Japan International Cooperation Agency
Ministry of Works and Supply, Republic of Zambia
Ministry of Transport and Energy, Republic of Zimbabwe

The Feasibility Study on the Proposed New Bridge Over the Zambezi River at Chirundu Border Post

Between

the Republic of Zambia
and
the Republic of Zimbabwe

Final Report
(Summary)

March 1993

Chodai Co., Ltd.

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1 US$ =	1,300 kws
1 US$ =	12.3 Z$

PREFACE

In response to the request of the Governments of the Republic of Zambia and the Republic of Zimbabwe, the Government of Japan decided to conduct the Feasibility Study on the Proposed New Bridge Over the Zambezi River at Chirundu Border Post between the Republic of Zambia and the Republic of Zimbabwe and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Zambia and Zimbabwe a study team headed by Mr. Yusuke Kajimura of Chodai Co., Ltd. The team was dispatched three times between June 1997 to January 1998.

The team held discussions with the officials concerned of the Governments of Zambia and Zimbabwe, and conducted field surveys in the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope this report will contribute to the promotion of the project and to the enhancement of friendly relations among three countries.

I wish to express my sincere appreciation to the officials of the Governments of the Republic of Zambia and the Republic of Zimbabwe for their close cooperation extended to the team.

March, 1998

Kimio Fujita
President
Japan International Cooperation Agency

Letter of Transmittal

March, 98

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

It is a great honour to submit herewith the final reports of the Feasibility Study on the Proposed New Bridge Over the Zambezi River at Chirundu Border Post between the Republic of Zambia and the Republic of Zimbabwe. The report includes the advice and suggestions of the concerned authorities of the Government of Japan and your Agency, as well as the comments made by Ministry of Works and Supply, Zambia and Ministry of Transport and Energy, Zimbabwe, and other authorities concerned in both countries.

This report describes conditions of the existing bridge, border post facilities and environment of the region, and presents feasibility of the new bridge construction and border post facilities improvement. Environmental aspects were duly considered through out the course of the study.

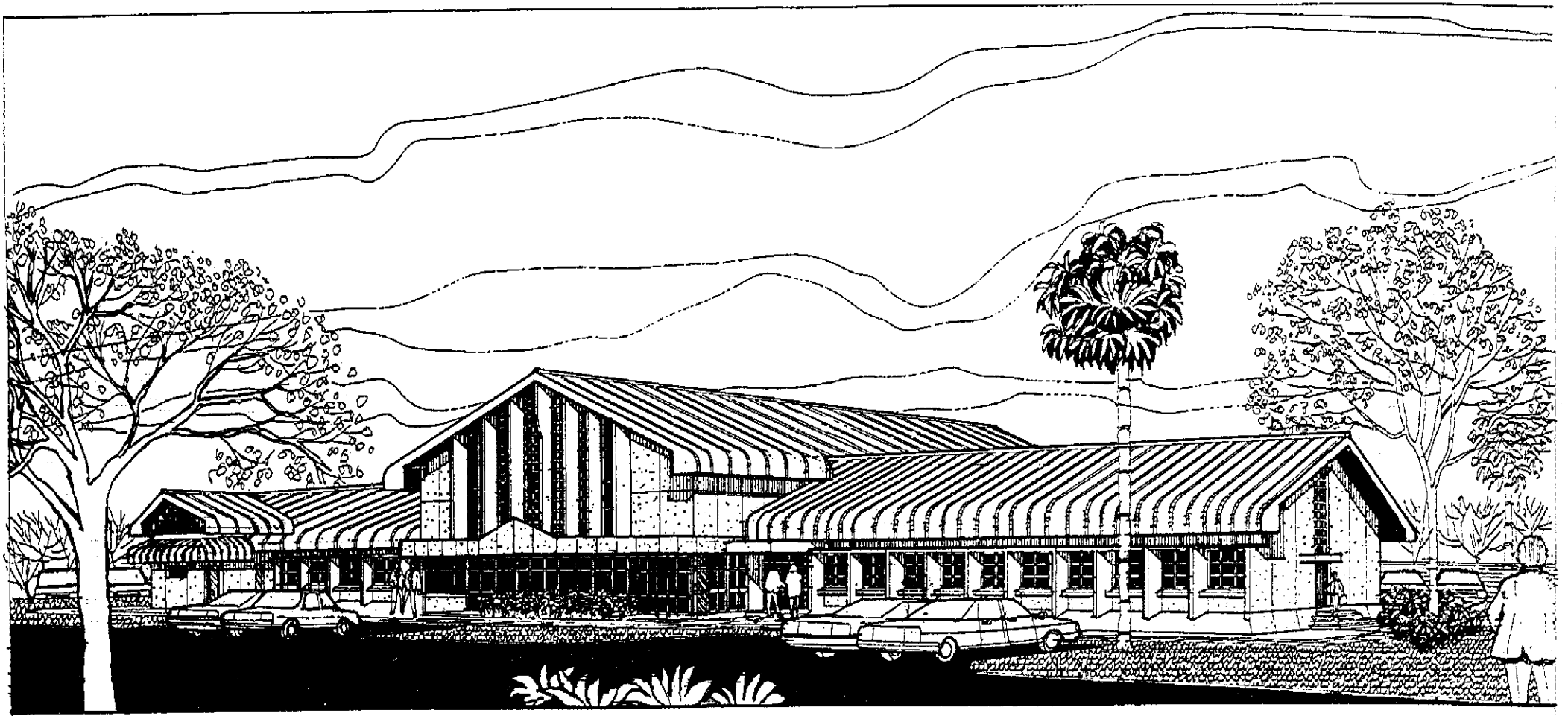
As a result of the analyses of the project from technical, environmental and economical viewpoint, a new bridge crossing at about 100m upstream from the existing bridge is recommended, with required improvements to border post facilities. It is strongly recommended to implement both the new bridge construction and border post facilities improvements, as either one of them would not facilitate the movements of traffic alone.

On behalf of the team, I wish to express our deep gratitude to your Agency, Ministry of Foreign Affairs, and other officials concerned for their valuable comments and suggestions to the Study. I also wish to express my heartfelt appreciation to the officials concerned of the Government of Zambia and the Government of Zimbabwe for their warm friendship and cooperation extended to us during the Study. I hope this report will contribute to the development of the Republic of Zambia and the Republic of Zimbabwe.

Yours Faithfully,

Yusuke Kajumura
Team Leader

Perspective View of Proposed New Bridge at Chirundu Border Post



A VIEW OF PASSENGER CONTROL BUILDING

1 DEVELOPMENT OF THE STUDY

The Chirundu Border Post is located on the Beira Corridor connecting Mozambique, Zimbabwe and Zambia. The existing bridge (Otto Beit Bridge) was constructed and opened for traffic in 1939 and has 5.5 meters carriageway with sidewalk of 0.9 meters on both sides. Only one vehicle is allowed to pass on the existing bridge at a time and 55 tons maximum vehicle weight limitation is strictly enforced due to the structural capacity of the Bridge. The Governments of Zambia and Zimbabwe requested the Government of Japan to conduct the Feasibility Study for the Construction of a Bridge over the Zambezi River, taking into consideration the necessity for improvement of the border post.

Issues concerning the existing bridge and border post facilities are as below.

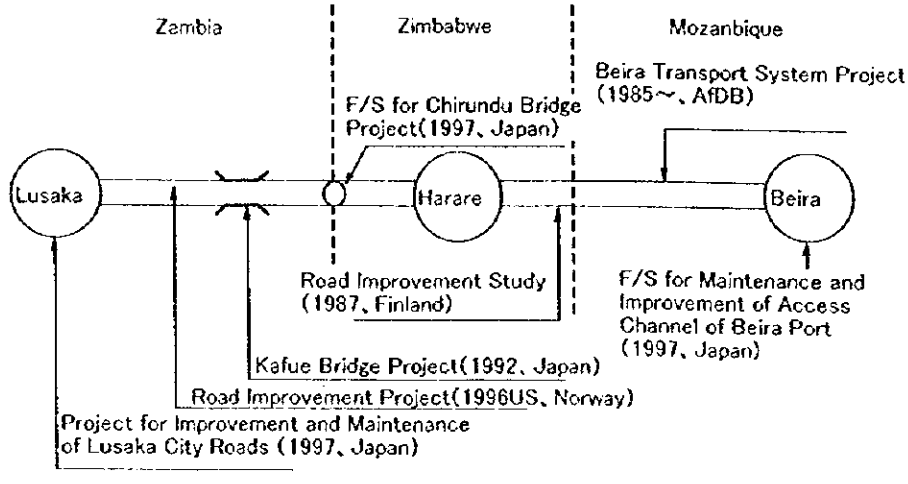
(1) Otto Beit Bridge

- Only one vehicle is allowed on a bridge at a time, hence traffic capacity is 30 vehicles per hour for both directions at maximum.
- 55 tons maximum vehicle weight limitation is strictly enforced due to the structural capacity of the Bridge. Heavier vehicles are forced to use border post at Kariba dam.
- Visual inspection to the existing bridge found no major defections of the structure.
- The existing bridge is maintained in sound condition. Usage under present limited operation will provide adequate service.
- Beira Corridor is considered as vital international corridor, many projects has been carried out to improve efficiency. Chirundu could be a bottleneck without any improvement.

(2) Border Post Facilities

- Capacity of the border post facilities is 25 vehicles per hour for both directions. Border post facilities are being bottleneck at Chirundu rather than the bridge.
- Border post is opened from 6:00 am to 6:00 pm, therefore 250 vehicles per day can be dealt with.
- Lack of both the facilities and personnel is causing serious shortage for inspection. Drug trafficking and smuggling are serious problem.

Projects on Beira Corridor



2 TRAFFIC CONDITIONS

Result of future traffic forecast study is as shown below.

Traffic Demand Forecast at Chirundu Border Post

Direction Zambia → Zimbabwe (Unit : vehicle / day)

Vehicle Type	1997			2002			2010		
	Loaded	Vacant	Total	Loaded	Vacant	Total	Loaded	Vacant	Total
3	1	0	1	1	0	1	1	0	1
4	33	0	33	11	0	11	66	0	66
5	2	0	2	3	0	3	1	0	1
6	6	0	6	8	0	8	12	0	12
7	1	18	19	2	22	24	1	33	37
8	0	2	2	11	1	18	25	6	31
9	1	3	1	3	3	6	1	1	8
10	8	36	11	13	18	61	21	71	98
Total	52	59	111	88	76	161	137	116	252

Direction Zambia ← Zimbabwe

Vehicle Type	1997			2002			2010		
	Loaded	Vacant	Total	Loaded	Vacant	Total	Loaded	Vacant	Total
3	0	0	0	0	0	0	0	0	0
4	23	0	23	17	0	47	70	0	70
5	2	0	2	2	0	2	3	0	3
6	9	0	9	8	0	8	11	0	11
7	13	2	15	22	2	23	33	4	36
8	2	2	4	4	11	17	6	25	31
9	3	1	4	3	3	5	4	4	8
10	19	4	53	48	13	61	71	24	98
Total	101	9	110	131	30	161	199	56	254

Source : JICA Study team's estimates and forecasts

Vehicle type: 3 : Motorcycle; 4 : Passenger car; 5 : Minibus; 6 : Bus; 7 : 2 axle Light Trucks; 8 : 2/3 axle Heavy Truck; 9 : 4/5 axle Truck; 10. 6 or more axle Truck

3 BRIDGE AND ROUTE ALTERNATIVES

The evaluation of alternative routes study was conducted from viewpoint of the technical, environmental and economic aspects. As a result of the study, the Alternative Route-A, 100m upstream of the Otto Beit Bridge, was selected as site for a new bridge construction and improvement of customs facilities.

As a result of bridge alternative study, 3 spans continuous PC box girder bridge was chosen as a best alternative, owing mainly to its cost and contribution to local economy. Preliminary design was conducted with following criteria.

a) Number of traffic lanes = 2-Lanes
b) Lane width = 3.5 meters
c) Shoulder width = 1.0 meter on both sides
d) Maintenance walk width = 0.75 on both sides

4 BORDER FACILITIES IMPROVEMENT STUDY

The improvement in the border post facilities and staff requirements will be made depending on the demand increase. However, some amount of investment shall be prepared immediately for improving the existing capacity of the facilities as well as improving the amenity conditions of the staff at border post. Taking into account the above mentioned matters, the following steps are recommended.

a) Initial investment during the three (3) years of construction; 40 % of total investment.
b) Complementary investment until 2010; 60 % of total investment.

Below is a summary of total land area required for necessary improvements of border post facilities for both countries. Stage construction was recommended for the border post facilities, due to huge construction cost.

ELEMENT	Zambia	Zimbabwe
FREIGHT TERMINAL	63,215 m²	61,681 m²
PASSENGER CONTROL BUILDING	13,956 m²	16,224 m²
PEDESTRIAN CONTROL BUILDING	1,025 m²	240 m²
DRUG ENFORCEMENT COMMISSION	928 m²	769 m²
POLICE STATION		820 m²
VEHICLE INSPECTION UNIT AND WEIGH BRIDGE	84 m²	116 m²
KIOSK AND FAST FOOD OUTLET	375 m²	375 m²
PERIMETER FENCING AND GUARDHOUSES	1,785 m²	2,181 m²
Total	81,368 m²	82,406 m²

5 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment was made to selected alternative route, which is 100m upstream of the existing bridge. There are no noteworthy environmental problems in these preliminary design results, however, there are some environmental problems and issue during the construction stage which need great attention.

Elements	Negative Impact	Mitigation Measure	Implementation
Soils	Potential for soil erosion.	1. Slopes should be re-vegetated 2. Slopes should be suitably graded.	D/D Stage Construction Stage
Vegetation	Destruction of river edge cliff vegetation	1. The areas to be cleared should be well marked to ensure that the area cleared of vegetation is kept to a minimum.	Site preparation stage
Resettlement	Demolition of police station in Zimbabwe	1. Alternative station must be built	Before demolition
Road Safety	Increased accidents	1. Traffic safety to be enforced by police	After construction
Noise	Noise and vibration	1. Contractor must limit the working hours to daylight hours.	Construction stage
Air Pollution	Increased in the air dust	1. Dust should be controlled with the use of water sprays.	Construction stage
Water Resource	Demolition of water treatment in Zambia	1. Alternative water treatment should be constructed	Before demolition
Water Resource	Demolition of water pipe line in Zimbabwe	1. Alternative water pipe line should be constructed	Before demolition
Water Resource	Risk of water pollution	1. Contractor must submit written details of the procedures.	Construction stage

6 PROJECT COST AND SCHEDULE

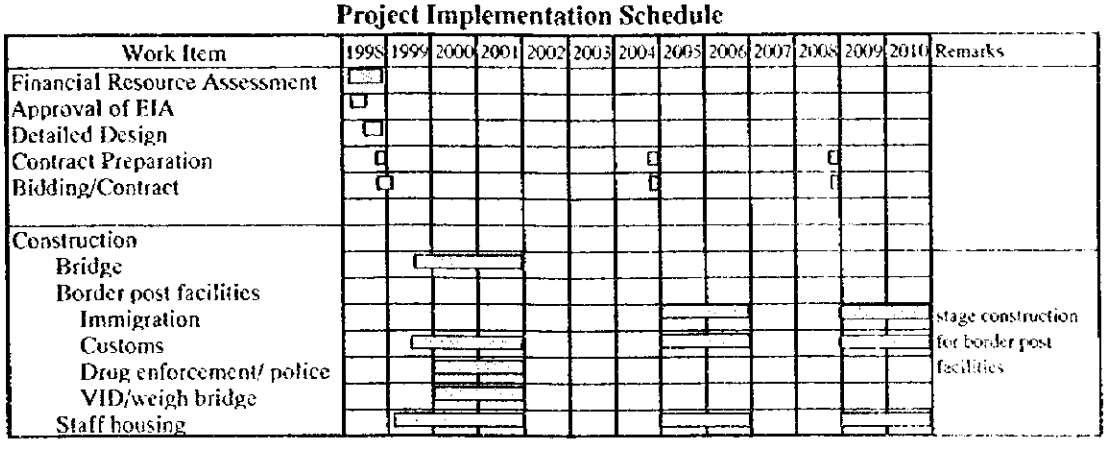
Below are summary of total project cost and construction schedule. As shown, the bridge is to be completed in three years and the border post facilities are to be constructed in separate stages.

Project Cost

US$ thousand

	Foreign (US$)	Local (US$)	Total (US$)
1. Direct Cost			
Bridge			
superstructure	3,431	2,236	5,667
substructure	3,751	1,746	5,497
sub total	7,182	3,982	11,164
Access Road	328	391	719
Border Post			
housing	8,616	6,769	15385
buildings	6,356	4,993	11,349
parking area	4,228	5,043	9,271
sub total	19,200	16,805	36,005
Direct Cost Total	26,710	21,178	47,888
2.Contingency(15%)	4007	3177	7,184
Total of 1~2	30,717	24,355	55,072
3.Indirect Cost(25%)	7,049	6,719	13,768
4.Engineering Cost(10%)	3,099	2,408	5,507
5.Land Acquisition	0	0	0
6.Conpensation	0	300	300
Total Project Cost	40,865	33,782	74,647

Project Implementation Schedule



7 ECONOMIC EVALUATION

Taking into account the conditions and characteristics of transportation and traffic, the following four (4) items were identified for benefits of the project.

a) Time saving benefits arising from less waiting time at border posts
b) Cost savings of heavy trucks for not detouring to Kariba dam
c) Vehicle operating cost savings of traffic which are over capacity of the existing bridge.
d) Cost required in the "without" case will be regarded as a benefit of the project.

As a result of economic evaluation, economic internal rate of return (EIRR) is estimated as 6.99 %. This value of EIRR is comparatively low compared with other infrastructure projects.

The following benefits can be expected as intangible benefits or social benefits.

a) Creation of working opportunities during project implementation period.
b) Contribution to the socio economic activities in Chirundu area.
c) Elimination of the smuggling and drug trafficking.
d) Promotion of the various kinds of developments in the Chirundu area.

8 RECOMMENDATION

(1) Border Post facilities and bridge structure shall be improved simultaneously in order to maximise the benefits from the project.

(2) Bridge route of 100 meters upstream from the existing bridge shall be adopted from viewpoints of economical, technical, and environmental aspects.

(3) Prestressed concrete girder bridge with 2-lanes shall be employed from viewpoints of economy.

(4) Stage construction for border post facilities shall be considered due to a huge amount of cost.

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List of Abbreviations

ASYCUDA	:	Automated System for Customs Data
CAMPFIRE	:	Communal Areas Management Programme for Indigenous Resources
CSO	:	Central Statistical Office
EIA	:	Environmental Impact Assessment
EMP	:	Environmental Management Plan
ESP	:	Environmental Support Programme
IRR	:	Internal Rate of Return
JICA	:	Japan International Cooperation Agency
MOTE	:	Ministry of Transport and Energy (of Zimbabwe)
MOWS	:	Ministry of Works and Supply (of Zambia)
Mpa	:	Mega Pascal
NEAP	:	National Environmental Action Plan
ECZ	:	National Environmental Council of Zambia
NGO	:	Non-governmental Organization
OD	:	Origin and Destination
SADC	:	Southern Africa Development Community
SATCC	:	Southern Africa Transport and Communication Committee
SITC	:	Standard International Trade Classification
SPT	:	Standard Penetration Test
TTC	:	Travel Time Cost
VAT	:	Value Added Tax
VOC	:	Vehicle Operating Cost
ZRA	:	Zambian Revenue Authority

1 INTRODUCTION

1.1. BACKGROUND

The Chirundu Border Post is located on the Beira Corridor connecting Mozambique, Zimbabwe and Zambia. This border post is the most important facility between Zambia and Zimbabwe for the movement of people and goods. The border post is composed of several facilities such as the bridge over the Zambezi River, customs and immigration offices, warehouses, vehicle inspection offices, police offices, clearing agency office, etc.

The existing bridge (Otto Beit Bridge) was constructed and opened for traffic in 1939 and has 5.5 meters carriageway with sidewalk of 0.9 meters on both sides. Only one vehicle is allowed to pass on the existing bridge at a time and 55 tons maximum vehicle weight limitation is strictly enforced due to the structural capacity of the Bridge.

The Governments of Zambia and Zimbabwe requested the Government of Japan to conduct the Feasibility Study for the Construction of a Bridge over the Zambezi River (hereinafter referred to as the Study), taking into consideration the necessity for improvement of the border post.

1.2. STUDY DEVELOPMENT

In response to the request from the Governments of Zambia and Zimbabwe, the Government of Japan agreed to conduct the Study. The Japan International Cooperation Agency (hereinafter referred to as JICA), official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, undertook the Study in close cooperation with the appropriate authorities in Zambia and Zimbabwe. The preparatory Study Team, headed by Mr. Kazutomo Abe, was dispatched by JICA to Zambia and Zimbabwe and the Scope of Work for the Study was agreed upon in February 1997.

1.3. THE STUDY PURPOSE

The objectives of the Study are as follows;

1) To conduct a Feasibility Study on the proposed new bridge over the Zambezi River as well as border post facilities at Chirundu Border Post.

2) To transfer relevant technology to counterparts of Zambia and Zimbabwe.

1.4. THE STUDY AREA

Two different levels of the Study Area were considered. For the engineering study purpose, a limited Study Area covered the existing Otto Beit Bridge as well as the natural conditions of Border Post at Chirundu area. However, for the transport and traffic study purpose, the Study Area included a large part of the SADC countries and took into account the characteristics necessary for the study.

1.5. STUDY ORGANIZATION

To conduct the Study, JICA organized the Study Team, headed by Mr. Yusuke Kajimura. JICA also set up the advisory Committee, chaired by Mr. Yoshitaka Yoshida, to provide advice for the Study. The Governments of Zambia and Zimbabwe organized the Counterpart Team and also the Steering Committee.

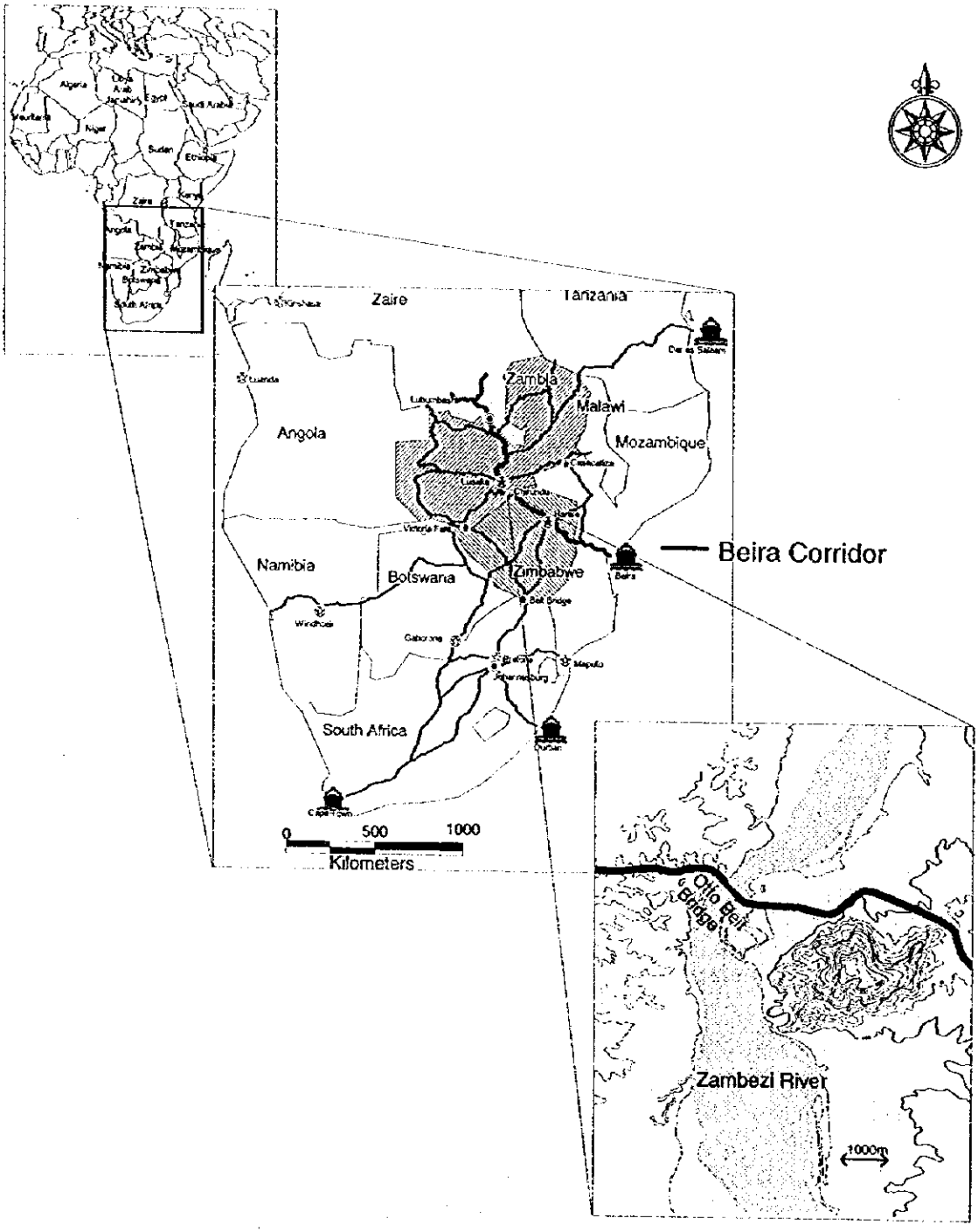


Figure 1 Location of Study Area and Study Site

2 EXISTING CONDITIONS OF THE STUDY AREA

2.1. SOCIO ECONOMIC CONDITIONS

(1) Zambia Side

Recent estimates place the per capita gross income at some US $350 per annum. Manufacturing sector occupies the primary position in terms of its contribution to GDP, however, the mining sector is still major source of foreign trade surplus. Textile, food processing and chemical goods for domestic consumption are major products in manufacture sector and large part of elementary products for production are imported.

(2) Zimbabwe Side

In 1994, estimates place per capita gross income at some US $ 500 per annum. Manufacturing sector occupies the primary position in terms of its contribution to GDP, however, agriculture and mining sector are still major sources of foreign trade surplus. Textile, foods processing and transport equipment are major products in manufacturing sector.

2.2. TRAFFIC CONDITIONS

The past trend of traffic volume on the Chirundu Border Post are shown in Table 1.

Table 1 Traffic Volume at Chirundu

Unit: vehicles/day

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Out	36	37	55	82	66	65	111	104	86	90	NA	82	137
In	34	49	56	63	69	61	103	118	93	102	NA	81	119
Total	70	86	111	145	135	126	214	222	179	192	NA	163	256

Out: Outbound from Zambia
In: Inbound to Zambia
NA: 1995 data is not available
1996 is result from SATCC survey
1997 is result from JICA survey

2.3. TOPOGRAPHIC CONDITIONS

The existing Otto Beit Bridge is located at the narrowest point of the Zambezi river at Chirundu Border point. At upstream of the Bridge, the riverbank at Zimbabwe side is steep cliff with riverside woods, and at Zambia side is steep cliff with riverside woods to swampy area. At downstream of the Bridge, gentle slopes ascend from the river edges. At Zambia side privately developed township is formed on the riverside slope. At Zimbabwe side relatively thick bush covers the river bank without artificial structure except for the floating police jetty and public boat launching pad.

2.4. ROAD NETWORK CONDITIONS

The Chirundu Border Post is located on the Beira Corridor at Chirundu area, and the Beira Corridor is connected from Beira Port to Lusaka through Harare. Distance from Lusaka to major sea port is shown in Figure 2.

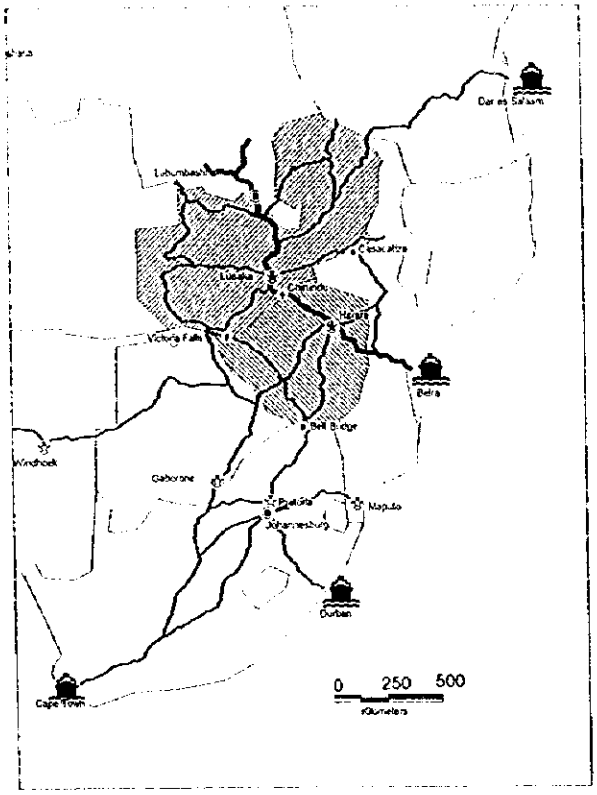


Figure 2 Road Network Configuration

From Lusaka to	Distance (km)
Port of Dar es Salaam	1,890
Beira Port via Harare	990
Beira Port via Casacatiza	1,240
Beit Bridge via Harare	1,070
Beit Bridge via Victoria Falls	1,120
Maputo Port via Harare, Beit Bridge	2,070

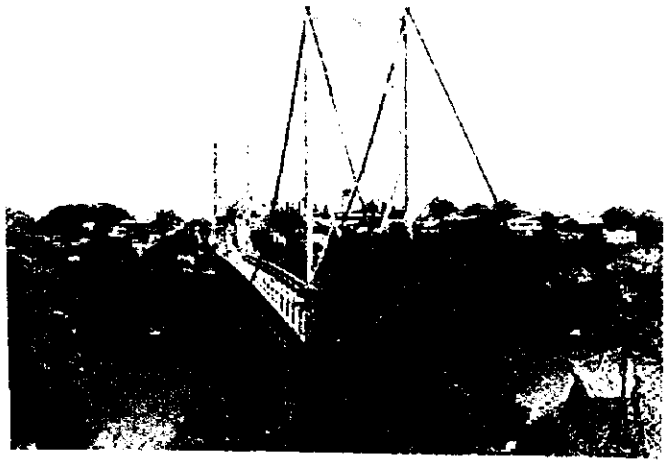


Photo 1 Existing Otto Beit Bridge

Photo 2 Existing Customs at Zambia

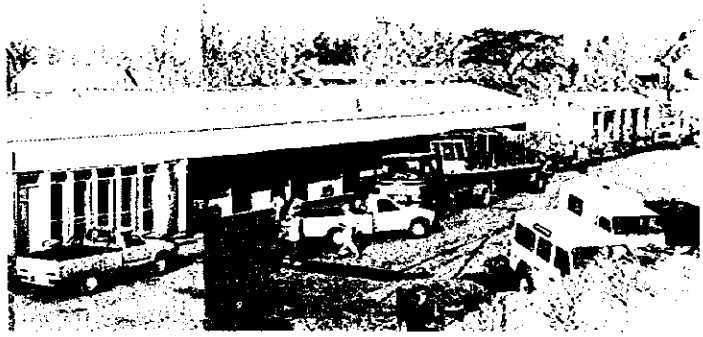


Photo 3 Existing Customs at Zimbabwe

3 TRAFFIC DEMAND FORECAST

The traffic demand forecast was conducted to forecast a future traffic volume in 2010 at Chirundu Border Post. The future traffic volume estimated was used to prepare a new bridge construction plan and to establish an improvement plan for customs and immigration systems and facilities.

3.1. BASIC CONSIDERATION FOR TRAFFIC PROJECTION

The JICA Study Team took into consideration the following four (4) factors which affect the future cargo volume from/to Zambia transported through the Chirundu Border Post.

a) Future economic development of Zambia
b) Future railway transportation in Zambia
c) Future promotion of the free-trade among SADC countries, and
d) Potential advantages of the Chirundu route compared with other competitive routes.

3.2. FUTURE TRAFFIC DEMAND

As a result of future traffic forecast study, the traffic volumes in 2002 and 2010 are presented in Table 2 below, and comparison of additional surveys for future traffic volume is presented Figure 3.

Table 2 Traffic Demand Forecast at Chirundu Border Post

Direction Zambia ---> Zimbabwe (Unit : vehicle / day)

Vehicle Type	1997			2002			2010		
	Loaded	Vacant	Total	Loaded	Vacant	Total	Loaded	Vacant	Total
3	1	0	1	1	0	1	1	0	1
4	33	0	33	44	0	44	66	0	66
5	2	0	2	3	0	3	4	0	4
6	6	0	6	8	0	8	12	0	12
7	1	18	19	2	22	24	4	33	37
8	0	2	2	14	4	18	25	6	31
9	1	3	4	3	3	6	4	4	8
10	8	36	44	13	48	61	24	74	98
Total	52	59	111	88	76	161	137	116	252

Direction Zambia <--- Zimbabwe

Vehicle Type	1997			2002			2010		
	Loaded	Vacant	Total	Loaded	Vacant	Total	Loaded	Vacant	Total
3	0	0	0	0	0	0	0	0	0
4	23	0	23	47	0	47	70	0	70
5	2	0	2	2	0	2	3	0	3
6	9	0	9	8	0	8	11	0	11
7	13	2	15	22	2	23	33	4	36
8	2	2	4	4	14	17	6	25	31
9	3	1	4	3	3	5	4	4	8
10	49	4	53	48	13	61	74	24	98
Total	101	9	110	131	30	161	199	56	254

Source : JICA Study team's estimates and forecasts

Vehicle type:
3 : Motorcycle
4 : Passenger car
5 : Minibus
6 : Bus
7 : 2 axle Light Trucks
8 : 2/3 axle Heavy Truck
9 : 4/5 axle Truck
10: 6 or more axle Truck

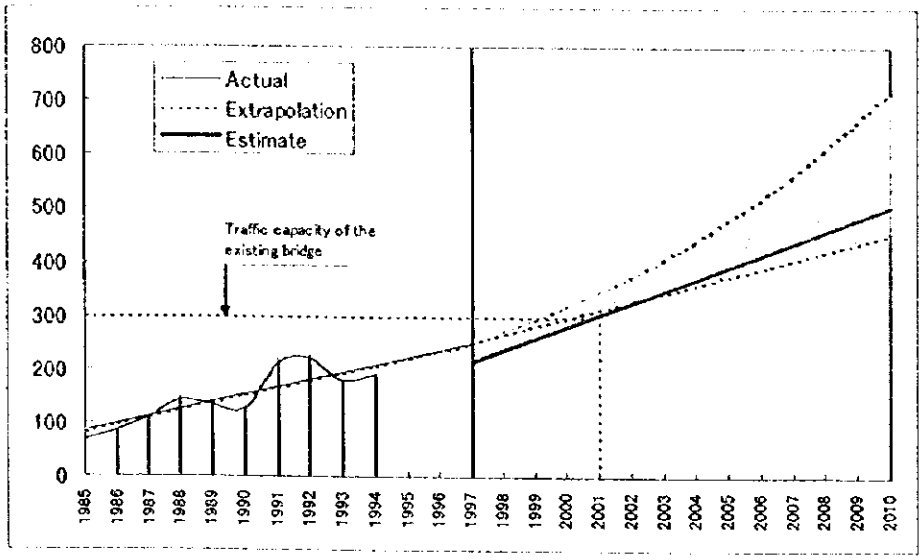


Figure 3 Future Daily Vehicle Traffic Demand at Chirundu Border Post

3.3. TRAFFIC DEMAND AND EXISTING FACILITIES

(1) Needs for the New Bridge (Figure 4)

Traffic capacity of the existing bridge is 300 vehicles per day under 12 hours operation. Future traffic demand will exceed this capacity by the year 2001, and under 14 hours operation, in 2003. Overflowed traffic have to detour to other route (Kariba dam, Victoria falls route, etc.)

(2) Needs for border post facilities improvements (Figure 5)

Dealing capacity of the border post facilities is estimated at 250 vehicles per day under 12 hours operation, and it will increase to 300 vehicles per day under 14 hours operation. Future traffic demand will exceed the capacity under 12 hours operation in 1999 and 14 hours operation 2001. Vehicles arrived during the day could be dealt in the evening, but when traffic volume exceeds the capacity of the border post, it will lead to malfunction of the border.

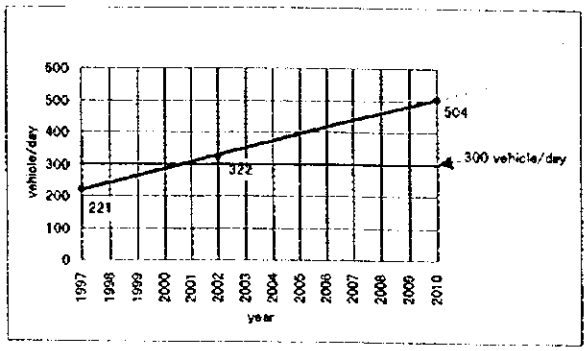


Figure 4 Traffic Volume and the Bridge Capacity

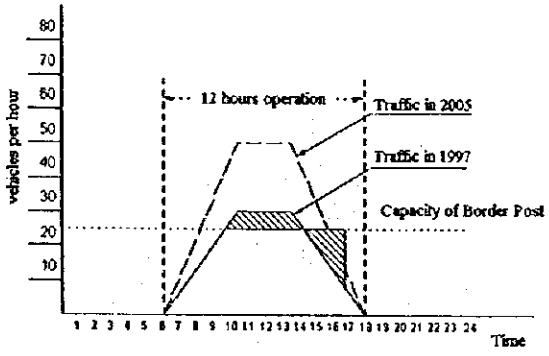


Figure 5 Traffic Volume and the Border Post Capacity

4 BRIDGE ROUTE ALTERNATIVES

The bridge route alternatives study was conducted to determine the most optimum location site for a new bridge construction and the improvement of customs and immigration facilities .

4.1. BASIC CONSIDERATION FOR ROUTE LOCATION

The JICA Study Team conducted the various field reconnaissance surveys in the Study Area and collected data to understand the conditions of survey site. As a result of analysis of various data and information collected, the following basic consideration items for route location were identified.

a) To select the most economical and rational bridge type.
b) To select the route with less technical problems.
c) To preserve the natural and social environmental as much as possible.
d) To avoid passing through the existing and future community as much as possible.
e) To utilize the existing border post facilities as much as possible.
f) To keep a compatibility with the future development plans of the area.

4.2. FORMULATION OF ALTERNATIVE ROUTES

As a result of field reconnaissance survey and analysis of data collected, three (3) Alternative Routes, Route-A, Route-B and Route-C were identified as shown in Figure 6. Dimensions of each alternative route are presented in Table 4.

4.3. EVALUATION OF ALTERNATIVE ROUTES

The evaluation of alternative routes study was conducted from viewpoint of the technical, economical, and environmental aspects. As a result of the study, the Alternative Route-A was selected for a new bridge construction and improvement of customs facilities sites. The major reasons for selection of alternative route are summarized in Table 3

Table 3 Comparison of Alternative Route

	Alt. Route -A	Alt. Route -B	Alt. Route -C
a) Economic aspect	A and B are almost equal	A and B are almost equal	Higher than A or B
b) Technical aspect	No major issues	Horizontal alignment is very tight	Difficult to use present facilities
c) Environmental	No major issues	Private housing to be removed	Enormous
d) Community	No major issues	No major issues	Issues in Zambia side
e) Border Post Facilities	Utilized	Utilized	Not utilized
f) Development Plan	Police housing to be removed	Interfere with future plans	Interfere with future plans
g) Others	Traffic control is easy	Horizontal alignment is very tight	

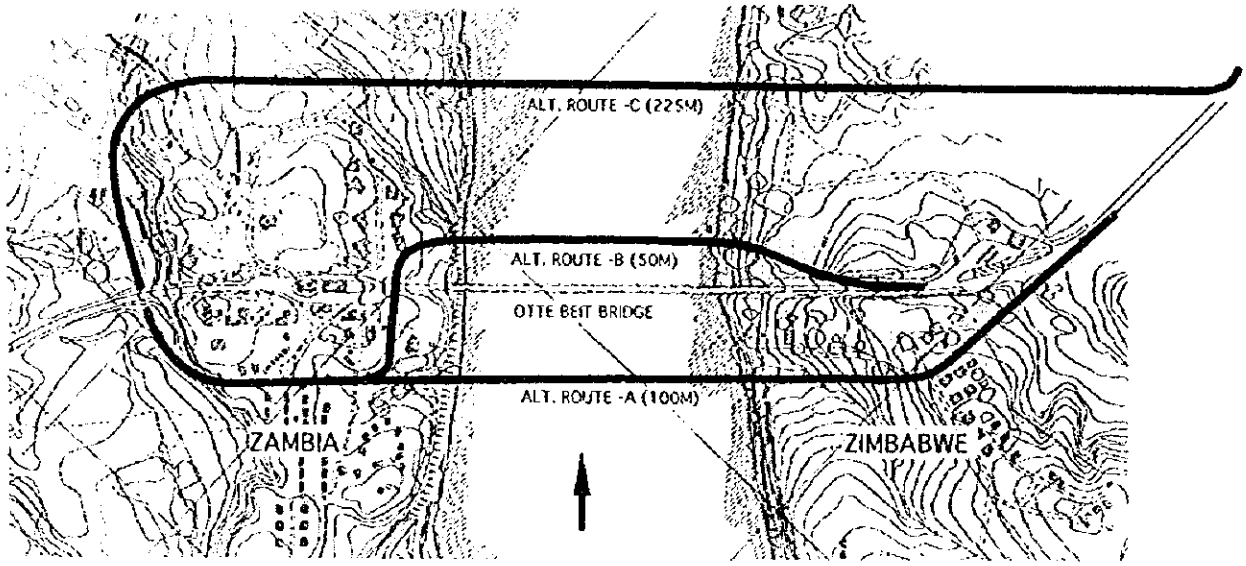


Figure 6 Location Plan of Each Alternative Route

Table 4 Dimension of Each Alternative Route

Items	Route-A	Route-B	Route-C	Remarks
River cross point (from existing bridge)	upstream about 100 m	downstream about 50 m	downstream about 225 m	
River width (m)	330	300	310	
Bridge length (m)	400	380+100	380	
Road length (m)	Zim=400 Zam=425	Zim=150 Zam=560	Zim=625 Zam=570	
Total length (road +bridge) (m)	1,225	1,190	1,570	
Max. longitudinal grade (%)	3.0	3.0	5.0	
Mini. curvature (m)	55	35	75	
No. of houses to be demolished	25	10	6	
Max. cutting height (m)	15.0	4.0	7.0	
Max. embankment height (m)	4.0	4.0	6.0	
Existing custom facilities	To be used	To be used	difficult	
Excavation volume (m3)	67,000	10,000	23,000	
Embankment volume (m3)	7,000	7,000	42,000	
Pavement volume (m3)	8,200	7,100	12,000	

5 BRIDGE TYPE ALTERNATIVES

The bridge type alternatives study was carried out based on the selected Bridge for Alternative Route-A. Taking into account the geometric and soil conditions and technical and economical aspects, the following four (4) alternative bridge types are identified.

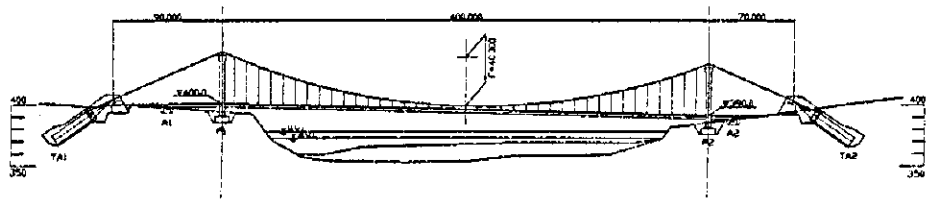
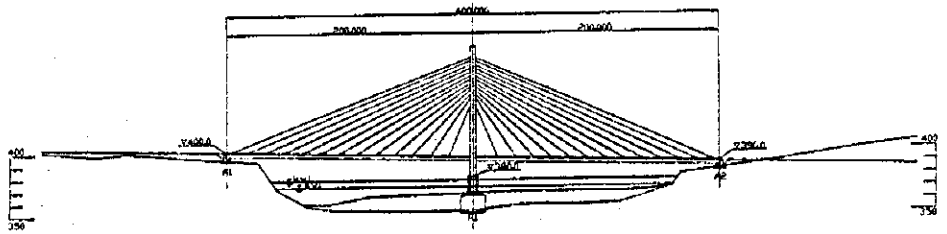
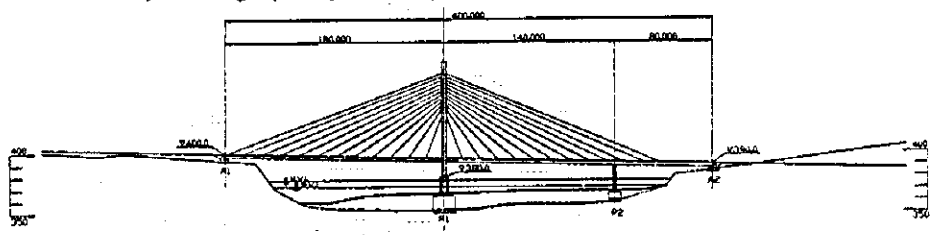
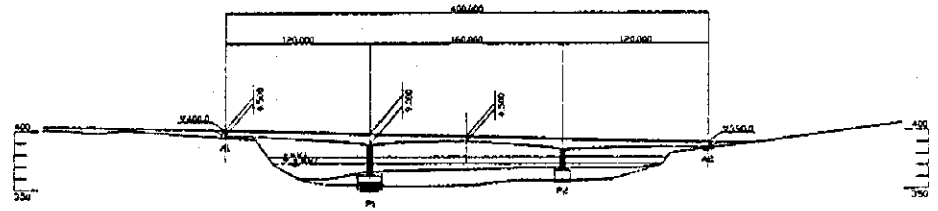
a) Suspension Bridge
b) Cable Stayed Bridge (Symmetric)
c) Cable Stayed Bridge (Not Symmetric)
d) Tree Span Continuous PC Box Girder Bridge.

As a result of comparative study as shown in Table 5, Three Span Continuous PC Box Girder Bridge is selected as the most economical bridge. The characteristics of each alternative bridge type are presented in Table 6.

Table 5 Summary of Comparison Study of Each Alternative Bridge Type

Route			Route "A" (100 m upstream from existing bridge); In Zimbabwe side, relocation of houses for police officials is required. High cut of hill also is needed. Existing border facilities are used. Formation level of bridge : 395 to 400 (from Zimbabwe side)									
Bridge Type			Suspension Bridge		Cable Stayed Bridge		Cable Stayed Bridge		PC Girder bridge			
General Description			400 m single span bridge, concrete girder, without pier in the river. Main cable anchored in the ground, no local experience with concrete girder.		Symmetrical type with 2 x 200 m spans, one pier in the river, 105 m high pylons in the middle of bridge, concrete girder, sufficient experience available.		Non symmetrical type with max. 180 m span two piers in the river, some 95 m high pylons, concrete girder, sufficient experience available.		3 spans PC box girder with max.160 m span, two piers in the river, one of which is very near to current flow, sufficient experience available.			
Evaluation	Construction cost (bridge / access)		US$32.9 million	X	US$21.1 million	△	US$21.3 million	△	US$18.5 million	◎		
	Construction	Bridge Structure	Careful attention must be paid for girder construction	△	Balanced cantilever-out construction, pier located on shallow river bed	○	Balanced cantilever-out construction, pier located on shallow river bed	○	Two piers construction in the river, near current flow	○		
		River Control	No problem	◎	Temporary bridge Near river center, easy	○	Temporary bridge near river center, easy	○	Temporary bridge near flow center, difficult	△		
	Environment	Natural Factors	No serious problem	○	Polluting river water anticipated	△	Polluting river water anticipated	△	Polluting river water anticipated	△		
		Social Factors	Relocation of officials' houses	△	Relocation of officials' houses	△	Relocation of officials' houses	△	Relocation of officials' houses	△		
	Aesthetic aspect		Harmonizes with existing bridge	◎	Very impressive	○	Impressive	○	Not impressive	△		
	Maintenance		Cable maintenance required	△	Cable maintenance required	△	Cable maintenance required	△	Less maintenance works	◎		
	Local economy contribution		Less than other alternatives	△	Local materials and labor used	○	Local materials and labor used	○	Mostly local materials / labor used	◎		
	IRR(%)								6.9			
	Total evaluation		△		○		△		◎			
Recommendation			No		Second		No		First			

Table 6 Comparison of Bridge Alternative

General View	Characteristics	Cost		Remarks
Alt. 1. Suspension Bridge 	• Single span suspension bridge with PC box girder • No foundation in the river, no interference with water flow • Foundation work in dry condition • Anchorage is divided into two parts beside the road • Dead load of PC girder is larger than that of steel girder. Therefore, cable cross section and the anchorage become bigger. • Same type as Otto-Beit Bridge, scenic impression is limited.	supers. subs. total	14.2 6.3 20.5	direct construction cost in million US$
Alt. 2. Cable Stayed Bridge (Symmetric) 	• Main girder is PC box • Main tower is RC solid section • Cable is multi-fan type of 2 planes • Main girder around the main tower is floating type. No vertical shoe is placed. • Construction is cantilever erection from the tower • Main tower is 2.5 times taller than that of existing bridge • Very impressive, and modern	supers. subs. total	8.5 4.4 12.9	direct construction cost in million US$
Alt.3 Cable stayed bridge (not symmetric) 	• Main tower is closer to Zambia than alt.2. Auxiliary pier is placed at Zimbabwean side • Tower and cable type is same as alt. 2 • Further study needed to assess pier. (cost and benefit) • Construction period is shorter than alt. 2 • Very symbolic	supers. subs. total	7.7 5.3 13.0	direct construction cost in million US$
Alt.4 Three spans continuous PC box girder 	• 3 spans continuous girder with varying depth • Cantilever erection from middle piers using four erection platforms. • Not very impressive • Foundation at Zambian side is close to the main flow, thus scouring is anticipated. Foundation is embedded deep into the bearing layer which results in larger coffer dam and concrete amount	supers. subs. total	5.7 5.5 11.2	direct construction cost in million US$

6 PRELIMINARY DESIGN OF BRIDGE

The preliminary design is conducted based on the Three Span Continuos PC Box Girder Bridge selected in previous section . The result of preliminary design study is shown in Figure 7 as general plan and elevation.

6.1. DESIGN OF CROSS SECTION

The following cross section elements are adopted.

a) Number of traffic lanes = 2-Lanes
b) Lane width = 3.5 meters
c) Shoulder width = 1.0 meter on both sides
d) Maintenance walk width = 0.75 on both sides

6.2. DESIGN CRITERIA

(1) Vehicle Load

Japanese vehicle load is applied. For designing of main bridge members, uniform main loading of 1.0 t/m2 of 10 meters length and uniform sub loading of 0.35 t/ m2 applied on the carriageway surface of 5.5 meters width. In addition to those, half of these loading are applied on the rest of the carriageway surface.

(2) Temperature Change

Concrete Structure ---------- For whole structure, 15 to 35 degrees
Difference between members, 5 degrees

(3) Seismic Load

As a result of analysis of data collected, the horizontal acceleration of 0.1 g is employed for the preliminary bridge design.

6.3. PRELIMINARY DESIGN

(1) Foundation

Result of borehole test on both banks show the existence of weathered rock layer just under the surface soil, therefore, spread footings for the abutments were designed to be located on the weathered rock layer on both banks.

(2) Substructure

The total height of piers is more than 30 meters. The shape of pier shaft is designed to be round type to reduce the resistance to water current. In order to minimize footing size and to improve construction safety, temporary cofferdam formed by steel pipe sheet pile was designed.

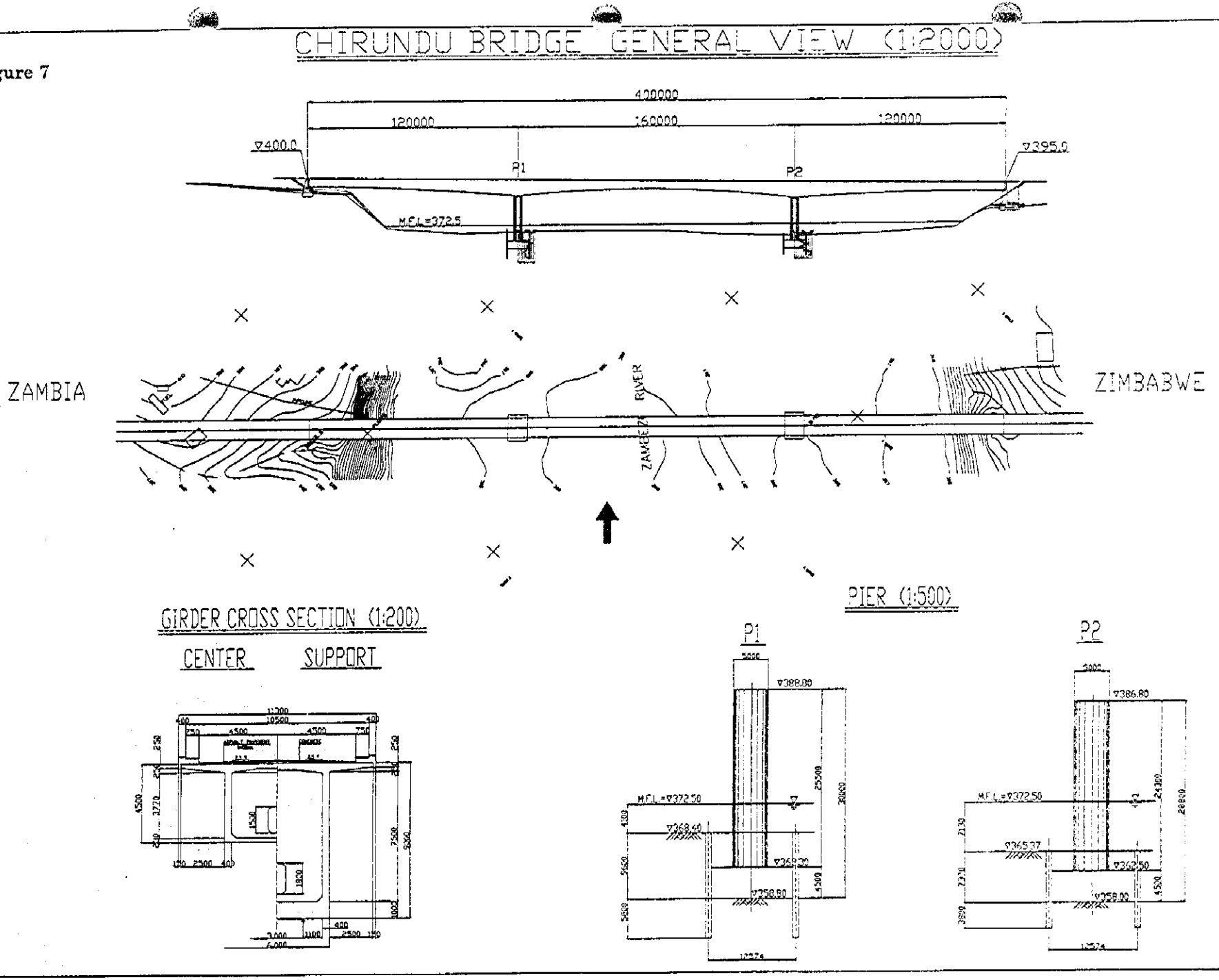
(3) Superstructure

Three (3) spans continuous prestressed concrete girder bridge was designed for the superstructure. The length of each span is 120 meters, 160 meters and 120 meters. Side span length of 120 m was adopted considering the need to leave green space (animal path) in front of an abutment (approximately 20 m) and space between pier and water current for both sides.

(4) Check by BS5400 Code

Major sections were checked by BS5400 code, and safety factors were found satisfactory for ultimate state condition.

Figure 7


CHIRUNDU BRIDGE GENERAL VIEW (1:2000)
420000
120000
180000
120000
▽400.0
▽395.0
P1
P2
M.C.L=372.5
ZAMBIA
ZIMBABWE
ZAMBEZI RIVER
GIRDER CROSS SECTION (1:200)
CENTER
SUPPORT
PIER (1:500)
P1
P2
▽388.80
▽386.80
M.C.L=372.50
▽368.40
▽365.37
▽362.50
▽358.80
▽359.00

7 BORDER FACILITIES IMPROVEMENT STUDY

7.1. PURPOSE OF IMPROVEMENT

As a result of the existing facilities and system survey and analysis of data collected, many problems and issues associated with existing customs and immigration system or facilities were identified. Taking into account these problems and issues, the following purpose of improvement of border posts are identified.

a) To check the freight goods based on the documents and by sight.
b) To levy customs duties on imported goods, and therefore, to protect domestic industries from smuggled goods.
c) To prevent trafficking of illegal drugs.
d) To shorten customs clearing time.
e) To simplify and shorten the immigration/ customs procedure for passengers.

7.2. IMPROVEMENT PROCESS

The improvement in the border post facilities and staff requirements will be made depending on the demand increase. However, some amount of investment shall be prepared immediately for improving the existing capacity of the facilities as well as improving the amenity conditions of the staff at border post. Taking into account the above mentioned matters, the following steps are recommended.

a) Initial investment during the three (3) years of construction; 40 % of total investment.
b) Complementary investment until 2010; 60 % of total investment.

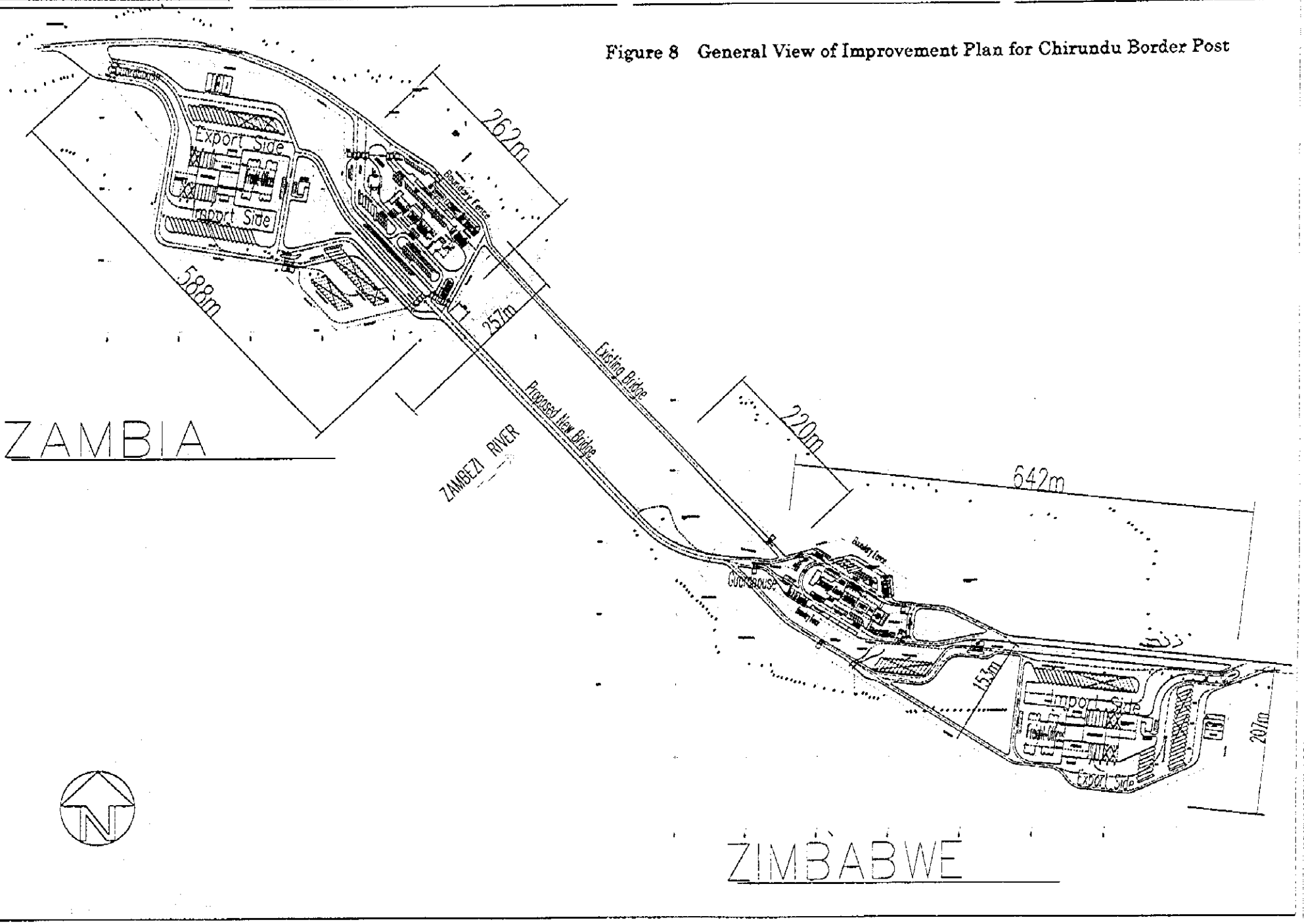
7.3. IMPROVEMENT PLAN

Taking into account the above mentioned matters, improvement plan for Zambia and Zimbabwe sides are established. The following seven (7) accommodation requirements are established by using the estimated future traffic demand and by coordinating with the various user departments of both countries, and satisfy their needs to operate a functional and efficient operation or system with the required controls.

a) Freight Terminal
b) Passenger Control Building
c) Pedestrian Control Building
d) Drug Enforcement Commission
e) Vehicle Inspection Unit and Weigh Bridge
f) Kiosk and Fast Food Outlet
g) Perimeter Fencing and Guardhouses
h) ASYCUDA one form system and computerization for customs procedures

The result of improvement plan for border post is shown in Figure 8.

Figure 8 General View of Improvement Plan for Chirundu Border Post



8 ENVIRONMENTAL IMPACT ASSESSMENT

The environmental study was carried out to evaluate the Alternative Bridge Routes in earlier stage of the Study, and again at final stage to evaluate the selected development plans of the new bridge construction plan and improvement of border facilities from the natural and social environmental aspects.

Environmental impact assessment was made to selected alternative route, which is 100m upstream of the existing bridge. There are no noteworthy environmental problems in these preliminary design results, however, there are some environmental problems and issue during the construction stage which need great attention. The major mitigation measures of environmental impact are presented in Table 7.

Table 7 Summary of Environment Impact Assessment

Elements	Negative Impact	Mitigation Measure	Implementation
Soils	Potential for soil erosion.	1. Slopes should be re-vegetated 2. Slopes should be suitably graded.	D/D Stage Construction Stage
Vegetation	Destruction of river edge cliff vegetation	1. The areas to be cleared should be well marked to ensure that the area cleared of vegetation is kept to a minimum.	Site preparation stage
Resettlement	Demolition of police station in Zimbabwe	1. Alternative station must be built	Before demolition
Road Safety	Increased accidents	1. Traffic safety to be enforced by police	After construction
Noise	Noise and vibration	1. Contractor must limit the working hours to daylight hours.	Construction stage
Air Pollution	Increased in the air dust	1. Dust should be controlled with the use of water sprays.	Construction stage
Water Resource	Demolition of water treatment in Zambia	1. Alternative water treatment should be constructed	Before demolition
Water Resource	Demolition of water pipe line in Zimbabwe	1. Alternative water pipe line should be constructed	Before demolition
Water Resource	Risk of water pollution	1. Contractor must submit written details of the procedures.	Construction stage

9 PROJECT COST AND IMPLEMENTATION SCHEDULE

9.1. PROJECT COST

The project cost was estimated based on the results of preliminary design for bridge and border facilities. The total project cost is estimated as US $ 74,647 thousand in 1997 prices as shown in Table 8.

Table 8 Project Cost

US$ thousand

	Foreign (US$)	Local (US$)	Total (US$)
1. Direct Cost			
Bridge			
superstructure	3,431	2,236	5,667
substructure	3,751	1,746	5,497
sub total	7,182	3,982	11,164
Access Road	328	391	719
Border Post			
housing	8,616	6,769	15385
buildings	6,356	4,993	11,349
parking area	4,228	5,043	9,271
sub total	19,200	16,805	36,005
Direct Cost Total	26,710	21,178	47,888
2.Contingency(15%)	4007	3177	7,184
Total of 1~2	30,717	24,355	55,072
3.Indirect Cost(25%)	7,049	6,719	13,768
4.Engineering Cost(10%)	3,099	2,408	5,507
5.Land Acquisition	0	0	0
6.Conpensation	0	300	300
Total Project Cost	40,865	33,782	74,647

9.2. IMPLEMENTATION SCHEDULE

Taking into account the characteristics of new bridge construction project, the implementation schedule of bridge construction was planned as shown in Table 9. The new bridge will be constructed in 3 years from 1999 to 2002. The land acquisition works and various engineering works will be conducted in 1999. 40 % of total border facilities will be completed by 2002, and the rest will be completed by 2010.

Table 9 Construction Schedule

Description		The 1st year (1999) 1 2 3 4 5 6 7 8 9 10 11 12	The 2nd year (2000) 1 2 3 4 5 6 7 8 9 10 11 12	The 3rd year (2001) 1 2 3 4 5 6 7 8 9 10 11 12	Remark
1. Mobilization		4M			
2. Temporary Works		3M			
Site Office and Construction Yard		5M			
Access road and Temporary Bridge				2M	
3. Bridge Construction Works					
Foundation	Pier No.1(P1)	3M	1M		
	Pier No.2(P2)	2.5M	1M		
Substructure	Abutment No.1(A1)	3M			
	P1	3.5M			
	P2	3.5M			
	Abutment No.2(A2)		5M		
Superstructure	A1(Support)		3M	2.5M	
	P1→A1(Overhang)		13M		
	P1→P2(Overhang)		13M		
	P2→P1(Overhang)		13M	1M	
	P2→A2(Overhang)		13M		
	A2(Support)		3M	2.5M	
Finishing Work				3M	
4. Approach Road					
Earth Work		4M		3M	
Pavement Work				4M	
5. Border Facility Construction Work					
Land Preparation			10M		
Buildings				15M	
Pavement				3M	
6. Site Clearing				1M	

10 ECONOMIC EVALUATION

10.1. WITH PROJECT AND WITHOUT PROJECT CASES

The economic evaluation was carried out based on the comparison of With and Without Cases. With Project case, that is a new bridge construction and improvement of border facilities, and Without Project case, that is the existing Otto Beit Bridge and Chirundu Border facilities with some improvement in accordance with the increased future traffic volume.

10.2. ITEMS OF BENEFIT

Taking into account the conditions and characteristics of transportation and traffic, the following four (4) items were identified for benefits of the project.

a) Avoidance of unintended waiting time which will occur in the With Project case.
b) Reception of heavy trucks which currently use the Kariba dam route.
c) Absorption of vehicles which will be forced to use Kariba dam in the Without Project case.
d) Avoidance of costs which will be required in With Project case.

10.3. ECONOMIC PROJECT COST

The economic project cost was estimated in the conduct of the economic evaluation of the project. The economic project cost was converted from the financial project cost using the conversion factors. The total economic project cost is estimated as US $ 39,013 thousand in 1997 price.

10.4. RESULTS OF ECONOMIC EVALUATION

As a result of economic evaluation, economic internal rate of return (EIRR) is estimated as 6.99 % as shown in Table 10. This value of EIRR is comparatively low compared with other infrastructure projects.

10.5. OTHER SOCIAL BENEFITS

6.99 % of EIRR is estimated as tangible benefit, and upon the completion of this project, the following benefits can be expected as intangible benefits or social benefits.

a) Creation of working opportunities during project implementation period.
b) Contribution to the socio economic activities in Chirundu area.
c) Elimination of the smuggling of goods and drug trafficking.
d) Promotion of the various kinds of developments in the Chirundu area.

Table 10 Cash Flow of Economic Evaluation

Unit: US$1000

Year	With case				Without case (improvement)		Benefits									Total Cost	Total Benefit	Balance
	Bridge	New Bridge Maintenance	Border facility	O/M	Facility improvement	O/M	TTC saving for passenger	TTC saving for loaded cargo	VOC savings for all vehicles	VOC savings for Heavy Vehicle	TTC saving for Heavy Vehicles	VOC saving for detoured vehicles	TTC saving for detoured vehicles	TTC saving for detoured cargo				
1996																		
1997																635		-635
1998	635															6,177		-6,177
1999	3,812		2,365													6,359		-6,359
2000	3,812		3,547		1,000											7,995		-7,995
2001	4,448		3,547													1,375	349	-1,026
2002		10	2,365		1,000		139	19	164	25	2					2,375	469	-1,906
2003		10	2,365				189	24	227	27	2					2,375	718	-1,657
2004		10	2,365				295	36	357	28	2					2,375	892	-1,483
2005		10	2,365				368	43	449	30	2					-625	1,180	1,805
2006		10	2,365		3,000		489	55	602	32	2					592	1,418	826
2007		10	591			10	588	63	731	34	2					592	1,789	1,197
2008		10	591			10	743	76	932	36	2					592	2,173	1,581
2009		10	591			10	901	88	1,144	38	2					592	3,811	3,219
2010		10	591			10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2011		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2012		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2013		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2014		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2015		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2016		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2017		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2018		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2019		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2020		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2021		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2022		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2023		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2024		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	3,763
2025		10		47		10	1,143	106	1,465	40	3	994	54	6		48	3,811	20,685
2026		10		47		10	1,143	106	1,465	40	3	994	54	6			IRR =	6.99%

* Balance of year 2026 includes residual of bridge and border post facilities, i.e, bridge = 10166, facilities = 6756.
* Maintentenance of existing bridge is counterbalanced between "with" and "without" case
* Operation/Maintenance (O/M) of border post facilities accounts for 0.2% of project cost for each cases.

11 CONCLUSION AND RECOMMENDATION

11.1. CONCLUSION

(1) The existing bridge can be used under present restrictions, but the loading capacity under the present bridge design standards, such as British Standard, Japanese Standard or South African Standard, indicate that the existing structure is not acceptable.

(2) Present traffic demand is 250 vehicles per day. It will increase to 500 vehicles in 2010.

(3) Traffic capacity of the bridge and the border facilities is 30veh/h 25veh/h, respectively.

(4) Bridge crossing point is selected at 100 m upstream of the bridge from viewpoints of economical, technical and environmental aspects.

(5) spans continuos PC box girder bridge is selected among other alternatives.

(6) Border post facilities is to be built in both countries, and shall be improved according to demand increase (stage construction)

(7) Alternative route have least impact to environment, nevertheless, impact during construction stage should carefully taken care of.

(8) Total project cost is estimated at US$ 74.6 million, of which US$18.5 million is for the bridge, US$32.0 is for the border post facilities.

(9) Economic internal rate of return for this project is 6.99%.

(10) The project will bring about other intangible benefits such as stricter inspection on drug trafficking, smuggling, or job opportunity.

11.2. RECOMMENDATION

(1) Border Post facilities and bridge structure shall be improved simultaneously in order to maximize the benefits from the project.

(2) Bridge route of 100 meters upstream from the existing bridge shall be adopted from viewpoints of economical, technical, and environmental aspects.

(3) Prestressed concrete girder bridge with 2-lanes shall be employed from viewpoints of economy.

(4) Stage construction for border post facilities shall be considered due to a huge amount of cost.