VOLUME 1 MAIN REPORT

Table of Contents

EXECUTIVE SUMMARY

VOLUME 3 PRELIMINARY DESIGN DRAWINGS

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
BM	Bench Mark
BMD	Bangladesh Meteorological Department
BoQ	Bill of Quantity
BWDB	Bangladesh Water Development Board
C/L	Center Line
DC	Deputy Commissioner
DoE	Department of Environment
DoF	Department of Fisheries
EIA	Environmental Impact Assessment
EL	Existing Level
EMP	Environmental Management Plan
GIS	Geographical Information System
GoB	Government of Bangladesh
HFL	High Flood Level
HWL	High Water Level
IEE	Initial Environmental Examination
BBA	BangladeshBridge Authority
LA	Land Acquisition
LGED	Local Government Engineering Department
LWL	Lowest Water Level
mPWD	Standard Public Works Datum in meter
MSL	MeanSea Level
MV	Motorized Vehicle
NMV	Non-Motorized Vehicle
NTC	Notice to Commence
O&M	Operation and Maintenance
PDB	Power Development Board
R	Regional
RHD	Roads and Highways Department
REB	Rural Electrification Board
RL	Reduced Level
RoW	Right of Way
SoB	Survey of Bangladesh
SPT	Standard Penetration Test
TL	Team Leader
ToR	Terms of Reference

EXECUTIVE SUMMARY

Abstract: Feasibility Study (October 2012), carried out by the Consultants (DevCon-DPM-KPL), recommended a bridge over the Kocha River on Perojpur – Jhalokathi Road along Sankerpasha-Uttar Bitabari. Later, Institute of Water Modelling (IWM) was commissioned to carry out among others an independent review of the hydraulic parameters. IWM has submitted its Final Report in October 2013, and its results are in close agreement with those of the Feasibility Study (FS) Consultants' estimation for the recommended alignment.

Based on overall considerations, the Consultants reconfirm its recommendation for implementing 2.00 km long Bekutia Bridge across the Kocha River along Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari (Alternate -2), located 3.82 kilometers downstream from the existing Bekutia ferry crossing with a bridge type as per Option-1 (400m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length). Estimated cost is about Tk. 858.00 crore (2012 price). For base case, EIRR is about 18%, while benefit-cost ratio is about 1.36. On the other hand, BBA may consider another alignment in course of Detailed Design Stage before taking a final decision, along Alternative -1 through existing Bekutia ferry crossing, which was considered by FS Consultant and recommended by IWM as well.

A. Introduction

The Government of Bangladesh represented by Bangladesh Bridge Authority (BBA) intends to construct a Bridge over Kocha River on Perojpur-Jhalokathi road in order to replace existing ferry crossing in Bekutia along Perojpur – Naikati- Rajapur Road (Z8702).

BBA in March 2011 appointed Joint Venture of DevCon-DPM and KPL as Consultant to carry out feasibility studies, and the Consultants submitted its Final Feasibility Report (FFR) in October 2012. Later in December 2012, BBA decided to carry out "Hydrological and Morphological Study" for the proposed bridge. For this purpose Institute of Water Modelling (IWM) was subcontracted to the FS Consultant as a specialized agency to carry out among others an independent review of the hydraulic parameters. IWM has submitted its Final Report in October 2013, and its results are in close agreement with those of the FS team estimation for the recommended alignment along Shankarpasha - Uttar Bhitabari (i.e. Alternate 2), located 3.82 kilometers [1] downstream of existing Bekutia ferry ghat.

This Final Feasibility Report (October 2013) details some of the primary surveys, investigations and estimations in connection with screening few alternative alignments from a number of locations/sites for the proposed bridge. Thereafter, one of those was selected as the best alignment from technical, economical, social and environmental considerations.

[1] IWM in its Final Report (October 2013) refers this point as 4.50 km downstream of existing Bekutia Ferry Ghat.

B. Traffic Survey and Forecast

The traffic survey and analysis provide the basis for traffic forecast and projection on the road/bridge project.

The summary of the study findings starting from traffic survey through traffic projection considering economic life span of 30 years and 50 years for 2-lane and 4-lane Carriageway Bridge respectively are as follows:

- From traffic projection of total motorized traffic (Table 2-13, Volume-2), it is found that AADT in the year 2047 is 36,003 veh/day which exceeds 35,000 veh/day, saturated capacity for a 2-lane carriageway bridge (Ref: ADB TA # 4821-BAN 2009).

- From traffic projection of total non-motorized traffic (Table 2-14, Volume-2), it is found that AADT in terms of PCU/hr in the year 2048 is 193 PCU/hr which is far less than 400 PCU/hr, the minimum requirement for provision of NMV lane.

- From traffic projection of total motorized traffic (Table 2.1-2, Volume-1), it is found that AADT in the year 2068 is 75056 veh/day which just exceeds 75000 veh/day, the saturated capacity of 4-lane carriageway bridge (Ref: ADB TA # 4821-BAN 2009).

For justification of 4-lane carriageway in economic life span of **50 years** non-motorized traffic projection was not considered.

From the traffic survey, forecast and projection, it may be concluded that the bridge together with both side approach roads is feasible for 2-lane single carriageway bridge considering economic life span of 30 years. The traffic projection made for NMV up to the end of economic life span of 30 years could not justify provision of NMV lane. On the other hand, traffic forecast and projection made considering economic life span of 50 years justifies provision of 4-lane dual carriageway bridge under Traffic Study perspective only.

C. River Hydrology and Hydraulic Study

The proposed bridge is located in Jhalokathi District under Barisal Division which is in the south-western region of Bangladesh. All rivers and canals in the region carry tidal flow during flood tide, and the flow adds up with overland flow in ebb tide, especially, during monsoon season. The proposed bridge will be across KochaRiver which is tidal river and is dominated by ebbing effect with high velocity and volume of discharge.

In course of river cross section survey, 12 cross sections were selected and surveyed in about 8.0km reach of the Kocha River (Pl. refer to Map-2 and Annexure-02, Volume-2). The cross sections are numbered in X-section ID: Kocha-001 to Kocha-0012. These cross sections were screened based on hydraulic consideration.

Furthermore, during detailed survey works, a total of 13 nos. additional cross sections from Ch 7+860 to Ch 10+660 were selected and surveyed of which 10 X-sections Ch 7+860 to Ch 9+660 were on either sides of the bridge alignment at 200m interval in order to verify uniformity and stability of the river. It is observed that the river X-section is stable from Ch8+660 to Ch 9+660. Depending on this findings the bank protection/revetment works were considered from Ch 8+660 to Ch 9+060 on the Left Bank and from Ch 8+460 to Ch 9+660 on the Right Bank(Pl. refer to Map-3 and Annexure-02, Volume-2). The revised bank protection works has been done incorporating comments from BWDB.

The peak tidal discharge was calculated to 14130 cumec (ref. Sub-section 3.7.3, Volume-2). This discharge was increased by 50% in order to establish design discharge (21,195 cumec), which compares well with IWM model results of 20,090 cumec. This will not be exceeded due to rise in sea water level or cyclonic surge in 1 in 100 year event. Following Table includes the results of FS Team and IWM for the alignment along Sankerpasha- Uttar Bitabari, 3.82 kilometers downstream from the existing Bekutia ferry crossing (Alternative-2).

Sl	Features	FS Team	IWM	Remarks
A	*Hydraulic Design Parameters*			
	Flood Discharge (m3/cumec)	21,195	20,090	Close
	Design High Water Level (mPWD)	3.05	3.22	100 yr
	Std High Water Level (mPWD)	2.74	3.13	100 yr
	Depth Average velocity (m/sec)	1.365	1.87*	*Maximum
	Surge level (mPWD)	Not provided	3.15	
	Sea Level Rise (cm)	Not provided	0.56	
B	*Scour*			
	General Scour (m)	3.53	3.60	Close
	Constriction Scour (m)	Negligible	0.80	
	Local Scour at Pier (m)	17.29	12.84	
	Total Scour (m)	20.82	17.24	FS Team on safe side
	Lowest be d level at the section (mPWD)	-14.00	-13.98	Almost same
	Scour level at Pier (mPWD)	-34.82	-31.22	Close

(Source: IWM's Final Report, Oct 2013, App E, Table 7)

D. Selection of Final Bridge Alignment

In the reconnaissance stage river X-section survey was conducted at 12 locations along a reach of 8.0 Km on Kocha River. After a 2-step screening of the cross sections from hydraulic considerations, the following three alternative locations were selected (Pl. refer to Map 4-1, Volume-2):

- **Alternative-1:** This is located along **Machimpur-Krishnanagar-Dumurtola-Bekutia,** 250 meters downstream from the existing Bekutia Ferry crossing.

- **Alternative-2:** This alignment is along **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari,** 3.82 kilometers downstream from the existing Bekutia ferry crossing and 5.25 km upstream from Charkhali Ferry crossing.

- **Alternative-3:** This one is along **Badura-BaieenGali-South Gazipur-Uttar Bitabari-MidiabadhBitabari,** 1.00 kilometer upstream from the existing Charkhali Ferry crossing.

The alternative alignments were then evaluated for technical feasibility and economic viability in an indicative manner (for details refer to Sub-section 4.3.2, Volume-2). For the purpose of indicative economic analysis, all structural and financial data are used from secondary sources. The prices were increased to represent the Project Cost at implementation year 2015-16 (assumed).

It is evident that total cost of project in an indicative manner is different for the three Alternatives. Again, the benefit will be different for each individual Alternative. A simple indicative economic analysis (at discount rate of 12% applicable during study) shows the following values of economic indicators (Pl. refer to Annexure-04, Volume-2 for details):

- Net Present Value (NPV) for: Alternative-1 = Tk.496 million
  Alternative-2 = Tk.5165 million
  Alternative-3 = Tk.1180 million

- Benefit Cost Ratio (BCR) for: Alternative-1 = 1.03
  Alternative-2 = 2.47
  Alternative-3 = 1.28

- Economic Internal Rate of Return (EIRR) for: Alternative-1 = 12.20 %
  Alternative-2 = 22.19 %
  Alternative-3 = 14.245 %

Considering the above-mentioned technical aspects and economic returns, **Alternative-2** (i.e. **Sankerpasha-Uttar Bitabari),** located 3.82 km downstream of existing Bekutia Ferry Ghat, is recommended as final location of the bridge.

E. Preliminary Design Criteria

The analysis and design of the bridge is in accordance with AASHTO LRFD Bridge Design Specification published by the American Association of State Highway and Transportation Officials (AASHTO) – Second Edition 1998.

F. Selection of Bridge Types

Detailed alignment survey was carried out along the final location Sankerpasha-**HorinaGazipur-Zolagati-Uttar Bitabari** (Alignment -2) at 3.82 kilometers downstream from the existing

Bekutia ferry ghat. From the alignment survey, **7.31 km** was found as total length - bridge and its approaches are as follows:

i. Bridge including both end viaducts: 2.00 km
ii. Approach road at Perojpur-end: 2.60 km; and
iii. Approach road at Jhalokathi-end: 2.71 km.

Three alternative types of bridge have been considered together with the following span arrangements:

Option	Span Arrangement and Lanes	Est Cost (Taka)	Remarks
Option 1	400.0m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length. *2 lane single carriage way*	5,643,936,186.00	*Recommended Option and the values of economic indicators (NPV, BCR and EIRR) are shown in Tables K-1 and K-2.*
Option 2	400.0m East End Viaduct + 9-120m spans plus 2-60m end spans+400m West End Viaduct => Total 2000m length. *2 lane single carriage way*	5,757,563,370.00	
Option 3	400.0m East End Viaduct + 7-150m spans plus 2-75m end spans+400m West End Viaduct => Total 2000m length. *2 lane single carriage way.*	5,757,563,370.00	

G. Environmental Impact Assessment

In accordance with GOB's environmental policies, Initial Environmental Examination (IEE) was carried out to assess the environmental impacts due to the proposed Bekutia bridge at the final location and to ensure compliance with their respective rules and policies. Thereafter, Environmental Impact Assessment (EIA) was made and finally, Environmental Management Plan (EMP) has been prepared to avoid/minimize any impact during construction and operation-maintenance phases, and that will enable integration of environmental provisions and management measures for the bridge.

The Project will have overall positive impacts with some negative impacts. Most of these negative impacts are mainly construction related and can be mitigated by the successful implementation of the EMP. This environmental assessment fully meets the harmonized environmental and socio-economic development in the area (for details see Volume 1, Appendix A).

The Project area is not adjacent to or within any environmentally sensitive areas like: Protected areas, Wetland, Mangrove, Estuaries, Buffer zone of protected area or any other Special area for protecting bio-diversity or Forest area. The bridge will facilitate on the movements of traffic and people. There will be some noise/disturbances during the construction period, and those will bring some inconvenience in living conditions in/near the project area due to noise/ vibration/ blasting etc, some chances of ecological degradation due to increased river bank erosion. Chance of water logging, Impact on Forest Area, Incidents of waterborne diseases, and Deterioration of surface water, Air Pollution etc and those will be minimized through environmental management plan. Direct and indirect benefits of employment generation will be there during the construction works and after construction. Through the project activities; potential Environmental Impact, Mitigation Measures, etc will be followed as part of environmental management plan during construction.

H. Resettlement and Land Acquisition

A detailed resettlement and land acquisition survey for the selected Bridge Alignment (Alternative-2) was conducted from October 18-28, 2011 for assessment of cost of compensation and relocation of affected persons and properties. The survey was conducted in the immediate vicinity of the final bridge alignment and both side approach road alignments.

Construction of Bekutia Bridge with viaduct and approach road will require land acquisition and displacement of residential households, shops and common properties. A total of 50 meter wide right of way (RoW) has been considered during detailed survey and it requires acquisition of about 33 ha land with displacement of 46 households of which 28 households are within the RoW and the others are on and/or close to the boundary, 3 shops and 4 community properties including land, structures, trees. No squatter households found within the right of way.

The total estimated cost for implementation of the RP is BDT 127,295,859 *(one hundred twenty seven million, two hundred ninety five thousand, eight hundred and fifty nine o*nly) equivalent to USD=1,697,278. It includes payment of compensation for structure & resettlement benefits with other allowances, operation cost of the RP implementing agency and independent monitoring and reviewing of the RP implementation. Resettlement funds will be provided based on the financing plan agreed by the Government and Donor Agency. The total estimated budget is shown in the Table EX 2, Appendix-B2.

I Toll Collection System

As mentioned in the ToR the bridge will be a toll bridge. Toll money collection will start after opening of the Bridge (estimated after year 2018). The infrastructure for toll collection will be on one end of the Bridge. It should be operated and maintained by

qualified Operator. Necessary cost of implementation, operation and maintenance has been incorporated in the cost stream of financial and economic analyses.

The toll rate for Truck, Bus and Light vehicles are considered at the existing rate in ferry crossing system. To be conservative in the benefit side these existing rates have been considered as starting toll rate in 2019. The toll collection money from 2019 through 2048 has been shown in the Sub-section 7.3.4which has been considered in the benefit stream of financial and economic analyses.

J Operation and Maintenance

Operation and Maintenance of different components of main bridge, viaducts, services and other ancillary structures of the Bekutia Bridge will be an essential activity in order to ensure long time durability and service of the bridge. The activities will include routine inspections in weekly or monthly basis, general inspection every two years' time and principal inspection every five years interval.

However, the Construction Company with due agreement and concurrence of Supervision Consultant and Manufacturer's specifications will prepare necessary Operation and Maintenance manual for the Main Bridge and Viaducts and its connections, supports, services and other ancillary structures. The Manuals will be detailed enough to be followed by qualified Operation and Maintenance Operator.

K Economic Evaluation

An economic appraisal of the proposed Bekutia Bridge project was carried out within the broad framework of cost-benefit analysis. The analysis was undertaken with and without project situation. It implies two scenarios: (i) first, a bridge will be constructed over the Kocha River with necessary approach roads and appurtenant structures considering an economic life span of 30 years, and (ii) second no bridge will be constructed and the ferry systems will continue in Bekutia and Charkhali Ferry Ghats.

The project costs and benefits have been identified and valued in monetary terms, using economic prices. The economic prices were calculated by applying a standard conversion factor 0.85 used for road sector in Bangladesh and accepted by RHD for economic evaluation of projects in recent years.

The annual stream of project costs and benefits in financial and economic terms were calculated over an **evaluation period of 30 years** which is normally considered for bridge structures. Discounted Cash flow (DCF) technique was used at a 15% discount rate for determining Net Present Value (NPV), Benefit Cost Ratio (BCR), Economic Internal Rate of Return (EIRR) and Financial Internal Rate of Return (FIRR). **The respective values are shown in Table-K1 and Table-K2.**

Apart from the above and to check economic viability of 4-lane dual carriageway bridge, the annual stream of project costs and benefits in economic terms were calculated over an **evaluation period of 50 years** which is not normally considered

for bridge structures. Discounted Cash flow (DCF) technique was used at 15% discount rate for determining Net Present Value (NPV), Benefit Cost Ratio (BCR) and Economic Internal Rate of Return (EIRR) considering the Base Case only. The respective values are shown in Table-K3.

For Economic justification of 150m span extra dosed bridge with 2-lane single carriageway, the annual stream of project costs and benefits in economic terms were calculated over an evaluation period of 50 years at discount rate of 15% which is presented in Table K-4.

The Project Cost has been applied in installment of 15%, 35%, 35% and 15% during 1st, 2nd, 3rd and 4th year of implementation respectively. The maintenance costs are recurring costs applicable after completion (2018) of the Project. So the maintenance cost has been duly applied from 2019. Both the annual routine maintenance and periodic maintenance costs are approximated to 0.2% of the Project cost

The benefits to be accrued out of the project for an economic life span of 30 years were evaluated for the following components:

- Cost savings from replacement of ferry system and time delay;
- Cost savings from ferry operation closure for bad weather condition;
- Cost savings from vehicle operating costs (VOC) due to reduced distance; and
- Toll Collection.

The sensitivity analysis was conducted for the following limits of change in benefit and cost streams of economic and financial values:

- Benefit reduced by 10% and Cost at the base value;
- Cost increase by 10% and benefit at the base value; and
- Benefit reduced by 10% and Cost increased by 10%.

Table K-1: The *Economic indicators* NPV, BCR and EIRR for base case including sensitivity analysis are presented below:

Sl. No.	Economic Evaluation	NPV (Million Tk.)	BCR	EIRR (%)
1.	Base Case	**1983**	**1.36**	**18.115**
2.	Benefit 10% reduced	**1231**	**1.22**	**16.985**
3.	Cost 10% increased	**1429**	**1.23**	**17.09**
4.	Benefit 10% reduced and Cost 10% increased	**676**	**1.11**	**16.015**

Table K-2: The *Financial indicators* NPV, BCR and FIRR for base case including sensitivity analysis are presented below:

Sl. No.	Financial Evaluation	NPV (Million Tk.)	BCR	FIRR (%)
1.	Base Case	**1772**	**1.25**	**17.225**
2.	Benefit 10% reduced	**887**	**1.13**	**16.143**
3.	Cost 10% increased	**1064**	**1.14**	**16.244**
4.	Benefit 10% reduced and Cost 10% increased	**178**	**1.02**	**15.214**

Table K-3: The *Economic indicators* NPV, BCR and EIRR evaluated for Base Case only for *4-lane dual carriageway bridge* are presented below:

Sl. No.	Economic Evaluation at discount rate of	NPV (Million Tk.)	BCR	EIRR (%)
1.	15%	**-2800**	**0.75**	**12.827**

Table K-4: The *Economic indicators* NPV, BCR and EIRR evaluated for Base Case only for 150 m span *Extra dosed Bridge with 2-lane single carriageway bridge* are presented below:

Sl. No.	Economic Evaluation at discount rate of	NPV (Million Tk.)	BCR	EIRR (%)
1.	15%	**-2213**	**0.77**	**13.028**

It appears from the **Table-K1 and Table-K2** that the NPV, BCR and EIRR/FIRR are *within acceptable limit* for the sensitivity analysis of Base Case, Benefit 10% reduced, Cost 10% increased, and Benefit 10%reduced and Cost 10%increased for a *2-lane single carriageway Bridge Project.*

Again, it appears from the **Table-K3** that the NPV, BCR and EIRR/FIRR *are not in acceptable limit for a 4-lane dual carriageway Bridge* Project. Moreover, it is important to note that in Barisal Division and around all long bridges, in terms of span length and total length, whether old or new, are 2-lane single carriageway bridges.

It also appears from the **Table-K4** that the NPV, BCR and EIRR/FIRR are not within the acceptable limit for a 150m span 2-lane single carriageway Extra dosed Bridge.

Over all, above economic analyses suggest that Option 1 (2-lane single carriageway bridge having 400.0m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length) is viable for the proposed Bridge.

L CONCLUSION AND RECOMMENDATION

Project Description

Alignment-2 (**Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari), located at** 3.82 kilometers downstream from the existing Bekutia ferry crossing and 5.25 kilometers upstream from Charkhali Ferry crossing is finally selected (refer to Map 4-1, Volume-2). Total alignment is of 7.31 km long - bridge and its approaches are as follows:

i. Bridge including both end viaducts: 2.00 km
ii. Approach road at Perojpur-end: 2.60 km;
iii. Approach road at Jhalokathi-end: 2.71 km;

Bridge Type

Out of three types, Post-tensioned Precast Segmental Box Girder bridge (Option 1) was considered to best suit the purpose on the basis of cost comparison. The Bridge will have the following span arrangement:

Option-1: 400m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length.

The East & West End Viaducts consists of 16 nos. 25.0m span deck-girder spans and the Main Bridge consists of:

- East End Module, 3-100m spans + 1-50m span'
- Middle Module, 5-100m spans; and
- West End Module, 3-100m spans + 1-50m span.

The support system for the Viaducts and the main bridge are as follows:

- *The Viaducts*: Pier bent consisting of pier cap, pier columns and pile cap supported on 600mm dia cast-in-situ bored piles. Short stem abutment with approach slab supported on elevated 600mm dia cast-in-situ bored piles.
- *The Main Bridge*: Pier bents consist of pier cap, pier wall(s) and pile cap supported on 1500mm dia cast-in-situ bored piles.

Navigation Clearance

The middle 5-span module will provide full navigation clearance of 76.22m horizontal distance and 18.30m vertical height as required by BIWTA Standard Class-I for Kocha River. The pile caps are setback to a distance of about 6.0m and 16.0m respectively from the 76.22mx18.30m navigation envelop for providing fender protection around pile caps.

However, the other two end modules will also provide navigation clearance between BIWTA Standard Class-I and Class-II. Specifically, only the end 100m spans of end modules are in BIWTA Standard Class-II. Thus, BekutiaBridge over KochaRiver will provide clear, safe and unfettered pass for all BIWTA Classified vessels.

Project Cost

The Table below shows the Project cost by component:

Sl No.	Description	Amount (BD Tk.)	Remark
01.	Construction Cost	Tk. 6,391,860,328	
02.	Engineering Cost:		
	a) Detailed Design	Tk. 159,796,508	2.5% of Sl No. 01
	b) Construction Supervision	Tk. 223,715,111	3.5% of Sl No. 01
03.	Land Acquisition, Resettlement and EMP.	Tk. 118,216,000	
04.	Administrative Cost	Tk. 50,172,762	10% of Sl No. 02 and 03.
05.	Physical Contingencies	Tk. 958,779,049	15% of Sl No. 01
06.	Price Contingencies	Tk. 386,707,550	15% of Sl No. 01, 02 and 05.
07.	VAT, TAX and DUTIES	Tk. 294,728,680	14% for importation @ 30% of Sl 01&02.
Total Project Cost:		**Tk. 8,583,975,989**	

The Maintenance cost, both routine and periodic are considered as 0.2 percent of the Project cost, except Price Contingencies, VAT, TAX and DUTIES.

The Project Cost for the Bekutia Bridge, Post-tensioned Precast Segmental Box Girder Bridge of 100m Span (Option 1), is Tk. 858.4crores. (USD[2] 111.00 million equivalent))

Recommendation

Based on overall considerations, the Consultants reconfirm its recommendation for implementing 2.00 km long Bekutia Bridge across the Kocha River along Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari (Alternate -2), located 3.82 kilometers downstream from the existing Bekutia ferry crossing with a bridge type as per Option-1 (400m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length). Estimated cost is about Tk. 858.00 crore (2012 price)**.** For base case, EIRR is about 18%, while benefit-cost ratio is about 1.36.

On the other hand, BBA may consider another alignment in course of Detailed Design Stage before taking a final decision, along Alternative -1 through existing Bekutia ferry crossing, which was considered by FS Consultant and recommended by IWM as well.

[2] Exchange Rate: Tk77.25 = USD 1.00

INTRODUCTION

Bangladesh being a riverine country is having an intricate network of tidal canals, rivers and estuaries in the south-western region, especially in the Barisal Division. Specifically, somewide discontinuities on the roadway at the intersection of tidal rivers having ferry services are hampering communication due to long delay in river crossing and limited ferry operating time. Moreover, natural calamities and mechanical problems of ferry create tremendous suffering to the motorists. These types of uncertainties are hampering trade, travel etc. and hindering development of educational institutions and other industrial developments.

Furthermore, construction of PadmaBridge will open a new horizon of all communications between project influence area and the eastern part of Bangladesh including the capital city Dhaka. Thus, development and improvement of road communication network within districts and divisional level appears to be a prerequisite in fulfilling important objectives and outcome of PadmaBridge.

As such, the Government of Bangladesh represented by Bangladesh Bridge Authority (BBA)intends to construct BekutiaBridge over KochaRiver on Perojpur-Jhalokathi road in order to replace existing ferry crossing along Perojpur–Naikati-Rajapur Road (Z8702). Construction of this bridge is expected to divert and generate increased volume of traffic along the route, remove the ferry crossing, reduce travel time and upgrade socio economic condition of that region.

The project area is characterized by peat basins, tidal flood plains and the Ganges floodplain. But tidal floodplain is predominant in the area. The tidal floodplain is bounded in the north by the Ganges floodplain and in the south by the south-coast, crisscrossed by numerous tidal creeks and canals. The tidal floodplain is strongly influenced by tide, salinity and rainfall. The average tide difference in KochaRiveris more than two meters. Most of the areas are between one to three meters above mean sea level and have a southward regional slope. The water and soil are saline due to tidal effect but in the rainy season salinity becomes low. Upland flow of fresh water from the upstream regions and the tides normally control the salinity of this region.

1. TECHNICAL ASPECTS

1.1 Traffic Survey and Study

The main objective of traffic survey and analysis is to establish the extent of traffic demand on a road project. The results of this process formulate the basis for traffic forecast and projection on the road project.

The details of the methodology, primary surveys, analysis, forecast and projection are included in Volume-2 of Final Feasibility Report.

2.1.1 Summary of Study Findings

The summary of the study findings starting from traffic survey through traffic projection are as follows:

- From traffic projection of total motorized traffic (**Table 2-13**, Volume-2) it is found that AADT in the year 2047 is 36003 veh/day which exceeds 35000 veh/day, the saturated capacity of 2-lane carriageway (Ref: ADB TA # 4821-BAN 2009).

- From traffic projection of total non-motorized traffic (**Table 2-14**, Volume-2) it is found that AADT in terms of PCU/hr in the year 2048 is 193 PCU/hr which is far less than 400 PCU/hr, the minimum requirement for provision of NMV lane.

- From traffic projection of total motorized traffic (***Table 2.1-2***, below) it is found that AADT in the year 2068 is 75056 veh/day which just exceeds 75000 veh/day, the saturated capacity of 4-lane carriageway bridge (Ref: ADB TA # 4821-BAN 2009). The Traffic growth rate considered for economic life span of 50 years is shown in Table 2.1-1.

- For justification of 4-lane carriageway in economic life span of **50 years** non-motorized traffic projection was not considered.

From the traffic survey, forecast and projection it may be concluded that the bridge together with both side approach roads is feasible for 2-lane single carriageway bridge considering economic life span of 30 years. The traffic projection made for NMV up to the end of economic life span of 30 years could not justify provision of NMV lane. On the other hand, traffic forecast and projection made considering **economic life span of 50 years** justifies provision of 4-lane dual carriageway bridge under that perspective only.

Table 2.1-1: Traffic Growth Rate Considered for 50 years Projection

Period	Truck	Bus	Light vehicles
2019-23	7%	9%	9%
2024-28	7%	8%	8%

Period	Truck	Bus	Light vehicles
2029-33	6%	8%	8%
2034-38	6%	7%	7%
2039-43	5%	6%	6%
2044-48	5%	6%	6%
2049-53	4%	5%	5%
2054-58	3%	4%	4%
2059-63	2%	3%	3%
2064-68	1.5%	2%	2%

Table 2.1-2: Projected Total Traffic

Year	Truck	Bus	Light Vehicle	Total Motorized
2018	425	529	3767	4720
2019	455	576	4105	5136
2020	486	627	4474	5587
2021	520	683	4876	6079
2022	556	744	5314	6614
2023	594	810	5792	7196
2024	635	874	6255	7764
2025	679	943	6755	8377
2026	726	1018	7295	9039
2027	776	1099	7878	9753
2028	830	1186	8508	10524
2029	879	1280	9188	11347
2030	931	1382	9923	12236
2031	986	1492	10716	13194
2032	1045	1611	11573	14229
2033	1107	1739	12498	15344
2034	1173	1860	13372	16405
2035	1243	1990	14308	17541
2036	1317	2129	15309	18755
2037	1396	2278	16380	20054
2038	1479	2437	17526	21442
2039	1552	2583	18577	22712
2040	1629	2737	19691	24057
2041	1710	2901	20872	25483
2042	1795	3075	22124	26994
2043	1884	3259	23451	28594
2044	1978	3454	24858	30290
2045	2076	3661	26349	32086
2046	2179	3880	27929	33988
2047	2287	4112	29604	36003

Table 2.1-2: Projected Total Traffic				
Year	Truck	Bus	Light Vehicle	Total Motorized
2048	2401	4358	31380	38139
2049	2497	4576	32949	40022
2050	2597	4805	34596	41998
2051	2701	5045	36326	44072
2052	2809	5297	38143	46249
2053	2921	5562	40050	48533
2054	3009	5785	41652	50445
2055	3099	6016	43318	52433
2056	3192	6257	45050	54499
2057	3288	6507	46853	56647
2058	3386	6767	48727	58880
2059	3454	6970	50188	60613
2060	3523	7179	51694	62396
2061	3594	7395	53245	64233
2062	3666	7616	54842	66124
2063	3739	7845	56487	68071
2064	3795	8002	57617	69414
2065	3852	8162	58770	70783
2066	3910	8325	59945	72180
2067	3968	8492	61144	73604
2068	4028	8661	62367	75056

1.2 River Hydrology and Hydraulic Study

The proposed bridge is located in Jhalokathi District under Barisal Division which is in the south-western region of Bangladesh. All rivers and canals in the region carry tidal flow during high tide, and the flow adds up with overland flow in low tide, especially, during monsoon season. The proposed bridge will be across KochaRiver which is tidal river and is dominated by ebbing effect of flowing water with high velocity and volume of discharge.

1.2.1 River System

KochaRiveroriginates from the confluence of the two prominent rivers Swarupkathi (Sandha) and Kaliganga then meets the Boleswar river at a short distance (within 10km). The BoleswarRiver falls into the bay at a distance of about 70km. Because of the obvious nature of coastal river, the hydrology of the area is dominated by inflows from the rivers in the upstream and tide propagation from the bay.

1.2.2 River Morphology

Morphology of KochaRiver is governed by the tidal flow and upland flow that results in alternate erosion and deposition of non-cohesive (sand/silt)materials on river bed. Being a tidal riverKocha is having flood tide and ebb tide in a semi diurnal manner.

The difference in water level ranges from 1.90m to 2.50m between the tides depending on lunar effect and upland flow towards this tidal river.The hydrodynamic action of reversible tidal flow implicates some bank erosion and sediment deposition in an alternate manner which causes widening of the waterway. Erosion was observed to have taken place alternately along the opposite banks in a sinusoidal manner.

The project area does not experience seasonal flooding similar to other northern and north-eastern part of Bangladesh.Possibilities of unexpected changes in the course and alignment of the rivers due to tidal flow accompanied by cyclonic surge has been under active consideration. Tide in the coast of Bangladesh is semi-diurnal in nature having two high andtwo low tides in about 24 hours time period. Therefore, the river bed is subjected to alternate erosion and deposition depending on the limiting condition of scouring and silting velocities of tidal flow, sediment load and grain size of non-cohesive bed materials. In long run such type of channel is expected to attain a tidal regime condition. But certain changed condition like rise in sea water level and higher discharge from the upland flow can cause high volume of tidal discharge and thereby the channel regime may change in such a condition.

1.2.3 River Cross Section Survey

In course of the cross section survey, 12-cross sections were surveyed across the Kochariver between Hularhat and Charkhali ferry ghat (Pl refer to Map 3-2 in Volume-2). Out of 12-cross section surveyed along 8.0 km length of study reach, some of these cross sections were superimposed on the secondary cross section of Jan 2011 conducted by IWM.It is observed that some siltation (0.5m to 3.0m) was taken place in those sections at a time interval of six (6) months. However, there has been little scour in some scattered locations (Pl refer to Volume-2)

The 12 X-sections surveyed were screened to sort out hydraulically stable and betterhighway connectivity and relevant structural requirements.

The screening process ends with the following three X-sections of KochaRiver to be considered as hydraulically suitable alternative locations for further processing together with connecting approach road alignment.

X-section ID	Water Level (m)	Wateway width (m)	Maximum depth (m)	Slope of Bank	Remark
Kocha-003	1.82	940/920*	16.5/15.93*	1:3.0	Alternative-3
Kocha-006	1.25	1200	15.2	1:4.0	Alternative-2
Kocha-009	0.50	840/1400*	20.0//20.75*	1:3.0	Alternative-1

* Linear waterway width at water level 1.25m PWD

2.2.4 Determination of Design Water Level

The extreme tidal water levels (highest and lowest) were collected from BIWTA for Kawkhali Station on KochaRiver (only one station on Kocha river) from 1988 through 2007. The yearly highest and lowest water level data were analyzed using

Gumbel Extreme Value Type I distribution for 5, 10, 25, 50 and 100 year return period water levels.

It is observed from the frequency analysis that the highest water level in 100 year return period is 3.05m PWD.The Standard High Water Level (SHWL) for the Kawkhaliis**2.74mPWD** (GEVT1)and Standard Low Water Level (SLWL) is **(-)0.21mPWD.** These values of water levelshave beenconsidered for design of the BekutiaBridge.

2.2.5 Determination of Design Discharge

In tidal channel the velocity of flow at the highest water level tends to zero. The velocity reaches a maximum value at a lower water level which varies from channel to channel. In KochaRiver this level has been adopted as 1.25m PWD.

Calculation of tidal discharge is complicated due to addition of upland flow of river water together with overland flow of water from surrounding flood plain through tidal canal and creeks into the river water during ebb flow. Thus, discharge during ebb tide is higher than the flood tide during dry season and much higher during monsoon season.

The calculated peak tidal discharge through Kocha river is 14130 cumec. And the corresponding velocity is 1.365 m/sec.

2.2.6 Waterway Width under Bridge

Due consideration was given to the eventualities of sea water level rise near the coast of Bangladeshandcyclonic surge in distant future. Rise in sea water level by one meter will raise water level in Kocha river which in turn will increase inundation of more flood plain area, increased discharge and velocity of water. However, it has been estimated that an increase in maximum tidal discharge by 50 per cent might be reasonable to provide hydraulic stability of the proposed bridge against the foregoing hazards (Reference: Preliminary Report, volume 2,Dapdapia Bridge on Barisal Patuakhali Road, Clause 3.3.7, Page 9 of 19 where, X-sectional area increased by 20% and velocity by 25% that results in discharge increased by 50%).

The peak tidal discharge is 14130cumec and an increase in discharge by 50% results in 21195cumec discharge which will not be exceeded due to rise in sea water level or cyclonic surge in 1 in 100 year event. The linear waterway or wetted perimeter required for this magnitude of discharge is, $W = 4.8\sqrt{(21195)} = 698.8$m. The regime approach of computation of linear waterway width (698.8m) together with flow constriction for about 14nos of 12.0m wide pile caps/piles (total 866.8m)is less than the existing water way width measured at Alternative-1: 1400m, Alternative-2: 1200m and Alternative-3: 940m. So, the anticipated maximum discharge would be accommodated within the existing waterway width in all three Alternatives.

2.2.7 Scour Depth

Potential scour can be a significant factor in analyzing a river crossing system, such as a bridge. The design of river crossing system involves an acceptable balance between

undue damage caused by backwater and undue damage caused by scour. It also should not cause high river crossing profile for traffic service.

The calculated total scour consists of general scour, constriction scour and local scour at bridge site is 20.82mfrom river bed level -14.0mPWD.

2.2.8 Afflux

For the proposed bridge across KochaRiver, the existing linear waterway is far greater than the calculated regime width from the peak/max discharge. So, there will be negligibleflow afflux caused by construction of the proposed bridge.

2.3 Navigation Standard and Clearance

Navigation Standards for classified, perennial waterways must cover the main dimensions of design vessels, waterways, navigation locks and clearances of bridges and overhead (power) lines.

According to the BIWTA requirement of navigation clearance, movement of ship, vessel etc.in the route of KochaRiverunder the proposed bridge will be Class I.

2. SELECTION OF FINAL ALIGNMENTS

3.1 Bridge Location Study

The bridge location study consists of identifying suitable locations for preliminary study and comparing the identified locations on technical and economical aspects for selecting the final alignment. Section 3.2elaborates the study aspects and a 2- step screening of twelve (12) X-sections for selecting three alternative bridge locations. Each of the three selected bridge locations together with appropriate connecting access road alignment was assessed fortechnical feasibility, social and environmental impacts, land acquisition and resettlement requirements and economic viability. The Methodology of selecting bridge location is in Volume-2.

3.2 Results of the Study

3.2.1 Screening Results

- Evaluation and Comparison of Cost

  The summary of evaluation and comparison of economic cost for each Alternative is presented below:

Sl. No	Alternative	Location	Length of bridge and viaduct (m)	Length of approach road (m)	Indicative Cost of bridge, viaducts, RTW and approach roads (millon, Tk.)	Indicative Cost of Resettlement (million, Tk.)	Total Indicative Cost of the Project (million, Tk.)
1.	Alternative-1	Near Bekutia	1400m+ 2x200m	6.524 km	4157.72	57.511	4215.23
2.	Alternative-2	Between 1&3	1200m+ 2x200m	6.60 km	3481.6	54.859	3536.459
3.	Alternative-3	Near Charkhali	1000m+ 2x300m	6.667km	3357.52	55.6155	3413.13

- Evaluation and Comparison of Benefits

The main benefit of this project is closely related to replacement of ferry services. Alternative-1 is 250m downstream fromBekutia Ferry service, Alternative-2 is in between the locations of Bekutia Ferry and Charkhali Ferry Ghat and Alternative-3 is 5.25km upstream from Charkhal Ferry service. For the purpose of indicative economic analysis the following ferry system and services cost has been considered:

- Replacement of ferry system and services; and
- Cost savings due to time delay in ferry crossing;

3.2.2 Selection of FinalBridge Location

Alternative-1: the name of the proposed alignment is **Machimpur-Krishnanagar-Dumurtola-Bekutia**250m downstream from the existing Bekutia Ferry crossing (refer to Map 4-1, Volume-2). The salient features of the location are as follows:

- Hydraulically the river X-section has a minimum waterway width of 840m from existing bank to bank at a river stage of 0.50 mPWD. But the width is 1400m at maximum water level. The maximum depth of water is 20.0m skewed to the right bank.
- At this location of bridge a very minimum length of approach road (0.633 km) is required for Bekutia end (west side/ left bank of Kocha river). A realignment **of** 5.891km is required for the east side/right bank of Kocha river (Kumirmara end).
- Construction of bridge at this location will replace the ferry system between Kumirmara and Bekutia vise-versa.
- About 90% of the boat services will be converted into road traffic after construction and opening of the bridge.

Alternative-2:the name of the proposed alignment is **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari**3.82 kilometers downstream from the existing Bekutia ferry crossing and upstream from Charkhali Ferry crossing (refer to Map 4-1, Volume-2). The salient features of the location are as follows:

- Hydraulically the river X-section has a waterway width of 1200m from existing bank to bank. The maximum depth of water is 15.20m at about middle of the X-section. The X-section is symmetrical about maximum depth of water.
- At this location of bridge2.60 km length of approach road is required for the west side/ left bank of Kocha river. A length of2.71 kmis required for the east side/ right bank of Kocha river.
- Construction of bridge at this location will replace both Bekutia and Charkhali ferry system.
- About 50% of the boat services from both ferry ghat will be converted into road traffic after construction and opening of the bridge.

Alternative-3:the name of the proposed alignment is **Badura-BaieenGali-South Gazipur-Uttar Bitabari-MidiabadhBitabari**5.25kilometersupstream from the existing Charkhali Ferry crossing (refer to Map 4-1, Volume-2). The salient features of the location are as follows:

- Hydraulically the river X-section has a waterway width of 940m from existing bank to bank. The maximum water depth is 16.50m skewed to the right bank.
- At this location of bridge 3.238 km length of approach road is required for the west side/ left bank of Kocha river. Another approach road of 3.429 kmis required for the east side/right bank of Kocha river.
- Construction bridge at this location will replace the Charkhaliferry system between Bhandariaand Zianagarvise-versa.
- About 90% of the boat services will be converted into road traffic after construction of the bridge.

For the purpose of indicative economic analysis, all structural and financial data are from secondary sources. The prices were increased to represent the Project Cost at implementation year 2015-16.

It is evident that total cost of project even in an indicative manner is different for the three Alternatives. Again, the benefit will be quite different for each individual Alternative. A simple indicative economic analysis shows the following values of economic indicators (Pl. refer to Annexure-04 for details):

- Net Present Value (NPV) for: Alternative-1 = Tk.496million
  Alternative-2= Tk.5165million
  Alternative-3 = Tk.1180million

- Benefit Cosst Ratio (BCR) for: Alternative-1 = 1.03
  Alternative-2 = 2.47
  Alternative-3 = 1.28

- Economic Internal Rate of Return (EIRR) for: Alternative-1 = 12.20%
  Alternative-2 = 22.19%
  Alternative-3 = 14.245%

Considering the above-mentioned technical aspects and economic returns of each Alternative, the final location of the bridge is Alternative-2.

3.3 Survey and Investigations at Selected Locations

After selection of the final bridge location, the Consultant conductedthe following detailed survey and investigation on the final bridge alignment.

- Topographic survey along the final bridge alignment;
- Geotechnical investigation of sub-soil in the river bed for main bridge and on the banks for both side approach viaducts;
- Land acquisition plan and resettlement action plan required for the final alignment.

3.3.1 Topographic Survey

A detailed topographic survey was conducted along the final alignment of Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari, In detailed survey the total length of alignment is 7.31 Km while it was 7.116 Km during reconnaissance survey. The alignment drawing has been presented in Appendix-C.

3.3.2 Sub-soil Investigation

Sub-soil investigation was carried out at the location of east and west viaduct and main bridge location. Two bore holes at each viaduct location and two bore holes in the Kocha river. The sub-soil investigation report has been enclosed in Appendix-D.

3.3.3 Land Acquisition and Resettlement

The land acquisition plan for the final alignment has been included in Appendix-BThe resettlement survey and action plan has been included in Chapter 6 of this volume.

4 PRELIMINARY DESIGN

4.1 Design Standard

The analysis and design of the bridge isin accordance with AASHTO LRFD Bridge Design Specification published by the American Association of State Highway and Transportation Officials (AASHTO) – Second Edition 1998.

4.2 Design Life

The design life of the bridge isin accordance with AASHTO-LRFD Specification.

According to the AASHTO-LRFD Specification design life of the proposed bridge is**75** years based on statistical derivation of transient loads.

4.3 Permanent Loads

The permanent dead loads are considered in accordance with Clause 3.5, AASHTO-LRFD. However, the permanent dead loads of the proposed bridge include self weight of the following items:

a) Bridge Superstructure
- Prestressed concrete bridge superstructure, single cell box girder, and its associated components.
- All superimposed dead loads (SDLs) such as, parapet/railing, footway, curb, light posts, utilities lines and its supportson superstructure. Wearing surface provided on the purposeddeck running surface.

b) Bridge Substructure
- Self weight of pier cap and associated SDLs of Bearings and Seismic device, working/inspection etc. These SDLs are light weight compared to DL of substructure of long span bridge.
- Self weight of pier column/wall, tie beam/bracings etc., and
- Self weight of pile cap.

c) Bridge Foundation
- Pile group.

However, earth pressure, surcharge loads and down drag loads are considered as permanent dead loads.

Density of the construction materials considered is shown in the following Table.

Table 1 Densities of the materials

Material	Density in kg/m^3
Bituminous Wearing Surface	2250
Compacted sand, silt and clay	1925
Loose sand, silt or gravel	1600
Concrete – Normal density	2400
Rolled gravel, Macadam or Ballast	2250
Steel	7850
Stone Masonry	2725
Water	1000

4.4 Live Loads

Vehicular Live Load

Design conforms to vehicular live loading AASHTO HL 93 which consists of:

i. Design truck;

ii. Design tandem; and

iii. Lane load

i) Design truck

The vehicle configurations (HL93 Truck - axle weights, spacing, etc) covered by this loading are described in the AASHTO standard is shown below:

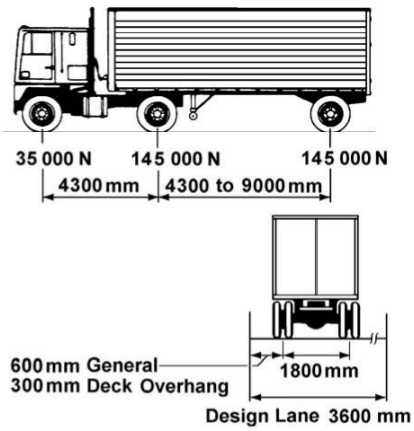

Figure 1 Characteristics of AASHTO HL-93 design truck

ii) Design Tandem

The design tandemconsists of a pair of 110 000 N axles spaced 1200 mm apart. The transverse spacing of wheels is taken as 1800 mm

iii) Design Lane Load

The design lane load consists of a load of 9.3 N/mm uniformly distributed in the longitudinal direction. The design lane load shall be assumed to be uniformly distributed over a width of 3000 mm in the transverse direction.

4.5 Dynamic Allowance

Dynamic allowance of the live load considered as 33% [not applicable for lane load].

4.6 Water Loads (WA)

The Water Loads (WA) of flowing water on the pier stem, pile cap and piles are considered in accordance with Clause 3.7, AASHTO-LRFD.

4.7 Wind Load (WL and WS)

The Wind Load (WL and WS) shall be in accordance with Clause 3.8, AASHTO-LRFD.

- Clause 3.8.1 – Horizontal Wind Pressure
- Clause 3.8.2 – Vertical Wind Pressure

The basic wind speed in the project area is 240km/hr in accordance with the Bangladesh National Building Code 1993 (BNBC, 1993). The Wind Speed map of the Code is presented in Figure no. 5-1 and enclosed in Annexure-03, Volume 2

Wind load acting on the superstructure is based on the bridge elevation exposed to the wind which consists of height from top of parapet up to soffit of box girder. Wind load on structure is calculated considering wind velocity of 240 km/hr.

Wind Pressure on Structures: WS

Design wind pressure, in MPa may be determined as

$P_D = P_B x\ V^2_{DZ}/25600$

P_D = Design wind pressure

P_B = base wind pressure specified in the following table

V_{DZ} = design wind velocity in km/h

Base pressure P_B corresponding to V_B = 240km/h

Structural Component	Windward load, MPa	Leeward load, MPa
Beams	0.0024	N/A
Larger flat surfaces	0.0019	N/A

4.8 Seismic Loading

The site of the proposed bridge is located within Zone 1 of the seismic zoning Map given in the BNBC, 1993. The zone coefficient of this area is 0.075..The Zoning Map of the Code is presented in Figure No. 5-2 and enclosed in Annexure-03, Volume 2.

The design is based on Clause 3.10, AASHTO LRFD with due regard for the Acceleration Coefficient (A).Earthquake acceleration is considered in two perpendicular planner directions. Vertical acceleration is not considered in the design.

4.9 Secondary Forces

Temperature

The change in temperature and/or variation of temperature across the depth of a structural member causes thermal strains and consequent internal forces in the member. The thermal strain is calculated from $\varepsilon_t = \alpha(T_2 - T_1)$. Where, α is the linear thermal expansion coefficient for Concrete. The following parameters are considered for the design:

- Coefficient of thermal expansion, α *for* Concrete : $12.0 \times 10^{-6}/^0C$
- Temperature difference : 35^0C

Shrinkage

Shrinkage effectsare considered in construction stage analysisand serviceability limit stress checking. CEB-FIP is followed to estimate Shrinkage strain. Other variable considered in Shrinkage effect analysis are:

- Relative humidity - 70 %
- Ordinary Portland Cement
- Age of Concrete at the beginning of Shrinkage - 7days

Creep

Creep effects are considered in construction stage analysis and serviceability limit stress checking. CEB-FIP Code is generally followed to estimate of Creep coefficient. Other variable in Creep effect analysis are:

- Relative humidity - 70 %
- Ordinary Portland Cement
- Age of Concrete at the beginning of loading- 10 days

Pre-stress

Prestressing steel considered are low-relaxation 7-wire strand conform to the requirements of AASHTO M 203M (ASTM A 416M), Grade 270 (1860mPa). The strands are 12.7mm nominal diameter with 98.7 mm^2area.

Ultimate stress, f_{pu} = 1860 mPa
Maximum stress applied, = 0.7 x f_{pu} = 1300 MPa
Wobble coefficient, k = 0.00066/m
Friction coefficient, μ = 0.25
Anchorage pull-in = 6mm

4.10 Other Loads

Construction load

Construction loads are considered as per the provision of Art. 5.14.2.3.2 of AASHTO LRFD. However, the dead load of Form Traveller for cast-in-situ box segment construction is 1100kN and live load is 0.5 kN/m^2

4.11 Construction Method

The following construction methods are considered suitable for specific type of MainBridge box girder:

- Launching Girder (Truss).
- Form Traveller.

4.12 Load Combinations

The bridge components are designed to satisfy the requirements of service and strength for load combinations specified in AASHTO Specifications

Table 1 Load combination and Load factors [As per AASHTO]

Load Combination Limit State	*DC DD DW EH EV ES EL*	*LL IM CE BR PL LS*	*WA*	*WS*	*WL*	*FR*	*TU CR SH*	*TG*	*SE*	Use One of These at a Time			
										EQ	*IC*	*CT*	*CV*
STRENGTH I (unless noted)	γ_p	1.75	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—
STRENGTH II	γ_p	1.35	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—
STRENGTH III	γ_p	—	1.00	1.40	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—
STRENGTH IV	γ_p	—	1.00	—	—	1.00	0.50/1.20	—	—	—	—	—	—
STRENGTH V	γ_p	1.35	1.00	0.40	1.0	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—
EXTREME EVENT I	γ_p	γEQ	1.00	—	—	1.00	—	—	—	1.00	—	—	—
EXTREME EVENT II	γ_p	0.50	1.00	—	—	1.00	—	—	—	—	1.00	1.00	1.00
SERVICE I	1.00	1.00	1.00	0.30	1.0	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—
SERVICE II	1.00	1.30	1.00	—	—	1.00	1.00/1.20	—	—	—	—	—	—
SERVICE III	1.00	0.80	1.00	—	—	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—
SERVICE IV	1.00	—	1.00	0.70	—	1.00	1.00/1.20	—	1.0	—	—	—	—
FATIGUE— *LL, IM & CE* ONLY	—	0.75	—	—	—	—	—	—	—	—	—	—	—

Table 2 Load factors for permanent load, γ_p [As per AASHTO]

Type of Load, Foundation Type, and Method Used to Calculate Downdrag		Load Factor	
		Maximum	Minimum
DC: Component and Attachments		1.25	0.90
***DC*: Strength IV only**		**1.50**	**0.90**
DD: Downdrag	**Piles, α Tomlinson Method**	**1.4**	**0.25**
	Piles, λ Method	**1.05**	**0.30**
	Drilled shafts, O'Neill and Reese (*1999*) Method	**1.25**	**0.35**
DW: Wearing Surfaces and Utilities		1.50	0.65
EH: Horizontal Earth Pressure			
• Active		1.50	0.90
• At-Rest		1.35	0.90
• *AEP* for anchored walls		1.35	N/A
EL: Locked-in Erection Stresses		1.00	1.00
EV: Vertical Earth Pressure			
• Overall Stability		1.00	N/A
• Retaining Walls and Abutments		1.35	1.00
• Rigid Buried Structure		1.30	0.90
• Rigid Frames		1.35	0.90
• Flexible Buried Structures other than Metal Box Culverts		1.95	0.90
• Flexible Metal Box Culverts		1.50	0.90
ES: Earth Surcharge		1.50	0.75

Materials

Design of concrete structures is based on the material properties cited herein and on the use of material properties that conform to the AASHTO-2007.Emphasis is given to locally available materials.

Strength of Concrete

The following characteristic strength of concrete is considered for the cast-in-situ and precast elements of the bridge:

- Precast segmental box girder = 50Mpa
- Precast I-girder = 40Mpa
- Deck concrete = 30Mpa
- Railing/parapet, footway = 30Mpa
- Pier head and Pier stem = 40 Mpa
- Pile cap and Piles = 35Mpa

Reinforcing Steel

Steel reinforcing bars are deformed bars. Reinforcing bars conform to the requirements of AASHTO M31, Grade 60 (ASTM A-615 Grade 60) with 420.0 Mpa yield strength. Reinforcing bars to be referred to in the contract plans and specifications by diameter and vary in size from 10mm to 32mm.

Prestressing steel shall be low-relaxation 7-wire strand conform to the requirements of AASHTO M 203M (ASTM A 416M), Grade 270 (1860mPa).

Design Considerations

The bridge components are designed following the requirements of service and strength limit state for load combinations specified in AASHTO Specifications

ServiceLimitState

Concrete stresses, deformations, and cracking, distribution of reinforcement, deflection and camber has been investigated at service limit state.

StrengthLimitState

Axial, Flexural, Shear strength and stability of concrete components have been investigated at strength limit state. Resistance factors that have been used were based on AASHTO Specifications

Resources

The following categories of resources are considered in the design process:

- Technology available;
- Skills for the various bridge construction processes;
- Available materials; and
- Standard practice in the region.

4.13 Pavement Design

The pavement section is designed following the AASHTO Guide for Design of Pavement Structures 1993. The estimated cumulative ESA is 5.0 millions over 10 years design life and it will be 10 million after 15 years.

As flexible pavement design allows stage construction, the proposed pavement is designed for 10 years design life. Thereafter an overlay will need to be provided so that the pavement can provide satisfactory level of service an increased duration of 5 years.

5 ALTERNATIVE BRIDGE TYPES

5.1 The Proposed Bridge Location

The final location of the proposed bridge is along **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari** which is a few kilometers downstream from the existing Bekutia ferry crossing and upstream from Charkhali Ferry crossing (refer to Map 4-1,Volume-2). The total length of the alignment is 7.116 km of which 2.842 km is .on the Perojpur end, 1.70 km is total length of proposed bridge and the 2.574 km road alignment is on the other side of KochaRiver.

5.2 AlternativeBridge Types

Three alternative types of bridge have been selected together with the following span arrangements:

a) Option-1: 400m East End Viaduct + 11-100m spans plus 2-50m spans+400m West End Viaduct => Total 2000m length;
b) Option-2: 400m East End Viaduct + 9-120m spans plus 2-60m spans+400m West End Viaduct => Total 2000m length; and
c) Option-3: 400m East End Viaduct + 7-150m spans plus 2-75m spans+400m West End Viaduct => Total 2000m length.

Standard and typical drawings for all three Options are presented in the Volume-3, Preliminary Design Drawings.

5.2.1 Bridge Superstructure

In the Option-1: the East & West End Viaducts consists of 16 nos. 25.0m span deck-girder spans and the MainBridge consists of:

- East End Module, 3-100m spans + 1-50m span'
- Middle Module, 5-100m spans; and
- West End Module, 3-100m spans + 1-50m span.

In the Option-2: the East & West End Viaducts consists of 16 nos. 25.0m span deck-girder spans and the MainBridge consists of:

- East End Module, 2-120m spans + 1-60m span'
- Middle Module, 5-120m spans; and
- West End Module, 2-120m spans + 1-60m span.

In the Option-3: the East & West End Viaducts consists of 16 nos. 25.0m span deck-girder spans and the MainBridge consists of 7-150m + 2-75m Extradosed Post-tensioned Precast Segmental Box Girder spans.

Standard and typical drawings for all three Options are presented in the Volume-3, Preliminary Design Drawings.

5.2.2 Bridge Substructure and Foundation

The support system for the Viaducts and the main bridge are as follows:

- The Viaducts: Pier bent consisting of pier cap, pier columns, tie beam and pile cap supported on 600mm diacast-in-situ bored piles. Short stem abutment with approach slab supported on elevated 600mm diacast-in-situ bored piles.
- The MainBridge: for Option-1 and Option-2 Pier bents consist of pier cap, pier wall(s) and pile cap supported on 1500mm diacast-in-situ bored piles. There will be 4 nos. of double-wall type pier for housing the modular expansion-contraction joints between middle and end modules, and between end modules and viaducts. Moreover, the end pier cap will provide access platform for entering inside the box for Inspection and Maintenance purposes.

- For Option-3 Pier bents consist of stay cable tower, pier cap, pier wall(s) and pile cap supported on 2500mm dia cast-in-situ bored piles. There will be 4 nos. of double-wall type pier for housing the modular expansion-contraction joints between middle and end modules, and between end modules and viaducts. Moreover, the end pier cap will provide access platform for entering inside the box for Inspection and Maintenance purposes.

Standard and typical drawings for all three Options are presented in the Volume-3, Preliminary Design Drawings.

5.2.3 Navigation Clearance

In Option-1 and Option-2, the middle 5-span module will provide full navigation clearance of 76.22m horizontal distance and 18.30m vertical height as required by BIWTA Standard Class-I for KochaRiver. The pile caps are setback to a distance of about 6.0m and 16.0m respectively from the 76.22mx18.30m navigation envelop for providing fender protection around pile caps.

However, the other two end modules will also provide navigation clearance between BIWTA Standard Class-I and Class-II. Specifically, only the end 100m spans of end modules are in BIWTA Standard Class-II. Thus, BekutiaBridge over KochaRiver will provide clear, safe and unfettered pass for all BIWTA Classified vessels.

In Option-3, the middle 5-span module will provide full navigation clearance of far greater than 76.22m horizontal distance and 18.30m vertical height as required by BIWTA Standard Class-I for KochaRiver.

5.3 Approach Road Alignment

The road alignment will be a 2-lane single carriageway on both sides of the bridge having the following components:

- Width of pavement is 7.3m (2x2.65m);
- Width of hard shoulder is 1.50m on both sides of pavement;
- Width of verge is 1.0m on both sides of the hard shoulder;
- Cross slope of pavement and hard shoulder drainage is 3% and of verge is 5%; and
- Road embankment side slope is 1(vertical): 2(horizontal) on both sides.

Both side Approach Road Alignment Drawing /Plan Profile Drawings are shown in the Volume-3, Preliminary Design Drawings.The design cross-section of the road pavement and embankment is shown in Figure-5.3.

The roadway will be within a Right of Way (RoW) width of 50m. The selection of RoW is based on future extension of roadway to 4-lane. However, in order to provide a smooth vertical gradient of 1.50% between ends of viaducts and approach roads a transition length of 740 m will be required where the RoW requirement will vary from 100m at abutment location to 50m at approach road end.

The existing road alignment starting from road intersection after BoleswarBridge, Perojpur to Sankarpasha and from Uttar Bhitabari to Chowmuhani and Naikati is in poor condition. These road sections will need improvement during or after implementation of the proposed bridge project.

5.4 Comparison of Cost

A detailed construction cost estimate has been prepared for the three alternative options in order to make a comparison of cost among the three options. The unit rates of items of work has been considered in USD($) . The summary has been presented in the **Table 5.4-1**below:

Table 5.4-1: Comparison of Construction Cost of Alternative Options

Sl. No.	Description of Item	**Option-1**	**Option-2**	**Option-3**
A.	Main Bridge-1200m	$52,599,308	$54,096,100	$119,671,954
		(Tk.4,063,296,578)	(Tk.4,178,923,762)	(Tk.9,244,658,419)
B.	2-Viaduct: 10@250m	$ 7,303,493	$**7,303,493**	$ 7,303,493
		(Tk.564,194,797)	(Tk.564,194,797)	(Tk.564,194,797)
C.	Approach Road	$13,057,862	$13,057,862	$13,057,862
		(Tk.1,008,719,811)	(Tk.1,008,719,811)	(Tk.1,008,719,811)

D.	Toll System	$100,000	$100,000	$100,000
		(Tk.7,725,000)	(Tk.7,725,000)	(Tk. 7,725,000)
TOTAL COST:		**$ 73,060,663**	**$74,557,455**	**$ 140,133,308**
		(Tk. 5,643,936,186)	**(Tk.5,759,563,370)**	**(Tk.10,825,298,028)**

The alternative options are selected only for the main bridge part (Sl. No. A in the Table 5.4-1) and keeping the others (Sl. No. B to F in the Table 5.4-1)remaining the same for three options.

It is obvious from the above Table 5.4-1 that **Option-1** is the lowest cost of construction of the bridge.

However, considering minimum width of waterway obstruction and adoption of state-of-the art technological application, the Option-3 has been considered for economic analysis. The values of economic indicators (NPV, BCR and EIRR) are shown in Table K-4.

5.5 Project Cost

The Project Cost includes the following components of cost:

1. Total Construction Cost;
2. Engineering Cost (Cost provisions for Detailed Design Consultants and Construction Supervision Consultants);
3. Land Acquisition, Resettlement and EMP;
4. Administrative Cost;
5. Physical Contingencies.
6. Price Contingency; and
7. VAT, TAX and Duties.

The Maintenance cost, both routine and periodic are considered as 0.2 percent of the Project cost, except Price Contingencies, VAT, TAX and DUTIES.

However, the table below shows the cost of the components of the Project Cost:

Sl No	Description	Amount (BD Tk.)	Remark
01.	Construction Cost	Tk. 6,391,860,328	Increased due to revised bank protect.
02.	Engineering Cost:		
	c) Detailed Design	Tk. 159,796,508	2.5% of Sl No. 01
	d) Construction Supervision	Tk. 223,715,111	3.5% of Sl No. 01
03.	Land Acquisition, Resettlement	Tk. 118,216,000	

Sl No	Description	Amount (BD Tk.)	Remark
	and EMP.		
04.	Administrative Cost	Tk. 50,172,762	10% of Sl No. 02 and 03.
05.	Physical Contingencies	Tk. 958,779,049	15% of Sl No. 01
06.	Price Contingencies	Tk. 386,707,550	15% of Sl No. 01, 02 and 05.
07.	VAT, TAX and DUTIES	Tk. 294,728,680	14% for importation @ 30% of Sl 01&02.
Total Project Cost:		**Tk. 8,583,975,989**	

The Project Cost for the Bekutia Bridge considering the Option-1, Post-tensioned Precast Segmental Box Girder Bridge of 100m Span, is Tk. 858.4crores. (USD 111.12 million, 1.0 USD = 77.25 Taka)

6 RESETTLEMENT

6.1 Introduction

The Government of Bangladesh through the Bridges Division under Ministry of Communications has undertaken a project to construct a bridge at Bekutiaover the river Kotcha under Jhalokathi district. The Consultants have conducted preliminary survey in three alternative bridge locations to select one technically, socially and environmentally viable rout for the bridge. After screening the final bridge location was selected along **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari**a total length of 7.31 Km including 2.0 Km length for the Main Bridge and Viaducts.

6.2 Objective of this survey

The objective of this assignment is to conduct detailed survey of the selected Bridge Location for assessment of cost of compensation and relocation of affected persons and properties for the improvement of access roads in the immediate vicinity of the proposed bridge alignment.

6.3 Methodology adopted for this Survey

A team of experienced field staff comprising of Enumerators, Supervisors and the Field Coordinator were deployed to conduct a detailed study along the final bridge alignment by the Sub-Consultant from 15th to 28thOctober 2011 for collection of information of land, structure, trees, common property resources, etc. through a structured questionnaire. The survey was conducted following the Right of Way (RoW) as required for construction of main bridge, viaduct and approach roads in the immediate vicinity of the proposed bridge locations. The survey has been carried out within 50 meterswidth of the road alignments. The routeof the final alignment and the length of coverage of access roads for the bridge areshown in Map 4-1 and in the Topographic Survey, Volume 2 of this report.

The list of affected structure (residential, commercial and common properties) type and ownership of land, category and species of trees, etc. were surveyed. Detailed report has been included in **Appendix-B2**.

Property valuation survey was conducted through a structured questionnaire by interviewing different types of people such as potential seller, potential buyer, trader, land broker, tree merchant, Imam, Teacher, etc. for determination of unit rate of affected land, structure and trees and preparation of budgetary cost estimate for the final alignment.

A total of 60 persons were interviewed. Average value of land structure and trees collected from the respondent has been considered for preparation of budgetary cost estimate. Land has been calculated in hectare, structures in square feet and trees in number.

6.4 Survey Findings

The name of the final alignment is **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari**3.82 kilometers downstream from the existing Bekutia ferry crossing and 5.25 kilometers upstream from Charkhali Ferry crossing (refer to Map 4-1, Volume-2). At this

location of bridge 2.60 km length of approach road is required for the west side/ left bank of Kocha river. A length of2.71 km is required for the east side/ right bank of Kocha river.

6.5 Land acquisition

In the final alignment a total of about 31.00ha land is needed to be acquired for approach road and viaduct of which about 3.50 ha homestead and orchard category, 0.75 ha others (ditch, road, water body, etc.) category and remaining are agriculture category of land.

A separate Land Acquisition Report has been enclose in Appendix-B.

6.6 Rehabilitation and Other Impacts

A total of 28 Households will experience significant impacts as a result of displacement including land and small businesses. There are no indigenous people (tribal or ethnic minorities) within the affected population.Mitigation of all impacts will be undertaken through implementation of this Resettlement Plan (RP). The RP identified, and proposed a number of remedial measures for addressing the gaps between national legislation and the requirements of the ADB Safeguard Policy Statement (SPS) 2009.

Details ofLand Acquisition and Resettlement Budget have been shown in Table 9.1, Appendix B2.

6.7 Trees Affected

Different species of trees (31,717), both fruit bearing and timber types have been affected in the right of way. A lot of bettle nut garden are affected and out of the total trees this species is more than 37%. Some commercially planted Mehoginin trees are affected. Out of the total affected trees (31717) about 14,444 fruit bearing, 11407 timber type, 3615 banana groves and 2251 bamboo bush got affected. This Resettlement Plan (RP) has kept provision for compensation for these trees owned by the people. Out of the total affected trees, 11616 are large, 8714 are medium, 7807 are small and 3580 are saplings by size. Table 2.6 & 2.7, Appendix-B2describe in detailed about the affected trees.

6.8 Estimated Cost of Land Acquisition and Resettlement

Considering land acquisition and resettlement issues a cost estimate has been prepared for the final alignment based on detailed survey data and property valuation survey result conducted during 15-28October 2011. All lands within 50m width of the alignment have been considered in preparing estimated budget. Cost estimate for land acquisition and resettlement requirement are shown in detail in Table 9.1, Appendix-B2.

7 ECONOMIC EVALUATION

7.1 General

An economic appraisal of the proposed BekutiaBridgeproject was carried out within the broad framework of cost-benefit analysis. The analysis was undertaken withand without project situation. It implies two scenarios first, a bridge will be constructed over the Kocha river with necessary approach roads and appurtenant structures considering an economic life span of 30 years, second no bridge will be constructed and the ferry systems will continue in Bekutia and Charkhali Ferry Ghats.

The project costs and benefits have been identified and valued in monetary terms, using economic prices. Economic prices are net of taxes, duties and royalties which are essentially in the nature of transfer payments of goods and services entering into project costs and benefits. The economic prices werecalculated by applying a standard conversion factor 0.85 used for road sector in Bangladesh and accepted by RHD for economic evaluation of projects in recent years.

The annual stream of project costs and benefits in financial and economic terms were calculated over an evaluation period of 30 years which is normally considered for bridge structures. Discounted Cash flow (DCF) technique was used at a 15% discount rate for determining Net Present Value (NPV), Benefit Cost Ratio (BCR), Economic Internal Rate of Return (EIRR) and Financial Internal Rate of Return (FIRR).

7.2 Estimation of Cost

The project implementation cost comprises of Construction costs, Engineering costs, Land Acquisition, Resettlement, EMP, Administrative costs and Physical contingencies.The maintenance costs are recurring costs and will be applicable after completion (2018) of the Project, so the maintenance cost has been duly applied from 2019. Both the annual routine maintenance and periodic maintenance costs are approximated to 0.2% of the Project cost. The following Table shows the cost components considered for financial and economic analyses.

Sl No.	Description	Amount (Million BD Tk.)	
		Financial	Economic
01.	Construction Cost	Tk. 6391.86	Tk. 5433.08
02.	Engineering Cost:		
	a) Detailed Design	Tk. 159.80	Tk. 135.83
	b) Construction Supervision	Tk. 223.72	Tk.190.16
03.	Land Acquisition, Resettlement and EMP.	Tk. 118.22	Tk. 100.48
04.	Administrative Cost	Tk. 50.17	Tk. 42.65
05.	Physical Contingencies	Tk.958.78	Tk. 814.96
06.	Price Contingencies	Tk. 386.71	
07.	VAT, TAX and DUTIES	Tk. 294.73	
Total Cost:		**Tk. 6993.243**	**Tk. 6717.16**

7.3 Estimation of Benefits

The benefits to be accruedout of the project consist of thefollowing components:

- Cost savings from replacement of ferry system and time delay;
- Cost savings from ferry operation closure for bad weather condition;
- Cost savings from vehicle operating costs (VOC) due to reduced distance; and
- Toll Collection.

7.3.1 Cost savings from replacement of ferry system and Time Delay

It was revealed from the selection process/study of final bridge location that construction of bridge at this approved location will replace both the Bekutia and Charkhali ferry system and services which will virtually accrue benefit for the project. The useful service life of ferry system consisting of gangway, pontoon, ferry boats etc. have been considered 10 years together with routine maintenance and engine overhauling as required.

Another benefit will be accrued from ferry crossing time delay and waiting time in approaches which was counted during traffic survey. It was estimated that the time required for vehicles to load on and unload from the ferry is 20 minutes, river crossing time is 20 minutes and vehicle queue waiting for ferry at approach is average 30 minutes. So, on average 70 minutes is required for crossing Kocha river.

The results of a detailed analysis of cost involved in ferry system and ferry crossing time delay for 30 years show the following financial and economic benefits which are considered in the benefit stream:

Table showing the Economic Benefits (in Million Taka)

Year	Investment Cost of Ferry	Maint. Cost of Ferry	Operation Cost of Ferry	Total Ferry Cost (Economic)	Ferry time delay cost Savings (Economic)	**Total Cost (Economic)**
2011	96.3	26.10	76.13	168.75	246.65	415.40
2012	96.3	26.10	76.13	168.75	250.35	419.10
2013	96.3	26.10	76.13	168.75	254.10	422.85
2014	0	26.10	76.13	86.89	257.92	344.81
2015	0	26.10	76.13	86.89	261.78	348.68
2016	0	31.32	87.54	101.03	265.71	366.75
2017	0	31.32	87.54	101.03	269.70	370.73
2018	0	31.32	87.54	101.03	273.74	374.78
2019	0	31.32	87.54	101.03	295.64	396.68
2020	0	31.32	87.54	101.03	319.29	420.33
2021	144.45	31.32	87.54	223.82	344.84	568.65
2022	144.45	31.32	87.54	223.82	372.42	596.24

Year	Investment Cost of Ferry	Maint. Cost of Ferry	Operation Cost of Ferry	Total Ferry Cost (Economic)	Ferry time delay cost Savings (Economic)	**Total Cost (Economic)**
2023	144.45	31.32	87.54	223.82	402.22	626.04
2024	0	31.32	87.54	101.03	434.40	535.43
2025	0	31.32	87.54	101.03	469.15	570.18
2026	0	31.32	87.54	101.03	506.68	607.71
2027	0	37.58	105.05	121.24	547.21	668.45
2028	0	37.58	105.05	121.24	590.99	712.23
2029	0	37.58	105.05	121.24	638.27	759.51
2030	0	37.58	117.84	132.11	689.33	821.44
2031	288.9	37.58	117.84	377.68	744.48	1122.15
2032	288.9	37.58	117.84	377.68	804.04	1181.71
2033	288.9	37.58	117.84	377.68	868.36	1246.03
2034	0	37.58	170.82	177.14	937.83	1114.97
2035	0	37.58	170.82	177.14	1012.85	1190.00
2036	0	37.58	170.82	177.14	1093.88	1271.03
2037	0	45.10	170.82	183.53	1181.39	1364.93
2038	0	45.10	170.82	183.53	1275.90	1459.44
2039	288.9	45.10	170.82	429.10	1377.98	1807.07
2040	0	45.10	170.82	183.53	1488.21	1671.75
2041	288.9	45.10	170.82	429.10	1607.27	2036.37
2042	288.9	45.10	170.82	429.10	1735.85	2164.95
2043	288.9	45.10	170.82	429.10	1874.72	2303.82
2044	0	54.12	170.82	191.20	2024.70	2215.90
2045	288.9	54.12	170.82	436.77	2186.67	2623.44
2046	0	54.12	170.82	191.20	2361.61	2552.81
2047	0	54.12	170.82	191.20	2550.54	2741.74
2048	0	54.12	170.82	191.20	2754.58	2945.78
						43,360

7.3.2 Cost Savings from Closure of Ferry Operation for Bad Weather Condition

It is obvious from the location of the KochaRiver, not far from Bay-of-Bengal and prevailing weather condition there that during cyclonic weather the ferry system remains suspended for about a month every year. The suspension of ferry crossing for break down of engine and other rehabilitation reason were not considered. This event of closure of ferry operation causes loss of business and trade. Thus, construction of bridge will switch over these losses to benefit.

The benefits calculated from the above scenario is presented in the following Table and included in the benefit stream of financial and economic analysis.

Table showing the Economic Benefits (in Million Taka)

Year	Truck Amount (Tk.)	Bus Amount (Tk.)	Light vehicle Amount (Tk.)	Total Amount (Million Tk.)
2018	4,406,400	5,484,672	5,628,515	15.5196
2019	4,717,440	5,971,968	6,118,665	16.8081
2020	5,038,848	6,500,736	6,650,201	18.1898
2021	5,391,360	7,081,344	7,230,427	19.7031
2022	5,764,608	7,713,792	7,860,780	21.3392
2023	6,158,592	8,398,080	8,545,483	23.1022
2024	6,583,680	9,061,632	9,216,077	24.8614
2025	7,039,872	9,777,024	9,939,584	26.7565
2026	7,527,168	10,554,624	10,720,902	28.8027
2027	8,045,568	11,394,432	11,563,200	31.0032
2028	9,465,984	13,526,093	13,719,674	36.7118
2029	10,024,819	14,598,144	14,781,715	39.4047
2030	10,617,869	15,761,434	15,928,578	42.3079
2031	11,245,133	17,015,962	17,163,750	45.4248
2032	11,918,016	18,373,133	18,498,004	48.7892
2033	12,625,114	19,832,947	19,934,086	52.3921
2034	13,377,830	21,212,928	21,305,216	55.8960
2035	14,176,166	22,695,552	22,773,107	59.6448
2036	15,020,122	24,280,819	24,341,243	63.6422
2037	15,921,101	25,980,134	26,019,238	67.9205
2038	18,554,469	30,572,847	30,592,097	79.7194
2039	19,470,275	32,404,458	32,393,496	84.2682
2040	20,436,261	34,336,431	34,300,515	89.0732
2041	21,452,429	36,393,857	36,322,452	94.1687
2042	22,518,778	38,576,736	38,464,420	99.5599
2043	23,635,308	40,885,068	40,731,528	105.2519
2044	24,814,564	43,331,397	43,134,352	111.2803
2045	26,044,001	45,928,270	45,678,004	117.6503
2046	27,336,165	48,675,686	48,370,966	124.3828
2047	28,691,055	51,586,191	51,222,998	131.5002
2048	30,121,217	54,672,330	54,245,954	139.0395

7.3.3 Cost savings from vehicle operating costs (VOC) due to reduced distance

It is revealed from the traffic study together with alternative bridge alignment survey and investigations that only traffic toward the Regional Highway from Perojpur (intersection near Baleswat Bridge) to Charkhali to Bhandaria to Rajapur will have a distance saving of about 7.0 Km after construction of the proposed bridge. As such, the savings in VOC for the trafficis only in terms of reduced distance over the bridge.

The VOC was considered for International Roughness Index (IRI) of 10 for the aforementioned route. The cost VOC in terms of Taka/Km has been adopted from Table 4.19: Sensitivity of Financial VOC of Motorised Vehicle to Road Roughness (Tk./Km), page 28, Road User Cost Study for LGED Roads, Final Report, August 2009.

The estimated savings in terms of VOC is shown the following Table which has been included in the benefit stream for the financial and economic analyses.

Table showing the Economical Benefits (in Million Taka)

Year	Truck	Bus	Light Vehicle	Financial VOC savings Tk. In million	Economic VOC savings Tk. In million
2018	3,009,115	10,527,380	13,049,423	26.586	22.598
2019	3,221,523	11,462,705	14,220,303	28.905	24.569
2020	3,441,011	12,477,632	15,498,571	31.417	26.705
2021	3,681,740	13,592,062	16,891,156	34.165	29.040
2022	3,936,630	14,805,994	18,408,451	37.151	31.578
2023	4,205,680	16,119,429	20,064,310	40.389	34.331
2024	4,495,971	17,393,063	21,668,208	43.557	37.024
2025	4,807,503	18,766,200	23,400,279	46.974	39.928
2026	5,140,276	20,258,740	25,270,916	50.670	43.069
2027	5,494,290	21,870,682	27,290,511	54.655	46.457
2028	5,876,624	23,602,029	29,472,920	58.952	50.109
2029	6,223,557	25,472,678	31,828,537	63.525	53.996
2030	6,591,731	27,502,532	34,374,681	68.469	58.199
2031	6,981,146	29,691,591	37,121,746	73.794	62.725
2032	7,398,882	32,059,754	40,090,515	79.549	67.617
2033	7,837,859	34,607,022	43,294,847	85.740	72.879
2034	8,305,157	37,014,986	46,322,507	91.643	77.896
2035	8,800,776	39,602,055	49,564,944	97.968	83.273
2036	9,324,716	42,368,228	53,032,550	104.725	89.017
2037	9,884,057	45,333,407	56,742,646	111.960	95.166
2038	10,471,719	48,497,592	60,712,553	119.682	101.730
2039	10,988,579	51,403,069	64,353,366	126.745	107.733
2040	11,533,760	54,467,751	68,212,420	134.214	114.082
2041	12,107,262	57,731,438	72,303,572	142.142	120.821
2042	12,709,085	61,194,130	76,640,678	150.544	127.962
2043	13,339,229	64,855,827	81,237,594	159.433	135.518
2044	14,004,774	68,736,431	86,111,642	168.853	143.525
2045	14,698,641	72,855,840	91,276,678	178.831	152.006
2046	15,427,908	77,214,056	96,750,022	189.392	160.983

Year	Truck	Bus	Light Vehicle	Financial VOC savings Tk. In million	Economic VOC savings Tk. In million
2047	16,192,577	81,830,979	102,552,460	200.576	170.490
2048	16,999,728	86,726,510	108,704,776	212.431	180.566

7.3.4 Toll collection

As mentioned in the ToR the bridge will be a toll bridge. Toll money collection will start after opening of the Bridge (estimated after yr. 2018). The infrastructure for toll collection will be on one end of the Bridge. It should be operated and maintained by qualified Operator. Necessary cost of implementation, operation and maintenance has been incorporated in the cost stream of financial and economic analyses.

The toll rate for Truck, Bus and Light vehicles are considered at the existing rate in ferry crossing system. To be conservative in the benefit side these existing rates have been considered as starting toll rate in 2019. The toll collection money from 2019 through 2048 has been shown in the following table which has been considered in the benefit stream of financial and economic analyses.

Table showing the Economical Benefits (in BD Taka)

	Truck	Bus	L/vehicle	Total Amount
Year	Amount (Tk.)	Amount (Tk.)	Amount (Tk.)	(in BD Taka)
2019	42,142,464	53,349,581	54,660,075	150,152,119
2020	45,013,709	58,073,242	59,408,466	162,495,416
2021	48,162,816	63,260,006	64,591,814	176,014,636
2022	51,497,165	68,909,875	70,222,964	190,630,004
2023	55,016,755	75,022,848	76,339,650	206,379,253
2024	58,814,208	80,950,579	82,330,287	222,095,075
2025	62,889,523	87,341,414	88,793,617	239,024,554
2026	67,242,701	94,287,974	95,773,394	257,304,069
2027	71,873,741	101,790,259	103,297,920	276,961,920
2028	84,562,790	120,833,096	122,562,424	327,958,310
2029	89,555,052	130,410,086	132,049,987	352,015,125
2030	94,852,961	140,802,140	142,295,301	377,950,402
2031	100,456,520	152,009,257	153,329,496	405,795,273
2032	106,467,610	164,133,320	165,248,838	435,849,767
2033	112,784,348	177,174,328	178,077,832	468,036,508
2034	119,508,618	189,502,157	190,326,596	499,337,371
2035	126,640,420	202,746,931	203,439,753	532,827,104
2036	134,179,753	216,908,652	217,448,433	568,536,838
2037	142,228,500	232,089,201	232,438,525	606,756,226
2038	165,753,257	273,117,436	273,289,402	712,160,096
2039	173,934,453	289,479,827	289,381,893	752,796,173

	Truck	Bus	L/vehicle	Total Amount
2040	182,563,933	306,738,787	306,417,930	795,720,649
2041	191,641,697	325,118,458	324,480,573	841,240,728
2042	201,167,747	344,618,842	343,615,481	889,402,069
2043	211,142,081	365,239,937	363,868,313	940,250,330
2044	221,676,770	387,093,814	385,333,546	994,104,131
2045	232,659,745	410,292,546	408,056,839	1,051,009,130
2046	244,203,075	434,836,132	432,113,966	1,111,153,173
2047	256,306,761	460,836,643	457,592,118	1,174,735,522
2048	269,082,874	488,406,150	484,597,185	1,242,086,209

7.4 Evaluation Process

The viability of the Project has been assessed in terms of Net Present Value (NPV) and Benefit cost Ratio (BCR), Economic Internal Rate of Return (EIRR), and Financial Internal Rate of Return (FIRR) by applying the discounted cash flow (DCF) technique to the annual stream of net benefits of the project. The foregoing indicators were calculated through a fundamental method for the base case of Economic and Financial values.

7.5 Sensitivity Analysis

The sensitivity analysis was conducted for the following limits of change in benefit and cost streams of economic and financial values:

- Benefit reduced by 10% and Cost at the base value;
- Cost increase by 10% and benefit at the base value; and
- Benefit reduced by 10% and Cost increased by 10%.

7.6 Summary of Evaluation Process

The Economic indicators NPV, BCR and EIRR/FIRR were calculated considering 15% discount rate for economic life span of 30 years as shown in Table K-1 and Table K-2.

Justification of 4-lane dual carriageway was done based on economic life span of **50** years and at discount rate of 15% which is presented in Table K-3.

Economic justification of 150m extradosed bridge with 2-lane single carriageway was done based on economic life span of 30 years and at discount rate of 15% which is presented in Table K-4.

Table K-1: The Economic indicators NPV, BCR and EIRR for base case and sensitivity analysis are presented below:

Sl. No.	Economic Evaluation	NPV (Million Tk.)	BCR	EIRR (%)
1.	Base Case	**1983**	**1.36**	**18.115**
2.	Benefit 10% reduced	**1231**	**1.22**	**16.985**
3.	Cost 10% increased	**1429**	**1.23**	**17.09**
4.	Benefit 10% reduced and Cost 10% increased	**676**	**1.11**	**16.015**

Table K-2: The Financial indicators NPV, BCR and FIRR for base case and sensitivity analysis are presented below:

Sl. No.	Financial Evaluation	NPV (Million Tk.)	BCR	FIRR (%)
1.	Base Case	**1772**	**1.25**	**17.225**
2.	Benefit 10% reduced	**887**	**1.13**	**16.143**
3.	Cost 10% increased	**1064**	**1.14**	**16.244**
4.	Benefit 10% reduced and Cost 10% increased	**178**	**1.02**	**15.214**

Table K-3: The Economic indicators NPV, BCR and EIRR evaluated for Base Case only for 4-lane dual carriageway bridge are presented below:

Sl. No.	Economic Evaluation at discount rate of	NPV (Million Tk.)	BCR	EIRR (%)
1.	15%	**-2800**	**0.75**	**12.827**

Table K-4: The Economic indicators NPV, BCR and EIRR evaluated for Base Case only for 150m span Extradosed Bridge with 2-lane single carriageway are presented below:

Sl. No.	Economic Evaluation at discount rate of	NPV (Million Tk.)	BCR	EIRR (%)
1.	15%	**-2213**	**0.77**	**13.028**

It appears from the **Table-K1 and Table-K2** that the NPV, BCR and EIRR/FIRR are in acceptable limit for the sensitivity analysis of Base Case, Benefit 10% reduced,

Cost 10% increased, and Benefit 10%reduced and Cost 10%increased for a 2-lane single carriageway Bridge Project.

Again, it appears from the **Table-K3** that the NPV, BCR and EIRR/FIRR are not in acceptable limit for a 4-lane dual carriageway Bridge Project. Moreover, it is important to note that in Barisal Division and around all long bridges, in terms of span length and total length, whether old or new, are 2-lane single carriageway bridge

It also appears from the **Table-K4** that the NPV, BCR and EIRR/FIRR are not in acceptable limit for a 150m span 2-lane single carriageway Extradosed Bridge.

Over all it appears from the above results of economic analyses that the Bridge Project is economically viable for 2-lane single carriageway bridge having 400.0m East End Viaduct + 11-100m spans plus 2-50m end spans+400m West End Viaduct => Total 2000m length;

7.7 Conclusion and Recommendation

7.7.1 Project Description

The name of the final alignment is **Sankerpasha-HorinaGazipur-Zolagati-Uttar Bitabari** a few kilometers downstream from the existing Bekutia ferry crossing and upstream from Charkhali Ferry crossing (refer to Map 4-1, Volume-2). At this location of bridge 2.842 km length of approach road is required for the west side/ left bank of KochaRiver. A length of3.074 km is required for the east side/ right bank of KochaRiver.

7.7.2 The Proposed Bridge Type

The bridge type selected through cost comparison among three Options is Post-tensioned Precast Segmental Box Girder bridge with the following span arrangement:

Option-1: 250.0m East End Viaduct + 11-100m spans plus 2-50m spans+250m West End Viaduct => Total 1700m length.

The East & West End Viaducts consists of 10 nos. 25.0m span deck-girder spans and the MainBridge consists of:

- East End Module, 3-100m spans + 1-50m span'
- Middle Module, 5-100m spans; and
- West End Module, 3-100m spans + 1-50m span.

The support system for the Viaducts and the main bridge are as follows:

- The Viaducts: Pier bent consisting of pier cap, pier columnsand pile cap supported on 600mm dia cast-in-situ bored piles. Short stem abutment with approach slab supported on elevated 600mm dia cast-in-situ bored piles.
- The MainBridge: Pier bents consist of pier cap, pier wall(s) and pile cap supported on 1500mm dia cast-in-situ bored piles. There will be 4 nos. of double-wall type pier for housing the modular expansion-contraction joints between middle and end modules, and between end modules and viaducts. Moreover, the end pier cap is kept wider for proving space for fixing base of launching girder/form traveler in

erection of end segments. It will subsequently be used as access platform for entering inside the box for Inspection and Maintenance purposes.

The middle 5-span module will provide full navigation clearance of 76.22m horizontal distance and 18.30m vertical height as required by BIWTA Standard Class-I for KochaRiver. The pile caps are setback to a distance of about 6.0m from the 76.22mx18.30m navigation envelop for providing fender protection around pile caps.

However, the other two end modules will also provide navigation clearance between BIWTA Standard Class-I and Class-II. Specifically, only the end 100m spans of end modules are in BIWTA Standard Class-II. Thus, BekutiaBridge over KochaRiver will provide clear, safe and unfettered pass for all BIWTA Classified vessels.

7.7.3 Recommendations of the Study

The recommendations for the Feasibility of Bekutia Bridge on Perojpur-Jhalokathi road over Kocha River are as follows:

- The Bridge is feasible from technical assessment and economically viable from economic and financial evaluation;
- The bridge is also feasible from social, environmental and resettlement perspectives; and
- Rehabilitation and improvement will be required for roads connecting from intersection after Baleswar bridge in Perojpur to starting point of approach road (east) at Sankarpasha; and from end point of approach road (west) to Naikati intersection.

Overall the Consultants highly recommend implementation the BekutiaBridge project at the selected location over KochaRiver.