Chapter 5 Technical Analysis

This chapter, consisting of three sections, discusses the results of technical analysis of the Project.

The first part involves the present state of the project road; and the fundamental policy of the improvement program and the second part clarifies the alternative improvement plans studied, based on the policy mentioned in the foregoing part. The last part deals with the process of calculating the costs of improvement and maintenance as well as the results of these calculations.

5.1 The Present State of Maintenance of the Project Road and Establishment of Improvement Level

1) The Present State of Maintenance of the Project Road

(See photographs in Vol. 2.)

a. General

The project road, located in moist tropical forests with much rainfalls, mostly passes through dense jungles except for where it passes through towns, villages and agricultural farms.

The project road from Tshopo River to Aruwimi River passes along a slightly rolling ridge with elevations ranging from 400 m to 470 m. The jungle along this section of the road comprises of 20 to 30 m tall trees and thick bushes of shorter trees of 5 to 6 m tall underneath and weeds on the ground. The road between Aruwimi River and Likati River passes through comparatively flat or slightly rolling terrain at an elevation of 400 to 470 m. This section of the road is surrounded by dense jungle and trees taller than 40 m are frequently observed. There are also many marshes. From Likati River to Bomu River the road is located on a terrain with elevations varying from 400 to 590 m and the terrain north of Monga is comprising of low rolling hills. Vegetation

of more or less savanna nature starts to appear along this section of the the road. The trees lessen in height to 5 to 6 m and the jungle becomes sparse but the area near the rivers is covered with dense jungle.

b. Road Surface

The project road is presently a dirt road mostly with a width of 3.5 to 5.5 m.

Approximately one third of the entire route passes through land with silty soils. It is these sections of the road that turn into muddy pools during the wet season.

Other sections of the road pass through lateritic soil terrain, but because of the lack of maintenance work, pots and holes are observed at many places, prohibiting smooth operation by vehicular traffic. It is only in the vicinity of Kisangani and in the towns of Buta, Banalia and Bondo troughout the entire route that passenger cars can be operated all year round.

c. Alignment

Since the entire route of the project road is situated on a terrain of gentle undulation, most of the sections have a grade of less than 4% except for short sections at approaches to rivers where the road sags with a 5 to 14% grade. The total length of the sections with grades of more than 4% is about 30 km, and that with grades exceeding 7% is merely 5 km.

As for alignment, many severe curves are seen throughout the entire route. Of the total 1,450 curves, there are 1,022 curves with raddi of 230 m or less which is the minimum radius allowed in the present national road design standards. The total length of these curves reaches 198 km. 339 of these 1,022, are curves with raddi of less than 100 m covering some 70 km.

d. Drainage and Crossing Culverts

The surface of the existing road is generally lower than the surface of the surrounding ground. As the side ditches in most of the sections have already been buried, rain water accumulates on the road surface, causing muddy pools.

Even in the sections of the road with side ditches not completely buried, the grade of the side ditches is not steep enough for draining and the ditches are shallow. Thus, the ditches must be improved firstly.

Where the grade of the road exceeds 4% rainwater running over the road surface causes errosion.

Where the jungle exists next to the road, often bamboo hovers over the road, obstructing sunlight and the road is often a muddy pool even in the dry season.

There are only 163 culverts which cross the road throughout the entire route. This indicates that the proportion of existing culverts is only one for every 5 km of the road on an average. Culverts are seldom seen north of Dulia. Moreover these culverts are too small in size to drain water and thus many of the culverts are clogged with dirt. Consequently the road floods during wet seasons where the culverts cross the road.

e. Bridges

There exist 134 bridges, most of them made of wood, along the route and the total length of the bridges is approximately 1,300 m.

Wooden bridges number 119, of which 60% have a span of 2.0 to 5.0 m. Only 10 bridges have a span of more than 10.0 m.

The wooden bridges are in extremely poor condition, for only a small portion of the bridges are made of timber and the rest are merely constructed of logs or undressed materials. The bridges are all for one-lane traffic with a weight capacity of 8 tons and a speed limit of 10 KPH is imposed.

There exist 3 reinforced concrete bridges (total length: 37 m) with widths varying from 4.0 to 6.5 m, all for one-lane traffic.

Three plate girder bridges (total length: 29 m) are observed throughout the entire route. Its width is approximately 6 m.

There are 12 steel trussed bridges (total length: 650 m), all for one-lane traffic. The weight capacity of these bridges varies from 2 vehicles of 10 to 12 tons per span and a speed limit of 10 KPH is imposed.

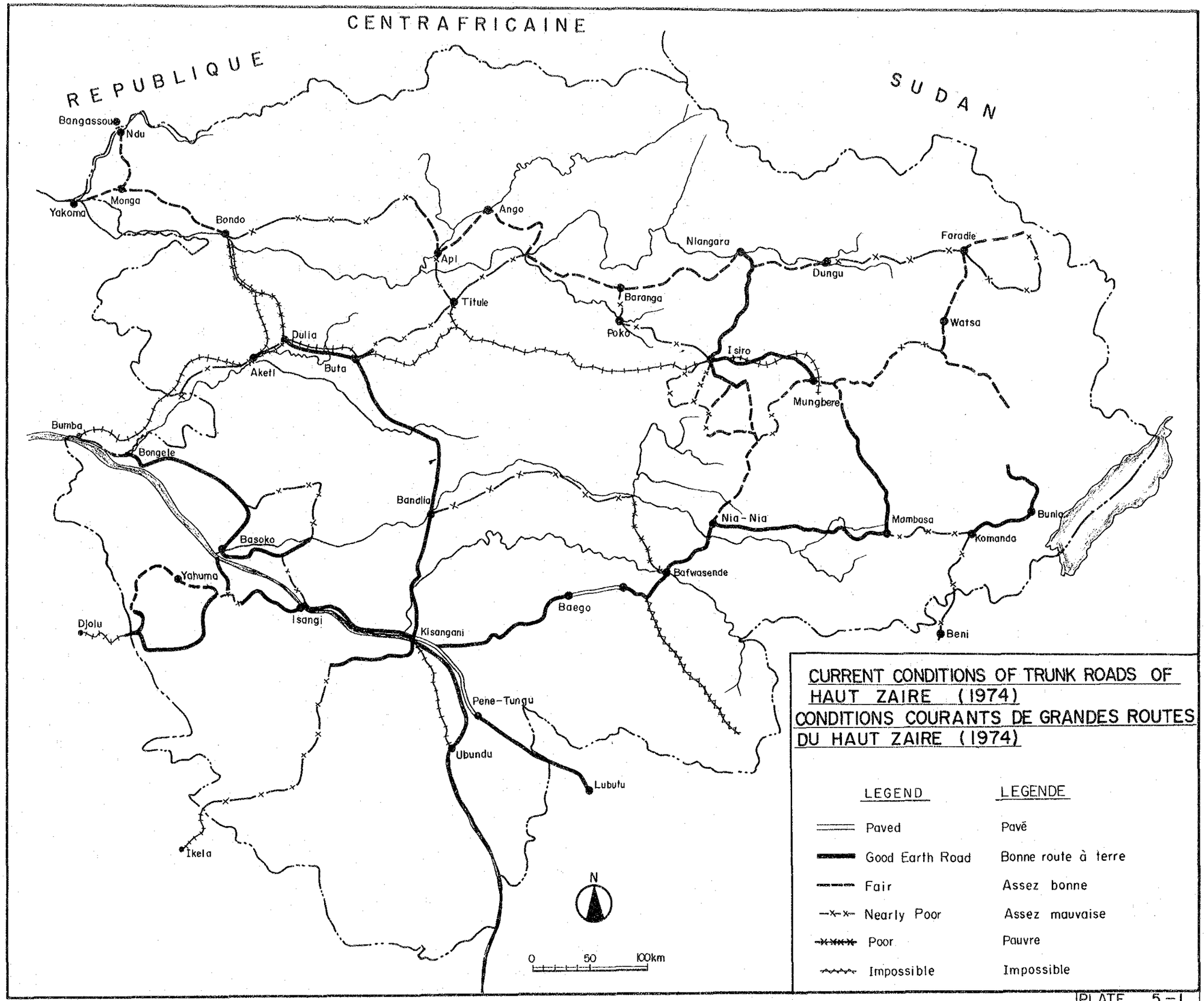
The steel bridges are 16 to 22 years old and widening or reinforcement is almost impossible.

f. Ferries

Going northward, ferry service is provided at the Aruwimi River (640 m wide), the Uélé River (200 m wide), the Bili River (150 m) and the Bomu River (360 m wide). The ferry boats used are; 35-ton engined boat at the Aruwimi River, a 28-ton engined boat at the Uélé River, an 8-ton row boat at the Bili River and a 12-ton engined boat at the Bomu River.

2) Establishment of Improvement Level and Design Standards to be adopted

Since the route investigated is classified as a lst class national road in Ziare and the design standards for national roads set by the Zaire Government for design speed for example vary from 80 to 110 km on flat land, to 55 to 80 km on hilly terrain; the following design standards have been adopted based on the standards of Zaire, taking into consideration the local topographical features and the economy of the improvement program.



CURRENT CONDITIONS OF TRUNK ROADS OF HAUT ZAIRE (1974)
CONDITIONS COURANTS DE GRANDES ROUTES DU HAUT ZAIRE (1974)

LEGEND	LEGENDE
Paved	Pavé
Good Earth Road	Bonne route à terre
Fair	Assez bonne
Nearly Poor	Assez mauvaise
Poor	Pauvre
Impossible	Impossible

PLATE 5-1
PLANCHE 5-1

Table 5.1 Design Standards Adopted

	Sections south of Lindi River	Sections north of Lindi River
1. Design speed	100 KPH	80 KPH
2. Width of right of way	40 m	40 m
3. Width of carriageway	6.6 m	6.0 m - 6.6 m
4. Width of shoulder	2.2 m	0.0 m - 2.2 m
5. Sight distance	160 m	110 m
6. Minimum radius of curvature	350 m	230 m
7. Maximum longitudinal grade	3%	4%
8. Maximum composite grade 1/	8%	8%
9. Lateral slope of carriageway		
(a) Paved road	3%	3%
(b) Laterite road	4%	4%
10. Lateral slope of shoulder	4%	4%
11. Bridge		
(a) Design load	BS - 153	BS - 153
(b) Width of carriageway (including allowance for drainage)	8.0 m	7.0 m - 8.0 m
(c) Width of sidewalks (for bridges longer than 50m)	2 x 1.5 m	2 x 1.5 m
(d) Clearance of bridge	4.5 m	4.5 m

Note 1/ Represents the maximum value of composite grade which combines longitudinal grade and lateral slope of carriageway.

5.2 Improvement Program

1) Fundamental Policy of Improvement Program

The fundamental concept for the improvement program is as follows:

i) The result of studies made on the improvement of the existing road on the construction of a new road has proved that the improvement utilizing the alignment of the existing road is most reasonable. Therefore, the improvement program is generally based on the improvement along the existing road and where construction of a shortcut road is expected to entail traffic benefits greater than the construction cost involved, a shortcut road will be constructed.

The reasons supporting improvement utilizing the alignment of the existing road, as is evident, lies in the following points:

- The existing road connects the principal towns together with the productive areas within the Project Area and is a direct route.
- The existing road is located on a terrain with relatively favorable topographical and hydrological conditions. The alignment of the existing road is generally reasonable and with partial improvement the required standards for improvement may easily be attained because 77% (538 km) of the existing alignment can be utilized as the parts of the improved road which results in much economy of the construction.
  The term "existing road" used herein means the completed state of the road between Kisangani and Buta which is being rehabilitated at present and the presently maintained state of the road between Buta and Ndu.

ii) For furtherance of the effect of investment, step-by-step improvement will be made depending on the volume of estimated traffic.

2) Outline of Alternative Improvement Programs

Two improvement programs have been worked out for comparison.

Alternative I

- A two-lane paved road with width of 11 m (Carriageway width: 6.6 m shoulder width 2 x 2.2 m) is contemplated throughout the entire route with a cleared zone of 13.5 m wide on each side of the road.

- Existing wooden bridges will be replaced with pipe-culverts or reinforced concrete bridges and the existing reinforced concrete bridges, plate girder bridges and steel trussed bridges will be widened throughout the entire route.

- Landing facilities will be constructed at three ferry sites. Ferry service across the Aruwimi River will be abolished and a steel bridge with the width of two-lane and walkways will be constructed instead. Thus, most of the improvement works will be performed at the initial stage of the Project.

Alaternative II

- An all-weather two-lane road is intended at the initial stage of the Project with a cleared zone of 10 - 11 m wide on each side of the road.

- Depending on the estimated volume of traffic, the width of the road will range from 6 to 11 meters. The width of cleared right of way will accordingly vary from 26 to 31 meters.

- The road between Kisangani and Banalia will be paved at the initial stage of the Project while the Banalia-Buta section will be paved in a later stage. The road north of Buta will have a laterite wearing course for the entire Project period.

- Existing wooden bridges will be replaced either with pipe culverts or reinforced concrete bridges at the initial stage of the Project. Reinforced concrete bridges and plate girder bridges will be widened to 8 to 11 m. Steel trussed bridges will be widened at a later stage depending on the volume of traffic.

- Ferry services at four sites will continue to exist and landing facilities will be constructed at the initial stage of the Project. As for the Aruwimi River, additional ferry boats will be provided depending on the volume of traffic.

- These improvement programs will be carried out in four phases. The details of these two improvement programs are shown respectively in Tables 5.2 and 5.3.

- Plates 5.2 to 5.3 shows standards cross sections of the road at principal route sections for the respective programs.

- Plate 5.4 shows the types of the pavement to be applied according to the type of subgrade soils and the estimated volume of traffic.

Reduction of the road length due to improvement in either Alternative I and Alternative II is estimated to be about 2.64% (19 km), by which the total length of road will be reduced from 718.6 km to 699.6 km. (See Vol. 2, Table 3.4.2)

Table 5.2 Details of Improvement Program

(Alternative I)

Item of Improvement	Location of Route Section	Details of Improvement	
		Phase I (1979-1983)	Phase II (1991)
1. Platform width of road	Entire route	2.2m + 6.6m + 2.2m = 11.0m	——
2. Alignment	South of the Lindi River	Improve into R $\geq$ 380 m	——
	North of the Lindi River	Improve into R $\geq$ 230 m	——
3. Longitudinal grade	South of the Lindi River	Improve into i $\leq$ 3%	——
	North of the Lindi River	Improve into i $\leq$ 4%	——
4. Clearing width	Entire route	Clear the width of 36 - 40 m	——
5. Pavement	Entire route	Surface dressing	Overlay (Kisangani-Banalia)
		Cement stabilized base course	
		Laterite sub-base course	
6. Culverts	Entire route	Improve 18 locations and newly install at locations	——
7. Wooden bridges	Entire route	Replace at 122 locations with pipe culverts	——
		Replace at 7 locations with reinforced concrete bridges	——
8. Reinforced concrete bridges	South of Banalia	Replace 3 bridges (total length 37m) with 8 m wide reinforced concrete bridge	——
9. Plate girder bridges	South of Banalia	Replace 3 bridges (total length 29m) with 8 m wide reinforced concrete or plate girder bridges	
10. Steel trussed bridges	Lindi River (257 m) Rubi River (100 m) Likati River (84 m)	Replace with composite or P.C. girder bridges of 1.5m + 8.0m + 1.5m = 11.0m in width	——
	Zambeke River (28 m) Kole River (20 m) Tele River (42 m) Yeme River (16 m) Longa River (25 m)	Replace with P.C. girder bridges of 8 m in width (without sidewalks)	
	Aruwimi River (640 m)	Abolish the existing ferry and construct a new composite girder bridge of 1.5m + 8.0m + 1.5m = 11.0m in width	——
	Libogo River (75 m)	Construct a new P.C. girder bridge of 1.5m + 8.0m + 1.5m = 11.0m in width	——
11. Ferry landing facilities	Both banks of Uele River	Newly construct	——
	Both banks of Bili River		——
	Both banks of Bomu River		——

Note: 1/ Typical sections of pavement are shown in Plate 5.4

Table 5.3 Details of Improvement Program (Alternative II)

Note: 1/ Typical sections of pavement are shown in Plate 5.2

Item of Improvement	Location of Route Section	Phase I (1979 - 1983)	Phase II (1984 - 1956)	Phase III (1987 - 1994)	Phase IV (1994 - 1997)
1. Platform width of road	Kisangani - Banalia	2.2 + 6.6 + 2.2 = 11.0 m	———	———	———
	Banalia - Dulia	1.5 + 6.0 + 1.5 = 9.0 m	———	———	———
	Dulia - Ndu	0 + 6.0 + 0 = 6.0 m	———	———	———
2. Alignment	Entire route	(The same as Alternative I)	———	———	———
3. Longitudinal grade	Entire route	(The same as Alternative I)	———	———	———
4. Clearing width	Kisangani - Banalia	31 - 33 m	———	———	———
	Banalia - Dulia	29 m	———	———	———
	Dulia - Ndu	21 m	———	———	———
5. Pavement 1/	Kisangani - Banalia	(The same as Alternative I)	———	(The same as Alternative I	———
	Banalia - Ndu	Laterite surface	———	Banalia - Buta surface dressing	———
6. Culverts	Entire route	(The same as Alternative I)	———	———	———
7. Wooden bridges	Entire route	(The same as Alternative I)	———	———	———
8. Reinforced concrete bridges	South of Banalia	(The same as Alternative I)	———	———	———
9. Plate girder bridges	South of Banalia	(The same as Alternative I)	———	———	———
10. Steel trussed bridges	Lindi Bridge (257m)	———	Replace with a new composite girder bridge of 1.5 +8.0+1.5=11.0m in width	———	———
	Rubi Bridge (100m)	———	Replace with a new P.C. girder bridge of 1.5+7.0 +1.5=10.0m in width	———	———
	Zambeke Bridge (28m)	———			
	Kole Bridge (20m)	———		Replace with P.C. girder bridge of 7m in width	
	Tele Bridge (42m)	———			
	Yeme Bridge (16m)	———			
	Likati Bridge (84m)	———	———	Replace with P.C. girder bridge of 1.5+7.0+1.5= 10.m in width	———
	Libogo Bridge (75m)	———	———	Replace with P.C. girder bridge of 1.5+7.0+1.5= 10.0m in width	———
11. Ferry landing facilities	Aruwimi River	———	Newly construct a 35 ton-type ferry boat and a ferry landing facility	Newly construct a 35 ton-type ferry boat and a ferry landing facility	Newly construct a 35 ton-type ferry boat and a ferry landing facility
	Uele River	Newly construct	———	———	———
	Bili River		———	———	———
	Bomu River		———	———	———

PLATE
PLANCHE 5-2

TYPICAL CROSS SECTION / PROFIL EN TRAVERS TYPE (ALTERNATIVE-I)

SECTION TRONÇON KISANGANI – NDU

Unit / Unité: m

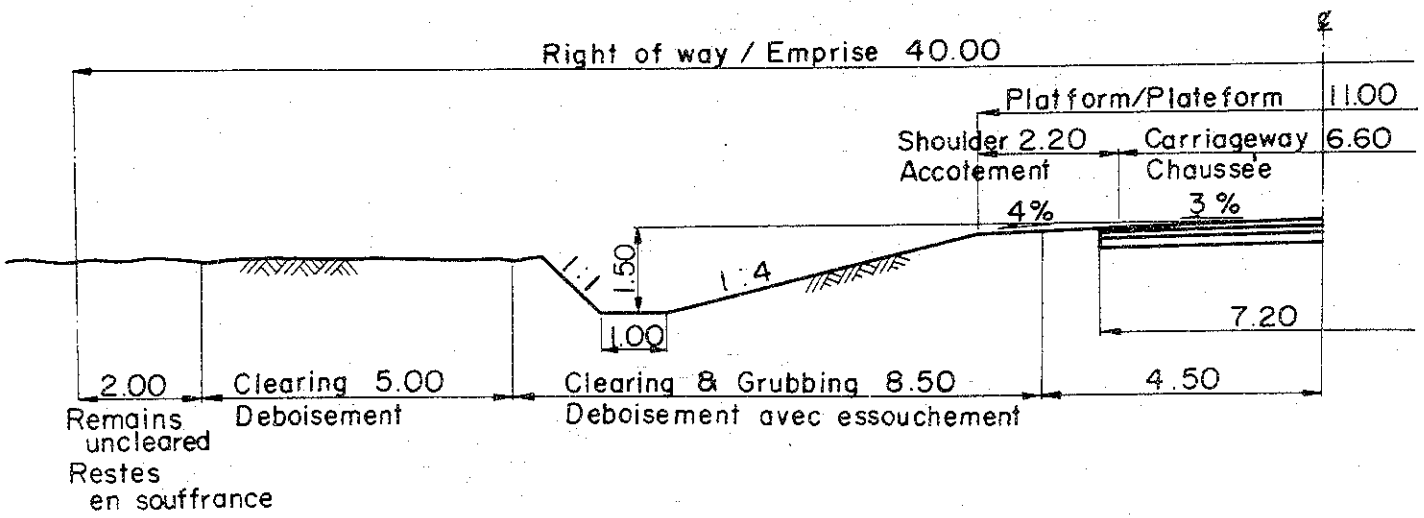
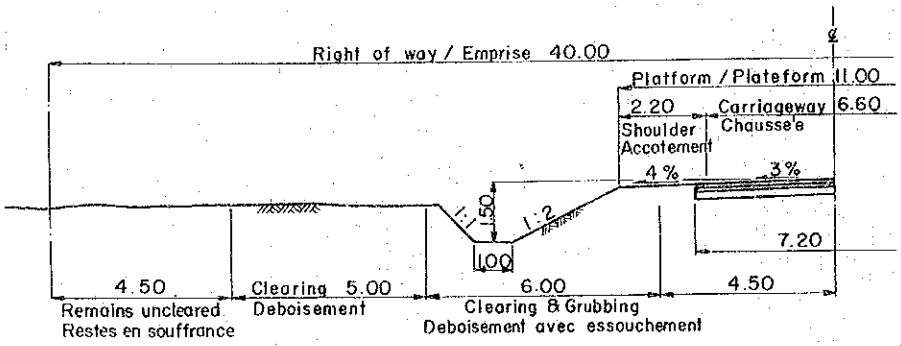


PLATE
PLANCHE 5-3

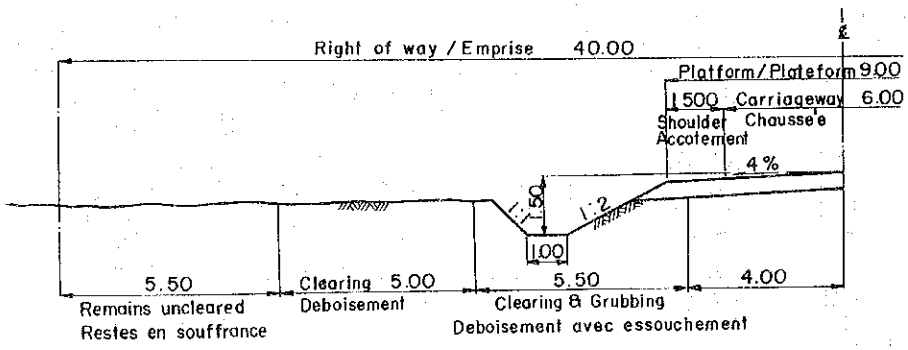
TYPICAL CROSS SECTIONS / PROFILS EN TRAVERS TYPE (ALTERNATIVE-II)

SECTION TRONÇON KISANGANI – BANALIA

Unit/Unité



SECTION TRONÇON BANALIA – DULIA



SECTION TRONÇON DULIA – NDU

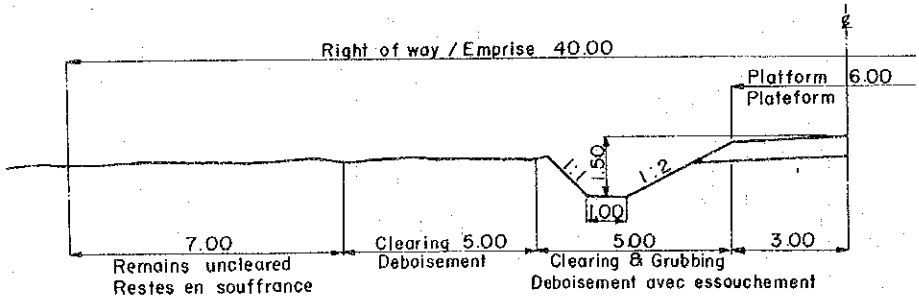
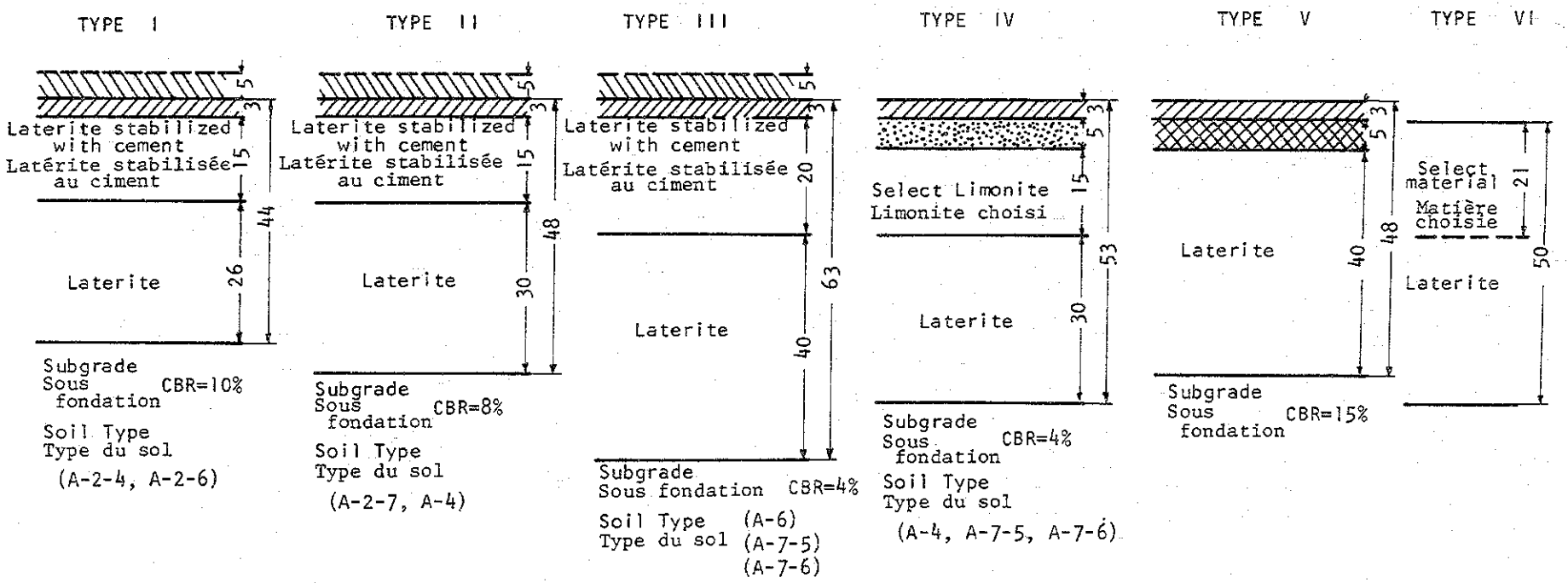


PLATE
PLANCHE 5-4 TYPES OF PAVEMENT / TYPES DU REVÊTEMENT (Unit / Unité : cm)



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	

Legend / Legende

- 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)

5.3 Costs of Improvement and Maintenance Works

1) Conditions of Cost Estimation

The cost estimation of improvement and maintenance of the road is based on the following conditions:

a. Construction to be performed by all-in contract.

b. Cost is as of April, 1975.

c. Cost of improvement works and the volume of works required for maintenance will apply when the rehabilitation presently underway is completed.

2) Composition of Costs of Improvement and Maintenance Works and Basic Method of Cost Estimation

The purpose to the cost estimation is to obtain the total project cost as well as to clarify the classification of the currency components, such as foreign currency, domestic currency and tax for cost/benefit analysis.

The basic method used for cost estimation is as follows:

a. The items composing construction cost are mainly labor, equipment and material costs. These costs are further broken down in detail. Construction unit cost and the unit cost composition (domestic currency, foreign currency and tax) have been estimated based on the local investigation of construction materials, a study of construction methods, past construction achievement of the local contractors and the construction unit costs used by the Ziare Government in recent years.

b. As for the cost of improvement works, direct construction costs for each work, drainage work, pavement work, bridge work and ferry facility improvement work have been estimated from the quantity of

works estimated from the preliminary design plans prepared according to the improvement alternatives and the unit costs estimated under item "a" above.

Overhead costs for the direct construction cost have been estimated for the two improvement alternatives referring to the past construction data of similar works in Zaire, and are included in the unit costs.

Contingency, costs of final engineering and supervision of construction have been calculated in proportion to the net construction cost comprised of direct construction costs and overhead costs, referring to the past data.

c. The cost of maintenance works has been estimated by establishing levels of maintenance and the method of work required respectively for the existing road and the improved road. Likewise, the cost of improvement work, composition of the cost of maintenance work, classified by foreign currency component, domestic currency components and tax component is also clarified.

3) Cost of Improvement Works

Cost of improvement works is shown in Tables 5.4 and 5.5 for Alternative I and in Tables 5.6 and 5.7 for Alternative II. The total construction cost including taxes for Alternative I is 77.6 million Zaires and the average improvement cost per kilometer throughout the route is 111,000 Zaires.

The total construction cost including taxes for Alternative II is 53.1 million Zaires which is approximately 30% less than that of Alternative I. The average improvement cost per kilometer throughout the route is 76,000 Zaires.

The proportion of foreign currency component to the total improvement cost is approximately 50% for the two alternatives.

Table 5.4 Improvement Costs of Project Road by Item (Alternative I)

Tableau 5.4 Coûts d'amélioration de la route de projet par article 1/

(Unit / Unité : 1,000 Zaires)

Division		Kisangani - Banalia	Banalia - Buta	Buta - Bondo	Bondo - Bangassou	Total
Item / Article						
Total Length / Longueur totale (km)		122.6	187.8	197.9	190.6	698.9
Phase-I (1977-1983)	Earthworks / Terrassements 2/	5,590	3,349	2,494	3,002	14,435
	Drainage / Drainage	1,296	1,658	1,448	1,646	6,048
	Pavement / Pavage	6,360	8,603	7,767	6,572	29,302
	Bridges / Ponts	2,009	5,229	1,459	108	8,805
	Ferries / Bacs	-	-	18	23	41
	Final engineering & supervision / Technique de l'ingénieur finale & surveillance	1,678	2,072	1,450	1,248	6,448
	Contingency / Faux frais divers	2,288	2,826	1,978	1,703	8,795
	Total	19,221	23,737	16,614	14,302	73,874
Phase-II (1991-1992)	Pavement / Pavage	2,992	-	-	-	2,992
	Final engineering & supervision / Technique de l'ingénieur finale & surveillance	330	-	-	-	330
	Contingency / Faux frais divers	449	-	-	-	449
	Total	3,771	-	-	-	3,771
Grand total cost / Coût total		22,992	23,737	16,614	14,302	77,645
Cost per 1 km / Coût par 1 km		187.5	126.4	84.0	75.0	111.1

Table 5.5 Currency Components of Improvement Costs of Project Road (Alternative-I)
Tableau Composition de monnaie de coûts d'amélioration de la route de projet

	Total Cost (including taxes) Coût total (inclu taxes)	Total Cost (excluding taxes) Coût total (enclu taxes)	Foreign Currency Component Partie composante de monnaie étrangère	Local Currency Component Partie composante de monnaie locale
Cost (Unit: 1,000 Z) Coût (Unité: 1,000 Z)	77,645	64,149	38,886	25,263
Percentage (%) Pourcentage (%)	100	82.6	50.1	32.5

Notes on Table 5.4 and 5.5.
Notes on Tableau 5.4 et 5.5

1) Costs are based on the cost level of April 1975 and without adjustment by shadow-pricing and discounting.
Coûts sont basés au niveau du coût d'avril 1975 et sans arrangement du prix économique et prix faible.

2) Costs of Overhead, Temporary Work, Mobilization, etc. are included in each improvement cost by item.
Coûts des frais généraux, ouvrage temporaire, mobilisation, etc. ont inclu dans chaque coût d'amélioration par article.

3) Earthworks include Clearing, Cuts and Fills, Side Slopes Protection.
Terrassements inclu abattage d'arbre, déblai et couche de forme, protection de talus.

4) Currency composition is based on the assumption that fuels are refined at domestic refinaries using imported crude oils.
Composition de monnaie et basée dans le supposition que combustible raffinent au raffineur domestique de faire usage des huiles brutes importées.

Table 5.6 Improvement Costs of Project Road by Item (Alternative-II)
Tableau Coûts d'amélioration de la route de projet par article

(Unit / Unité : 1,000 Zaires)

ivision			Kisangani - Banalia	Banalia - Buta	Buta - Bondo	Bondo - Bangassou	Total
tem/Article							
Total length (km) / Longueur totale (km)			122.6	187.8	197.9	190.6	698.9
hase-I (1979-1983)	Earthworks	/ Terrassements	4,356	1,774	1,404	1,997	9,531
	Drainage	/ Drainage	1,178	1,547	1,226	1,365	5,316
	Pavement	/ Pavage	6,360	1,371	1,838	1,791	11,360
	Bridges	/ Ponts	-	-	343	96	439
	Ferries	/ Bacs	-	17	18	23	58
	Final engineering & supervision	/ Technique de l'ingénieur finale & surveillance	1,309	522	531	580	2,942
	Contingency	/ Faux frais divers	1,784	706	725	791	4,006
	Total	/ Total	14,987	5,937	6,085	6,643	33,652
hase-II (1985-1986)	Bridges	/ Ponts	2,009	550	-	-	2,559
	Ferries	/ Bacs	-	120	-	-	120
	Final engineering & supervision	/ Technique de l'ingénieur finale & surveillance	221	74	-	-	295
	Contingency	/ Faux frais divers	301	101	-	-	402
	Total	/ Total	2,531	845	-	-	3,376
hase-III (1991-1994)	Pavement	/ Pavage	2,993	8,167	-	-	11,160
	Bridges	/ Ponts	-	416	974	-	1,390
	Ferries	/ Bacs	-	120	-	-	120
	Final engineering & supervision	/ Technique de l'ingénieur finale & surveillance	329	963	107	-	1,399
	Contingency	/ Faux frais divers	449	1,305	146	-	1,900
	Total	/ Total	3,771	10,971	1,277	-	15,969
Phase-IV (1977)	Ferries	/ Bacs	-	120	-	-	120
	Final engineering & supervision	/ Technique de l'ingénieur finale & surveillance	-	13	-	-	13
	Contingency	/ Faux frais divers	-	18	-	-	18
	Total	/ Total	-	151	-	-	151
Grand total cost / Coût total			21,289	17,904	7,312	6,643	53,148
Cost per 1 km / Coût par 1 km			173.6	95.3	36.9	34.9	76.0

Table 5.7 Currency Components of Improvement Costs of Project Road by Item (Alternative-II)
Tableau Composition de monnaie de coûts d'amélioration de la route de projet

	Total Cost (including taxes) Coût total (inclu taxes)	Total Cost (excluding taxes) Coût total (enclu taxes)	Foreign Currency Component Partie composante de monnaie étrangère	Local Currency Component Partie composante de monnaie locale
Cost (Unit: 1,000 Z) Coût (Unité: 1,000 Z)	53,149	43,881	26,576	17,305
Percentage (%) Pourcentage (%)	100	82.6	50.0	32.6

Notes on Table 5.6 and 5.7.
Notes on Tableau 5.6 et 5.7.

1) Costs are based on the cost level of April 1975 and without adjustment of shadow-pricing and dicounting.
Coûts sont basés au niveau du cout d'avril 1975 et sans arrangement du prix économique et prix faible.

2) Costs of Overhead, Temporary Work, Mobilization, etc. are included in each improvement cost by item.
Coûts des frais généraux, ouvrage temporaire, mobilisation, etc. ont inclu dans chaque coût d'amélioration par article.

3) Earthworks include Clearing, Earthworks, Side Slope Protection.
Terrassements inclu abattage d'arbre, déblai et couche de forme, protection de talus.

4) Cost of Maintenance Works

The cost of maintenance of the existing road has been estimated at the cost required to maintain the road condition under which a very muddy state does not occur throughout the year and yet adequate for maintaining the average vehicular speed (36 - 40 km/hr in dry seaons and 18 - 20 km/hr in rainy seasons) (See Supporting Report 2.3.2).

The cost of maintenance of the improved road has been estimated by establishing methods of maintenance for fixed portions regardless of the traffic volume (cost of maintenance of shoulder, side-slope, side ditches and cleared zone) and for variable portions depending on the traffic volume (maintenance of road surface) for both the improved laterite road and paved road.

The results are as follows:

Cost of maintenance of improved laterite road (C)

$C = (430 + 3.4 \times ADT)$ Z/km/year

Cost of maintenance of paved road (C')

$ADT \leq 1,500$ $C' = 430 + 600 = 1,030$ Z/km/year

$ADT > 1,500$ $C' = 1,030 + 0.4 \times (ADT - 1,500)$ Z/km/year

The cost of maintenance of bridges and ferry facilities has also been estimated. The maintenance cost of ferry boats includes operational expenses.

Operating Speed Levelsto be maintained by Maintenance Work

(KPH)

	Paved Surface	Improved Laterite Surface	Existing Earth Road	
			Dry months	Wet months
Light Vehicles	75	60	40	20
Heavy Vehilces	70	55	36	18

(See Vol. 2, 2.3.2.)

Chapter 6. Evaluation of the Project

This chapter describes the method of benefit-cost analysis adopted in the economic evaluation of the study as well as the work procedures and results of the analysis.

6.1 The Methodology of Benefit-Cost Analysis

1) The Method and Process of Analysis

The economic justification of a project is made by comparing the present value of the benefits that may be expected from the implementation of the project and that of the costs of the project. In this study, two methods, namely the benefit/cost ratio method and the internal rate of return method were adopted.

a. Benefit/Cost Ratio (R')

In the benefit/cost ratio method, the annual costs and benefits related to the implementation of the project area estimated for the analysis period, then converted to present worth with a suitable discount rate and then to calculate the ratio derived dividing the accumulated benefits with the accumulated costs. The project is considered economically feasible if the ratio (R') is greater than 1. The method may be expressed in a formula as follows:

$$R' = \frac{\sum_{t=1}^{n} \left\{ \frac{Bt}{(1+r)^t} \right\}}{\sum_{t=1}^{n} \left\{ \frac{Ct + AEt}{(1+r)^t} \right\} - \frac{S}{(1+r)^n}}$$

where n : Analysis period (number of years)

r : Discount rate

Bt : Benefits of the t year

Ct : The cost of improvement of the road for the t year
AEt : The cost of maintenance of the road for the t year
S : The residual value of the road at the end of analysis period

b. Internal Rate of Return (R)

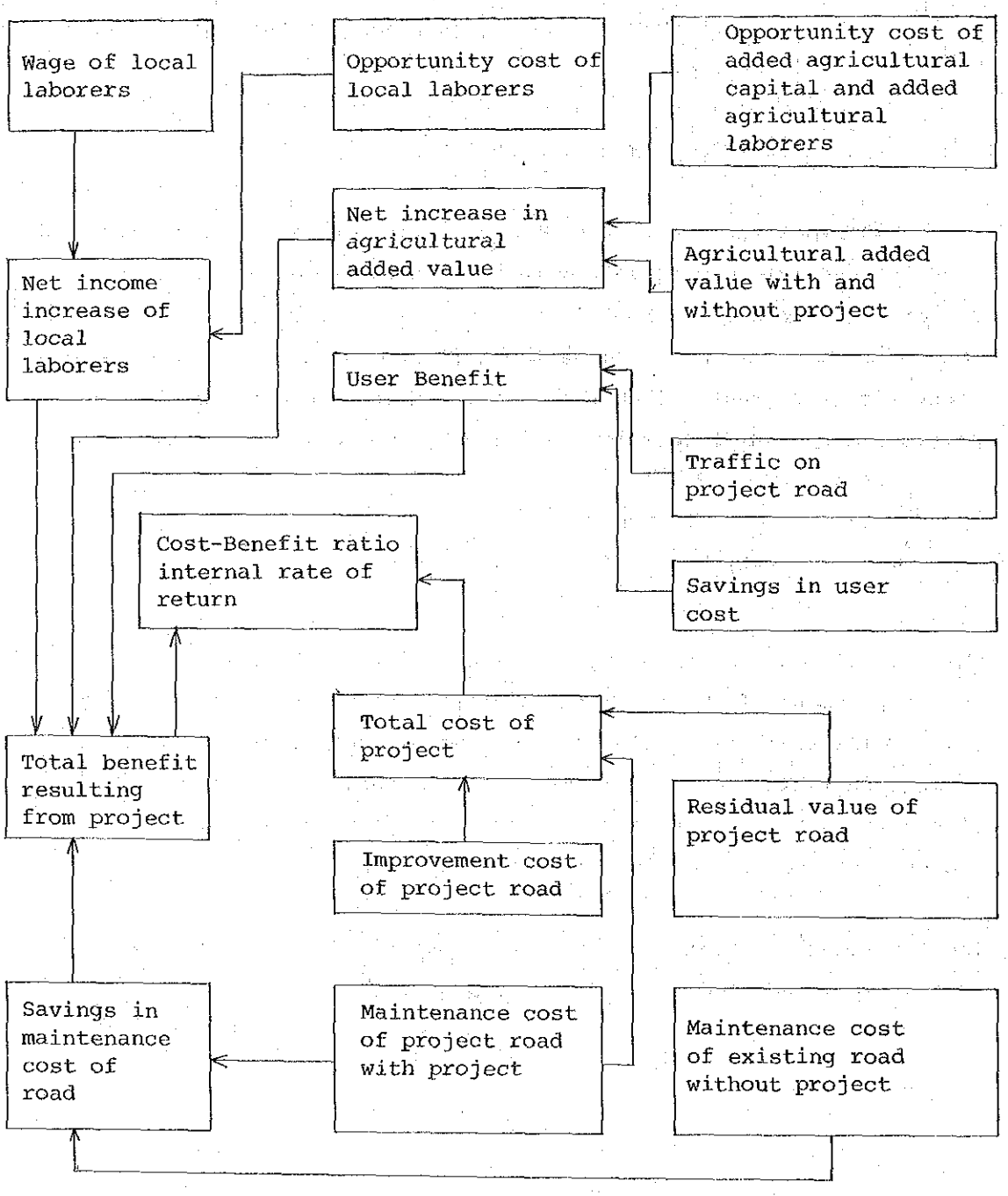
In the internal rate of return method a discount rate is determined so that the accumulated present worth of benefits is equal to the accumulated present worth of costs. In the following formula, if the internal rate of return (R), which makes the left side of the formula equal the right side, is greater than the opportunity cost of capital of the project, then the project is considered economically feasible.

$$\sum_{t=1}^{n} \frac{Bt}{(1+R)^t} = \sum_{t=1}^{n} \left\{ \frac{Ct + AEt}{(1+R)^t} \right\} - \frac{S}{(1+R)^n}$$

The cost elements of the project are composed of the costs required for the improvement of the road and the costs for the maintenance of the road, while the benefit elements consist of four items which are the savings in vehicle operation costs, the savings in maintenance costs of the road, the net increase in added value of agricultural products and the net increase of income of construction laborers.

The flow-chart of Plate 6.1 shows the outline of the process of benefit-cost analysis adopted in this study.

Plate 6.1. Process of Cost-Benefit Analysis



2) Basic Concept Regarding the Main Conditions of Analysis

The basic concept regarding the various important points in the benefit-cost analysis are described below.

a. The Analysis Period of Costs and Benefits

The year of commencement of construction work is assumed to be 1979, and in the Alternative II, some additional investment is proposed nearly 20 years later. Thus, in order to include the effects of this additional investment in the analysis, the analysis period is determined at 30 years after commencement of construction work.

b. Residual Value of the Project

Since the analysis period is long, the residual value at the end of the analysis period is anticipated to be negligibly small. Therefore in this study the residual value is assumed to be zero.

c. Discount Rate

Theoretically, the discount rate adopted should be equal to the opportunity cost of the capital in Zaire. However, since this is very difficult to determine in this study, the discount rate of 12% was adopted considering the international level of rate of interest and the discount rate used in other similar projects in Zaire.

d. Shadow Rate

It is very difficult to assess the economic value of the Zaire currency and in this study, the economic value of one Zaire was assumed to be 1/1.5 that of the official rate in the economic analysis. This assumption was also adopted in the feasibility study for the Bukavu-Kindu Road*. This item will be taken up in the sensitivity analysis.

Note: * Technical and Economic Feasibility Study for the Bukavu-Kindu Road, ADB, Final Report, March 1974

6.2 Benefits and Costs

The benefits that may be expected of the implementation of the project are the vehicle operating benefits, the saving in the maintenance costs of the road, the net increase in added value of agricultural products and the net increase in income of the labourors employed in the implementation of the project. The methods of estimation and the results are described below.

1) Vehicle Operating Benefits

The vehicle operating benefits are estimated for each section of both Alternative I and Alternative II by calculating the saving in operating costs per vehicle by type of vehicle for both normal traffic and developed traffic and applying this to the forecasted traffic volume. The results are as shown in Table 6.1 and Table 6.2. The benefit per vehicle for developed traffic is assumed to be the same as that for normal traffic for the reasons discussed in the Supporting Report. (See Vol. 2, 4.2.1)

2) Net Increase in Added Value of Agricultural Products

The net increase in the added value of agricultural products is obtained by estimating the gross increase in value of agricultural products through the improvement of the road and then subtracting the additional agricultural investment capital and the opportunity cost of the additional agricultural labour force. In the calculation of the added value, the producers' cost of the products rather than the consumer cost is adopted in order to avoid counting the benefits twice in relation to the vehicle operating benefits calculated for developed traffic. The results are as shown in Table 6.1 and Table 6.2

The benefit of this kind will be subject to a sensitivity analysis.

3) Benefit of Local Construction Labourers

This is obtained by estimating the net increase in income of the labourers employed in the improvement construction work and deducting from it the opportunity cost of the labourers. The results are as shown in Table 6.1 and Table 6.2.

4) Benefit due to Savings in Maintenance Costs of the Road

The benefit through savings in maintenance costs of the road is derived through deducting the estimated maintenance costs for the improved road from that for the existing road and the results are shown in Table 6.1 and Table 6.2

5) Project Cost

The cost items of the project are the costs of improvement of the road and the maintenance costs of the improved road, and are as shown in Tables6.1 and 6.2. However, since these are the financial costs of the project they cannot be adopted outright in the economic analysis. For this reason, the economic costs of improvement and maintenance are estimated by deducting from the financial costs the tax components and then applying the shadow rate to the foreign currency portion of the costs. The results are as shown in Tables 6.3 and 6.4.

Table 6.1 Tableau

Costs and Benefits of Project by Year (Alternative-I)
(Present Value discounted at 12%)

Coûts et bénéfices de projet en année (Alternative-I)
(Valeur escomptée actuelle à 12%)

{ Indicated in present value discounted at 12% to the 0th year (1979) which is immediately before the commencement of construction. }

{ Indiqué à valeur escomptée actuelle à 12% à 0(Zéro) année (1979) quelle est en avant le commencement immédiat de la construction. }

(Unit / Unité : 1,000 Zaires)

T / T	Year / Année	Net Increase in Added Value / Augmentation nette dans la valeur ajoutée	User Benefit / Bénéfice d'usagers	Net Increase in Unskilled Laborers' Income / Augmentation d'usagers dans main-d'ouvre non spécialisée	Savings in Maintenance Cost / Economie dans le coût d'entretien	Total Benefit / Bénéfice totale	Maintenance Cost of Proposed Road / Coût d'entretien de route proposée	Maintenance Cost of Existing Road / Coût d'entretien de route existante	Improvement Cost (with shadow rate) / Coût d'amélioration (avec taux économique)	Improvement Cost (without shadow rate) / Coût d'amélioration (sans taux économique)
1	1980			1,005		1,005			22,994	17,453
2	1981			897		897			17,901	13,835
3	1982			801		801			15,983	12,353
4	1983	99	599	238	-73	863	444	370	5,775	4,471
5	1984	377	1,073		-66	1,384	396	331		
6	1985	593	1,493		-59	2,028	354	295		
7	1986	759	1,840		-52	2,547	316	264		
8	1987	883	2,131		-47	2,968	282	235		
9	1988	971	2,366		-42	3,295	252	210		
10	1989	1,000	2,377		-37	3,340	225	188		
11	1990	1,012	2,367		-33	3,346	201	168		
12	1991	1,009	2,340	2	-30	3,321	179	150	572	439
13	1992	996	2,298	1	-27	3,269	161	134	418	321
14	1993	974	2,204		-25	3,153	144	119		
15	1994	944	2,116		-23	3,036	130	106		
16	1995	909	2,021		-22	2,909	117	95		
17	1996	871	1,922		-20	2,773	105	85		
18	1997	831	1,821		-18	2,633	94	76		
19	1998	789	1,720		-17	2,492	84	68		
20	1999	747	1,619		-16	2,350	76	60		
21	2000	705	1,520		-14	2,211	68	54		
22	2001	663	1,424		-13	2,074	61	48		
23	2002	622	1,331		-11	1,942	54	43		
24	2003	582	1,242		-10	1,814	49	38		
25	2004	520	1,109		-9	1,619	43	34		
26	2005	464	990		-8	1,446	39	31		
27	2006	414	884		-7	1,291	35	27		
28	2007	370	789		-6	1,153	31	24		
29	2008	330	705		-6	1,029	28	22		
30	2009	295	629		-5	919	25	19		
	Total	18,730	42,930	2,944	-696	63,907	3,993	3,294	63,643	48,872

Note: In the table, the tax component is excluded even in the improvement cost without shadow rate as for the case of being not discounted (see Table 4.3.9 in Vol. 2).

Dans le Tableau, part de taxe est exclue même dans le coût d'amélioration sans taux économique quant à faire peu de cas d'escompte. (voir Tableau 4.3.9 à Vol. 2)

Table 6.2 Costs and Benefits of Project by Year (Alternative II)
(Present Value discounted at 12%)

Tableau Coûts et bénéfices de projet en année (Alternative II)
(Valeur escomptée actuelle à 12%)

{ Indicated in present value discounted at 12% to the 0th year (1979) which is immediately before the commencement of construction. }

{ Indiqué à valeur escomptée actuelle à 12% à 0(Zéro) année (1979) quelle est en avant le commencement immédiat de la construction. }

(Unit / Unité : 1,000 Zaires)

T	Year	Net Increase in Added Value	User Benefit	Net Increase in Unskilled Laborers' Income	Savings in Maintenance Cost	Total Benefit	Maintenance Cost of Proposed Road	Maintenance Cost of Existing Road	Improvement Cost (with shadow rate)	Improvement Cost (without shadow rate)
T	Année	Augmentation nette dans la valeur ajoutée	Bénéfice d'usagers	Augmentation d'usagers dans main-d'ouvre non spécialisée	Economie dans le coût d'entretien	Bénéfice totale	Coût d'entretien de route proposée	Coût d'entretien de route existante	Coût d'amélioration (avec taux économique)	Coût d'amélioration (sans taux économique)
1	1980			453		453			10,473	7,949
2	1981			434		434			8,154	6,302
3	1982			387		387			7,280	5,626
4	1983	99	521	138	101	859	269	370	2,631	2,037
5	1984	377	968		83	1,428	248	336	115	78
6	1985	593	1,363	25	65	2,046	230	295	909	702
7	1986	759	1,691	22	38	2,510	225	264	734	566
8	1987	883	1,966		25	2,874	210	235		
9	1988	971	2,188		16	3,175	194	210		
10	1989	1,000	2,196		9	3,205	179	188		
11	1990	1,012	2,186		4	3,202	164	168	89	61
12	1991	1,009	2,159	29	-10	3,187	159	150	857	660
13	1992	996	2,120	26	-12	3,130	146	134	561	433
14	1993	974	2,032	33	-2	3,037	121	119	1,136	872
15	1994	944	2,086	30	-2	3,058	108	106	1,014	779
16	1995	909	1,994		-2	2,901	97	95		
17	1996	871	1,897		-3	2,765	87	85		
18	1997	831	1,799		-7	2,623	83	76	21	16
19	1998	789	1,699		-7	2,481	75	68		
20	1999	747	1,601		-7	2,341	67	60		
21	2000	705	1,503		-7	2,201	60	54		
22	2001	663	1,409		-6	2,066	54	48		
23	2002	622	1,317		-6	1,933	49	43		
24	2003	582	1,229		-6	1,805	44	38		
25	2004	520	1,097		-5	1,612	39	34		
26	2005	464	980		-4	1,440	35	31		
27	2006	414	875		-4	1,285	31	27		
28	2007	370	731		-4	1,097	28	24		
29	2008	331	697		-3	1,025	25	22		
30	2009	295	623		-3	915	25	19		
	Total	18,730	40,926	1,577	241	61,475	3,052	3,294	33,974	26,082

Note: In the table, the tax component is excluded even in the improvement cost without shadow rate as for the case of not being discounted (see Table 4.3.10 in Vol. 2).

Dans le Tableau, part de taxe est exclue même dans le coût d'amélioration sans taux économique quant à ne pas faire de cas d'escompte (voir Tableau 4.3.10 à Vol. 2).

Table 6.3 Tableau

Shadow-Priced Improvement Costs of Project Road (Without discounting)

Prix économique de coûts d'amélioration de la route de projet (sans escompte)

(Alternative-I)

(Unit / Unité : 1,000 Zaires)

T	Year / Année	Ndu - Bondo	Bondo-Buta	Buta-Banalia	Banalia-Kisangani	Yearly Total / Annuel total
1	1980	4,986	5,751	8,275	6,701	25,713
2	1981	4,347	5,049	7,215	5,845	22,456
3	1982	4,347	5,049	7,215	5,845	22,456
4	1983	1,760	2,043	2,920	2,365	9,088
5	1984					
6	1985					
7	1986					
8	1987					
9	1988					
10	1989					
11	1990					
12	1991				2,230	2,230
13	1992				1,825	1,825
Total		15,440	17,892	25,625	24,811	83,768

Note: 1/ Foreign currency component is multiplied by 1.5
Monnaie étrangère componant a multiplié par 1,5.

Costs in the table are on the basis of the cost level of April 1975.
Coûts dans le tableau sont à la base de niveau du coût d'Avril 1975.

(See Supporting Report Table 4.3.9)
(Voir Rapport final du Projet, Tableau 4.3.9)

Table 6.4 Tableau

Shadow-Priced Improvement Costs of Project Road (Without discounting)

Prix économique de coûts d'amélioration de la route de projet (sans escompte)

(Alternative-II)

(Unit / Unité : 1,000 Zaires)

T	Year / Année	Ndu-Bondo	Bondo-Buta	Buta-Banalia	Banalia-Kisangani	Yearly Total / Annuel total
1	1980	2,316	2,121	2,068	5,225	11,730
2	1981	2,019	1,849	1,804	4,556	10,228
3	1982	2,019	1,849	1,804	4,556	10,228
4	1983	817	749	731	1,843	4,140
5	1984			44	160	204
6	1985			351	1,444	1,795
7	1986			351	1,271	1,622
8	1987					
9	1988					
10	1989					
11	1990		45	28	238	311
12	1991		726	713	1,901	3,340
13	1992		547		1,901	2,448
14	1993			5,550		5,550
15	1994			5,550		5,550
16	1995					
17	1996					
18	1997			162		162
Total		7,171	7,886	19,156	23,095	57,308

Note: 1/ Foreign currency component is multiplied by 1.5
Monnaie étrangère componant a multiplié par 1,5.

Costs in the table are on the basis of the cost level of April 1975.
Coûts dans le tableau sont à la base de niveau du coût d'Avril 1975.

(See Supporting Report Table 4.3.10)
(Voir Rapport final du Projet, Tableau 4.3.10)

6.3 Results of Economic Analysis

In the economic analysis of the project the benefit/cost ratio method and the internal rate of return method were adopted, and five cases of analysis were carried out by alternative, varying evaluating conditions as follow as it is done in so-called sensitivity analysis:

(a) Shadow rate is applied to the cost of improvement or not;

(b) The net increase in added value of agricultural products is included in or excluded from the benefit;

(c) Savings in time cost is included in or excluded from the benefit; and,

(d) The benefit due to the developed traffic per trip is assumed to be a half or same as that due to the normal traffic.

It is understood from Table 6.5 that even Alternative II shows such low values as 0,531 in the benefit / cost ratio which is much smaller than 1.0 and 7.4 % in the internal rate of return which is much smaller than the discount rate of 12 % under the severest conditions; and Alternative I shows worse values than Alternative II under the same conditions. Consequently, both Alternatives are not economically justified under such conditions.

Viewing Alternatives by route section, the following facts are found from Table 6.6 that:

- In Alternative I the route section between Kisangani and Banalia is economically justified in all cases except the most severe one;
- In Alternative II the route section between Kisangani and Buta is economically justified in all cases except the most severe case.

Next, viewing overall the project, it is understood from the results of the economic evaluations that:

- In Alternative II the route section between Kisangani and Banalia is approximately economically justified under the most severe conditions because the benefit / cost ratio is nearly 1.0;
- In Alternative II, if it is viewed under the conditions except the most severe conditions, the benefit / cost ratio of the entire route shows a favorable value in each case as shown in from # 6 to # 9 and it is recommended to improve the entire route if the financial situation permits.

Table 6.5 Results of Economic Analysis (Kisangani-Bangassou)

Case	Alter-native	Exchange rate for estimating improvement cost	Benefit due to net increase in added value	Benefit due to savings in time cost	Benefit due to developed traffic	Internal rate of return	Benefit/ cost ratio	Maximum possible investment (1,000 Zaires)	Total benefit (present value) (1,000 Zaires)	Total project cost (present value) (1,000 Zaires)
# 1	I	OR x 1.5	Yes	Yes	Normal	0.115	0.945	59,913	63,908	67,636
# 2	I	OR	Yes	Yes	Normal	0.138	1.209	59,917	63,908	52,863
# 3	I	OR x 1.5	No	Yes	Normal	0.085	0.668	41,185	45,176	67,636
# 4	I	OR	No	Yes	Normal	0.105	0.855	41,185	45,176	52,863
# 5	I	OR x 1.5	No	No	1/2 x Normal	0.051	0.305	18,834	20,659	67,636
# 6	II	OR x 1.5	Yes	Yes	Normal	0.176	1.662	58,478	61,529	37,026
# 7	II	OR	Yes	Yes	Normal	0.207	2.107	58,478	61,529	29,196
# 8	II	OR x 1.5	No	Yes	Normal	0.135	1.156	39,746	42,798	37,026
# 9	II	OR	No	Yes	Normal	0.163	1.466	39,746	42,798	29,196
#10	II	OR x 1.5	No	No	1/2 x Normal	0.074	0.531	18,283	19,687	37,026

Notes: 1) Yes means considered, and No means ignored.

2) OR means the original exchange rate of US$1.00 = Z 0.50.

3) Normal means the same amount as much as that due to the normal traffic; while 1/2 x Normal means the half amount of that due to the normal traffic.

4) The net increase in local unskilled laborers' income and savings in maintenance cost of the road occupy a small percentage in the total benefit and are not considered as items of changing condition in the analysis but their amounts are included in the total benefit.

Table 6.6 Results of Economic Analysis by Alternative and by Section

Case	Alter-native	Exchange rate for estimating improvement cost	Benefit due to net increase in added value	Benefit due to savings in time cost	Benefit due to developed traffic	B/C Ratio by Route Section										Entire route
						(1) Bangassou Monga	(2) Monga Bondo	(3) Bondo Likati	(4) Likati Dulia	(5) Dulia Buta	(6) Buta Tele	(7) Tele Kole	(8) Kole Banalia	(9) Banalia Bengamisa	(10) Bengamisa Kisangani	
# 1	I	OR x 1.5	Yes	Yes	Normal	0.056	0.056	0.164	0.169	0.241	0.879	0.935	0.530	2.639	2.367	0.945
# 2	I	OR	Yes	Yes	Normal	0.072	0.071	0.207	0.216	0.307	1.123	1.196	0.682	2.397	3.046	1.209
# 3	I	OR x 1.5	No	Yes	Normal	0.048	0.047	0.123	0.128	0.177	0.623	0.663	0.383	1.845	1.656	0.668
# 4	I	OR	No	Yes	Normal	0.062	0.060	0.156	0.163	0.225	0.797	0.848	0.493	2.375	2.131	0.855
# 5	I	OR x 1.5	No	No	1/2 x Normal	0.022	0.022	0.056	0.058	0.081	0.262	0.303	0.175	0.844	0.757	0.305
# 6	II	OR x 1.5	Yes	Yes	Normal	0.129	0.166	0.381	0.334	0.432	1.508	1.539	1.143	3.027	2.792	1.662
# 7	II	OR	Yes	Yes	Normal	0.164	0.206	0.473	0.425	0.549	1.902	1.944	1.417	3.893	3.519	2.107
# 8	II	OR x 1.5	No	Yes	Normal	0.117	0.151	0.294	0.258	0.324	1.045	1.069	0.780	2.088	1.926	1.156
# 9	II	OR	No	Yes	Normal	0.149	0.187	0.365	0.328	0.411	1.319	1.350	0.967	2.685	2.476	1.466
#10	II	OR x 1.5	No	No	1/2 x Normal	0.054	0.069	0.135	0.119	0.149	0.481	0.492	0.358	0.960	0.884	0.531

Notes: 1) Yes means considered, and No means ignored.

2) OR means the original exchange rate of US$ 1.00 = Z 0.50.

3) Normal means the same amount as much as that due to the normal traffic; while 1/2 x Normal means the half amount of that due to the normal traffic.

4) As for the benefit and the cost by route section, refer to Table 4.3.5 and Table 4.3.6 respectively.