SMEC
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SYSTRA ACE BANGLADESH

CONSULTANCY SERVICES FOR DETAILED FEASIBILITY STUDY AND DESIGN FOR CONSTRUCTION OF 01 (ONE) BRIDGE ADJACENT TO ZERO POINT IN MYMENSINGH TOWN, 02 (TWO) BRIDGES ADJACENT TO MYMENSINGH EPZ, 04 (FOUR) BRIDGES ON BORDER ROAD AND 2ND SOMESHWARI BRIDGE RESPECTIVELY OF MYMENSINGH ZONE UNDER ROADS AND HIGHWAYS DEPARTMENT, BANGLADESH.

Bridge Construction and Maintenance Circle
Roads and Highways Department

FINAL

FEASIBILITY STUDY REPORT (NITAI BRIDGE)

VOLUME 4 – SUMMARY REPORT

26 June 2024

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ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
AP	Affected People
ARIPA	Acquisition and Requisition of Immovable Property Ordinance
BBS	Bangladesh Bureau of Statistics
BDT	Bangladeshi Taka
BGB	Border Guard Bangladesh
BHMS	Bridge Health Monitoring System
BIWTA	Bangladesh Inland Water Transport Authority
BNBC	Bangladesh National Building Code
BOT	Build, Operate and Transfer
CAAB	Civil Aviation Authority Bangladesh
CBR	California Bearing Ratio
CCL	Cash Compensation Law
CPR	Community Property Resources
CTC	Classified Traffic Count Survey
DTM	Digital Terrain Model
ECC	Environmental Clearance Certificate
ECR	Environmental Conservation Rules
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EPC	Engineering, Procurement and Construction
ESA	Equivalent Single Axel
ESAL	Equivalent Single Axel Load
FFWC	Flood Forecasting and Warning Centre
GAD	General Arrangement Drawing
GDP	Gross domestic product
GIS	Geographic Information System
GVA	Gross Value Added
HYSD	High Yield Strength Deformed
IC	Intersection Count
IDC	Interest During Construction

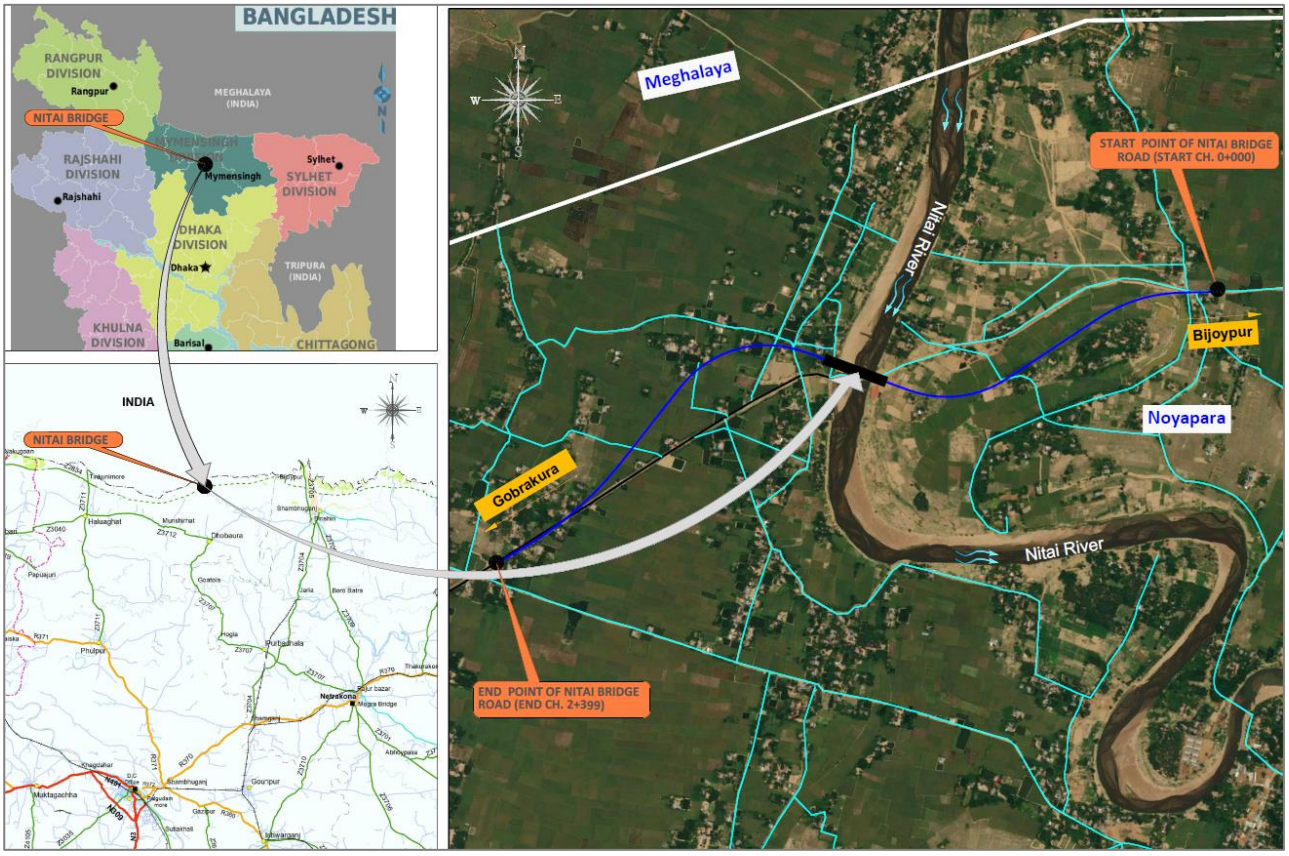
IEE	Initial Environmental Examination
IMF	International Monetary Fund
IRC	Indian Roads Congress
IRR	Internal Rate of Return
IWM	Institute of Water Modelling
LOS	Level of Service
MC	Mid-Block Count
MCA	Multi Criteria Analysis
MMA	Methyl-Meth-Acrylate
MMAT	Mean Monthly Ambient Temp
MORTB	Ministry of Road Transport and Bridges
MSA	Million Standard Axel
MSL	Mean Sea Level
NPV	Net Present Value
ODS	Origin-Destination Survey
PCSE	Passenger Car Space Equivalent
PCU	Passenger Car Unit
PPE	Personal Protective Equipment
RE	Reinforced Earth
RHD	Roads and Highways Department
ROW	Right of Way
RMMS	Road Maintenance Management System
RSI	Roadside Interview Survey
SHWL	Standard High-Water Level
SMVT	Slow Moving Vehicular Traffic
SPT	Standard Penetration Test
VOS	Vehicle Occupancy Survey
VPS	Video Pedestrian Count Survey
VTS	Video Traffic Count Survey
WMAPT	Weighted Mean Annual Pavement Temperature
WPI	Wholesale Price Index
WTP	Willingness to Pay Survey
TPC	Total Project Cost

EXECUTIVE SUMMARY

INTRODUCTION

This Final Feasibility Report aims to assess the best option of the Nitai Bridge and the Project Alignment, by examining all aspects of a project preparation, including technical, environmental, social aspects as well as economic viability.

LOCATION MAP



NEED FOR NITAI BRIDGE OVER NITAI RIVER

The Border Road Z-2834 traversing through Mymensingh and Netrokona Districts connects Kalmakanda & Durgapur Upazila of Netrokona District and Haluaghat & Dhobaura Upazila of Mymensingh district. The length of the border road (Z-2834) in Mymensingh part is 42 km. If Nitai Bridge is constructed on the 48th kilometre of the border road along with Mahadev, Someshwari and Ganeshwari Bridge on the 9th, 35th and 21st kilometres respectively, the road will be fully integrated and Netrokona border area will be directly connected with Mymensingh District. The road is also important for expansion of business & trade between Bangladesh, India and other land locked nearby countries. Further this will enhance the connectivity to various centres of tourist attraction located in Netrokona district. The border road would also create as infrastructure, having potentiality to facilitate movement of international transit traffic which would promote international trade and commerce for adjoining countries as well as for Bangladesh. This would contribute in economic development of Bangladesh and also generate additional revenue.

There is a temporary bridge constructed with bamboo on the Nitai River for the river crossing of passengers and local vehicles. Construction of this new bridge would facilitate direct connectivity between Netrokona and Mymensingh Districts through the border road.

TRAFFIC SURVEYS AND TRAFFIC ANALYSIS

Traffic Surveys

The following Traffic Surveys have been conducted:

1. Video Traffic Count Survey (VTS)
2. Video Pedestrian Count Survey (VPS)
3. Roadside Interview Survey (RSI), including
   - Origin-Destination Survey (ODS)
   - Vehicle Occupancy Survey (VOS)
   - Willingness to Pay Survey (WTP)

- Traffic Analysis – Base Traffic

Base AADT as on August 2023 and corresponding PCU for the existing road (Z2834) on the proposed nitai bridge location have been presented below.

Year	Types of traffic		Truck	Bus	Microbus	Utility vehicle	Car	Baby Taxi/CNG/Auto	Tempo/Leguna	Motorcycle	Bicycle	Rickshaw	Rickshaw Van	Cart	Total
Base year 2023	**Existing Traffic (2023)**		-	-	-	-	-	-	-	-	-	-	-	-	-
Opening year 2027	Applying growth rate on present traffic		-	-	-	-	-	-	-	-	-	-	-	-	-
	Diverted traffic	Only for Nitai Bridge	83	9	13	3	4	34	1,109	1,271	322	87	46	4	2,986
		For four bridges (Regional traffic through border roads)	241	119	58	22	90	-	-	-	-	-	-	-	530
	Land port traffic (between Bangladesh and India)		497	7	8	4	4	-	-	-	-	-	-	-	519
	Transit traffic (India to India traffic using Bangladesh Road)		99												99
	Tourist traffic		3	10	5	5	6	2	28	30	6	10	1	2	107
	Induce traffic		4	2	1	0	2	0	9	34	13	0	1	0	67
	Total		**928**	**148**	**85**	**34**	**105**	**36**	**1,146**	**1,334**	**341**	**97**	**48**	**6**	**4,308**

- Traffic Capacity Analysis – Proposed Lane Configuration

On the basis of present traffic data analysis and projected AADT, the number of lanes has been considered for the proposed Nitai bridge. The salient points of the calculations are as per following.

Projection Period	Year	Traffic Volume in AADT		Traffic Volume in PCU		Lane Number (Based on peak hour demand)		Lane Number (Round up)	
		Daily	Peak hour	Daily	Peak hour	LOS B	LOS C	LOS B	LOS C
Base year	2023	0	0	0	0	-	-	-	-
Traffic opening year	2027	4,308	530	5,821	716	0.82	0.56	2.00	2.00
Opening +5 year	2032	6,164	758	7,872	968	1.11	0.76	2.00	2.00
Opening +10 year	2037	7,966	980	9,730	1,197	1.37	0.94	2.00	2.00
Opening +15 year	2042	10,464	1,287	12,193	1,500	1.71	1.18	2.00	2.00
Opening +20 year	2047	12,814	1,576	14,427	1,775	2.03	1.39	4.00	2.00

ENGINEERING SURVEYS AND INVESTIGATIONS

- Road Inventory and Road Condition Surveys

Road Inventory and Road Condition Survey has been done through vehicle mounted video camera along with visual inspection from approximately Km 45+000 to Km 49+130.

The existing carriageway width varies from 4.8 to 5.2m with flexible bituminous pavement. The existing pavement was found to be in good condition. Drainage system was found inadequate.

- Drone Videography Survey

The Consultant carried out drone videography along the proposed alignment options. This included aerial view of at least 150 m on both side of the proposed alignment centreline and the videography file has been submitted to RHD as soft copy. The consultants also prepared an “Aerial Reconnaissance Report” to have preliminary assessment of the impact of the proposed project corridor would render on the existing social and environmental set-up. A sample output of this report is given below:

- Topographic Survey

Based on the DFSR workshop held on March 13, 2024, Alignment Option 1 received approval from RHD. Detailed topographic survey has been conducted along the approved alignment. Generally, detailed survey work covered an area, 30m on either side of the proposed alignment. The topographic Survey Report along with soft copy of the topographic survey drawing has also been submitted.

GPS main control points were established based on WGS-84 coordinates of the Survey of Bangladesh, and drawings were produced using the UTM projection system, after applying necessary corrections Three nos. Permanent Benchmarks of size 400 x 400 x 1000mm, were installed at suitable locations. With reference to the PBMs and secondary TBM pillars, detailed Topographic survey have been conducted using Total Station. Cross sections at every 25m distance along the alignment have been surveyed and recorded.

OUTLINE OF THE OPTION STUDY RESULTS

Based on detailed site reconnaissance and map study, two alternative alignment options have been proposed identifying suitable Bridge locations over the Nitai River. Among these options, the Alignment Option 1 emerged as the most preferred choice based on reports such as the Alignment Option Study Report, Bridge Option Study Report, and Multi-criteria Analysis. Accordingly, the Draft Feasibility Study Report (DFS) recommended Alignment Option 1 with a Bowstring Steel Arch + PSC I Girder.

Following this recommendation, a workshop was held on March 13, 2024, where RHD (Roads and Highways Department) officials approved **Alignment Option 1** with the **Steel Tied Arch + PSC I Girder Bridge**. **The form has been preferred in terms of constructability and possibility of having advantage during packaging of Construction Contract with other steel bridges along the border road (Mahadev & Ganeshwari)**. Subsequently, a topographic survey was conducted, resulting in minor adjustments to the preferred alignment based on actual survey data and geometric design parameters.

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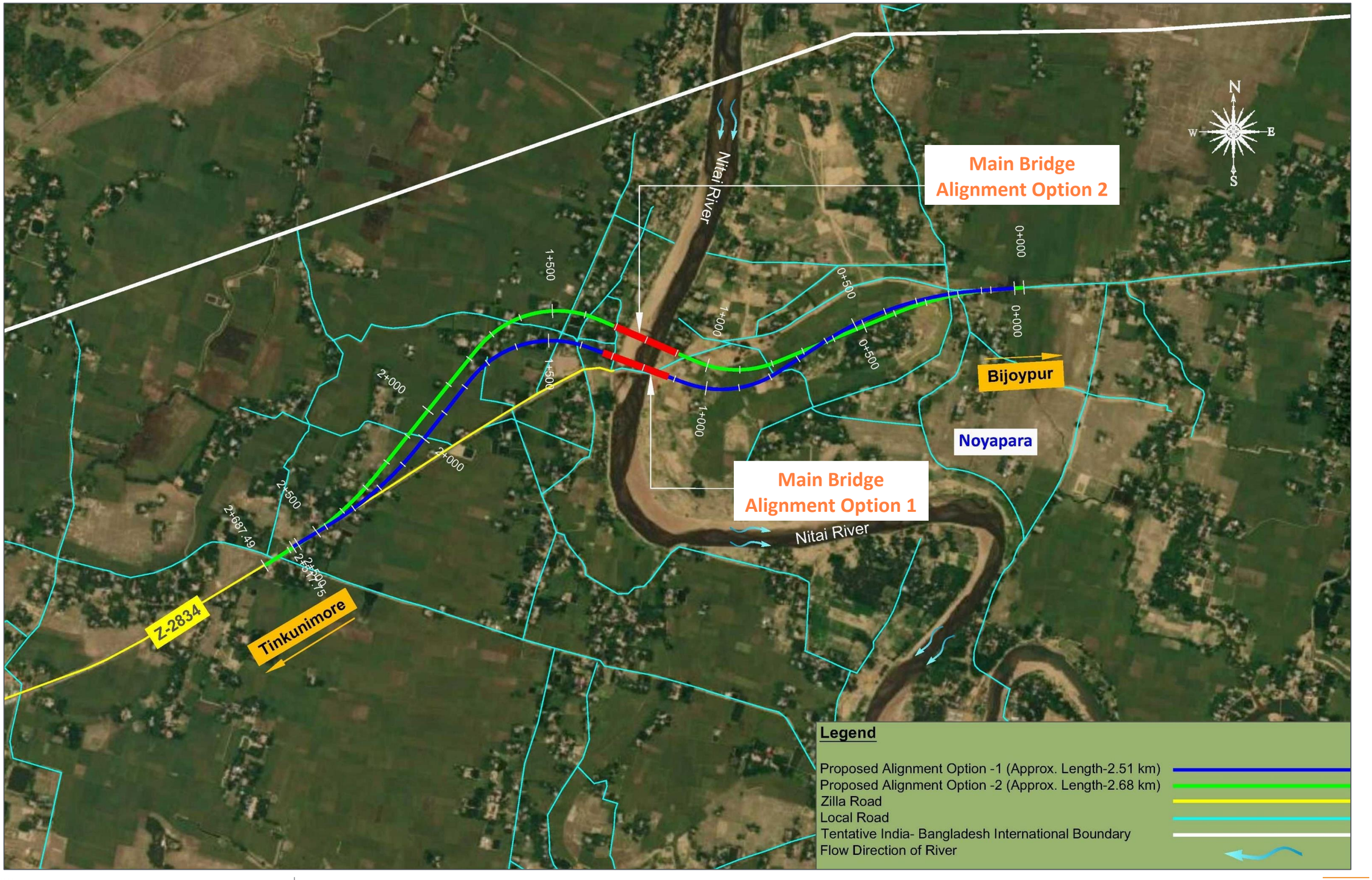
- Alignment Option Study

In this study, these two alignment options have been evaluated based on some assigned parameters for highway & bridge engineering, social, environmental, hydro-morphological and cost aspects. The calculation of the evaluation has shown below.



DECISION MATRIX OF ALIGNMENT OPTION STUDY

BASIC ASPECTS	PARAMETERS	UNIT	RELATION	MAX. SCORE	WEIGHTAGE	WEIGHTED MAXIMUM SCORE	OPTION - 1		OPTION - 2	
							QTY	SCORE	QTY	SCORE
Highway Engineering	Total Length	km	Equation 1	10	0.050	0.500	2.53	0.50	2.69	0.47
	Length of at grade highway	km	Equation 1	10	0.050	0.500	1.68	0.50	1.84	0.46
	Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.050	0.500	799.26	0.48	770.51	0.50
	Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.050	0.500	177.03	0.50	239.91	0.37
Bridge Engineering*	Total Length of Main Bridge	km	Equation 1	10	0.300	3.000	0.21	3.00	0.21	3.00
	Total Length of viaduct section of the bridge	km	Equation 1	10	0.300	3.000	0.64	3.00	0.64	3.00
	Score of the Best option	score	Equation 2	10	0.300	3.000	138.46	3.00	138.46	3.00
Social	Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.075	0.750	12.00	0.75	23.00	0.39
	Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.075	0.750	0.00	0.75	0.00	0.75
	Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.075	0.750	0.00	0.75	0.00	0.75
	Approximate Total land to be acquired	Ha	Equation 1	10	0.075	0.750	8.16	0.75	8.70	0.70
	Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.075	0.750	7.15	0.75	7.70	0.70
Environment	Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.075	0.750	0.00	0.75	0.00	0.75
	Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.075	0.750	100.00	0.75	132.00	0.57
	Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.075	0.750	0.68	0.75	0.94	0.54
Hydro-Morphological#	Rank of the Bridge Option	Rank	Equation 1	10	0.200	2.000	1.00	2.00	2.00	1.00
	River Training Works - Approximate Bank Length	m	Equation 1	10	0.200	2.000	364.00	2.00	364.00	2.00
Indicative Cost*	Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.300	3.000	152.16	3.00	152.16	3.00
	Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.300	3.000	361.01	3.00	363.21	2.98
Total Score				**190**				**26.98**		**24.93**
Percentage Score				**100**				**99.93**		**92.34**
RANK								**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1C in Alignment Option 1 & Bridge Option 2C in Alignment Option 2. Refer "Bridge Option Study Report (Nitai Bridge)" – Document No.: 5060143-8BRP-STR-RPT-005-R2.*

 # The parameter values pertain to Bridge Site B (nearly matches with Bridge Location at Alignment Option 1) & Bridge Site A (nearly matches with Bridge Location at Alignment Option 2). Refer "Hydro-Morphological study of Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM)

From the overall consideration of the evaluation, the **Alignment option 1** holds the **Rank 1** position.

- Bridge Option Study

In the bridge option study, a set of span arrangement with three different bridge forms have been presented for each alignment option. All the options have been merited on the basis of scoring marks representing various evaluation criteria. Suitable bridge option has been proposed by evaluation through decision matrix and on the basis of highest scoring. All the bridge options are as detailed below:

Bridge Options in Alignment Option 1 & 2

- Option A: Steel Tied Arch + PSC I-Girder
- Option B: Balance Cantilever
- Option C: Bowstring Steel Truss + PSC I-Girder

Suitable bridge option has been proposed by evaluation through decision matrix and best scoring, as shown below:

DECISION MATRIX OF BRIDGE OPTION STUDY – ALIGNMENT OPTION 1 and 2

SL. NO.	ASPECTS	PARAMETER	UNIT	RELATION	WEIGHTAGE	MAX SCORE	Option A (Steel Tied Arch +PSC I-Girder)		Option B (Balanced Cantilever)		Option C (Bowstring Steel Truss +PSC I Girder)	
							QTY	SCORE	QTY	SCORE	QTY	SCORE
A1	Design & Serviceability	Depth of superstructure	m	Equation-1	15%	10	2.00	4.00	5.40	1.48	0.80	10.00
A2	Design & Serviceability	Skew angle	degree	Equation-1		5	0.00	5.00	0.00	5.00	0.00	5.00
A3	Design & Serviceability	Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Annexure-1		10	125.00	10.00	120.00	9.86	90.00	9.00
A	Sub Score - Design & Serviceability					25		19.00		16.34		24.00
B1	Constructability	Total bridge length	m	Equation-1	15%	10	205.0	10.00	260.0	7.88	210.0	9.76
B2	Constructability	Maximum single span Length (for Difficulty, duration, safety hazards)	m	Annexure-2		15	125.00	14.52	120.00	11.52	90.00	15.00
B	Sub Score - Constructability					25		24.52		19.40		24.76
C1	Aesthetic	Suitability with the terrain and culture		Based on judgement	20%	15	Best	15.00	Good	5.00	Better	14.00
C2	Aesthetic	Integrity between superstructure and substructure				15	Better	7.00	Best	15.00	Good	5.00
C	Sub Score - Aesthetic					30		22.00		20.00		19.00
D1	Environment	Total carbon consumption Proportionate to structural concrete quantity	cum	Equation-1	20%	10	7890.0	10.00	17131.0	4.61	8434.1	9.35
D2	Environment	Obstruction in waterway due to structure inside the perennial river	m	Equation-1		20	7.0	20.00	12.4	11.29	7.5	18.67
D	Sub Score - Environment					30		30.00		15.90		28.02
E1	Cost	Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation-1	30%	15	50.40	14.81	76.65	9.74	49.76	15.00
E2	Cost	Approximate Cost of Superstructure	Cr (BDT)	Equation-1		15	83.61	10.53	58.72	15.00	69.50	12.67
E3	Cost	Approximate Maintenance cost for entire service life	Cr (BDT)	Equation-1		15	60.30	14.83	67.69	13.21	59.63	15.00
E	Sub Score - Cost					45		40.18		37.95		42.67
	Total Score					**155**		**135.70**		**109.59**		**138.46**
	Percentage Score					**100**		**87.55**		**70.70**		**89.33**
	Preferred Option						**Option C (Bowstring Steel Truss +PSC I Girder))**					

From the overall consideration of the evaluation, the **Bridge Option C (Bowstring Steel Truss +PSC I Girder)** is observed as **preferred option**.

From the Table above it can be seen that the total score of Option C (Bowstring Steel Truss + PSC I Girder) is 1.78% higher than Option A (Steel Tied Arch + PSC I-Girder). Further it can be observed that Option C (Bowstring Steel Truss + PSC I Girder) is 19% (nearly) higher than Option B (Balanced Cantilever). Hence it can be inferred that Option A (Steel Tied Arch + PSC I-Girder) and Option C (Bowstring Steel Truss +PSC I Girder) are more or less equally preferable. Option B (Balanced Cantilever) is not preferable here with respect to Option A (Steel Tied Arch + PSC I-Girder) and Option C (Bowstring Steel Truss + PSC I Girder) based on the parameters related to suitability with terrain and culture for being near hill region.

But according to the MOM (Ref. GEN-MOM-0036) The preferred bridge option would be as below:

- The proposed preferred alignment option-1 is acceptable.
- The main bridge form shall be **bridge option A (Steel Tied Arch + PSC I Girder)** with span arrangement of 2 X 40.0m + 1 X 125.0m 2 X 40.0m.
- The form has been preferred in terms of constructability and possibility of having advantage during packaging of Construction Contract.

It shall be noted that, 40+125+40m span in workshop MOM is based on DFSR submission where approach viaduct was multiple span of simply supported 40m PSC I Girder system. Now the viaduct arrangement rearranged with 32+40+32 m integral module for further optimization. Accordingly, main bridge span arrangement has been updated as 32+125+32 while combining with approach viaduct.

The salient features of the preferred option are given below:

For alignment option 1 & 2 both preferred span arrangement and bridge form option is A:

Span arrangement -	1 x 32 + 1 x 125 + 1 x 32 m
Total length of main bridge -	189.0 m
Skew angle -	0 degree
Superstructure type -	125.0m m & 32.0m Steel Tied Arch & PSC I Girder
Overall Deck width -	1 x 19.85 m
Support condition -	Simple Supported
Lane configuration -	2 lane + 2 Lane -SMVT
Structural feature -	Steel Tied Arch with PSC I Girder Bridge.

For the option of the bridge, soffit level takes into account the climate change effect (0.38 m anticipated sea level rise) as inferred in the “Hydro-Morphological study of Nitai Bridge at 47th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020” dated in November 2021 by Institute of Water Modelling (IWM).

SCHEMATIC VIEW OF NITAI BRIDGE (STEEL TIED ARCH BRIDGE + PSC I GIRDER) IN ALIGNMENT OPTION 1

- Multicriteria Analysis

The final decision matrix for concurring the Alignment Option was developed by combining the individual scores of the parameters with the application of weightage for different Criteria as detailed below

CRITERIA	WEIGHTAGE
Highway Engineering Criteria	0.050
Bridge Engineering Criteria	0.300
Social Criteria	0.075
Environment Criteria	0.075
Hydro-Morphological Criteria	0.200
Indicative Cost Criteria	0.300
Total	**1.00**

After considering the weighted criteria, Option 1 obtained a score of 93.0%, outperforming Option 2, which scored 89.81%. This margin indicates the clear preference for Option 1, emphasizing its superior suitability for the project. For a detailed breakdown, please refer to the Multicriteria Decision Matrix in **Section 10** of the report.

The choice for the Alignment Option was also ratified through Sensitivity Analysis. "*Sensitivity of the final scoring with respect to the adopted weightages*" has been done, by developing decision matrixes in 4 scenarios with different weightage combinations, as detailed below.

Aspect	Weightage Adopted in Different Scenarios			
	Scenario I	Scenario II	Scenario III	Scenario IV
Highway Engineering Criteria	0.050	0.050	0.050	0.167
Bridge Engineering Criteria	0.300	0.300	0.300	0.167
Social Criteria	0.050	0.075	0.050	0.167
Environment Criteria	0.050	0.075	0.050	0.167
Hydro-Morphological Criteria	0.200	0.250	0.300	0.167
Indicative Cost Criteria	0.350	0.250	0.250	0.167
Total	**1.00**	**1.00**	**1.00**	**1.00**

Scenario	Option 1	Option 2
Scenario I	93.13%	90.43%
Scenario II	92.74%	89.05%
Scenario III	92.62%	88.92%
Scenario IV	95.14%	88.76%
Preferred Option	**Preferred**	

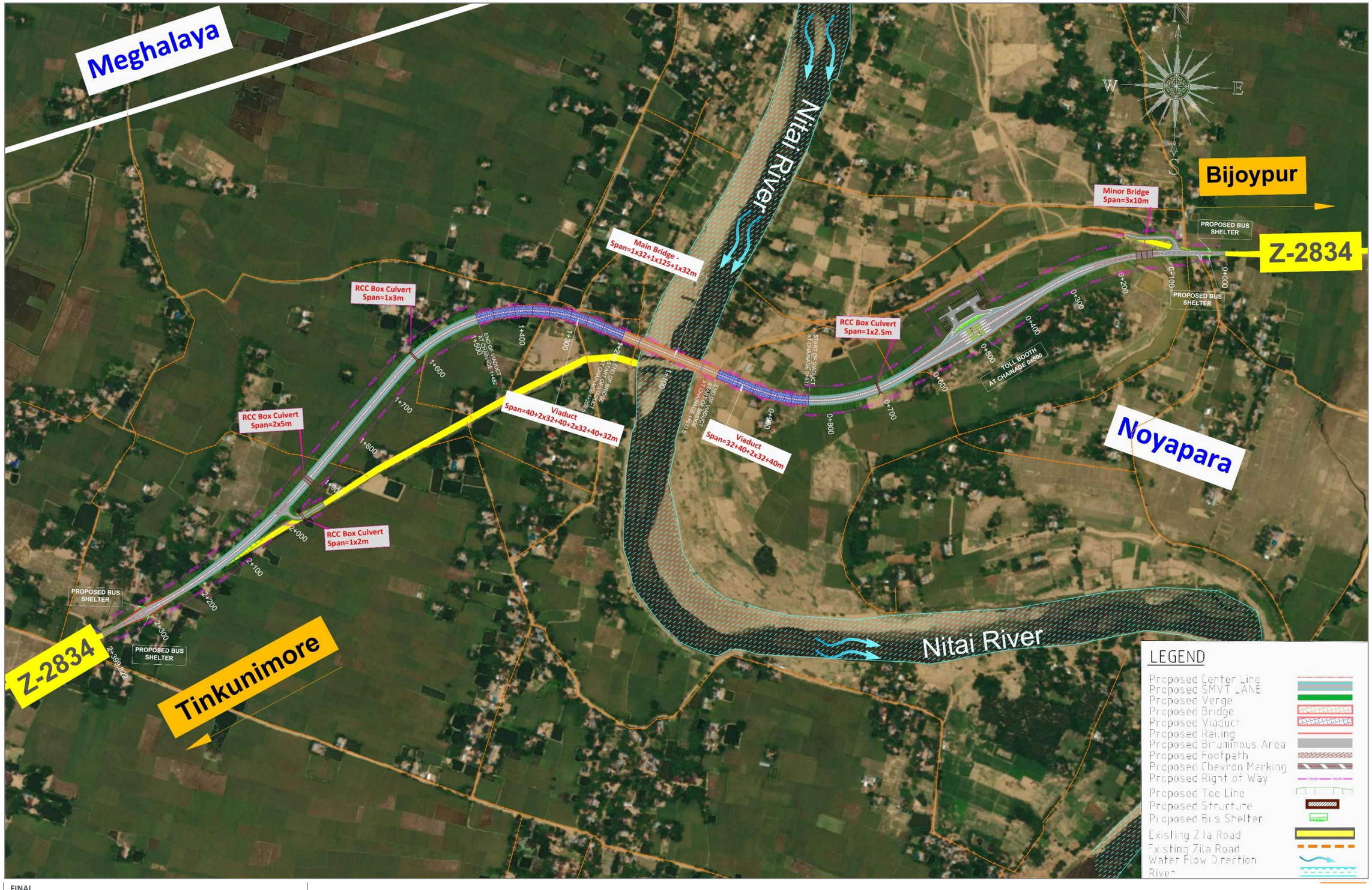
The results of Tables above infer very clearly the Alignment Option 2 as the Rank 1 in all the Scenarios, the detailed Multicriteria Decision Matrix of the scenarios is in **Section 10** of the report. The difference in the score between the two Alignment Options ranges from 2.70% to 6.38%. The high score of the Alignment Option 2 is attributable to its superiority, primarily with respect to Bridge Engineering, Hydro–Morphological Studies and Indicative Cost aspects.

Hence it can be well inferred that Alignment Option 1 is the preferred as well as approved alignment with respect to the Bridge location as well as overall Project Road Alignment.

Further, it may please be noted that, **the proposed Bridge Location in the Alignment Option 1 also matches closely with the Preferred Option as per Hydro-morphological Study carried out in 2021 by Institute of Water Modelling (IWM).**

The Preferred Alignment Option 1 along with the Bridge and viaduct locations has been schematically presented in below.

SCHEMATIC PLAN OF APPROVED ALIGNMENT OPTION



PRELIMINARY ENGINEERING AND DEVELOPMENT PROPOSAL

- Geometric Design

The Nitai bridge road is a **Rural Collector Road**, and the **Design Speed of the proposed road is 80 kmph**. The total length of the project road is **2.40 km**. The engineering study has been carried out based on the approved alignment (Based on the DFS workshop held on 13th March 2024) and Steel Tied Arch bridge form**.** The geometric design of the road has been done following "A Policy on Geometric Design of Highways and Streets (AASHTO) 2018, 7th Edition". The design parameters for horizontal and vertical alignment have been validated and briefly detailed in this study.

- Typical Cross-section

The summary of the typical cross sections proposed has been presented below.

Sr. No.	TCS Type	TCS Description	Proposed ROW (M)	Length (KM)
1	TCS 1	Typical Cross Section for Merging with Existing Road with Embankment Height Less Than 2 M at Rural Areas	30	0.025
2	TCS 2	Typical Cross Section for Merging with Existing Road with Paved Shoulder (Varies) with Embankment Height Less Than 2 M at Rural Areas	30	0.088
3	TCS 3	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) for Embankment Height 3M to 6M with Two Lane Service Road at Right Side	69	0.075
4	TCS 4	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) for Embankment Height 3M to 6M at Rural Areas	54	0.020
5	TCS 5	Typical Cross Section for Two Lane Carriageway with Varies SMVT Lane with Embankment Height 3M to 6M at Rural Areas	54	0.070
6	TCS 6	Typical Cross Section for Two Lane Carriageway with SMVT Lane with Embankment Height 3M to 6M at Rural Areas	50 to 54	0.925
7	TCS 7	Typical Cross Section of Two Lane Carriageway with SMVT Lane at Merging Section with Toll Plaza	54 to 102	0.220
8	TCS 8	Typical Cross Section for Toll Plaza Location (With SMVT Lane)	102	0.055
9	TCS 9	Typical Cross Section for Two Lane Carriageway at Bridge and Viaduct Sections (With SMVT Lane)	24	0.645
10	TCS 10	Typical Cross Section for Two Lane Carriageway with Varies SMVT Lane with Embankment Height 2M to 3.5M at Rural Areas	42	0.065
11	TCS 11	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) with Embankment Height Less Than 2M at Rural Areas	42	0.042
12	TCS 12	Typical Cross Section for Two Lane Carriageway with Bus Bay (Varies) in Rural Areas	42	0.095

13	-	Junction Development	-	0.075
Total Length (km)				2.400

- Service Road

After following the existing road upto Km 0+080, the proposed road has been realigned for proposed Nitai bridge. Thus, to ensure existing local connectivity, a service road has been proposed with a minor junction at km 0+090 for entry and exit from the main thoroughfare. The proposed service road of width 7.3m, extends from km 0+105 to km 0+180 on right side of the proposed highway.

- Access Strategy

The project road serves as an access route to the new Nitai Bridge over Nitai River, running in the vicinity of the existing road with nearby settlements and intersecting local roads. To minimize disruption to the existing road network, an access strategy has been devised, segmenting the project into 3 nos. zones based on the entry points to the proposed road which are defined below.

- Zone A: Access via the at-grade junction with earthen road at km 0+050.
- Zone B: Access via the at-grade junction with service road at km 0+090.
- Zone C: Access via the at-grade junction with RHD road at km 1+990.

- Pavement Design

The recommended pavement composition based on AASHTO method is given below

Based on AASHTO method for design traffic of 23 MSA, the recommended pavement composition for the project road has been presented below

Layers	Thickness (mm)
Asphalt Wearing Course	50
Asphalt Base Course	190 (In three layer- 60, 60 & 70 mm each)
Aggregate Road Base (Base Type I)	200
Granular Subbase	100
Improved Subgrade (CBR 8%)	300

The pavement system for the concrete bridge deck and viaduct shall have a total thickness of approx. 54 mm and consists of the following components:

- Wearing course: 50 mm dense graded Bituminous concrete
- Tack coat: approx. 200 micrometres
- Waterproofing membrane: 2-4 mm synthetic resin-based membrane (sprayed in two layers)
- Primer: concrete deck primer (sprayed)

The waterproofing system shall be an elastomeric polyurethane or Methyl-Meth-Acrylate (MMA) based waterproofing system for concrete bridge decks.

- Embankment Design & Slope Stability Analysis

Considering the aforementioned road safety considerations, the following have been adopted in the project.

- The minimum side slope of 2:1 (H: V) for embankments higher than 2 meters ensures stability by preventing excessive lateral movement.
- For embankments less than 2 meters in height, a gentler slope of 3:1 (H:V) is implemented.

As per the available secondary data and previous experience, the summary of Slope stability analysis is tabulated below.

Chainage	Fill Height (m)		GWT (m)	FOS-Short Term (static)	FOS-Short Term (Seismic)	Remark
	LHS	RHS				
0+690	6.96	1 m BGL	1.57	1.10	Safe	0+190

- Drainage Design

The project roads are approach roads to the proposed Bridge. A significant portion of this road comprises high embankments. The measures that have been considered for drainage mitigation are as follows:

- Provision of Chute drain has been provided for embankment sections more than 3.0m.
- 2.0m wide toe drain with PCC lining has been provided in all highway sections except slip road, Toll Plaza, Bridge and Viaduct locations.
- 1.0m and 1.5m wide footpath cum drain are proposed on the slip road section and Toll Plaza section, respectively.
- Standard crossfall and Drainage spouts has been provided to ensure drainage at Bridge and Viaduct sections.

- Design of Auxiliary Functions

Toll Plaza & Weighbridge

A 3+3 lane toll plaza has been proposed at Km 0+503 and a space of 110m x 45m has been kept for provision of Toll Administrative Building and other ancillary facilities. However, considering entire alignment of border road, provision of toll plaza will be finalised as per directive from the RHD. Only, Space proofing for proposed Toll Plaza has been done at this stage. The operational and other aspects will be thoroughly addressed in subsequent stages in discussion with RHD officials.

Weigh bridge facility has not been considered for this project since the length of the project corridor is 2.4km only and serves primarily as an approach to the Nitai Bridge. Hence, provision of an axle load regulatory control station has not been envisaged. Further, there is a need for internal discussion by RHD keeping in view of the "Installation of Axle Load Control Stations at the Source of Freight Transport on Important Highways of Roads and Highways Department" project, being undertaken by RHD. Provision of weigh bridge for this project can be further decided based on this discussion.

Bus Bays & Stopping Places

Two locations have been identified for proposing bus stops with bus bays and two additional locations for bus stops without bus bays along the project corridor.

Sl. No.	Chainage	Side	Location	Remarks
1	0+030	RHS	Near start junction at km 0+090	Bus Stop Without Bus Bay
2	0+030	LHS		Bus Stop Without Bus Bay
3	2+310	RHS	Near end point at km 2+400	Bus Stop with Bus Bay
4	2+310	LHS		Bus Stop with Bus Bay

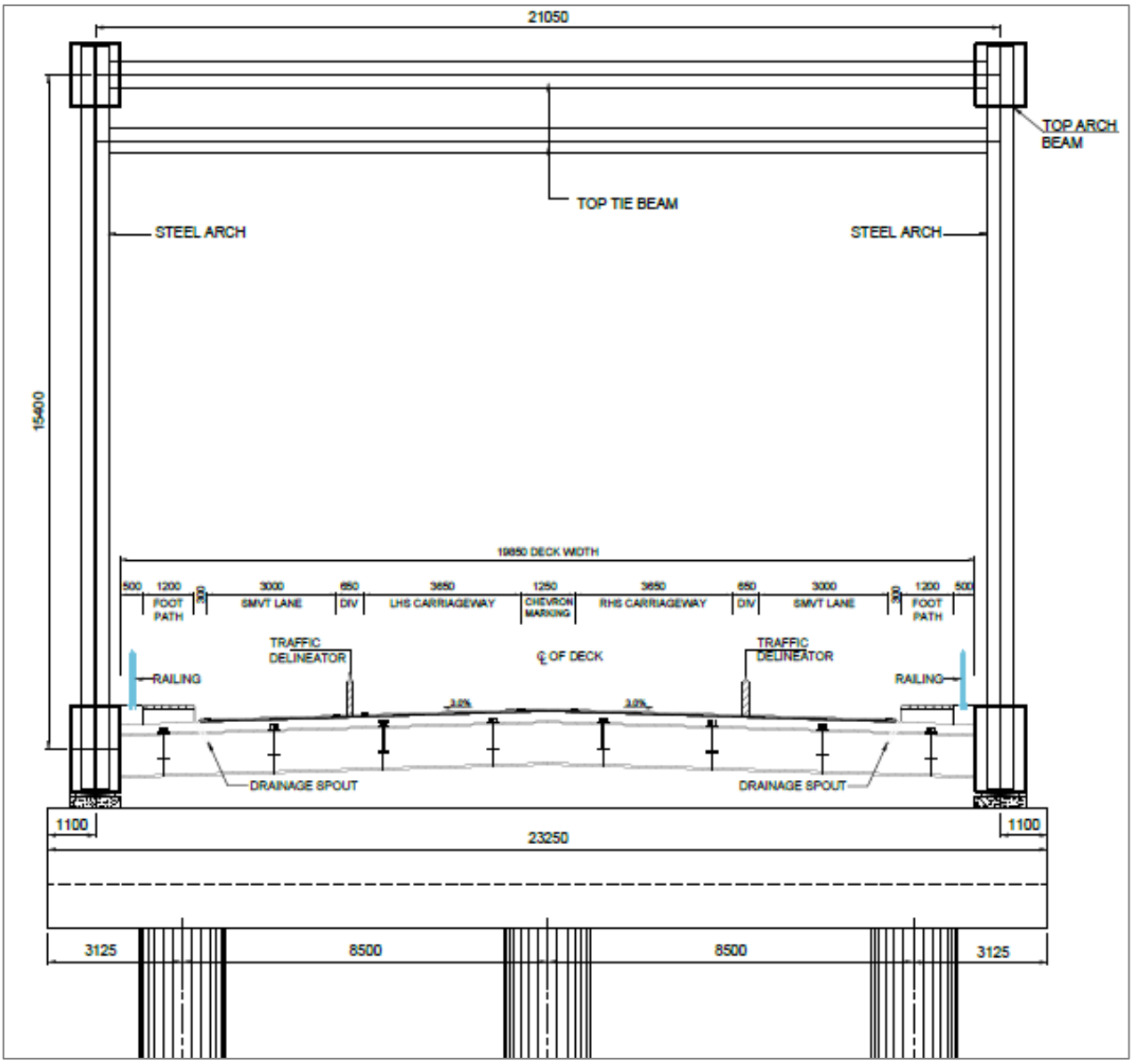
PRELIMINARY ENGINEERING – BRIDGE

Since the river is designated as Navigational Class IV, in accordance to the BIWTA norms horizontal clearance of 20m and vertical clearance of 5m has been considered. Standard High-Water Level (SHWL) value of 16.26 mSOB has been considered as per BIWTA clearance certificate. This SHWL value also considers the climate change effect (0.38 m anticipated sea level rise).

Span Arrangements

Section	Superstructure	Span Arrangement
Viaduct (Bijoypur Side)	PSC I Girder	(32+40+32)m +32m+40m = 176 m
Main Bridge	Steel Tied Arch & PSC I Girder	1x32+1x125+1x32= 189 m
Viaduct (Tinkunimor Side)	PSC I Girder	32+40+32)m+(32+40+32)m+32m+40m =280m

Typical Main Bridge Cross Section for Steel Tied Arch Bridge



Geotechnical overview of the Bridge Site

Geotechnical investigation for foundation design has not been carried out for this bridge site as on date. In absence of data the secondary data shared by RHD "Report on geotechnical investigation for the proposed 1422.15 m long P.C girder Brahmaputra Bridge- 3 over Brahmaputra River on Rahmatpur- Ramvadrapur road Ch: 0+415 under Mymensingh road division, Mymensingh." has been used. The available geotechnical study is located roughly 70 kilometres away from the planned bridge location.

The sub-soil has five distinct layers / stratum of more or less uniform thickness throughout as follows.

Stratum-I-Very loose silty fine sand (3 m thick)

Stratum-II-Medium dense silty fine sand (15 m thick)

Stratum-III-Stiff Clay (9 m thick)

Stratum-IV-Dense Sand, (14.5 m thick)

Stratum-V-Very Dense Sand, (8.5 m thick)

The thickness of scourable strata at this bridge site is taken as 8.45 m as per hydro morphological report titled, "Hydro-Morphological Study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh Portion) during the year 2019-2020" conducted by IWM.

Unit weight of loose/ medium dense sand is 18 kN/m3 and the corresponding value for dense sand is 19 kN/m3.

PRELIMINARY ENVIRONMENTAL ASSESSMENT

- Scope of Environmental Assessment

The proposed project falls under the Orange Category as per the Environmental Conservation Rules (ECR), 2023 & amendments thereof. An Initial Environmental Examination (IEE) study is required for the project and the project would require Environment Clearance from the Department of Environment (DoE), Bangladesh.

The Initial Environmental Examination (IEE) will encompass several key objectives such as evaluation of the existing environmental conditions within the Project Impact Area (PIA) and surrounding regions. Moreover, it will identify potential positive and negative environmental risks throughout the project's lifecycle, from pre-construction to construction and operation phases. It will also address various risks, including those related to the environment, health and safety, climate change, and disaster risk, by formulating appropriate mitigation measures. Finally, it will propose suitable institutional mechanisms to effectively implement and manage an Environmental Management Plan (EMP).

- Environmental, Climate Change and Disaster Risk Analysis

The initial assessment identified various potential impacts of the project spanning environmental, climatic, and disaster-related aspects. These impacts include alterations to the land's topography and geological conditions, disruptions to both terrestrial and aquatic ecosystems, soil erosion, and the generation of debris and dust. Construction activities are expected to increase sediment load and water pollution, degrade air quality through the release of dust and gas emissions, and elevate noise pollution. The destruction of habitats for flora and fauna, along with health and safety risks for workers and local communities, are significant concerns. Furthermore, the effects of climate change and natural disasters could intensify these impacts. Socio-economic consequences such as increased poverty, healthcare issues, reduced ecological resilience, and energy insecurity are also anticipated. This holistic view underscores the multifaceted nature of the project's potential repercussions, emphasizing the need for comprehensive mitigation strategies to address these varied challenges.

- Impacts and Mitigation Measures

Based on the preliminary assessment due to implementation of proposed project, a summary of impacts and possible mitigation measure are presented below:

Parameters	Impacts	Mitigation Measures
Land	Acquisition of land	• Avoid or minimize the area of acquisition. • Preparation and approval of land acquisition plans before implementation
	Impact on land use	• Construction activities to be restricted within PRoW.
Biological Environment	Loss of trees and vegetation	• Avoid or minimize the cutting of trees. • Compensatory plantation should be done as per prevalent rules & regulations
	Impact on Wildlife	• Protective measures for wildlife conservation • Avoid habitat destruction & fragmentation. • Awareness Training to workers for wildlife conservation, antipoaching, etc.
	Impact on Avian Fauna	• Avoid habitat destruction
Ambient Air	Dust generation due to movement of vehicles on unpaved roads	• The unpaved roads shall be sprinkled with water to control the fugitive dust emissions.
	Air pollution from hot mix/ Concrete/ asphalt plants	• It will be ensured that the Concrete, Asphalt and Hot Mix Plants are licensed and authorized for operation by concerned authorities
	Increased dust levels due to earth work and construction activities	• Immediate shifting of excavated earth in covered vehicles • Frequent sprinkling of water on excavated earth
	Increased air pollution from machineries	• Preventive maintenance of machineries to meet emission standards
	Air Pollution due to operation of DG sets	• DG sets, if used, shall adhere to air emission standards as per prevailing laws of GoB. • Stack heights shall be maintained as per standards
Noise	Increased Noise Levels during Construction	• Maintenance of equipment and vehicles to meet noise level standards as per laws. • Provision of Personal Protective equipment, earmuffs, etc. for the construction labour • Avoiding construction activities during night-time
	Noise impact due to operation of DG sets	• DG sets, if used, shall adhere to noise level standards as per prevailing laws of GoB.

Parameters	Impacts	Mitigation Measures
	Impact of Noise on Sensitive Receptors	• Provision of Noise Barrier • Delineation of Silence Zone/Signage
Water Resources	Changes to hydrological regime, increased flooding, siltation hampering stream flows, etc.	• Minimal disruption to natural stream flow • Minimum erosion of riverbanks • Revegetation for physical stabilization
	Degradation of Riverbanks due to excavation and construction activities	• Preventive measures like provision of silt fencing, oil interceptors etc during construction shall be adopted
Occupational Health & Safety	Occupational Health & Safety	• Adequate provision of PPE and safety equipment's • Periodic Safety trainings & safety audit • Periodic Health awareness and health check-up camps for workers
	Community Health & Safety	• Provision of Safety barriers and signages/ warning measures • Periodic Health awareness and health check-up camps for local community
Natural Hazards	Cyclones, Floods & Earthquake Hazard	• Design and construction methods should be modified/ updated as to adopt the projected impact. • Use of alternative material & technology

INITIAL SOCIAL ASSESSMENT AND PRELIMINARY LAND ACQUISITION

- Land Use

The approach roads of Nitai bridge is situated in the rural area of Dhobaura Upazila, Mymensingh District. Following table has been shown the land use for acquisition.

SL No	Land Category	Area (Sqm2)	Area (acre)	Area (hector)	Percentage (%)
1	Agricultural	67258.94	16.62	6.73	60.10
2	Barren Land	1264.26	0.31	0.13	1.13
3	Commercial	160.42	0.04	0.02	0.14
4	Residential	10119.01	2.50	1.01	9.04
5	River	1088.07	0.27	0.11	0.97
6	Transportation	9129.38	2.26	0.91	8.16
7	Vegetation	10450.38	2.58	1.05	9.34
8	Waterbody	12436.08	3.07	1.24	11.11
	Total	**111906.54**	**27.65**	**11.19**	**100.00**

- Poverty Rate and Sex Ratio

The following table has been shown the poverty rate and sex ratio of Mymensingh District & Dhobaura Upazila.

Content by District	Mymensingh	Dhobaura
Average Poverty Rate in HIES 2016 (Upper limit)	29.0	42.2
Sex Ratio	96.66	97

- Potentially Affected Structures and Categories

The extent of impacts of the affected structures could not be analysed here in this stage of study without authenticated field observations that has been presented below.

Category of the Structure	Type of Structure at the Nitai Bridge					Total (Unit)
	Multi-storied	Pucca	Semi-Pucca	Tin-made	Katcha/Jupri	
Residential	0	0	2	18	2	22
Commercial	0	0	0	4	0	4
CPR	0	0	0	0	0	0
Total=	**0**	**0**	**2**	**22**	**2**	**26**

COST ESTIMATE

Cost Estimate is an important component of the feasibility study as it provides vital input to economic evaluation. The cost estimation has been prepared for the approved alignment, based on the improvement proposals and preliminary design adopted at this stage. However, in absence of Geotechnical Report, this Cost Estimate is approximate and will be further updated in the next stages of study based on detailed investigations and further designs. The summary of project cost has been presented below.

Note: According to the Cost Estimation Classification Matrix prepared by the AACE International (The Association for the Advancement of Cost Engineering) the cost estimate prepared during the feasibility stage may vary from -20% to +20%.

Division	Description	Amount (BDT)	Amount in Cr. (BDT)
	Construction Cost		
1	General & Site Facilities (2% Of Construction Cost)	68,622,590.98	6.86
2	Earth Work	112,670,939.00	11.27
3	Sub-Base, Base-Courses	67,485,809.00	6.75
4	Bituminous Pavement Courses	161,132,830.00	16.11
5	Cross Drainage Structures - Culverts	45,084,490.11	4.51
6.01	Structures - Minor Bridge	64,113,126.63	6.41
6.02	Structures - Viaduct	1,392,300,000.00	139.23
6.02	Structures - Main Bridge	1,088,996,039.95	108.90

Division	Description	Amount (BDT)	Amount in Cr. (BDT)
7	Drainage & Protection Works	30,399,659.29	3.04
8	Traffic Signs, Marking And Road Appurtenances	25,696,263.00	2.57
9	Toll Plaza	269,454,392.00	26.95
10	River Training Works	142,446,000.00	14.24
11	Electromechanical Works	19,350,000.00	1.94
12	Bridge Health Monitoring System	12,000,000.00	1.20
	A. Total Construction Cost	**3,499,752,140**	**349.98**
	Non - Civil Works		
1	Land Acquisition, Resettlement & Compensation (10% of Civil Cost)	349,975,214.00	35.00
2	Utility Shifting (Lump Sum)	10,000,000.00	1.00
B	**Total Non-Civil works Cost**	**359,975,214**	**36.00**
C	**Total Capital Cost (A+B)**	**3,859,727,354**	**385.97**
D	Contingency		
1	Price Adjustment (15% of Civil Cost)	524,962,821	52.50
2	Contingency		
a)	Physical Contingency (2% of Civil Works)	69,995,043	7.00
b)	Price Contingency (2% of Civil Works)	69,995,043	7.00
D	**Total Price Adjustment and Contingency Cost**	**664,952,907**	**66.50**
E	**Total Project Cost (C+D)**	**4,524,680,261**	**452.47**

ECONOMIC ANALYSIS

The Economic Analysis has been done in a combined perspective, considering the overall total cost and benefit of all the four bridges namely Nitai, Someshwari-3, Ganeshwari, and Mahadev. This has been done keeping in view of the fact that the overall benefit of the project influence area can only happen once the through connectivity of Z-2834 has been established between Haluaghat to Sunamganj, for which construction of all four bridges is essential.

The benefits on the construction of the bridge are as briefed as below -

- Saving in VOC and Time cost.
- Reduction in Emission.
- Incremental Output from Govt. Expenditure
- Impact on Economic Activities and Income Augmentation

Following are the results of Economic Analysis and Sensitivity Analysis:

Estimation of EIRR and NPV

- EIRR: 20.6%
- NPV @12%: 1430.8 Crores BDT
- EBCR: 1.8

Sensitivity Analysis – 10% rise in cost

- EIRR: 19.0%
- NPV @12%: 1253.8 Crores BDT
- EBCR: 1.6

Sensitivity Analysis – 20% drop in Benefits

- EIRR: 17.0%
- NPV @12%: 782.7 Crores BDT
- EBCR: 1.4

Sensitivity Analysis – All cases together

- EIRR: 15.6%
- NPV @12%: 605.1 Crores BDT
- EBCR: 1.3

Considering immense socio-economic benefits to the Project influence area, the project is strongly recommended for consideration of implementation for having high EIRR of 20.6%.

FINANCIAL ANALYSIS

The total cost of entire project is BDT. 492.1 Cr. including interest during construction. The construction is assumed to commence in 2024 and will be completed by the end of 2026. The facility will be opened in 2027. The land acquisition cost & rehabilitation cost are included in "Total Project Cost without IDC" (BDT. 452.5 Cr.) since that will be borne by the Government of Bangladesh. The details are presented in the table below.

Sl. No.	Cost Items	Amount (BDT. Cr.)
A	Total Project Cost without IDC	452.5
B	Interest During Construction (IDC)	39.6
C	Total Project Cost to the authority	**492.1**

Financial Model (Annuity Based Model)

The following assumptions have been made for Financial Analysis:

- Construction Start Year: 2024.
- Construction End Year: 2026.
- Construction Period: 3.0 Years.
- Opening of the facility: 2027.
- Loan from Bank: 70% and Equity from private party: 30%.
- Inflation Rate: 5.0% per annum.
- Interest rate during and after construction: 8.5% per annum.

The summary of Financial Analysis (Annuity based model) is shown below

Fund Details	Project IRR	Project NPV	Nominal WACC	Equity IRR	Equity NPV	Average DSCR	Average LLCR
Grant-0%, Debt-70% & Equity-30%	12.2%	BDT. 70.1 Cr.	10.8%	16.0%	BDT. 0.3 Cr.	2.15	2.89

Financial Model (Revenue based model)

This considers two distinct costs: the total capital cost and the total project cost. The entire cashflow, Project Internal Rate of Return (PIRR) and Net Present Value (NPV) have been presented below.

- Financial Analysis – Considering total capital cost.
  - PIRR: 3.55%
  - NPV@5%: -77.2 Crores BDT
  - Total Capital Cost: 452.5 Crores BDT
  - FBCR: 0.94
- Financial Analysis – Considering total project cost.
  - PIRR: 4.65%
  - NPV@5%: -16.8 Crores BDT
  - Total Project Cost: 386 Crores BDT
  - FBCR: 1.10

The financial analysis precisely shows that, the bridge does not have high revenue generating capability due to low level of traffic in the region. The toll revenue does not even recover the initial investment even in first thirty years of operation. Hence, net financial support will be required from Govt. of Bangladesh.

RISK AND SENSITIVITY ANALYSIS

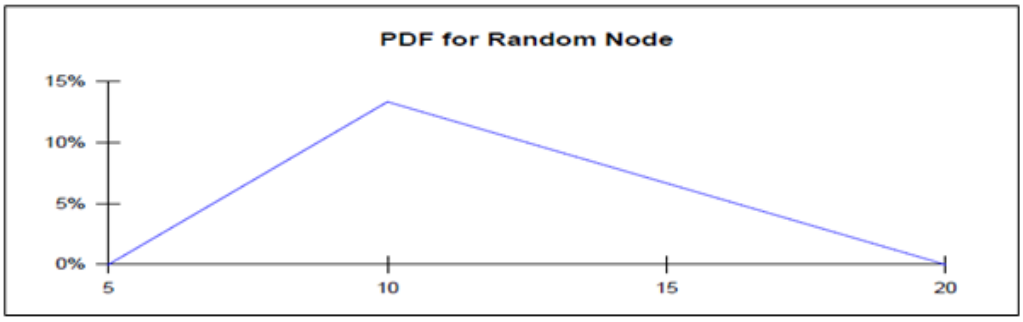
The prime objective of quantitative risk assessment of any project asserts the associated risk of cost overrun which will impact the completion target of the project with respect to planned time horizon. In most of the cases, the cost overrun causes delay in project completion as the authority needs further approval of additional unplanned funds from its government or from the lending agency. Hence, the 'delay' creates shorter economic life of the asset or the infrastructure which is incapable of generating economic benefits to the society (which is fundamental objective of any infrastructure projects)—hence, delay due to cost overrun causes limited generation of social well-being and deprives society from its claimed pleasure and well-being.

This section focuses on the quantitative risk assessment of the project with respect to possibility of the cost overrun due to change in cost parameters during construction period. Moreover, the analysis is an ex-ante risk analysis which intimate the authority about possible degree of risk of cost overrun, so that the authority knows the amount of unplanned need of budget in advance during construction period—hence, the project does not get delayed due to arrangement of unplanned additional funds with the same level of predetermined scope of work

Estimation of Probability of Total Project Cost (TPC)

- Triangular Distribution

The following figure shows Probability Density Function for analysis of discrete value of parameters for Random Node of Triangle Distribution. The 'trend' primitive has the format as shown below Trend (lower limit, most likely, upper limit)



Source: Vanguard Manual

The table below shows the different parameters which will be used in the Monte Carlo Simulation by using the Vanguard to estimate the Total Project Cost (TPC) based on the aggregate civil cost.

Stochastic Variables	Lower Value	Most Likely	Higher Value
General & Site Facilities (2% Of Construction Cost)	1.36%	1.52%	1.71%
Earth Work	2.37%	2.49%	2.99%
Sub-Base, Base-Courses	1.42%	1.49%	1.79%
Bituminous Pavement Courses	3.38%	3.56%	4.27%
Cross Drainage Structures - Culverts	0.95%	1.00%	1.20%
Structures - Minor Bridge	1.35%	1.42%	1.70%
Structures - Viaduct	26.67%	30.77%	32.82%
Structures - Main Bridge	21.11%	24.07%	27.73%
Drainage & Protection Works	0.67%	0.67%	0.81%
Traffic Signs, Marking And Road Appurtenances	0.56%	0.57%	0.68%
Toll Plaza	5.90%	5.96%	7.15%
River Training Works	3.12%	3.15%	3.78%
Electro Mechanical Works	0.42%	0.43%	0.51%
Bridge Health Monitoring System	0.26%	0.27%	0.32%
Land Acquisition, Resettlement & Compensation (Lump Sum)	7.66%	7.73%	9.28%
Utility Shifting (Lump Sum)	0.22%	0.22%	0.23%
Price Adjustment	11.60%	11.60%	11.60%
Physical Contingency	1.55%	1.55%	1.55%
Price Contingency	1.55%	1.55%	1.55%

Simulation Analysis

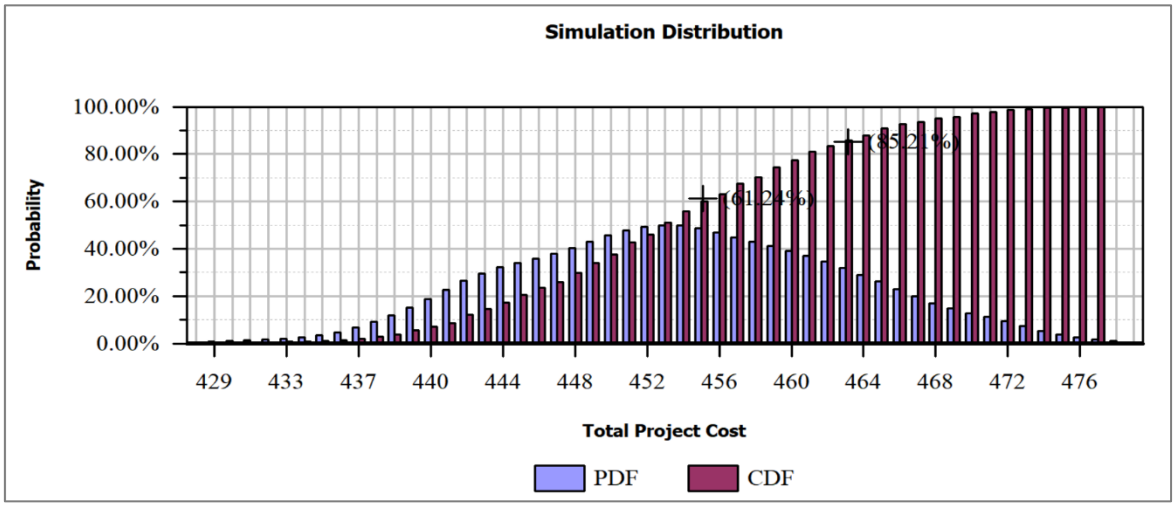
The summary sheet from of Monte Carlo simulation shows that mean TPC is BDT. 458 Cr. The maximum TPC may be BDT. 481 Cr. and the minimum maybe BDT. 432 Cr. The likely TPC, that is, mean TPC is BDT. 458 Cr. The mean and median are almost the same that is a normal distribution. The following figure is showing both

Cumulative and Probability Distribution Functions (CDF & PDF) of Total Project Cost. The Monte Carlo Simulation of TPC is showing that there is 80% chance that the TPC of New Bridge under current civil cost will be below BDT. 465 crore and 60% chance the TPC would be BDT. 459 Cr.

Simulation Summary

Measure	*Total Project Cost*
Observations	1,000
Mean	458
Standard Deviation	9
Posterior STD	3e-1
Variance	78
Minimum	432
5th Percentile	443
Median	458
95th Percentile	473
Maximum	481

The Figure below displays both the Cumulative Distribution Function (CDF) and the Probability Distribution Function (PDF)of the Total Project Cost.



The risk analysis assesses the potential impact of various risks that might affect the project cost overrun overtime. Understanding these risks is crucial for project authorities to allocate additional funds in advance, which could prevent delays in project completion.

HUMAN RESOURCES AND ADMINISTRATIVE SUPPORT ANALYSIS

The Nitai bridge has been proposed as a Steel Tied Arch + PSC I Girder with span arrangement of 1 x 32.0m + 1 x 125.0m + 1 x 32.0m. The implementation of this Project thus needs specific technical expertise pertinent to Steel Tied Arch bridges. The Roads and Highways Department (RHD) has successfully implemented the commissioning of the Kalna Bridge at Kashiani which is a steel arch bridge with a span arrangement of 6 x 40m + 1 x 1500m + 6 x 40m, M.A Khan Bridge at Sylhet which is a steel truss bridge with a span arrangement of 1 X 25m + 1 X 40m + 1 X 120m + 1 X 40m and 2nd Meghna Bridge & 2nd Gumti Bridge which are steel box

girder bridges. Thus, they have the right technical and managerial work force to implement the Nitai Bridge also. At the same time, RHD is successfully operating and maintaining the Kalna Bridge, M.A Khan Bridge and hence is organisationally well equipped to maintain the functional output of the proposed bridge.

INSTITUTIONAL AND LEGAL ANALYSIS

The Road Master Plan, 2009 stipulates that new bridges should be constructed on missing links. Besides, a target has been fixed to construct 37,500 meters of bridge/culvert as a strategy of the road transport sector in the 8th Five Year Plan (2021-2025) to achieve the Perspective Plan 2041. Thus, construction of the Nitai Bridge envisaged by the Roads and Highways Department, at critical missing link over Nitai River has been envisaged within the legal purview of the Road Master Plan, 2009, 8th Five Year Plan (2021-2025) & the Perspective Plan 2041. The Assets of Roads and Highways Department have been conservatively estimated at Taka 46,000 crore (US$8,000 million) of which by far the largest proportion is the value of the 22,096.303 kms of road and the 18,258 bridges. These assets are probably the greatest asset of any organisation in Bangladesh and maintaining their value is vital to its economy. This places a great responsibility on the Roads and Highways Department. Thus, the policy and institutional setup of RHD is well aligned with the successful implementation of the proposed Nitai Bridge. The Roads and Highways Department (RHD) has successfully implemented the commissioning of the Kalna Bridge at Kashiani which is a steel arch bridge with a span arrangement of 6 x 40m + 1 x 1500m + 6 x 40m, M.A Khan Bridge at Sylhet which is a steel truss bridge with a span arrangement of 1 X 25m + 1 X 40m + 1 X 120m + 1 X 40m, 2nd Meghna Bridge & 2nd Gumti Bridge which are steel box girder bridge. Thus, they have the right technical and managerial work force to implement the Nitai Bridge also. As RHD is well experienced in implementing similar projects as such no governance issue has been envisaged in implementing this Project.

CONCLUSION AND RECOMMENDATION

- The Border Road (Z-2834) is the critical element of connecting the border areas of Kalmakanda, Durgapur, Dhobaura & Haluaghat Upazila and eventually connecting the border area with Sunamganj, Netrokona and Mymensingh district centres. There is a critical gap at 47th Km of the existing road near Ghoshgaon due to Nitai River. Thus, the proposed Nitai bridge has extreme importance for ensuring connectivity between the border areas.
- The border road would also create as infrastructure, having potentiality to facilitate movement of international transit traffic which would promote international trade and commerce for adjoining countries as well as for Bangladesh. This would contribute in economic development of Bangladesh and also generate additional revenue.
- The construction of the bridge will lead to savings in VOC, time costs and reduction in emission.
- The construction of the new bridge will increase the health care facilities and will also enhance the educational opportunities.
- The bridge will lead to the development of tourism industry.
- The Project (comprising Nitai, Someshwari-3, Ganeshwari & Mahadev) has been found to be economically viable with an EIRR of 20.60% and Net Present Value (at 12% Discount rate) of 1430.8 Crores BDT.

Considering immense socio-economic befits to the Project Influence Area and economic viability**, this Project is recommended to be executed as per the approved Alignment Option and approved Bridge form, mentioned in this report.**

1 BASIC INFORMATION

1.	Name of the Project	:	Consultancy Services for Detailed Feasibility Study and Design for Construction of 01 (one) bridge adjacent to Zero Point in Mymensingh town, 02 (two) bridges adjacent to Mymensingh EPZ, 04 (four) bridges on Border Road and 2nd Someshwari bridge respectively of Mymensingh Zone under Roads and Highways Department, Bangladesh
2.	(a) Sponsoring Ministry/Division (b) Implementing Agency	: :	Government of Bangladesh (GoB)
3.	Project Objectives (Project to be taken based on the study)	:	The feasibility study of Nitai Bridge aimed to evaluate the viability of proposed development projects in the region. Through comprehensive analysis of infrastructure, market dynamics, and socio-economic factors, it provided valuable insights into potential opportunities and challenges. The findings from this study will inform strategic decision-making and facilitate the sustainable growth of the area.
4.	Estimated Project Cost (Taka in Crore)	:	452.47
5.	Sector & Sub-Sector	:	RHD
6.	Project Category (Based on Environment Conservation Rules 1997)	:	Orange category
7.	Projection Geographic Location (a) Countrywide (b) Division (c) District (d) Upazila (e) Others (City Corporation/Pourashva)		 Bangladesh Mymensingh Mymensingh Dhobaura
8.	Project Duration	:	Construction Start Year: 2024. Construction End Year: 2026. Construction Period: 3.0 Years. Open for traffic for Commercial Operation from 2027.

2 INTRODUCTION

2.1 Project Background

Bangladesh with its fast-growing economy aspires to become a middle-income country which in return would require improved land route connectivity to support the potential need in the growth of vehicular movement due to growth in the GDP. The economic growth will induce growth in freight traffic and higher socio-economic growth, which would contribute in increase in the usage of private vehicles, whereas population growth would maintain the demand of public transport. Hence the demand of road network is growing while a good road network will allow the benefit of the economic growth to spread across the country and reveal new opportunities.

Since the country is covered by rivers and water bodies there are many road networks rely on ferry service for the connectivity. The existing ferry services have their own limitations to achieve uninterrupted flow, due to capacity and availability of the service. Therefore, it is essential to construct bridges to ensure safer uninterrupted traffic flow and availability of service around the clock.

The Road Master Plan 2009 has made specific recommendations for the construction of bridges in the road network. In addition, the 8th Five-Year Plan (2021-2025) has set a target of constructing 36,500 m bridges & culverts as a strategy for the road transport sector.

Mymensingh Division is the eighth administrative division of the nation. In 2015, The division has been formed by separation from Dhaka division consisting the districts of Mymensingh, Jamalpur, Sherpur and Netrokona. The bridges along the border districts will play a crucial role in improving the trading between Bangladesh and land locked countries to utilise the Bangladesh ports for their exports & imports.

Considering the above scenario and in line with the policy of gradual construction of new bridges, RHD has selected 8 channel gaps to construct new bridges, in various locations of Mymensingh Zone of RHD, considering their strategic location, river width, AADT and socio-economic potential of the project areas. The studies are being carried out keeping in view of local conditions like, availability of skilled manpower, local construction material, accessibility issues, etc. Name of these bridges and extend of study are -

- Brahmaputra Bridge adjacent to Zero Point in Mymensingh Town over Brahmaputra River: Detailed Feasibility Study and Detailed Design
- Mahadev Bridge over Mahadev River at 9th km of Broder Road (Z2834): Detailed Feasibility Study and Detailed Design
- Ganeshwari Bridge over Ganeshwari River at 21st km of Broder Road (Z2834): Detailed Feasibility Study and Detailed Design
- Someshwari Bridge-3 over Someshwari River at 35th km of Broder Road (Z2834): Detailed Feasibility Study and Detailed Design
- Nitai Bridge over Nitai River at 47th km of Broder Road (Z2834): Detailed Feasibility Study and Detailed Design
- Brahmaputra Bridge (Ishwarganj) at Ishwarganj-Uchakhila-Ahmedabad Bazar-Trishal Road (Z3043) over Brahmaputra River: Detailed Feasibility Study and Conceptual / Preliminary Design
- 1 (one) bridge at 11th km of Ishwarganj-Uchakhila-Ahmedabad Bazar-Trishal Road (Z3043): Detailed Feasibility Study and Conceptual / Preliminary Design
- Someshwari Bridge-2 over Someshwari River at 36th km of Shyamganj-Zaria-Birishiri-Durgapur Road (Z3704): Detailed Feasibility Study and Conceptual / Preliminary Design

The Project Location Map showing the 8 Bridges has been presented in Figure 2-1, below.

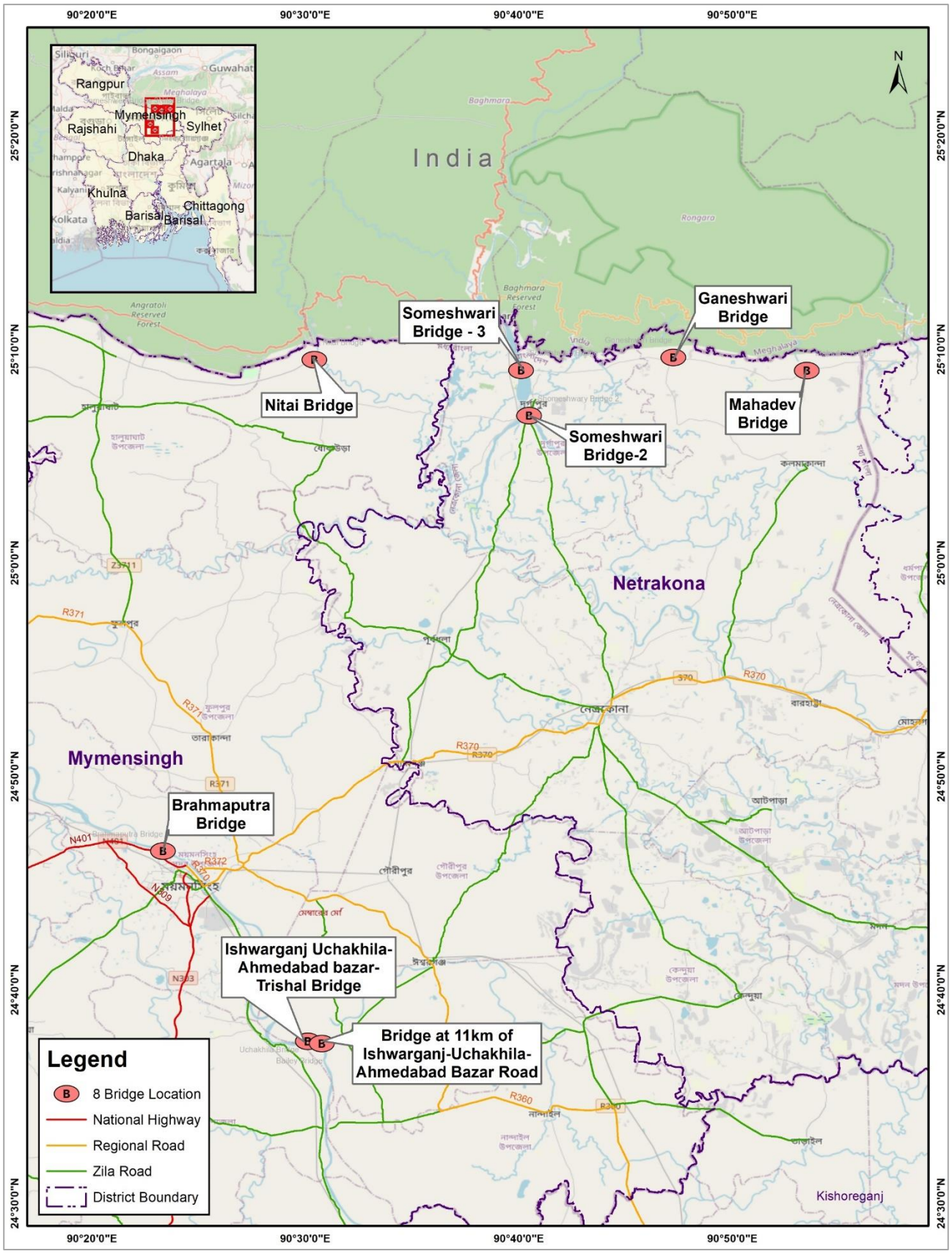


Figure 2-1: Project Location Map

2.2 Objective

The objective of the entire study is to provide a safe, reliable, and uninterrupted road connectivity over Nitai River in Kalmakanda, Netrokona districts. Further the Feasibility Study aims to concur on the best alignment option and main bridge form encompassing all techno – economical as well as Social, Environmental and Financial parameters. The framework of the study is primarily based on the guidelines of the Planning Commission, Government of Bangladesh. Furthermore, the Consultant has conducted a further detailed study mainly with regard to the Option Studies and other technical aspects.

2.3 Approach and Methodology

At this stage of the project, several critical tasks have been completed to facilitate the feasibility study:

- Traffic Surveys: Comprehensive studies including desktop analysis, survey planning, data collection, and capacity assessments
- Engineering Surveys: Involving reconnaissance, road inventory, condition assessments, drone videography, and topographic surveys.
- Market Demand Analysis: Assessing the need for the proposed infrastructure.
- Alignment Options and Bridge Forms: A thorough comparative study led to selecting the preferred option
- Preliminary Engineering Studies: Formulating development proposals based on analyses.
- Environmental and Social Assessments: Evaluating potential impacts, including land acquisition
- Initial Social Assessment and Preliminary Land Acquisition Assessment
- Cost, Economic, and Risk Analyses: Evaluating feasibility from various perspectives

2.4 Organisation of the Final Feasibility Report

- Volume I – Main Report
  - Executive Summary
  - Chapter 1 – Introduction
  - Chapter 2 – Traffic Surveys and Analysis
  - Chapter 3 – Engineering Surveys and Investigation
  - Chapter 4 – Market Demand Analysis
  - Chapter 5 – Option Study
  - Chapter 6 – Preliminary Engineering and Development
  - Chapter 7 – Preliminary Environmental Assessment
  - Chapter 8 – Initial Social Assessment and Preliminary Land Acquisition
  - Chapter 9 – Cost Estimate
  - Chapter 10 – Economical Analysis
  - Chapter 11 – Financial Analysis
  - Chapter 12 – Risk and Sensitivity Analysis
  - Chapter 13 – Human Resources and Administrative Support Analysis
  - Chapter 14 – Institutional and Legal Analysis
  - Chapter 15 – Conclusion and Recommendation
- Volume II – Sub Reports
- Volume III – Drawings
  - Part A – Roadworks
  - Part B – Structures
- Volume IV – Summary Report

3 MARKET DEMAND ANALYSIS

3.1 Problem Statement

The direct impact of the proposed bridges will be on the people of Kalmakanda & Durgapur Upazilas of Netrokona districts and Haluaghat & Dhobaura of Mymensingh districts. These four Upazilas will be connected via proposed four bridges with each other. Hence, Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the new road alignment plays the most vital role to improve the connectivity between two districts on the road alignment of Z2834. The entire old route via Z3712, Z3707, Z3704 and Kalmakanda-Durgapur Road is about 128.4 km long which will be replaced by 44.8 km road length including proposed Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the new road alignment. The Figure 3-1 shows the proposed new road on which all four bridges are situated at 9th, 21st, 35th and 48th km with respective bridges like, Mahadev bridge, Ganeshwari bridge, Someshwari bridge, and Nitai bridge, Again, the existing route has been depicted through bold redline which is approximately 75 km from Panchogaon Notun Bazar (near Mahadev bridge) and Nitai bridge of Mymensingh district.

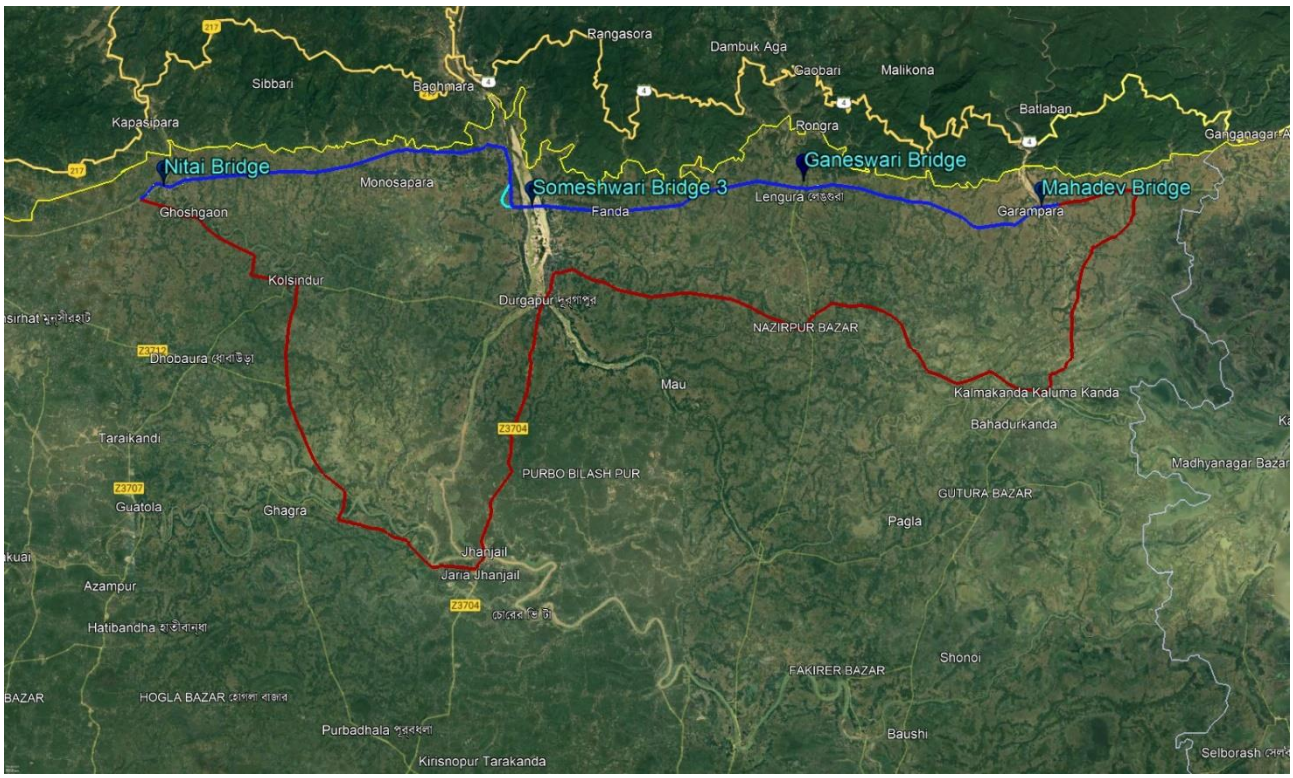


Figure 3-1: Existing Vehicular Route (red line) vs Proposed Route (blue line)

The proposed bridges will have severe impact on the people of peripheral and adjacent areas of the alignment from Nitai Bridge to Panchogaon Notun Bazar. Hence, Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge of new alignment plays the most vital role to improve the intra and inter regional connectivity which will improve the equitable distribution of economic power which will lead to equitable economic growth.

However, it is very evident, the local inhabitants of these Upazilas, mainly, Kalamunda, Durgapur of Netrokona district and Haluaghat & Dhobaura Upazilas of Mymensingh district facing severe connectivity problem with district headquarter Netrokona Sadar and Mymensingh Sadar, respectively. There is significant amount potential loss due to connectivity issue. The data show there are skewed distribution of social fundamental amenities in two Sadar compare to other Upazilas. It is also true that overnight these livelihood facilities are not possible to establish as that will create huge cost to the government and suboptimal demand & allocation of resources. Hence, smooth connectivity facility will be a win-win situation for both parties

which will be fulfilled by the proposed bridge. A brief socio-economic profile of these Upazilas is depicted below:

Table 3-1 : Brief Socio-Economic Profiles

Economic Parameters	Netrokona Sadar	Kalmakanda	Durgapur	Mymensingh Sadar	Haluaghat	Dhobaura
Land Area (Sq. km)	341.71	376.22	278.28	281	357.11	
Mouza	279	179	134	132	145	96
Population in 2001	372785	271912	224893	674452	290043	172152
Population Density (no/sq. km)	1091	1848	805	1736	812	686
Literacy Rate (%)	44.04%	-	39.50%	49.9%	57%	36.75%
Growth Centres	16	31	19	61	29	-
Land Area under Irrigation (Hctr.)	237.92	23500	20470	25780	28350	-
Primary Schools	29	2	9	132	167	-
Secondary Schools	32	22	25	6	25	-
Hospital	1	0	0	1	1	-
Colleges	5	1	4	9	5	-
Bank	7	3	6	56	-	-
Factory Heavy Industry	0	0	0	1	-	-
Factory Small Industry	222	134	15	5534	-	-

Source: District Websites

3.2 Relevance of the Project

The need of the proposed bridge has already been substantiated by a brief socio-economic data but that is not limited to it. There are some other broader aspects of the bridge:

1. Savings in journey time and cost of travelling of existing passengers and freight traffic on the said alignment due to construction of proposed bridges.
2. The direct impact of the proposed bridges will be on the people of peripheral and adjacent areas of the alignment from Nitai Bridge to Panchogaon Notun Bazar. Hence, Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge of new alignment plays the most vital role to improve the intra and inter regional connectivity which will improve the equitable distribution of economic power which will lead to equitable economic growth.
3. Construction of new bridge will increase health care facilities and will save time, cost of treatment and life of several hundred people of the region of new proposed connectivity to be established; especially of new born babies who are referred to nearest districts sadar for urgent attention.
4. Construction of Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the road alignment will increase educational opportunities and facilities. The bridges will save cost of education as well as will bring opportunities of higher education within their means. This will be a boon especially

to girl students of region and to the students of poor families who cannot afford to provide residential facilities at Mymensingh and Dhaka or near to national Capital Region (NCR).

5. There will be considerable impact on price level in the area as the transportation cost of consumer goods will be reduced substantially owing to reduction in time of transporting goods from Mymensingh and Netrokona districts.
6. There will be widening of marketing facilities of agricultural products of Mymensingh and Netrokona districts for having majority of growth centres including fish export enabling rise in income of people engaged in fishing and fishery activities and farming activities
7. Construction of bridge will increase manifold arrival of domestic as well as international tourists which will lead to development of tourism as industry.
8. There will be rise in local income level for construction of Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the road alignment. The bridges will ensure all weather connectivity leading to more generation of economic activities owing to marketing of surplus agricultural products, growth in tourist traffic, rise in domestic and international trade etc.

There will be substantial improvement in favour of 'law & order' near the international border area due to accessibility of police, army and border security forces. Moreover, there will be substantial improvement in import-export between India and Bangladesh. Presently, Gobrakura Land Port is active in Mymensingh district with India in Meghalaya and the import-export operations are taking place through manual Land Custom Station (LCS). An upgradation proposal is on the way to upgrade the manual system to electronic custom system (ECS) which will facilitate faster movement of inter-border goods along with passenger movements. Hence, there will be an economic boom for the region in terms of income augmentation of the districts and upazilas.

3.3 Proposed Project Interventions

The direct impact of the proposed bridges will be on the people of Kalmakanda & Durgapur upazilas of Netrokona districts and Haluaghat & Dhobaura of Mymensingh districts. These four upazilas will be connected via proposed four bridges with each other. Hence, Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the new road alignment plays the most vital role to improve the connectivity between two districts on the road alignment of Z2834. The entire old route via Z3712, Z3707, Z3704 and Kalmakanda-Durgapur Road is about 128.4 km long which will be replaced by 44.8 km road length including proposed Nitai Bridge, Someshwari Bridge 3, Ganeshwari Bridge, and Mahadev Bridge on the new road alignment. The following Figure 8.1 shows the scenario and road user savings has been estimated accordingly with help of HDM4. The blue bold line shows the proposed new road on which all four bridges are situated at 9th, 21st, 35th and 48th km with respective bridges like, Mahadev bridge, Ganeshwari bridge, Someshwari bridge, and Nitai bridge, Again, the existing route has been depicted through bold redline which is approximately 75 km from Panchogaon Notun Bazar (near Mahadev bridge) and Nitai bridge of Mymensingh district.

3.4 Stakeholders

Consultant will establish the following stakeholders as internal and external at both design and construction phase of the project and the list will be updated as project staff begin to open workshops.

Internal Stakeholders	External Stakeholders
Government of Bangladesh (GoB)	Other planning and implementation agencies
Roads and Highways Department (RHD)	Government Ministries
Project Steering Committee	Bangladesh Rural Electrification Board
Project Implementation Committee	Border Guard Bangladesh

Contractors	Municipalities
Suppliers	Office of the DCs
	NGOs

3.5 Demand Analysis

3.5.1 Current Demand

The current socio-economic data show there are significant amount of people who are suffering from road connectivity issue and the economic cost to the society is significantly very high.

3.5.2 Future Demand

The future demand will be significantly on higher side as Bangladesh is one of the high growth rate economies having almost 1.1% of population growth rate as per The World Bank data. The exact future demand analysis could be done after complete traffic survey where actual potential need of the bridge will get reflected. It is also evident that there exist high elasticity value of net export and road sector gross value added due to nearest land port presence with India. The export import data shows there exist 3.75% of growth rate per year in Bangladesh which will promote further development of the region.

3.5.3 Constraints

The prime constraint of any connectivity improvement focused bridge is the funding and loan repayment. Since the purchasing power of rural people are comparatively low compared to the urban habitats. The bridge will improve the economy of the locality overtime but loan repayment will start from the starting of first construction day. However, funding is the only constraint here.

3.6 SWOT Analysis

The SWOT analysis shows the Strength-Weakness-Opportunity-Threat of the project which has been discussed in subsequent section of this report:

Strength: The Prime Strength of the project is the social need of the project in terms of development of the local economy. Presently, connectivity is the only issue which is being faced significantly by the local people and potential economic loss due high waiting time at ferry ghat.

Weakness: The major Weakness of the project is funding, as the project is not financially very lucrative due to two reasons: a) the affordability of local people is very low for having low economic activity where the connectivity is the major issue and b) funding of the project and loan repayment if any, having low traffic intensity in the area which will increase overtime.

Opportunity: This the most vital aspect of the bridge which is the enhancement of new economic Opportunities for the local people as all-weather connectivity will be established and will act that as a game changer in the region. There will substantial improvement in human capital as the limitation of education and health care hurdles will be almost removed or will be significantly minimized. The economic activities will increase and that will lead to a higher economic growth in the locality.

Threat: In this this case he Threat and weakness is almost same due same nature of the problem—funding of the bridge. If the construction gets delayed or it get cancelled due to lack of fund that will be disastrous situation for the locality as the suffering continue for another long finite time horizon and suffering will increase overtime.

4 TECHNICAL/TECHNOLOGICAL & ENGINEERING ANALYSIS

4.1 Location

The proposed bridge over Nitai River is located at 47th Km of border road Z-2834 near Ghoshgaon, at Dhobaura, Mymensingh. The total length of the project road is **2.40 km.**

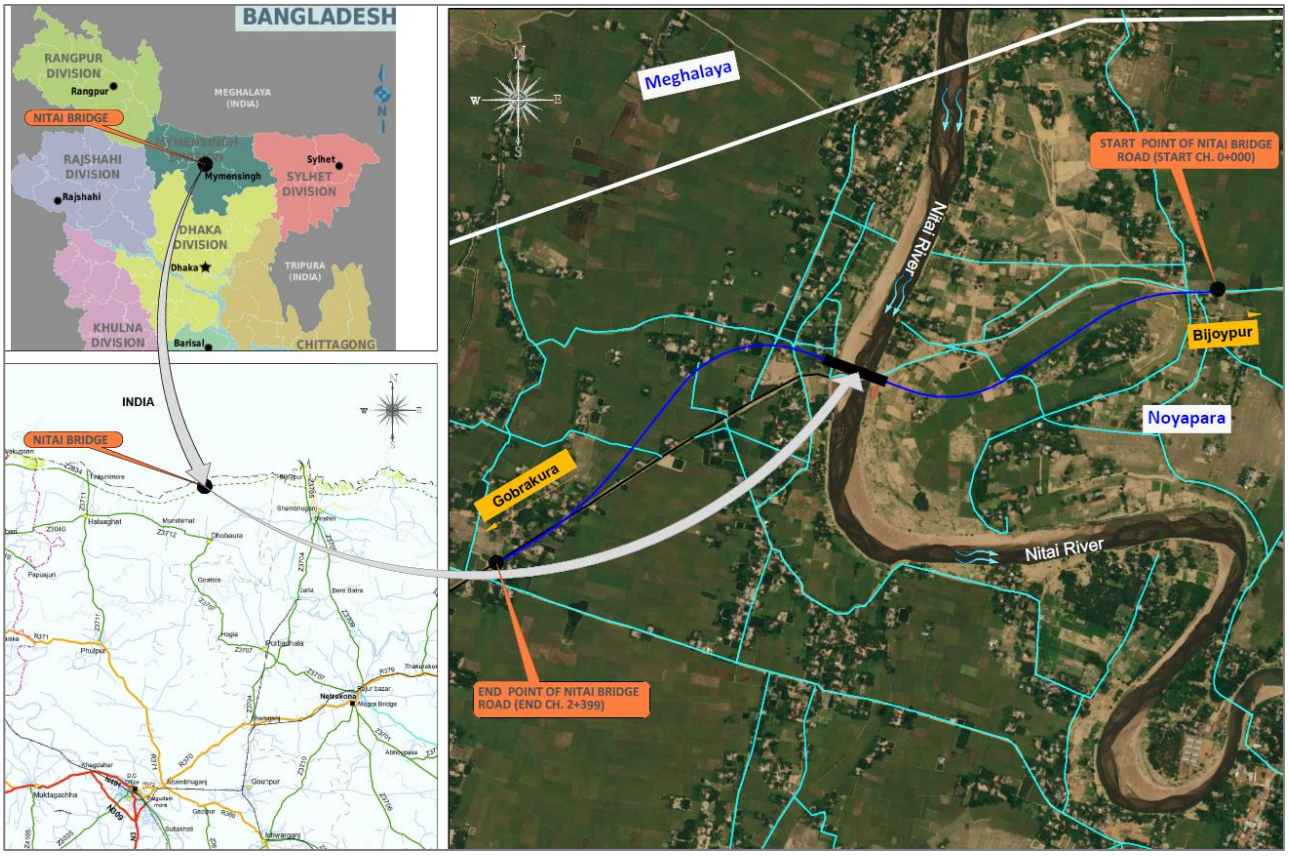


Figure 4-1: Proposed Nitai Bridge Location Map

The Project site, the Nitai Bridge and its approach road at both ends are situated in the rural area of Mymensingh District. Throughout the proposed alignment, land use distribution comprises 16.62 acres (60.10.%), waterbody consists of ponds and canals occupied is the 2nd highest about 3.07 acres (11.11%) of land required, vegetation area occupies 2.58 acres (9.34%), residential land occupies 1.01 acres (9.04%) , transportation/road area occupied 2.26 acres (08.16%), barren land occupies 0.31acres (1.13%), river occupies 0.27 acres (0.97%%), and commercial land occupies is very minimum, 0.04 acres almost (0.14%) of the total land.

In assessing potentially affected structures, housing stands as a fundamental human right. These structures serve residential, commercial, and community purposes, categorized by construction materials. The assessment identifies 22 residential and 4 commercial structures, emphasizing the diverse roles these buildings play within the community.

Throughout the Project alignment, it was determined that the project requires a land area of 27.65 acres initially. Following the completion of georeferencing mouza maps, these will be accurately overlaid to create a plot schedule. Subsequently, a Land Acquisition Plan (LAP) with detailed drawing is on the preparation stage and will be submitted to the client for review.

In addition to the LAP drawings, a utility shifting drawing has been prepared and submitted to the client for review. This plan ensures seamless coordination for relocating utilities, underscoring our commitment to a smooth construction process for the Nitai bridge project.

4.2 Technical Design

4.2.1 Traffic Surveys & Analysis

In conducting a feasibility study, comprehensive traffic surveys play a crucial role in assessing the viability and potential impact of a proposed project. For the study purpose the following Traffic Surveys have been conducted:

- Video Traffic Count Survey (VTS)
- Video Pedestrian Count Survey (VPS)
- Roadside Interview Survey (RSI), including.
  - Origin-Destination Survey (ODS)
  - Vehicle Occupancy Survey (VOS)
  - Willingness to Pay Survey (WTP)

The forecasted traffic for the proposed Nitai bridge area incorporates various factors, including organic growth, induced/generated traffic from future economic zones, land ports and potential international transit traffic due to proposed infrastructure developments.

To capture this short-term additional traffic, 2% (an assumption by the transport planning team) of the total traffic of the opening year has been added for a period of 5 years.

Table 4-1 shows the calculated opening year traffic of 2027 as well as the base year traffic of 2023. The opening year traffic considered generated traffic, diverted traffic, land port traffic, potential transit traffic, induced traffic etc., which are categorized in the table.

Table 4-1: Classified calculated opening year traffic (2027)

Year	Types of traffic		Truck	Bus	Microbus	Utility vehicle	Car	Baby Taxi/CNG/Auto	Tempo/Leguna	Motorcycle	Bicycle	Rickshaw	Rickshaw Van	Cart	Total
Base year 2023	**Existing Traffic (2023)**		-	-	-	-	-	-	-	-	-	-	-	-	-
Opening year 2027	Applying growth rate on present traffic		-	-	-	-	-	-	-	-	-	-	-	-	-
	Diverted traffic	Only for Nitai Bridge	83	9	13	3	4	34	1,109	1,271	322	87	46	4	2,986
		For four bridges (Regional traffic through border roads)	241	119	58	22	90	-	-	-	-	-	-	-	530
	Land port traffic (between Bangladesh and India)		497	7	8	4	4	-	-	-	-	-	-	-	519
	Transit traffic (India to India traffic using Bangladesh Road)		99												99
	Tourist traffic		3	10	5	5	6	2	28	30	6	10	1	2	107
	Induce traffic		4	2	1	0	2	0	9	34	13	0	1	0	67
	Total		**928**	**148**	**85**	**34**	**105**	**36**	**1,146**	**1,334**	**341**	**97**	**48**	**6**	**4,308**

The number of required lanes for the Nitai Bridge is estimated based on the traffic data analysis, projected AADT and above mention assumptions.

The proposed number of lanes is calculated for the Nitai Bridge as illustrated in Table 4-2. The considerations of the calculations are as follows;

- The number of lanes required is estimated from the peak hour traffic.
- Design speed is considered as 80 kmph
- The lane calculation of the proposed bridge is based on the Level of service LOS B (875 PCU/ lane/hr) and the Level of service LOS C (1,275 PCU/lane/hr).

Table 4-2: Number of lanes for the proposed Nitai bridge

Projection Period	Year	Traffic Volume in AADT		Traffic Volume in PCU		Lane Number (Based on peak hour demand)		Lane Number (Round up the number)	
		Daily	Peak hour	Daily	Peak hour	LOS B	LOS C	LOS B	LOS C
Base year	2023	0	0	0	0	-	-	-	-
Traffic opening year	2027	4,308	530	5,821	716	0.82	0.56	2.00	2.00
Opening +5 year	2032	6,164	758	7,872	968	1.11	0.76	2.00	2.00
Opening +10 year	2037	7,966	980	9,730	1,197	1.37	0.94	2.00	2.00
Opening +15 year	2042	10,464	1,287	12,193	1,500	1.71	1.18	2.00	2.00
Opening +20 year	2047	12,814	1,576	14,427	1,775	2.03	1.39	4.00	2.00

The calculation suggests that in the opening year of 2027, the proposed Nitai Bridge will require 2 lanes up to 2042 (15 years after the opening year) to support peak hour traffic demand in LOS B. In 2047 (20 years after the opening year), considering land port and transit traffic, the bridge will require 4 lanes for LOS B. On the other hand, 2 lane bridge is sufficient until 2047 for LOS C.

4.2.2 Design Standards - Highway

The summary of design standards is as follows:

- Geometric Design –
  - "A Policy on Geometric Design of Highways and Streets (AASHTO) 2018, 7th Edition".
  - "Geometric Design Standards Manual of RHD (Revised) June 2005"
- Typical Cross-section –

  The cross sections have been prepared in reference to MOM Ref. no: GEN-MOM-004, dated June 06, 2023 (Volume 1 – Appendix I) which considers elements from the "Bridge Design Standards for Roads & Highways Department January 2004" and the "Geometric Design Standards Manual of RHD (Revised) June 2005".
- Pavement Design –
  - The pavement design has been finalized as per "AASHTO Guide for Design of Pavement Structures, AASHTO, Washington, D.C., 1993".
  - Comparative analysis has also been done based on "Guidelines for the Design of Flexible Pavements, IRC :37-2018, 4th Revision, 2018", "AASHTO Guide for Design of Pavement Structures, AASHTO, Washington, D.C., 1993" and "Geometric Design Standards Manual of RHD (Revised) June 2005".

  - Weather factors like temperature change, rainfall etc. for pavement design are considered from Austroads guidelines.
- Embankment Design & Slope Stability Analysis –
  - "A Policy on Geometric Design of Highways and Streets (AASHTO) 2018, 7th Edition".
- Road Furniture –
  - "Geometric Design Standards Manual of RHD (Revised) June 2005"
  - "A Policy on Geometric Design of Highways and Streets (AASHTO) 2018, 7th Edition"

4.2.3 Geometric Design

The main components included in the geometric design of road alignment are:

- Alignment and Geometry
  - Horizontal alignment
  - Vertical alignment
- Cross-sectional elements
- Service Road/Slip Road
- Junctions

These components are essential for ensuring the safe, efficient, and sustainable design of road alignments, as outlined in the Final Feasibility Study Report of Nitai Bridge, Volume-I.

The road is a Rural collector road with a Design Speed of 80 kmph with total length of 2.40 km.

- Recommended Pavement Design for Road

Based on AASHTO method for design traffic of 23 MSA, the recommended pavement composition for the project road has been presented below.

Table 4-3: Recommended Pavement Design

Layers	Thickness (mm)
Asphalt Wearing Course	50
Asphalt Base Course	190 (In three layer- 60, 60 & 70mm each)
Aggregate Road Base (Base Type I)	200
Granular Subbase	100
Improved Subgrade (CBR 8%)	300

The pavement system for the concrete bridge deck and viaduct shall have a total thickness of approx. 54 mm and consists of the following components:

- **Wearing course**: 50 mm dense graded Bituminous concrete
- **Tack coat**: approx. 200 micrometres
- **Waterproofing membrane**: 2-4 mm synthetic resin-based membrane (sprayed in two layers)
- **Primer**: concrete deck primer (sprayed)

The waterproofing system shall be an elastomeric polyurethane or Methyl-Meth-Acrylate (MMA) based waterproofing system for concrete bridge decks.

The recommended pavement composition for Toll Plaza and service/slip road for design traffic of 10 MSA based on AASHTO method is represented in the **Final Feasibility Study Report of Nitai Bridge, Volume-I.**

4.2.4 Design Standards- Bridge

The Design Standards of Bangladesh would be followed in principle for design and analysis of bridges in this project. If any provision is not available in local codes, other standards like AASHTO/IRC will be referred. Some of the standards and codes that will be used for design of bridges as per RFP are listed below:

- RHD bridge designer's handbook.
- BNBC code and pertinent design standard can be used to design the earthquake resilient structure.
- AASTHO - LRFD
- Road Note
- Indian Road Congress
- Austroads

Analysis and design of bridges, viaducts and other structures will be carried out as per above standards and guidelines.

4.2.5 Bridge Form

Table 4-4 outlines the evaluation of final bridge form along with approach viaducts, considering key guiding aspects such as navigational requirements, data from hydrological and morphological reports, and bridge aesthetics. Following a Multi-Criteria Analysis (MCA), the highest scoring bridge option under the preferred alignment was identified and recommended by the consultant. For detailed information on the Option Study and Recommendation on Bridge form and Span arrangements, please refer to **Section-10** of the report.

Table 4-4: Details of the Main Bridge & Viaduct

Section	Superstructure	Span Arrangement
Viaduct (Bijoypur Side)	PSC I Girder	(32+40+32)m +32m+40m = 176 m
Main Bridge	Steel Tied Arch & PSC I Girder	1x32+1x125+1x32= 189 m
Viaduct (Tinkunimor Side)	PSC I Girder	32+40+32)m+(32+40+32)m+32m+40m =280m

After evaluation of various options, Option 1A, characterized as Steel Arch Bridge, is approved for the project. The decision comes following careful consideration of factors such as navigational requirements, hydrological and morphological data, ease of construction as well as bridge aesthetics.

The summary of HMS and hydrological assessment have been given below.

Sl. No.	Description	Quantity	Remark
1	Standard High-Water Level (SHWL) With Climate Change Effect	16.260 m SOB	Refer Section 6.3.2.6 Volume 1.
2	Design High Water Levels including climate change impact (m SoB)	18.0 m SOB	Refer Section 6.3.2.4 Volume 1.
3	Vertical Clearance for navigation	5.00 m	Refer Section 6.3.2.4 Volume 1.
4	Depth of bridge superstructure (From Soffit to Finished Deck Top Level)	2.35 m	As per GAD (Refer FFSR Volume III, Part B- Structure Drawings)
5	Minimum Required Finished Road level at main bridge portion	24.65 m SOB	

Sl. No.	Description	Quantity	Remark
6	Proposed finished road level at Center	24.65 m SOB	Considering 5.7m vertical clearance for roads at both banks.

4.3 Output Plan

- Cross Sectional Elements

The total length of the project road is 2.40 km. The proposed carriageway primarily consists of a two-lane configuration with SMVT lanes on both sides. Each lane on the main carriageway is 3.65 meters wide, while SMVT lanes are 3 meters wide. Additionally, a 1.5-meter-wide paved shoulder is proposed for normal two-lane carriageways, with a 1.0-meter-wide verge on both sides.

At bridge and viaduct sections, the footpath width is proposed to be 1.2 meters, while a 1.0-meter-wide footpath cum drain is planned for slip road sections. Utility corridors of 2.0 meters width are allocated within the Right-of-Way (ROW) on both sides of the carriageway for utility services.

- Typical Cross-Section

The project road is recommended to be a two-lane carriageway with SMVT lane on both sides. The summary of Typical Cross Sections for proposed Nitai Bridge Alignment has been presented in Table 4-5.

Table 4-5: Summary of Typical Cross sections

Sr. No.	TCS Type	TCS Description	Proposed ROW (M)	Length (KM)
1	TCS 1	Typical Cross Section for Merging with Existing Road with Embankment Height Less Than 2 M at Rural Areas	30	0.025
2	TCS 2	Typical Cross Section for Merging with Existing Road with Paved Shoulder (Varies) with Embankment Height Less Than 2 M at Rural Areas	30	0.088
3	TCS 3	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) for Embankment Height 3M to 6M with Two Lane Service Road at Right Side	69	0.075
4	TCS 4	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) for Embankment Height 3M to 6M at Rural Areas	54	0.020
5	TCS 5	Typical Cross Section for Two Lane Carriageway with Varies SMVT Lane with Embankment Height 3M to 6M at Rural Areas	54	0.070
6	TCS 6	Typical Cross Section for Two Lane Carriageway with SMVT Lane with Embankment Height 3M to 6M at Rural Areas	50 to 54	0.925
7	TCS 7	Typical Cross Section of Two Lane Carriageway with SMVT Lane at Merging Section with Toll Plaza	54 to 102	0.220
8	TCS 8	Typical Cross Section for Toll Plaza Location (With SMVT Lane)	102	0.055
9	TCS 9	Typical Cross Section for Two Lane Carriageway at Bridge and Viaduct Sections (With SMVT Lane)	24	0.645

Sr. No.	TCS Type	TCS Description	Proposed ROW (M)	Length (KM)
10	TCS 10	Typical Cross Section for Two Lane Carriageway with Varies SMVT Lane with Embankment Height 2M to 3.5M at Rural Areas	42	0.065
11	TCS 11	Typical Cross Section for Two Lane Carriageway with Paved Shoulder (without SMVT Lane) with Embankment Height Less Than 2M at Rural Areas	42	0.042
12	TCS 12	Typical Cross Section for Two Lane Carriageway with Bus Bay (Varies) in Rural Areas	42	0.095
13	-	Junction Development	-	0.075
Total Length (km)				2.400

The typical cross sections drawings have been presented in the Final Feasibility Study Report of Nitai Bridge, Volume-III Part A.

- Cross Section of Steel Arch Bridge & Viaduct

Steel Arch Bridge type superstructure of 125m (L) main span has been proposed to minimize the numbers of piers under main river and to satisfy the requirement of Navigational criteria. It mainly consists of Composite (Steel Grider + Concrete slab) deck along with steel tied arch. The cross sections of steel arch bridge is presented in the figure below.

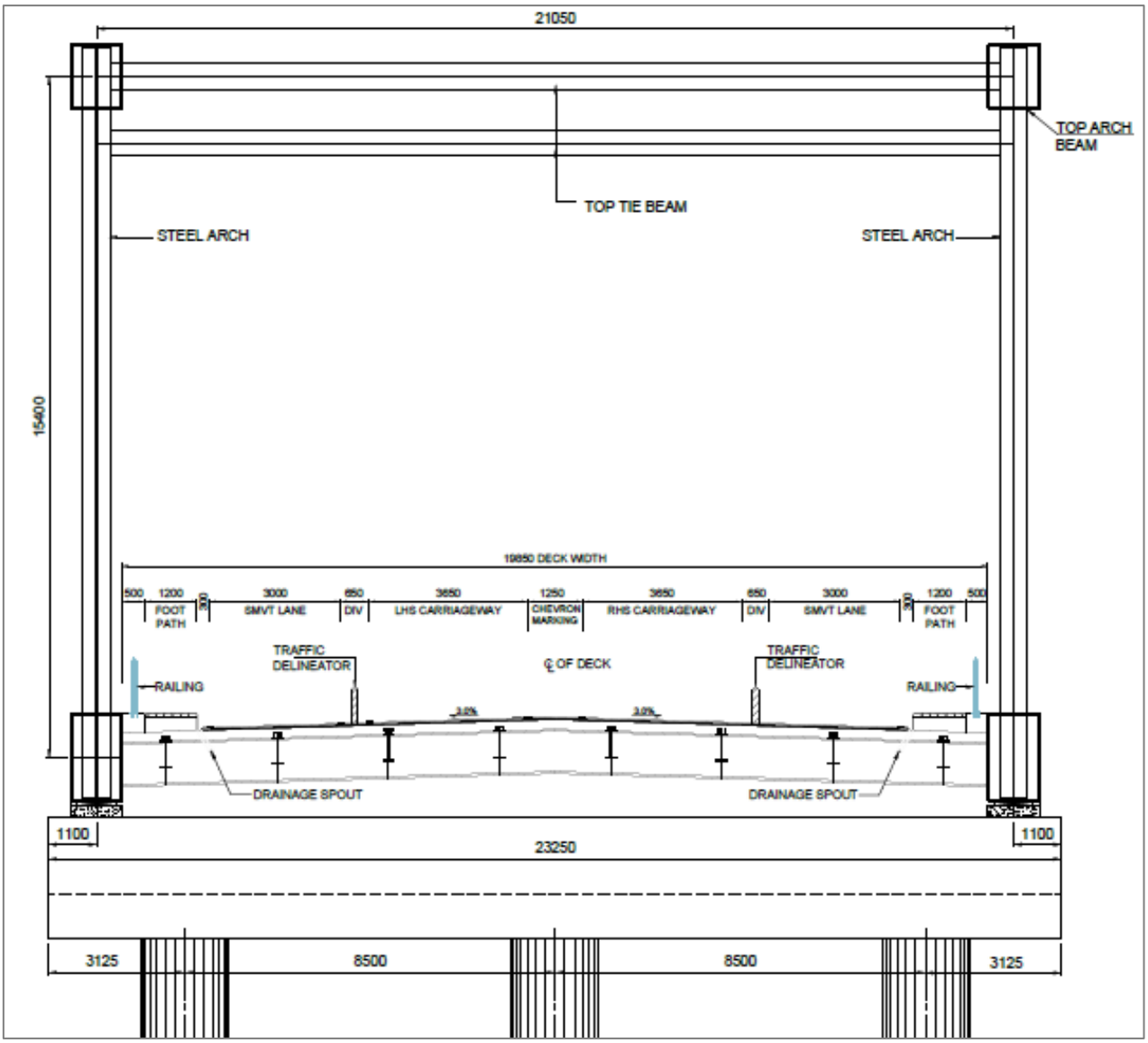


Figure 4-2: Cross Section of Steel Arch bridge

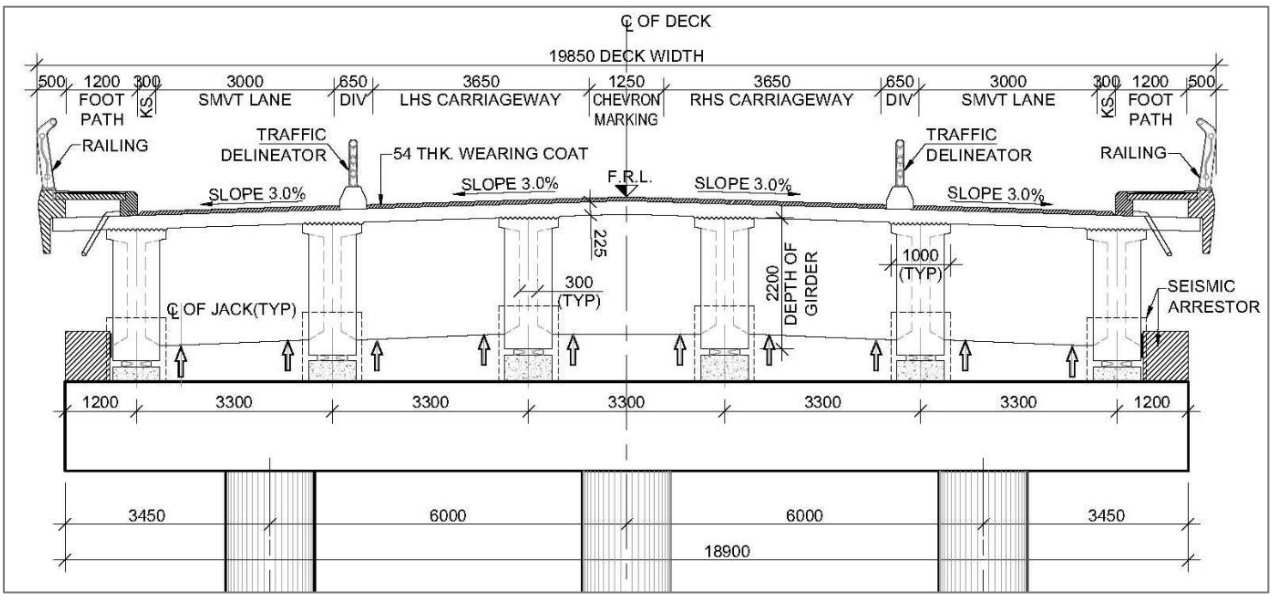


Figure 4-3: Cross Section of PSC I-Girder Type Viaduct

- Service Road

A service road has been proposed with a minor junction at km 0+080 for entry and exit from the main thoroughfare. The proposed service road of width 7.3m, extends from km 0+105 to km 0+180 on right side of the proposed highway.

- Access Strategy

The project road serves as an access route to the new Nitai Bridge over Nitai River, running in the vicinity of the existing road with nearby settlements and intersecting local roads. To minimize disruption to the existing road network, an access strategy has been devised, segmenting the project into 3 nos. zones based on the entry points to the proposed road which are defined below.

- Zone A: Access via the at-grade junction with earthen road at km 0+050.
- Zone B: Access via the at-grade junction with service road at km 0+090.
- Zone C: Access via the at-grade junction with RHD road at km 1+990.

Details of access plan have been presented in Table 4-6 below. Also, a schematic representation of Access Plan has been presented in Figure 4-4 below.

Table 4-6: Details of Access Strategy

Location of Cross Road	Type of Cross Road	Access Zone	Access Strategy
0+050	Earthen Road	Zone A	Access via at-grade junction at km 0+050
0+050	RHD Road	Zone B	Access via the at-grade junction with service road at km 0+090
0+735	Earthen Road		
1+050	RHD Road		
1+295	LGED	Zone C	Access via the at-grade junction with service road at km 1+990
1+352	Earthen Road		
1+580	Earthen Road		
2+150	RHD Road		

Figure 4-4: Schematic Plan of Access Strategy

- Toll plaza & Weighbridge

A 3+3 lane toll plaza has been proposed at Km 0+503.

The 3+3 lanes toll plaza has been proposed with each toll lane having a width of 3.2 m. Additionally, SMVT lanes of 3.0 m width has been proposed in both directions for slow moving local traffic. Traffic islands of 1.9m width has been placed between each toll lanes to accommodate toll booths.

Weigh bridge facility has not been considered for this project since the length of the project corridor is 2.4km only and serves primarily as an approach to the Nitai Bridge. Hence, provision of an axle load regulatory control station has not been envisaged. Further, there is a need for internal discussion by RHD keeping in view of the "Installation of Axle Load Control Stations at the Source of Freight Transport on Important Highways of Roads and Highways Department" project, being undertaken by RHD. Provision of weigh bridge for this project can be further decided based on this discussion. However, additional land will be required for provision of weigh bridge facility.

- Bus bays & stopping place

The bus stop and bus bay design will be addressed in the subsequent study phase. Currently, two locations have been identified for proposing bus stops with bus bays and two additional locations for bus stops without bus bays along the project corridor.

Table 4-7: Location of Proposed Bus Stop and Bus Bay

Sl. No.	Chainage	Side	Location	Remarks
1	0+030	RHS	Near start junction at km 0+090	Bus Stop Without Bus Bay
2	0+030	LHS		Bus Stop Without Bus Bay
3	2+310	RHS	Near end point at km 2+400	Bus Stop with Bus Bay
4	2+310	LHS		Bus Stop with Bus Bay

- Road Furniture

Road markings, Road Signs, Road Delineators have been proposed along the entire length of project highway in accordance with Bangladesh Road Sign Manual (Volume I &II), March 2000 at this stage. These will be further validated as per the Road Safety Audit report. Additionally, traffic Safety Barriers have been proposed as per Clause no. 5.2.1 of 'Roadside Design Guide 2011 (AASHTO)'.

The proposed road furniture includes a comprehensive array of traffic signs, road markings, road delineators, and safety barriers to enhance safety and guidance for road users. These measures aim to ensure efficient traffic flow, improve visibility, and mitigate risks on the roadway.

The usage of traffic signs, road markings, delineators, and traffic barriers are comprehensively outlined in Volume-I of the Final Feasibility Study Report for the Nitai Bridge.

4.4 Cost Estimate

The cost estimation has been prepared for the approved alignment, based on the improvement proposals and preliminary design adopted at this stage. However, in the absence of Geotechnical Report, this Cost Estimate is approximate and will be further updated in the next stages of study based on detailed investigations and further designs.

The Cost Estimate prepared for the approved alignment (Alignment Option 1) and approved Bridge Option A (Steel Arch bridge) has been presented below.

Division	Description	Amount (BDT)	Amount in Cr. (BDT)
	Construction Cost		
1	General & Site Facilities (2% Of Construction Cost)	68,622,590.98	6.86
2	Earth Work	112,670,939.00	11.27
3	Sub-Base, Base-Courses	67,485,809.00	6.75
4	Bituminous Pavement Courses	161,132,830.00	16.11
5	Cross Drainage Structures - Culverts	45,084,490.11	4.51
6.01	Structures - Minor Bridge	64,113,126.63	6.41
6.02	Structures - Viaduct	1,392,300,000.00	139.23
6.02	Structures - Main Bridge	1,088,996,039.95	108.90
7	Drainage & Protection Works	30,399,659.29	3.04
8	Traffic Signs, Marking And Road Appurtenances	25,696,263.00	2.57
9	Toll Plaza	269,454,392.00	26.95
10	River Training Works	142,446,000.00	14.24
11	Electromechanical Works	19,350,000.00	1.94
12	Bridge Health Monitoring System	12,000,000.00	1.20
	A. Total Construction Cost	**3,499,752,140**	**349.98**
	Non - Civil Works		
1	Land Acquisition, Resettlement & Compensation (10% of Civil Cost)	349,975,214.00	35.00
2	Utility Shifting (Lump Sum)	10,000,000.00	1.00
B	**Total Non-Civil works Cost**	**359,975,214**	**36.00**
C	**Total Capital Cost (A+B)**	**3,859,727,354**	**385.97**
D	Contingency		
1	Price Adjustment (15% of Civil Cost)	524,962,821	52.50
2	Contingency		
a)	Physical Contingency (2% of Civil Works)	69,995,043	7.00
b)	Price Contingency (2% of Civil Works)	69,995,043	7.00
D	**Total Price Adjustment and Contingency Cost**	**664,952,907**	**66.50**
E	**Total Project Cost (C+D)**	**4,524,680,261**	**452.47**

4.5 Implementation Timeline

The construction of the project is scheduled to commence in 2024 and will conclude in 2026. The Project Road is expected to be accessible to traffic at the end of 2027.

5 ENVIRONMENTAL SUSTAINABILITY, CLIMATE RESILIENCE AND DISASTER RISK ANALYSIS

5.1 Environmental, Climate Change and Disaster Risk Analysis

An Initial Environmental Examination (IEE) Report will be conducted to evaluate the project's risks concerning environmental, climate, and disaster aspects. This examination aims to determine the extent to which climate change and natural hazard risks affect short-term, medium-term, and long-term socio-economic and strategic development goals, plans, programs, and targets. Climate change significantly impacts a country's vital ecosystems and sectors, including agriculture, forestry, health, local economic activities, and biodiversity. Additionally, climate change exacerbates local and regional issues such as poverty, inadequate healthcare, unequal resource distribution, declining ecological resilience, and energy insecurity.

Constructing climate-resilient bridges necessitates strategic selection of materials. Utilizing Supplementary Cementitious Materials (SCMs) such as fly ash and slag cement not only reduces the carbon footprint but also enhances the structural strength of the bridges. Epoxy-coated and galvanized steel are essential for preventing corrosion, especially in coastal regions. Carbon-resilient cables provide additional durability for cable-stayed bridges. Other effective materials include geopolymer cement, high-performance concrete (HPC), and fusion-bonded epoxy (FBE)-coated Thermo-Mechanically Treated (TMT) bars. For river protection, it is crucial to understand tidal influences and erosion patterns. Considering factors such as wind load, seismic effects, and sea level rise is essential to ensure the structural integrity of the bridges. Additionally, implementing mitigation measures during construction is vital to minimize environmental impact.

5.1.1 Impacts of Environmental, Disaster & Climate Change

The initial assessment identified several potential project impacts across environmental, health, and disaster-related aspects. The acquisition of land will alter land use patterns, leading to the loss of trees and vegetation, which adversely affects wildlife and avian fauna. Dust generation from vehicle movement on unpaved roads, combined with air pollution from hot mix, concrete, and asphalt plants, as well as machinery and diesel generator (DG) sets, will deteriorate air quality. Construction activities will increase sediment load and water pollution, elevate dust levels, and raise noise levels, impacting sensitive receptors. Hydrological changes, such as increased flooding and siltation, could disrupt stream flows and degrade riverbanks due to excavation and construction activities. The loss of flora and fauna habitats, coupled with health and safety concerns for workers and nearby communities, are significant issues. Additionally, climate change and natural hazards like cyclones, floods, and earthquakes could exacerbate these impacts, leading to socio-economic repercussions such as poverty, healthcare challenges, reduced ecological resilience, and energy insecurity. These potential impacts underscore the need for comprehensive mitigation strategies to address environmental degradation and protect human health and safety.

5.1.2 Counter measures to reduce the impacts

Several counter measures will be proposed to mitigate the anticipated impacts and the same will be implemented. To minimize land acquisition, the area will be kept to a minimum, with land acquisition plans approved before implementation. Construction activities will be restricted within the Project Right of Way (PRoW) to manage land use impacts. To counter the loss of trees and vegetation, tree cutting will be minimized, and a compensatory plantation program will be executed as per regulations. Wildlife and avian fauna will be protected by avoiding habitat destruction, implementing conservation measures, and conducting awareness training for workers on wildlife protection and anti-poaching. Dust generation from vehicle movement on unpaved roads will be controlled by sprinkling water, and air pollution from hot mix, concrete, and asphalt plants will be managed by ensuring these plants are licensed. Dust from earthwork and construction activities will be mitigated by shifting excavated earth in covered vehicles and frequent water sprinkling. Preventive maintenance of machinery and adherence to emission standards for diesel generator (DG) sets will address air pollution. Noise levels during construction will be controlled by maintaining equipment, providing personal protective equipment (PPE), and avoiding night-time activities. Noise from

DG sets will comply with noise standards, and noise barriers and silence zones will protect sensitive receptors. Hydrological changes will be managed by minimizing stream flow disruption, preventing riverbank erosion, and stabilizing banks through re-vegetation. Occupational health and safety will be ensured through PPE provision, safety training, and health check-ups, while community health and safety will be supported by safety barriers, signage, and health awareness programs. Finally, design and construction methods will be updated to withstand cyclones, floods, and earthquakes, incorporating alternative materials and technologies to enhance resilience.

5.1.3 Cost for mitigation of the negative impacts

The cost for mitigation of the negative impacts will be finalized during IEE preparation stage.

5.1.4 Alternative Costs

No such alternative costs have been proposed. The proposed project requires minimal environmental impact.

5.1.5 Assessment Type

The project has been categorized according to the laws and regulations of Department of Environment (DoE), Bangladesh.

According to the Environment Conservation Rules (2023), the proposed project falls under **orange category as the proposed bridge length is 189 m**. Hence, as per the DoE requirements an Initial Environmental Examination (IEE) Report will be submitted to the DoE for approval. The IEE report shall be submitted to the DoE getting Site Clearance Certificate (SCC) and Environmental Clearance Certificate (ECC).

5.1.6 Resettlement Issues

Field verification reveals that the Nitai bridge project will displace 22 units, primarily rural households, and 4 commercial structures, mainly small shops, raising concerns about resettlement and potential livelihood losses for shop workers. Although the displacement is relatively minor compared to the densely populated rural areas affected, disrupting independently operated rural establishments highlights the need for careful consideration of the project's impact.

5.2 Assessment of Disaster Resilience of the project

5.2.1 Contingency Plan for Emergency Disaster Management

A comprehensive contingency plan for emergency disaster management, prioritizing the safety of all parties involved is included in the plans for the Nitai Bridge project. The plan clearly outlines evacuation procedures, featuring marked routes, designated assembly points, and appointed personnel to guide evacuees, alongside regular drills to ensure everyone is familiar with the protocols. Institutional arrangements ensure the swift shutdown of utilities, with designated personnel and clear protocols for managing electricity, gas, water, and other essential services. General safety procedures emphasize staying calm, following instructions, seeking refuge indoors or in open areas during earthquakes, and evacuating immediately in case of fire, floods, or cyclones. This robust plan aims to minimize risks and ensure an effective response to emergencies throughout the project's lifecycle.

5.2.2 Business Continuity Plan

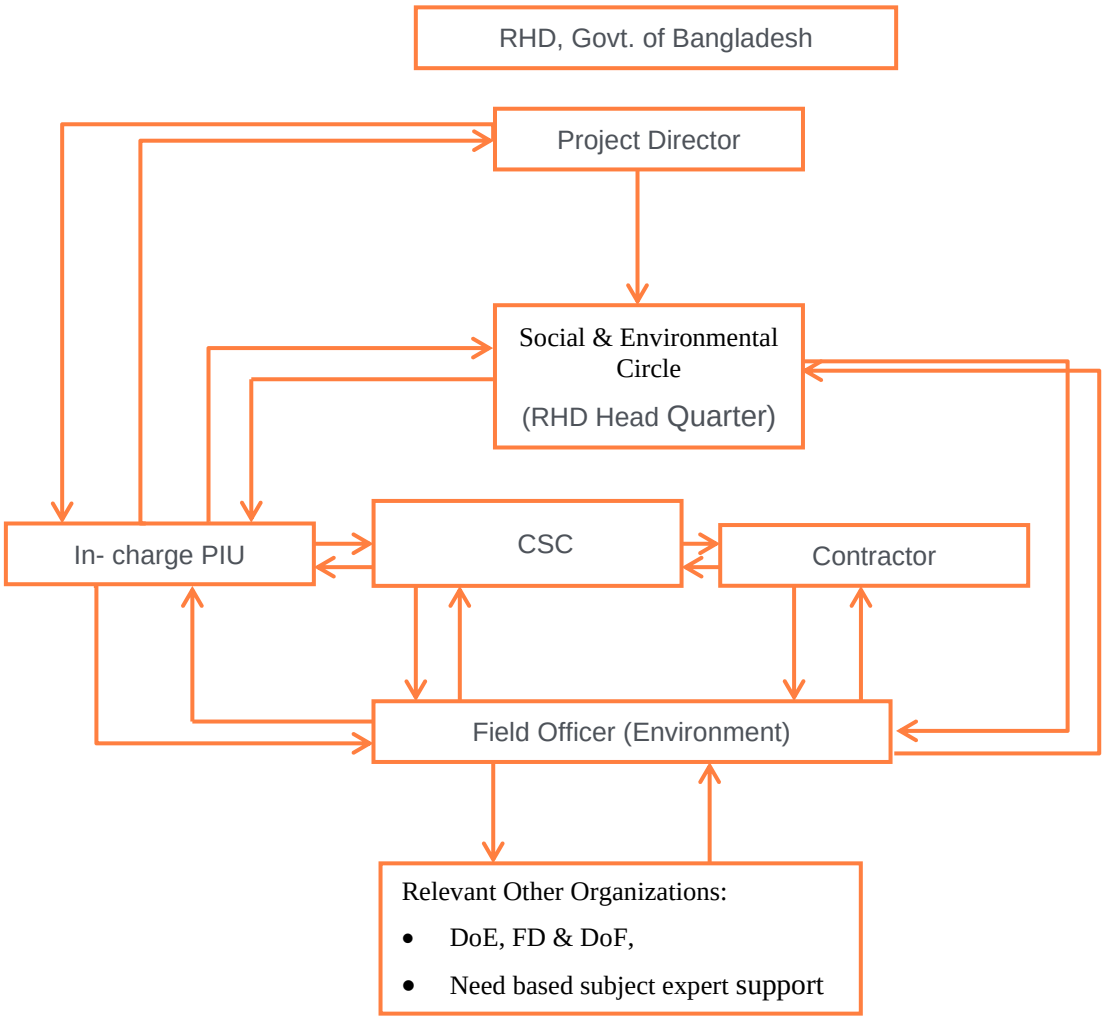
Response and recovery priorities, focusing on safety, infrastructure protection, and utility service restoration is emphasized in the Business Continuity Plan for the Nitai bridge project. Ensuring the safety and security of personnel and surrounding communities is paramount, with emergency response teams mobilized immediately. Infrastructure protection measures are implemented to safeguard the bridge structure and prevent further damage. Restoring utility services, especially electricity, water supply, communication, and transportation, is prioritized. Efforts concentrate on restoring power to essential facilities, ensuring water availability, reestablishing communication networks, and maintaining transportation routes to ensure uninterrupted project operations. This comprehensive plan aims to maintain project continuity and minimize disruptions during emergencies.

5.2.3 Time of Recovery

The duration required for rehabilitation after a disaster, encompassing efforts to rebuild infrastructure, restore services, and assist affected communities is referred by the Time of Recovery. The proposed Nitai Bridge project is located in a high-risk earthquake zone (zone 4) and design factors have been included accordingly, so no impacts are anticipated. But as the project area is located in the coastal region of Bangladesh, it is prone to storm surges, cyclones, and sea level rise and these potential effects of climate change have been accounted for in the design. However, it is important to note that the recovery timeline is not fixed and can be influenced by various factors, including the availability of resources, the level of coordination among stakeholders, and the resilience of the affected communities.

5.2.4 Reporting of Residual Risks

The reporting of residual risks involves identifying and documenting any remaining risks after implementing mitigation measures. This process is crucial for assessing the project's disaster resilience and allows stakeholders to proactively address vulnerabilities. The Environmental Field Officer will primarily report any residual risks to the Construction Supervision Consultant (CSC). The CSC is responsible for reporting progress to the Roads and Highways Department (RHD). The reporting procedure is illustrated in the figure below.



6 COST-BENEFIT ANALYSIS

6.1 Financial Analysis

6.1.1 Component of Cost-Benefit Analysis

Based on the discussion held with the RHD officials on the alternative options it was informed by RHD that project may be implemented through government funds/international funds, hence revenue-based model & Annuity Based Model will be applicable to check the financial sustainability of the project from toll as prescribed by RHD Toll Policy, 2014. However, toll shall be imposed on the bridge and collected by the authority to generate sufficient revenues while still helping to improve accessibility.

Detailed calculation is presented in the Final Feasibility Study Report of Nitai Bridge, Volume-I.

The entire 30 years of toll rate has been presented in following Table 6-1. The toll will be effective from 2027 and will be changing in every three years up to next 30 years, that is, 2053.

Table 6-1: Toll Rate Nitai Bridge from 2024 to 2053

Year	Vehicle Categories											
	HT	MT	LB	ST	Tractors	Mini Bus	Micro Bus	Utility	Car	Tempo/3W	2W	NMT
2027	415	330	165	150	125	100	85	65	65	40	20	5
2028	415	330	165	150	125	100	85	65	65	40	20	5
2029	415	330	165	150	125	100	85	65	65	40	20	5
2030	440	350	175	160	130	105	90	70	70	40	20	5
2031	440	350	175	160	130	105	90	70	70	40	20	5
2032	440	350	175	160	130	105	90	70	70	40	20	5
2033	460	365	185	170	140	110	95	75	75	45	20	5
2034	460	365	185	170	140	110	95	75	75	45	20	5
2035	460	365	185	170	140	110	95	75	75	45	20	5
2036	485	385	195	175	145	115	100	75	75	45	25	10
2037	485	385	195	175	145	115	100	75	75	45	25	10
2038	485	385	195	175	145	115	100	75	75	45	25	10
2039	510	405	200	185	155	120	105	80	80	50	25	10
2040	510	405	200	185	155	120	105	80	80	50	25	10
2041	510	405	200	185	155	120	105	80	80	50	25	10
2042	530	420	210	195	160	125	110	85	85	50	25	10
2043	530	420	210	195	160	125	110	85	85	50	25	10
2044	530	420	210	195	160	125	110	85	85	50	25	10
2045	555	440	220	205	165	130	115	90	90	55	25	10
2046	555	440	220	205	165	130	115	90	90	55	25	10

2047	555	440	220	205	165	130	115	90	90	55	25	10
2048	580	460	230	210	175	140	120	90	90	55	30	10
2049	580	460	230	210	175	140	120	90	90	55	30	10
2050	580	460	230	210	175	140	120	90	90	55	30	10
2051	600	480	240	220	180	145	125	95	95	55	30	10
2053	600	480	240	220	180	145	125	95	95	55	30	10
2052	600	480	240	220	180	145	125	95	95	55	30	10

The toll policy outlines exemptions for certain categories of vehicles, including emergency vehicles, police, defence force, and others as specified. These vehicles will not be charged to use the road, provided they produce official warrants or acceptable documentation as proof of exemption. Additionally, discounts will be offered to frequent users to ensure transportation fees remain affordable.

6.1.2 Monetary Value

The total project cost of entire stretch for Nitai Bridge including Land acquisition, Resettlement & Rehabilitation, Utility shifting, departmental supervision, Environmental Program Management (EMP) cost, Toll Plaza Construction Cost, Contingencies etc. is BDT 452.5 crore. The construction is assumed to commence in 2024 and will be completed by the end of 2026. The new corridor will be opened for traffic in 2027. The broad components of construction cost are as follows

6.1.3 Construct of Cash Flow

The goal of this analysis is ultimately to derive the project cash flows over the forecast period for the analysis of the investment return on selected implementation structure. The cash flows are calculated using a build-up approach. The analysis focuses on the annual cash flows arising from the project. The Internal Rate of Return (IRR) of project on net cash flow has been determined to understand the extent of financial return available to investors.

Total Project Cost (TPC)

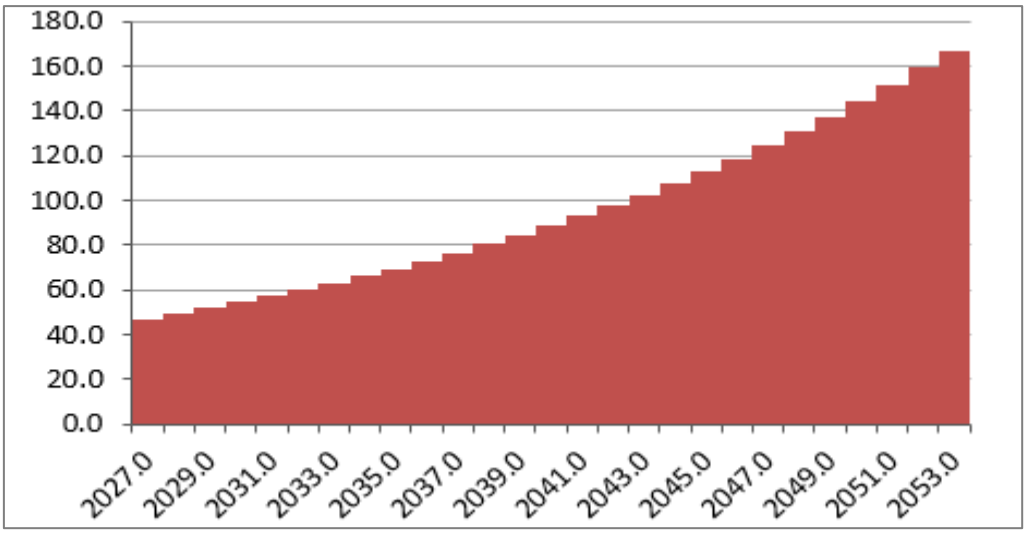
The total cost of entire project is BDT. 492.1 Cr. including interest during construction. The construction is assumed to commence in 2024 and will be completed by the end of 2026. The facility will be opened in 2027. The land acquisition cost & rehabilitation cost are included in “Total Project Cost without IDC” (BDT. 452.5 Cr.) since that will be borne by the Government of Bangladesh. Details are summarised in the table below.

Table 6-2: Total Project Cost (real price @ 2023 price level)

Sl. No.	Cost Items	Amount (BDT. Cr.)
A	Total Project Cost without IDC	452.5
B	Interest During Construction (IDC)	39.6
C	Total Project Cost to the authority	**492.1**

Financial Analysis—Annuity Based Model

The Government of Bangladesh to the private party and bank as a loan repayment method for 25 years among which first 3 years will be moratorium period and rest 22 years will be effective loan repayment period where Govt. of Bangladesh has to pay the loan with mutually agreed interest rate of 8.5%. The analysis shows the Net Present Value (NPV) of the project is positive and having Project IRR of more than 8.5% which is determined by the amount of inflation adjusted-annuity that would be paid to the private party and bank bi-annually.



Source: Financial Model

Figure 6-1: Nominal Revenue from Annuity Payment (BDT, Cr.)

The Table 6-3 below depicts the summary of the Financial Analysis under the current setting of analysis under this scenario:

Table 6-3: Summary of Financial Evaluation

Fund Details	Project IRR	Project NPV	Nominal WACC	Equity IRR	Equity NPV	Average DSCR	Average LLCR
Grant-0%, Debt-70% & Equity-30%	12.2%	BDT. 70.1 Cr.	10.8%	16.0%	BDT. 0.3 Cr.	2.15	2.89

The entire scenario of the analysis of Financial Evaluation outlined in Volume-I of the Final Feasibility Study Report for the Nitai bridge.

The cash flow Figure 6-2 as shown below indicates that income from annuity has steady rising trend. The O&M costs increase over time. The following Table shows the Total Cash flow (Nominal) of the project in figures in every six months of interval.

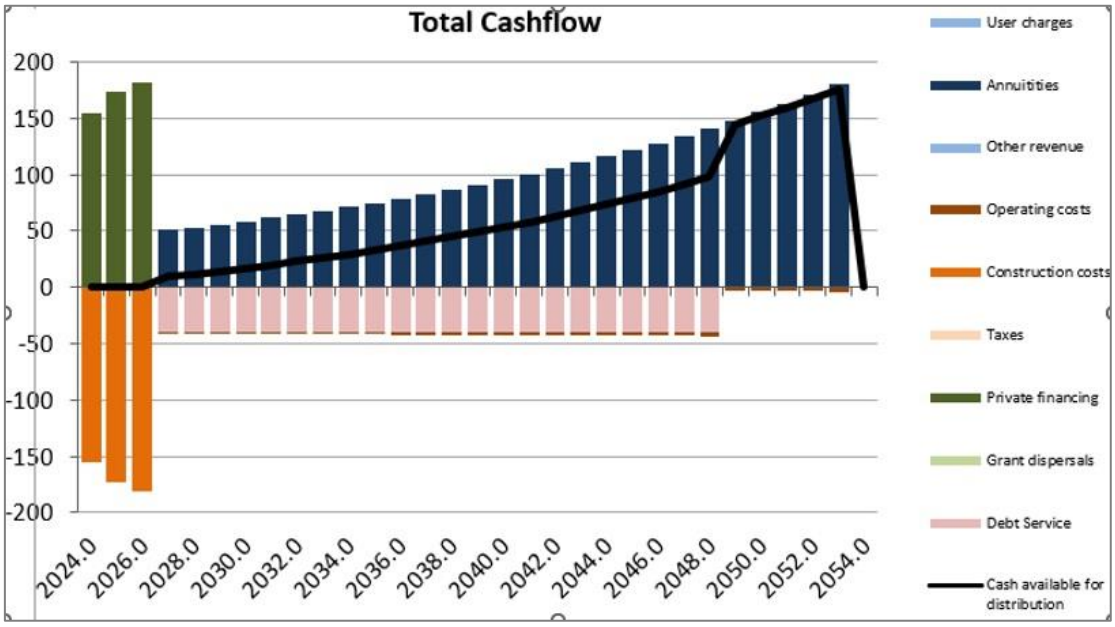


Figure 6-2: Total Cash Flow (BDT, Cr.)

The bi-annual project cash flow (nominal) is outlined in Volume-I of the Final Feasibility Study Report for the Nitai Bridge. The analysis, based on this setup, covers the entire cash flow and summary. The project will operate from 2027 to 2053, covering a 30-year period.

6.1.4 Indicators (FNPV, FBCR, FIRR)

Three indicators for financial analysis include Financial Net Present Value (FNPV), Financial Benefit Cost Ratio (FBCR), and Financial Internal Rate of Return (FIRR).

Financial Analysis for selected option—Revenue Based Model

The results of the financial analysis are summarized below.

- Financial Analysis – Considering total capital cost.
  - PIRR: 3.55%
  - NPV@5%: -77.2 Crores BDT
  - Total Capital Cost: 452.5 Crores BDT
  - FBCR: 0.94

The analysis shows that the project has weak revenue generating capability with respect to its total capital cost and financially unviable. The project yields IRR of 3.55% with NPV value of BDT. -77.2 Cr.

- Financial Analysis – Considering total project cost.
  - PIRR: 4.65%
  - NPV@5%: -16.8 Crores BDT
  - Total Project Cost: 386 Crores BDT
  - FBCR: 1.10

The analysis shows that the project has weak revenue generating capability with respect to its total project cost and financially unviable. The project yields IRR of 4.65% with NPV value of BDT. -16.8 Cr.

The financial analysis precisely shows that, the bridge does not have high revenue generating capability due to low level of traffic in the region. The toll revenue does not even recover the initial investment even in first thirty years of operation. Hence, net financial support will be required from Govt. of Bangladesh.

6.2 Estimation of Net Cashflow

Table 6-4 shows the net cashflow of the project. Column 3 shows the total fund required to fund the project by the private party and Column 2 shows the external support required from Govt. of Bangladesh to construct the bridge, as the toll revenue is incapable of generating required fund for annuity payments.

Table 6-4: Net Cashflow included required Govt. Support (BDT, Cr.)

Years	Revenue from Toll	Fund Required from GoB	Total Annuity Required	Maintenance Cost	Cash flow before financing	Bank Loan Repayment		Cash available for Dividend Payout	Dividends paid
						Interest	Principal		
Coln. No.	1	2	1+2=3	4	5	6	7	8	9
2027	14.2	33.5	47.7	-0.9	46.8	-31.5	-6.4	8.8	-8.8
2028	15.1	35.0	50.1	-1.0	49.1	-31.0	-7.0	11.1	-11.1
2029	16.0	36.6	52.6	-1.0	51.6	-30.4	-7.6	13.6	-13.6
2030	17.8	37.4	55.2	-1.1	54.2	-29.8	-8.2	16.2	-16.2

Years	Revenue from Toll	Fund Required from GoB	Total Annuity Required	Maintenance Cost	Cash flow before financing	Bank Loan Repayment		Cash available for Dividend Payout	Dividends paid
						Interest	Principal		
Coln. No.	1	2	1+2=3	4	5	6	7	8	9
2031	18.7	39.3	58.0	-1.1	56.9	-29.1	-8.9	18.9	-18.9
2032	19.6	41.3	60.9	-1.2	59.7	-28.3	-9.7	21.7	-21.7
2033	21.3	42.7	64.0	-1.3	62.7	-27.5	-10.5	24.7	-24.7
2034	22.0	45.1	67.2	-1.3	65.8	-26.6	-11.4	27.8	-27.8
2035	22.8	47.7	70.5	-1.4	69.1	-25.6	-12.4	31.1	-31.1
2036	25.4	48.6	74.0	-1.5	72.6	-24.6	-13.4	34.6	-34.6
2037	26.3	51.5	77.7	-1.5	76.2	-23.4	-14.6	38.2	-38.2
2038	27.3	54.3	81.6	-1.6	80.0	-22.2	-15.8	42.0	-42.0
2039	29.6	56.1	85.7	-1.7	84.0	-20.8	-17.2	46.0	-46.0
2040	30.7	59.2	90.0	-1.8	88.2	-19.4	-18.6	50.2	-50.2
2041	31.9	62.6	94.5	-1.9	92.6	-17.8	-20.2	54.6	-54.6
2042	34.1	65.1	99.2	-1.9	97.3	-16.1	-21.9	59.3	-59.3
2043	35.1	69.1	104.2	-2.0	102.1	-14.2	-23.8	64.1	-64.1
2044	36.0	73.3	109.4	-2.1	107.2	-12.2	-25.8	69.2	-69.2
2045	38.5	76.4	114.9	-2.3	112.6	-10.0	-28.0	74.6	-74.6
2046	39.5	81.1	120.6	-2.4	118.2	-7.6	-30.4	80.2	-80.2
2047	40.5	86.1	126.6	-2.5	124.1	-5.0	-32.9	86.1	-86.1
2048	44.4	88.6	133.0	-2.6	130.3	-2.2	-35.7	92.4	-92.4
2049	45.5	94.1	139.6	-2.7	136.9	0.0	0.0	136.9	-136.9
2050	46.6	100.0	146.6	-2.9	143.7	0.0	0.0	143.7	-143.7
2051	49.1	104.8	153.9	-3.0	150.9	0.0	0.0	150.9	-150.9
2052	50.2	111.4	161.6	-3.2	158.4	0.0	0.0	158.4	-158.4
2053	51.4	118.3	169.7	-3.3	166.4	0.0	0.0	166.4	-166.4

6.3 Economic Analysis

6.3.1 Component of Cost-Benefit

The reductions in disbenefits lead to savings. The total savings expressed in quantitative and qualitative terms are the total benefits arising from the bridge system. The total quantitative benefits and costs at economic prices determine the IRR and NPV of the project. However, the following components of benefits have been quantified in the main report of economic analysis.

- Saving in VOC and Time cost.
- Reduction in Emission.
- Incremental Output from Govt. Expenditure
- Impact on Economic Activities and Income Augmentation

6.3.2 Adjustments

All the data have been collected from secondary data sources (mentioned in the main report) and adjusted with help of well-practiced statistical tools (extensively explained in the main report).

6.3.3 Standard Conversion Factors (SCF)

The SCF has been determined by the export-import data of Bangladesh to convert the financial cost to economic cost of the project and presented in Table 6-5.

Table 6-5: SCF Calculation

Imports (c.i.f) (Tk., million)	8,573,922
Import Tariff (Tk., million)	437879
Exports (f.o.b.) (Tk., million)	6,581,506
Export Tariff (Tk., million)	0.0
Net Trade Taxes (Tk., million)	437,879
Total Trade (Tk., million)	15,155,428
SCF	**0.97**

6.3.4 The final Cash Flow of benefit streams

The final benefit stream has been presented with respect to the aforesaid benefits which are likely to be generated after successful completion of the project with the stipulated time frame. It is also to be noted that the total tangible and non-tangible benefits are not limited to these benefits.

Table 6-6: Cost-Benefit Streams of Nitai Bridge (combining four border bridges)

Years	Capital Investment	Road User Savings	Savings in SCC	ICOR	Import-Export GVA	Total Savings	Total Net Benefit
2024	876.8	0.0	0.0	0.0	0.0	0.0	-876.8
2025	657.6	0.0	0.0	0.0	0.0	0.0	-657.6
2026	657.6	0.0	0.0	0.0	0.0	0.0	-657.6
2027	6.4	37.0	10.4	429.4	56.4	533.2	526.8
2028	6.4	54.4	11.3	413.6	58.5	537.8	531.4
2029	6.4	63.8	12.4	399.5	60.7	536.3	529.9
2030	6.4	76.5	13.6	387.4	63.0	540.3	533.9
2031	6.4	95.7	15.2	376.6	65.3	552.8	546.4

2032	6.4	127.2	17.3	367.1	67.8	579.4	573.0
2033	6.4	173.8	20.1	358.6	70.3	622.8	616.4
2034	6.4	198.1	22.0	351.0	72.9	644.0	637.6
2035	6.4	200.6	23.1	344.1	75.7	643.5	637.1
2036	6.4	202.3	24.3	337.9	78.5	643.0	636.6
2037	6.4	205.9	25.5	332.2	81.5	645.1	638.7
2038	6.4	207.8	26.8	327.0	84.5	646.1	639.7
2039	6.4	207.1	28.1	322.2	87.7	645.1	638.7
2040	6.4	221.0	29.5	317.8	91.0	659.3	652.9
2041	6.4	225.8	31.0	313.8	94.4	664.9	658.5
2042	6.4	234.2	32.6	310.0	97.9	674.7	668.3
2043	6.4	243.3	34.4	306.5	101.6	685.8	679.4
2044	6.4	247.4	35.9	303.2	105.4	691.9	685.5
2045	6.4	251.0	37.5	300.2	109.4	698.1	691.7
2046	6.4	254.5	39.1	297.3	113.5	704.4	698.0
2047	6.4	259.6	40.8	294.6	117.7	712.8	706.4
2048	6.4	264.3	42.6	292.1	122.1	721.2	714.8
Capital Cost at Financial Price		2259.8	SCF	Economic Internal Rate of Return (EIRR)			20.6%
Capital Cost at Economic Price		2192.0	0.97	Net Present Value (NPV) at 12%			1430.8
Economic Benefit Cost Ratio (EBCR)							1.8

6.3.5 Assumptions

The following assumptions are made for the analysis:

- The analysis period is 25 years including construction period.
- The construction period is assumed to be for 3 years (2024 to 2026).
- The commercial operational date (COD) will be 2027.
- The analysis period is from 2024 to 2048.
- The standard conversion factors to convert financial price to economic price is 0.97.
- The HDM4 has been calibrated for L1 level only as per standard practice.
- The HDM4 input data has been used from RHD published data of 2017-2018, which has been updated for the year 2023-2024.

6.3.6 Key Results of Economic Analysis

Estimation of EIRR and NPV

- Economic Internal Rate of Return (EIRR): 20.6%
- Net Present Value (NPV) @12%: 1430.8 Crores BDT
- Economic Benefit Cost Ratio (EBCR): 1.8

Sensitivity Analysis – 10% rise in cost

- EIRR: 19.0%
- NPV @12%: 1253.8 Crores BDT
- EBCR: 1.6

Sensitivity Analysis – 20% drop in Benefits

- EIRR: 17.0%
- NPV @12%: 782.7 Crores BDT
- EBCR: 1.4

Sensitivity Analysis – All cases together

- EIRR: 15.6%
- NPV @12%: 605.1 Crores BDT
- EBCR: 1.3

Considering immense socio-economic benefits to the Project influence area, the project is strongly recommended for consideration of implementation for having high EIRR of 20.6%.

7 HUMAN RESOURCES AND ADMINISTRATIVE SUPPORT ANALYSIS

The Nitai bridge has been proposed as a Steel Tied Arch + PSC I Girder with span arrangement of 1 x 32.0m + 1 x 125.0m + 1 x 32.0m. The implementation of this Project thus needs specific technical expertise pertinent to Steel Tied Arch bridges. The Roads and Highways Department (RHD) has successfully implemented the commissioning of the Kalna Bridge at Kashiani which is a steel arch bridge with a span arrangement of 6 x 40m + 1 x 1500m + 6 x 40m, M.A Khan Bridge at Sylhet which is a steel truss bridge with a span arrangement of 1 X 25m + 1 X 40m + 1 X 120m + 1 X 40m and 2nd Meghna Bridge & 2nd Gumti Bridge which are steel box girder bridges. Thus, they have the right technical and managerial work force to implement the Nitai Bridge also. At the same time, RHD is successfully operating and maintaining the Kalna Bridge, M.A Khan Bridge and hence is organisationally well equipped to maintain the functional output of the proposed bridge.

8 INSTITUTIONAL AND LEGAL ANALYSIS

The Road Master Plan, 2009 stipulates that new bridges should be constructed on missing links. Besides, a target has been fixed to construct 37,500 meters of bridge/culvert as a strategy of the road transport sector in the 8th Five Year Plan (2021-2025) to achieve the Perspective Plan 2041. Thus, construction of the Nitai Bridge envisaged by the Roads and Highways Department, at critical missing link over Nitai River has been envisaged within the legal purview of the Road Master Plan, 2009, 8th Five Year Plan (2021-2025) & the Perspective Plan 2041. The Assets of Roads and Highways Department have been conservatively estimated at Taka 46,000 crore (US$8,000 million) of which by far the largest proportion is the value of the 22,096.303 kms of road and the 18,258 bridges. These assets are probably the greatest asset of any organisation in Bangladesh and maintaining their value is vital to its economy. This places a great responsibility on the Roads and Highways Department. Thus, the policy and institutional setup of RHD is well aligned with the successful implementation of the proposed Nitai Bridge. The Roads and Highways Department (RHD) has successfully implemented the commissioning of the Kalna Bridge at Kashiani which is a steel arch bridge with a span arrangement of 6 x 40m + 1 x 1500m + 6 x 40m, M.A Khan Bridge at Sylhet which is a steel truss bridge with a span arrangement of 1 X 25m + 1 X 40m + 1 X 120m + 1 X 40m, 2nd Meghna Bridge & 2nd Gumti Bridge which are steel box girder bridge. Thus, they have the right technical and managerial work force to implement the Nitai Bridge also. As RHD is well experienced in implementing similar projects as such no governance issue has been envisaged in implementing this Project.

9 RISK AND SENSITIVITY ANALYSIS

The main goal of quantifying project risks is to understand the possibility of cost overruns, which can disrupt the project's completion within the planned time. These overruns often lead to delays because authorities require extra funds, shortening the asset's economic life and limiting its benefits to society. This chapter focuses on assessing the risk of cost overruns during construction by analysing potential changes in cost parameters. It's an early analysis that helps authorities anticipate and budget for potential overruns, ensuring the project stays on track without compromising its scope.

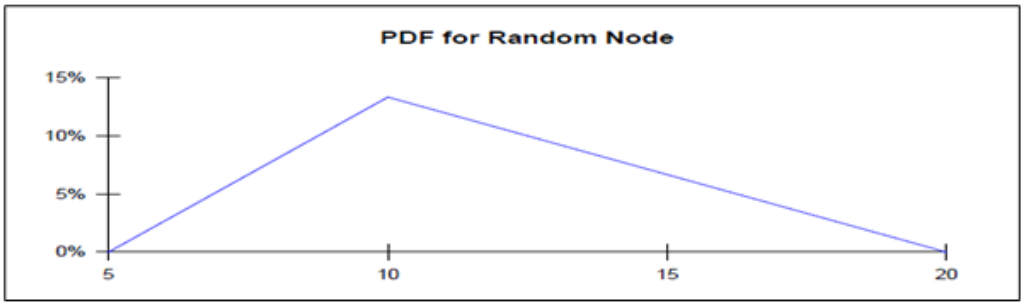
9.1 Estimation of Probability of Total Project Cost (TPC)

The below table shows the different parameters which will be used in the Monte Carlo Simulation by using the Vanguard to estimate the Total Project Cost (TPC) based on the aggregate civil cost.

Table 9-1: Stochastic Variable Inputs.

Stochastic Variables	Lower Value	Most Likely	Higher Value
General & Site Facilities (2% Of Construction Cost)	1.36%	1.52%	1.71%
Earth Work	2.37%	2.49%	2.99%
Sub-Base, Base-Courses	1.42%	1.49%	1.79%
Bituminous Pavement Courses	3.38%	3.56%	4.27%
Cross Drainage Structures - Culverts	0.95%	1.00%	1.20%
Structures - Minor Bridge	1.35%	1.42%	1.70%
Structures - Viaduct	26.67%	30.77%	32.82%
Structures - Main Bridge	21.11%	24.07%	27.73%
Drainage & Protection Works	0.67%	0.67%	0.81%
Traffic Signs, Marking And Road Appurtenances	0.56%	0.57%	0.68%
Toll Plaza	5.90%	5.96%	7.15%
River Training Works	3.12%	3.15%	3.78%
Electro Mechanical Works	0.42%	0.43%	0.51%
Bridge Health Monitoring System	0.26%	0.27%	0.32%
Land Acquisition, Resettlement & Compensation (Lump Sum)	7.66%	7.73%	9.28%
Utility Shifting (Lump Sum)	0.22%	0.22%	0.23%
Price Adjustment	11.60%	11.60%	11.60%
Physical Contingency	1.55%	1.55%	1.55%
Price Contingency	1.55%	1.55%	1.55%

The values considered for triangular distribution is presented in the Figure below:



Source: Vanguard Manual

Figure 9-1: Triangular Distribution.

9.2 Simulation Analysis

The Monte Carlo simulation shows that mean TPC is BDT. 458 Cr. The maximum TPC may be BDT. 481 Cr. and the minimum maybe BDT. 432 Cr. The likely TPC, that is, mean TPC is BDT. 458 Cr. The mean and median are almost the same that is a normal distribution. The following Figure 9-3 is showing both Cumulative and Probability Distribution Functions (CDF & PDF) of Total Project Cost. The Monte Carlo Simulation of TPC is showing that there is 80% chance that the TPC of New Bridge under current civil cost will be below BDT. 465 crore and 60% chance the TPC would be BDT. 459 Cr.

Simulation Summary

Measure	*Total Project Cost*
Observations	1,000
Mean	458
Standard Deviation	9
Posterior STD	3e-1
Variance	78
Minimum	432
5th Percentile	443
Median	458
95th Percentile	473
Maximum	481

Figure 9-2: Simulation Summary of Total Project Cost (BDT, Cr.)

The CDF and PDF of TPC (BDT, Cr.) is shown below.

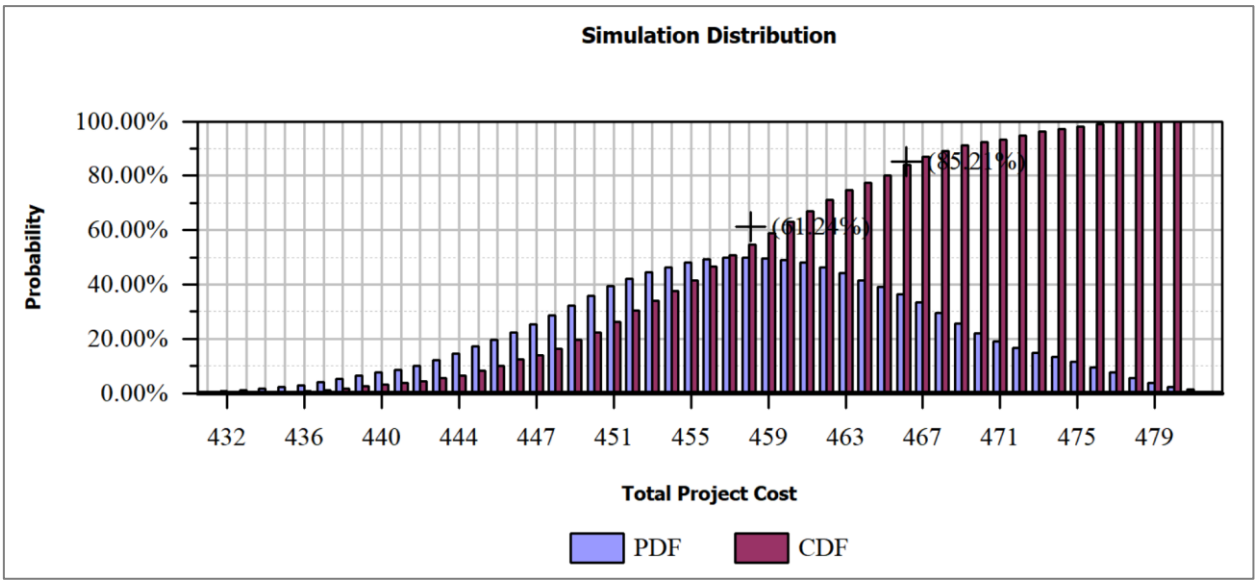


Figure 9-3: The CDF and PDF of TPC (BDT, Cr.)

9.3 Cost Escalation Risks

Table 9-2: Cost Escalation Risk

Type of Risk	Risk	Cost Driver	Mitigation
Force Majeure Risk	Weather	Life Cycle Cost and/or Performance Payment/Toll	In case of Force Majeure event the affected party will be compensated and impacts to be mitigated as per provision of agreement.
	Force Majeure during operations	O&M Cost and possibly Performance Payment/Toll	
	Uninsurable risks (throughout the period)	Life Cycle Cost and/or Performance Payment/Toll	
	Political Force Majeure	O&M Cost and possibly Performance Payment/Toll	
Revenue Risk	Non-availability of road	Government Budget	-
	Volume risk	O&M Cost and possibly Performance Payment/Toll	
	Underperformance caused by tolling system	O&M Cost and possibly Performance Payment/Toll	-
O&M Risk	Increased maintenance due to traffic volume	O&M Cost and possibly Performance Payment/Toll	-
	Incorrect estimates and cost overruns	O&M Cost and possibly Performance Payment/Toll	
	Actual operating and maintenance costs higher than anticipated	O&M Cost and possibly Performance Payment/Toll	-

Type of Risk	Risk	Cost Driver	Mitigation
	Equipment used becomes prematurely obsolescent	Life Cycle Cost	-
Performance Risk	Labour and material availability	Life Cycle Costs	
	Interface with sub-contractors	Life Cycle Costs	-
	Change in scope of service specifications by RHD	Life Cycle Costs	
	Expansion for traffic accommodation at ramps and interchanges due to traffic growth, or signalization	Life Cycle Costs	-
	Future interchanges or additional lanes	Life Cycle Cost	
	Damage caused by unauthorized tyres e.g., spikes	Life Cycle Costs	Responsibility of RHD
	Damage/injury to third parties	Life Cycle Costs	
	Damage to works, however caused, except as excluded	Life Cycle Costs	
	Water/air/soil pollution	Life Cycle Cost and/ or Performance Payment/Toll	
	Third party claims and accidents	Life Cycle Cost and/ or Performance Payment/Toll	
	Overloaded Vehicles	Life Cycle Cost and/or Performance Payment/Toll	
	Legal loading limits increased	Life Cycle Cost and/or Performance Payment/Toll	
	Traffic accidents	Life Cycle Cost and/or Performance Payment/Toll	
	Off road incidents	O&M Cost	
	Workplace Health and Safety	O&M Cost	
	Labour disputes	O&M Cost	
	Vandalism	Performance	

Type of Risk	Risk	Cost Driver	Mitigation
	Development Around Project Site Requiring Further Over Bridges or Under Passes or other Demographic Changes	Payment/Toll	
	Traffic Management	Life Cycle Cost	
Market Risk	Base interest rates to Financial Close	O&M Cost and possibly Performance Payment/Toll	
	Interest spread risk to Financial close	Life Cycle Costs	
	Currency fluctuations	Life Cycle Costs	
	Inflation on Construction Costs	Life Cycle Cost	
	Inflation on Operation, Maintenance, Rehabilitation	Life Cycle Cost	
	Costs of finance on change of requirements	Life Cycle Cost	
Other Market Risk	Change in law	Life Cycle Cost	
	General	Life Cycle Costs	
	Change in Toll operator	Life Cycle Costs	

9.4 General Description of Risk & Mitigation

Table 9-3: General Risk and Mitigation

Type of Risk	Risk	Cost Driver	Risk Allocation	Mitigation
Design Risk	Time overrun due to delays in approval of detailed design	Construction Costs	RHD	Timely Deployment of Proof Consultant
	Time overrun due to delays in approval of working drawings	Construction Cost	RHD	Timely Deployment of Construction Supervision Consultant
Site Risk	Land acquisition for the Project	Construction Cost	RHD	Proper Mitigation in the Contract Agreement between RHD & Contractor.
	Site Security	Construction Cost	RHD & Contractor	
	Environmental	Construction Cost	Contractor	

Construction Risk	Quality assurance and quality control	Construction Cost	Contractor	Proper Mitigation in the Contract Agreement between RHD & Contractor.
	Achieving Construction Standards and Specifications	Construction Cost	Contractor	
	Fit for purpose manuals, approvals and statutory certificates	Construction Cost	Contractor	
	Cost overrun and delay not caused by a relief or compensation event	Construction cost	Contractor	
	Shifting of utilities	Construction Cost	Contractor	
	Delays caused by Private Party	Construction Cost	Contractor	
	Delays due to Client's changes	Construction and possibly O&M cost	RHD	
	Labour disputes	Construction Cost	Contractor	
	Project management /integration / delay	Construction Cost	Contractor	
	Damage/injury to third parties	Construction Cost	Contractor	
	Adequacy of insurance	Construction Cost	Contractor	
	Sub-contractor insolvency	Construction Cost	Contractor	
Post-construction risk	Latent defects	Life Cycle Cost	Contractor	
	Workplace Health and Safety	Life Cycle Cost	Contractor	

9.5 Sensitivity of Risks

The following Table 9-4 shows the sensitivity of risks associated with the project and its duration to impact the project, mainly during construction.

Table 9-4: Sensitivity of Risks

Sl. No	Risk Area	Sensitivity	Relevance
1	Delays in land acquisition	High	Construction Period
2	External Linkages	Low	Construction Period
3	Financing Risk	Medium	Construction Period

Sl. No	Risk Area	Sensitivity	Relevance
4	Planning	Medium	Construction Period
5	Approvals	High	Construction Period
6	Design Risk	Medium	Construction Period
7	Construction Risk	Medium	Construction Period
8	Technology Risk	Low	Throughout
9	O&M Risk	Medium	Throughout
10	Traffic Risk	High	Throughout
11	Payment Risk	High	Throughout
12	Financial Risk	Medium	Throughout
13	Change in Law	Low	Throughout
14	Force Majeure	Low	Throughout
15	Sponsor Risk	Medium	Throughout
16	Government event risk	Low	Throughout
17	Guarantor Risk if Government	Low	Throughout

10 ALTERNATIVE/OPTION ANALYSIS

Based on the detailed site reconnaissance and map study, two alternative alignment options have been proposed considering the suitable Bridge locations over the Nitai River. Further, a joint site visit of the Consultant with the RHD officials for the alignment review was done on 16 February 2024. Among these options, the Alignment Option 1 emerged as the most preferred choice based on reports such as the Alignment Option Study Report, Bridge Option Study Report, and Multicriteria Analysis. Consequently, the Draft Feasibility Study Report (DFS) recommended Alignment Option 1 with a Bowstring Steel Truss Bridge.

Following this recommendation, DFSR workshop was held on March 13, 2024, where RHD (Roads and Highways Department) officials approved **Alignment Option 1** with the **Steel Tied Arch Bridge**. Subsequently, a topographic survey was conducted, resulting in minor adjustments to the preferred alignment based on actual survey data and geometric design parameters.

These adjustments do not have any significant impact on the overall suitability and ranking of the proposed alignment. Hence, the Alternative Alignment Option study, decision matrix, and sensitivity analysis prepared during the DFS stage have been retained.

10.1 Evaluation of Alternative Bridge Options through Decision Matrix

In this study, a set of span arrangements (3 options for Alignment Option 1 and 2) has been finalized for each alignment option. All the options have been evaluated based on some common parameters. Accordingly, a suitable bridge option has been decided based on the best scoring bridge. All the 3 options are detailed below:

Bridge Options in Alignment Option 1 and Alignment Option 2

- Option A: Steel Tied Arch + PSC I-Girder
- Option B: Balanced Cantilever Bridge
- Option C: Bowstring Steel Truss + PSC I-Girder

Suitable bridge option has been proposed through the best scoring according to evaluation through decision matrix as given presented below.

DECISION MATRIX OF BRIDGE OPTION STUDY – ALIGNMENT OPTION 1 and 2

SL. NO.	ASPECTS	PARAMETER	UNIT	RELATION	WEIGHTAGE	MAX SCORE	Option A (Steel Tied Arch +PSC I-Girder)		Option B (Balanced Cantilever)		Option C (Bowstring Steel Truss +PSC I Girder)	
							QTY	SCORE	QTY	SCORE	QTY	SCORE
A1	Design & Serviceability	Depth of superstructure	m	Equation-1	15%	10	2.00	4.00	5.40	1.48	0.80	10.00
A2	Design & Serviceability	Skew angle	degree	Equation-1		5	0.00	5.00	0.00	5.00	0.00	5.00
A3	Design & Serviceability	Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Annexure-1		10	125.00	10.00	120.00	9.86	90.00	9.00
A	Sub Score - Design & Serviceability					25		19.00		16.34		24.00
B1	Constructability	Total bridge length	m	Equation-1	15%	10	205.0	10.00	260.0	7.88	210.0	9.76
B2	Constructability	Maximum single span Length (for Difficulty, duration, safety hazards)	m	Annexure-2		15	125.00	14.52	120.00	11.52	90.00	15.00
B	Sub Score - Constructability					25		24.52		19.40		24.76
C1	Aesthetic	Suitability with the terrain and culture		Based on judgement	20%	15	Best	15.00	Good	5.00	Better	14.00
C2	Aesthetic	Integrity between superstructure and substructure				15	Better	7.00	Best	15.00	Good	5.00
C	Sub Score - Aesthetic					30		22.00		20.00		19.00
D1	Environment	Total carbon consumption Proportionate to structural concrete quantity	cum	Equation-1	20%	10	7890.0	10.00	17131.0	4.61	8434.1	9.35
D2	Environment	Obstruction in waterway due to structure inside the perennial river	m	Equation-1		20	7.0	20.00	12.4	11.29	7.5	18.67
D	Sub Score - Environment					30		30.00		15.90		28.02
E1	Cost	Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation-1	30%	15	50.40	14.81	76.65	9.74	49.76	15.00
E2	Cost	Approximate Cost of Superstructure	Cr (BDT)	Equation-1		15	83.61	10.53	58.72	15.00	69.50	12.67
E3	Cost	Approximate Maintenance cost for entire service life	Cr (BDT)	Equation-1		15	60.30	14.83	67.69	13.21	59.63	15.00
E	Sub Score - Cost					45		40.18		37.95		42.67
	Total Score					**155**		**135.70**		**109.59**		**138.46**
	Percentage Score					**100**		**87.55**		**70.70**		**89.33**
	Preferred Option						**Option C (Bowstring Steel Truss +PSC I Girder))**					

From the overall consideration of the evaluation, the **Bridge Option C (Bowstring Steel Truss + PSC I Girder)** is observed as **preferred option for both Alignment option 1 and 2**.

it can be seen that the total score of Option C (Bowstring Steel Truss + PSC I Girder) is 1.78% higher than Option A (Steel Tied Arch + PSC I-Girder). Further it can be observed that Option C (Bowstring Steel Truss + PSC I Girder) is 19% (nearly) higher than Option B (Balanced Cantilever). Hence it can be inferred that Option A (Steel Tied Arch + PSC I-Girder) and Option C (Bowstring Steel Truss +PSC I Girder) is more or less equally preferable. And Option B (Balanced Cantilever) is not preferable here with respect to Option A (Steel Tied Arch + PSC I-Girder) and Option C (Bowstring Steel Truss + PSC I Girder) based on the parameters related to suitability with terrain and culture for being near hill region.

But according to the MOM (Ref. GEN-MOM-0036) The preferred bridge option would be as below:

- The proposed preferred alignment option-1 is acceptable.
- The main bridge form shall be bridge option A (Steel Tied Arch + PSC I Girder) with span arrangement of 2 X 40.0m + 1 X 125.0m 2 X 40.0m.
- The form has been preferred in terms of constructability and possibility of having advantage during packaging of Construction Contract.

It shall be noted that, 40+125+40m span in workshop MOM is based on DFSR submission where approach viaduct was multiple span of simply supported 40m PSC I Girder system. Now the viaduct arrangement rearranged with 32+40+32 m integral module for further optimization. Accordingly, main bridge span arrangement has been updated as 32+125+32 while combining with approach viaduct.

The salient features of the preferred option are given below:

Option A: Steel Tied Arch + PSC I-Girder:

This option has been adopted primarily from navigational requirement.

Span arrangement -	1 x 32 + 1 x 125 + 1 x 32 m
Total length of main bridge -	189.0 m
Skew angle -	0 degree
Superstructure type -	125.0m m & 32.0m Steel Tied Arch & PSC I Girder
Overall Deck width -	1 x 19.85 m
Support condition -	Simple Supported
Lane configuration -	2 lane + 2 Lane -SMVT
Structural feature -	Steel Tied Arch with PSC I Girder Bridge

For both the options, soffit level considers the climate change effect (0.38 m anticipated sea level rise) as inferred in the “Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh Portion)” Dated in November 2021, done by Institute of Water Modelling (IWM).

10.2 Evaluation of Multi-Criteria Analysis Through Final Decision Matrix

The final decision matrix for concurring the Alignment Option was developed by combining the individual scores of the parameters with the application of weightage for different Criteria as detailed below.

CRITERIA	WEIGHTAGE
Highway Engineering Criteria	0.050
Bridge Engineering Criteria	0.300
Social Criteria	0.075
Environment Criteria	0.075

CRITERIA	WEIGHTAGE
Hydro-Morphological Criteria	0.200
Indicative Cost Criteria	0.300
Total	**1.00**

The choice for the Alignment Option was also ratified through Sensitivity Analysis. "*Sensitivity of the final scoring with respect to the adopted weightages*" has been done, by developing decision matrixes in 4 scenarios with different weightage combinations, as detailed below.

Aspect	Weightage Adopted in Different Scenarios			
	Scenario I	Scenario II	Scenario III	Scenario IV
Highway Engineering Criteria	0.050	0.050	0.050	0.167
Bridge Engineering Criteria	0.300	0.300	0.300	0.167
Social Criteria	0.050	0.075	0.050	0.167
Environment Criteria	0.050	0.075	0.050	0.167
Hydro-Morphological Criteria	0.200	0.250	0.300	0.167
Indicative Cost Criteria	0.350	0.250	0.250	0.167
Total	**1.00**	**1.00**	**1.00**	**1.00**

MULTICRITERIA DECISION MATRIX

BASIC ASPECTS	SUB ASPECTS	PARAMETERS	UNIT	RELATION	MAX. SCORE	WEIGHTAGE	WEIGHTED MAXIMUM SCORE	OPTION - 1		OPTION - 2	
								QTY	SCORE	QTY	SCORE
Highway Engineering		Total Length	km	Equation 1	10	0.050	0.50	2.52	0.50	2.69	0.47
		Length of at grade highway	km	Equation 1	10	0.050	0.50	1.68	0.50	1.84	0.46
		Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.050	0.50	799.26	0.48	770.51	0.50
		Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.050	0.50	177.03	0.50	239.91	0.37
Bridge Engineering*	Design	Depth of superstructure	m	Equation 1	10	0.300	0.80	3.00	0.80	3.00	3.00
		Skew angle (w.r.t. Equation 2ion of flow)	degree	Equation 1	5	0.300	0.00	1.50	0.00	1.50	1.50
		Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Equation 1	10	0.300	90.00	3.00	90.00	3.00	3.00
	Constructability	Total bridge length	m	Equation 1	10	0.300	210.00	3.00	210.00	3.00	3.00
		Maximum single span Length (for Difficulty, duration, safety hazards)	m	Equation 2	15	0.300	90.00	4.50	90.00	4.50	4.50
	Aesthetic	Suitability with the terrain and culture	Based on judgement		15	0.300	4.50	Better	3.00	Better	3.00
		Integrity between superstructure and substructure			15	0.300	4.50	Good	1.50	Good	1.50
	Environment	Total carbon consumption proportionate to structural concrete quantity	cum	Equation 1	10	0.300	8434.10	3.00	8434.10	3.00	3.00
		Obstruction in waterway due to structure inside the perennial river	m	Equation 1	20	0.300	7.50	6.00	7.50	6.00	6.00
Social		Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.075	0.75	12.00	0.75	23.00	0.39
		Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Approximate Total land to be acquired	Ha	Equation 1	10	0.075	0.75	8.16	0.75	8.70	0.70
		Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.075	0.75	7.15	0.75	7.70	0.70
Environment		Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.075	0.75	100.00	0.75	132.00	0.57
		Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.075	0.75	0.68	0.75	0.94	0.54
Hydro-Morphological Studies#		Rank of the Bridge Option	Rank	Equation 2	10	0.200	2.00	1.00	2.00	2.00	1.00
		Stability of the Bank: Approximate Bank Length requiring River Training Works	m	Equation 1	10	0.200	2.00	364.00	2.00	364.00	2.00
Indicative Cost*		Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.300	3.00	152.16	3.00	152.16	3.00
		Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation 1	15	0.300	4.50	49.76	4.50	49.76	4.50
		Approximate Cost of Superstructure	Cr (BDT)	Equation 1	15	0.300	4.50	69.50	4.50	69.50	4.50
		Approximate Maintenance cost for entire service life	Cr (BDT)	Equation 1	15	0.300	4.50	59.63	4.50	59.63	4.50
		Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.300	3.00	361.01	3.00	363.21	2.98
Total Weighted Score							**65**		**59.98**		**57.93**
Percentage Score									**93.00**		**89.81**
RANK									**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1A in Alignment Option 1 & Bridge Option 2A in Alignment Option 2. Refer "Bridge Option Study Report (Mahadev Bridge)" – Document No.: 5060143-8BRP-STR-RPT-006-R1*

 # The parameter values pertain to Bridge Site B (nearly matches with the Bridge Location at Alignment Option 1) and Bridge Site A (nearly matches with the Bridge Location at Alignment Option 2). Bridge Site C and Bridge Site D as shown in the Hydro-morphological report is respectively 100 m and 800 m downstream of termination point of the Border Road on the left and right bank of Mahadev River. Hence, these locations are as such not considered. Refer "Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM).

MULTICRITERIA DECISION MATRIX – SENSITIVITY ANALYSIS FOR SCENARIO I

BASIC ASPECTS	SUB ASPECTS	PARAMETERS	UNIT	RELATION	MAX. SCORE	WEIGHTAGE	WEIGHTED MAXIMUM SCORE	OPTION - 1		OPTION - 2	
								QTY	SCORE	QTY	SCORE
Highway Engineering		Total Length	km	Equation 1	10	0.050	0.50	2.52	0.50	2.69	0.47
		Length of at grade highway	km	Equation 1	10	0.050	0.50	1.68	0.50	1.84	0.46
		Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.050	0.50	799.26	0.48	770.51	0.50
		Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.050	0.50	177.03	0.50	239.91	0.37
Bridge Engineering*	Design	Depth of superstructure	m	Equation 1	10	0.300	0.80	3.00	0.80	3.00	3.00
		Skew angle (w.r.t. Equation 2ion of flow)	degree	Equation 1	5	0.300	0.00	1.50	0.00	1.50	1.50
		Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Equation 1	10	0.300	90.00	3.00	90.00	3.00	3.00
	Constructability	Total bridge length	m	Equation 1	10	0.300	210.00	3.00	210.00	3.00	3.00
		Maximum single span Length (for Difficulty, duration, safety hazards)	m	Equation 2	15	0.300	90.00	4.50	90.00	4.50	4.50
	Aesthetic	Suitability with the terrain and culture	Based on judgement		15	0.300	0.300	Better	3.00	Better	3.00
		Integrity between superstructure and substructure			15	0.300	0.300	Good	1.50	Good	1.50
	Environment	Total carbon consumption proportionate to structural concrete quantity	cum	Equation 1	10	0.300	8434.10	3.00	8434.1	3.00	3.00
		Obstruction in waterway due to structure inside the perennial river	m	Equation 1	20	0.300	7.50	6.00	7.50	6.00	6.00
Social		Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.050	0.50	12.00	0.50	23.00	0.26
		Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Approximate Total land to be acquired	Ha	Equation 1	10	0.050	0.50	8.16	0.50	8.70	0.47
		Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.050	0.50	7.15	0.50	7.70	0.46
Environment		Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.050	0.50	100.00	0.50	132.00	0.38
		Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.050	0.50	0.68	0.50	0.94	0.36
Hydro-Morphological Studies#		Rank of the Bridge Option	Rank	Equation 2	10	0.200	2.00	1.00	2.00	2.00	1.00
		Stability of the Bank: Approximate Bank Length requiring River Training Works	m	Equation 1	10	0.200	2.00	364.00	2.00	364.00	2.00
Indicative Cost*		Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.350	3.50	152.16	3.50	152.16	3.50
		Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation 1	15	0.350	5.25	49.76	5.25	49.76	5.25
		Approximate Cost of Superstructure	Cr (BDT)	Equation 1	15	0.350	5.25	69.50	5.25	69.50	5.25
		Approximate Maintenance cost for entire service life	Cr (BDT)	Equation 1	15	0.350	5.25	59.63	5.25	59.63	5.25
		Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.350	3.50	361.01	3.50	363.21	3.48
Total Weighted Score							**66**		**61.23**		**59.46**
Percentage Score									**93.13**		**90.43**
RANK									**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1C in Alignment Option 1 & Bridge Option 2C in Alignment Option 2. Refer "Bridge Option Study Report (Mahadev Bridge)" – Document No.: 5060143-8BRP-STR-RPT-006-R1*

 # The parameter values pertain to Bridge Site B (nearly matches with the Bridge Location at Alignment Option 1) and Bridge Site A (nearly matches with the Bridge Location at Alignment Option 2). Bridge Site C and Bridge Site D as shown in the Hydro-morphological report is respectively 100 m and 800 m downstream of termination point of the Border Road on the left and right bank of Mahadev River. Hence, these locations are as such not considered. Refer "Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM).

MULTICRITERIA DECISION MATRIX – SENSITIVITY ANALYSIS FOR SCENARIO II

Basic Aspects	Sub Aspects	Parameters	Unit	Relation	Max. Score	Weightage	Weighted Maximum Score	Option - 1		Option - 2	
								QTY	SCORE	QTY	SCORE
Highway Engineering		Total Length	km	Equation 1	10	0.050	0.50	2.52	0.50	2.69	0.47
		Length of at grade highway	km	Equation 1	10	0.050	0.50	1.68	0.50	1.84	0.46
		Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.050	0.50	799.26	0.48	770.51	0.50
		Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.050	0.50	177.03	0.50	239.91	0.37
Bridge Engineering*	Design	Depth of superstructure	m	Equation 1	10	0.300	0.80	3.00	0.80	3.00	3.00
		Skew angle (w.r.t. Equation 2ion of flow)	degree	Equation 1	5	0.300	0.00	1.50	0.00	1.50	1.50
		Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Equation 1	10	0.300	90.00	3.00	90.00	3.00	3.00
	Constructability	Total bridge length	m	Equation 1	10	0.300	210.00	3.00	210.00	3.00	3.00
		Maximum single span Length (for Difficulty, duration, safety hazards)	m	Equation 2	15	0.300	90.00	4.50	90.00	4.50	4.50
	Aesthetic	Suitability with the terrain and culture	Based on judgement		15	0.300	0.300	Better	3.00	Better	3.00
		Integrity between superstructure and substructure			15	0.300	0.300	Good	1.50	Good	1.50
	Environment	Total carbon consumption proportionate to structural concrete quantity	cum	Equation 1	10	0.300	8434.10	3.00	8434.1	3.00	3.00
		Obstruction in waterway due to structure inside the perennial river	m	Equation 1	20	0.300	7.50	6.00	7.50	6.00	6.00
Social		Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.075	0.75	12.00	0.75	23.00	0.39
		Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Approximate Total land to be acquired	Ha	Equation 1	10	0.075	0.75	8.16	0.75	8.70	0.70
		Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.075	0.75	7.15	0.75	7.70	0.70
Environment		Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.075	0.75	0.00	0.75	0.00	0.75
		Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.075	0.75	100.00	0.75	132.00	0.57
		Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.075	0.75	0.68	0.75	0.94	0.54
Hydro-Morphological Studies#		Rank of the Bridge Option	Rank	Equation 2	10	0.250	2.50	1.00	2.50	2.00	1.25
		Stability of the Bank: Approximate Bank Length requiring River Training Works	m	Equation 1	10	0.250	2.50	364.00	2.50	364.00	2.50
Indicative Cost*		Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.250	2.50	152.16	2.50	152.16	2.50
		Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation 1	15	0.250	3.75	49.76	3.75	49.76	3.75
		Approximate Cost of Superstructure	Cr (BDT)	Equation 1	15	0.250	3.75	69.50	3.75	69.50	3.75
		Approximate Maintenance cost for entire service life	Cr (BDT)	Equation 1	15	0.250	3.75	59.63	3.75	59.63	3.75
		Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.250	2.50	361.01	2.50	363.21	2.48
Total Weighted Score							**62**		**57.73**		**55.24**
Percentage Score									**92.74**		**88.73**
RANK									**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1C in Alignment Option 1 & Bridge Option 2C in Alignment Option 2. Refer "Bridge Option Study Report (Mahadev Bridge)" – Document No.: 5060143-8BRP-STR-RPT-006-R1*

 # The parameter values pertain to Bridge Site B (nearly matches with the Bridge Location at Alignment Option 1) and Bridge Site A (nearly matches with the Bridge Location at Alignment Option 2). Bridge Site C and Bridge Site D as shown in the Hydro-morphological report is respectively 100 m and 800 m downstream of termination point of the Border Road on the left and right bank of Mahadev River. Hence, these locations are as such not considered. Refer "Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM).

MULTICRITERIA DECISION MATRIX – SENSITIVITY ANALYSIS FOR SCENARIO III

BASIC ASPECTS	SUB ASPECTS	PARAMETERS	UNIT	RELATION	MAX. SCORE	WEIGHTAGE	WEIGHTED MAXIMUM SCORE	OPTION - 1		OPTION - 2	
								QTY	SCORE	QTY	SCORE
Highway Engineering		Total Length	km	Equation 1	10	0.050	0.50	2.52	0.50	2.69	0.47
		Length of at grade highway	km	Equation 1	10	0.050	0.50	1.68	0.50	1.84	0.46
		Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.050	0.50	799.26	0.48	770.51	0.50
		Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.050	0.50	177.03	0.50	239.91	0.37
Bridge Engineering*	Design	Depth of superstructure	m	Equation 1	10	0.030	0.80	3.00	0.80	3.00	3.00
		Skew angle (w.r.t. Equation 2ion of flow)	degree	Equation 1	5	0.030	0.00	1.50	0.00	1.50	1.50
		Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Equation 1	10	0.030	90.00	3.00	90.00	3.00	3.00
	Constructability	Total bridge length	m	Equation 1	10	0.030	210.00	3.00	210.00	3.00	3.00
		Maximum single span Length (for Difficulty, duration, safety hazards)	m	Equation 2	15	0.030	90.00	4.50	90.00	4.50	4.50
	Aesthetic	Suitability with the terrain and culture	Based on judgement		15	0.300	0.030	Better	3.00	Better	3.00
		Integrity between superstructure and substructure			15	0.300	0.030	Good	1.50	Good	1.50
	Environment	Total carbon consumption proportionate to structural concrete quantity	cum	Equation 1	10	0.030	8434.10	3.00	8434.1	3.00	3.00
		Obstruction in waterway due to structure inside the perennial river	m	Equation 1	20	0.030	7.50	6.00	7.50	6.00	6.00
Social		Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.050	0.50	12.00	0.50	23.00	0.26
		Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Approximate Total land to be acquired	Ha	Equation 1	10	0.050	0.50	8.16	0.50	8.70	0.47
		Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.050	0.50	7.15	0.50	7.70	0.46
Environment		Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.050	0.50	0.00	0.50	0.00	0.50
		Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.050	0.50	100.00	0.50	132.00	0.38
		Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.050	0.50	0.68	0.50	0.94	0.36
Hydro-Morphological Studies#		Rank of the Bridge Option	Rank	Equation 2	10	0.300	3.00	1.00	3.00	2.00	1.50
		Stability of the Bank: Approximate Bank Length requiring River Training Works	m	Equation 1	10	0.300	3.00	364.00	3.00	364.00	3.00
Indicative Cost*		Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.250	2.50	152.16	2.50	152.16	2.50
		Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation 1	15	0.250	3.75	49.76	3.75	49.76	3.75
		Approximate Cost of Superstructure	Cr (BDT)	Equation 1	15	0.250	3.75	69.50	3.75	69.50	3.75
		Approximate Maintenance cost for entire service life	Cr (BDT)	Equation 1	15	0.250	3.75	59.63	3.75	59.63	3.75
		Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.250	2.50	361.01	2.50	363.21	2.48
Total Weighted Score							**61**		**56.73**		**54.46**
Percentage Score									**92.62**		**88.92**
RANK									**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1C in Alignment Option 1 & Bridge Option 2C in Alignment Option 2. Refer "Bridge Option Study Report (Mahadev Bridge)" – Document No.: 5060143-8BRP-STR-RPT-006-R1*

 # The parameter values pertain to Bridge Site B (nearly matches with the Bridge Location at Alignment Option 1) and Bridge Site A (nearly matches with the Bridge Location at Alignment Option 2). Bridge Site C and Bridge Site D as shown in the Hydro-morphological report is respectively 100 m and 800 m downstream of termination point of the Border Road on the left and right bank of Mahadev River. Hence, these locations are as such not considered. Refer "Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM).

MULTICRITERIA DECISION MATRIX – SENSITIVITY ANALYSIS FOR SCENARIO IV

BASIC ASPECTS	SUB ASPECTS	PARAMETERS	UNIT	RELATION	MAX. SCORE	WEIGHTAGE	WEIGHTED MAXIMUM SCORE	OPTION - 1		OPTION - 2	
								QTY	SCORE	QTY	SCORE
Highway Engineering		Total Length	km	Equation 1	10	0.167	1.67	2.52	1.67	2.69	1.56
		Length of at grade highway	km	Equation 1	10	0.167	1.67	1.68	1.67	1.84	1.52
		Horizontal Geometry: Total length of curves having Superelevation	m	Equation 1	10	0.167	1.67	799.26	1.61	770.51	1.67
		Horizontal Geometry: Total deflection angle	degree	Equation 1	10	0.167	1.67	177.03	1.67	239.91	1.23
Bridge Engineering*	Design	Depth of superstructure	m	Equation 1	10	0.167	0.80	1.67	0.80	1.67	1.67
		Skew angle (w.r.t. Equation 2ion of flow)	degree	Equation 1	5	0.167	0.00	0.83	0.00	0.83	0.83
		Maximum single span Length (for Functionality, Analysis, indeterminacy, performance etc.)	m	Equation 1	10	0.167	90.00	1.67	90.00	1.67	1.67
	Constructability	Total bridge length	m	Equation 1	10	0.167	210.00	1.67	210.00	1.67	1.67
		Maximum single span Length (for Difficulty, duration, safety hazards)	m	Equation 2	15	0.167	90.00	2.50	90.00	2.50	2.50
	Aesthetic	Suitability with the terrain and culture	Based on judgement		15	0.167	0.167	Better	1.67	Better	1.67
		Integrity between superstructure and substructure			15	0.167	0.167	Good	0.83	Good	0.83
	Environment	Total carbon consumption proportionate to structural concrete quantity	cum	Equation 1	10	0.167	8434.10	1.67	8434.1	1.67	1.67
		Obstruction in waterway due to structure inside the perennial river	m	Equation 1	20	0.167	7.50	3.33	7.50	3.33	3.33
Social		Approximate no. of Structures to be dismantled	Nos.	Equation 1	10	0.167	1.67	12.00	1.67	23.00	0.87
		Number of Sensitive Buildings like mosque, graveyard, etc. to be dismantled	Nos.	Equation 1	10	0.167	1.67	0.00	1.67	0.00	1.67
		Livelihood Impact/Impact on local market (No of Shops affected)	Nos.	Equation 1	10	0.167	1.67	0.00	1.67	0.00	1.67
		Approximate Total land to be acquired	Ha	Equation 1	10	0.167	1.67	8.16	1.67	8.70	1.56
		Approximate Agricultural Land to be acquired	Ha	Equation 1	10	0.167	1.67	7.15	1.67	7.70	1.55
Environment		Approximate Fisheries Land to be acquired	Ha	Equation 1	10	0.167	1.67	0.00	1.67	0.00	1.67
		Impact on Vegetation (Approximate no. of trees affected)	Ha	Equation 1	10	0.167	1.67	100.00	1.67	132.00	1.26
		Impact on Waterbody (Area of Pond excluding Fisheries)	Ha	Equation 1	10	0.167	1.67	0.68	1.67	0.94	1.21
Hydro-Morphological Studies#		Rank of the Bridge Option	Rank	Equation 2	10	0.167	1.67	1.00	1.67	2.00	0.83
		Stability of the Bank: Approximate Bank Length requiring River Training Works	m	Equation 1	10	0.167	1.67	364.00	1.67	364.00	1.67
Indicative Cost*		Approximate Cost of the Viaduct Section	Cr (BDT)	Equation 1	10	0.167	1.67	152.16	1.67	152.16	1.67
		Approximate Cost of Substructure & Foundation	Cr (BDT)	Equation 1	15	0.167	2.50	49.76	2.50	49.76	2.50
		Approximate Cost of Superstructure	Cr (BDT)	Equation 1	15	0.167	2.50	69.50	2.50	69.50	2.50
		Approximate Maintenance cost for entire service life	Cr (BDT)	Equation 1	15	0.167	2.50	59.63	2.50	59.63	2.50
		Approximate Total Civil Construction Cost	Cr (BDT)	Equation 1	10	0.167	1.67	361.01	1.67	363.21	1.66
Total Weighted Score							**53**		**49.95**		**46.60**
Percentage Score									**95.14**		**88.76**
RANK									**1.00**		**2.00**

** The parameter values pertain to the Bridge Option 1A in Alignment Option 1 & Bridge Option 2A in Alignment Option 2. Refer "Bridge Option Study Report (Ganeshwari Bridge)" – Document No.: 5060143-8BRP-STR-RPT-002-R1*

 # The parameter values pertain to Bridge Site B (nearly matches with both the Bridge Location at Alignment Option 1 and Alignment Option 2). Bridge Site B helps in the existing connectivity route on the 2 sides of the river Bridge Site A, Bridge Site C & Bridge Site D as shown in the Hydro-morphological report is 200 m, 50 m upstream and 507 m downstream of existing Rubber Dam. Hence, these locations are as such not considered. Refer "Hydro-Morphological study of Mahadev Bridge at 9th Km, Ganeshwari Bridge at 20th Km, Someshwari Bridge at 36th Km and Nitai Bridge at 50th Km of Border Road (Netrokona and Mymensingh Portion) during the year 2019-2020" dated in November 2021 by Institute of Water Modelling (IWM)

The results from the Tables above infer very clearly the Alignment Option 1 as the Rank 1 in all the Scenarios. The difference in the score between the two Alignment Options, in the 4 Weightage Scenarios ranges only from 2.70% to 6.38%. The high score of the Alignment Option 1 accredits to its superiority, primarily with respect to Highway Engineering, Social, Environment, Hydro–Morphological Studies, and Indicative Cost aspects.

Hence it can be well inferred that Alignment Option 1 is the preferred alignment with respect to the Bridge location as well as overall Project Road Alignment.

Further, it can be noted that, **the proposed Bridge Location in the Alignment Option 1 also matches tentatively with the Preferred Option as per Hydrological and Morphological Study carried out in 2022 by Institute of Water Modelling (IWM).**

Based on the workshop was held on March 13, 2024, **RHD (Roads and Highways Department) officials approved Alignment Option 1 with the Steel Arch Bridge**.

11 RECOMMENDATION AND CONCLUSION

- The Border Road (Z-2834) is the critical element of connecting the border areas of Kalmakanda, Durgapur, Dhobaura & Haluaghat Upazila and eventually connecting the border area with Sunamganj, Netrokona and Mymensingh district centres. There is a critical gap at 47th Km of the existing road near Ghoshgaon due to Nitai River. Thus, the proposed Nitai bridge has extreme importance for ensuring connectivity between the border areas.
- The border road would also create as infrastructure, having potentiality to facilitate movement of international transit traffic which would promote international trade and commerce for adjoining countries as well as for Bangladesh. This would contribute in economic development of Bangladesh and generate additional revenue.
- The construction of the bridge will lead to savings in VOC, time costs and reduction in emission.
- The construction of the new bridge will increase the health care facilities and will also enhance the educational opportunities.
- The bridge will lead to the development of tourism industry.
- The Project (comprising Nitai, Someshwari-3, Ganeshwari & Mahadev)) has been found to be economically viable with an EIRR of 20.60% and Net Present Value (at 12% Discount rate) of 1430.8 Crores BDT.

Considering immense socio-economic befits to the Project Influence Area and economic viability**, this Project is recommended to be executed as per the approved Alignment Option and approved Bridge form, mentioned in this report**.