Planning, Economic Survey, 1975/76.

14. Ministry of Agriculture, Food and Natural Resources, Sudan Year Book of Agricultural Statistics, 1974.

15. National Planning Commission: Transport Statistical Bulletin, 1974.

16. National Planning Commission: Transport Statistical Bulletin, 1975.

17. Odier, Lionel, The Economic Benefit of Road Construction and Improvements: Paris, France, Publications ESTOUP, 1963.

18. Ohta Y. and Goto N.: Estimation of S-wave Velocity in Terms of Characteristics Indices of Soil, Geophisical Exploration, Vol. XXIX, No. 4 (1976).

19. Peurifoy, R. L.: Construction Planning, Equipment and Methods 2nd, Ed., McGraw Hill-Kogakusha Ltd., 1970 : Tokyo, Japan

20. Road Research Laboratory, Road Note 29, A Guide to the Structural Design of Pavements for New Reads : Her Majesty's Stationery Office, 1970, Great Britain.

21. Road Research Laboratory, Road Note 31, A Guide to the Structural Design of Bituminous-surfaced Roads in Tropical and Sub-tropical Countries : Her Majesty's Stationery Office, 1966, Great Britain.

22. Sudan Railways Corporation, Annual Report, 1975/76.

23. UNESCO, Low Cost Roads: Butter Worths, London, Great Britain.