The existing ferry is a 28 ton-type using 4 steel pontoons and equipped with two 100-horse-powered diesel engines which started its operation in 1965. The loading capacity is 2 large trucks or 4 TOYOTA Land Cruisers or 6 compact passenger cars. At the landing facilities there exist ramps, but the facilities are not appropriate for loading and unloading large buses which have long overhangs in front and rear.

The operation of the ferry has been entrusted to local ONAFITEX since 1974. Usually crossing the river takes 15 minutes and if the waiting time is added, it takes about 25 to 30 minutes on an average. The operation starts at 7:30 and ends at 19:30 every day, being operated by a crew of 4 men in one shift. They crossed the river 12 times carrying 3 vehicles and 13 passengers a day on an average according to the operation record in 1973. Usually there are more than 100 passengers a day who cross the river using canoes in addition to those who use the ferry. (See Photo 12.)

(3) Ferry Across Bili River at Faka (the 2nd Section)

Bili River is about 150 m wide at the ferry site and is 15 m and 8 m deep in the wet season and the dry season respectively. The current velocity is 1.0 m/sec in the wet season and 0.3 m/sec in the dry season. The existing ferry is the type of 8 ton, using 3 steel boats, and its loading capacity is one large truck or 2 Toyota Land Cruisers. The ferry is operated by a rowing crew of 8 men in the wet season and a crew of 6 men in the dry season. It has no landing facility at present and a large bus having overhangs in front and rear cannot possibly be loaded or unloaded.

Crossing the river takes about 15 minutes. The crew men do not usually stay on board but work in the field nearby when they have no traffic, so calling crew men to the ferry takes about 20 to 30 minutes and the average crossing time is about 30 to 45 minutes if the waiting time is included. The ferry operation has been entrusted to local ONAFITEX since 1974. According to the operation record, the ferry crossed the river 3 times carrying 5 vehicles a day on an average in 1973. (See Photo 13.)

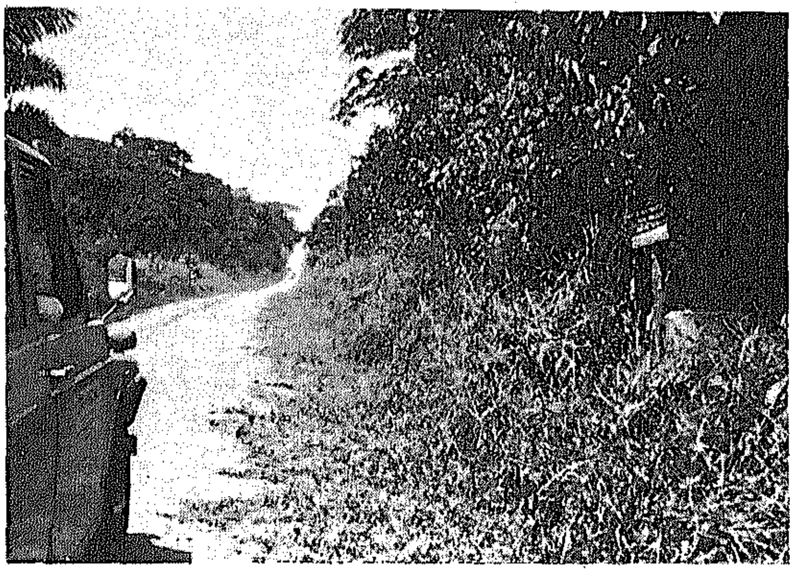


Photo. 1. Road conditions in dry season at PK 101 (between Kisangani and Banalia)

Photo. 2. Road conditions in wet season at PK 78 (between Likati and Bondo)

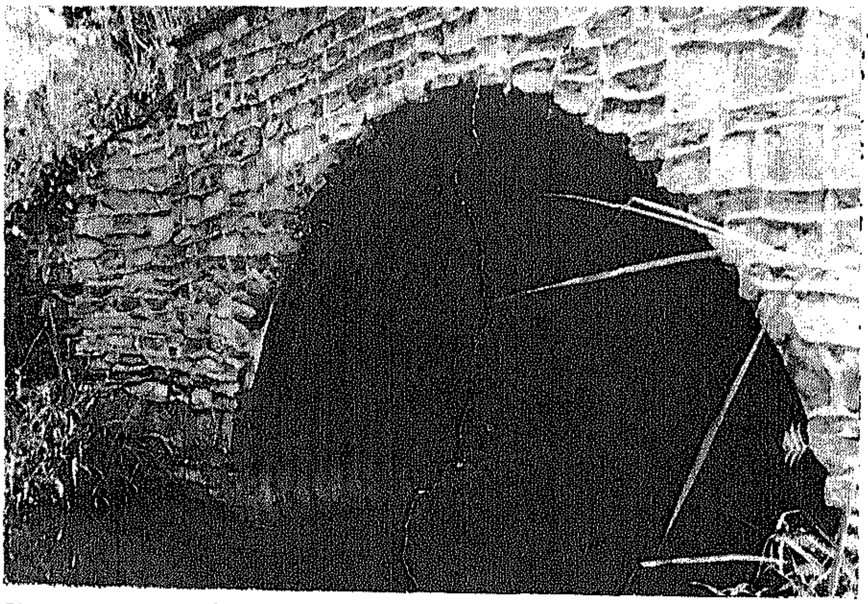


Photo. 3. Culvert of pipe-arched type at PK 143
(between Banalia and Buta)

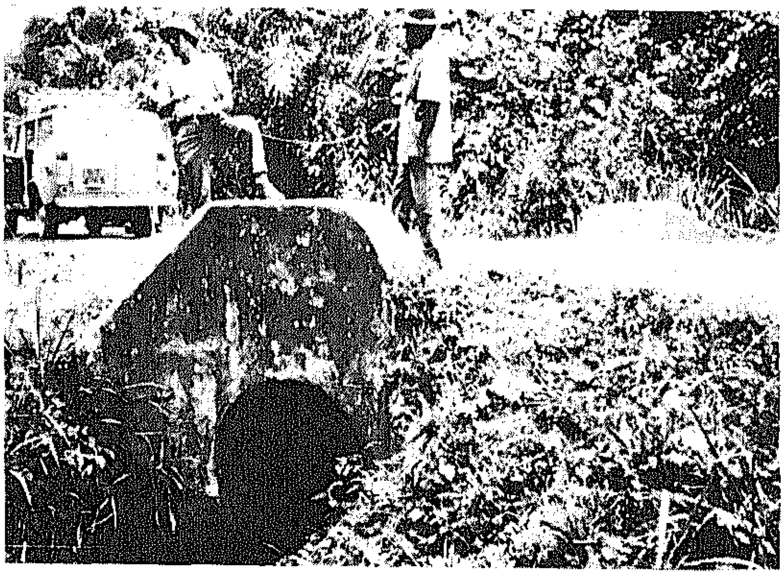


Photo. 4. Pipe culvert at PK 69 (between Likati and Bondo)

Photo. 5. Turn-out ditch at PK 200
(between Banalia and Buta)

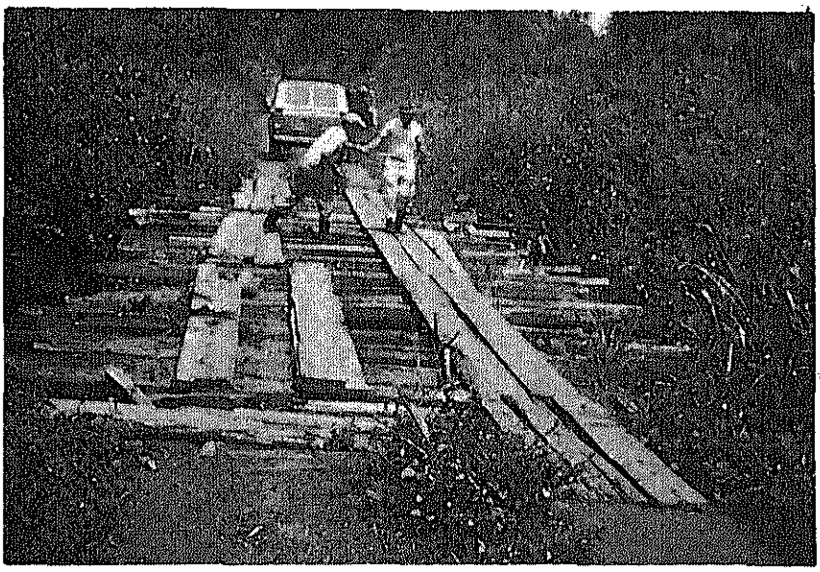


Photo. 6. Wooden bridge at PK 66.2 (between Buta and Dulia)

Photo. 7. Wooden bridge at PK 48.7 (between Dulia and Likati)

Photo. 8. Libogo Bridge commonly used by railway and road at PK 77 (between Likati and Bondo)

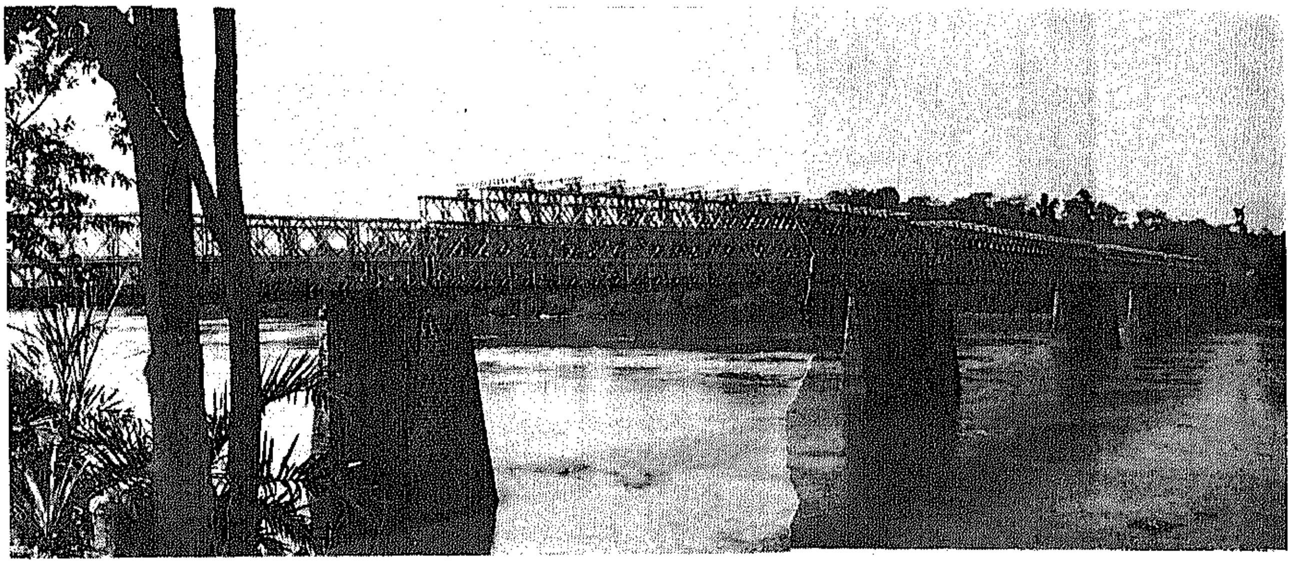


Photo. 9. Lindi River Bridge at PK 37 (single lane balley trussed type)

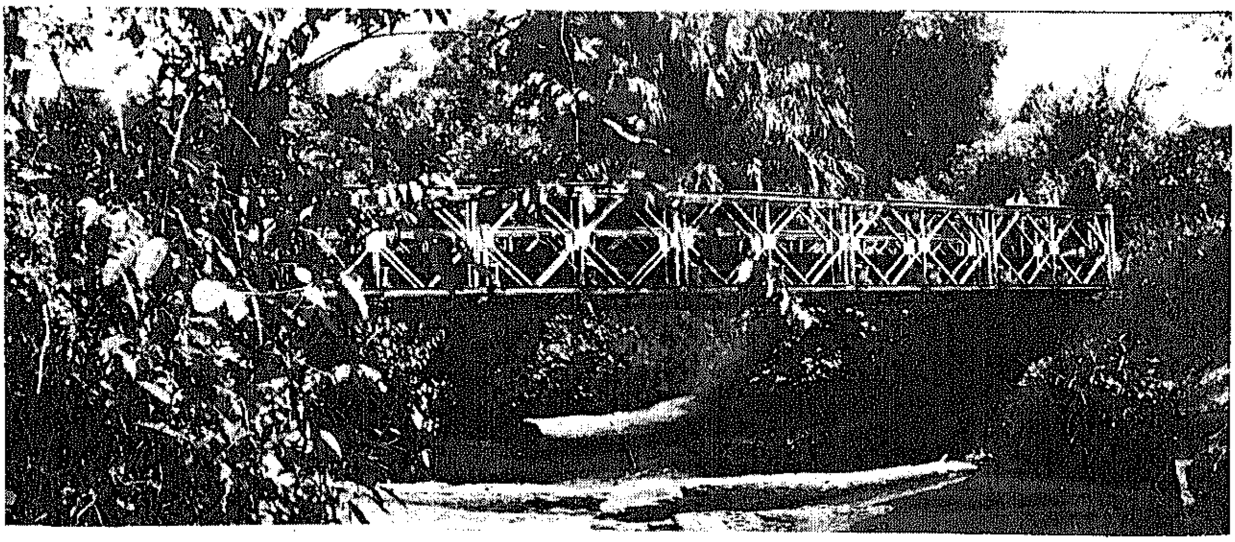


Photo. 10. Kole River 1st Bridge at PK 204 (single lane bally trussed type)

Photo. 11. At River Aruwimi (Banalia)

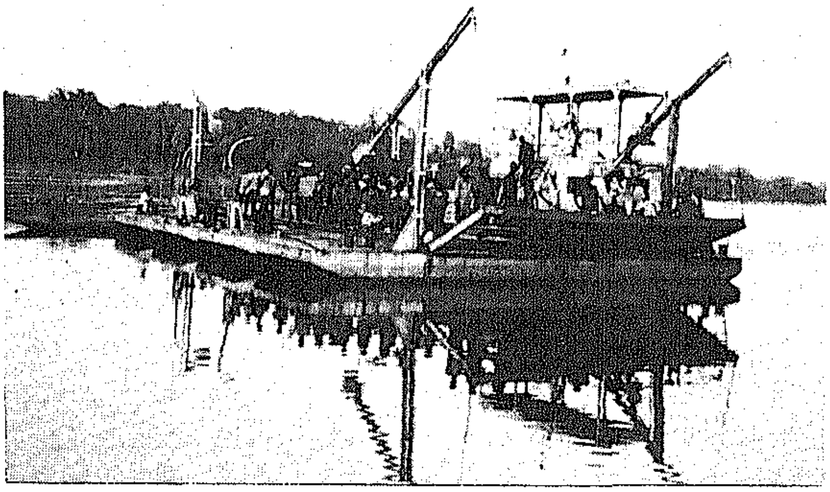


Photo. 12. At River Uele (Bondo)

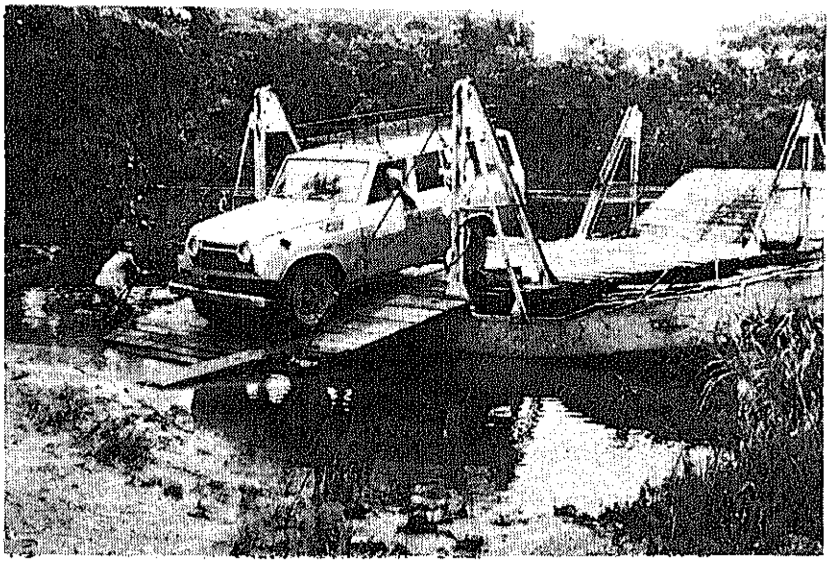


Photo. 13. At River Bili (Faka)

(4) Ferry Across Bomu River at Ndu (the 1st section)

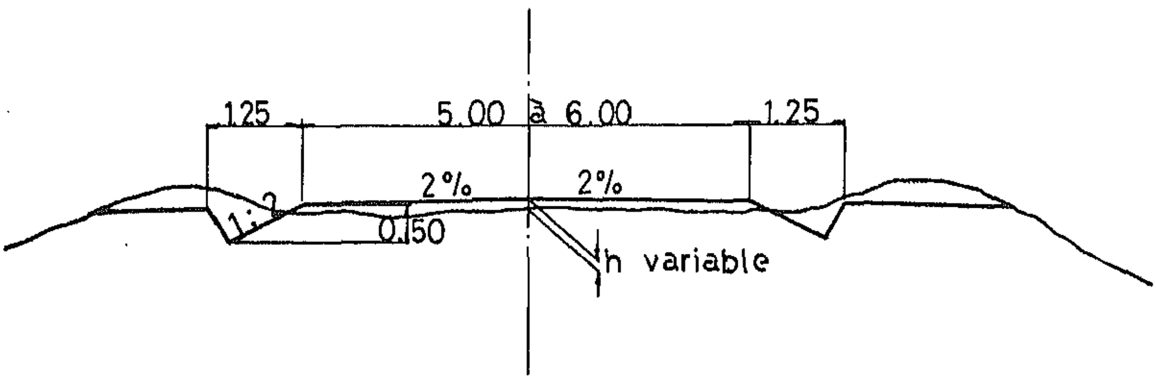
Bomu River, which flows on the border between Zaire and Central Africa, is about 360 m wide at the ferry site and 8 m and 3.5 m deep in the wet season and the dry season respectively. The current velocity is 1.0 m/sec in the wet season and 0.6 m/sec in the dry season. The ferry is a 12-ton-type using 3 steel boats and is equipped with a diesel engine. The loading capacity is a large trunk or 2 Toyota Land Cruisers. As for landing facilities it has a rampway only on the side of Ndu and it is impossible to load and unload a large bus having overhangs in fromt and in rear. One crossing of the river requires about 20 minutes, but usually takes one hour or more because the ferry is not always well in order. According to the operation record, the ferry crossed the river 6 times carrying 1 vehicle and 15 passengers a day on an average in 1973.

3.2.4 Existing Road Rehabilitation Program

A road rehabilitation program is underway by the financial aid or the IBRD in the stretch of 316 km long between Kisangani and Buta excluding the 3 km long paved portion on the Kisangani side. In this stretch of the project road the program has been preceeded by the maintenance work with a budget of about 200 Z/km before and during the rehabilitation work. In this program the stretch between PK 6.4 and PK 132 and also between PK 322 and PK 324, which have been 5.0 to 5.5 m wide, are being widened up to 6.0 m and the stretch between PK 132 and PK 322 which has been 4.0 to 4.5 m wide is being widened up to 5.0 m and the whole stretch is to be overlaid with a layer of select materials which is 12 cm in thickness on an average after being scarified into the depth of 10 to 15 cm and is provided a shallow V-shaped side ditch on each side, including cleaning the existing pipe-culverts, constructing additional pipe-culverts and replacing an existent bridge at PK 205 with a new reinforced concrete bridge. The typical cross-sections of the rehabilitated road are shown in the plate. (Refer to the following page.) The rehabilitation program was commenced in June 1974 by Dumez Zaire, a local contractor, with the total contract amount of 2.1 million Zaires and the schedule of 630 days. The original contract amount was revised in December 1975 due to the cost escalation. The contractor set up their base camp and the motor pool at Malili north of Banalia and started the work northward and southward from Banalia. This rehabilitation is a kind of minor improvement of the road and is not the king of improvement which aims at up-grading the geometric characteristics of the existing alignment and its design speed.

The stretch between Buta and Ndu has presently no definite rehabilitation program of any king except the routine maintenance work.

TYPICAL CROSS SECTION OF ROAD REHABILITATION BY IBRD'S FINANCIAL AID



3.2.5 Road Maintenance System

The maintenance of roads in Zaire had been partially aided by USAID financially before 1970, but the Zaire Government has been completely responsible for the budget of road maintenance since 1971. The real maintenance work of roads had been entrusted for a long time to local enterprises or local village chiefs under contract with the government.

The successive price escalation in construction and maintenance work in recent years compelled the local private agencies to supplement the lacking amount of road maintenance budget by themselves if they intend to keep the road in required conditions. Such a system did not work well particularly in such an economically critical period after the oil crisis, and consequently resulted in the accelerating deterioration of roads since then. The project road was not an exemption.

The government increased the average budget of road maintenance gradually from 170 zaires to 250 zaires and 400 zaires per km of road per year to cope with the soaring price but the Government decided to entrust the maintenance work to qualified construction contractors on contract with the government since 1974, and favorable results of the new system are expected. The budget of maintenance of the project road for the years 1974 - 1977 at the stage of December 1974, is different by section and by year but is 1,000 ziares as maximum, 200 zaires as minimum and 350 zaires as an average per km of road per year. (See 3.5.2 (2) (a).)

The road maintenance administration of Haut Zaire Regional Government concerning the project road in the stage of December 1974 is as follows:

The project road belongs partially to Kisangani Road Section and partially to Isiro Road Section, both of which are under the direction of Regional Director of Office of Roads who is stationed in Kisangani. Under those road section offices there exist many road zone offices;

those existing along the project road are at Kisangani, Banalia, Buta and Dulia. The road maintenance work of the project road is presently executed by Dumez Zaire, local contractor, under the supervision of road section chiefs.

Regional Office of Roads owns and operates a motor pool at Kisangani and the equipment of the motor pool is rented to such contractors in case of undertaking the road maintenance work in the Region; but it is not rented to such contractors in case of undertaking rehabilitation or new construction of roads. The latter contractors are not authorized to utilize the local government motor pool for the purpose of repairing their own equipment but should install their own reparing facilities in case of rehabilitation program or new construction project of roads.

3.3 Design Standards

3.3.1 Policy of Evaluating Design Standards

On proposing the road design standards to be applied to Kisangani-Bangassou section of the project road, the following items have been taken into consideration.

(1) Current Traffic and Future Forecast

The current volume of traffic is 470 vehicles/day in the outskirts of Kisangani, and 60 vehicles/day in the outskirts of Buta and less than 30 vehicles/day in other midpoint areas. The future volume of traffic, in the 20th year after the opening of the project road is expected to be some 2,400 vehicles/day between Kisangani and Banalia, some 80 to 420 vehicles/day between Banalia and Dulia and some 10 to 60 vehicles/day north of Dulia. (See Table 3.3.5.)

Meantime, the Office of Roads classifies this section of the project road as primary national road, giving priority by section as follows:(1)

Section	Route No.	Total Length	Priority
Kisangani - Buta	#421	approx. 320 km	1
Buta - Dulia	#445	" 75 km	1
Dulia - Monga	#471	" 250 km	2
Monga - Ndu	#473 & #483	" 72 km	3

As shown above, the volume of traffic becomes smaller and the priority gets lower as the road proceeds northward. However, since the project road is not only a national road within the territory of Zaire but also an international road linking 6 countries involved, the suitable minimum design standards should be maintained to meet such requirements.

(2) Road Design Standards of Zaire Government

As for the road design standards, it is the policy of the survey team to follow the road design standards of Zaire Government basically, taking into consideration the role of international character the project road will fulfil.

Note: (1) Division Programation et Plannification, Office des Routes Direction Generale "Route Prioritaires" (Liste de Departement Rehabilitation en plus de la Grande Boucle et les Trois Autres Boucles, Mars 1974)

The road design standards of Zaire Government are shown in Table 3.3.1 and Plate 3.3.1, each item of which is reviewed and commented in the following paragraphs.

3.3.2 Review of Design Standards

(1) Design Speeds

Primary national roads of Zaire have such range of design speed, as 80 to 110 km/hr for flat terrain and, 55 to 80 km/hr for hilly terrain and 40 to 50 km/hr for mountainous terrain. As a result of field studies, the survey team judged that most of the Kisangani-Bangassou section be classified as hilly terrain except the stretch of approximately 35 km near Kisangani which is to be classified as flat terrain. The present road is an earth road for the entire section except a paved section of about 3 km in length on Kisangani side. Although the current vehicular regulations of Zaire stipulated that the maximum speed permitted be 70 km/hr for light buses and 60 km/hr for trucks, it is desirable to improve the existing alignment of the road so that the maximum design speed be maintained at 100 km/hr in flat terrain and 80 km/hr in hilly terrain in anticipation of being paved in the future and from a viewpoint of its international nature. Therefore, the maximum speed limits defined by the current vehicular regulations of Zaire will have to be revised by the time of completion of the improvement of the project road.

Table 3.3.1 Geometric Characteristics of Roads for Average Types of Terrain

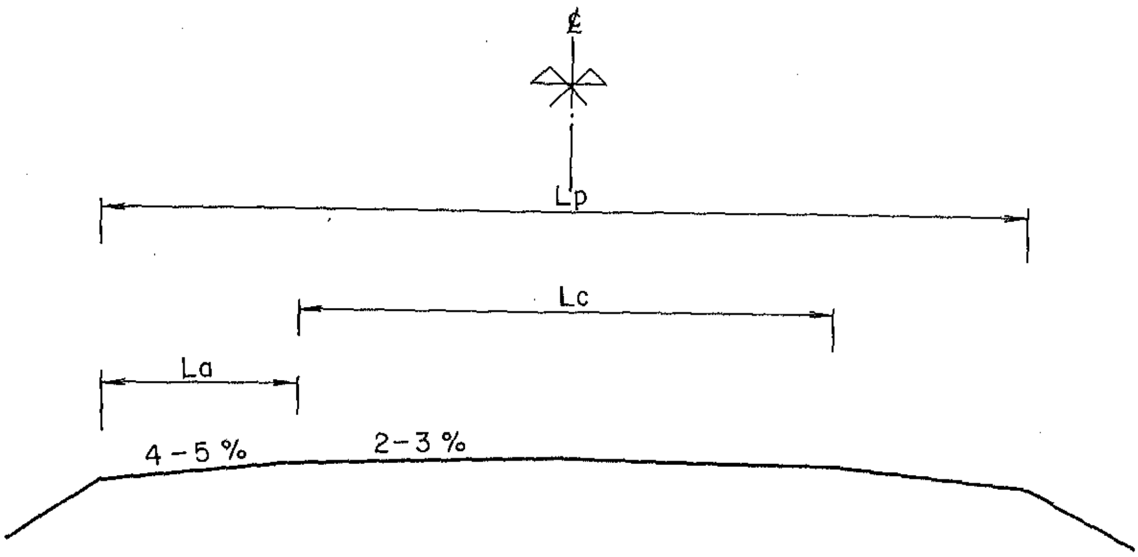
(Office of the Road in the Republic Zaire)

Class of Road	Terrain	Design speed (km/h)	Minimum radius of horizontal curvature (*) (m)	Maximum grade of profile (%)	Maximum length of grade (m)	Width of platform (driveway and shoulders) (m)
Princi-pal	Flat	80-110	190-360	4	-	10-13
	Rolling	55-80	90-190	5-7	600 (4%)	10-13
	Mountainous	40-55	50-90	7-9	400 (6%)	8-10
Second-aly	Flat	60-80	110-190	5	-	10-12
	Rolling	50-60	75-110	5-7	-	10-12
	Mountainous	35-50	35-75	7-9	750 (6%)	8-9
Other	Flat	50-60	75-110	7	-	7.5-8
	Rolling	35-50	35-75	7-9	-	7.5-8
	Mountainous	25-35	30-35	9-12	1000 (9%)	7.5-8

(*) Absolute minimum radius of curvature is given by applying 10% of superelevation and 0.16 of side friction value.

SOURCE: REPUBLIQE DU ZAIRE, OFFICE DES ROUTES DEPARTMENT CONSTRUCTION "CARACTERISTIQUES DES ROUTES POUR DIVERS TYPES DE TERRAIN" NO. NGA/04

PLATE / PLANCHE 3.3.1 STANDARD WIDTHS OF NATIONAL ROAD IN ZAIRE / LARGEURS NORMALES DE LA ROUTE NATIONALE AU ZAIRE



Lp = Width of platform / Largeur de Plateforme

Lc = Width of carriageway / Largeur de Chaussée

La = Width of shoulder / Largeur d'Accotement

	Flat and rolling terrain Terrain plat et vallonne			Mountainous terrain Terrain montagneux		
Type of road Type de route	Lp (m)	Lc (m)	La (m)	Lp (m)	Lc (m)	La (m)
Principal Principale	11	6.6	2.2	8-9	6	1-1.5
Secondary Secondaire	9	5.5-6	1.75-1.5	8	5.5-6	1.25-1
Other Autre	6	6	—	5-6	5-6	—

Source : REPUBLIQUE DU ZAIRE, OFFICE DES ROUTES DEPATEMENT CONSTRUCTION "NORMES GEOMETRIQUES" NO. NGD/04

(2) Width of Right-of-Way

The results of the field survey over the whole section of the project road have revealed that there exist not many high embankments and deep cuts on this road, and a width of right-of-way of 40 m is considered to be sufficient. Therefore, as shown in Plates B-2-1 ~ B-3-3, a width of 40 m was proposed basically in this study regardless of whether it is in urban area, village area, or forest area.

(3) Width of Carriage Way

The design standards for national roads of Zaire stipulate that the width of carriage way be 6.6 m for primary roads, 5.5 m to 6.0 m for secondary roads, and 6.0 m for other roads.

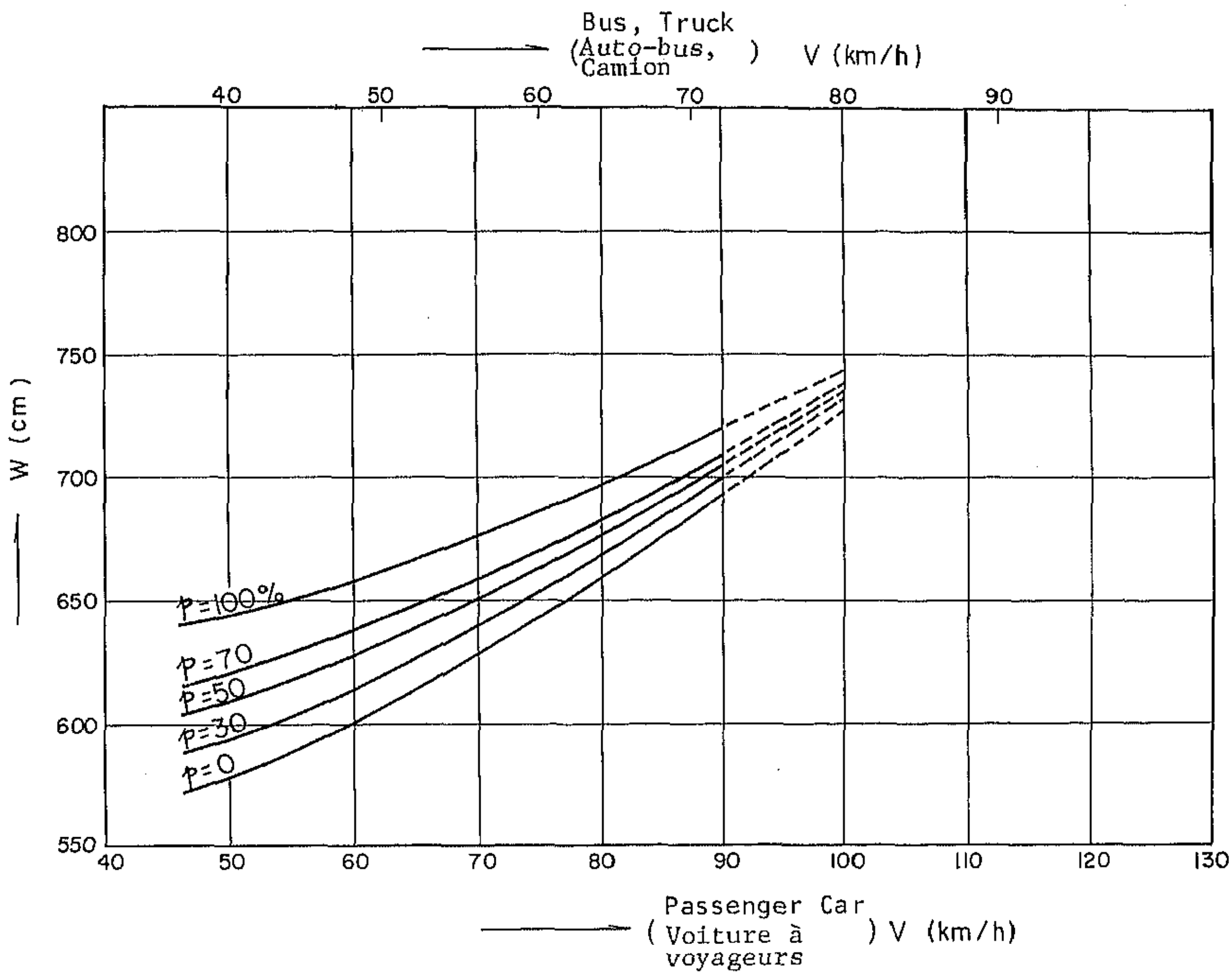
Generally speaking, the width of a carriage way should be the total of physical width of two vehicles and the width required for safe passing or overtaking.

The maximum width of a vehicle is set at 2.5 m in the agreement of International Road Traffic. The allowance for width required for passing or overtaking varies with the driving speed and traffic volume; and thus it is difficult to determine the allowance rationally; therefore, the allowance has to be determined experimentally.

Plate 3.3.2 shows the results of experiments conducted in Japan to find the minimum width of a carriage way required for vehicles running in opposite directions on a two-lane road without decreasing the speed of both vehicles, using parameters of driving speeds and traffic pattern expressed in share by type of vehicles.(1) According to these experiments, for driving speed of 80 km/hr of passenger cars and the share of buses and trucks of 50%, a width of 6.75 m is required for a 2-lane carriage way. The width of a lane influences much on the volume of traffic and driving comfort.

PLATE 3.3.2 MINIMUM CARRIAGEWAY WIDTH OF A 2-LANE ROAD DETERMINED BY OPERATING EXPERIMENTS

PLANCHE 3.3.2 LARGEUR DE CHAUSSEE MINIMUM D'UNE 2-VOIE DE CIRCULATION DETERMINEE PAR EXPERIENCES D'OPERATION



V: Design Speed (km/h)
Vitesse de base (km/h)

W: Carriageway width of 2-lane road (cm)
Largeur de chaussée de 2-voie de circulation (cm)

P: The sharing rate of the total of buses and trucks in ADT (%)
Total de taux de partage d'auto-bus et camions au Trafic quotidien moyen (%)

Note: (1) Japan Road Association, <u>Manual of Geometric Design Policy, Nov. 1960</u>

On the other hand, the standards of Zaire for primary roads stipulate that the width of a 2-lane carriage way be 6.6 m for flat and hilly terrains, which is not largely different from the above width experimentally obtained and little difference is considered in driving comfort. Therefore, a width of 6.6 m is considered satisfactory. However, in the stretches north of Banalia, the current traffic is much less than that between Kisangani and Banalia and even in the 20th year after the opening of the Project Road, traffic is anticipated to be approximately 80 - 420 vehicles/day between Banalia and Dulia and approximately 10 - 60 vehicles/day in the stretch north of Dulia.

The design standards of Zaire classify roads by priority into three classes, namely primary roads, secondary roads and other roads as shown in Table 3.3.1.

However, if the roads are classified by design traffic volume, they may be approximately shown as follows:

Principal roads	500 < ADT < 5,000
Secondary roads	100 < ADT < 500
Other roads	ADT < 100

If this classification by traffic volume is applied, the following width of carriage way by section may be determined according to the design standards of Zaire (Plate 3.3.1) and widths of the project road was proposed as follows:

Section	Platform Width	Width of Carriage Way	Width of Shoulder
Kisangani - Banalia	11.0 m	6.6 m	2.2 m
Banalia - Dulia	9.0 m	6.0 m	1.5 m
Dulia - Bangassou	6.0 m	6.0 m	-

(4) Width of Shoulders

Road shoulders are parts of a road which protect the carriage way that is a principal part of a road, and insure safety and comfort of driving and further offer room for passing of large vehicles and for emergency parking for vehicles in troubles.

In Zaire, the shoulder is stipulated that the width be 2.2 m for principal roads, 1.75 m - 1.5 m for secondary roads and nil for other roads on flat and hilly terrains. Although it is desirable for the width of shoulder to be 2.5 m on flat terrain (design speed 100 km/hr), width of 2.2 m stipulated by the design standards of Zaire seems to be sufficient in view of comparatively small anticipated volume of traffic in the future. (See Plate 3.3.1.)

Meanwhile, although a width of 1.75 m is desirable on hilly terrain, a width of 1.5 m stipulated by Zaire standards is also considered to be sufficient because of extremely small anticipated volume of traffic in the future in the northern sections. It is doubtful that no shoulder is required for the class of other roads; but it is considered that the width of 6.0 m of carriage way in this class of road includes that of shoulders.

After deliberate studies, a width of 2.2 m was proposed in the stretch between Kisangani-Banalia, 1.5 m in the stretch between Banalia and Dulia and no shoulder for the stretches south of Dulia.

(5) Sight Distance

Sight distance is a very important factor for safety and comfortable driving. In Zaire, AASHO standards have been adopted; according to the standards the sight distance of 140 m is required for 100 km/hr and 100 m for 80 km/hr on dry pavement, and 155 m for 100 km/hr and 110 m for 80 km/hr on wet pavement.

The stopping distance is generally expressed by the braking distance and is obtained by the following formula:

$$D = \frac{Vt}{3.6} + \frac{V^2}{2gf.(3.6)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3\text{-}1)$$

where, D = Braking Distance (m)

V = Driving Speed (km/hr)

f = Coefficient of friction between tires and road surface in longitudinal direction

t = Reaction time required until the driver presses brake pedal (sec.)

g = Acceleration due to gravity (m/sec^2)

The reaction time varies with different circumstances; but for the purpose of calculation here t = 2.5 sec was taken from AASHO standards and g = 9.8 m/sec^2 are introduced in formula (3-1) above.

Thus, $D = 0.694\ V + 0.00394\frac{V^2}{f}$ .... (3-2)

Although coefficient of friction in longitudinal direction varies with the conditions of tire, the road surface and the braking condition; sight distance has been calculated as shown in Table 3.3.2, assuming the road to be in the wet conditions for driving safety and the driving speed to be 85% of design speed. Table 3.3.2 shows the calculation of sight distances.

Table 3.3.2 Sight Distance

Design Speed (km/hr)	Average Operating Speed (km/hr)	f	0.694V	$0.00394\frac{V^2}{f}$	D (m)
100	85	0.30	58.9	44.8	153
80	68	0.31	47.1	58.7	106

Therefore, the sight distance of 160 m on flat terrain and 110 m for hilly terrain were proposed in this study.

(6) Minimum Radius of Curvature

The minimum radius of curvature is determined automatically by design speed. In Zaire, however, the figures are 190 - 360 m for flat terrain and 90 - 190 m for hilly terrain (See Table 3.3.1.).

The minimum radius of curvature is generally represented by the following formula:

$$R \geqq \frac{V^2}{127\ (f+i)} \quad \text{.....................} \quad (3\text{-}3)$$

where; R = the Minimum Radius of Curvature (m)

V = Design Speed (km/hr)

f = Coefficient of side friction between tires and road surface

i = Superelevation of road surface (expressed in tangent value)

Values of f are generally as shown in Table 3.3.3. For the following calculations f-value of 0.15 was proposed to allow for driving safety.

Table 3.3.3 Coefficient of Side Friction between Tires and Road Surface

	Paved Road		Laterite Road	
	Dry Season	Wet Season	Dry Season	Wet Season
Value of f	0.35 - 0.50	0.13 - 0.15	0.30 - 0.40	0.13 - 0.15

As for i-values, i = 0.10 was proposed for paved roads as the maximum value, taking into consideration safety of vehicle stopping at curves and i = 0.05 as the maximum value for laterite roads to keep them from erosion by surface water.

From the above conditions, the minimum radii of curve calculated for flat terrain (design speed 100 km/hr) and hilly terrain (design speed 80 km/hr) are obtained as follows, provided, however, the average driving speed on laterite road is set at 70 km/hr.

Flat terrain

Paved road: $$R \geqq \frac{100^2}{127 \times (0.10 + 0.15)} \fallingdotseq 315 \text{ m}$$

Laterite road: $$R \geqq \frac{70^2}{127 \times (0.05 + 0.15)} \fallingdotseq 195 \text{ m}$$

Hilly terrain

Paved road: $$R \geqq \frac{80^2}{127 \times (0.10 + 0.15)} \fallingdotseq 200 \text{ m}$$

Laterite road: $$R \geqq \frac{70^2}{127 \times (0.05 + 0.15)} \fallingdotseq 195 \text{ m}$$

According to the results of these trial calculations, the radius of curvature for laterite road may be made smaller than that of paved road and accordingly a sharper curve may be employed. However, to prepare for paving the laterite road in the future, a larger radius of curvature should be employed in the improvement, because if the larger radius is used for laterite road from the beginning the design speed would be secured only by adjusting the superelevation when the road is paved. However, on the Project road, sharp curves are seen only at the sag of the road where it crosses streams where the longitudinal profile is also steep. Generally speaking, the maximum composite grade of superelevation and longitudinal grade should be set at below 8%. When longitudinal grades of 3% for flat terrain and 4% for hilly terrain are adopted, superelevation for the respective terrain should be less than the followings.

Flat terrain $\sqrt{3.0^2 + i^2} \leqq 8.0 \quad \therefore i \leqq 7.4\%$

Hilly terrain $\sqrt{4.0^2 + i^2} \leqq 8.0 \quad \therefore i \leqq 6.9\%$

If these values are applied to formula (3-3), then we get the minimum radii of curvature for paved road as follows:

Flat terrain $R \geqq \frac{100^2}{127 \times (0.074 + 0.15)} \doteqdot 350 \text{ m}$

Hilly terrain $R \geqq \frac{80^2}{127 \times (0.069 + 0.15)} \doteqdot 230 \text{ m}$

Therefore, the minimum radius of 350 m for flat terrain (design speed 100 km/hr) and that of 230 m for hilly terrain (design speed 80 km/hr) were proposed in this study.

(7) Maximum Longitudinal Grade

As for the maximum longitudinal grade, the standards of Zaire stipulate 3 - 4% for flat terrain and 5 - 7% for hilly terrain. (See Table 3.3.1.)

As mentioned in the foregoing paragraph, from the viewpoint of desirability of composite grade below 8%, longitudinal grade is related with superelevation and ultimately with the minimum radius of curve. Since the minimum radius of curvature has been determined with the condition that the maximum longitudinal grades are 3% for flat terrain and 4% for hilly terrain, those maximum longitudinal grades were also proposed to be adopted.

(8) Cross-Fall of Carriage Way Surface

The Cross-fall of carriage way surface of 2 - 3% on paved road, 3 - 4% on gravel or laterite road is generally considered suitable to the local conditions. In Zaire a slope of 2 - 3% is stipulated for the cross-fall of carriage way surface as shown in Plate 3.3.1.

The existing road is deteriorated at numerous locations which the survey team believes, were caused due to lack of the appropriate cross-fall of the road surface.

For the purpose of effective lateral drainage, the survey team proposed the values of 3% for paved roads and 4% for laterite roads.

(9) Lateral Slope of Shoulders

For slope of shoulders, Zaire standards stipulate 4 - 5% (See Plate 3.3.1.). The survey team proposed 4% both for paved and laterite road as the maximum limit to prevent the erosion of shoulders by surface water.

(10) Design Load for Bridges

In view of the current and the future trend of vehicle load, not only domestic but also international, BS-153 Design Load recommended by ECA for the TAH was proposed as the design live load for bridges and affiliated structures.[1]

3.3.3 Proposed Design Standards for the Project Road

As for the results of studies made under paragraph 3.3.2, the survey team proposed the following design standards to be applied to the project road between Kisangani and Bangassou. Judging from the local topography, the section between Kisangani and PK 35 is to be designed with 100 km/hr and from PK 35 northward to Bangassou with 80 km/hr. Table 3.3.4 shows the proposed Design Standards to be adopted for the project road.

Note (1): ECA "Trans-African Highway ... Study of Legal and Administrative Barriers" September 1974

Table 3.3.4 The Proposed Design Standards to be Adopted for Project Road

	South of PK 35 from Kisangani	North of PK 35 from Kisangani	
1. Design Speed	100 Km/h	80 Km/h	
2. Width of Right of Way	40 m	40 m	
3. Width of Carriage Way	6.6 m	6.0-6.6 m	W=6.6m Kisangani-Banalia W=6.0 Banalia-Bangassou
4. Width of Shoulder	2.2 m	0-2.2 m	Ws=2.2m Kisangani-Banalia Ws=1.5 Banalia-Dulia Ws=0 Dulia-Banagassou
5. Sight Distance	160 m	110 m	
6. Minimum Radius of Currature	350 m	230 m	
7. Maximum Longitudinal Grade	3%	4%	
8. Maximum Composite Grade	8%	8%	
9. Cross Fall of Carriage Way Surface			
(1) Paved Road	3%	3%	
(2) Gravel or Laterite	4%	4%	
10. Shoulder Cross fall	4%	4%	
11. Design Load for Bridges	BS-153	BS-153	
12. Width of Carriage way on Bridges	8.0 m	7.0-8.0 m	W=8.0 Kisangani-Banalia W=7.0 Banalia-Kisangani
13. Width of Sidewalks on Bridges (only for bridges longer than 50 m in length)	1.5m x 2	1.5m x 2	
14. Overhead Clearance on Bridges	4.5 m	4.5 m	

Table 3.3.5 Traffic Forecast by Section with Project Road Improvement

(Unit: vehicle/day)

T	Year	Section 1 & 2 Bangassou - Bondo	Section 3,4 & 5 Bondo - Buta	Section 6,7 & 8 Buta - Banalia	Section 9 & 10 Banalia - Kisangani
1	1980				
2	81				
3	82				
4	83	2	6	37	82
5	84	2	9	56	202
6	85	3	12	77	337
7	86	3	18	99	482
8	87	3	23	123	639
9	88	4	29	148	808
10	89	5	33	170	910
11	1990	5	37	192	1,017
12	91	6	41	215	1,128
13	92	7	44	240	1,243
14	93	8	49	259	1,333
15	94	8	49	277	1,440
16	95	8	50	295	1,547
17	96	8	52	314	1,653
18	97	8	53	332	1,760
19	98	8	55	350	1,867
20	99	8	56	368	1,973
21	2000	8	57	386	2,080
22	01	8	58	404	2,187
23	02	8	59	423	2,294
24	03	8	61	441	2,400
25	04	"	"	"	"
26	05	"	"	"	"
27	06	"	"	"	"
28	07	"	"	"	"
29	08	"	"	"	"
30	09	"	"	"	"

Note: (1) This table is referred to Table 2.4.33.

(2) The project road was assumed to be opened to traffic in 1983.

3.4 Improvement Plan

3.4.1 General Description

As for the current conditions of the project road, most of the stretch is an earth road of 3.5 to 6.0 m in width which is deficient not only in road width, horizontal alignment, and longitudinal profile, but also in strength and width of culverts and bridges and serviceability of the road surface when compared to the levels required as a national primary road; it is evident that a drastic improvement of the road is essential in order to serve for the reconstruction of the local economy and also to be opened for traffic as an international road.

3.4.2 Basic Improvement Policy

The existing road is considered, from the viewpoint of the route planning, to be reasonable if it is improved as a section of the project road according to the following reasons:

a) The existing road is the sole north-south road linking the important towns existent in the project area in the shortest way;

b) The population and the farm lands that are to be benefited by the improvement of the project road exist already along the existing road;

c) The alignment of the existing road passes through comparatively favorable terrain of highland, detouring marshy areas;

d) If the existing road is improved, about 78 per cent of the total length of the road, which corresponds to about 558 km in accumulated length, can be utilized in the improvement, whereby much savings in construction costs can be anticipated over against building a complete new alignment over the whole stretch.

As already mentioned in 3.2, the existing road is not presently in such service level as requested for the national primary road in alignment, platform width, bridges and culverts, and the surface conditions so as to enable the smooth operation of vehicles throughout the year. Although the section between Kisangani and Buta is presently under rehabilitation work by the aid of IBRD, this work is not the improvement of the basic characteristics of the existing road, such as the horizontal alignment and the longitudinal profile, but a mere widening of the present platform width of 4 - 5 m to 5 m and of 5 - 6 m to 6 m and overlaying laterite soils of an average 12 cm in thickness on the wearing course of the existing earth road.

The survey mission studied in their Phase I field survey the approximate economic feasibility of ideally improving the road into the design standards proposed by UN-ECA: 7 m wide in carriageway, 2.5 m wide in shoulders, and all-paved road asphalt concrete pavement in the section south of Buta and surface dressing in the section south of Buta with the design speed of 80 - 100 km/hr; and the ferry at Aruwimi River would be replaced with a 2-lane highway bridge. But it became clear that such improvement would not be economically justified because of the scarcity of future traffic, particularly in northern sections.

Accordingly, it was the mission's main objective in the Phase II field survey to try to lower the design standards and still keep the decrease in benefits at a minimum.

The mission reached the conclusion, after discussing with UN-ECA and Office des Routes of the Zaire Government, that the minimum level which the project road might maintain in the design standards is "all-weather road with the alignment of the design speeds of 80 - 100 km/hr," with which the mission formulated the basic improvement policy as follows:

i) The existing road should be basically improved; and, in addition, partial short-cuts which are economically justified should also be included in the improvement;

ii) In the section between Kisangani and Buta where IBRD Rehabilitation program is underway, the completed state of the rehabilitation should be considered to be the existing condition (See dotted lines in Plates B-2-1 and B-3-1.);

iii) The project road is divided into 4 divisions of approximately uniform traffic density in the future traffic demand, and appropriate design standards corresponding to the traffic demand of each division should be decided, although the comparatively common factors of the road as a whole should be maintained;

iv) Improvement should be carried out in stages according to the increase in traffic demand so as to keep the investment most effective; and

v) In the improvement of the project road the most appropriate types of structure and way of construction should be adopted taking into account the conditions affected by the local weather, hydrology, soils, and geology.

3.4.3 Improvement Alternatives

The following two improvement alternatives were proposed following the improvement policy mentioned above and according to the design standards mentioned in 3.3.3 and 3.4.2. Both alternatives are identical in the improvement of horizontal alignment, longitudinal profile, culverts, wooden bridges and ferry landing facilities; but Alternative II is slightly narrower in platform width and forest-clearing width and steeper in side slopes of embankment and would be more delayed in the implementation of investment than Alternative I. At Aruwimi River, the existing ferry is replaced with a 2-lane highway bridge in Alternative I; while in Alternative II the existing ferry continues to operate and the number of ferries is gradually increased according to the increase of the traffic demand. The defference between the two alternatives is slight, but the salient difference is the following point:

Alternative I : The whole stretch is to be improved into a road of uniform width. Most of this will be done in Phase I.

Alternative II: The whole stretch is divided into several sections of comparatively uniform traffic density, each section having different platform width and the improvement being implemented in stages according to the increase in traffic demand.

(1) Alternative I

Phase I

a) Platform width will be widened up to:

(shoulder)		(Carriageway)		(shoulder)	
2.2 m	+	6.6 m	+	2.2 m	= 11.0 m

b) Radii of curves are to be improved up to:

$R \geqq 350$ m (South of PK 35 on Route #421)

$R \geqq 230$ m (North of PK 35 on Route #421)

c) Longitudinal Profile grades are to be decreased down to:

$i \leqq 3$ per cent (South of PK 35 on Route #421)

$i \leqq 4$ per cent (North of PK 35 on Route #421)

d) Forest will be cleared up to the width: (See Plate 3.4.3.)

Widening section of the existing road 36 m

Re-aligned section including short cuts 40 m

e) Pavement: Surface dressing is to be laid on the 6.6 m width over the whole stretch.

f) Culverts are to be lengthened at 18 locations due to platform widening and will be newly installed at 444 locations.

g) Existing wooden bridges are to be replaced at 122 locations with culverts and at 7 locations with reinforced concrete bridges of 8m in width, the total length of concrete bridges is 122 m.

h) Existing reinforced concrete bridges are to be improved to 8 m in width at 3 locations, the accumulated length of bridges being 37 m.

Existing plate-girder bridges (under 12 m in span length) are to be improved to 8 m width at 3 locations, accumulated length being 29 m.

i) Existing steel trussed bridges are to be replaced with wider and stronger bridges of 1.5 m + 8.0 m + 1.5 m = 11.0 m in width at:

- Lindi River (257 m)
- Rubi River (100 m)
- Likati River (84 m)

Existing steel trussed bridges are to be replaced with wider and stronger bridges of 8.0 m in width (without side walk) at:

- Zambeke River (28 m)
- Kole River (20 m)
- Tele River (42 m)
- Yeme River (16 m)
- Longa River (25 m)

(Removed steel bridges will be usable on other roads.)

j) New steel bridges are to be built as 1.5 m + 8.0 m + 1.5 m = 11.0 m in width at:

- Aruwimi River (640 m), replacing the existing ferry;
- Likati River at Libogo (75 m) where the existing road has used a railway bridge commonly.

k) Ferry landing facilities are to be built on both banks of:

- Uélé River
- Bili River
- Bomu River

Phase II (9th Year after the Project Road is opened)

Overlaying the pavement with a layer of asphalt concrete 5 cm in thickness over the section between Kisangani and Banalia.
(As to typical cross sections of the road, see Plates B-2-1 & B-2-2.)

(2) Alternative II

Phase I

a) Platform width will be widened up to:

(shoulder)		(carriageway)		(shoulder)			
2.2 m	+	6.6 m	+	2.2 m	=	11.0 m	(Kisangani-Banalia)
1.5 m	+	6.0 m	+	1.5 m	=	9.0 m	(Banalia-Dulia)
0	+	6.0 m	+	0	=	6.0 m	(Dulia-Ndu)

b) Radii of curves will be improved identically as in Alternative I.

c) Longitudinal profile grades will be improved as in Alternative I.

d) Forest clearing width: (See Plate 3.4.1, 3.4.2, B.2.1, B.2.2)

- Widening sections of the existing road

  31 m (Kisangani-Banalia)

  29 m (Banalia-Dulia)

  26 m (Dulia-Ndu)

- Re-aligned sections including short-cuts

  33 m (Kisangani-Banalia)

  29 m (Banalia-Dulia)

  26 m (Dulia-Ndu)

e) Pavement:

- In the section between Kisangani and Banalia the pavement is identical to Alternative I.
- In the section between Banalia and Ndu the road surface is covered with the wearing course of laterite soils.

f) Culverts are to be improved or newly-installed identically with Alternative I.

g) Wooden bridges are to be replaced or improved identically with Alternative I.

h) Ferry landing facilities are to be built on both banks at:

- Aruwimi River
- Uélé River
- Bili River
- Bomu River

<u>Phase II</u> (3rd year after the Project Road is opened)

a) Reinforced concrete bridges are to be replaced at 3 locations with those 8 m in width, the accumulated length being 37 m.

Existing plate-girder bridges (under 12 m in span length) are to be replaced with those of 8 m in width at 3 locations, the accumulated length being 29 m.

b) Existing steel trussed bridges are to be replaced with stronger ones at:

- Lindi River (257 m) with a bridge of
  1.5 m + 8.0 m + 1.5 m = 11.0 m in width
- Rubi River (100 m) with a bridge of
  1.5 m + 7.0 m + 1.5 m = 10.0 m in width

(4th year after the project road is opened)

a) A second ferry, 35-ton type with engine and the affiliated landing facilities, is to be provided at Aruwimi River.

Phase III (9th year after the Project Road is opened)

a) Existing trussed bridges are to be replaced with stronger and 7 m - wide steel bridges at:

- Zambeke River (28 m)
- Kole River (20 m)
- Tele River (42 m)
- Yeme River (16 m)
- Longa River (25 m)

and with a bridge 1.5 m + 7.0 m + 1.5 m = 10.0 m in width at:

- Likati River (84 m)

(Removed steel bridges will be usable on other roads.)

b) A new steel bridge 1.5 m + 7.0 m + 1.5 m = 10.0 m in width is to be built on Likati River at Libogo (75 m).

c) Ferry and landing facilities:
A third ferry, 35-ton type with engine and the affiliated landing facilities, is to be provided at Aruwimi River.

d) Pavement:
The pavement between Kisangani and Banalia is to be overlayed with a layer of asphalt concrete 5 cm in thickness.

(11th year after the Project Road is opened)

a) Pavement:
The earth road between Banalia and Buta is to be paved with surface

dressing 3 cm in thickness with macadam base course.

Phase IV (15th year after the Project Road is opened)

a) The fourth ferry, 35-tone type with engine and the affiliated landing facilities, is to be provided at Aruwimi River.

(3) Appropriate Time of Stage Construction

The appropriate time of the stage construction in Alternative II was determined approximately following the policy described below:

a) Pavement Overlaying:
The section between Kisangani and Banalia is estimated to be the most congested section where the traffic demand will reach 500,000 passings in terms of accumulated number of axles equivalent to 8.2 tons in one direction in the 10th year after the Project Road is opened; and it is generally recognized that this stage is the appropriate time of overlaying.[1/] It is scheduled in the 9th year after the opening of the road.
The section between Banalia and Buta is estimated to be the second most congested section but is somewhat smaller in traffic than the section between Kisangani and Banalia and is estimated to reach 260 in ADT in the 11th year after the road is opened, which is considered to be the appropriate time to pave with surface dressing together with a macadam base course.

b) Construction of Bridges:
It is estimated that all bridges should have the strength to allow the safe passing (without speed restriction lower than the design speed) of vehicles equivalent to B.S.-153 loading at least until the 10th year after the Project Road is opened.

1/ Source: UNESCO: Low Cost Roads, Design, Construction and Maintenance, 1971, Chapter 4.

All existing bridges are deficient in such strength. On the other hand, all existing bridges are 1-lane wide which should be expanded to 2-lanes to allow for future traffic. Therefore, the priority of constructing bridges is determined according to the grade of deficiency in strength against B.S.-153 loading.

i) In the 3rd year after the road is opened the average daily traffic is expected to exceed 300 on the following bridges:
   - Lindi River Bridge (257 m)
   - 3 reinforced concrete bridges and 3 plate girder bridges (122 m in total)

   Those bridges are to be improved into the reinforced concrete bridges 8 m in width in this year.
   - Rubi River Bridge (100 m)

   This bridge is to be replaced with a new 2-lane bridge in the same year.

ii) In the 9th year after the road is opened, all other existing steel trussed bridges, which are mostly Bailey Truss type, are to be replaced with new 2-lane bridges.

The existing Bailey-trussed type bridges are classified according to their type names used among Bailey-Truss grup in Table 3.4.1. They were given priority of improvement first judging from their strength from their type and span length. But the final priorities were determined by taking into consideration the traffic demand and the total bridge length at every locations. Lindi River Bridge would be replaced with a new bridge at the same time as Rubi River Bridge, because the former will have a traffic of 337 vehicles in the 3rd year after the road is opened; the future traffic demand will grow rapidly after then, too. The other existing steel trussed bridges are scheduled to be replaced in the 9th year after the road is opened, so all bridges are scheduled to have the strength of B.S.-153 loading till the 10th year.

Table 3.4.1 Improvement Priority of Existing Steel Trussed Bridges

Section	Name of River	Bridge Length	Span Length	Type of Bridge	Final Priority of Improvement
10	Lindi River	245.5 m	2 x 24.4 m 3 x 47.5 m 1 x 54.9 m	Bailey-DD,DT	2
8	Zambeke	28.8 m	28.0 m	Warren Truss	2
8	Kole	19.0 m	18.3 m	Bailey-DS	3
7	Tele	39.9 m	39.65 m	Bailey-DD	2
6	Yeme	15.4 m	15.25 m	Bailey-SS	2
6	Rubi	93.8 m	2 x 46.88 m	Bailey-TD	1
5	Longa	24.8 m	24.4 m	Bailey-DS	2
4	Likati	80.40	2 x 39.65 m	Bailey-DD	2
3	Likati at Libogo	72.0 m	2 x 24.0 m 1 x 18.0 m	Pratt Truss	2

Note: The order of bridge strength of Bailey-type bridges according to the type is shown in the following from weak type (on the left hand) to stronger type (on the right hand):

SS; DS; SSR; TS; DSR; DD; TSR; DDR; TD; DT; TT; TDR.

c) Increasing the Number of Ferries at Aruwimi River:

The transporting capacity of the existing ferry (35-ton type) is estimated as follows:

4 vehicles/trip x 2.5 trips/h x 12 h/day = 120 vehicles/ferry/day

$ADT < 120$ (in the 4th year when ADT=99 the 2nd ferry will be added with the landing facility.)

$120 \leqq ADT < 240$ (in the 9th year when ADT=215 the 3rd ferry will be added with the landing facilities.)

$240 \leqq ADT < 360$ (in the 15th year when ADT=332 the 4th ferry will be added with the landing facility.)

$360 \leqq ADT < 480$ (after the 21th year when ADT=441<480, there will be no more necessity of additional ferries.)

(4) Estimated Reduction of Road Length and Steep Grades due to Improvement of Alignment

The total length of the project road which starts from PK 3.6 on the north bank of Tshopo River at Kisangani and ends on the north bank of Bomu River at Bangassou is estimated to be reduced as follows due to the improvement of the alignment:

(Existing Road)	
Total road length	718.6 km
Total stretches of ferry operation	1.35 km
Total route length	719.95 km
(Improved Road by Alternative I)	
Total road length	698.96 km
The length of new bridge at Aruwimi River	0.64 km
Total stretches of ferry operation	0.71 km
Total route length	700.31 km
(Improved Road by Alternative II)	
Total road length	698.96 km
Total stretches of ferry operation	1.35 km
Total route length	700.31 km

In other words, both Alternatives I and II are estimated to have a reduction of 19.6 km in length which corresponds to 2.72 per cent of the total route length due to the improvement of the alignment. The reduction by section and the reduction by curved portion are shown in details in Table 3.4.2 (1), (2) and A.3.4.3 respectively.

The length and the distribution of steep grades in the profile are improved by the improvement as shown in Table 3.4.2 (2).

Table 3.4.2 (1) Length of Road before and after Improvement by Section

(Unit: km)

Section		Existing Road			Alternative I			Alternative II		
No.	PK	Road	Ferry	Total	Road	Ferry	Total	Road	Ferry	Total
(Kisangani)										
10	3.6 - 50.0	46.4	-	46.4	44.92	-	44.92	44.92	-	44.92
9	50.0 - 129.0	79.0	-	79.0	77.69	-	77.69	77.69	-	77.69
8	129.0 - 206.0	77.0	0.64	77.64	73.885	-	73.885	73.245	0.64	73.885
7	206.0 - 235.8	29.8	-	29.8	28.19	-	28.19	28.19	-	28.19
6	235.8 - 324.3	88.5	-	88.5	86.375	-	86.375	86.375	-	86.375
(Buta)										
5	0 - 75.5	75.5	-	75.5	74.62	-	74.62	74.62	-	74.62
(Dulia)										
4	0 - 65.5	65.5	-	65.5	64.83	-	64.83	64.83	-	64.83
3	65.5 - 125.0	59.5	0.20	59.7	58.465	0.20	58.665	58.465	0.20	58.665
2	125.0 - 250.0	125.0	0.15	125.15	122.335	0.15	122.485	122.335	0.15	122.485
1	250.0 - 322.4	72.4	0.36	72.76	68.285	0.36	68.645	68.285	0.36	68.645
Total		718.6	1.35	719.95	699.6	0.71	700.31	698.955	1.35	700.31

Note: Length of bridges are included in the length of road.

Table 3.4.2-(2) Length and Distribution of Profile Grades by section of Existing Road and Improved Road

Section	Distance (km)		Existing Road (km)				Improved Road (km)			
	Existing Road	Improved Road	< 3%	3-5%	5-7%	7%<	< 3%	3-5%	5-7%	7% <
# 10	46.4	44.92	43.2	1.9	0.9	0.4	41.72	3.2	-	-
# 9	79.0	77.69	68.5	4.9	3.4	2.2	67.19	10.5	-	-
# 8	77.0	73.26	74.9	1.9	0.2	-	71.19	2.07		
# 7	29.8	28.19	29.6	0.2	-	-	27.99	0.2	-	-
# 6	88.5	86.37	86.4	1.6	0.5	-	84.27	2.1	-	-
# 5	75.5	74.62	72.45	1.4	1.05	0.6	71.57	3.05	-	-
# 4	65.5	64.83	63.69	0.36	0.95	0.5	63.02	1.81	-	-
# 3	59.5	58.46	55.3	4.2	-	-	54.26	4.2	-	-
# 2	125.0	122.34	105.6	15.65	3.3	0.45	102.94	19.4	-	-
# 1	72.4	68.28	61.15	6.9	1.85	2.5	57.03	11.25	-	-
Total	718.6	698.96	660.79	39.01	12.15	6.65	641.18	57.78	-	-
			(92.0%)	(5.4%)	(1.7%)	(0.9%)	(92.0%)	(8.0%)	(0%)	(0%)

Note: In the improved road the length and the distribution of profile agades are same in both alternatives I and II.

3.4.4 Description of Improvements

(1) Land Purchase and Compensation

Since the lands are all state-owned, it is not necessary to purchase the right-of-way. In this construction the right-of-way should be marked off with boundary marks.

The houses existent in the clearing and grubbing zones shall be moved out of the right-of-way and proper compensation shall be provided for the movement of houses and plantation trees to be felled. The houses on the right-of-way but not included in the clearing zones may remain as they are, but the construction of additional new houses on the right-of-way shall be subject to permission of Regional Office of Roads.

(2) Clearing and Grubbing

In such tropical rain forest areas roads extending in the east-and-west direction receive sunshine all day long keeping the road surface dry unless they are under the shade of bamboo bushes and trees. However, all the project road except for the section between Buta and Dulia (that is about 90 per cent of the entire length) extends in the north-and-south direction and is under the influence of the shade of trees on both sides. Thus, the road surface does not dry easily; it soon changes into muddy pools, and traffic is often suspended by fallen trees.

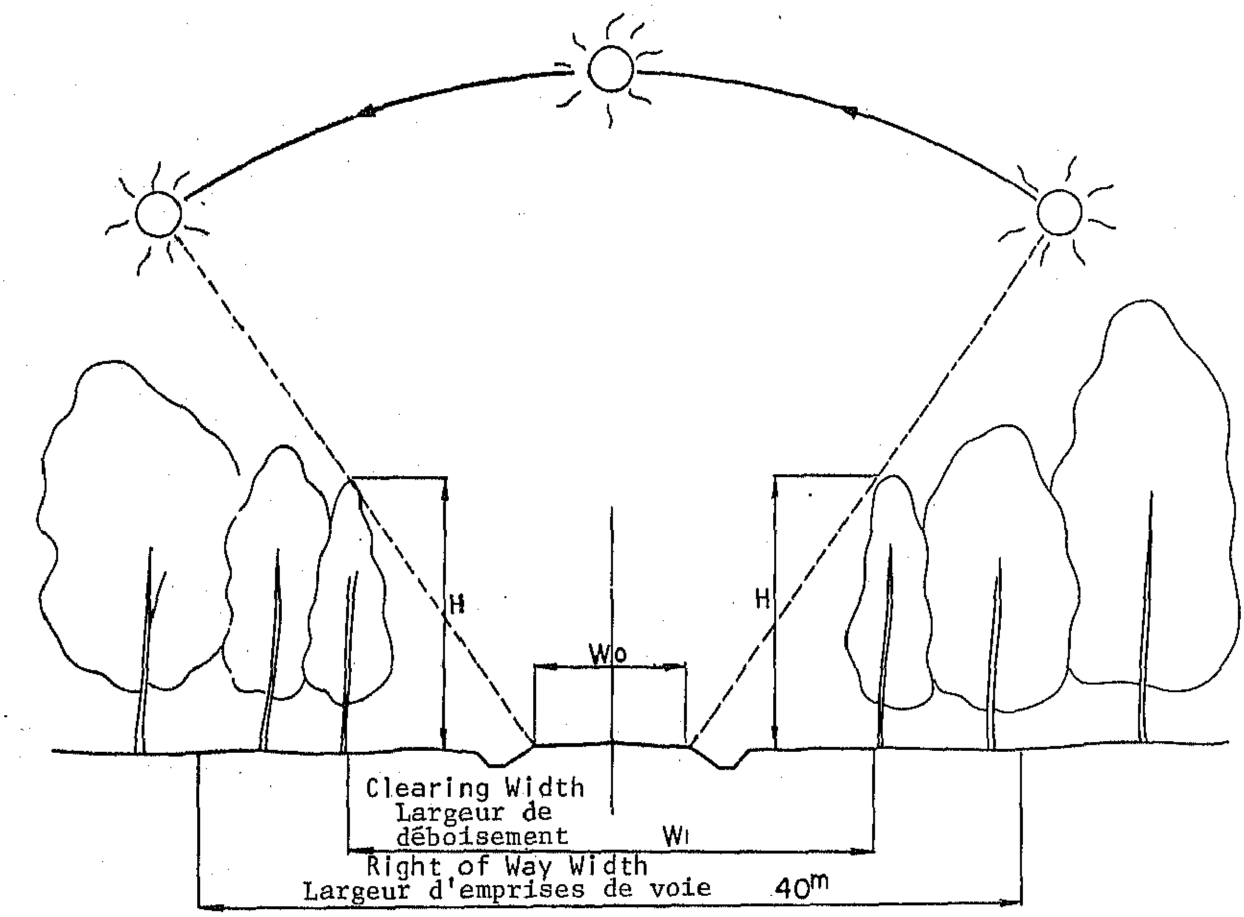
Below is shown the relation among the road width W_0, the clearing width W_1, the tree height H at the clearing boundary line and the duration of sunshine on the road extending in the north-and-south direction. (See Plate 3.4.1.)

In the case of Alternative I with the platform width of 11 m, the clearing width of 36 m and the tree height of 10 to 18 m, the theoretical duration of 100% sunshine on the road is calculated at approximately 4 hours and 40 min. to 6 hours and 50 minutes, and in case of Alternative II with the platform width of 6 m, the clearing width of 26 m and tree height of 10 to 18 m in the section north of Dulia, the duration of sunshine on the road is calculated at 3 hours 50 minutes to 6 hours. The tree height is generally 10 to 15 m in north of Dulia and is 10 m or less of sparse bushes north of Bondo, and therefore the duration of sunshine on the road in view of the clearing width is considered within the acceptable range securing at least 4 to 6 hours a day. Even outside of clearing zones trees more than 20 m tall within the right-of-way should be felled.

PLATE
PLANCHE 3.4.1

FOREST CLEARING WIDTH, TREE HEIGHT AND THEORETICAL SUN-SHINE HOURS ON ROAD SURFACE (NORTH-SOUTH ROAD)

LARGEUR DE DEBOISEMENT, HAUTE D'ARBRE ET DUREE D'ENSOLEILLEMENT THEORIQUE SUR SURFACE DE ROUTE (NORD-SUD ROUTE)



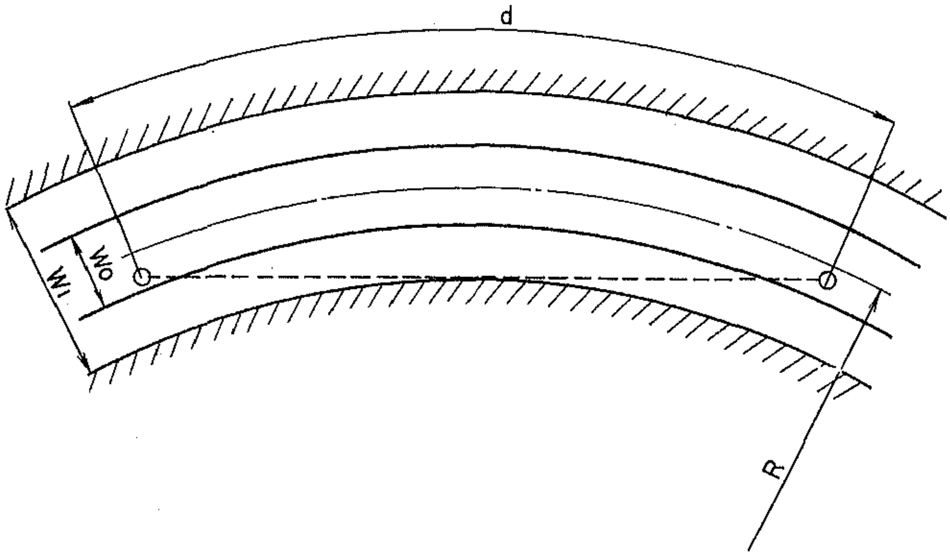
Clearing Width Largeur de déboisement W_l (m)	Platform Width Largeur de plateforme W_o (m)	Height of Tree Haute d'arbre H (m)	100% Sun-Shine Hours on Road Surface (hour, minute) 100% Durée d'ensoleillement sur surface de route (heure, minute)	
		18	4	40
36	11	15	5	20
		10	6	50
		18	3	50
26	6	15	4	30
		10	6	0

In the above-mentioned clearing width, even if the road is closed by the 18 m high fallen trees at right angle to the road in case of Alternative I or 13 m high trees in the case of Alternative II, at least one lane can be secured for traffic.

Next, the relation between the clearing width and the sight distance at curved portions has been examined and the results (shown in Plate 3.4.2) indicate that the clearing width in curved portions allows the securing of the required sight distance. However, in the cleared zones inside of curves, weeding should be done often as a part of the road maintenance work in order to insure constant sight distance.

In construction, clearing and grubbing can be limited within the exterior boundary of side ditches, while only clearing is adequate outside of ditches.

PLATE 3.4.2 WIDTH OF FOREST CLEARING AND SIGHT DISTANCE
PLANCHE LARGEUR DE DEBOISEMENT ET DISTANCE D'EMPLACEMENT



Design Speed Vitesse de base (km/h)	Av. Operat'g Speed Vitesse de marche V (km/h)	Radius of Curvature Rayon de courbure R (m)	Clearing Width Largeur déboisement Wi (m)	Platform Width Largeur plateforme Wo (m)	Min. Stop'g Distance Min. distance d'arrêt D (m)	Sight Distance Distance de visibilité d (m)
100	85	380	36	6.6	153	223
			31	6.6	153	205
80	68	230	36	6.6	106	174
			31	6.6		161
			26	6.0	106	146

Note :

(1)
$$d = 2\pi (R - W_o/4) \times \frac{2\cos^{-1}\frac{R - W_i/2}{R - W_o/4}}{2\pi}$$
$$= (R - W_o/4) \times 2\cos^{-1}\frac{R - W_i/2}{R - W_o/4}$$

(2) Calculation of D is referred to 3.3.2(5).
Calculation de D est rattaché à 3.3.2(5).

(3) Filling

It was found through the field surveys that there exists no so-called alluvium soil deposits on the project road and there seems to exist no location which requires special measures to be taken against any base sliding and settlement due to the solidification of embankments. Even the locations of silty soils which are considered weaker than lateritic soils in bearing power shows the CBR values in the range to allow pavement design on them and can be considered to have no problem as subgrade soils except muddy spots.

Muddy spots existing in silty stretches along the project road are caused by the excessive water content in the soil during the wet season and the disturbing action by the wheels of passing vehicles. Therefore, the surface soil at these muddy spots should be replaced with highly permeable lateritic soils at least to the thickness of 50 cm. Stretches requiring such replacement of soil reach the accumulated length of about 19.5 km in the section between Dulia and Bondo. Such soil replacement work should be executed during the dry season.

As described in 3.2.1, the surface of the existing road is generally lower than the surrounding ground, being disadvantageous for drainage. Consequently, the improved road surface shall be kept at least 30 cm higher than the surrounding natural grounds and 50 cm higher than the existing road surface in order to keep the road surface well-drained.

As for the side slopes, the slope of 1:4 is adopted in Alternative I considering the convenience of using a grader for maintenance, but in Alternative II the slope of 1:2 is adopted for the purpose of saving fill.

On the shoulders and side slopes sodding shall be done to keep them from erosion by surface water.

As for the filling materials, the soils excavated from side-ditches shall be used if the soil is favorable. In the sections with unfavorable soil lateritic soil shall be excavated and carried from the pre-determined borrow pits in the respective sections.

(4) Side ditches and Turn-out ditches

Principally, side-ditches shall be simply excavated in the form shown in Plate B-2-1 and B-3-1. The local topographical features are mostly so flat that over a long distance that it will be difficult to have a slope for drainage in the side-ditches. In such portions an average of 4 turn-out ditches per km of side ditch shall be provided at right angles to the side ditches so as to discharge the water into bushes or lowlands.

In the portions of side ditches where the profile slope exceeds 4 per cent, lining shall be applied to the faces of ditches to keep them from being eroded. The accumulated length of such side-ditches to be lined reaches about 19 km.

In urban and village areas 5 m-long pipe culverts shall be provided every 30 m at the side-ditches to provide an access way to cross the ditches (See Plate B-4) and their accumulated length reaches about 55.4 km.

(5) Improvement of Horizontal Alignment

(i) Alignment

The improvement of severe curves with radii less than the minimum allowable radius for the purpose of securing the design speed is identical in both Alternatives I and II and shall be executed in Phase I.

The improvement of curves including transition curves shall be sufficiently studies in the stage of final engineering for the respective locations, but the approximate concepts of improvement of the alignment are shown in the alignment diagram of Plates B-1-1 to B-1-19. Since the Plates show the existing alignment by a thin line, and the improved alignment by a thick line, the locations where the improvement is only the widening of the existing alignment the thick line overlaps the thin line.

Also the alignment diagram shows the present status with a thin line and the improved alignment with a thick line. The numerals show the radii of curvature in meters for the present status and for the improvement. However, even for the present status the radii are shown only for such severe curves with the radii less than 300 m. The number of curved portions in the present status and after the improvement by radius range are as shown in Table 3.4.3.

On the project road in the urban areas of Banalia, Buta, Bondo, and Monga the speed is assumed to be limited at 35 km/hr and therefore, the streets in the urban areas are not subject to the improvement.

The shortening of the existing road due to the improvement of the horizontal alignment is estimated to reach about 19.6 km as a whole including short-cuts, corresponding to the shortening rate of 2.72 per cent.

Table 3.4.3 Number of Curved Portions before and after Improvement

Range of Radii	Before Improvement	After Improvement
$R < 230$ m	1,022 (70%)	7[1] (1%)
$230 \leqq R < 380$	84 (6%)	62 (12%)
$380 \leqq R < 500$		98 (19%)
$500 \leqq R < 1000$	344 (24%)	121 (23%)
$1000 \leqq R < 3000$		197 (37%)
$3000 \leqq R$		44 (8%)
Total	1,450 (100%)	529 (100%)

Note (1): The curves of R<230 m at 7 locations remaining after the improvement are those existent in urban areas where speed regulations are to be enforced.

(2): As for the number of curves by section, see A.3.4.8.

(ii) Short-Cuts

Concerning short-cuts, after studying 48 prospective sites on construction cost, maintenance costs of the existing and the new alignment, operating costs on the existing and the new alignment, 7 economical short-cuts were selected which warrant such improvements. The accumulated length of newly aligned portions of the 7 short-cuts comes to about 45 km. (For the details of this approximate economic study by site, see A.3.4.1 & A.3.4.2.)

(iii) Widening Portions and Re-Aligned Portions

Of the total length of the improved road, the re-aligned portions, which are completely apart from the existing alignment, reach about 161 km in the accumulated length, including the length of 45 km of the 7 short-cuts. (For these details by location, see A.3.4.3.)

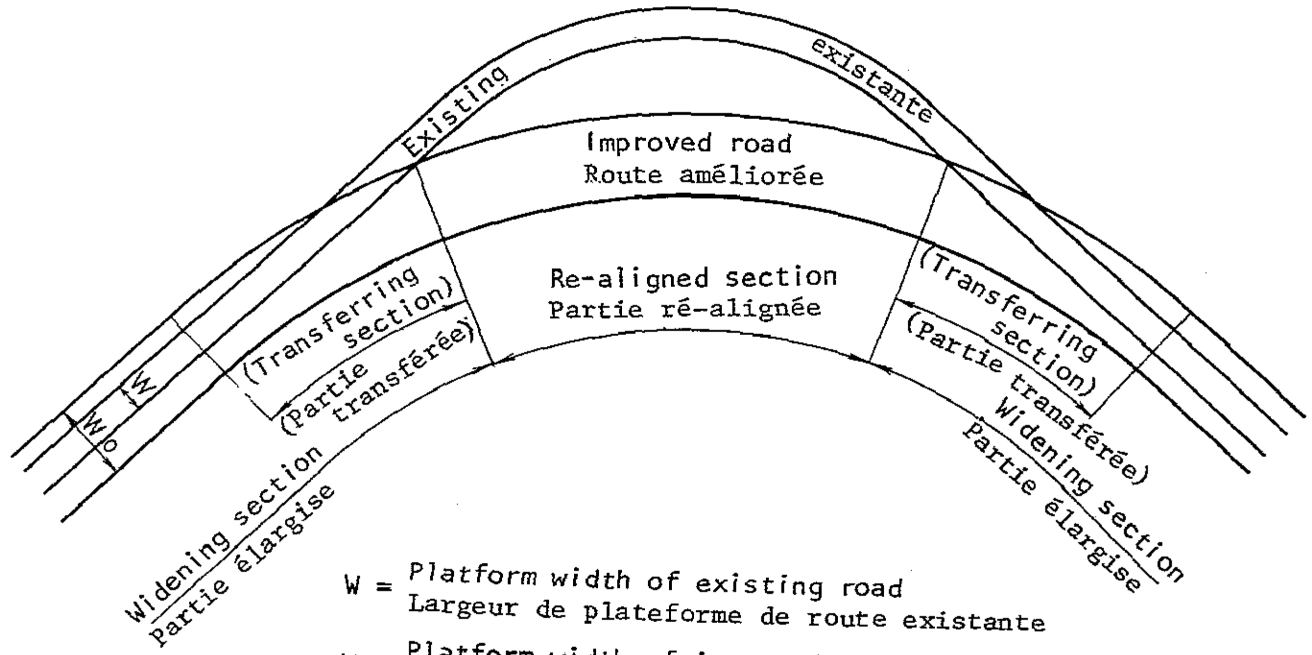
The rest of the portions are all the widening portions which include the transferring portions as shown in Plate 3.4.3. The accumulated length of the widening portions reaches about 538 km.

The rates of share of those portions as a whole are as follows:

Accumulated re-aligned portions	Approx. 161 km (23%)
Accumulated widening portions	Approx. 538 km (77%)
Total length of the improved road	Approx. 699 km(100%)

PLATE 3.4.3 WIDENING SECTION AND RE-ALIGNED SECTION OF IMPROVED ROAD

PLANCHE PARTIE ELARGISE ET RE-ALIGNE DE ROUTE AMELIOREE



W = Platform width of existing road
Largeur de plateforme de route existante

W_o = Platform width of improved road
Largeur de plateforme de route améliorée

(6) Longitudinal Profile Grades

There are 141 portions on the existing road where the longitudinal profile grades are steeper than the design standards as shown in Table 3.2.3 and the accumulated length of improvement for such grade portions reaches 30.5 km. In these portions the profiles are improved by raising sags and cutting down crests. The present status and the locations to be so improved are shown in Plates B-1-1 to B-1-19 on scale of 1:50,000 horizontally and 1:5,000 vertically. In those Plates the thin line shows the existing profile while the thick line shows the improved profile.

(7) Crossing Culverts

In the widening portions including the transferring portions, the crossing culverts shall be principally extended, and the damaged or clogged ones shall be replaced with new ones. In checking the culvert size the following two methods were adopted:

(a) The basin areas were calculated by using a map on the scale of 1:50,000 (without contour line) and the rainfall intensity; and then the discharges and, accordingly, the size of culverts were determined. (See A.3.4.4.)

(b) In the field surveys floodmarks were searched for by inquiring of local inhabitants and then the flood water levels were confirmed, from which the flood discharge and, consequently, the size of culvert were determined.

At the locations where basin areas were unknown because the respective rivers are not indicated on the map, method (b) was pursued, omitting the calculation. When the pipe sizes by the calculation of (a) were smaller than those by the calculation method (b), the latter were adopted.

Really, sizes of most culverts were determined by method (a). As a result of this study many existing culverts were found to be short of flowing capacity; many additional culverts are needed. The summary of the improvement of culverts is as follows:

Extension of existing culverts	18 locations
Culverts to be newly installed including 122 locations of wooden bridges to be replaced with culverts	555 locations
Total	573 locations

(For structural details and locations of culverts, see Plates B-5-1, B-5-2, B-1-1 to B-1-19.)

(8) Ferries and Landing Facilities

Presently, ferries exist at the 4 locations of Banalia, Bondo, Faka and Ndu on the project road, playing an important role of transporting local inhabitants, travellers and their vehicles. Of the 4 locations of ferries, 3 locations except Aruwimi River can be used continuously in this project as they are except for providing their landing facilities according to the traffic demand in the future.

The results of the study on improving the ferry landing facilities are presented in the following:

(a) Natural Conditions of Locations

Flood Water Levels: There is a considerable fluctuation of water level between the dry season and the wet season, but since the reliable past data on the water levels at those ferry sites could not be obtained in the survey, the flood water levels were calculated from one observation each in the dry season and the wet season in 1974 conducted by the survey team and from the estimated high water levels of 10-year frequency. The results are as shown in Table 3.4.4. Since the observation data are insufficient, appropriate consideration must be made in the stage of final engineering.

River Bank: Although deep borings were not carried out in the survey on river banks at ferry sites, stable bearing stratums were confirmed at the depth of 2 to 5 m below the ground surfaces by auger borings conducted in the neighborhood of river banks. In dry season a part of river bed rock appears on the water at most of those rivers.

(b) Types of Landing Facilities and Ferries

The sliding-stage-type of landing facility was selected in order to cope with the fluctuation of river water level and because it is easily operated. The details of the stage are shown in Plate B-7.

The type of ferry to be increased in number where it is necessary is principally assumed to be identical with the existing ferry.

Table 3.4.4 Water Levels of Rivers at Ferry Sites (expressed in Altitude)

(Unit : m)

River Name	(1) Water Level in Dry Season	(2) Water Level in Wet Season	(3) Flood Level	Range of Water Level Fluctuation	
				(2)-(1)	(3)-(1)
Aruwimi	414.1	416.5	416.6	2.4	2.5
Uele	465.9	469.9	471.3	4.0	5.4
Bili	464.0	465.0	465.1	1.0	1.1
Bomu	469.4	473.8	474.1	4.4	4.7

Note: (1) & (2) ..... observed by survey team in 1974
(3) ..... observed in the past or estimated

(c) Improvements of Ferry Landing Facilities and Ferries

Alternative I

(Phase I) 1979 - 1980 — Construction of new landing facilities on both banks of the following rivers:

- Uele River
- Bili River
- Bomu River

Alternative II

(Phase I) 1979 - 1980 — Construction of new landing facilities on both banks of the following rivers:

- Aruwimi River (1979)
- Uélé River (1979)
- Bili River (1980)
- Bomu River (1980)

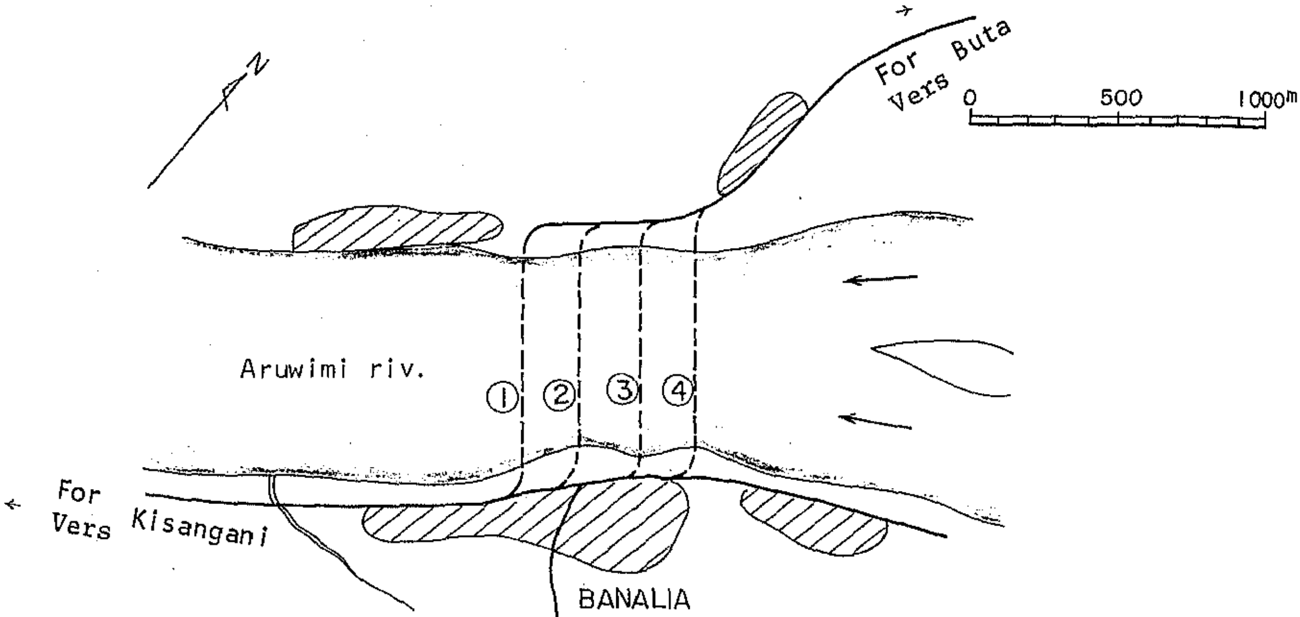
(Phase II) in the 4rd year after the opening of the road
- Aruwimi River: Second ferry, 35-ton-type with engine, will be manufactured and installed together with its landing facilities.

(Phase III) in the 9th year after the opening of the road
- Aruwimi River: Third ferry, 35-ton-type with engine, will be manufactured and installed together with its landing facilities.

(Phase IV) in the 15th year after the opening of the road
- Aruwimi River: Fourth ferry, 35-ton-type with engine, will be manufactured and installed together with its landing facilities.

The locations of additional ferries at Aruwimi River are proposed as shown in Plate 3.4.4, in which each location is 200 m apart.

PLATE 3.4.4 LOCATIONS OF ADDITIONAL FERRY AT BANALIA (ALTERNATIVE II)
PLANCHE SITUATIONS AU BAC ADDITIONNEL A BANALIA (ALTERNATIVE II)



Note : ① Existing Ferry (35 ton type with engine)
Bac existant (35 ton type avec machine)

② 2nd Ferry (35 ton type with engine)
2e Bac (35 ton type avec machine)

③ 3rd Ferry (35 ton type with engine)
3e Bac (35 ton type avec machine)

④ 4th Ferry (35 ton type with engine)
4e Bac (35 ton type avec machine)

(9) Bridges

The bridge length at each river was determined from the river width at the time of flooding by 50-year frequency except Arúwimi River where thé flood of 100-year frequency was considered. Length would usually be a little longer than the existing bridge.

Types of Super-structure

Generally, the types of bridge super-structure are selected by the effective span length and the subsurface conditions of the river-bed. Although any subsurface investigation by means of deep boring was not conducted in the field survey, the river-beds were generally considered to be stable by viewing the types of rock of the river-beds which appeared on the water during the dry season. Anyway, the subsurface conditions should be confirmed by boring in the stage of final engineering. Therefore, the types of super-structure were selected by placing the emphasis on the effective span length. The under clearance of girders shall be at least 2.0 m above the flood water level, in respect to the opinion of Office of Route. As for the design loading, B5-153 is considered to be appropriate which was recommended by UN-ECA. Considering such conditions, the following types were selected:

Effective Span Length (L)	Types of Super-structure
$L \leqq 18$ m	Reinforced concrete-slab bridge
18 m < $L \leqq$ 30m	Pre-stressed concrete-girder bridge
30 m < L	Composite plate-girder bridge

Type of Sub-structure

Generally, the types of abutment are selected according to height, and that of pier by considering the form to best minimize the scouring of the river-bed by peripheral flow around the pier in local rivers. Considering such conditions, the following types were selected:

Abutments

Height	Types of Abutment
H < 10 m	Reinforced concrete of inverted T type
10 m $\leqq$ H	Reinforced concrete of buttress type

Piers — Reinforced concrete of oval section

The preliminary design plans of the bridges which are longer than 30 m are shown in Plates B-6-1 to B-6-6.

Influence of Earthquake

The influence exerted on structures by seismic action was not overlooked, particularly in this project area where M 3.8 of seismic action was recorded in Kisangani. There seems to exist an earthquake zone in the area from Kisangani to Walikale in the southeast, and also in the vicinity of Bafwasende, which is about 240 km east-northeast from Kisangani; two earthquakes of M 4.5 and M 3.9 were recorded there in 1965. Judging from these seismological observation data, it is considered reasonable to take into account the influence of earthquakes in designing the structures including bridges in the final engineering.

Plate B-8 shows the earthquake records and their magnitudes observed in this area in the past.

(10) Pavement

(a) Pavement Width

The pavement width (or the carriageway width) was proposed as follow by alternative improvement and by stretch: (See 3.3.2.(3))

Stretch	Alternative I	Alternative II
Kisangani-Banalia	6.6 m Phase I Surface dressing Phase II Overlaying	6.6 m Phase I Surface dressing Phase II Overlaying
Banalia - Buta	6.6 m Phase I Surface dressing	6.0 m Phase III Surface dressing
Buta - Ndu	6.6 m Phase I Surface dressing	

For the purpose to keep the subgrade of the pavement from being penetrated by surface water the base course is made 0.3 m wider on both sides than the surface course and the thickness of the surface course is tapered off on this allowance width. (See Plates 3.4.5 and 3.4.6.)

(b) Pavement Types

(i) Calculation of Pavement Thickness

The thickness of the pavement is calculated by the following formulae:

$$H = \frac{58.5P^{0.4}}{CBR^{0.6}} < H' = \Sigma D_i \quad \dots\dots\dots \quad (3\text{-}4)$$

$$D = \frac{2.2P^{0.4}}{CBR^{0.3}} < D' = \Sigma a_i D_i \quad \dots\dots\dots \quad (3\text{-}5)$$

where, H' = Actual total thickness of pavement (cm)
D' = Actual pavement structural number
H = Total theoretical thickness of pavement (cm)
D = Theoretical pavement structural number
P = Design wheel load (ton)
Di = Thickness of each layer (cm)
ai = Coefficient of relative strength of each layer
CBR = CBR value of the subgrade soils

(ii) CBR Values of Subgrade Soils

The subgrade soils of the project road are classified as shown in A.3.4.5 in Vol.3. Appropriate CBR values were determined as shown in Table 3.4.5 according to the soil classification by the field survey by the survey team and the laboratory-tests conducted by National Laboratory for Public Work in Kinshasa. (See A.3.3.2 and A.3.3.3)

Table 3.4.5 CBR Values of Subgrade Soils

AASHO Classification	Casagrande Classification	CBR Value
A-2-4 A-2-6	SC, SM, GC, GW	more than 10%
A-2-7 A-4	SC, SM, GC	8%
A-6 A-7-5 A-7-6	SC, CL, CH	4%

Note on Formulae (3-4) and (3-5):

Source: Dr. H. Takeshita, Consideration on the Structural Number, Second International Conference on the Structural Design of Asphalt Pavements Proceedings. p.407 - 412, University of Michigan, 1967.

(iii) Pavement Types (Alternative I)

(Original Pavement)

Design wheel load

According to the estimated traffic as shown in Table 3.3.5 the design wheel load for the pavement structure in the section of Kisangani-Banalia are determined on the following assumption:

- The original pavement of surface dressing is executed in Phase I;
- The overlaying is carried out in the 9th year after the road is opened for traffic because the cumulative number of equivalent 8200 kg axles (4100 kg per wheel) in one direction is expected to reach 500,000 in the 10th year; (1)
- The design wheel load for the accumulated traffic until the 9th year after the opening is calculated as P=3.5 tons.

The minimum target values of H and D

The following H and D are obtained by applying CBR values as shown in Table 3.4.5 and P = 3.5 tons to Formulae (3-4) and (3-5):

if CBR = 15, then H = 19.0 cm
if CBR = 10, then H = 24.3 cm and D = 2.53;
if CBR = 8, then H = 27.7 cm and D = 2.70; and
if CBR = 4, then H = 42.0 cm and D = 3.33

The pavement Types in Alternative I

As for the original pavement of the alternative I the following four types of the pavement are proposed, and the relation between H and H' and also D and D' are as follows: (See Plate 3.4.6.)

(Type I) H' = 43 cm > H = 24.3 cm; D' = 2.56 > D = 2.53
(Type II) H' = 48 cm > H = 27.7 cm; D' = 2.73 > D = 2.70
(Type III) H' = 63 cm > H = 42.0 cm; D' = 3.56 > D = 3.33
(Type IV) H' = 53 cm > H = 42.0 cm; D' = 3.59 > D = 3.33

Following the policy to pave all the way between Kisangani and Ndu in Alternative I one of those four proposed types of pavement is applied to each portion according to the soil condition and keep the improved surface at least about 50 cm higher than the existing road surface for the porpose of efficient surface drainage although the estimated

Note (1): Source: UNESCO, Low Cost Roads, Design, Construction and Maintenance, 1971, Chapter 4, p.79.

traffic is much less in sections north of Banalia than the section Kisangani-Banalia.

(Overlaying for Section Kisangani-Banalia)

Design wheel load

The design wheel load for the traffic after the 10th year to the 27th year for the section Kisangani-Banalia is calculated as P = 5.4 tons. Therefore, the pavement is proposed to be overlaid with a layer of asphalt concrete of 5 cm thick in the 9th year.

The Minimum target value of H and D

The following H and D are obtained by applying CBR values and P = 5.6 tons to Formulae (3-4) and (3-5):

if CBR = 10%, then H =28.8cm D = 3.24

if CBR = 8%, then H =33.0cm; D = 3.47

if CBR = 4%, then H =50.0cm; D = 4.27

Pavament Types and their Thickness

The following three types of pavement structure are proposed and the relation between H and H' and also D and D' are as follows:

(Type I) H' = 49 cm > H =28.8cm; D' = 3.44 > D = 3.24

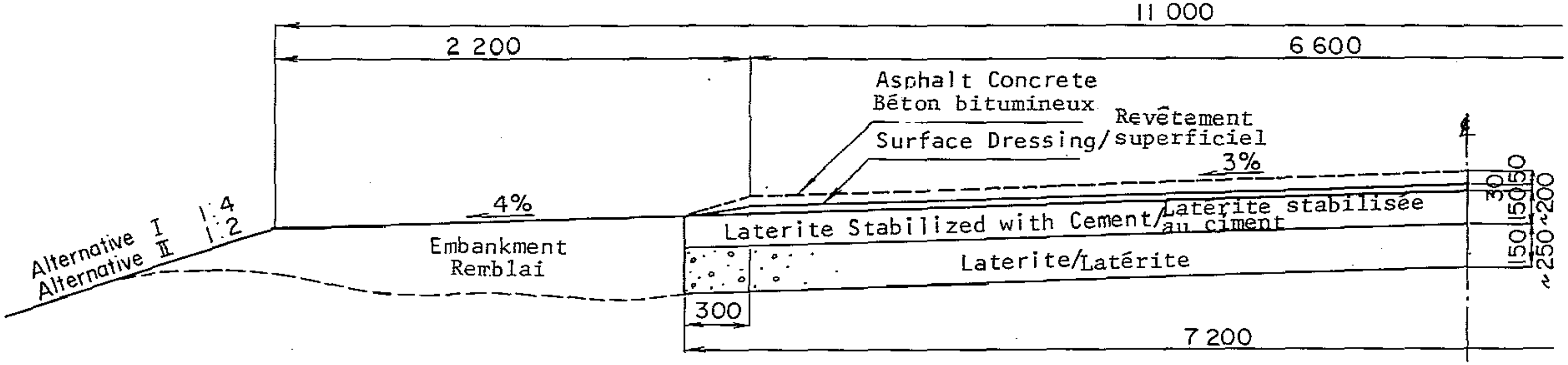
(Type II) H' = 53 cm > H =33.0cm; D' = 3.61 > D = 3.47

(Type III) H' = 68 cm > H =50.0cm; D' = 4.44 > D = 4.27

(As the process of pavement design calculation, see Vol 3.)

PLATE 3.4.5 PAVEMENT CROSS SECTION
PLANCHE 3.4.5 PROFILS EN TRAVEL TYPE

(Alternative I
Alternative II Kisangani - Banalia)



PAVEMENT CROSS SECTION
PROFILS EN TRAVEL TYPE

Alternative II
(Banalia ∿ Buta)

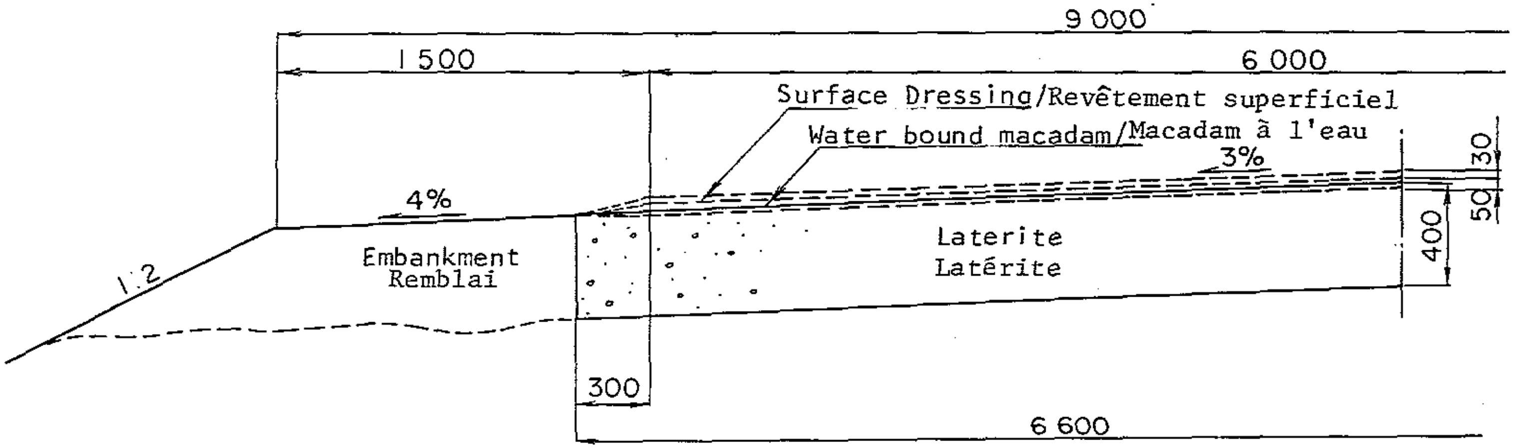
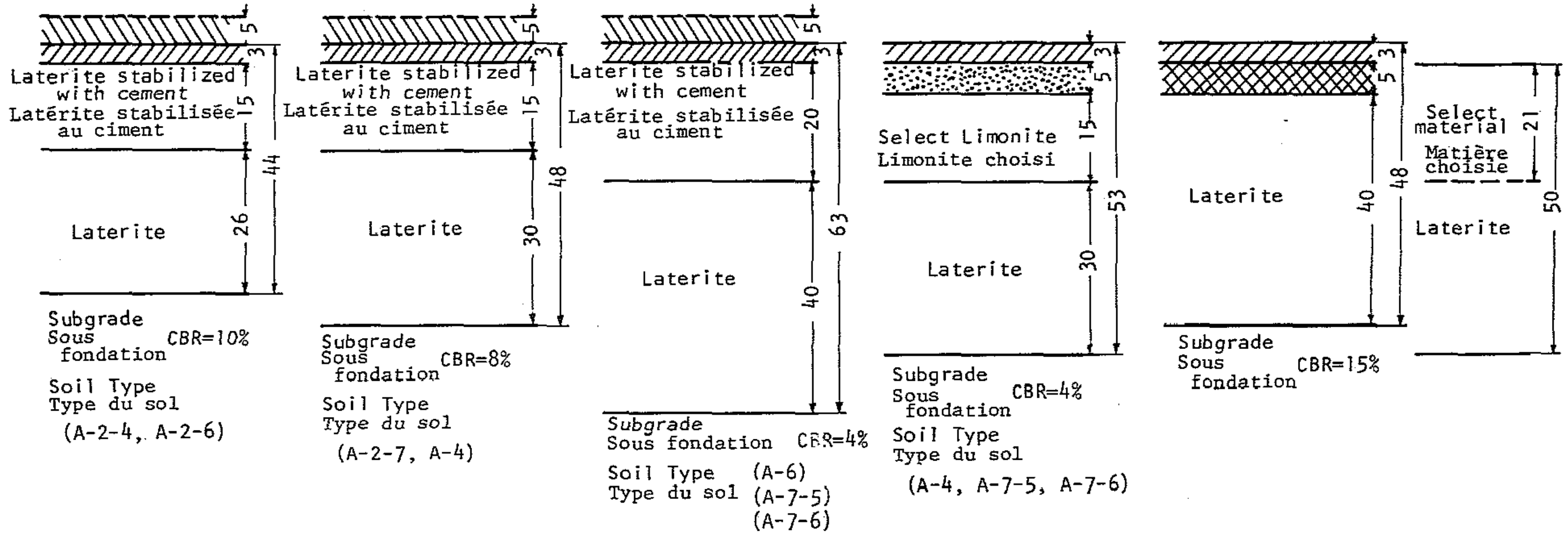


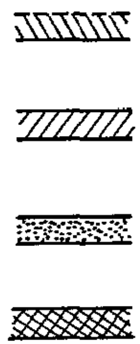
PLATE 3.4.6 TYPICAL SECTIONS OF PAVEMENT
PLANCHE COUPE TYPIQUE DE REVETEMENT



Pavement Type by Division, by Alternative

Division	Alternative I	Alternative II
Kisangani ∿ Banalia	Type I, II, III	Type I, II, III
Banalia ∿ Buta		Type V
Buta ∿ Monga		Type VI
Monga ∿ Ndu	Type I, II, IV	

<u>*Legend*</u> / <u>*Legende*</u>



: Overlaying with asphalt concrete (5 cm)
Morts-terraings avec béton d'asphalte (5 cm)

: Surface dressing (3 cm)
Revêtement superficiel (3 cm)

: Asphalt bound Limonite (5 cm)
Limonite à l'asphalte (5 cm)

: Water bound macadam (5 cm)
Macadam à l'eau (5 cm)

(iv) Pavement Types in Alternative II

(Original Pavement and Overlaying for Section Kisangani-Banalia)

The pavement types and the optimum time of paving this section are just same as those in Alternative I which should be carried out in Phase I and should be overlaid in Phase III.

(Pavement Type for Section Banalia-Buta)

The sections north of Banalia are opened for traffic as a laterite road in Phase I, but the section Banalia-Buta, which is expected to have the ADT of 240 in the 10th year and 420 in the 20th year, is proposed to pave in the 11th year. Its cumulative number of equivalent 8200 kg axles in one direction after it is paved is expected handly to reach 500,000 until the 27th year according to the traffic estimate, it is considered not necessary to overlay the pavement during the life span of this road. (1)

Design Wheel Load

According to the estimated traffic between the 12th year and the 27th year P = 3.5 tons is obtained as the design wheel load of the pavement.

CBR Value of Subgrade Soils

The surface of laterite subgrade between Banalia and Buta is expected to be compacted by the passing traffic during 11 years after it is opened for traffic and the CBR value is expected to increase at least up to 15%.

Minimum Target Value of H and D

The following H and D are obtained by applying CBR value of 15% and P = 3.5 tons:

$$H = 19.0 \text{ cm}; \; D = 2.24$$

Pavement Type

The following type of pavement is proposed and the relation between H and H' and also D and D' are as follows:

(Type V) $H' = 48 \text{ cm} > H = 19 \text{ cm}; \; D' = 2.23 > D = 2.24$

In all sections north of Buta in Alternative II the road is surfaced with the pavement type VI in which the existing road surface is raised by 50 cm in thickness by filling with laterite and particularly the top layer of 20 cm out of 50 cm is covered and well compacted with such select soils containg much limonite gravels wherever such materials are available.

Note (1) UNESCO: "Low Cost Road, Design, Construction and Maintenance" 1971, Chapter 4, P.79.

(v) Surface Dressing

This is bituminous treatment which is the most widely used of in African countries and is known also as 'seal-coat' and 'surface treatment'. It consists of essentially of applying a film of binder followed by a layer of stone chippings, one stone thick, after which the surface is rolled before opening to traffic. It is usually known that it is not necessary to be overlaid before the cumulative number of equivalent 8200 kg axles in one direction of two lane road reaches 500,000.

(vi) Base Course

It is proposed that the cement stabilized base course is to be used instead of water-bound macadam as the base course of the pavement in Phase I because the distribution of aggregate materials is polarized and scarce and its development is not in favorable state while laterite of good quality is abundant particularly northern sections along the project road. According to the test data of local lateritic soils by the National Laboratory of Public Works the optimum quantity of cement for soil stabilization is 6%, which secures the uniaxial compressive strength of 30 kg/cm^2 in 7 days. The cement stabilized base course is executed in one layer in case of 15 cm thick and in two layers in case of 20 cm thick. The width of the base course is 7.2 m wide at the straight section.

In the sections north of Bondo limonite gravel is abundant. In Alternative I the type IV of pavement is proposed, in which the base course of select limonite gravel of 20 cm thick is used. The top portion of this base course is stabilized by distributing bituminous emulsion of 5 ℓ/m^2.

In the section between Banalia and Buta the pavement of surface dressing type is executed in Phase III, its base course is proposed to use the water-bound macadam type of 5 cm thick because the development of quarries to produce aggregates is expected to progress in the area along the road until then to satisfy the local demand. (See Plate 3.4.6)

(Vii) Sub-Base Course

Laterite is proposed to be used as the sole materials of the sub-base course over the whole stretch of the road, and it is hauled to the sections of silty soils notwithstanding its long haul distance. The thickness of the sub-base course varies 25 cm to 40 cm according to the quality of the soils of the sub-grade.

(viii) Laterite Surfaced Earth Road

In Alternative II sections between Banalia and Buta only the Laterite Layer, which constitutes the sub-base course of the future pavement, is constructed in Phase I and all rest sections remain as earth road, the surface of which are all covered with laterite. Therefore, the laterite to be used as the surface course in those sections should be select materials, preferably containing limonite gravels as much as possible. Generally, such an earth road is paved with river gravels but it is almost impossible in this project area to obtain such river gravels for the purpose; and this is the reason why the select materials as mentioned above is specified as its quality in order to resist the surface wear of the earth road.

(ix) Total Thickness of Pavement

The total thickness of the original pavement including the surface dressing varies 43 cm to 63 cm according to the soils characteristics of the subgrade, and placing the pavement of those thickness on the existing road surface almost satisfies the requisite condition of raising the existing road surface for the purpose of the efficient surface drainage.

(c) Accumulated Length of Pavement by Type

The details of the length of pavement by location and by type of pavement and their accumulated length are shown in A.3.4.5, but their summary is as follows:

Table 3.4.6 Accumulated Length of Pavement by Alternative & By Type

(Unit: km)

Type of Pavement	Alternative I	Alternative II	
	When Phase I is completed	When Phase I is completed	When Phase III is completed
I	310 (45%)	31 (4%)	31 (4%)
II	127 (18%)	13 (2%)	13 (2%)
III	226 (32%)	78 (11%)	78 (11%)
IV	35 (5%)	-	-
V	-	-	188 (27%)
Laterite	-	576 (83%)	388 (56%)
Total	698 (100%)	698 (100%)	698 (100%)

(d) Local Aggregate Situation

The developed quarries of qualified materials are scarce in the area along the project road except for the Kisangani area (See A.3.2.2.). As for the coarse aggregates not only for pavement but also for structural concrete it is necessary to confirm the quantity of resources by deep borings in the stage of the final engineering at every outcrops of rock which are not many in location. As for the fine aggregates clean sand should be collected along rivers in the dry season and should be stored for the construction. Much sand may not be collected at one place due to the nature of local rivers.

Utilization of limonite gravel which is abundant in the northern section of the road as an available material is one of the economy of the construction. It is adequate for the materials of base course of pavement and foundation and a part of sub-structures but have problems in strength as the materials of super-structures and in the resistance against wear as the materials of surface course of the pavement. It is necessary to develop quarries at outcrops existing along the road for such purpose, and the aggregates thus produced have to be transported to the construction sites notwithstanding the long haul distance. Most of the existing rock outcrops are gneiss, granite and sand stone. Average haul distance of the proposed sites of quarries in each section is estimated at 37.8 km, the longest is 78 km in the 5th section and the shortest is 5 km in the 4th section. (See 3.5.1 (2))

3.4.5 Construction Program

(1) General Description

The entire project road consisting of 10 sections for cost estimations are grouped into 4 construction divisions between Kisangani and Bangassou, bordering at Banalia, Buta and Bondo as the proposed tendering units.

The time required for the improvement of the project road construction is estimated at four-and-a-half years with the following yearly progress, using the minimum equipment.

From April, 1979	9 months	8%
1980	12 months	20%
1981	12 months	30%
1982	12 months	30%
To September, 1983	9 months	12%
	54 months	100%

(2) Construction Schedule

As for the construction schedule is referred to A.3.4.6 for Alternative I and A.3.4.7 for Alternative II.

Even when the final engineering are carried out smoothly, approximately 2 years and 8 months will be required either for Alternative I or II from the time of submission of the final report and the project commencement.

In this study, it is assumed that if the final report is submitted at the end of March, 1976, contractors will be selected at the end of November, 1978, the mobilization will be commenced in December, 1978 and the real construction in April 1979. The mobilization includes the procurement and the transportation of materials and equipment, the recruiting of laborers, setting up field offices. By the end of September, 1983, Phase I will be finished and the road will be opened for traffic.

(3) Local Contractors and Their Experiences

When the Project is implemented, it is anticipated that an international tender will take place. It is needless to say that the leading contractors in Zaire will be entitled to participate in the tender.

The followings are major contractors actively engaged in the road construction projects in Zaire in recent years. They are mostly European firms which corporated in Zaire.

SOZAGEC Co.
SEASAF Co.
Dumon Van der Vin Co.
Dumez Zaire Co.
PARISI Co.
SOTORAF Co.
SONOZATRA Co.

Office of Roads does not register the contractor at present. Although the above seven firms often participate in the Rehabilitation Program in Zaire, three firms, namely, Dumez Zaire Co., Dumon Van der Vin Co. and SONOZATRA Co. have branch offices and motor pools in Kisangani in the Haut Zaire Region.

The followings are lists of the typical road and airport construction projects in Zaire executed within the past five years, by five firms:

SOZAGEC Co. (Société Zairoise de Genie Civil)

1974/75	Rehabilitation of the Road Isiro - Poko (130 km);
1974/75	Rehabilitation of the Road Isiro - Wamba (117 km);
1974/75	Rehabilitation of the Road Isiro - Niangara (145 km);
1974/75	Rehabilitation of the Road Titule - Dingila (79 km);
1974/75	Rehabilitation of the Road Dingila - Poko (147 km);
1974	Drainage and asphalt paving work in the City of Kinshasa;
1974	Rehabilitation of Roads in Lisala;
1973	Drainage work in the City of Kinshasa;
1973	Drainage and other work at Mbandaka

The average of annual turn-over of this firm in recent years amounts approximately to 7 to 8 million Zaires.

SEASAF Co.

1973/74 Rehabilitation of the Road Ruindi - Beni (238 km);

1973/74 Rehabilitation of the paved road Nsele - Kenge (216 km);

1973/74 Rehabilitation of the paved road Boma - Tshela (133 km);

1973/74 Rehabilitation of the Road Senge - Kikwit (108 km)

This firm has undertaken such projects as INGA, MALUKU and SOZIA in the country and is engaged in a wide range of activities. The average annual turn-over in recent years amounts to 10,000,000 to 12,000,000 Zaires.

Dumez Zaire Co.

1974/75 Rehabilitation of the Road Kisangani - Buta (316 km)

The history of this firm in this country is comparatively short; however, a wide range of undertaking by this firm is seen in several African countries. Presently, this firm has its construction base near Banalia for the rehabilitation work mentioned above. This firm has its branch office and a motor pool in Kisangani and is engaged in the maintenance work of the project road between Kisangani and Ndu.

Dumon Van der Vin Co.

1972/75 Construction of New International Airport of Kisangani;

1974/75 Rehabilitation of the Road Kisangani - Penetungu (213 km long paved road);

1972/73 Rehabilitation of the Road Insiki - Ngindinga (79 km);

1972/73 Rehabilitation of the Road Kisangani - Yatolema (101 km)

This firm is presently engaged in the construction of a new airport in Kisangani, for which the firm has already developed a quarry producing about 550 tons of aggregates daily at 15 km east of the City. The firm has a branch office and a motor pool in Kisangani.

PARISI Co.

1974/75	Rehabilitation of the paved road Lubumbashi - Kasubalesa (91 km);
1974/75	Rehabilitation of the Road Kananga - Dema (57 km);
1974/75	Rehabilitation of the Road Luputa Pont -- Pont Luilu (101 km);
1974/75	Rehabilitation of the Road Malanga - Luozi (96 km);
1974/75	Rehabilitation of the Road Kananga - Lac Mukamba (11 km long, paved road);
1974/75	Rehabilitation of the Road Kananga - Nbujimayi (163 km);
1974/75	Rehabilitation of the Road Mbuji Mayi --Kabinda (131 km);
1974/75	Rehabilitation of the Road Kananga - Bulungu (65 km);
1974/75	Rehabilitation of the Road Mwene Ditu - Luputa (43 km).

This firm has an influence over the southern regions of this country.

Judging from their construction experiences in this country, each of those firms is believed to be capable of executing 2.5 to 3.0 million Zaires' worth of road construction annually if its force is concentrated.

3.5 Construction Cost of Improvement and Maintenance Cost

3.5.1 Construction Cost of Improvement

(1) General Description

In estimating the construction cost, appropriate unit prices were determined after studying unit prices of similar projects in recent years obtained from Office of Roads and the current market prices of construction materials and the labor prices established by the Government.

However, the unit prices of aggregates and filling materials, which constitute an important part of the materials to be used in this project, are estimated by route section, taking into consideration the locations of quarry and borrow pit.

As mentioned previously, the above 10 route sections were grouped into 4 construction divisions, and the construction costs were accumulated for each of these four divisions.

Alternative I and II are planned in stage construction, from Phase I to Phase II in the former and from Phase I to Phase IV in the latter. (See A.3.4.6 for Alternative I and A.3.4.7 for Alternative II.)

All costs are calculated at the cost level of April, 1975.

(2) Unit Prices

This paragraph is the description of the basis of unit prices for this project.

(a) Official Material Prices and Transportation Charges

The official prices of main construction materials in Kinshasa as of November, 1974 are as follows:

	Official Price in Kinshasa (1)	Estimated Average Price in Project Area
Cement	32.98 Z/ton	60.00 Z/ton
Asphalt RC_2	165.70 Z/ton	186.90 Z/ton
Gasoline	0.22 Z/lit.	0.26 Z/lit.
Fuel Oil	—	0.13 Z/lit.
European Steel bars	411.08 Z/ton	473.00 Z/ton
Sand (for concrete)	3.15 Z/m^3	3.50 Z/m^3 (at quarry)
Crushed stone	4.67 Z/m^3	3.50 Z/m^3 (at quarry)

Source (1) : Departement Travaux Publics et de l'Amenagement du Territoire Annex a Letter No. 601.1/D.G/0463 T.P. & A.T. du Wercuriales des Materiaux pour la Ville de Kinshasa et Zones Annexs, Novembre 1974.

However these unit prices were adjusted to the cost level of April, 1975 before applying to the estimation. Those Kinshasa prices for sand and crushed stone are not used in the estimation, since they are calculated for locally available materials.

The freight transportation charges are shown in Table 3.5.1.

Table 3.5.1 Table of Freight Transportation Charges

Kind of Freight	Matadi - Kisangani	Kinshasa-Buta	Kinshasa - Bondo
Construction Equipment	64.42 Z/ton	51.33 Z/ton	52.29 Z/ton
Steel bridges	54.95 "	44.29 "	45.12 "
Steel bars	47.68 "	39.05 "	39.88 "
Gasoline	37.40 "	31.13 "	31.85 "
Cement	30.21 "	24.72 "	25.41 "
Asphalt	25.63 "	21.12 "	21.81 "

Source: ONATRA April 1975

Fill materials: In the sections of lateritic soils, the material excavated from side ditches is assumed to be used as the filling materials. In the sections of silty soils, the filling materials are assumed to be transported with trucks from the section of lateritic soils. The average haul distance by section and by division have been assumed as follos:

Average Haul Distance of Fill Materials (Unit : km)

Division	Section	Average by Section
IV	# 10	12.4
	# 9	7.4
III	# 8	2.0
	# 7	2.9
	# 6	0.8
II	# 5	0.8
	# 4	1.7
	# 3	2.2
I	# 2	1.3
	# 1	1.0

Aggregates: Most of the aggregates for both concrete and pavement are estimated to be excavated in every section as follow except for Section # 10 where the aggregates for concrete are assumed to be excavated from the vicinity of PK 36 km of the gravel will be transported from Simisimi in the west of

Kisangani, while aggregates for pavement are assumed to be produced at a crushing plant to be established nearby Tshopo River for this project. Prospective quarry sites of aggregates, except for Section #10, are as follows:

Average Haul Distance of Aggregates

Section	Location of prospective quarry site	Type of stone	Average haul distance (km)
#10	Tshopo River	Hard Sandstone	23
#9	PK 120 km Vicinity of Banalia	Hard Sandstone	40
#8 & #7	Old mine 30 km east of Kole	Ore	78 45
#6	30 km east of Buta	Granite	74
#5	Vicinity of 55 km from Buta	Limonite	45
#4	7 locations in the section	"	5
#3	121 - 123 km from Dulia	Granite	30
#2	13 locations at 164 - 247 km from Dulia	Limonite	6.5
#1	Vicinity of 247 km from Dulia	"	39

As for the aggregates for the pre-stressed concrete and the surface dressing course of pavement in the sections where only limonite in available qualified aggregates from other sections should be used.

Materials to be imported: Such materials as asphalt, reinforcing steel bars, manufactured steel bridges, corrugated pipes, steel wires for pre-stressed concrete, steel for temporary works, oils and all types of equipment are assumed to be imported. As for cement, 70% is assumed to be imported and the rest will be produced at a cement plant to be constructed in Kisangani. As for fuels those refined domestically from the imported crude oil is estimated to be used.

(b) Labor Wage

Minumum wages and family allowance common to various types of laborer established by the Ministerial Proclamation[1] dated 23 December, 1970 stipulates the following wage zones in the project area:

Zone I	Kisangani
Zone II	Buta & Aketi Zones
Zone III	Other Zones

Source (1): Ministere du Travaux et de la Prevoyance Sociale. Ordinance No.70-341 Du 23 Decembre 1970 Portant Reglementation des Salaires Minima Interprofessionnels et des Allocations Familiales Minima

Labor wages are calculated by the basic wages stipulated for each zone plus allowances for family, leave, unemployment, overtime, housing and commuting, medical expenses and welfare pension; however, to simplify the calculation for the purpose of the feasibility study, the following average labor unit prices are adopted.

Table 3.5.2 shows the daily wages by type of workers and type of job.

Table 3.5.2 Daily Wages of Workers

Classification	Daily wage	Type of job
Undkilled Labor(A)	Z 1.20	Common Laborer
" (B)	Z 1.25	Earth Worker
Half-skilled Labor	Z 1.50	Mechanic, Assistant operator
Skilled Labor	Z 1.70	Carpenter, Mason, Reinforcement bar worker, Paver, Plasterer, Painter and Plumber
High-skilled Labor	Z 2.00	Machine & equipment operator, Automobile driver
Foreign Expert	Z10.00	Superviser of equipment operator

(c) Construction Equipment

Construction equipment of European origin will be used. The operators will be Zairean and one foreign supervisor will be appointed for every four units of equipment.

(3) Contractor's Overhead Cost

During the stage of Feasibility study, it is impossible to calculate the indirect work cost in detail. Therefore, the construction cost is assumed at 1.3 times as much as the direct construction cost.

30% of the direct construction cost is the overhead cost and is included in unit costs which involve the common temporary work cost, the field administration cost and the general administration cost of the contractor and the compensation cost for the local houses, etc. to be removed from right-of-way. And the overhead cost is included in the unit prices for the purpose of simplification of calculation in this report.

However, for the pavement work under Phase II of Alternative I and Phase IV of Alternative II, which are constructed independently of other works with much less total cost than that of Phase I and for which the proportion of common temporary work cost gets higher to the direct construction cost, the construction cost is assumed at 1.4 times as much as the direct construction.

(4) Construction Cost

The relation among the construction cost, the quantity of work and unit price is as follows:

Construction cost = (quantity of work) x (unit price including overhead cost)

For calculation of the improvement cost of each phase of work under Alternatives I and II for each route section and the entire construction division, the paragraph in appendices shown in Table 3.5.3 should be referred to.

Table 3.5.3 Appendix Number showing Details of Construction Cost

Phase	Construction Cost by Route Section		Construction Cost by Construction Division	
	Alternative I	Alternative II	Alternative I	Alternative II
I	A.3.5.3	A.3.5.7	A.3.5.2	A.3.5.6
II	A.3.5.4	A3.5.8	A.3.5.4	A.3.5.8
III	-	A3.5.8.	-	A.3.5.8.
IV	-	A3.5.8.	-	A.3.5.8.

(5) Other Costs

As for other costs, contingencies, the cost of final engineering, and the cost of the supervision of construction are considered.

(a) Contingencies

Contingencies are the costs to cover the deficiency in construction cost caused by unforeseen geological conditions, partial alteration of design and the difference between the results of feasibility study and the actual conditions of work and also the additional final engineering cost and supervision cost relating to the increaed qnantity of work. This cost item is assumed to be 15 per cent of the construction cost.

(b) Cost of Final Engineering

The cost of final engineering includes the cost of route and topographical survey and the cost of geological boring in addition to the cost of design work of construction plans. The ratio of each item to the construction cost is assumed as follows:

Costs of topographical and route surveys 1.0%
Cost of geological borings 0.6%
Cost of design work of construction plans 4.4%

Cost of final engineering ... Construction cost x 6.0%

(c) Cost of Supervision of Construction

Supervision of construction is comprised of construction progress control, quality control, and cost control to be carried out by a combined force of foreign and local engineers headed by a foreign expert who is also in charge of design and training of the local engineer.

The cost of supervision of construction includes such items as direct personnel expense, office expense, training expense, vehicle expense, testing expense and overhead expense, the total of which is estimated at 5% of the construction cost.

(d) Compensation Cost

Since the compensation cost is included in the overhead cost of contractor in this report, the amount of compensation cost is not shown.

However, for reference, the approximate calculation is shown below to indicate what percentage the compensation cost occupies of the construction cost.

Since the land is state-owned, no cost is required for the purchase of right-of-way. The compensation cost required is only for plants in plantations to be filled and houses to be relocated.

Alternative I:

- Plantations 142,650 m^2 x Z2/m^2 = Z 285,300