CHAPTER 3

TRAFFIC DEMAND FORECAST

3. TRAFFIC DEMAND FORECAST

3.1 General

In this chapter, future traffic volume is estimated on NH-1. As the first step, future traffic volume is estimated based on transport demand (i.e. number of registered vehicles) and the growth parameter (i.e. GDP) affecting the demand for vehicles. Secondly, the effect of the railway and seaport on Chittagong is considered in future traffic.

The total numbers of lanes required are determined in accordance with forecasted traffic volume and standard road capacity. It is found that at least 10-lanes will be required to cope with traffic volume forecasted in 2030. But, widening of NH-1 to more than10-lanes is not realistic. However GoB has a master plan to develop a toll road connecting Dhaka-Chittagong corridor as 8-lanes ahead of Kanchpur Bridge and 6-lanes beyond Gumti Bridge. Therefore, the required numbers of lanes for 2nd bridges are proposed as 4-lanes so as to concurrent with the GoB master plan.

3.2 Future Traffic Growth

The methodology adopted for traffic forecasting incorporates perspective growth envisaged in the economy and changes in transport demand elasticity over a period of time. Thus, past trends in traffic growth, the economy perspective and transport demand elasticity have been studied in detail to forecast traffic demand. The time period for forecasting traffic demand is assumed to be 20 years. The following approaches are adopted for determining the traffic growth rates.

- Based on Trend analysis:
  - ✓ Based on Vehicle Registration Data
- Based on social economic Trend analysis:
  - ✓ Growth of Gross Domestic Product (GDP)

3.2.1 Vehicle Increasing Trend Analysis

The growth of traffic is an important factor for understanding the development of the project area. In this regard, the future traffic increasing trend can be developed by studying historical trends of vehicles. Accordingly, this traffic increasing trend analysis can be computed by considering the registered vehicles as well as the vehicles presently traveling on the road.

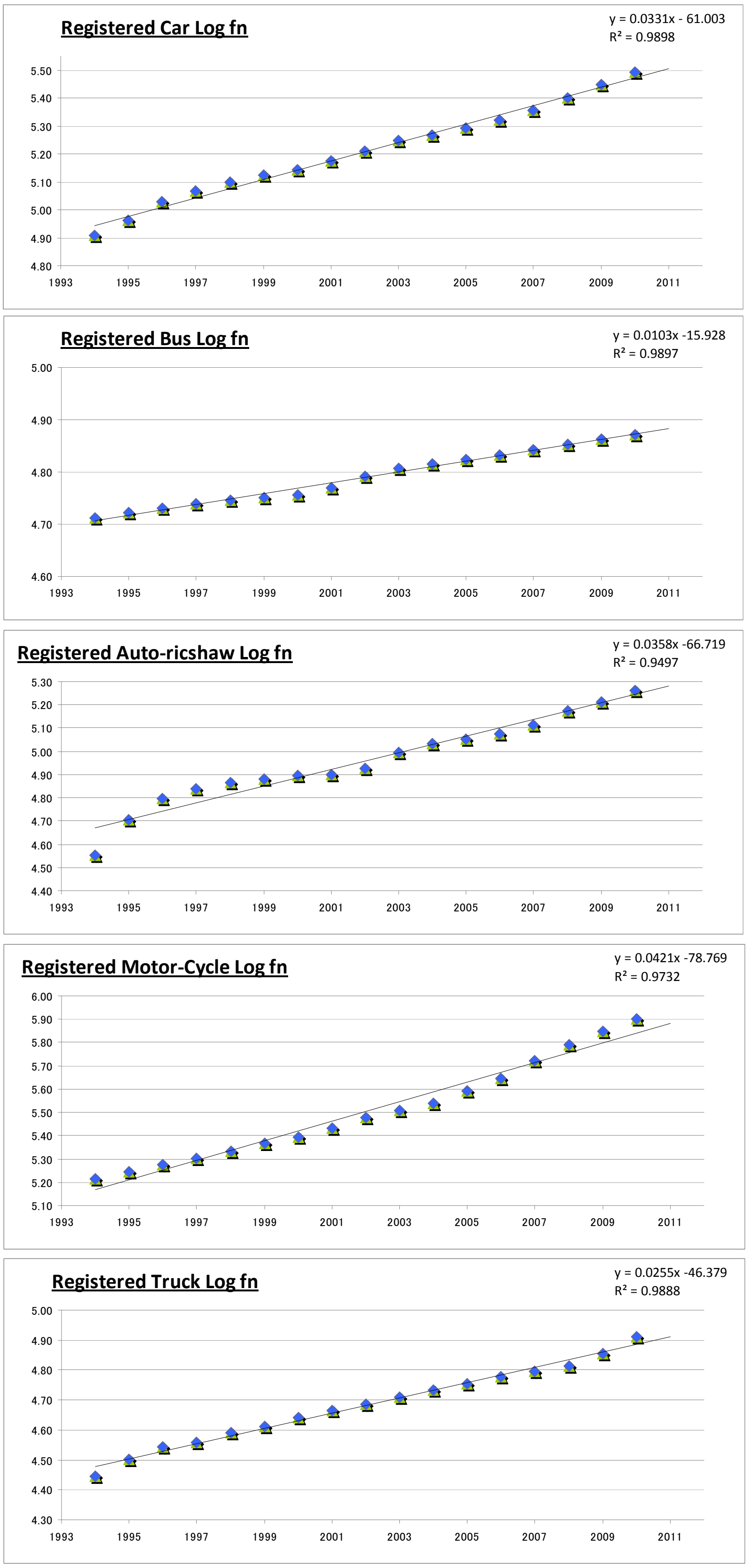
(1) Based on Vehicle Registration Data

The traffic growth rate is an important parameter to predict the expected traffic demand in the future. In this respect, the vehicle registration data is a key measure for traffic growth and for corresponding supporting data the number of registered motor vehicles in Bangladesh is collected from the Bangladesh Road Transport Authority (BRTA). The collected data, Figure 3.2.1, is formulated in terms of the relation between the logarithmic value of the number of registered vehicles and the year. This figure also shows the best fit regression line from which traffic growth rate can be computed. The computed growth rate results are listed in Table 3.2.1.

Table 3.2.1 Growth Rate by Trend Analysis Using Vehicle Registration Data

Registered Vehicle Type	By Regression	By Annual Compound Growth Rate
Car / Jeep	7.04 %	8.83 %
Bus / Minibus	2.41 %	2.32 %
Auto-rickshaw	8.59 %	11.15 %
Motor-Cycle	10.18 %	10.43 %
Truck	6.05 %	6.97 %

Source: JICA Study Team



Source: JICA Study Team

Figure 3.2.1 Log-Log Regressions Based on Vehicle Registration Data

Table 3.2.2 Number of Motor Vehicles Register in Bangladesh

Year	Motor Car	Jeep/St. Wagon	Taxi	Bus	Minibus	Truck	Auto-rickshaw/ Auto-tempo	Motor-Cycle	Total in vehicles	Total in pcu
PCU Equivalency	1.00	1.00	1.00	3.00	3.00	3.00	0.75	0.75		
Type of Vehicles up to 1995	51,312	27,460	1,908	27,510	24,007	27,919	35,586	163,699	359,401	468,452
1995	60,026	29,911	1,936	27,724	25,092	31,706	50,539	175,088	402,022	514,659
1996	72,504	32,319	1,995	27,873	25,887	34,870	62,523	189,065	447,036	561,399
1997	80,858	33,778	2,009	27,972	26,753	36,152	69,087	201,145	477,754	591,950
1998	86,734	36,483	2,112	28,258	27,355	38,885	73,490	215,670	508,987	625,693
1999	91,720	38,752	2,328	28,525	27,834	40,903	75,630	232,181	537,873	655,444
2000	95,807	40,269	2,908	28,862	28,238	43,628	78,765	246,795	565,272	685,338
2001	102,394	43,337	3,679	29,456	29,456	46,203	79,162	271,204	604,891	727,530
2002	109,151	47,119	5,912	30,196	31,770	48,580	84,641	300,251	657,620	782,489
2003	116,196	49,364	10,932	30,617	33,364	51,375	98,497	321,347	711,692	837,443
2004	121,606	51,878	11,472	31,474	33,986	53,958	107,453	346,288	758,115	883,516
2005	128,037	55,841	11,987	32,257	34,347	56,749	112,330	389,514	821,062	942,307
2006	136,484	61,381	12,262	33,277	34,588	59,814	119,228	440,620	897,654	1,013,050
2007	148,425	67,031	12,277	34,645	34,970	62,335	129,758	525,751	1,015,192	1,115,215
2008	165,352	73,568	12,286	35,987	35,277	64,944	148,829	619,292	1,155,535	1,235,921
2009	186,813	82,595	12,298	37,171	35,597	71,505	163,731	704,434	1,294,144	1,365,649
2010	207,503	90,635	12,298	38,404	35,908	81,561	182,749	792,933	1,441,991	1,509,817

Source: BRTA

3.2.2 Based on Socio-Economic Trend Analysis

(1) Growth of Gross Domestic Product

Generally, Gross Domestic Product (GDP) is an indicator of the economic strength of any country, which also reflects the growth of traffic and overall economic performance of that country as well. In this regard, GDP data from years 1997 - 1998 to 2010 – 11 is obtained from Bangladesh Bureau of Statistics, which is summarized in Table 3.2.3. The GDP data from 1995-1996 has been calculated at constant price. For the growth rate calculation, both the log regression and annual compound growth rate method are applied, and the obtained results are shown in Table 3.2.4. It shows that the growth of GDP is found to be 8.08 % and 8.45 % by regression and annual compound growth rate analysis, respectively.

Table 3.2.3 GDP Growth (GDP at constant 1995 – 1996)

Year	GDP(million TK)
1997	1,752,850
1998	1,844,480
1999	1,934,290
2000	2,049,280
2001	2,157,350
2002	2,252,610
2003	2,371,010
2004	2,519,680
2005	2,669,740
2006	2,993,970
2007	3,402,660
2008	3,930,87,
2009	4,427,600
2010	4,986,350

Source: Bangladesh Economic Review Data Edited by JICA Study Team

Table 3.2.4 Growth Rate by Trend Analysis Based on GDP

By Regression	By Annual Compound Growth Rate
8.08 %	8.45 %

Source: JICA Study Team

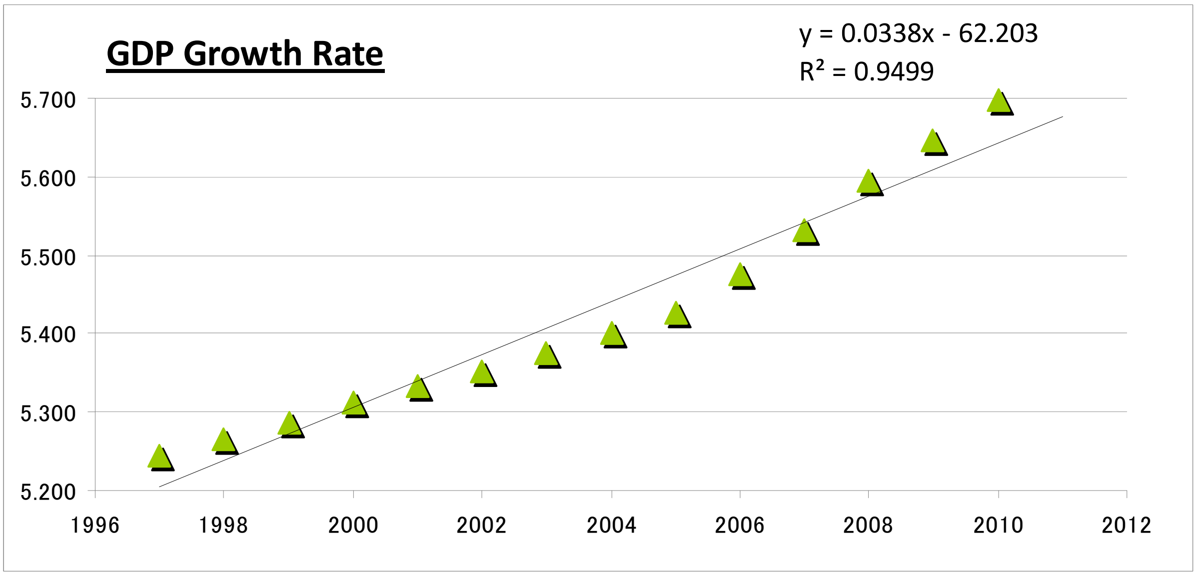


Figure 3.2.2 Growth of GDP

3.2.3 Growth Rate of Future Traffic Volume

Transport demand elasticity is one of the methods of establishing relationships between transport demand (i.e. number of registered vehicles) and the growth parameter (i.e. GDP) affecting the demand for vehicles. This relationship may remain static or may change in the future due to disproportionate changes in the future growth or parameters and/or technological changes in vehicle characteristics. Transport elasticity is a measure of the percentage change in transport demand with respect to percentage change in the parameters influencing the demand. The predictor formula is as below;

$$\text{Elastic coefficient value } (e) = \frac{\text{Percentage change in trasport indicators}}{\text{Percentage change in economic indicators}}$$

Where,

Transport indicator: number of registered vehicles

Economic indicator: Gross Domestic Product (GDP)

Table 3.2.5 Transport Demand Elasticity Values

Vehicle Type	Elasticity Value
Car / Jeep/ St.Wagon/Taxi	1.06
Bus / Minibus	0.36
Auto-rickshaw	1.02
Motor-Cycle	1.44
Truck	0.89

Source: JICA Study Team

Note; Elasticity value of above vehicle type apply to below vehicle type.

Car / Jeep/ St.Wagon/Taxi => Utility, Car/Taxi
Bus / Minibus => Large Bus/Mini Bus, Microbus
Auto-rickshaw => Baby-taxi/Tempo
Motor-Cycle => Motor-Cycle
Truck => Large/Medium/Small Truck

< Reference: Definition of Utility>

Utility indicates Pick-ups, jeeps and four wheels drive vehicles, such as Pajero and LandRover in Manual Traffic Counts Instruction Guide by RHD.

Figure. Image of Utility

Source: Manual Traffic Counts Instruction Guide by RHD

The predictor formula of growth rate is as below;

$$G = e \times G_{GDP}$$

Where : e = Elasticity of Transport demand

G_{GDP} = Gross domestic product growth rate

G= growth rate

GDP growth in Bangladesh has remained steady in recent years (1997 – 2010). The ministry of finance estimates that GDP growth will remain within a range of 6.7 %-8.0 % in the next term (2011-2015). Based on this range, 8.0 % is used as the high assumption for GDP, 6.7 % is used as the low assumption for GDP and their average 7.35 % is used as the medium assumption in this study. Accordingly, the study assumed the following rates of GDP growth and overall traffic increase when carrying out estimations of future traffic volumes.

Table 3.2.6 Growth Rates for All Type Vehicles

	GDP Growth (%)	Large/Medium/Small Truck	Large Bus/Mini Bus	Microbus	Utility	Car/Taxi	Baby-taxi /Tempo	Motor-Cycle	Weighted Average by vehicle category
High Assumption	8.00 %	7.12 %	2.88 %	2.88 %	8.48 %	8.48 %	8.16 %	11.52 %	6.21 %
Medium Assumption	7.35 %	6.54 %	2.65 %	2.65 %	7.79 %	7.79 %	7.50 %	10.58 %	5.71 %
Low Assumption	6.70 %	5.96 %	2.41 %	2.41 %	7.10 %	7.10 %	6.83 %	9.65 %	5.20 %

Source: JICA Study Team

3.2.4 Comparison of Growth Rates by Different Methods

The growth rates determined by different methods are summarized in Table 3.2.7.

Table 3.2.7 Comparison of Growth Rates by Various Methods

Method	Growth rates of vehicles (%)				
	Car / Jeep	Bus / Mini-bus	Auto-rickshaw	Motor-Cycle	Truck
Trend Analysis based on Registered Vehicle Data	7.04 %	2.41 %	8.59 %	10.18 %	6.05 %
Analysis based on Transport and economic data (Medium assumption)	7.79 %	2.65 %	7.5 %	10.58 %	6.54 %

Source: JICA Study Team

3.3 Growth Rate Based on Other Studies

1) Consultancy services for detailed Design and construction supervision of civil works of 4-laning of Dhaka-Chittagong highway project

The following growth rates were adopted in consultancy services for “detailed Design and construction supervision of civil works of 4-laning of Dhaka-Chittagong highway project, 2006 by national engineering services Pakistan (Pvt.) Limited (NESPAK) in association with MEPC, DCP and KPL, Bangladesh”.

Year 2006-2010: 8 % per year for all types of vehicles

Year 2010-2030: 6 % per year for all types of vehicles

2) 8-Laning of Jatrabari-Kanchpur Road (Polder Road)

The following growth rates were adopted in 8-Laning of Jatrabari-Kanchpur Road (Polder Road), 2011.

Year 2007-2031: 10 % per year for all types of vehicles

3) Consultancy services for feasibility study for Dhaka-Chittagong Expressway (PPP) project report

The growth rates adopted for this project are listed in Table 3.3.1.

Table 3.3.1 The Growth Rates for All Types of Vehicle

Year	Car/Jeep/Taxi/Microbus	Bus/Minibus	Auto Rickshaw	Motorcycle	Truck
2007-2011	9.00	4.00	5.50	7.00	7.50
2012-2016	8.57	3.84	5.18	6.67	7.25
2017-2021	8.16	3.69	4.86	6.36	7.00
2022-2026	7.77	3.53	4.57	6.06	6.75
2027-2031	7.40	3.38	4.28	5.77	6.50
2032-2036	7.05	3.24	4.00	5.49	6.25
2037-2041	6.72	3.09	3.73	5.22	6.00
2042	6.39	2.95	3.48	4.96	5.75

Source: Consultancy services for feasibility study for Dhaka-Chittagong Expressway (PPP) project

4) JICA Special Assistance for Project Formation for Chittagong City Ring Road Project, 2009

Table 3.3.2 Growth Rate for Chittagong City Ring Road Project

Municipality	Division	2008-2010	2010-2015	2015-2020	2020-2030
Traffic Growth (%)	High Assumption	7.0	6.5	6.0	5.0
	Low Assumption	5.57	5.17	4.78	3.98

Source: JICA Special Assistance for Project Formation for Chittagong City Ring Road Project, 2009

3.4 Adopted Growth Rates for the Present Project

3.4.1 Adopted Growth Rates

The growth rates formulated by different methods are summarized in Table 3.4.1. The values obtained from both methods are very close and their difference is insignificant. Therefore, the values calculated from the transport and economic indicators are adopted for the project.

Table 3.4.1 Adopted Growth Rates

High Assumption

Year	GDP Growth(%)	Large/Medium/ Small Truck	Large Bus/Mini Bus	Microbus	Utility	Car/Taxi	Baby-taxi /Tempo	Motor Cycle	Average
2012-2016	8.00%	7.12%	2.88%	2.88%	8.48%	8.48%	8.16%	11.52%	6.21%
2017-2021	7.60%	6.76%	2.74%	2.74%	8.06%	8.06%	7.75%	10.94%	5.90%
2022-2026	7.22%	6.43%	2.60%	2.60%	7.65%	7.65%	7.36%	10.40%	5.60%
2027-2031	6.86%	6.10%	2.47%	2.47%	7.27%	7.27%	7.00%	9.88%	5.32%
2032-2036	6.52%	5.80%	2.35%	2.35%	6.91%	6.91%	6.65%	9.38%	5.06%

Medium Assumption

Year	GDP Growth(%)	Large/Medium/ Small Truck	Large Bus/Mini Bus	Microbus	Utility	Car/Taxi	Baby-taxi /Tempo	Motor Cycle	Average
2012-2016	7.35%	6.54%	2.65%	2.65%	7.79%	7.79%	7.50%	10.58%	5.71%
2017-2021	6.98%	6.21%	2.51%	2.51%	7.40%	7.40%	7.12%	10.05%	5.42%
2022-2026	6.63%	5.90%	2.39%	2.39%	7.03%	7.03%	6.77%	9.55%	5.15%
2027-2031	6.30%	5.61%	2.27%	2.27%	6.68%	6.68%	6.43%	9.07%	4.89%
2032-2036	5.99%	5.33%	2.16%	2.16%	6.35%	6.35%	6.11%	8.62%	4.65%
2037-2041	5.69%	5.06%	2.05%	2.05%	6.03%	6.03%	5.80%	8.19%	4.41%
2042-2046	5.40%	4.81%	1.95%	1.95%	5.73%	5.73%	5.51%	7.78%	4.19%

Low Assumption

Year	GDP Growth(%)	Large/Medium/ Small Truck	Large Bus/Mini Bus	Microbus	Utility	Car/Taxi	Baby-taxi /Tempo	Motor Cycle	Average
2012-2016	6.70%	5.96%	2.41%	2.41%	7.10%	7.10%	6.83%	9.65%	5.20%
2017-2021	6.37%	5.66%	2.29%	2.29%	6.75%	6.75%	6.49%	9.17%	4.94%
2022-2026	6.05%	5.38%	2.18%	2.18%	6.41%	6.41%	6.17%	8.71%	4.69%
2027-2031	5.74%	5.11%	2.07%	2.07%	6.09%	6.09%	5.86%	8.27%	4.46%
2032-2036	5.46%	4.86%	1.96%	1.96%	5.78%	5.78%	5.57%	7.86%	4.24%

Source: JICA Study Team

3.4.2 Comparison of Estimated Growth Rates by Other Studies

The computed growth rate is also compared with other projects related to NH-1 which is financed by ADB, RHD and JICA. The finding of the present study is very close to their proposed growth rates except for the “8-lane Jatrabari-Kanchpur Road Project”.

Table 3.4.2 Comparison of Estimated Growth Rates by Other Studies

Year	4-lane Dhaka-Chittagong highway project	8-lane Jatrabari-Kanchpur Road project	Dhaka-Chittagong Access Controlled Highway	Chittagong City Ring Road Project		Adopted Growth Rates For This project
				High	Low	
2012	6.0 %	10.0 %	6.00 %	6.25 %	4.98 %	5.71 %

Source: JICA Study Team

3.5 Future Traffic Volume

3.5.1 Future Traffic Volume

Projected traffic volume is shown below. Passenger Car Unit Values which are used in Bangladesh in Table 3.5.1 are adopted in this project.

Table 3.5.1 Projected Traffic Volume at Kanchpur Bridge

	1	2	3	4	5	6	7	8	9	10	
Year	**Heavy Truck**	**Medium Truck**	**Small Truck**	**Large Bus**	**Mini bus**	**Microbus**	**Utility**	**Car /Taxi**	**Baby-taxi /Tempo**	**Motor Cycle**	**Total**
PCU Equivalency	3.00	3.00	3.00	3.00	3.00	3.00	1.00	1.00	0.75	0.75	
2012	14,921	10,252	7,046	14,875	11,297	7,676	2,690	3,237	4,104	773	76,872
2013	15,897	10,922	7,507	15,268	11,596	7,880	2,900	3,489	4,412	855	80,726
2014	16,937	11,637	7,998	15,672	11,903	8,088	3,126	3,761	4,743	945	84,810
2015	18,045	12,398	8,521	16,087	12,218	8,302	3,369	4,054	5,098	1,045	89,138
2016	19,226	13,209	9,078	16,513	12,541	8,522	3,632	4,370	5,480	1,156	93,727
2017	20,421	14,030	9,642	16,928	12,857	8,736	3,901	4,693	5,871	1,272	98,350
2018	21,690	14,902	10,242	17,353	13,180	8,955	4,190	5,041	6,289	1,400	103,241
2019	23,037	15,828	10,878	17,789	13,511	9,181	4,500	5,414	6,737	1,541	108,415
2020	24,469	16,811	11,554	18,236	13,851	9,411	4,833	5,815	7,216	1,696	113,893
2021	25,990	17,856	12,272	18,695	14,199	9,648	5,190	6,245	7,730	1,866	119,692
2022	27,524	18,910	12,997	19,141	14,538	9,878	5,555	6,684	8,253	2,044	125,526
2023	29,149	20,027	13,764	19,598	14,885	10,114	5,946	7,154	8,812	2,240	131,689
2024	30,870	21,209	14,577	20,066	15,241	10,356	6,364	7,657	9,408	2,454	138,201
2025	32,692	22,461	15,437	20,546	15,605	10,603	6,811	8,195	10,045	2,688	145,084
2026	34,622	23,787	16,349	21,036	15,977	10,856	7,290	8,772	10,724	2,945	152,359
2027	36,564	25,121	17,265	21,513	16,340	11,103	7,777	9,358	11,414	3,212	159,667
2028	38,615	26,530	18,234	22,002	16,710	11,354	8,297	9,983	12,147	3,504	167,376
2029	40,781	28,018	19,256	22,501	17,089	11,612	8,851	10,649	12,928	3,822	175,508
2030	43,068	29,589	20,336	23,011	17,477	11,875	9,442	11,361	13,759	4,168	184,088
2031	45,483	31,249	21,477	23,533	17,874	12,145	10,073	12,120	14,644	4,547	193,144
2032	47,907	32,914	22,621	24,040	18,259	12,407	10,712	12,889	15,538	4,939	202,225

Source: JICA Study Team

Table 3.5.2 Projected Traffic Volume at Meghna and Gumti Bridges

	1	2	3	4	5	6	7	8	9	10	
Year	**Heavy Truck**	**Medium Truck**	**Small Truck**	**Large Bus**	**Mini bus**	**Microbus**	**Utility**	**Car /Taxi**	**Baby-taxi /Tempo**	**Motor Cycle**	**Total**
PCU Equivalency	3.00	3.00	3.00	3.00	3.00	3.00	1.00	1.00	0.75	0.75	
2012	10,012	14,831	5,392	12,413	5,958	8,786	2,740	2,937	1,882	195	65,147
2013	10,667	15,802	5,745	12,742	6,116	9,018	2,954	3,166	2,023	216	68,448
2014	11,364	16,835	6,121	13,079	6,277	9,257	3,184	3,413	2,175	238	71,944
2015	12,108	17,937	6,521	13,425	6,444	9,502	3,432	3,679	2,338	264	75,648
2016	12,900	19,110	6,948	13,780	6,614	9,753	3,700	3,965	2,513	292	79,575
2017	13,701	20,297	7,379	14,127	6,780	9,998	3,973	4,259	2,692	321	83,529
2018	14,553	21,559	7,838	14,482	6,951	10,250	4,267	4,574	2,884	353	87,711
2019	15,457	22,899	8,325	14,846	7,125	10,507	4,583	4,913	3,089	389	92,134
2020	16,418	24,322	8,843	15,219	7,305	10,772	4,922	5,276	3,309	428	96,813
2021	17,438	25,833	9,392	15,602	7,488	11,042	5,287	5,667	3,545	471	101,765
2022	18,467	27,358	9,946	15,974	7,667	11,306	5,659	6,065	3,785	516	106,744
2023	19,558	28,973	10,534	16,356	7,850	11,576	6,056	6,492	4,041	565	112,001
2024	20,712	30,684	11,156	16,746	8,038	11,852	6,482	6,948	4,314	619	117,552
2025	21,935	32,495	11,814	17,146	8,230	12,135	6,938	7,437	4,606	678	123,415
2026	23,230	34,414	12,512	17,556	8,426	12,425	7,426	7,960	4,918	743	129,609
2027	24,533	36,344	13,213	17,954	8,617	12,707	7,922	8,491	5,234	810	135,826
2028	25,909	38,382	13,954	18,361	8,813	12,995	8,451	9,059	5,570	884	142,379
2029	27,362	40,535	14,737	18,778	9,013	13,290	9,016	9,664	5,928	964	149,286
2030	28,897	42,808	15,564	19,204	9,217	13,592	9,618	10,309	6,310	1,052	156,569
2031	30,517	45,209	16,436	19,639	9,426	13,900	10,260	10,998	6,715	1,147	164,249
2032	32,143	47,618	17,312	20,063	9,629	14,200	10,911	11,696	7,125	1,246	171,943

Source: JICA Study Team

3.5.2 Study of Chittagong Port Development

Many imported and exported goods are transported through the Dhaka-Chittagong corridor from Chittagong port. The above method considers the growth rate that includes Chittagong port demand, but it is not enough to consider Chittagong port demand. Compared between the annual growth rate of this project and Chittagong port annual growth rate, Chittagong port growth rate is larger than the annual growth rate of this project. Therefore, the gap between the annual growth rate of this project and Chittagong port annual growth rate is considered as additional demand. The stepwise process is shown below.

STEP1: Calculation of growth rate of Chittagong Port and Deep Sea Port

STEP2: Estimate the modal share of roads in port demand

STEP3: Estimate the share of traffic volume that passes over the target road within the above road traffic volume

STEP4: Calculation of the share of the above traffic volume within NH-1 traffic volume

STEP5: Calculation of additional traffic demand using the port growth rate regarding the above traffic volume

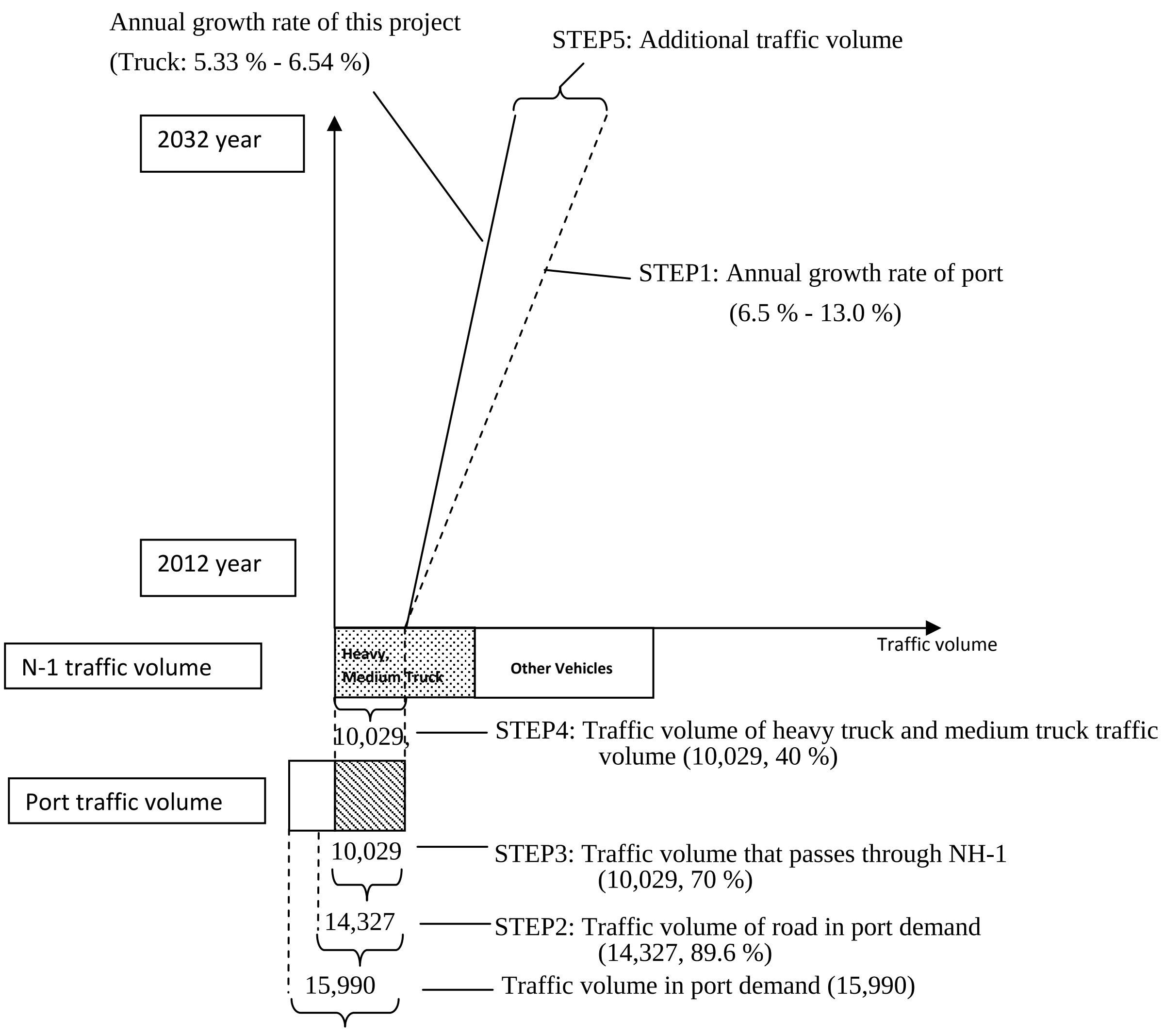


Figure 3.5.1 Concept of Study Method

(1) STEP1: Calculation of the annual growth rate of Chittagong port and Deep sea port

In accordance with the report "Techno-economic feasibility study of a deep sea port, June 2009" planned general cargo traffic volume and container traffic volume, the annual growth rate is calculated as follows;

Table 3.5.3 Yearly Growth Rate of Chittagong Port and Deep Sea Port

< General Cargo Traffic Volume > (Unit: 1,000Tons)

	2006	2015	2020	2035	2055
Chittagong Port	6,949	7,169	8,000	8,000	8,000
Deep Sea Port	0	0	3,290	16,528	39,556
Total	6,949	7,169	11,290	24,528	47,556
Total (TEU)	504	519	818	1,777	3,446
Annual growth rate		0.3%	9.5%	5.3%	3.4%

*average container weight (13.8ton/TEU)
"Techno-economic feasibility study of a deep sea port, June 2009"

< Container Traffic Volume > (Unit: 1,000TEU)

	2006	2015	2020	2035	2055
Chittagong Port	827	1,833	1,500	2,000	2,000
Deep Sea Port	0	0	2,007	7,529	18,598
Total	827	1,833	3,507	9,529	20,598
Annual growth rate		9.2%	13.9%	6.9%	3.9%

< General Cargo + Container Traffic Volume > (Unit: 1,000TEU)

	2006	2015	2020	2035	2055
①Total TEU	1,331	2,352	4,325	11,306	24,044
Annual growth rate		**6.5%**	**13.0%**	**6.6%**	**3.8%**

Source: JICA team based on “Techno-economic feasibility study of a deep sea port, June2009"

(2) STEP2: Estimate the modal share of roads in port demand

Within port demand, the modal share of roads is not mentioned in the report “Techno-economic feasibility study of a deep sea port, June 2009". Therefore, the modal share of roads in containers (89.6 %) is used in the “Dhaka-Chittagong trunk railway transportation capacity enhancement project, November 2006”.

Table 3.5.4 Traffic Volume of Road from Port

< General Cargo + Container Traffic Volume > (Unit: 1,000TEU)

	2006	2012	2015	2020	2035	2055
①Total TEU	1,331	1,945	2,352	4,325	11,306	24,044
Annual growth rate			**6.5%**	**13.0%**	**6.6%**	**3.8%**

	2012
②TEU/day (①/365)	5,330
③PCU/day(②×3.0)	15,990
④Traffic volume of road (③×89.6%)	14,327

Source: JICA team

(3) STEP3: Estimate the share of traffic volume that passes over the target road within the above road traffic volume

Not all of the traffic volume generated at the port passes from Chittagong to Dhaka direction. The share of traffic volume that goes to Dhaka direction (70 %) and the other areas directed (30 %) from Chittagong is obtained from the OD survey results by “Consultancy services for feasibility study and conceptual design of Dhaka-Chittagong expressway (PPP) project, January 2008”. Therefore, the share of traffic volume that goes from Chittagong port to Dhaka direction (70 %) is used to calculate the traffic volume on NH-1.

Table 3.5.5 Traffic Volume that Passes over NH-1

< **General Cargo + Container Traffic Volume** > (Unit: 1,000TEU)

	2006	2012	2015	2020	2035	2055
①Total TEU	1,331	1,945	2,352	4,325	11,306	24,044
Annual growth rate			**6.5%**	**13.0%**	**6.6%**	**3.8%**

	2012
②TEU/day (①/365)	5,330
③PCU/day(②×3.0)	15,990
④Traffic volume of road (③×89.6%)	14,327
⑤Traffic volume on N-1 (④×70%)	**10,029**

Source: JICA team

(4) STEP4: Calculation of the share of the above traffic volume within NH-1 traffic volume

The above traffic volume is calculated from port demand. The traffic volume (10,029 PCU/day) accounts for 40 % of all Heavy Truck and Medium Truck traffic volume on NH-1 traffic volume (24,843 PCU/day).

(5) STEP5: Calculation of additional traffic demand using the port annual growth rate regarding the above traffic volume

Additional traffic demand is calculated by using the gap in growth rate.

Table 3.5.6 Additional Traffic Demand

Year	Annual growth rate of truck in this project	Traffic volume estimated growth rate of this project	Annual growth rate of port	Traffic volume estimated growth rate of port	Additional demand
2012	6.54%	10,029	6.5%	10,029	0
2013	6.54%	10,685	6.5%	10,685	0
2014	6.54%	11,384	6.5%	11,383	-1
2015	6.54%	12,129	13.0%	12,127	-2
2016	6.54%	12,922	13.0%	13,698	776
2017	6.21%	13,768	13.0%	15,472	1,705
2018	6.21%	14,623	13.0%	17,476	2,853
2019	6.21%	15,532	13.0%	19,740	4,208
2020	6.21%	16,497	6.6%	22,296	5,799
2021	6.21%	17,522	6.6%	23,771	6,249
2022	5.90%	18,611	6.6%	25,344	6,733
2023	5.90%	19,710	6.6%	27,021	7,311
2024	5.90%	20,874	6.6%	28,808	7,935
2025	5.90%	22,106	6.6%	30,714	8,608
2026	5.90%	23,411	6.6%	32,746	9,335
2027	5.61%	24,793	6.6%	34,913	10,120
2028	5.61%	26,184	6.6%	37,223	11,039
2029	5.61%	27,652	6.6%	39,685	12,033
2030	5.61%	29,203	6.6%	42,311	13,108
2031	5.61%	30,841	6.6%	45,110	14,269
2032	5.33%	32,571	6.6%	48,094	15,524

Source: JICA Study Team

3.5.3 Study of Railway Development

The Dhaka-Chittagong trunk railway transportation capacity enhancement project is progressing through JICA and ADB. This project is for enhancement of the capacity of transportation by conducting double tracking of the railway between Dhaka and Chittagong. Therefore, if the level of rail service is improved, the improvement of rail modal share is expected.

(1) Container traffic volume

According to the report "Dhaka-Chittagong trunk railway transportation capacity enhancement project, November 2006", by development of the railway, the modal share of roads is decreased from 89.6 % to 80.0 %. The traffic volume is shifted due to traffic volume generated from the port. The shifted traffic volume is shown in Table 3.5.7.

Table 3.5.7 Shifted Traffic Volume to Railway from Road

Year	Annual growth rate of port	Traffic volume estimated growth rate of port	Modal shear of road	Shifted traffic volume to railway
2012	6.5%	10,029	89.6%	
2013	6.5%	10,685	89.6%	
2014	6.5%	11,383	89.6%	
2015	13.0%	12,127	89.6%	
2016	13.0%	13,698	80.0%	1,315
2017	13.0%	15,472	80.0%	1,485
2018	13.0%	17,476	80.0%	1,678
2019	13.0%	19,740	80.0%	1,895
2020	6.6%	22,296	80.0%	2,140
2021	6.6%	23,771	80.0%	2,282
2022	6.6%	25,344	80.0%	2,433
2023	6.6%	27,021	80.0%	2,594
2024	6.6%	28,808	80.0%	2,766
2025	6.6%	30,714	80.0%	2,949
2026	6.6%	32,746	80.0%	3,144
2027	6.6%	34,913	80.0%	3,352
2028	6.6%	37,223	80.0%	3,573
2029	6.6%	39,685	80.0%	3,810
2030	6.6%	42,311	80.0%	4,062
2031	6.6%	45,110	80.0%	4,331
2032	6.6%	48,094	80.0%	4,617

Source: JICA Study Team

(2) Passenger traffic volume

Passenger traffic also shifted to railway by improvement of the railway service level. Additional traffic demand is supposed to be expected from the “Dhaka-Chittagong trunk railway transportation capacity enhancement project, November 2006”.

Table 3.5.8 Passenger Forecast

(Daily Average Passenger)

Year	Growth (%)	Daily Traffic Demand without Project	Growth Rate of Passenger Traffic Demand (%)	Final Demand Demand with Project
2005	3.8%	5,440		
2006	3.8%	5,647		
2007	3.8%	5,861		
2008	3.8%	6,084		
2009	3.8%	6,315		
2010	3.8%	6,555		
2011	3.8%	6,804	<30% of potential demand>	8,846
2012	3.8%	7,063	<50% of potential demand>	10,594
2013	3.8%	7,331	<80% of potential demand>	13,196
2014	3.8%	7,610	<100% of potential demand>	15,220
2015	2.5%	7,800	2.5%	15,600
2016	2.5%	7,995	2.5%	15,990
2017	2.5%	8,195	2.5%	16,390
2018	2.5%	8,400	2.5%	16,800
2019	2.5%	8,610	2.5%	17,220
2020	2.5%	8,825	2.5%	17,650
2021	2.5%	9,046	2.5%	18,091
2022	2.5%	9,272	2.5%	18,544
2023	2.5%	9,504	2.5%	19,007
2024	2.5%	9,741	2.5%	19,482
2025	2.50%	9,985	2.50%	19,970

Source: Dhaka-Chittagong trunk railway transportation capacity enhancement project, November 2006

Passenger traffic volume shifted from road traffic to railway traffic is calculated based on the following assumptions;

- All additional railway traffic volume is derived from road traffic.
- Additional railway passenger volume is derived from large bus passengers.
- Number of large bus passengers in each bus is 44 people as determined in the OD survey.
- Within the additional railway passenger volume, the passenger share between Dhaka-Chittagong is 58 %. (The daily passengers of Dhaka-Chittagong: 7500, The total daily passengers: 13000)
- Total annual passenger traffic grows at a rate of 2.5 % from 2026 to 2032.

Table 3.5.9 Shifted Passenger Traffic Volume to Railway from Road

(Daily Average Passenger)

Year	Growth(%)	Daily Traffic Demand without project	Growth Rate of Passenger Traffic Demad(%)	Final Demand Demand with Project	Transferred traffic from Road to Railway (Passenger /day)	Transferred traffic between Dahka and Chittagong* (Passenger /day)	Transferred from Road to Railway (Large bus /day)	Transferred from Road to Railway (puc/day)
2005	3.8%	5,440						
2006	3.8%	5,647						
2007	3.8%	5,861						
2008	3.8%	6,084						
2009	3.8%	6,315						
2010	3.8%	6,555						
2011	3.8%	6,804	<30% of potential demand>	8,846	2,042	1,184	27	81
2012	3.8%	7,063	<50% of potential demand>	10,594	3,531	2,048	47	140
2013	3.8%	7,331	<80% of potential demand>	13,196	5,865	3,402	77	232
2014	3.8%	7,610	<100% of potential demand>	15,220	7,610	4,414	100	301
2015	2.5%	7,800	2.5%	15,600	7,800	4,524	103	308
2016	2.5%	7,995	2.5%	15,990	7,995	4,637	105	316
2017	2.5%	8,195	2.5%	16,390	8,195	4,753	108	324
2018	2.5%	8,400	2.5%	16,800	8,400	4,872	111	332
2019	2.5%	8,610	2.5%	17,220	8,610	4,994	113	340
2020	2.5%	8,825	2.5%	17,650	8,825	5,119	116	349
2021	2.5%	9,046	2.5%	18,091	9,045	5,246	119	358
2022	2.5%	9,272	2.5%	18,544	9,272	5,378	122	367
2023	2.5%	9,504	2.5%	19,007	9,503	5,512	125	376
2024	2.5%	9,741	2.5%	19,482	9,741	5,650	128	385
2025	2.5%	9,985	2.5%	19,970	9,985	5,791	132	395
2026	2.5%	10,235	2.5%	20,469	10,235	5,936	135	405
2027	2.5%	10,490	2.5%	20,981	10,490	6,084	138	415
2028	2.5%	10,753	2.5%	21,506	10,753	6,237	142	425
2029	2.5%	11,022	2.5%	22,043	11,022	6,393	145	436
2030	2.5%	11,297	2.5%	22,594	11,297	6,552	149	447
2031	2.5%	11,580	2.5%	23,159	11,580	6,716	153	458
2032	2.5%	11,869	2.5%	23,738	11,869	6,884	156	469

* Daily Passenger Average between Dahka and Chittagong 7,500 (58% of total daily average passenger)
(Total Daily Passenger Average 13,000)

Source: JICA Study Team

3.5.4 Adopted Future Traffic Volume

Projected traffic volume is shown below;

Table 3.5.10 Projected Traffic Volume at Kanchpur Bridge site

Year	1	2	3	4	5	6	7	8	9	10				
	Heavy Truck	Medium Truck	Small Truck	Large Bus	Mini bus	Microbus	Utility	Car /Taxi	Baby-taxi /Tempo	Motor Cycle	Total	Traffic from port	Traffic to railway	Total
PCU Equivalency	3.00	3.00	3.00	3.00	3.00	3.00	1.00	1.00	0.75	0.75				
2012	14,921	10,252	7,046	14,875	11,297	7,676	2,690	3,237	4,104	773	76,872	-	140	76,732
2013	15,897	10,922	7,507	15,268	11,596	7,880	2,900	3,489	4,412	855	80,726	(0)	232	80,494
2014	16,937	11,637	7,998	15,672	11,903	8,088	3,126	3,761	4,743	945	84,810	(1)	301	84,508
2015	18,045	12,398	8,521	16,087	12,218	8,302	3,369	4,054	5,098	1,045	89,138	(2)	308	88,828
2016	19,226	13,209	9,078	16,513	12,541	8,522	3,632	4,370	5,480	1,156	93,727	776	1,631	92,871
2017	20,421	14,030	9,642	16,928	12,857	8,736	3,901	4,693	5,871	1,272	98,350	1,705	1,809	98,245
2018	21,690	14,902	10,242	17,353	13,180	8,955	4,190	5,041	6,289	1,400	103,241	2,853	2,010	104,084
2019	23,037	15,828	10,878	17,789	13,511	9,181	4,500	5,414	6,737	1,541	108,415	4,208	2,235	110,388
2020	24,469	16,811	11,554	18,236	13,851	9,411	4,833	5,815	7,216	1,696	113,893	5,799	2,489	117,202
2021	25,990	17,856	12,272	18,695	14,199	9,648	5,190	6,245	7,730	1,866	119,692	6,249	2,640	123,301
2022	27,524	18,910	12,997	19,141	14,538	9,878	5,555	6,684	8,253	2,044	125,526	6,733	2,800	129,459
2023	29,149	20,027	13,764	19,598	14,885	10,114	5,946	7,154	8,812	2,240	131,689	7,311	2,970	136,030
2024	30,870	21,209	14,577	20,066	15,241	10,356	6,364	7,657	9,408	2,454	138,201	7,935	3,151	142,985
2025	32,692	22,461	15,437	20,546	15,605	10,603	6,811	8,195	10,045	2,688	145,084	8,608	3,343	150,349
2026	34,622	23,787	16,349	21,036	15,977	10,856	7,290	8,772	10,724	2,945	152,359	9,335	3,548	158,146
2027	36,564	25,121	17,265	21,513	16,340	11,103	7,777	9,358	11,414	3,212	159,667	10,120	3,766	166,021
2028	38,615	26,530	18,234	22,002	16,710	11,354	8,297	9,983	12,147	3,504	167,376	11,039	3,999	174,416
2029	40,781	28,018	19,256	22,501	17,089	11,612	8,851	10,649	12,928	3,822	175,508	12,033	4,246	183,295
2030	43,068	29,589	20,336	23,011	17,477	11,875	9,442	11,361	13,759	4,168	184,088	13,108	4,509	192,687
2031	45,483	31,249	21,477	23,533	17,874	12,145	10,073	12,120	14,644	4,547	193,144	14,269	4,788	202,624
2032	47,907	32,914	22,621	24,040	18,259	12,407	10,712	12,889	15,538	4,939	202,225	15,524	5,086	212,662

Source: JICA Study Team

Table 3.5.11 Projected Traffic Volume at Meghna and Gumti Bridge sites

Year	1	2	3	4	5	6	7	8	9	10					
	Heavy Truck	**Medium Truck**	**Small Truck**	**Large Bus**	**Mini bus**	**Microbus**	**Utility**	**Car /Taxi**	**Baby-taxi /Tempo**	**Motor Cycle**	**Total**	**Traffic from port**	**Total**	**Traffic to railway**	**Total**
PCU Equivalency	3.00	3.00	3.00	3.00	3.00	3.00	1.00	1.00	0.75	0.75					
2012	10,012	14,831	5,392	12,413	5,958	8,786	2,740	2,937	1,882	195	65,147	-	65,147	140	65,008
2013	10,667	15,802	5,745	12,742	6,116	9,018	2,954	3,166	2,023	216	68,448	(0)	68,447	232	68,215
2014	11,364	16,835	6,121	13,079	6,277	9,257	3,184	3,413	2,175	238	71,944	(1)	71,943	301	71,642
2015	12,108	17,937	6,521	13,425	6,444	9,502	3,432	3,679	2,338	264	75,648	(2)	75,647	308	75,338
2016	12,900	19,110	6,948	13,780	6,614	9,753	3,700	3,965	2,513	292	79,575	776	80,350	1,631	78,719
2017	13,701	20,297	7,379	14,127	6,780	9,998	3,973	4,259	2,692	321	83,529	1,705	85,234	1,809	83,424
2018	14,553	21,559	7,838	14,482	6,951	10,250	4,267	4,574	2,884	353	87,711	2,853	90,564	2,010	88,554
2019	15,457	22,899	8,325	14,846	7,125	10,507	4,583	4,913	3,089	389	92,134	4,208	96,341	2,235	94,106
2020	16,418	24,322	8,843	15,219	7,305	10,772	4,922	5,276	3,309	428	96,813	5,799	102,612	2,489	100,123
2021	17,438	25,833	9,392	15,602	7,488	11,042	5,287	5,667	3,545	471	101,765	6,249	108,014	2,640	105,374
2022	18,467	27,358	9,946	15,974	7,667	11,306	5,659	6,065	3,785	516	106,744	6,733	113,477	2,800	110,677
2023	19,558	28,973	10,534	16,356	7,850	11,576	6,056	6,492	4,041	565	112,001	7,311	119,311	2,970	116,342
2024	20,712	30,684	11,156	16,746	8,038	11,852	6,482	6,948	4,314	619	117,552	7,935	125,487	3,151	122,336
2025	21,935	32,495	11,814	17,146	8,230	12,135	6,938	7,437	4,606	678	123,415	8,608	132,023	3,343	128,680
2026	23,230	34,414	12,512	17,556	8,426	12,425	7,426	7,960	4,918	743	129,609	9,335	138,944	3,548	135,396
2027	24,533	36,344	13,213	17,954	8,617	12,707	7,922	8,491	5,234	810	135,826	10,120	145,946	3,766	142,179
2028	25,909	38,382	13,954	18,361	8,813	12,995	8,451	9,059	5,570	884	142,379	11,039	153,418	3,999	149,419
2029	27,362	40,535	14,737	18,778	9,013	13,290	9,016	9,664	5,928	964	149,286	12,033	161,319	4,246	157,074
2030	28,897	42,808	15,564	19,204	9,217	13,592	9,618	10,309	6,310	1,052	156,569	13,108	169,677	4,509	165,168
2031	30,517	45,209	16,436	19,639	9,426	13,900	10,260	10,998	6,715	1,147	164,249	14,269	178,518	4,788	173,729
2032	32,143	47,618	17,312	20,063	9,629	14,200	10,911	11,696	7,125	1,246	171,943	15,524	187,467	5,086	182,380

Source: JICA Study Team

3.6 Required Number of Lanes

3.6.1 Capacities of Multiple-Lane Roads

The road traffic capacity is decided by following the guideline "Geometric Design Standards, RHD". The guideline states that the road traffic capacity is about 1400 PCU/hr./lane applicable for multiple lanes. This value is similar to Level of service 'C' defined in AASHTO Highway Capacity Manual, 2000.

Table 3.6.1 Traffic Capacity

Design Type	Design year Traffic volume PCU / peak hour (typical MV AADT)	No. of lanes
1	4500-8500 (19,000-36,00)	6

Source: Geometric Design Standards by RHD, 2000

Table 3.6.2 LOS Criteria for Multilane Highways

		LOS				
Free-Flow Speed	Criteria	A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Maximum volume to capacity ratio (v/c)	0.32	0.50	0.72	0.92	1.00
	Maximum service flow rate (pc/h/ln)	700	1100	1575	2015	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum v/c	0.30	0.47	0.68	0.89	1.00
	Maximum service flow rate (pc/h/ln)	630	990	1435	1860	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum v/c	0.28	0.44	0.64	0.85	1.00
	Maximum service flow rate (pc/h/ln)	560	880	1280	1705	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Maximum v/c	0.26	0.41	0.59	0.81	1.00
	Maximum service flow rate (pc/h/ln)	490	770	1120	1530	1900

Source: Highway Capacity Manual 2000

3.6.2 Required Number of Lanes

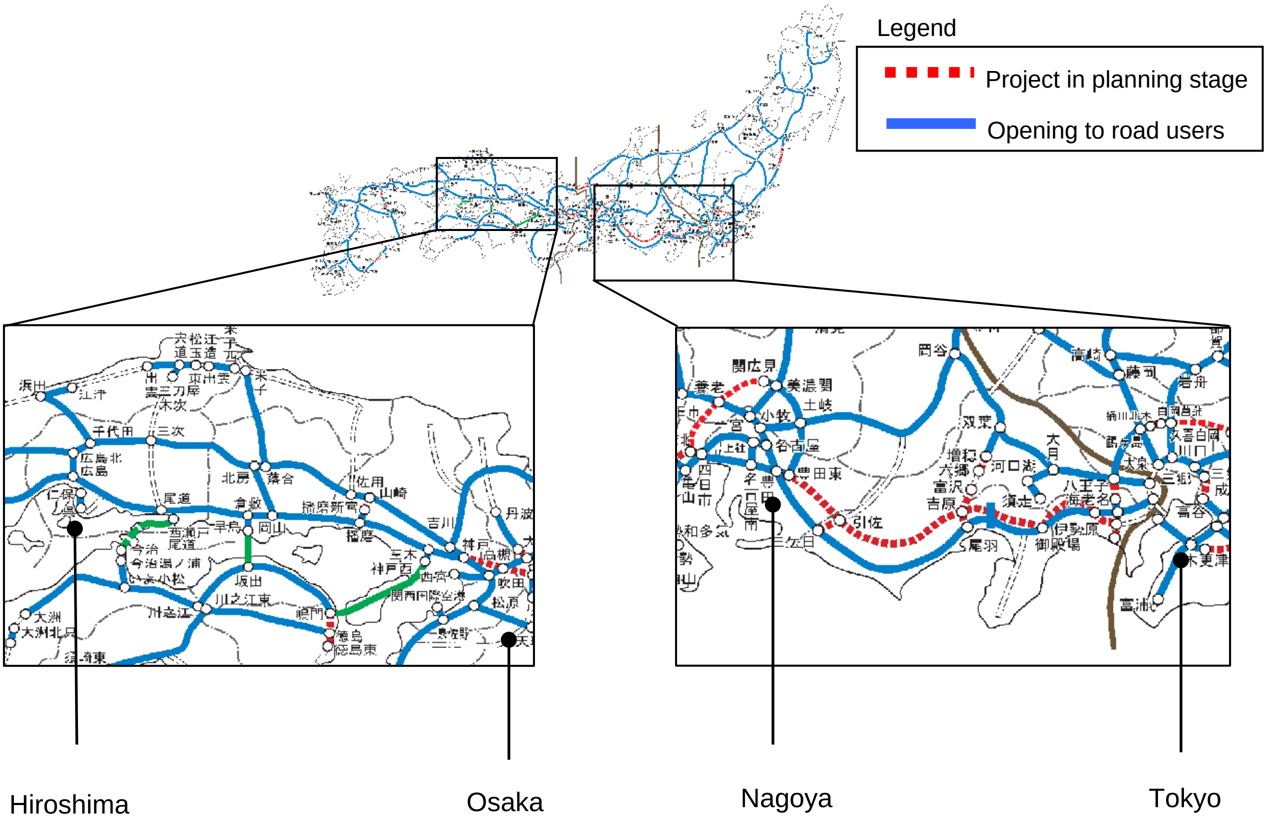
Based on the road traffic capacity defined above, the required number of lanes for each bridge has been predicted. It is noted that peak hour volume on the existing highway is estimated as 7.78 % of ADT for Kanchpur site and 6.79 % of ADT for the Meghna and Gumti sites. Peak hour ratios (7.78 %, 6.79 %) are calculated based on traffic survey in this project.

Table 3.6.3 Required Number of Lanes for Kanchpur Bridge

Year	Peak hour ratio 7.78 %			Peak hour ratio 6.79 %		
	Total traffic volume (PCU/day)	Peak Hour Flow (PCU/hour)	Required No. of Lanes	Total traffic volume (PCU/day)	Peak Hour Flow (PCU/hour)	Required No. of Lanes
2012	76,732	5,970	6	65,008	4,414	4
2013	80,494	6,262	6	68,215	4,632	4
2014	84,508	6,575	6	71,642	4,864	4
2015	88,828	6,911	6	75,338	5,115	4
2016	92,871	7,225	6	78,719	5,345	4
2017	98,245	7,643	6	83,424	5,664	6
2018	104,084	8,098	6	88,554	6,013	6
2019	110,388	8,588	8	94,106	6,390	6
2020	117,202	9,118	8	100,123	6,798	6
2021	123,301	9,593	8	105,374	7,155	6
2022	129,459	10,072	8	110,677	7,515	6
2023	136,030	10,583	8	116,342	7,900	6
2024	142,985	11,124	8	122,336	8,307	6
2025	150,349	11,697	10	128,680	8,737	8
2026	158,146	12,304	10	135,396	9,193	8
2027	166,021	12,916	10	142,179	9,654	8
2028	174,416	13,570	10	149,419	10,146	8
2029	183,295	14,260	12	157,074	10,665	8
2030	192,687	14,991	12	165,168	11,215	10
2031	202,624	15,764	12	173,729	11,796	10
2032	212,662	16,545	12	182,380	12,384	10

Source: JICA Study Team

The target year of the present study is considered as 2032 which is 20 years far from now. From the traffic study results, it is found that the required number of lanes for NH-1 is almost 10-lanes. But, frankly speaking, widening of NH-1 into 10-lanes is not appropriate plan as a national development plan. Therefore, development of an alternative corridor that connects two mega cities of Bangladesh (Dhaka, Chittagong) is required, and this route can be aligned parallel to NH-1 or any other alignment within new Right of Way (ROW). For instance, an expressway implemented in Japan can be taken into consideration, which is shown below.



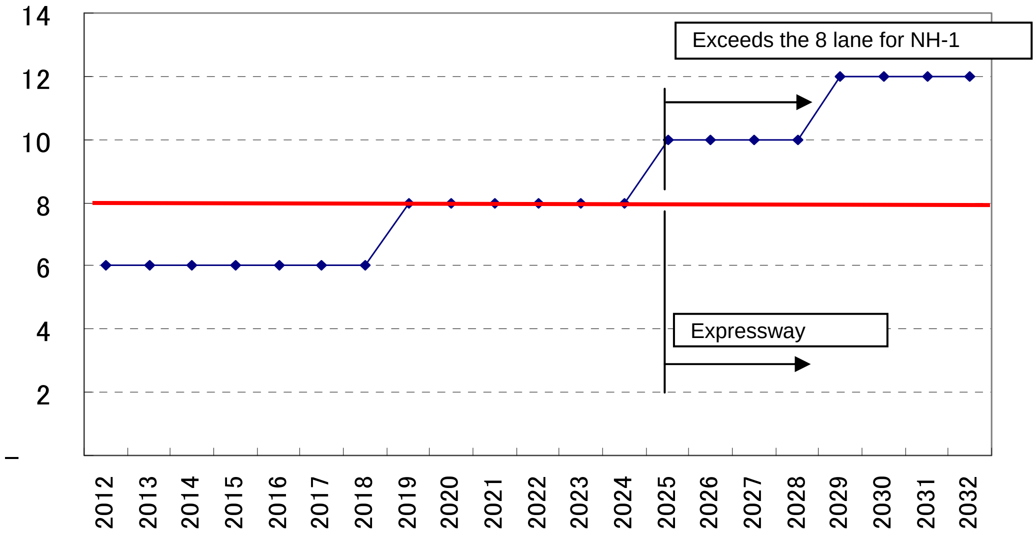
There are many parallel routes connecting major cities.

Source: Japan expressway holding and debt repayment agency HP

Figure 3.6.1 Expressways in Japan

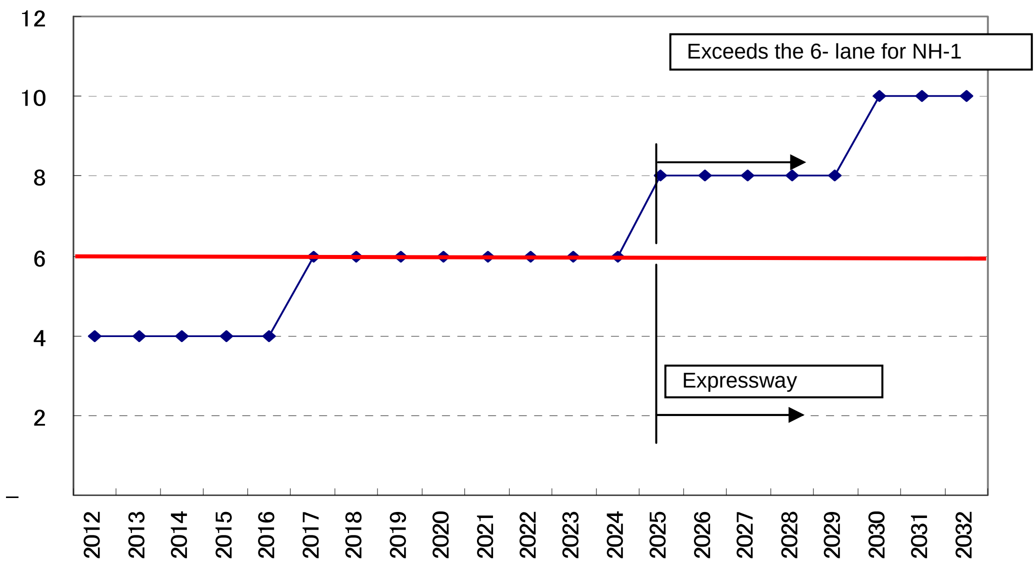
3.6.3 Alternative Corridor (Expressway)

GoB has a plan to develop the Dhaka-Chittagong Expressway which is based on PPP Design and supported by ADB-TA Loan. The project study is expected to be completed in September 2015. If this project runs smoothly, this project implementation is expected to be completed in 2025. Based on their previous FS-report, the lane number of expressway is found to be 4-lanes. As of traffic volume in 2032 studied and forecasted in the bridge project , the required number of lanes between Dhaka and Chittagong is found to be 12-lanes and 10-lanes for Kanchpur and Meghna, Gumti Bridges respectively. Therefore, considering the PPP based expressway project, the number of lanes required for Kanchpur and Meghna, Gumti



Source: JICA Study Team

Figure 3.6.2 Required Lane Numbers for Kanchpur Site and Expressway Opening



Source: JICA Study Team

Figure 3.6.3 Required Lane Numbers for Meghna and Gumti Sites and Expressway Opening

3.6.4 Adopted Number of Lanes Considering Other Studies

(1) Kanchpur site

In accordance with the 4-lane project findings, the corridor road connecting from Kanchpur Bridge to Chittagong end is expected to be widened into more than 10-lanes in order to cope with the traffic volume forecasted in 2031.

- Consultancy services for detailed Design and construction supervision of civil works of 4-laning of Dhaka-Chittagong highway project

Table 3.6.4 Projected Traffic Volume and Required Number of Lanes

Year	8-lane road from Jatrabari-Kanchpur	Present study (Kanchpur)
2009	84,172 (8-lane)	-
2012	107,063 (10- lane)	76,732 (6-lane)
2022	290,640 (Above 12- lane)	129,459 (8-lane)
2031	1,040,457 (Above 12-lane)	202,624 (12-lane)
2032	-	212,662 (12-lane)

Source: JICA Study Team

(2) Meghna and Gumti sites

The traffic study on Meghna and Gumti sites are also included in the Dhaka-Chittagong access control road (PPP) project. But, unfortunately, they did not clearly mention anything about the widening of NH-1 or the number of lanes required. Moreover, based on their own traffic studies, the alternative route (bypass) alignment parallel to NH-1 was also proposed, which will be connected between Gumti (Chittagong side) to Comilla. Therefore, considering the present traffic study and the study of the PPP project, the number of lanes required for NH-1 would be more than 10.

- Consultancy services for feasibility study and conceptual design of Dhaka-Chittagong Expressway (PPP) Project

Table 3.6.5 Projected Traffic Volume and Required Number of Lanes

Year	Dhaka-Chittagong highway (PPP) project	Present study (Meghna, Gumti)
2007	38,984 (N.A)	-
2012	53,941 (N.A)	65,008 (4 lane)
2016	69,748 (N.A)	78,719 (4 lane)
2022	101,540 (N.A)	110,677 (6 lane)
2030	165,001 (N.A)	165,168 (9 lane)
2032	185,692 (N.A)	182,380 (9 lane)

Source: JICA Study Team

3.6.5 Adopted Number of Lanes for This Project

(1) Adopted number of lanes

Adopted number of lanes is decided considering the following plans and the relationship with expressway mentioned in Section 3.6.3.

- ◆ Kanchpur Bridge
  - ✓ 8–lane project connecting Jatrabari-Kanchpur road is being planned by RHD to widen the NH-1 into 8 lanes.
- ◆ Meghna, Gumti Bridge
  - ✓ Dhaka-Chittagong highway with 6-lanes is being planned by GoB (refer to SIXTH FIVE YEAR PLAN FY2011-2015)
  - ✓ Another plan of Dhaka-Chittagong expressway (PPP) project. But widening of NH-1 into more than 10-lanes is not realistic for national development plan. Therefore, development of Dhaka-Chittagong expressway parallel to NH-1 or any other means within new ROW will be more appropriate to keep redundancy of road network.

Table 3.6.6 Adopted Number of Lanes for this Project

Bridge site	Adopted number of lanes	Existing bridge	2nd bridge
Kanchpur	8-lane	4-lane	4-lane
Meghna / Gumti	6-lane	2-lane	4-lane

Source: JICA Study Team

(2) Progress of related project

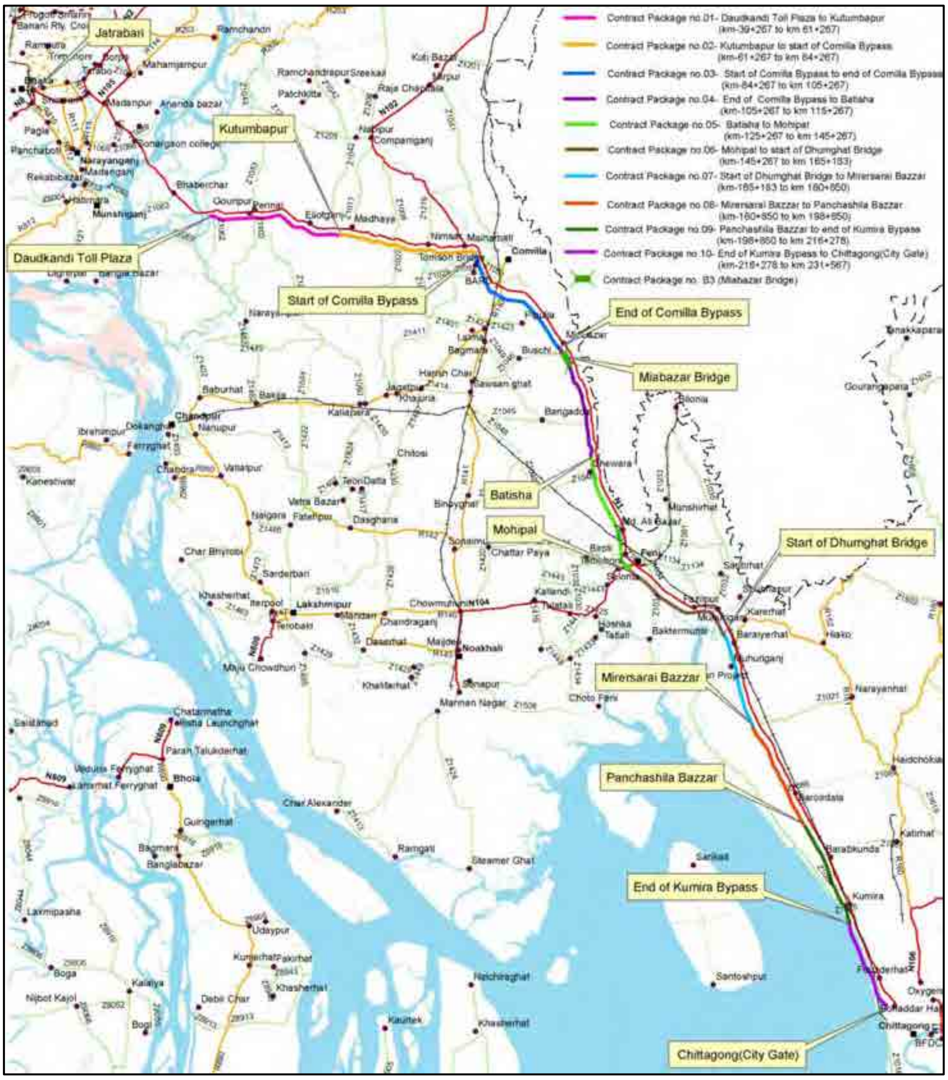
The progress of related projects is shown below.

1) 8-lane project connecting Jatrabari-Kanchpur road

- Detail design already completed in January 2011
- No land acquisition required.
- Construction progress is 2 %
- Opening year targeted in July 2013.

2) 4-Laning of Dhaka-Chittagong Highway Project

- Construction is divided into 10 sections. The progress is 20 % of total construction.
- Opening year targeted in January 2014.



Source: RHD Web site

Figure 3.6.4 Location of 4-Laning of Dhaka-Chittagong Highway Project

3) 6-lane Dhaka-Chittagong Highway Project

This project is still under GoB planning stage. Currently, there is no initiation to carry out its feasibility.

4) Dhaka-Chittagong access controlled highway

The plan for the Dhaka-Chittagong Expressway (PPP) project is supported by ADB-TA Loan. The study is expected to be completed in September 2015.

CHAPTER 4

SELECTION OF OPTIMUM ROUTE

4. SELECTION OF OPTIMUM ROUTE

4.1 General

In this chapter, three alternative routes are planned for each bridge. These alternatives are located at upstream side and downstream side of the respective existing bridges. Of which, the preferable alternative is close and next to the existing bridge and others are distant so as to avoid the influence of scouring. The preferable route is optimized by evaluation of comprehensive items including the environmental and the economic aspects.

Furthermore, intersection analysis for Kanchpur intersection has been studied in this chapter. The possible alternatives to ease operation of the intersection are planned and accordingly the preferable alternative has been proposed.

4.2 Alternative Routes

The distance between the existing bridge and the 2nd bridge is mainly governed by several factors, which are listed as follows;

(1) Construction cost

This project includes the existing bridge retrofitting and the 2nd bridge construction. The construction cost of bridge substructures is minimized by aligned the 2nd bridge next to the existing one.

(2) Obstacles

In the existing bridge, light pole base exists at the outer side of bridge surface end and its base width is found to be 60 cm. Moreover, the minimum margin of 20 cm is taken into consideration in order to secure scaffolding access.

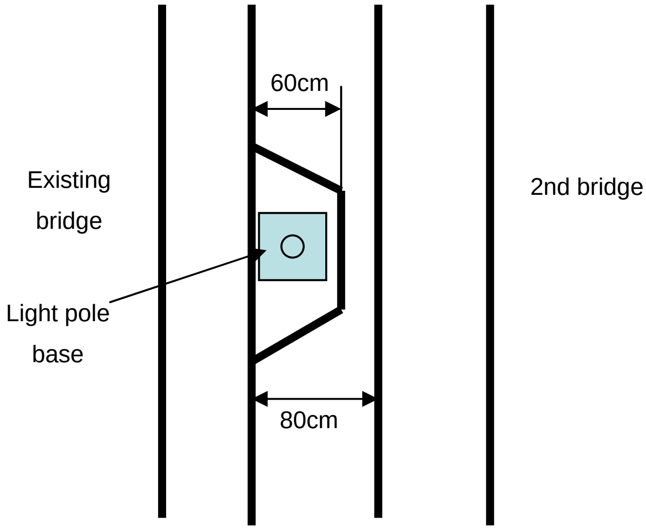


Figure 4.2.1 Light Pole Base Size

(3) Constructability

The minimum clearance required for construction is the width of sheet pile or the grip of sheet pile driving machine. Accordingly, the minimum width required is 25 cm.

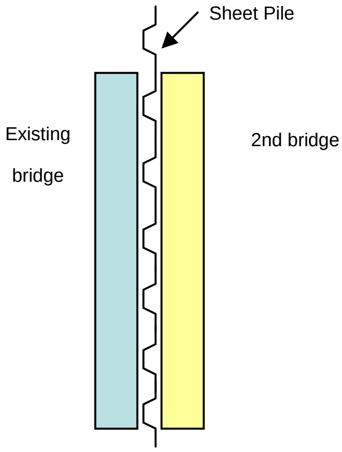


Figure 4.2.2 Concept of Construction Plan

(4) Conclusion

Considering the aforesaid factors, the minimum clearance between the existing bridge and the 2nd bridge is set at 80 cm.

4.2.1 Kanchpur Bridge

Three alternative routes, namely, Route A, Route B and Route C, are comprehensively evaluated for the construction of 2nd Kanchpur Bridge. Of which, Route A and Route C are located at downstream side and upstream side respectively and are closest to the existing bridge. These alternatives are planned to minimize the impact on the surrounding environment. On the other hand, another alternative route (Route B), located at downstream side and within RHD land boundary, is planned to avoid the influence of scouring on bridge foundation.

Table 4.2.1 Alternative Routes for 2nd Bridge

Name of Route	Description of Route	
Route A	Location	Next to existing bridge (downstream), Location that minimize resettlement and avoidance of land acquisition
	Traffic flow	One direction on existing bridge (four outbound lanes) One direction on 2nd bridge (four inbound lanes)
Route B	Location	Route that provides adequate distance (more than 100m) from existing bridge (downstream), Location that avoid the influence of scouring
	Traffic flow	Both directions along existing bridge (two outbound lanes, two inbound lanes) Both directions along 2nd bridge (two outbound lanes, two inbound lanes)
Route C	Location	Next to existing bridge (upstream), Location that reduce the land acquisition
	Traffic flow	One direction along existing bridge (four inbound lanes) One direction along 2nd bridge (four outbound lanes)

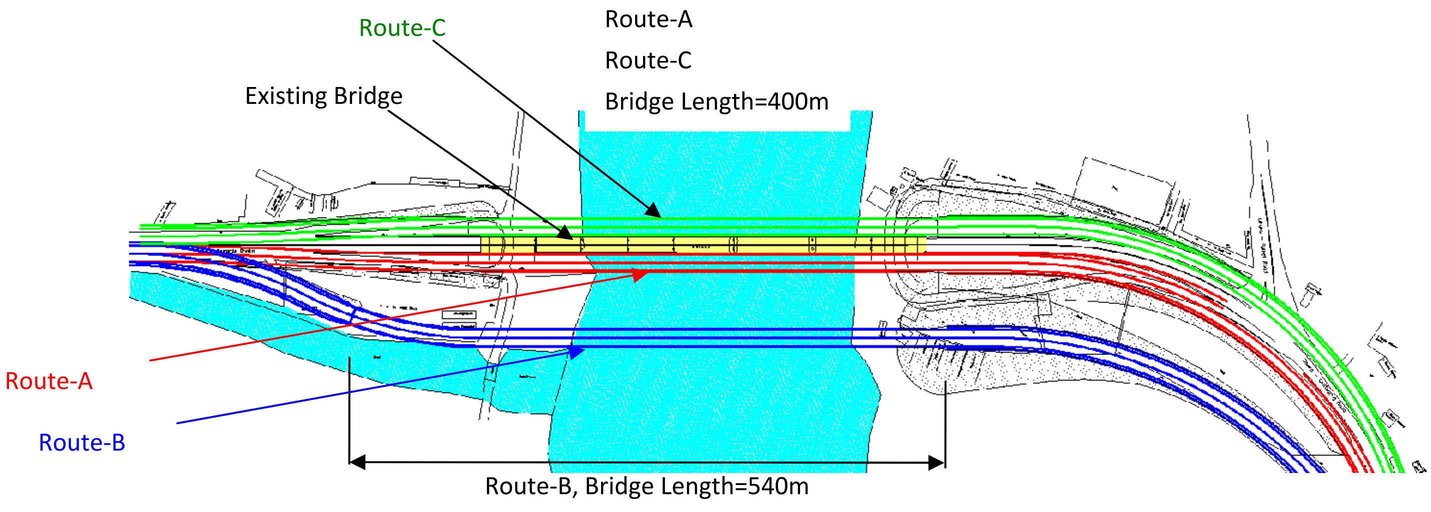


Figure 4.2.3 Alternative Routes for Kanchpur Bridge

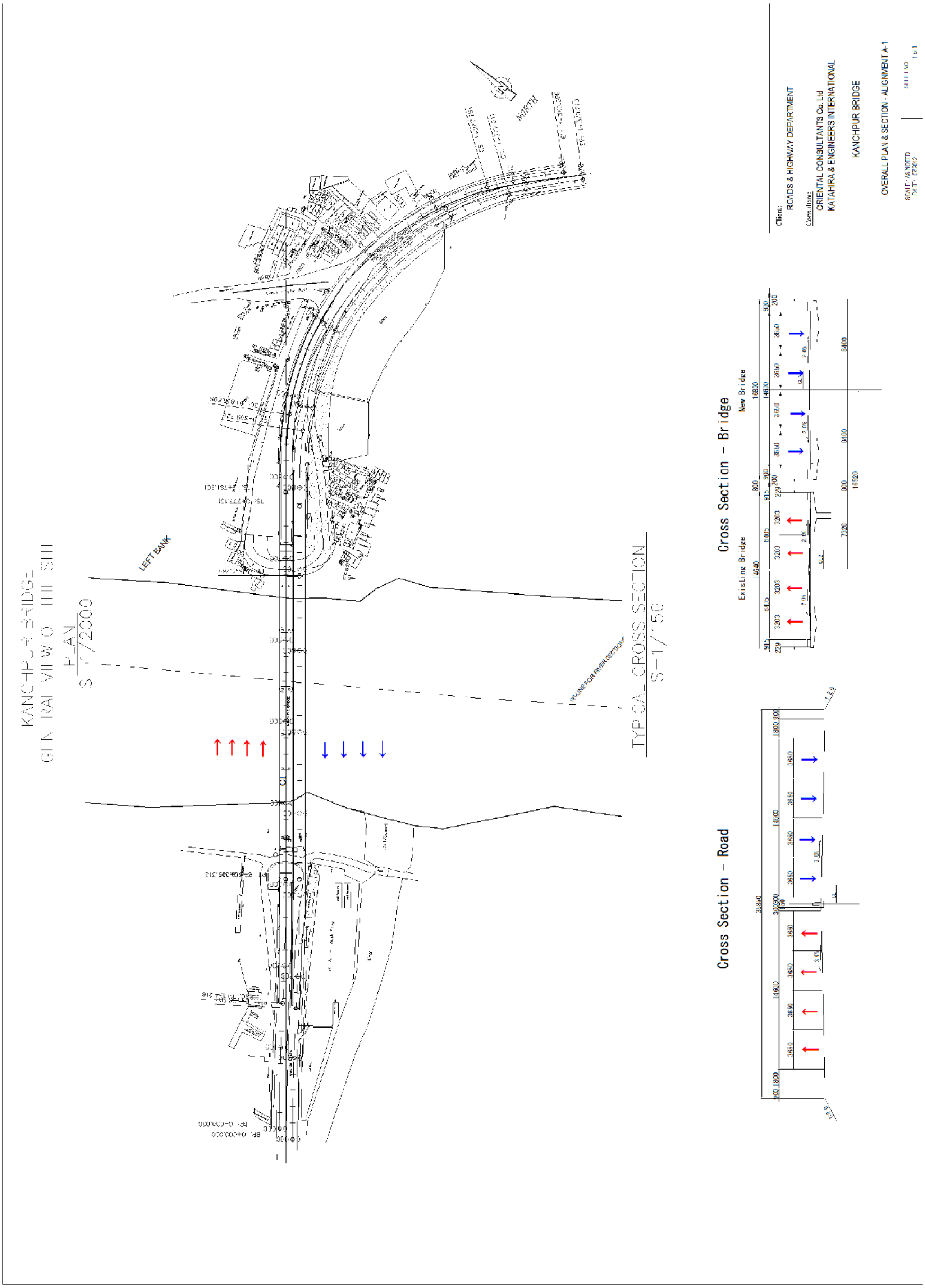


Figure 4.2.4 Route A for Kanchpur Bridge

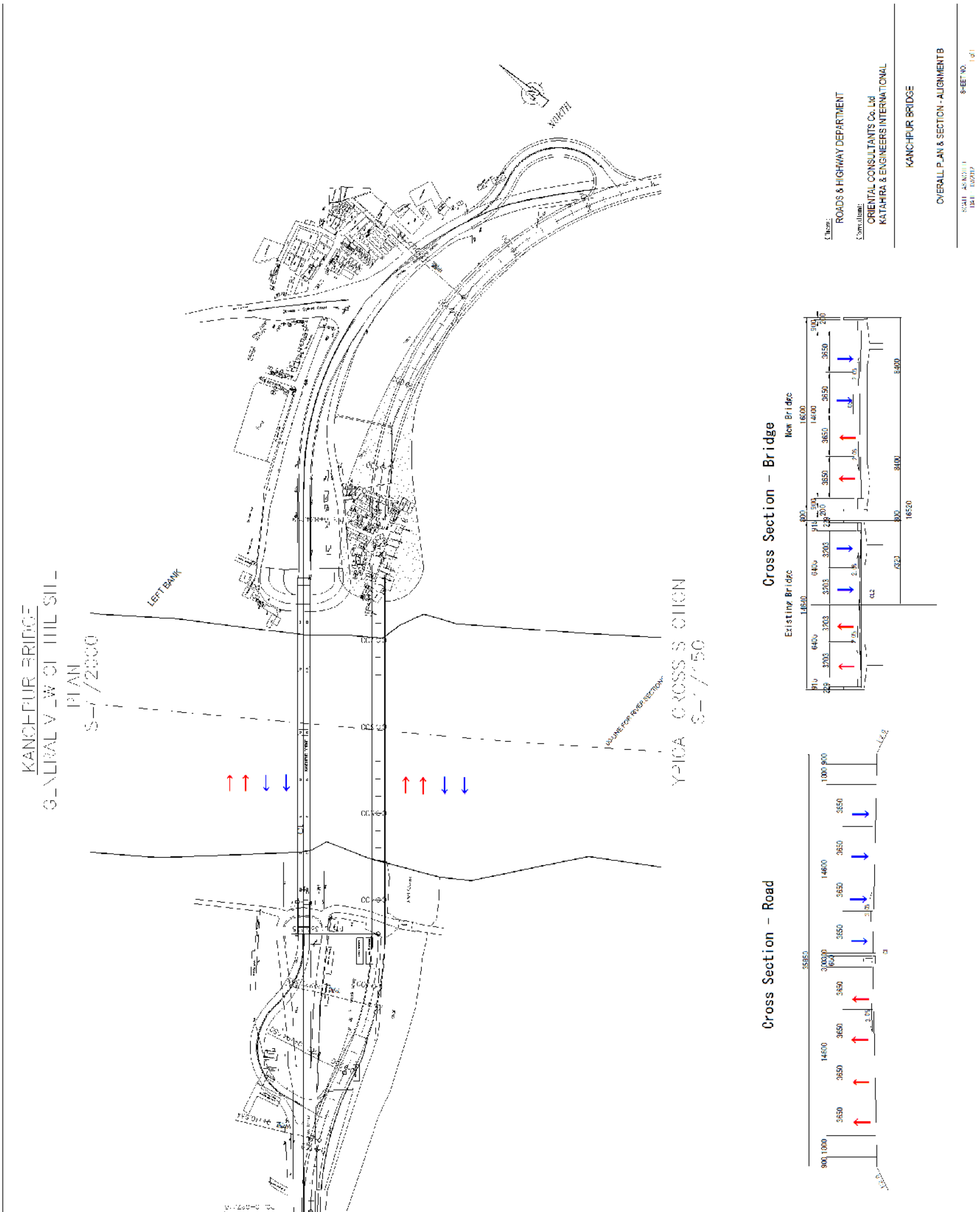


Figure 4.2.5 Route B for Kanchpur Bridge

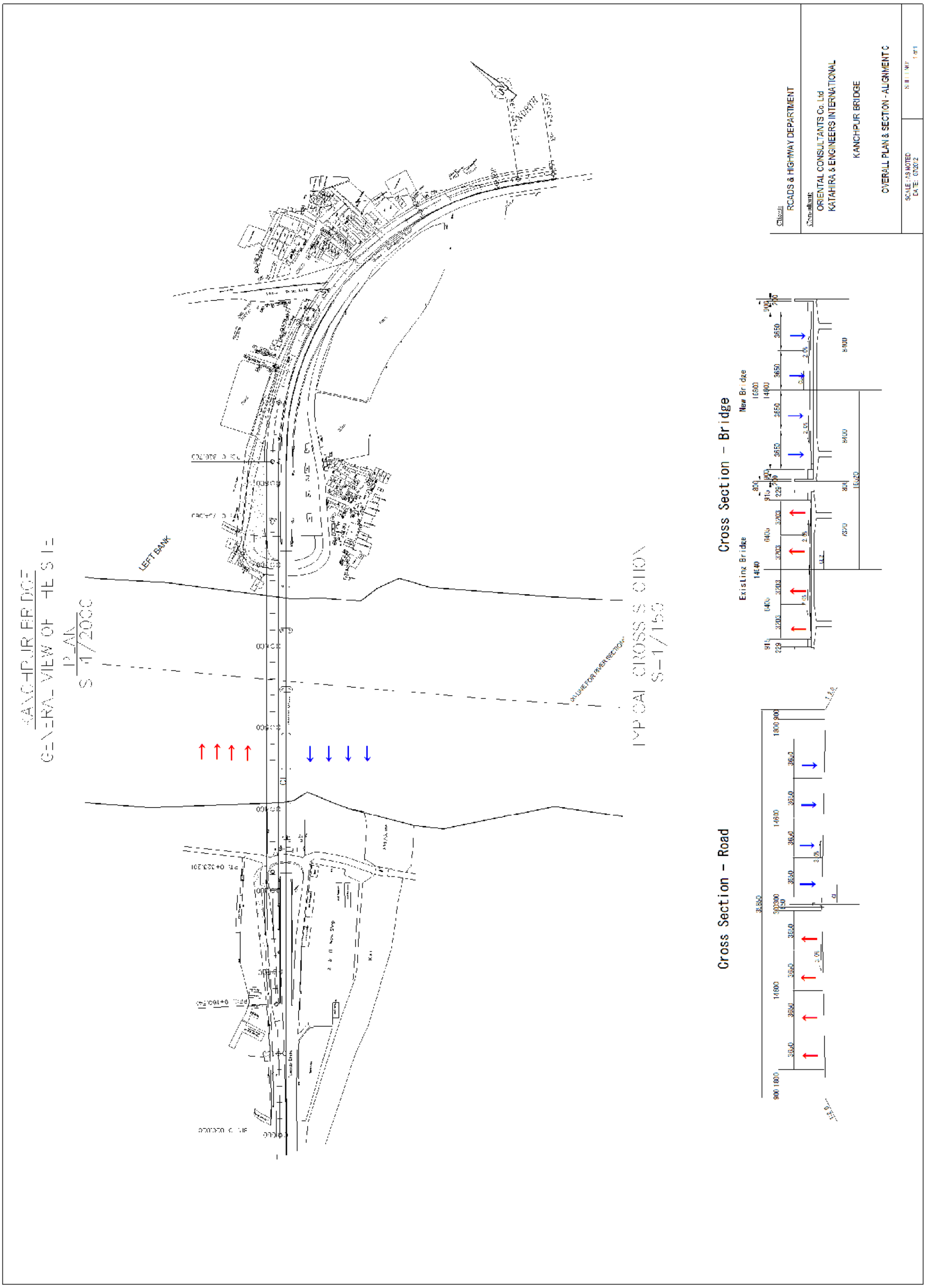


Figure 4.2.6 Route C for Kanchpur Bridge

4.2.2 Meghna Bridge

Similar to 2nd Kanchpur Bridge, three alternative routes, namely, Route A, Route B and Route C, are comprehensively evaluated for the construction of 2nd Meghna Bridge. Of which, Route A, located at upstream next and parallel to the existing bridge, is planned to minimize the impact on the surrounding environment. On the other hand, Route B is planned at upstream along the old ferry route but this route selection causes huge resettlement issue especially in Chittagong side. In order to minimize this pressing resettlement issue, Route C is planned next to the Route B. Moreover, no route is planned at downstream and next to the existing bridge. This is because such route selection generates several smaller curves which will raise a question of safe and smooth driving. A brief summary of route alternatives is shown in Table 4.2.2.

Table 4.2.2 Alternative Routes for 2nd Bridge

Name of Route	Description of Route	
Route A	Location	Next to existing bridge Location that minimizes the influence on Holcim Cement factory's land (south side) and minimize resettlement
	Traffic flow	One direction on existing bridge (two inbound lanes) Both directions on 2nd bridge (three outbound lanes, one inbound lane)
Route B	Location	Provide distance of 250 m upstream near the old ferry route
	Traffic flow	One direction along existing bridge (two inbound lanes) Both directions along 2nd bridge (three outbound lanes, one inbound lane)
Route C	Location	Provide distance of 250 m upstream of shifted ferry route Minimize resettlement issue (Ctg. side) on Route B
	Traffic flow	One direction along existing bridge (two inbound lanes) Both directions along 2nd bridge (three outbound lanes, one inbound lane)

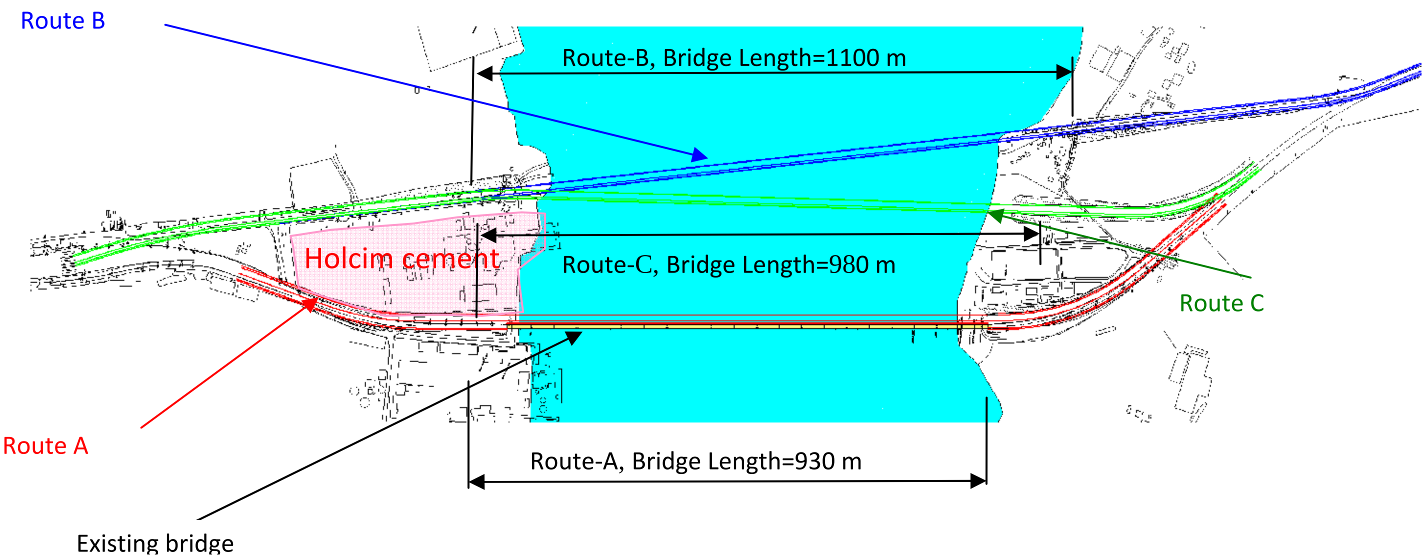


Figure 4.2.7 Alternative Routes for Meghna Bridge

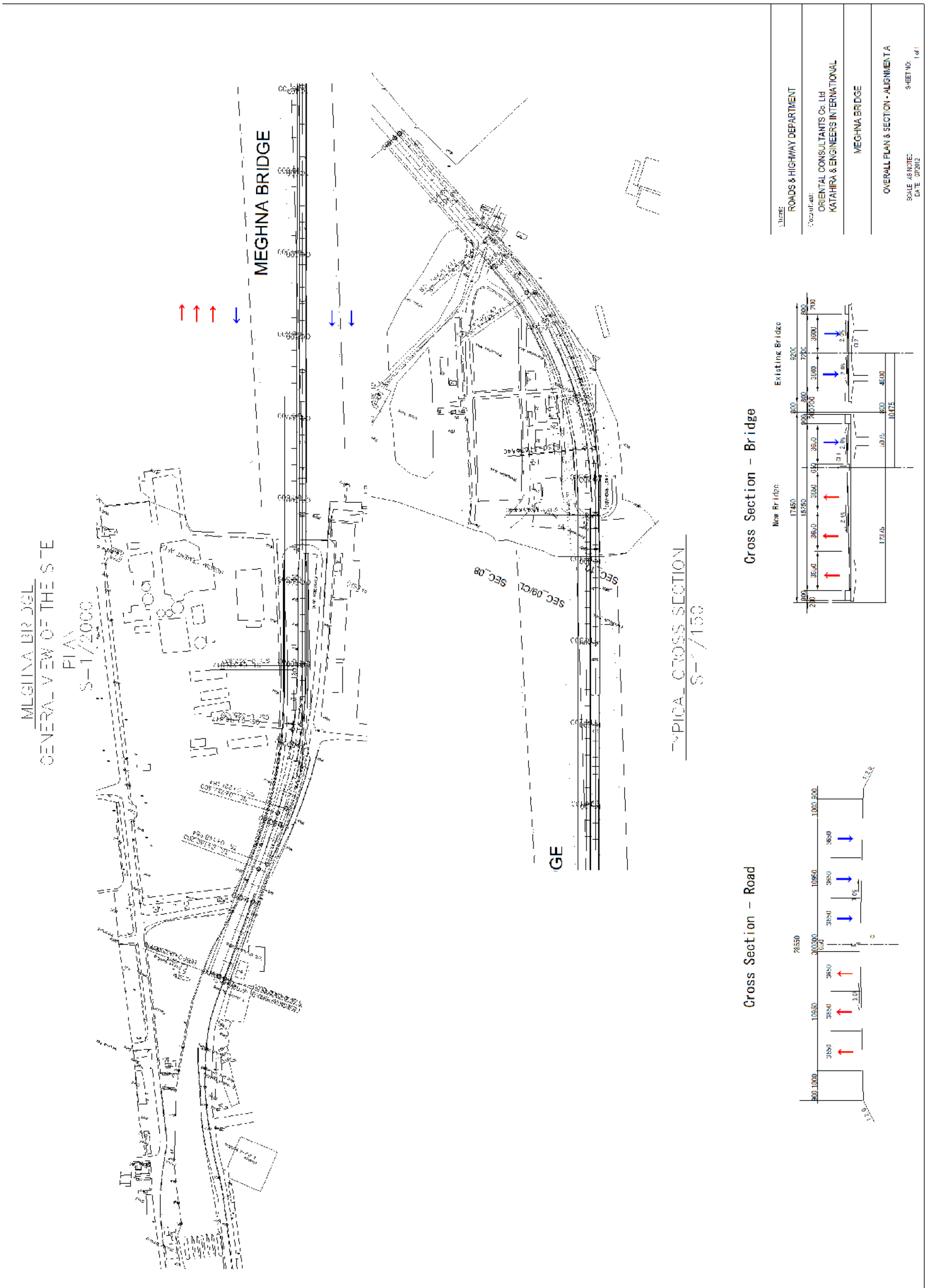


Figure 4.2.8 Route A for Meghna Bridge

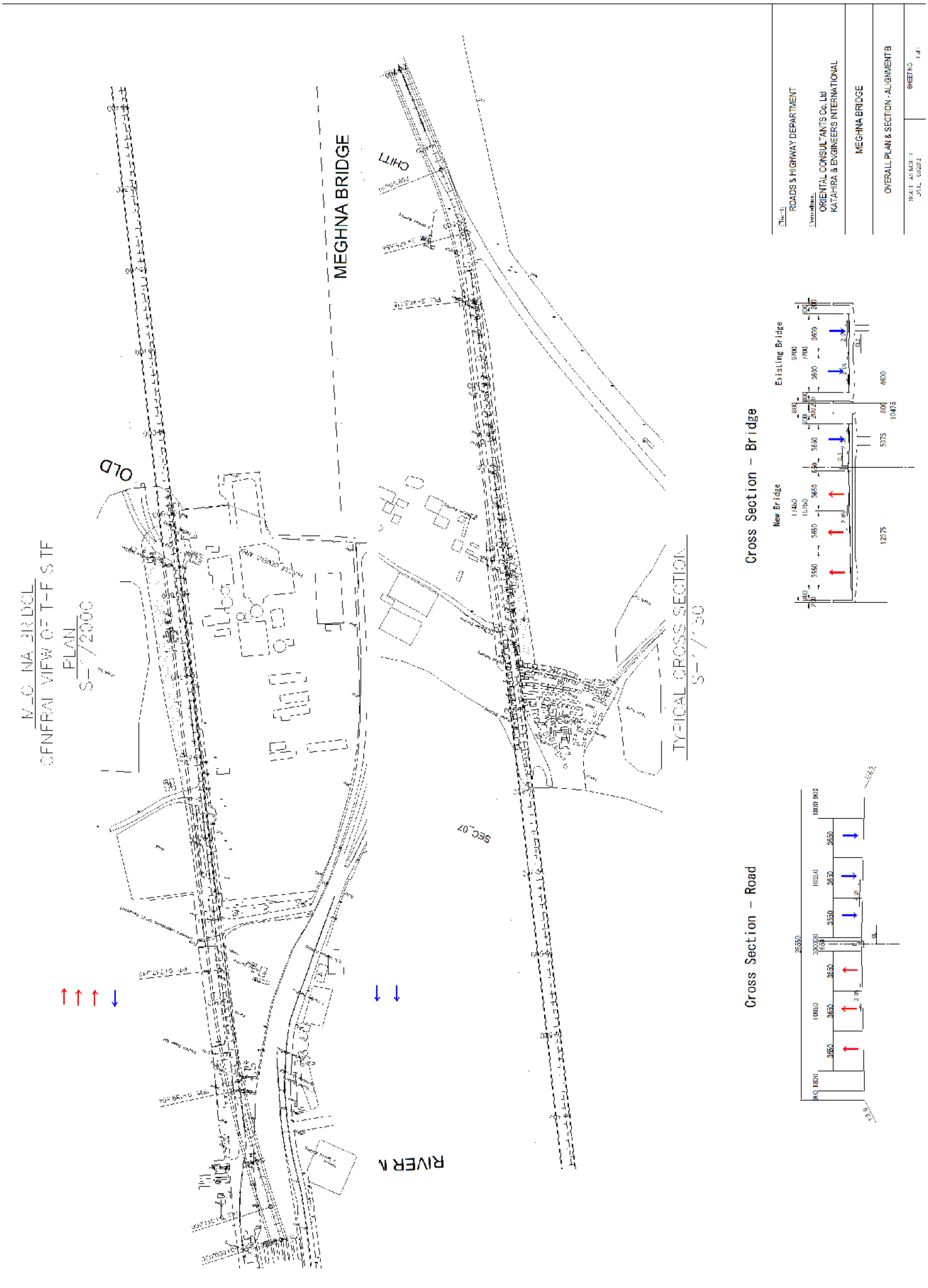


Figure 4.2.9 Route B for Meghna Bridge

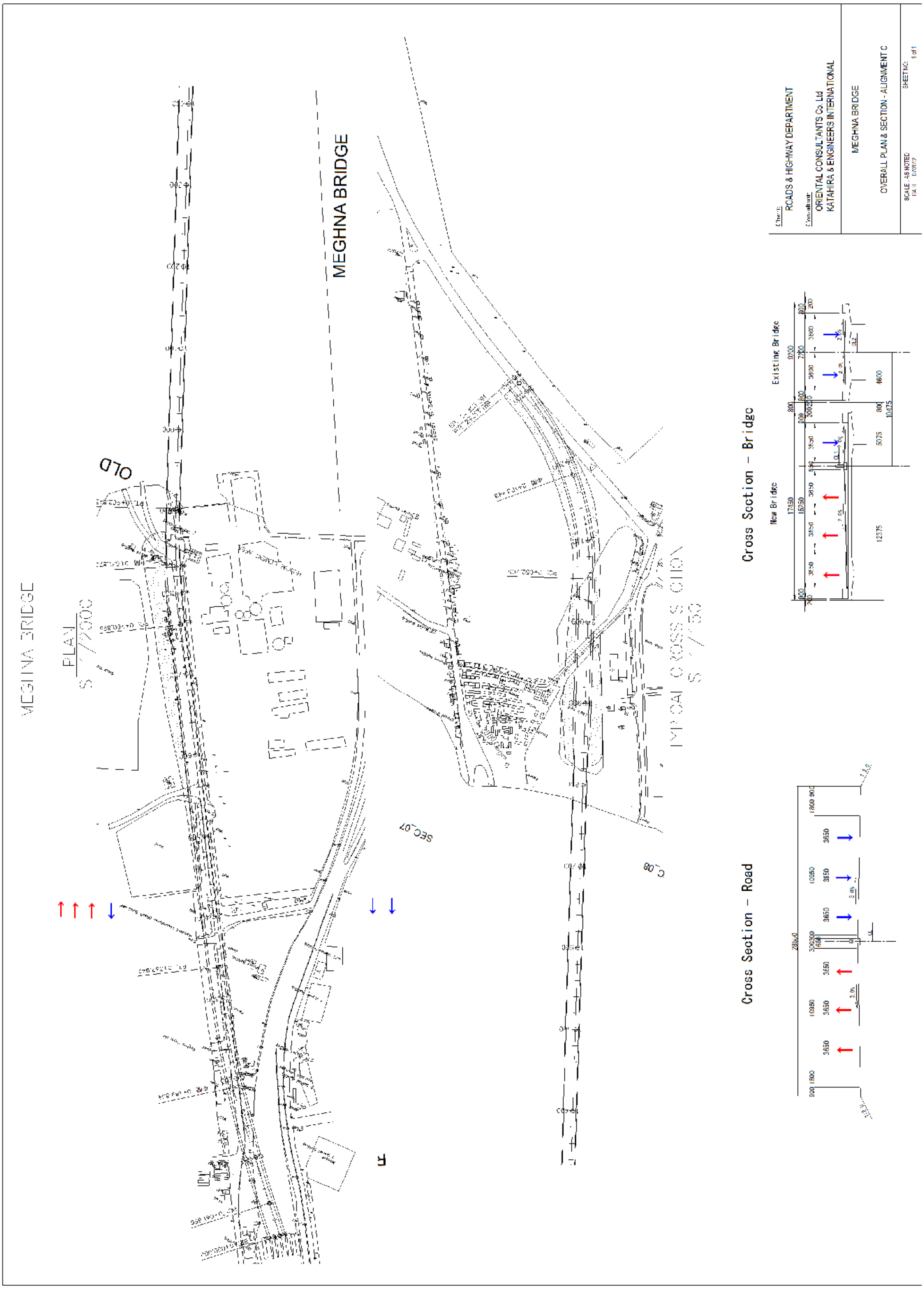


Figure 4.2.10 Route C for Meghna Bridge

4.2.3 Gumti Bridge

Similar to 2nd Kanchpur Bridge and 2nd Meghna Bridge, three alternative routes, namely, Route A, Route B and Route C, are also comprehensively evaluated for the construction of 2nd Gumti Bridge. Of which, Route A and Route C are located at downstream side and upstream side respectively and are closest to the existing bridge. These alternatives are planned to minimize the impact on the surrounding environment. On the other hand, another alternative route (Route B), located at downstream side and within RHD land boundary, is planned to avoid the influence of scouring on bridge foundation.

Table 4.2.3 Alternative Routes for 2nd Bridge

Name of Route	Description of Route	
Route A	Location	Next to existing bridge (downstream), Location that minimize resettlement and avoid land acquisition
	Traffic flow	One direction on existing bridge (two outbound lanes) One direction on 2nd bridge (three inbound lanes, one outbound lane)
Route B	Location	Route that provides adequate(more than 100m) distance from existing bridge (downstream), Location that avoid the influence of scouring
	Traffic flow	One direction on existing bridge (two outbound lanes) Two directions on 2nd bridge (three inbound lanes, one outbound lane)
Route C	Location	Next to existing bridge(upstream), Location that minimize resettlement
	Traffic flow	One direction on existing bridge (two outbound lanes) Two directions on 2nd bridge (three outbound lanes, one inbound lane)

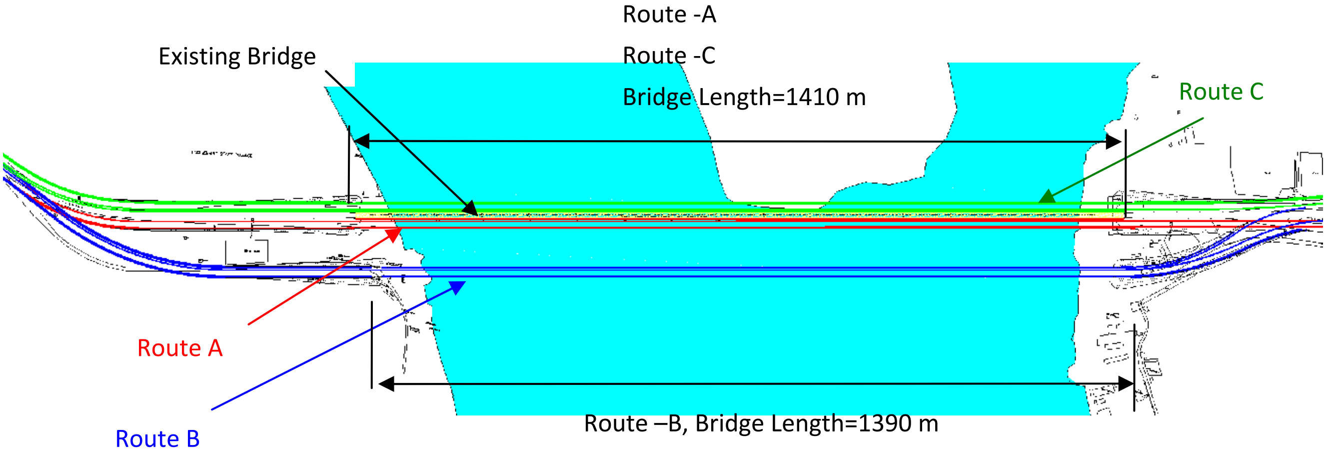


Figure 4.2.11 Alternative Routes for Gumti Bridge

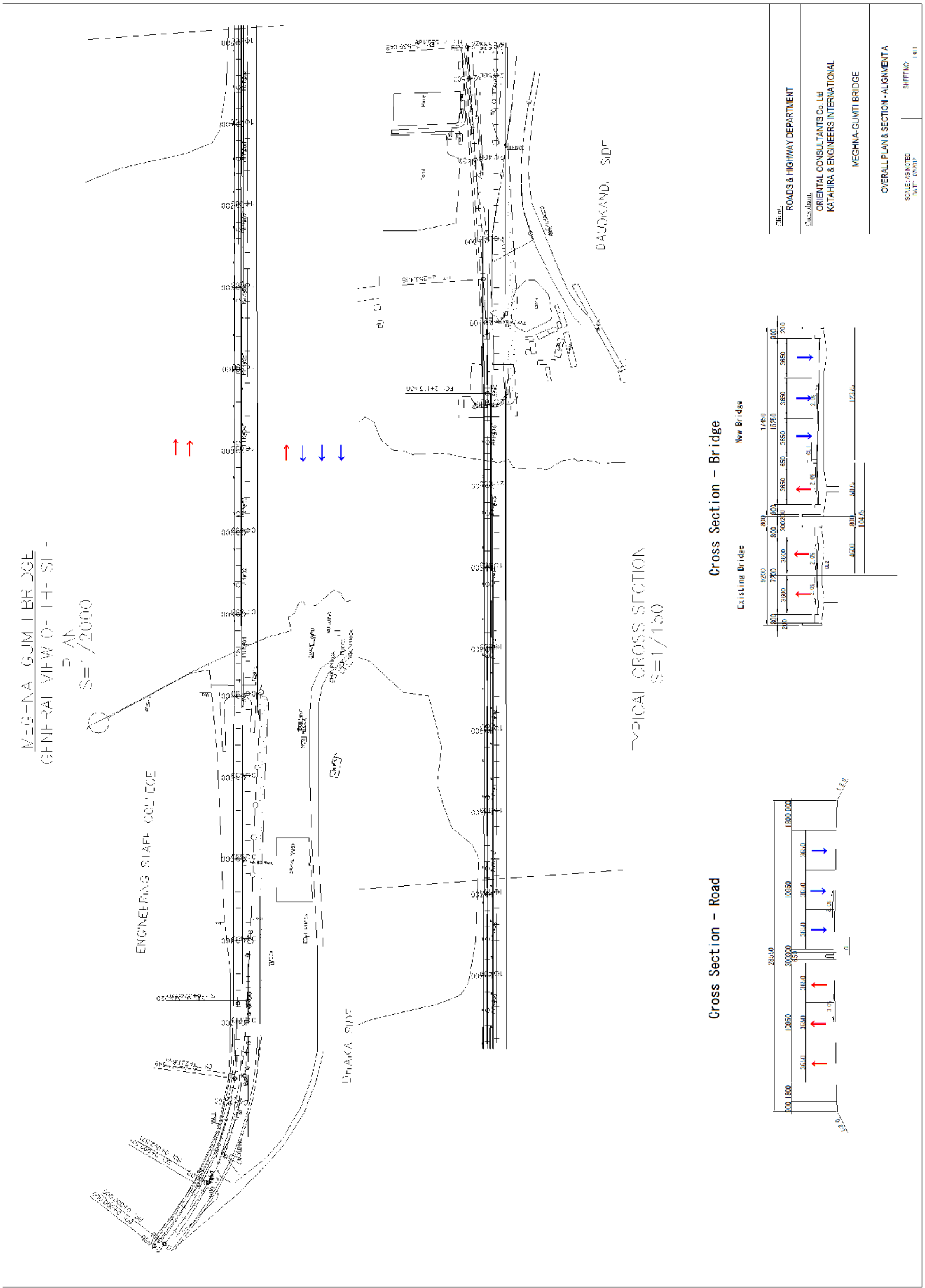


Figure 4.2.12 Route A for Gumti Bridge

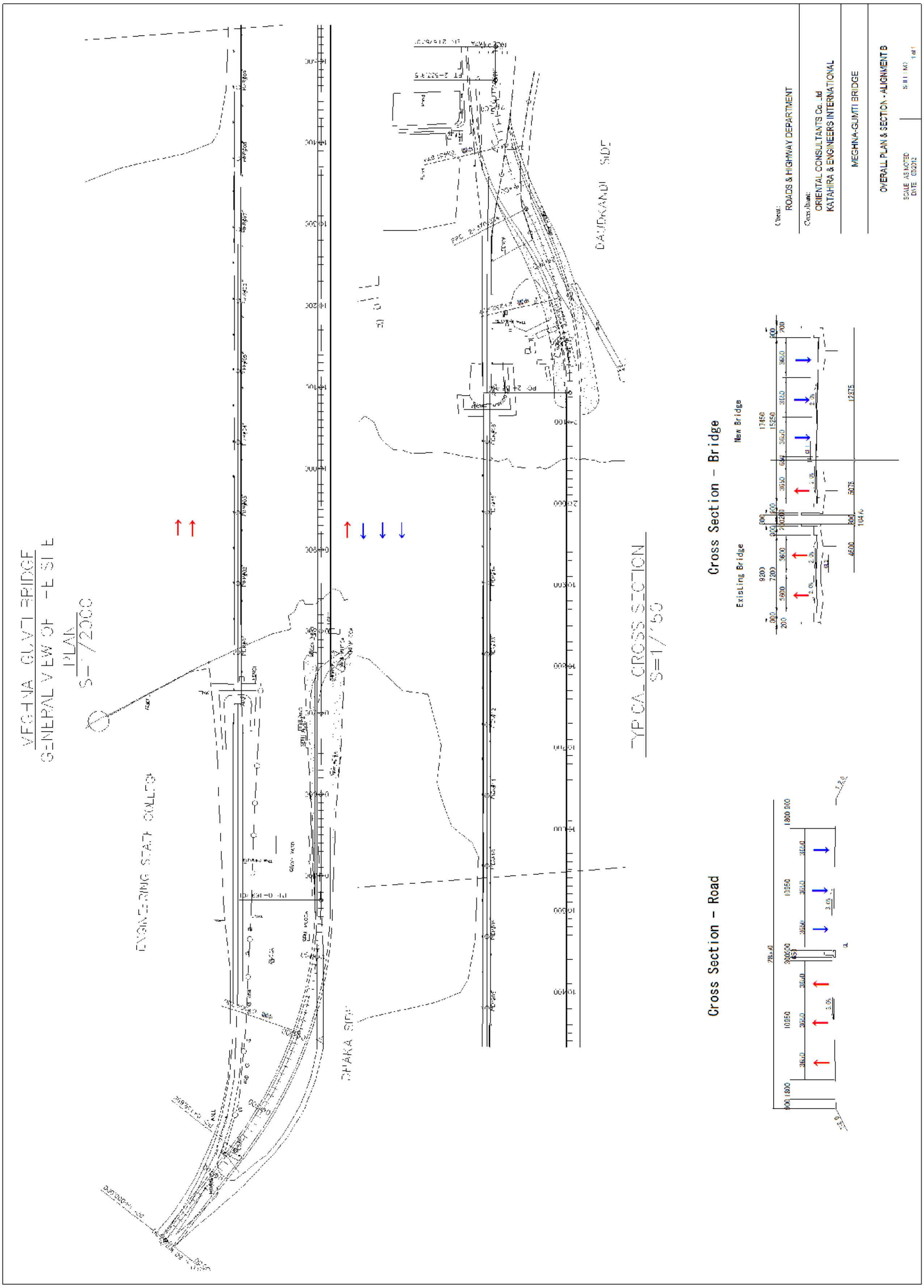


Figure 4.2.13 Route B for Gumti Bridge

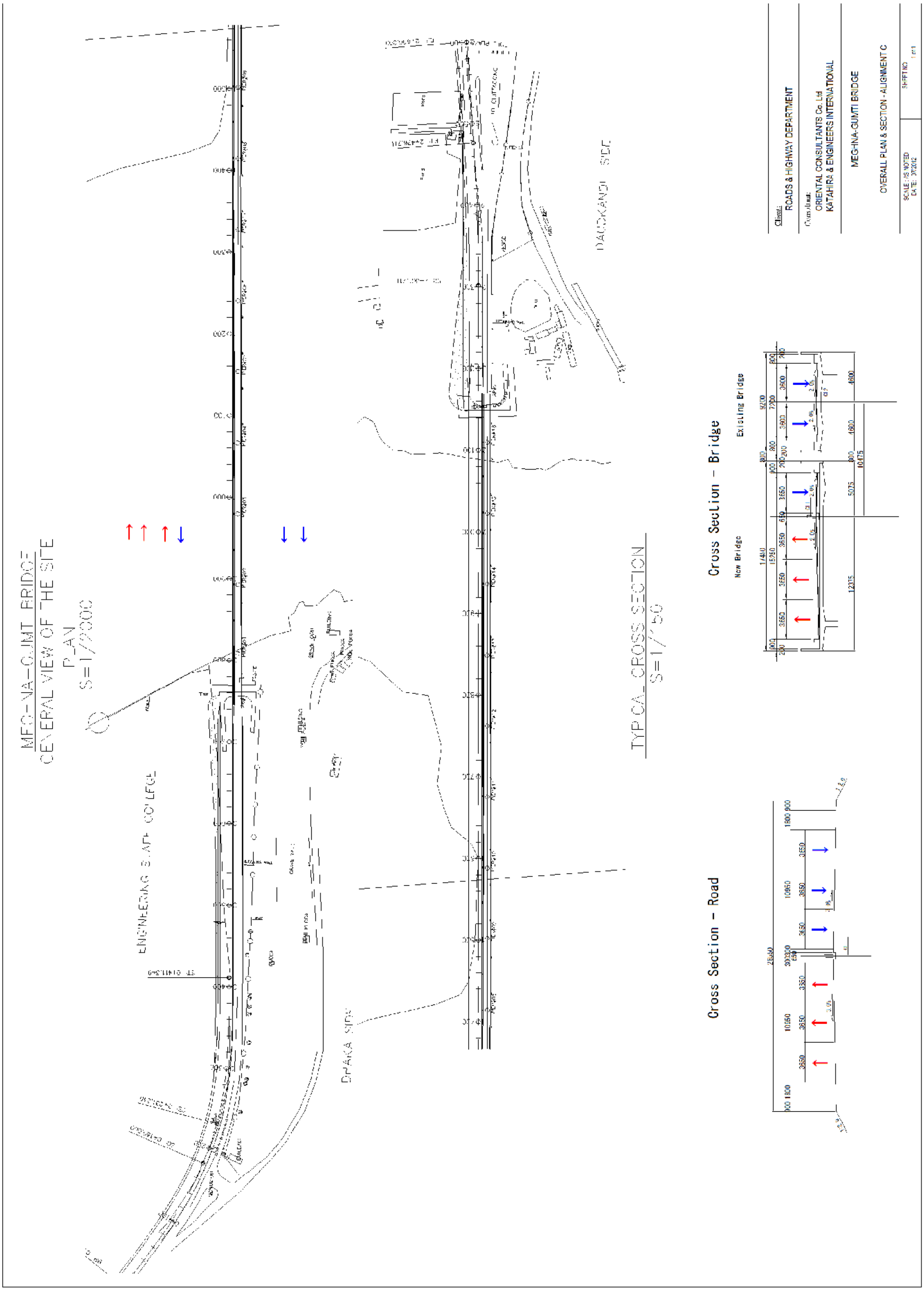


Figure 4.2.14 Route C for Gumti Bridge

4.3 Comprehensive Evaluation

4.3.1 Evaluation Items

Numerous evaluation items were considered for the optimum solution as shown in Table 4.3.1.

Table 4.3.1 Evaluation Items

Evaluation items	
Convenient to road users	
Impact on Socio- environment	Resettlement (number of residents, shops)
	Public facilities
	Land acquisition (area, landowners)
	Traffic safety for vessels
	Economic activities (sand unloading, ferry terminal operation, factory etc.)
Impact on natural environment	Ecosystem
	Hydrological conditions (bank erosion, scouring, flooding)
	Noise / Air pollution
	River flow
	Landscape
Obstacles (steel towers, water pipes, gas pipes)	
Construction condition	
Project cost	

(1) Convenient to road users

This item evaluates the safety for the drivers to pass over the route.

The plan with no problems regarding traffic management or traffic flow is evaluated as "◎". The plan with some problems to prevent traffic management or traffic flow is evaluated as "○", "△".

(2) Resettlement impact on Socio- environment

This item evaluates the number of structures affected because of construction of the new route.

The resettlement impact is evaluated relatively. The smallest number of structures is evaluated as "◎". The plan with number of structures exceeds 10 structures of the smallest one is evaluated as "○", while that exceeds 50 of the smallest one is evaluated as "△".

In this route selection, only the area of the main route is considered as the affected area, and the earth filling area for the approach embankment or construction yard were not considered because their impacts are assumed as similar/ common to all routes.

The number of structures within the proposed route were counted and rounded up based on the number of roofs identified through Google maps and a site reconnaissance.

(3) Public facilities impact on Socio- environment

This item evaluates the impact on public facilities like schools and Mosques.

The plan with no impact on public facilities (school and Mosque) is evaluated as "◎". The plan with impact on public facilities (school and Mosque) is evaluated as "△".

(4) Land acquisition impact on Socio- environment

This item evaluates additional land acquisition area. The plan with no additional land acquisition is evaluated as "◎". The plan with additional land acquisition is evaluated as "△".

(5) Traffic safety for vessels impact on Socio- environment

This item evaluates pier locations which influence the traffic safety for vessels.

The plan for a 2nd bridge location that is next to the existing is evaluated as "◎". Because these foundations are combined, so influence on the traffic safety is negligible. The plan for a 2nd bridge location that is some distance from the existing is evaluated as "○". Because these foundations are separated, so there is a small influence on the traffic safety.

(6) Economic activities

This item evaluates the impact on economic activities like shops, sand loading workers, and fishery.

This economic activity is evaluated relatively. The points assigned are "shop: 2.0, stall: 1.0, sand loading worker: 1.0, cultivating farm: 5.0, fishery: 5.0". The lowest point plan is evaluated as "◎". The plan with number of structures exceeds 10 point of the lowest one is evaluated as "○", while that exceeds 50 point of the lowest one is evaluated as "△".

(7) Ecosystem impact on natural environment

This item evaluates impacts regarding natural fauna and flora.

This item evaluates the number of objects relocated by construction of the new route. The plan with no direct impact on subjects (trees, plantation) and with some impact during construction is evaluated as "○". The plan with some impact on trees is evaluated as "△".

(8) Hydrological conditions impact on Socio- environment

This item evaluates pier scale and number of piers to impact on bank erosion, scouring and flooding.

If some foundations are combined, scoring is enlarged. So, the plan in which the 2nd bridge location is next to the existing is evaluated as "○". The plan in which the 2nd bridge location is some distance from the existing is evaluated as "◎".

(9) Noise / Air pollution impact on Socio- environment

This item evaluates the noise / air pollution impact on the closest houses after construction.

The plan in which there are no houses or few houses along the new access road is evaluated as "◎". The plan in which there are several houses along the new access road is evaluated as "○". The plan in which there are many houses or a school along the new access road is evaluated as "△".

(10) River flow impact on Socio- environment

This item evaluates pier scale and number of piers and their impact on river flow.

The plan in which the 2nd bridge location is next to the existing is evaluated as "◎", because these foundations are combined, so impact on river flow is negligible. The plan in which the 2nd bridge location is some distance from the existing is evaluated as "○", because these foundations are separated, so impact on river flow is slight.

(11) Landscape impact on Socio- environment

This item evaluates the landscape between the existing bridge and the 2nd bridge.

The plan in which the 2nd bridge location is next to the existing is evaluated as "◎", because these bridges are located in parallel, so both bridges look integrally. The plan in which the 2nd bridge location is some distance from the existing is evaluated as "○", because both bridges are separated, so the scenery looks complicated.

(12) Obstacles

This item evaluates the number of obstacles relocated by construction of the new route. The plan with no obstacles is evaluated as "◎". The plan with some obstacles is evaluated as "○", "△".

(13) Construction condition

This item evaluates the construction period (construction scale). The construction period directly depends on the important factor of bridge length which is evaluated relatively.

The construction plan with the shortest period is evaluated as "◎". The construction plan with period that exceeds 5 % of the shortest period is evaluated as "○", while that exceeds 5 % of the shortest period is evaluated as "△".

On other hand, if the construction plan with the period is less than 5 % of shortest period, then the another factor earthwork volume is taken into consideration for evaluation. If the earthwork volume exceeds 5,000 m^3 to the lowest value is evaluated as "○", while that amount exceeds 10,000 m^3 to the lowest value is evaluated as "△".

(14) Project cost

This item evaluates project cost including the 2nd bridge, existing bridge and approach road. Project cost is evaluated relatively. The most economical plan is evaluated as "◎". The plan with a project cost 5 % more than the most economical one is evaluated as "○", while that which is 10 % more than the most economical one is evaluated as "△".

4.3.2 Result of Evaluation

The methods to evaluate items are given in 4.3.1. Basically, each item will be evaluated according to the method given. In this section, additional explanations are given to evaluate the items.

(1) Kanchpur bridge site

Regarding the item of convenience to the road user, the location of the new road is rated based on its distance to the intersection of national highway No.2, so for traffic management, an additional two intersections are required at the point of connecting to the existing road. But, the two intersections prevent smooth traffic flow and debase traffic safety.

Regarding the item of resettlement, after the determination of the final route, a census was undertaken covering all the affected area including the earth filling area and construction yards. In the Census survey, the number of actual affected households of Route A is 231 households, which includes one household with several rentees per one structure. It is estimated 5.1 households per one structure on an average. Based on such estimation, that of Route B and C is both 308 households. Therefore Route A is the most feasible due the fact that the number affected households is the smallest compared with the other plans.

Route A, which is close to the existing bridge, is selected, because route A has less impact on the socio-environment and natural environment and is one of the most economical routes compared to the other routes.

(2) Meghna bridge site

Regarding the item of resettlement, after the determination of the final route, a census was undertaken covering all the affected areas including the earth filling area and construction yards. In the Census survey, the number of actual affected households of Route A is 19 households, which includes one household with several rentees per one structure. It is estimated that there are 1.9 households per one structure on an average. Based on such estimation, that of Routes B and C are 475 households and 114 households, respectively.

Therefore Route A is the most feasible due the fact that the number affected household is the smallest compared with the other plans.

Route A, which is close to the existing bridge is selected, because route A has less impact on the socio-environment and natural environment and is one of the most economical routes compared to the other routes.

(3) Gumti bridge site

Regarding the item of resettlement, after the determination of the final route, a census was undertaken covering all the affected areas including the earth filling area and construction yards. In the Census survey, the number of actual affected households of Route A is 24 households, which includes one household with several rentees per one structure. It is estimated that there are 1.2 households per one structure on an average. Based on such estimation, that of Route B and C is 96 households and 24 households, respectively. Therefore Route A is the most feasible due to the fact that the number of affected households is the smallest compared with the other plans.

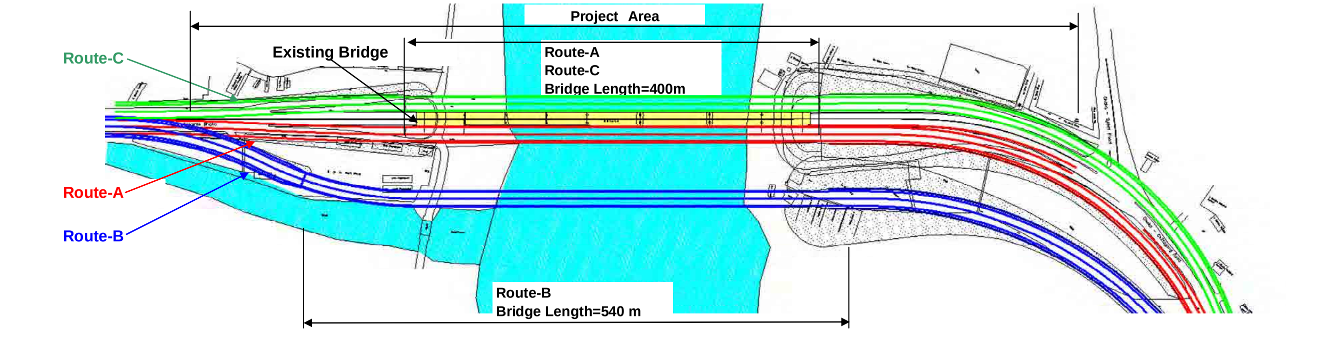
Route A, which is close to the existing bridge is selected, because route A has less impact on the socio-environment and natural environment and is one of the most economical routes compared to the other routes.

Finally, the routes of the respective three bridges are optimized in accordance with their comprehensive evaluation items and the optimized routes are shown in Table 4.3.2.

Table 4.3.2 Selected Routes

Bridge	Selected route
2nd Kanchpur	Route A
2nd Meghna	Route A
2nd Gumti	Route A

Table 4.3.3 Comparison Table at Kanchpur Site

Route alternatives		Route A		Route B		Route C	
Route image							
Route alignment		Next to existing bridge (down stream), Location that minimize resettlement and avoid land acquisition		Route that provides adequate(more than 100m) distance from existing bridge (down stream), Location that avoid the influence of scouring		Next to existing bridge (up stream), Location that reduce the land acquisition	
① Convenient to road user		No specific problem	◎	Two intersections are needed at the point of connecting existing road, so it's lower safe	△	No specific problem	◎
Impact on Socio-environment	② Resettlement	45 structure (15 houses, 20 shops,10 stalls)	◎	60 structure (40 houses, 20 shops)	○	60 structure (30 houses, 30 shops)	○
	③ Public facility	No	◎	Mosque relocation	△	No	◎
	④ Land acquisition (area、landowner)	0 m2	◎	5,000 m2	△	2,000 m2	△
	⑤ Traffic safety for vessels	Negligible (one foundation combined with both bridge)	◎	Slight (two foundations are separated)	○	Negligible (one foundation combined with both bridge)	◎
	⑥ Economic activities (sand unloading, ferry terminal operation, factory etc)	20 shops, 10 stalls 30 Sand loading/unloading workers	○	20 shops 30 Sand loading/unloading workers	◎	30 shops 60 Sand loading/unloading workers	△
Impact on natural environment	⑦ Ecosystem	Some impacts to natural fauna and flora during construction	○	Some impacts to natural fauna and flora during construction	○	Some impacts to natural fauna and flora during construction	○
	⑧ Hydrological conditions	Slight (enlarge scouring if some foundation will be conbined)	○	Negligible (scouring will be same around existing bridge)	◎	Slight (enlarge scouring if some foundation will be conbined)	○
	⑨ noise / air pollution	Moderate impact since some houses are remained along new accesses	○	Moderate impact since some houses are remained along new accesses	○	Moderate impact since some houses are remained along new accesses	○
	⑩ River flow	Negligible (one foundation combined with both bridge)	◎	Slight (two foundations are separated)	○	Negligible (one foundation combined with both bridge)	◎
	⑪ Landscape	Negligible (two bridges are close)	◎	Slight (two bridges are separated)	○	Negligible (two bridges are close)	◎
⑫ Obstacle Object (steel towers, water pipe, gas pipe)		No specific problem	◎	No specific problem	◎	No specific problem	◎
⑬ Construction condition		Construction period is shorter comparing to Route B Bridge Length: 400m Earthwork : 47,000m3	◎	Construction period is the longest Bridge Length: 540m Earthwork : 102,000m3	△	Construction period is shorter comparing to Route B Bridge Length: 400m Earthwork : 35,000m3	◎
⑭ Project cost		Low	◎	High	△	Low	◎
Evaluation		◎		△		○	

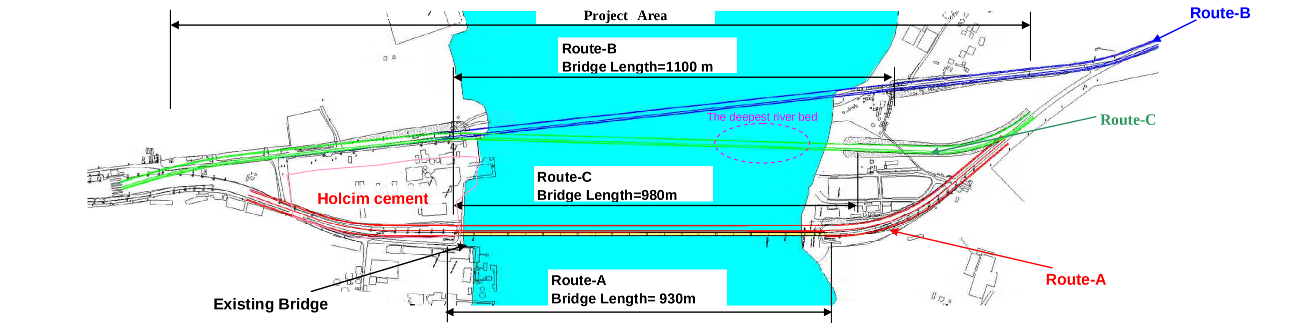
Legend ◎ : Excellent, ○ : Good, △ : Poor

Note: Number of structure within the proposed alignment were counted and rouded up based on the number of roofs identified through Google maps and site reconnaissance made

From the census survey, number of actual affected households of Route A is found to be 231 households, which include one household with several rentees per one structure. It is estimated 5.1 households per one structure on an average. Based on this assumption, the affected households under Route B and Route C would be both 308 households. Therefore, Route A is the most feasible route due to least affected households, comparing to other plans.

Source: JICA Study Team

Table 4.3.4 Comparison Table at Meghna Site

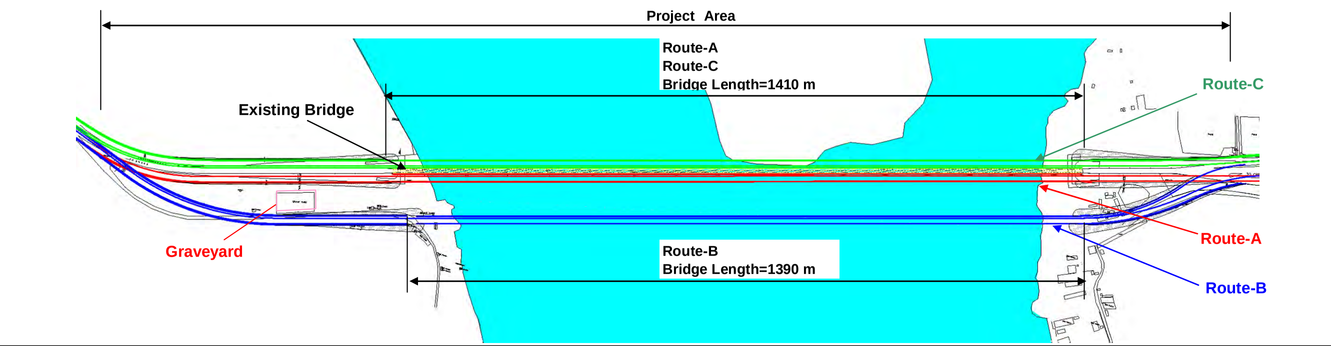
Route alternatives		Route A		Route B		Route C	
Route image							
Route alignment		Next to existing bridge Location that minimizes the influence on Holcim Cement factory's land (south side) and minimize resettlement		Provide distance of 250m upstream near the old ferry route		Provide distance of 250m upstream of shifted ferry route Minimize resettlement issue (Ctg. side) on Route B	
① Convenient to road user		No specific problem	◎	No specific problem	◎	No specific problem	◎
Impact on Socio-environment	② Resettlement*	10 structure (5 houses, 5 shops)	◎	250 structure (90 houses, 150 shops, 10 stalls)	△	60 structure (10 houses, 50 shops)	△
	③ Public facility	No	◎	Mosque relocation	△	No	◎
	④ Land acquisition (area,landowner)	15m from Holcim Cement boundary (RHD agreed with Holcim Cememt)	◎	0 m2	◎	0 m2	◎
	⑤ Traffic safety for vessels	Negligible (Integrated foundation)	◎	Slight (two foundations are separated)	○	Slight (two foundations are separated)	○
	⑥ Economic activities (sand unloading, ferry terminal operation, factory etc)	5 shops Fishery	◎	150 shops 50 Sand loading/unloading workers Fishery	△	50 shops 30 Sand loading/inloading workers Fishery	△
Impact on natural environment	⑦ Ecosystem	Small plantation Some impacts on natural fauna and flora during construction	△	Many roadside trees are needed to be cut	△	Many roadside trees are needed to be cut	△
	⑧ Hydrological conditions	Slight (accelerate scouring if some foundations in main channel are conbined, but bank erosion will be little)	○	Slight (impact on new bridge pier is little, but scouring around existing bridge pier will be increased due to protection works)	○	Worst (Increased scouring around new bridge pier due to new route along deepest riverbed, and existing bridge needs protection)	△
	⑨ Noise / air pollution	Negligible impact because few houses remain along new access on Chittagong side	◎	Severe impact because many houses and a school remain along new access	△	Severe impact because many houses and school remain along new access	△
	⑩ River flow	Negligible (Integrated foundation)	◎	Slight (two foundations are separated)	○	Slight (two foundations are separated)	○
	⑪ Landscape	Negligible (two bridges are close)	◎	Slight (two bridges are separated ,loss of road side trees)	○	Slight (two bridges are separated ,loss of road side trees)	○
⑫ Obstacle Object (steel towers, water pipe, gas pipe)		No specific problem	◎	No specific problem	◎	No specific problem	◎
⑬ Construction condition		Construction period is the shortest Bridge Length: 930m Earthwork : 39,000m3	◎	Construction period is the longest Bridge Length: 1,100m Earthwork : 84,000m3	△	Construction period is shorter comparing to Route B Bridge Length: 980m Earthwork : 128,000m3	○
⑭ Project cost		Low	◎	High	△	High	△
Evaluation		◎		△		○	

Legend ◎ : Excellent, ○ : Good, △ : Poor

Note: *Number of structures within the proposed alignment were counted and rouded up based on the number of roofs identified through Google maps and site reconnaissance survey
From the census survey, the number of affected households along Route A is found to be 19 households, which include one household with several rentees per one structure. It is estimated 1.9 households per one structure on an average. Based on this assumption, the affected households under Route B and Route C would be 475 and 114 respectively. Therefore, Route A is the most feasible route due to least affected households, comparing to other plans.

Source: JICA Study Team

Table 4.3.5 Comparison Table at Gumti Site

Route alternatives		Route A		Route B		Route C	
Route image							
Route alignment		Next to existing bridge (down stream), Location that minimize resettlement and avoid land acquisition		Route that provides adequate(more than 100m) distance from existing bridge (down stream), Location that avoid the influence of scouring		Next to existing bridge(up stream), Location that minimize resettlement	
① Convenient to road user		No specific problem	◎	No specific problem	◎	No specific problem	◎
Impact on Socio-environment	② Resettlement	20 structure (5 houses, 15 shops)	◎	80 structure (40 houses, 40 shops)	△	20 structure (20 shops)	◎
	③ Public facility	No	◎	No	◎	No	◎
	④ Land acquisition (area、landowner)	0 m2	◎	0 m2	◎	32,000m2	△
	⑤ Traffic safety for vessels	Negligible (one foundation combined with both bridge)	◎	Slight (two foundations are separated)	○	Negligible (one foundation combined with both bridge)	◎
	⑥ Economic activities (sand unloading, ferry terminal operation, factory etc)	15 shops 100 sand loading/unloading workers cultivating farm on sand bars Fishery	◎	40 shops 100 sand loading/unloading workers Fishery	△	20 shops 100 sand loading/unloading workers cultivating farm on sand bars Fishery	○
Impact on natural environment	⑦ Ecosystem	Some impacts to natural fauna and flora during construction	○	Some impacts to natural fauna and flora during construction	○	Some impacts to natural fauna and flora during construction	○
	⑧ Hydrological conditions	Slight (enlarge scouring if some foundation will be conbined)	○	Negligible (scouring will be same around existing bridge)	◎	Slight (enlarge scouring if some foundation will be conbined)	○
	⑨ noise / air pollution	No impact since no house remained along new access	◎	Moderate impact since several houses remained along new access	○	Negligible impact since few houses remained along new access	◎
	⑩ River flow	Negligible (one foundation combined with both bridge)	◎	Slight (two foundations are separated)	○	Negligible (one foundation combined with both bridge)	◎
	⑪ Landscape	Negligible (two bridges are close)	◎	Slight (two bridges are separated)	○	Negligible (two bridges are close)	◎
⑫ Obstacle Object (steel towers, water pipe, gas pipe)		No specific problem	◎	No specific problem	◎	No specific problem	◎
⑬ Construction condition		Construction period is shorter comparing to Route B Bridge Length: 1,410m Earthwork : 33,000m3	◎	Construction period is the longest Bridge Length: 1,390m Earthwork : 41,000m3	○	Construction period is shorter comparing to Route B Bridge Length: 1,410m Earthwork : 33,000m3	◎
⑭ Project cost		Low	◎	Slightly high	○	Low	◎
Evaluation		◎		△		○	

Legend ◎ : Excellent, ○ : Good, △ : Poor

Note: Number of structure within the proposed alignment were counted and rouded up based on the number of roofs identified through Google maps and site reconnaissance made

From the Census survey, number of actual affected households of Route A is 24 households, which include one household with several rentees per one structure. It is estimated 1.2 households per one structure on an average. Based on this assumption, the affected households under Route B and Route C would be 96 and 24 respectively. Therefore, Route A is the most feasible route due to least affected households, comparing to other plans.

Source: JICA Study Team

4.4 Kanchpur Intersection

(1) Introduction

Although the improvement of Kanchpur intersection is beyond the scope of this project, the preferable improvement plan is studied and proposed hereinafter. This is because any countermeasures against the traffic congestion at Kanchpur intersection is expected to influence to this project outcomes.

(2) Current situation

Kanchpur intersection is located at the intersection of NH-1 and NH-2. This site is highly congested due to large traffic volume movement and continuous traffic flow. There are several problems which may reduce the road capacity.

- Random parking of buses and CNG vehicles on the road / channel

Particular locations for bus stops and parking lots are required.

Figure 4.4.1 Current Situation

(3) Traffic volume

1) Traffic volume

Traffic volume is shown in Figure 4.4.2 for Kanchpur intersection. Future traffic volume is estimated by the ratio of future traffic volumes determined in this project. The ratios are 1.7(=129,412/76,714, 2022) and 1.9(=129,422/76,714, 2024). The year 2022 is assumed to be the opening year of this project. The year 2025 is assumed to be the opening year of the access controlled expressway.

2) Heavy vehicles

Heavy Trucks, Medium Trucks, Small Trucks, Large Buses, Mini Buses and Microbuses are categorized as Heavy vehicles (PCU = 3.0) in accordance with the specification by Geometric Design Standards for the Road and Highway Department. This method may consider not only vehicle space but also engine performance to decide road capacity. But, in the case of intersection analysis, the factor for vehicles only considers vehicle space. So, in the case of intersection analysis, Heavy Trucks, Medium Trucks, Large Buses and Mini Buses are categorized as Heavy vehicles (PCU = 2.0).

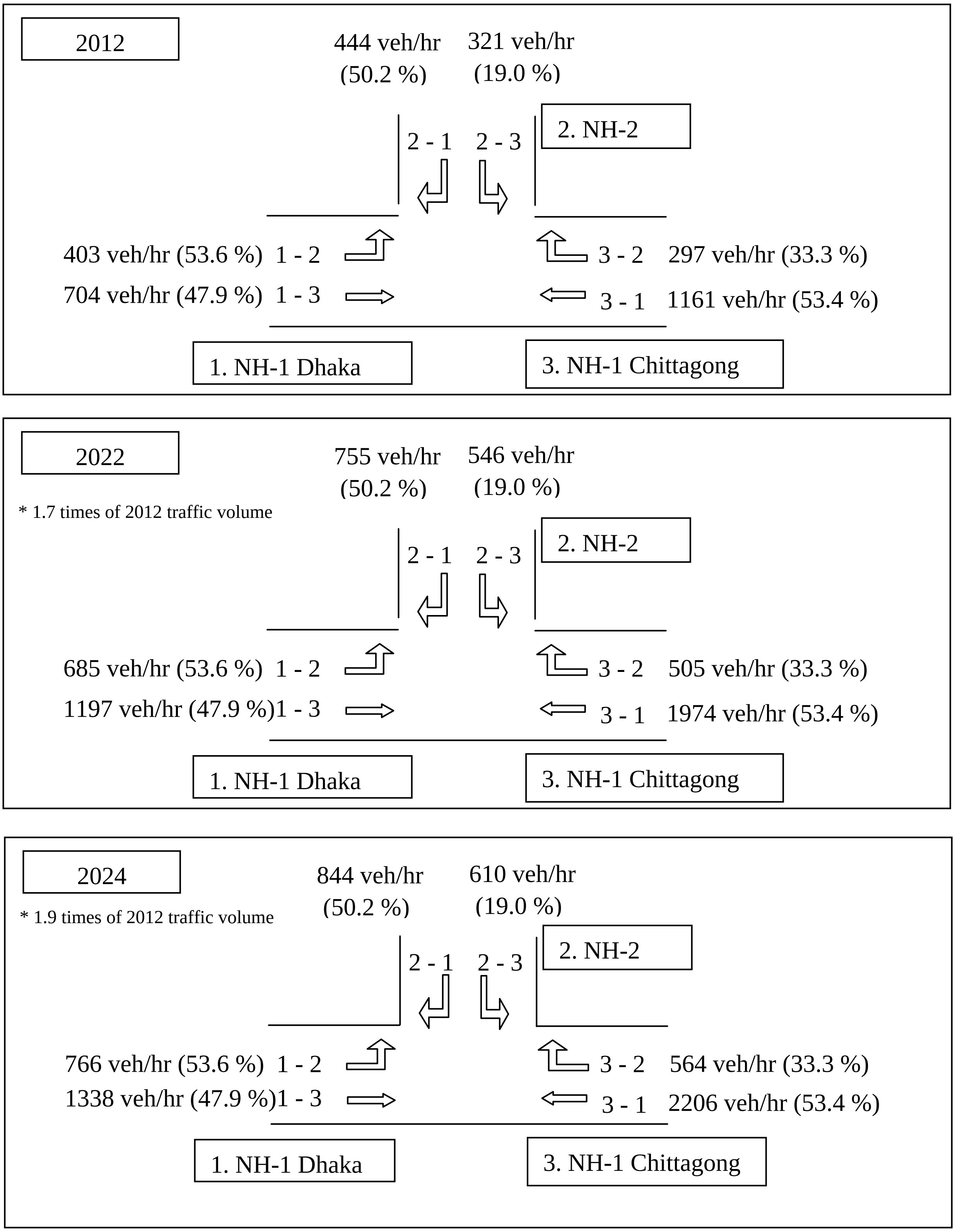


Figure 4.4.2 Traffic Volume at Kanchpur Intersection

(4) The improvement plan for Kanchpur intersection

The following alternatives are studied.

Option1: Signalized intersection + right-turn lane

Option2: Signalized intersection + "U-loop" lane

Option3: Fly-over of sub-flow + "U-loop" lane

Option4: Fly-over of sub-flow

Option5: Fly-over of main flow (outbound direction)

Option6: Fly-over of main flow (both directions)

Option7: Fly-over of sub-flow

1) Signalized intersection + right-turn lane

・Outline: Development of at grade intersection.

2) Signalized intersection + "U-loop" lane

・Outline: Development of at grade intersection,
Development of U-loop lane from Chittagong to NH-2 traffic flow).

・Outline (improved): Development of additional lane from NH-2 to Dhaka traffic flow and from NH-2 to Chittagong flow to improve traffic capacity based on original one.

3) Fly-over of sub-flow

・Outline: Development of flyover (2^{nd} level) from NH-2 to Dhaka traffic flow,
Development of flyover (3^{rd} level) from Chittagong to NH-2 traffic flow.

4) Fly-over of main flow (outbound direction)

・Outline: Development of flyover from Dhaka to Chittagong traffic flow.

・Outline (improved): Development of additional lane from Chittagong to NH-2 flow to improve traffic capacity based on original one.

5) Flyover of main flow (both directions)

- Outline: Development of flyover of NH-1 traffic flow.
- Outline (improved): Development of additional lane from Chittagong to NH-2 flow to improve traffic capacity based on original one.

6) Flyover of sub-flow

- Outline: Development of flyover from NH-2 to Dhaka traffic flow and Chittagong to NH-2 traffic flow.
- Outline (improved): Development of additional lane from Chittagong to NH-2 flow to improve traffic capacity based on original one.

7) Adopted option

The results obtained from the intersection analysis are shown in Table 4.4.1, which shows that it would be difficult to control the traffic flow through the development of Options-1 or 2. Furthermore, for Options-2 and 3, considerations on the additional resettlement issue and securing adequate and safe distance for the residents living nearby are necessary. The area around the U-loop plan is now developing by RHD. Options 4 to 7 are considered as the structural measures. Although under Options 4 to 6, the traffic flow is very smooth, these three options are more expensive than Option-7. Therefore, Option-7 is the most preferable measure considering with the least construction cost.

Additionally, in order to increase the road capacity level, it is desirable to prevent the drivers from suddenly stopping their moving vehicles alongside the road. This can be implemented by providing bus stops and sufficient parking spaces alongside the road.

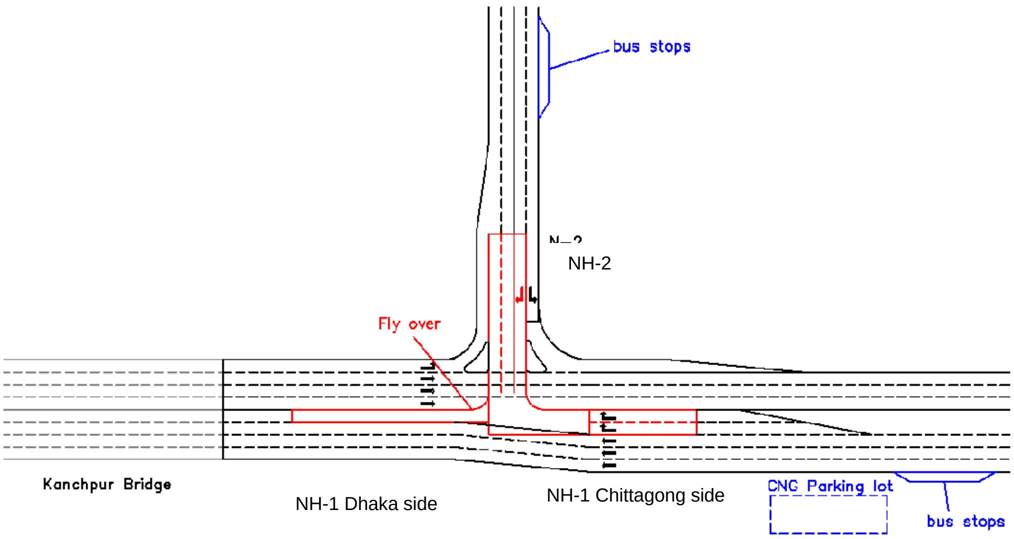
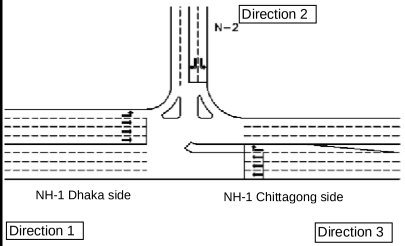
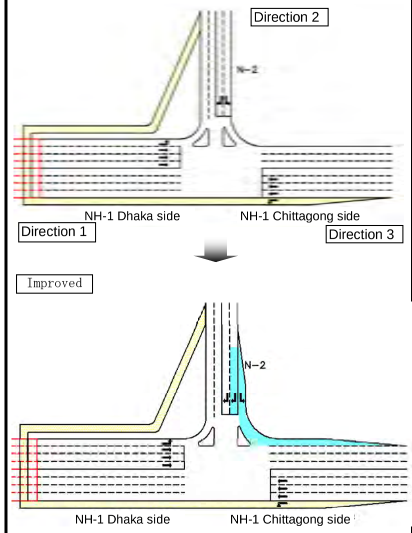
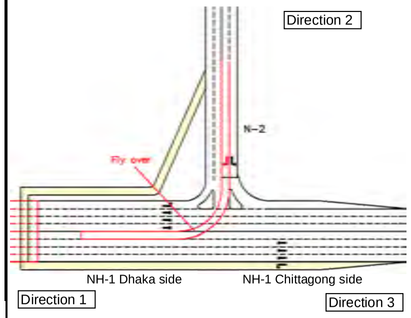
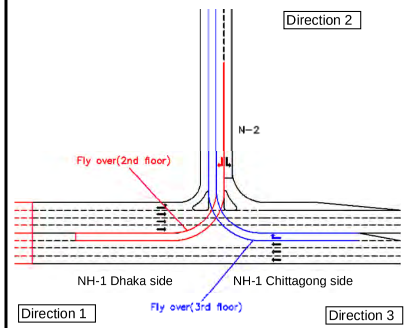
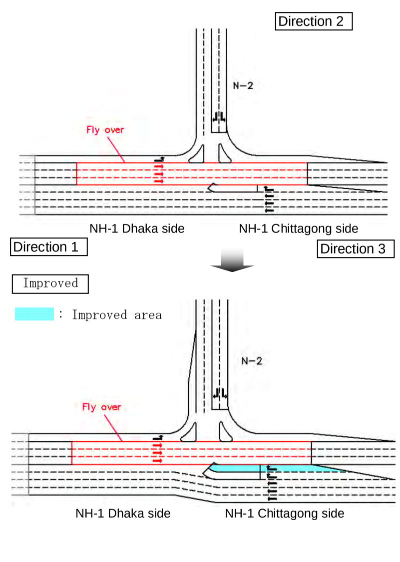
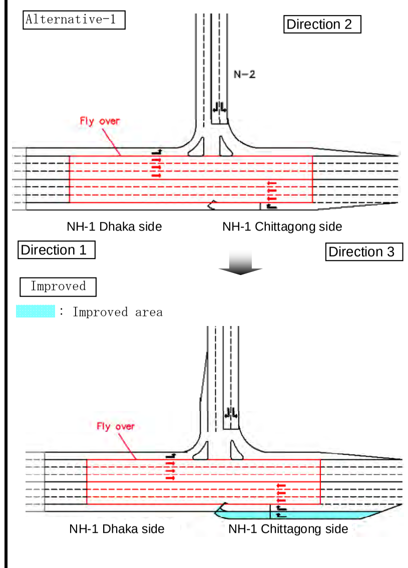
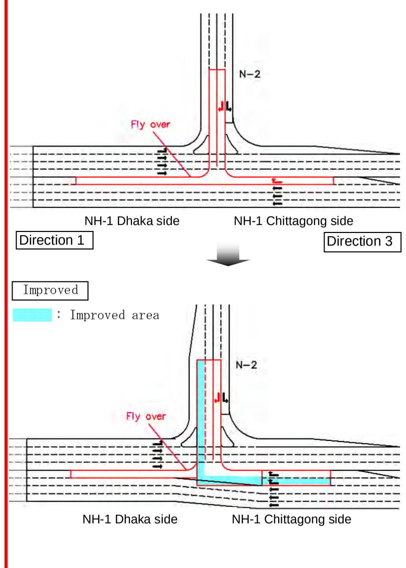


Figure 4.4.3 Adopted Option

Table 4.4.1 List of Intersection Analysis Results

	Option - 1		Option - 2		Option - 3		Option - 4	
	Signalized intersection + right-turn lane		Signalized intersection + "U-loop" lane		Fly-over of sub-flow + "U-loop" lane		Fly-over of sub-flow	
Plan								
Outline	Development of at grade intersection		Development of at grade intersection Development of U-loop lane from Chittagong to N-2 traffic flow		Development of fly-over from N-2 to Dhaka traffic flow Development of U-loop lane from Chittagong to N-2 traffic flow Fly-over length: 540m		Development of fly-over(2nd floor) from N-2 to Dhaka traffic flow Development of fly-over(3rd floor) from Chittagong to N-2 traffic flow Fly-over length: 440m(2nd floor), 680m(3rd floor)	
Intersection analysis (2022)	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 0.0651 | 0.777 | 2.049 | 1.312 | 1.330 | 2.152 v/c ratio for intersection (<1.0) 1.724	×	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 0.651 | 0.641 | 1.52 | 0.973 | 1.097 | - v/c ratio for intersection (<1.0) 1.282	×	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○
	-		Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 0.651 | 0.57 | 0.906 | - | 0.975 | - v/c ratio for intersection (<1.0) 0.95	○	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○
Intersection analysis (2024)	-		Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 0.729 | 0.637 | 1.013 | - | 1.09 | - v/c ratio for intersection (<1.0) 1.062	×	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○	Lane Group Capacity (<1.0) 1-2 | 1-3 | 2-1 | 2-3 | 3-1 | 3-2 - | - | - | - | - | - v/c ratio for intersection (<1.0) -	○
Project cost (million BDT)	-		-		334		1,153	
Application	not applicable		not applicable		○		○	
Evaluation	×		×		△		○	
Remarks	-		Additional resettlement will be required		Additional resettlement will be required			

		Option - 5	Option - 6	Option - 7
		Fly-over of main flow (outbound direction)	Fly-over of main flow (both direction)	Fly-over of sub-flow
Plan				
Outline		Development of fly-over from Dhaka to Chittagong traffic flow	Development of fly-over of N-1 traffic flow	Development of fly-over from N-2 to Dhaka traffic flow and Chittagong to N-2 traffic flow
		Fly-over length: 520m	Fly-over length: 520m	Fly-over length: 420m(N-1 side), 200m(N-2 side)
Intersection analysis (2022)	Lane Group Capacity (<1.0) 1-2	–	–	–
	1-3	–	–	–
	2-1	1.047	1.047	1.047
	2-3	–	–	–
	3-1	–	–	–
	3-2	1.076	1.076	1.076
	v/c ratio for intersection (<1.0)	1.058	1.058	1.058
	Evaluation	×	×	×
	Lane Group Capacity (<1.0) 1-2	–	–	–
	1-3	–	–	–
	2-1	0.942	0.942	0.942
	2-3	–	–	–
	3-1	–	–	–
	3-2	0.686	0.686	0.686
	v/c ratio for intersection (<1.0)	0.867	0.867	0.867
	Evaluation	○	○	○
Intersection analysis (2024)	Lane Group Capacity (<1.0) 1-2	–	–	–
	1-3	–	–	–
	2-1	0.994	0.994	0.994
	2-3	–	–	–
	3-1	–	–	–
	3-2	0.894	0.894	0.894
	v/c ratio for intersection (<1.0)	0.968	0.968	0.968
	Evaluation	○	○	○
Project cost (million BDT)		1,022	2,045	657
Application		○	○	○
Evaluation		○	△	◎
Remarks		-	-	-

Source: JICA Study Team

CHAPTER 5

HYDROLOGICAL AND HYDRAULIC ANALYSIS

5. HYDROLOGICAL AND HYDRAULIC ANALYSIS

5.1 Design Criteria

The design water level for this project is the 100-year return period water level.

5.2 Hydrological Analysis

Hydrological analysis was carried out to estimate the design discharges of streams at motorway crossing points which are required to estimate the hydraulic design outputs at bridges and also water levels. The corresponding catchment area of the stream was measured using topographic maps or/and referring to the data from nearby gauging stations.

In this section, the discharges around the three bridges are re-examined by discharge data which is collected in chapter 2.

5.2.1 Kanchpur Bridge

Up to now, there has been no river dredging plan near Kanchpur Bridge or for Lahkya river; hence the for the sake of this study, the discharge data for Kanchpur Bridge is estimated by using recently collected reference data.

There are two water level and discharge measuring stations, Demra at Lahkya River and Demra at Balu River. Both of the stations are monitored and maintained by BWDB. The discharge at Kanchpur Bridge is the accumulated discharge of Lahkya and Balu Rivers.

The 100-year return period discharge data at Demra (Lahkya) and Demra (Balu) station are estimated according to Japanese Government's technical standard, which is shown in Table 5.2.2 and Table 5.2.3. The 100-year return period discharge data at Kanchpur Bridge is 3480 [m^3/s], which is shown in Table 5.2.1 and Figure 5.2.1.

Table 5.2.1 100-Year Return Period Discharge at Kanchpur Bridge

	Demra (Lahyka) [m^3/s]	Demra (Balu) [m^3/s]	Kanchpur Bridge [m^3/s]
100-year discharge	2596	884	3480

Table 5.2.2 Occurrence Probability for Discharge at Demra (Lahkya) St.

		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	1705	1776	1772	–	1893	1879	–	–	–	–	–	–	–
	3	1891	1953	2019	–	2066	2056	–	–	–	–	–	–	–
	5	2125	2151	2311	–	2208	2209	–	–	–	–	–	–	–
	10	2443	2399	2703	–	2333	2351	–	–	–	–	–	–	–
	20	2761	2638	3106	–	2415	2452	–	–	–	–	–	–	–
	30	2947	2775	3349	–	2450	2497	–	–	–	–	–	–	–
	50	3182	2946	3665	–	2485	2545	–	–	–	–	–	–	–
	80	3397	3103	3965	–	2511	2581	–	–	–	–	–	–	–
	100	3500	3177	4112	–	2521	2596	–	–	–	–	–	–	–
	150	3686	3312	4383	–	2536	2620	–	–	–	–	–	–	–
	200	3818	3407	4581	–	2546	2635	–	–	–	–	–	–	–
	400	4136	3637	5072	–	2564	2665	–	–	–	–	–	–	–
SLSC(99%)		0.099	0.066	0.084	–	0.038	0.038	–	–	–	–	–	–	–
Error of Estimation		224	181	266	–	238	216	–	–	–	–	–	–	–

Source: Estimated by the study team according to Japanese Government technical standard

Table 5.2.3 Occurrence Probability for Discharge at Demra (Balu) St

		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	337	363	360	378	392	–	–	–	380	–	–	–	–
	3	406	429	455	446	460	–	–	–	445	–	–	–	–
	5	493	503	571	515	520	–	–	–	511	–	–	–	–
	10	611	595	734	592	577	–	–	–	585	–	–	–	–
	20	730	684	906	657	616	–	–	–	649	–	–	–	–
	30	799	735	1012	691	634	–	–	–	684	–	–	–	–
	50	886	798	1153	731	652	–	–	–	725	–	–	–	–
	80	966	856	1288	764	665	–	–	–	761	–	–	–	–
	100	1004	884	1355	779	671	–	–	–	778	–	–	–	–
	150	1073	934	1479	804	680	–	–	–	807	–	–	–	–
	200	1122	970	1571	821	685	–	–	–	828	–	–	–	–
	400	1240	1055	1801	859	695	–	–	–	875	–	–	–	–
SLSC(99%)		0.068	0.052	0.072	0.061	0.086	–	–	–	0.058	–	–	–	–
Error of Estimation		203	167	479	279	642	–	–	–	78	–	–	–	–

Source: Estimated by the study team according to Japanese Government technical standard

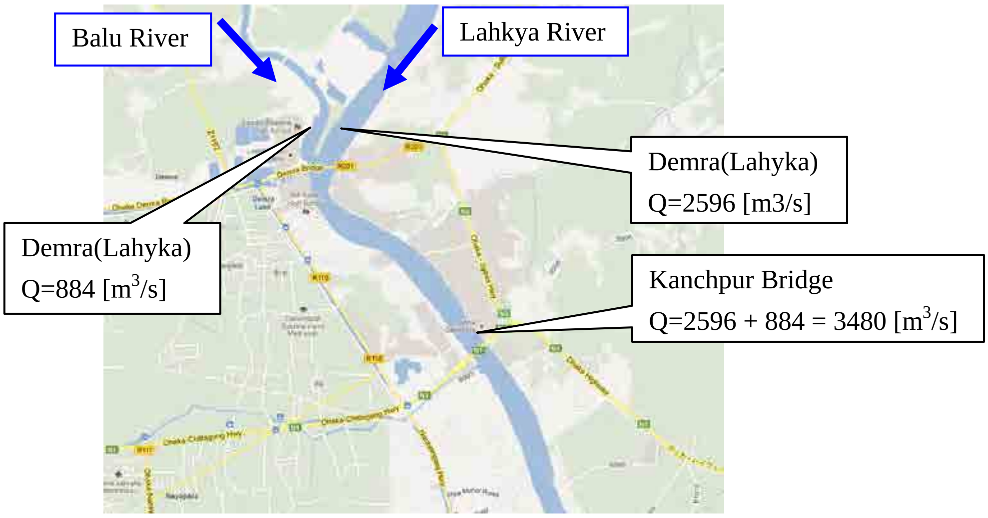


Figure 5.2.1 Location of Discharge Measuring Stations around Kanchpur Bridge

5.2.2 Meghna and Gumti Bridges

The design discharge should be determined by the maximum volume considering the former plan discharge and latest discharge data.

In the upper reaches of Meghna River, there is only one discharge measuring station at Bhairab Bazar which is maintained by BWBD. Hence, the discharge is estimated according to "Feasibility study on Gumti Bridges construction project - final report (1985), JICA". In this report, discharge at Bhairab Bazar is estimated at first, then discharge at Meghna and Gumti Bridges is estimated by considering the flow distribution to the main channel and branch of Meguna River and residual catchment area after Bhairab Bazar Station shown in Table 5.2.6.

The discharge with a 100-year return period, measured at Bhairab Bazar Station, is estimated by three methods shown in Table 5.2.4. The maximum discharge of the 100-year return period at Bhairab Bazar is found to be 23,700 [m^3/s] from the 1985's JICA Report.

Hence the 100-year return period discharge at Meghna and Gumti bridges are estimated below. The relevant relationship between discharge, catchment area and discharge distribution is shown in Figure 5.2.2.

- 100 year return period discharge of Meghna Bridge Q= 15,200m^3/sec.
- 100 year return period discharge of Gumti Bridge Q= 12,400m^3/sec.

Table 5.2.4 100-Year Return Period Discharge at Bhairab Bazar

	Discharge [m^3/s]	Remarks
1985 JICA report	23,700	Adopted in this research
Flood Action Plan 9B[1]	20,300	
Estimated using data collected in this study	22,848	See Table 5.2.5 and Figure 5.2.2

Table 5.2.5 Occurrence Probability for Discharge at Bhairab Bazar (Estimated)

		Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	Ishihara Takase	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM
Return Period in year	2	11888	12417	12348	12715	12771	12739	–	–	–	–	–	–	–
	3	13273	13738	13892	14072	14111	14080	–	–	–	–	–	–	–
	5	15017	15209	15709	15448	15445	15429	–	–	–	–	–	–	–
	10	17385	17058	18136	16994	16924	16943	–	–	–	–	–	–	–
	20	19753	18832	20615	18307	18179	18246	–	–	–	–	–	–	–
	30	21138	19852	22107	18994	18843	18941	–	–	–	–	–	–	–
	50	22882	21128	24040	19789	19621	19763	–	–	–	–	–	–	–
	80	24488	22295	25875	20459	20291	20477	–	–	–	–	–	–	–
	100	25250	22848	26766	20758	20596	20803	–	–	–	–	–	–	–
	150	26635	23851	28419	21274	21129	21378	–	–	–	–	–	–	–
	200	27618	24562	29618	21619	21494	21773	–	–	–	–	–	–	–
	400	29985	26273	30000	22384	22330	22685	–	–	–	–	–	–	–
SLSC(99%)		0.069	0.037	0.053	0.033	0.028	0.028	–	–	–	–	–	–	–
Error of Estimation		1617	1349	1694	1723	1359	1587	–	–	–	–	–	–	–

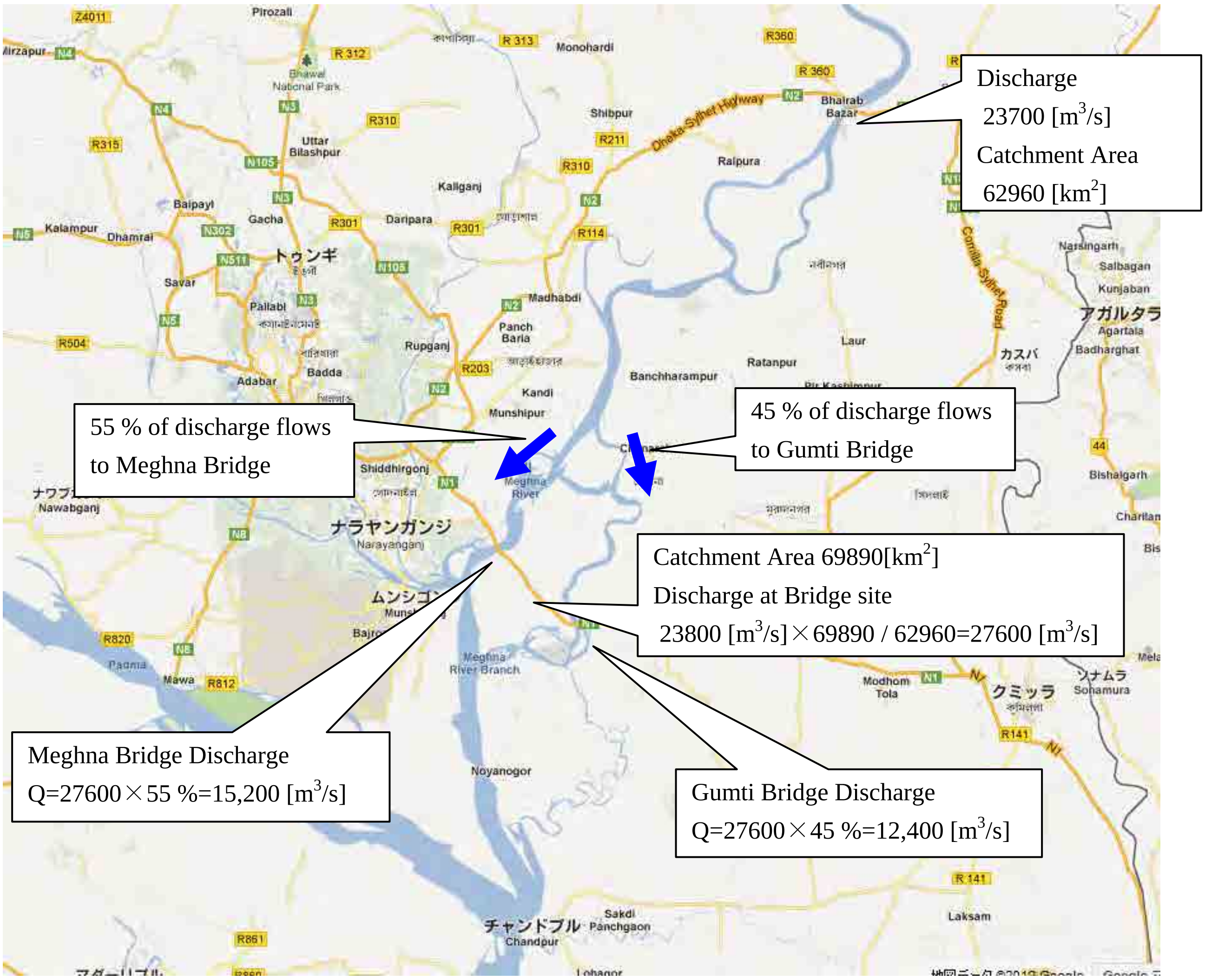
Source: Estimated by the study team according to Japanese Government technical standard

Table 5.2.6 Catchment Area of the Meghna River

	Outside of Bangladesh [km^2]	Inside of Bangladesh [km^2]	Total [km^2]
Catchment Area at Bhairab Bazar St.	41,390	21,570	62,960
Rest of Catchment Area Between Bridge Site And Bhairab Bazar St.	2,760	4,170	6,930
Catchment Area at Bridge Sites	44,150	25,740	69,890

Source: 1985's JICA report

[1] Flood Action Plan 9B: Meghna River Bank Protection Short Term Study, March 1990, IDA Credit



Source: Estimated by the study team according to1985's JICA report

Figure 5.2.2 Relationship between 100-Year Period Discharge and Catchment Area

5.3 High-Water Level Calculation

5.3.1 Method

Hydraulic design was carried out to obtain the design scour depth at the three bridges using Nays2D on i-Ric software platform developed by Professor Yasuyuki SHIMIZU of Hokkaido University (Japan). Nays2D is free software, which is capable of calculating unsteady horizontal two-dimensional river flows and riverbed variation / lateral erosion. The software can be downloaded from the website: http:// http://i-ric.org/en/.

Water surface profiles are computed from a horizontal two-dimensional lattice by solving the 2d-unsteady equation of motion. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion coefficients. Nays2D requires inputs for boundary conditions of upstream discharge and either downstream water level.

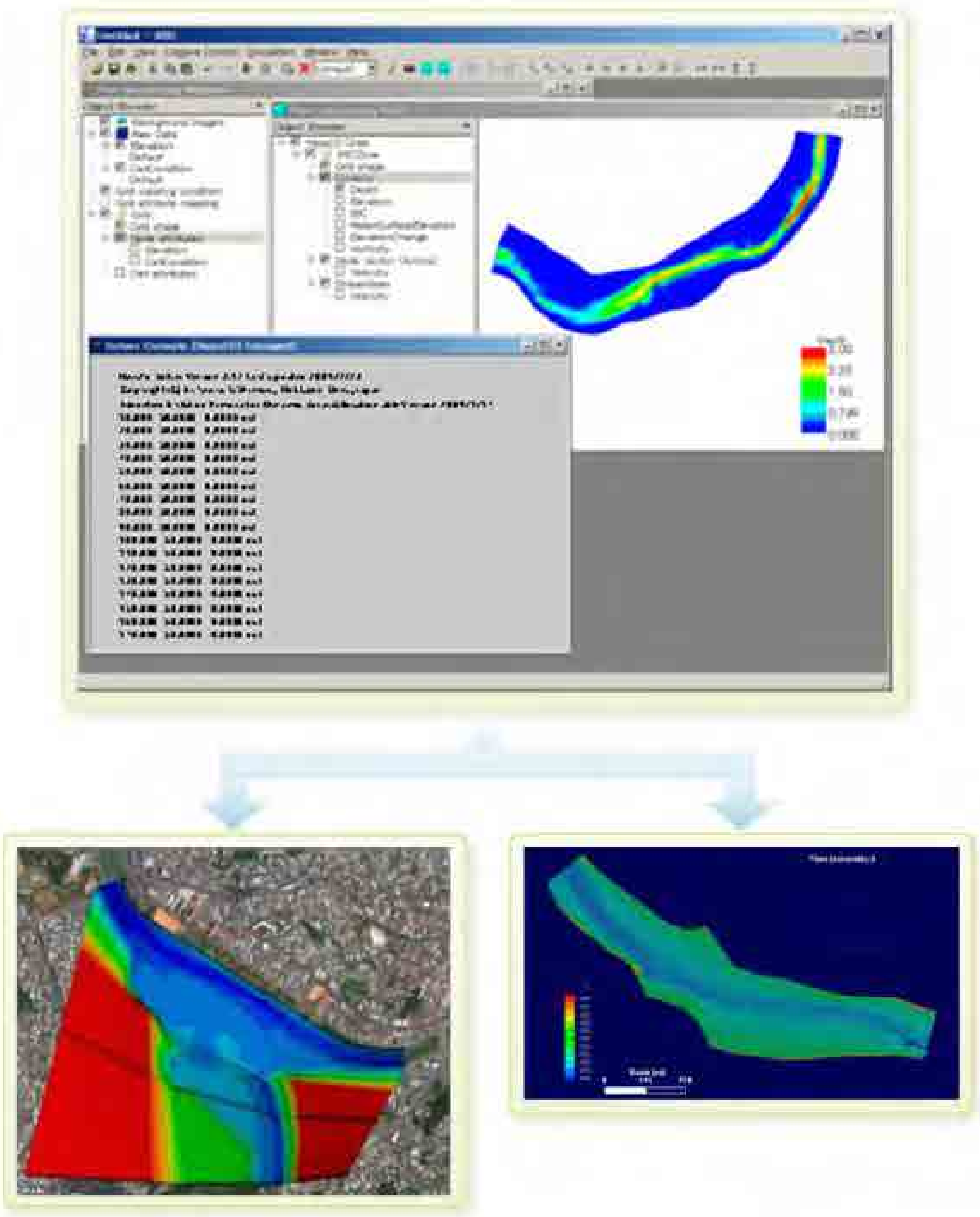


Figure 5.3.1 Example of Numerical Simulation Using NAYS2D Software on i-Ric Platform

The following procedure was adopted in the modeling.

- Channel bathymetrical condition is set up in the model using the river cross-sections taken upstream and downstream. Cross section data is used (will be updated by using new survey results).

- Channel roughness “Manning’s n” is adopted according to the bed material diameter d=0.167 [mm]. Manning's n value for d=0.167 [mm] is n=0.020 according to Japanese

Government's Technical Standard, that nunber is applied for the main river and flood plain.

- The upstream boundary condition is applied for the 100-year return period discharge for each bridge.

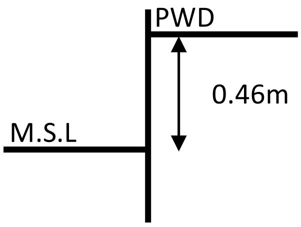
- The downstream boundary condition is applied for the 100-year return period watar level for each bridge, which is estimated according to Japanese Gorvernment's Technical Standard.

The boundary condition for the numerical model simulation is summarized in Table 5.3.1. Water Level measured at BWDB's station is transformed from PWD.m to MSL.m by the relationship shown in Figure 5.3.2.

Table 5.3.1 Boundary Condition for Hydraulic Analysis at Each Bridge
(100-Year Return Period)

Bridge Site	Discharge (m3/s)			Water Level					
	Measured Station		Upstream Discharge [m3/s]	Measured Station	[PWD.m]	[MSL.m]	Bed slope	Distance from station [m]	Downstream Water Level [MSL.m]
Kanchpur	Demra(Lahkya)	2596	3,480	Demra(Lahkya)	7.47	7.01	0.0001	4,180	6.59
	Demra(Balu)	884							
Meghna	Bhirab bazar	23700	15,200	Meghna Ferryghat	6.98	6.52	0.0001	1,332	6.39
Gumti			12,400	Daudkandi	7.36	6.90	0.0001	900	6.81

Source: Estimated by the study team according to Japanese Government technical standard



M.S.L = PWD -0.46 [m]

Figure 5.3.2 Relationship between BWDB's PWD.m and M.S.L.m

5.3.2 Numerical Simulation Results in 100-Year Return Period Flow Condition

To estimate scour around new bridge piers, the hydraulic flow condition with 100-year return period flood discharge is calculated by Nays2D software for each bridge.

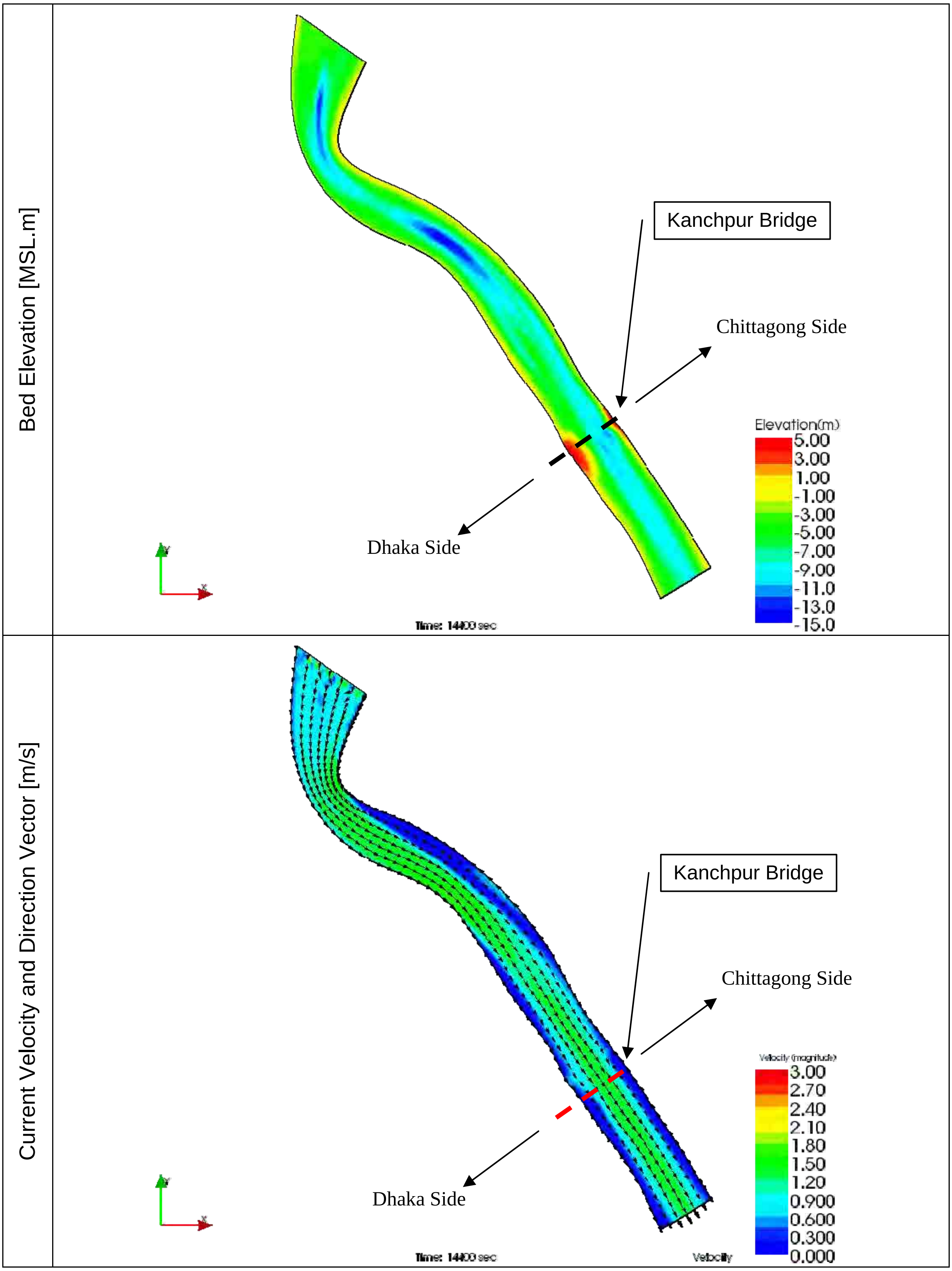
(1) Kanchpur Bridge

The hydraulic value of numerical analysis results at the bridge center line in 100-year return period discharge is shown in Table 5.3.2. Contour map of bed elevation, current velocity in 100-year return period flood in this model is shown in Figure 5.3.3. The hydraulic value shown in Table 5.3.2 will be used to estimate the local scouring around each pier at Kanchpur Bridge.

Table 5.3.2 Numerical Analysis Result for 100-Year Return Period at Kanchpur Bridge

Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	1.65	4.60	6.25	0.49
P1	2.76	3.49	6.25	0.62
P2	5.76	0.48	6.24	0.89
P3	12.04	-5.80	6.24	1.22
P4	14.90	-8.66	6.23	1.33
P5	16.44	-10.20	6.24	1.23
P6	12.67	-6.42	6.25	0.77
P7	2.61	3.65	6.26	0.28
A2	2.61	3.65	6.26	0.28

Source: Estimated by the study team



Source: Estimated by the study team

Figure 5.3.3 Bed Elevation and Current Velocity Contour around Kanchpur Bridge

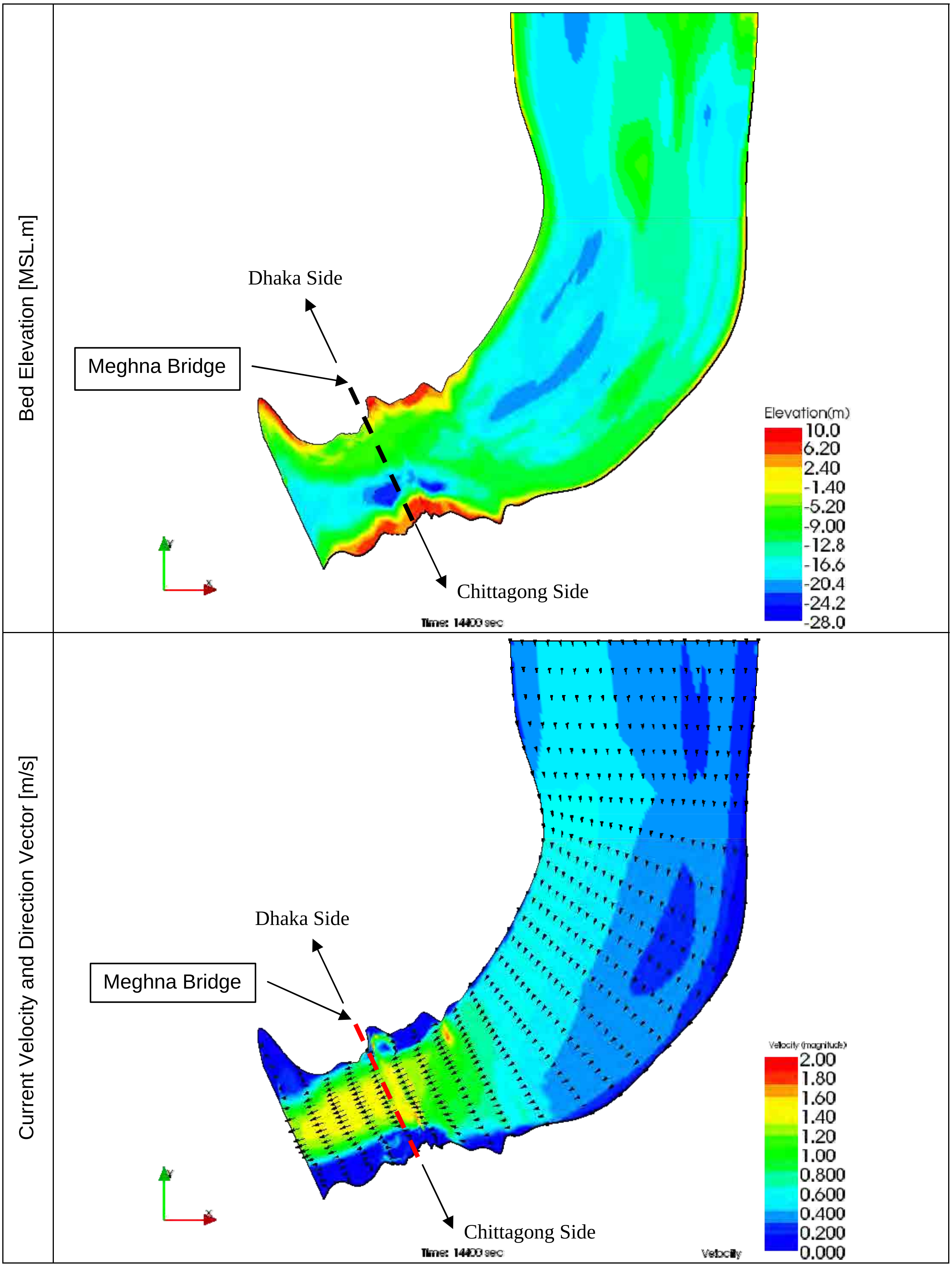
(2) Meghna Bridge

The hydraulic value of numerical analysis results at the center line of the bridge with a 100-year return period discharge is shown in Table 5.3.3. Contour map of bed elevation, current velocity in a 100-year return period flood in this model is shown in Figure 5.3.4. The hydraulic value shown in Table 5.3.3 will be used to estimate the local scouring around each pier at Meghna Bridge.

Table 5.3.3 Numerical Analysis Result for 100-Year Return Period at Meghna Bridge

Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	1.80	4.69	6.50	0.02
P1	2.87	3.62	6.50	0.13
P2	4.86	1.63	6.49	0.62
P3	7.78	-1.33	6.46	0.61
P4	13.91	-7.45	6.45	0.42
P5	14.27	-7.81	6.47	1.13
P6	15.23	-8.76	6.48	1.30
P7	18.54	-12.05	6.48	1.21
P8	23.89	-17.40	6.49	1.14
P9	27.23	-20.76	6.48	1.23
P10	25.97	-19.51	6.46	1.44
P11	16.41	-9.95	6.46	1.47
P12	1.36	5.11	6.48	1.07
A2	0.00	9.13	9.13	0.00

Source: Estimated by the study team



Source: Estimated by the study team

Figure 5.3.4 Bed Elevation and Current Velocity Contour around Meghna Bridge

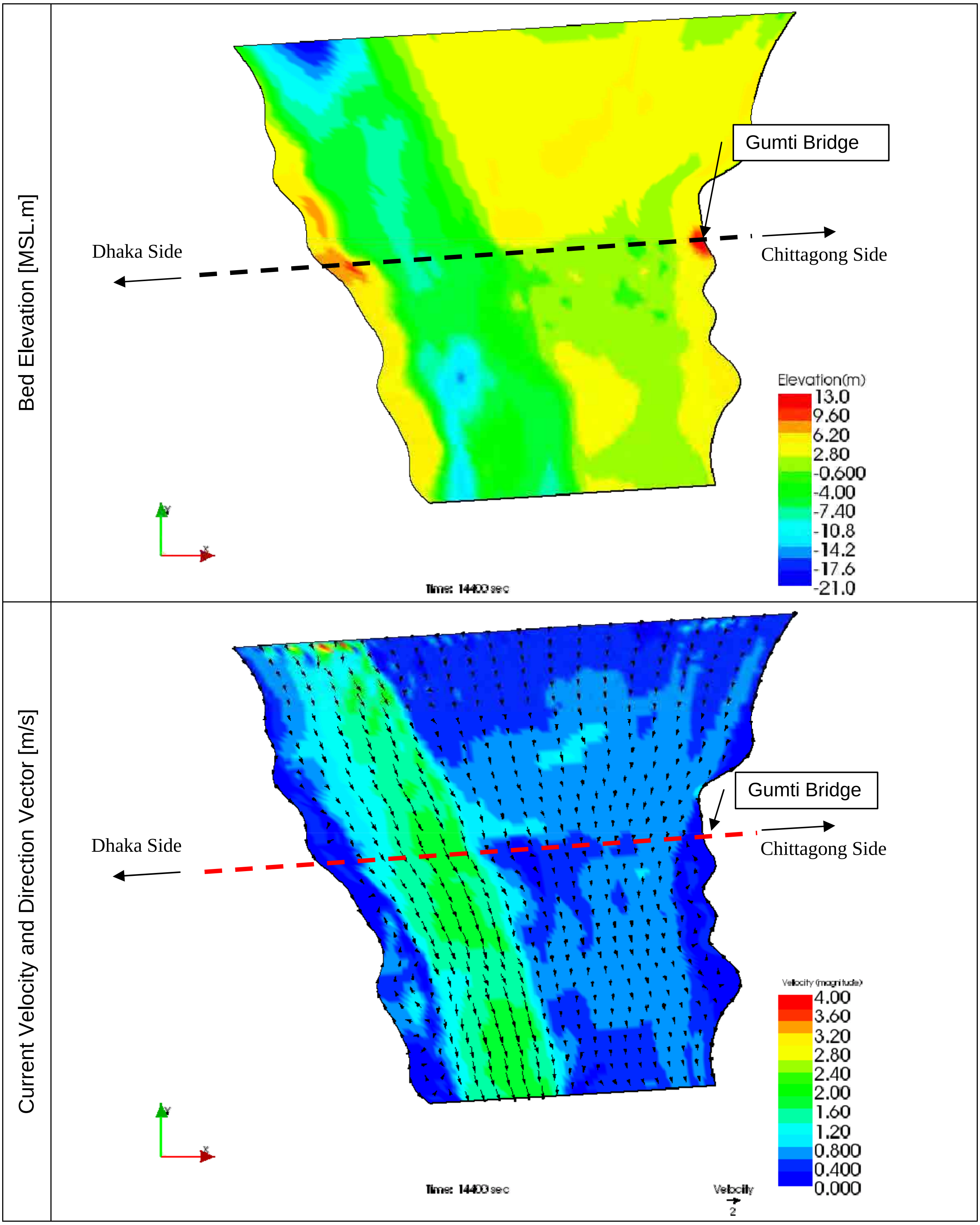
(3) Gumti Bridge

The hydraulic value of numerical analysis results at bridge center line in 100-year return period discharge is shown in Table 5.3.4.Contour map of bed elevation, current velocity in 100-year return period flood in this model is shown in Figure 5.3.5. The hydraulic value shown in Table 5.3.4 will be used to estimate the local scouring around each pier at Gumti Bridge.

Table 5.3.4 Numerical Analysis Result for 100-Year Return Period at Gumti Bridge

Pier No	Water Depth [MSL.m]	Bed Elevation [MSL.m]	Water Elevation [MSL.m]	Current Velocity [m/s]
A1	0.21	6.81	7.02	0.49
P1	2.94	3.64	6.58	1.01
P2	13.81	-7.22	6.59	1.29
P3	15.54	-8.94	6.60	1.48
P4	14.99	-8.39	6.60	1.62
P5	13.57	-6.97	6.60	1.71
P6	13.86	-7.28	6.58	1.65
P7	11.81	-5.23	6.58	0.48
P8	7.55	-0.96	6.59	0.27
P9	6.05	0.54	6.60	0.17
P10	5.68	0.91	6.59	0.49
P11	6.23	0.35	6.59	0.46
P12	6.50	0.08	6.59	0.43
P13	5.73	0.85	6.58	0.54
P14	8.19	-1.61	6.57	0.46
P15	6.70	-0.14	6.57	0.59
P16	5.17	1.38	6.56	0.75
A2	2.29	4.26	6.55	0.13

Source: Estimated by the study team



Source: Estimated by the study team

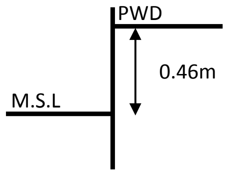
Figure 5.3.5 Bed Elevation and Current Velocity Contour around Gumti Bridge

5.3.3 Design Water Level

Based on the water level and discharge data collected from BWDB for the three rivers (Lahkya, Meghna and Gumti), the design parameters required to express the river flow and water level are calculated, which are summarized in Table 5.3.5.

Table 5.3.5 Design Water Level at Bridge Center Line

Design parameter		Kanchpur Bridge			Meghna Bridge			Gumti Bridge		
Design discharge (m3/sec)		3,480			15,200			12,400		
Water Level	point	Demra(Lahkya)		Bridge CL	Meghna Ferryghat		Bridge CL	Daudkandi		Bridge CL
	unit	PWD	M.S.L	M.S.L	PWD	M.S.L	M.S.L	PWD	M.S.L	M.S.L
	Design W.L (1/100)	7.36	6.90	6.57	6.98	6.52	6.49	7.36	6.90	6.91
	H.H.W.L	7.11	6.65	6.37	6.76	6.30	6.27	6.77	6.31	6.32
	L.H.W.L	5.07	4.61	4.29	3.50	3.04	3.01	4.40	3.94	3.95
	S.H.W.L	5.82	5.36	5.04	5.50	5.04	5.01	5.55	5.09	5.10
	L.L.W.L	0.48	0.02	-0.30	0.20	-0.26	-0.29	0.22	-0.24	-0.23



M.S.L = PWD -0.46 [m]

H.H.W.L	Highest high water level	Highest of annual highest water level in observation period
L.H.W.L	Lowest high water level	Lowest of annual highest water level in observation period
M.H.W.L	Mean high water level	Mean of annual highest water level in observaition period
L.L.W.L	Lowest low water level	Lowest watar level in observation period

It is noted that the available water level data collected for the last 50 years for Meghna and Gumti River along with that collected for the last 40 years for Lahkya River are taken as reference data for water level calculations.

- The water level data collected from BWDB is expressed in PWD units which are converted to MSL units by deducting 0.46 m. The water level data along the bridge axis expressed in MSL units is used for the present project.

- In Table 5.3.5, four categories of water level data are shown using MSL units. Among them, Mean High Water Level (M.H.W.L) that corresponds to the mean of annual highest water level in an observation period shall be used as the base for water surface elevation which is termed Standard High Water Level (S.H.W.L).

- Design water level with a 100 year return period corresponds to the design discharge shown in the table.

5.4 Estimation of Scour at Bridges

5.4.1 Basic Concept

Scouring at the bridges occurs due to the erosive action of flowing water, excavating and carrying away materials from the riverbed and its banks. The scour process is cyclic in nature, which makes it complicated to determine the magnitude of scour. Scour can be deepest near the peak of a flood; however, it is hardly visible since scour holes refill with sediment during the receding stage of the flood. In general, several floods may be needed to attain maximum scour under typical flow conditions at bridge crossings.

5.4.2 Methodology of Scour Computation

In designing the bridge substructure, some important data such as a careful study of the site and specific subsurface information are very important to evaluate the scour potential at piers and abutments. Total scour at bridge crossings is comprised of three components.

- Long-term Aggradations and Degradations
- Local scour

5.4.3 Long-Term Aggradations and Degradations

Aggravation and degradation are changes of streambed elevation in the long-term due to natural or man-induced causes which can affect the streambed. Aggradation involves the deposition of material eroded by the stream or water shedding from upstream of the bridge and degradation involves the lowering of the streambed due to the lack of sediment supply from upstream. Basically, they are to be evaluated independently from the hydraulic model. Generally, streams are considered to be stable and balance sediment transport, if the configuration is not changed in the long-term.

The historical change of cross section around Meghna Bridge is shown in Figure 5.4.2, which indicates that river bed height has widely declined from 1989 to 2012. It seems that river bed degradation is slight in the long term around Meghna Bridge. The result coincides with the results obtained from BWDB's regularly cross section survey shown in chapter 2 (Figure 2.1.5). It is also supposed that the degradation is not directly caused by the change of natural circumstance like discharge or sediment transport.

It is reported that illegal dredging is carried out in Bangladesh, which causes social problems on newspaper as Figure 5.4.3.

It is difficult to define the reason for the degradation. But it seems that illegal dredging has some direct impact on river bed elevation.

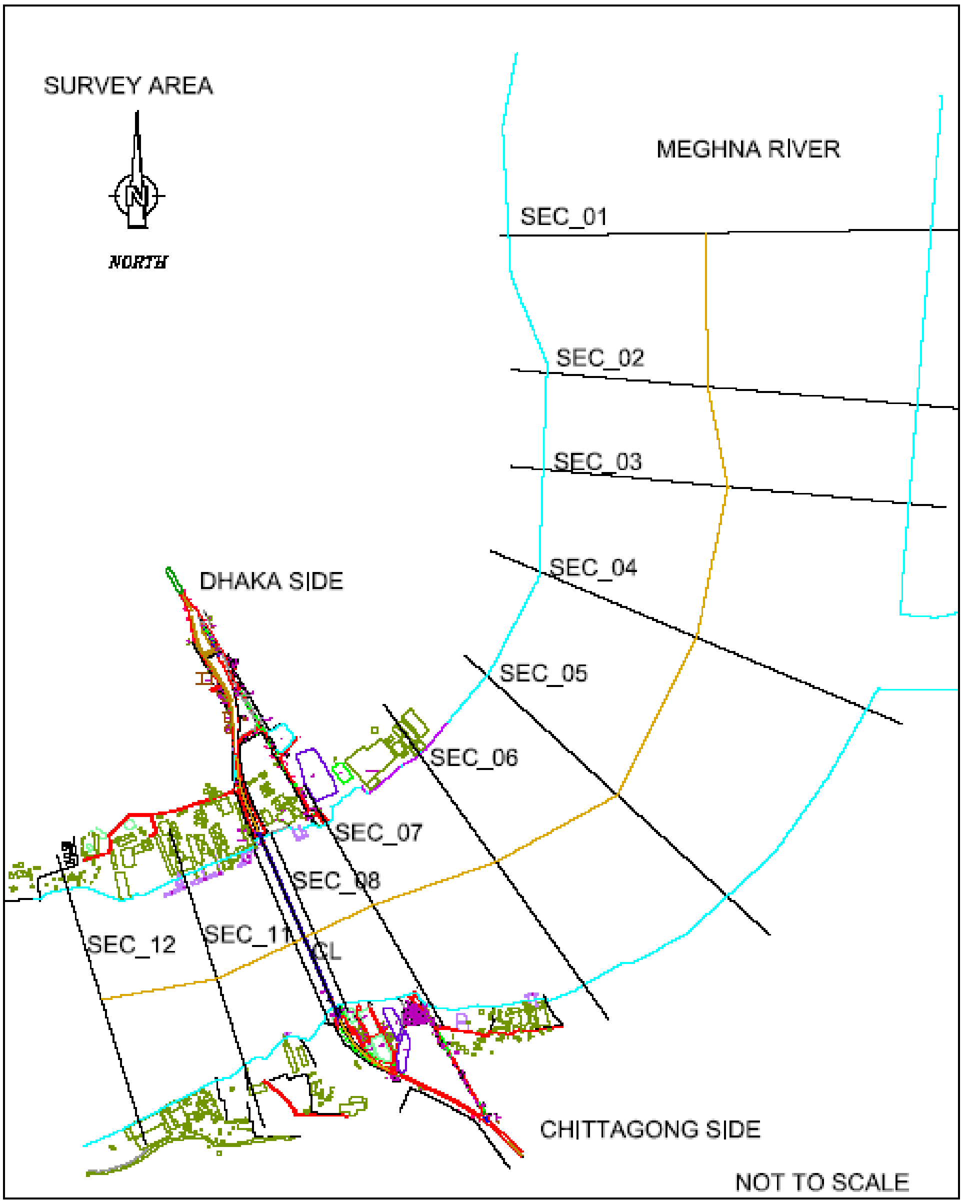


Figure 5.4.1 Topographic Survey Line around Meghna Bridge

Table 5.4.1 Longitudinal River Bed Profile of Meghna River

Sec No.	Distance Between Cross section (m)	Distance from CrossSec12 (m)	Lowest Bed Level R.L.m	Average Bed Level R.L.m	Refference
SEC12	-	0.0	-20.68	-14.98	
SEC11	538.4	538.4	-22.19	-14.31	
SEC10	316.1	854.6	-27.50	-13.92	
SEC9	139.4	994.0	-23.02	-12.40	Bridge Center Line
SEC8	63.9	1,057.8	-22.17	-11.92	
SEC7	274.1	1,331.9	-25.82	-13.41	
SEC6	597.4	1,929.4	-23.61	-15.79	
SEC5	634.2	2,563.6	-23.66	-15.78	
SEC4	810.9	3,374.5	-21.57	-15.91	
SEC3	707.2	4,081.7	-20.05	-14.44	
SEC2	468.5	4,550.2	-22.05	-16.48	
SEC1	706.2	5,256.4	-22.49	-13.34	

Source: Made by the study team

Figure 5.4.2 Historical Change of Cross Section Profile around Meghna Bridge


DHAKA MONDAY JUNE 11, 2012

The Daily Star

SECOND EDITION

Your Right to Know

QUICK RENTALS' IMPACT
Losses of state enterprises double to Tk 16,880 crore

MY DREAM
A programme showcases talent of differently abled Chinese artistes

REGIME ON 'LAST LEGS'
Abdel Basset says as Syrian Nat'l Council elects him new leader

Fresh tax on mobile calls

Govt mulls surcharge on cellphone users to create 'energy fund'

A syndicate illegally extracts silt from the Meghna in Narayanganj, causing land erosion nearby. A mobile court yesterday confiscated three dredgers and sentenced one person to three month's in jail in this connection.

PHOTO: PALASH KHAN

No hope of top leaders' release

Court order makes their

BNP's Dhaka rally today

Fresh agitation likely as party's 90-day deadline for restoring

Bus, launch service stalled

Arrests ahead of rally

DIATRIBES AGAINST PROF SAYEED

Sangsad regrets

Unparliamentary words to be expunged

Figure 5.4.3 Report regarding Illegal Dredging in the Newspaper

	
Dredging machine on a boat near Gumti Br.	Unload area at Kanchpur bridge

Figure 5.4.4 Dredging around the Bridge

5.4.4 Local Scour

(1) Overall

Local scour at piers or abutments is due to the removal of bed material as a result of formation of vortices known as the horseshoe vortex and wake vortex at their base. The horseshoe vortex results from the pileup of water on the upstream surface due to the obstruction and subsequent acceleration of the flow around the nose of the pier or abutment. The action of the vortex removes bed material around the base of the obstruction. In addition, to the horseshoe vortex around the base of a pier, there are vertical vortices downstream of the pier called the wake vortex. Both the horseshoe and wake vortices remove material from the pier base region. The intensity of wake vortices diminishes rapidly as the distance downstream of the pier increases. As a result, there is often deposition of material immediately downstream of a long pier.

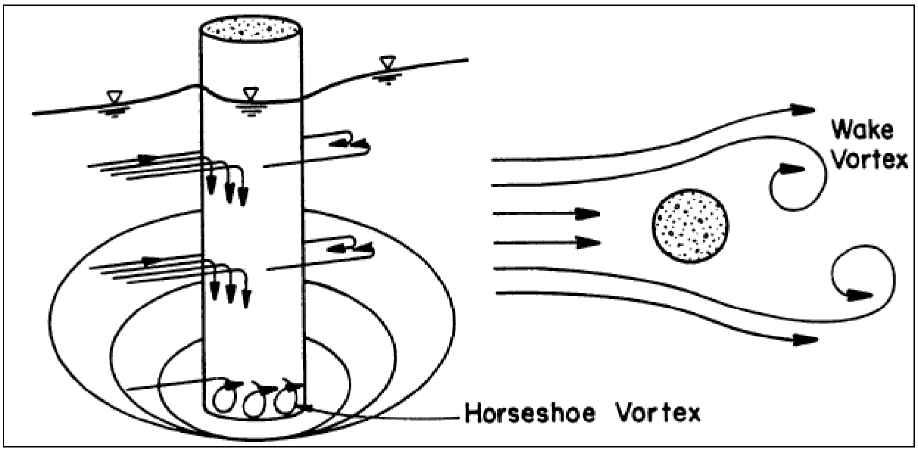


Figure 5.4.5 Schematic Representation of Scour at a Pier

(2) Method

To predict the scouring around a bridge pier, it is important to recognize bed condition after a flood event. Scouring is caused by unbalance of river bed material transportation, which is classified into three types as shown below. If there is no bed material transportation around the bridge pier, no scouring has occurred. When sediment transportation around the bridge pier is more than the material transported from upstream, then scouring is assumed to be caused around the bridge pier (Clear water scour). When the bed material around the bridge pier and upstream pier is moved (Dynamic balance Condition), it is difficult to predict the scouring around the bridge pier. This is because the bed material moves with morphing bed topography and causes sand waves like dunes, ripple, flat bed and antidunes.

The water depth of Meghna and Kanchpur rivers is very deep, with a maximum 20 – 30 m depth, and bed material diameter is very small (d50 is about 0.1 – 0.2 mm, fine sand). Then, the non-dimension Tractive force (τ^*) parameter which is the index of bed material transportation will be large, and the bed condition seems to be balanced under dynamic action.

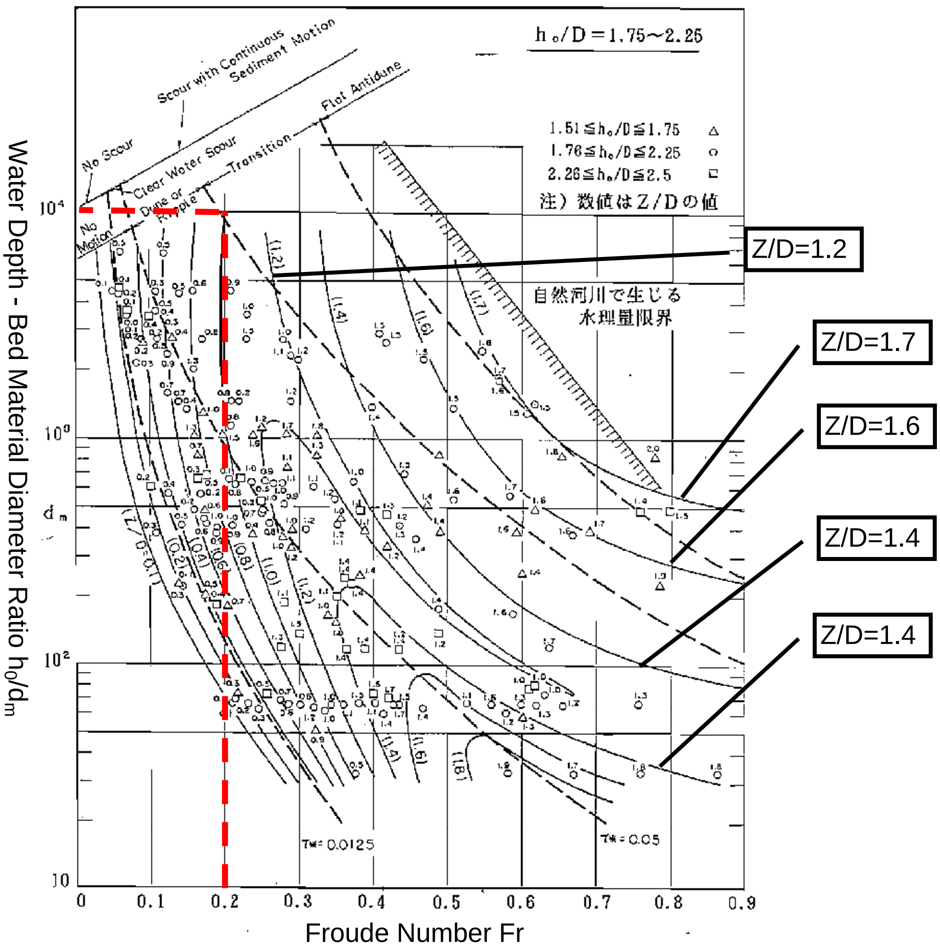
1. $Q_{So} = Q_{si} = 0$: No Scour
2. $Q_{So} > Q_{si} = 0$: Clear water scour (Static balance Condition)
3. $Q_{So} > Q_{si} > 0$: Scour with continuous sediment motion (Dynamic Balance Condition)

where:
Q_{So} = Bed material transport around pier
Q_{si} = Bed material transport from upstream of pier

In this study, a method for predicting the scouring around bridge piers based on the Japanese Public Work Research Institute (PWRI) is recommended. This method considers both live-bed and clear-water pier scouring and predicts maximum pier scour depths with hydraulic data calculated with Nays2D and charts shown in Figure 5.4.6.

Example
[hydraulic condition]
-Scour Depth Z
-Pier Width D = 5 m
-Froude Number Fr = 0.2
-Bed Material Diameter
 dm = 1 mm
-Water Depth h_0= 10 m

then
-h_0/D = 2
-$h_0/dm = 10^4$
-Z/D = 1.0 (from chart)
-Z = 5.0 m



Source:Technical Guideline by PWRI of JAPAN[2]

Figure 5.4.6 Chart for Scour Depth (Z/D) Estimation

[2] Problem of Bridge Pier from Flood Control, Public Works Research Institute of Japan, Nov 1993

5.4.5 Scour Estimation Results

Results of scour computations by the PWRI (Public Work Research Institute of Japan) method are shown in Table 5.4.2 to Table 5.4.4, which is calculated for the "Separated " and "Merged" situation. Lowest bed height with scouring around pier is calculated from the latest bed height surveyed in this study work.

"Separated" means

-> Existing and new bridge basements are separated

-> The width of the pier against the river flow is the width of the Existing Bridge Basement

"Merged" means

-> Existing and new bridge basements are merged by SPSP (Steel Pipe Sheet Pile)

-> The width of the pier against the river flow is the width of the New Bridge Basement

Scouring depth is affected by Pier width as shown in Figure 5.4.6, then the depth of scouring "Merged" is deeper than "Separated".

Hence Blue lines of "Merged" in Figure 5.4.9 to Figure 5.4.8 are lower than the lines of "Separated".

New and existing bridges must be designed for the bed height considering the local scouring by SPSP width.

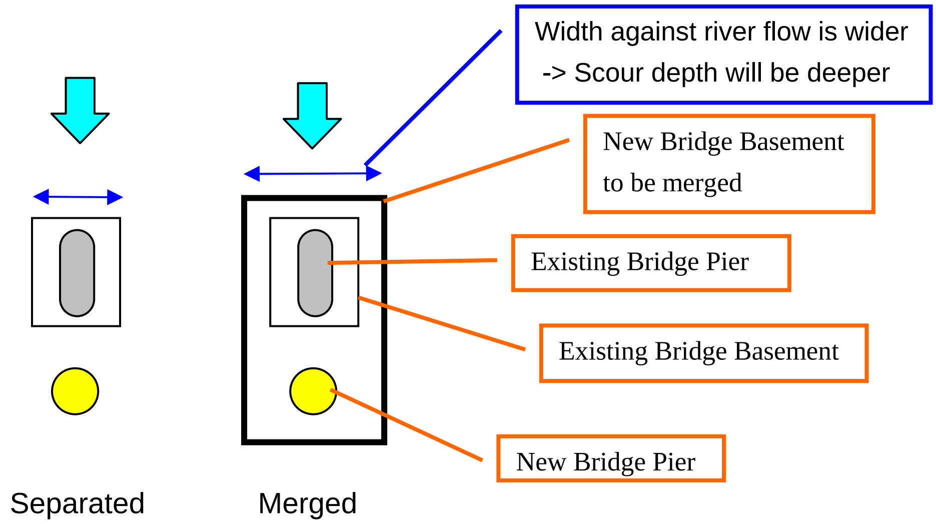
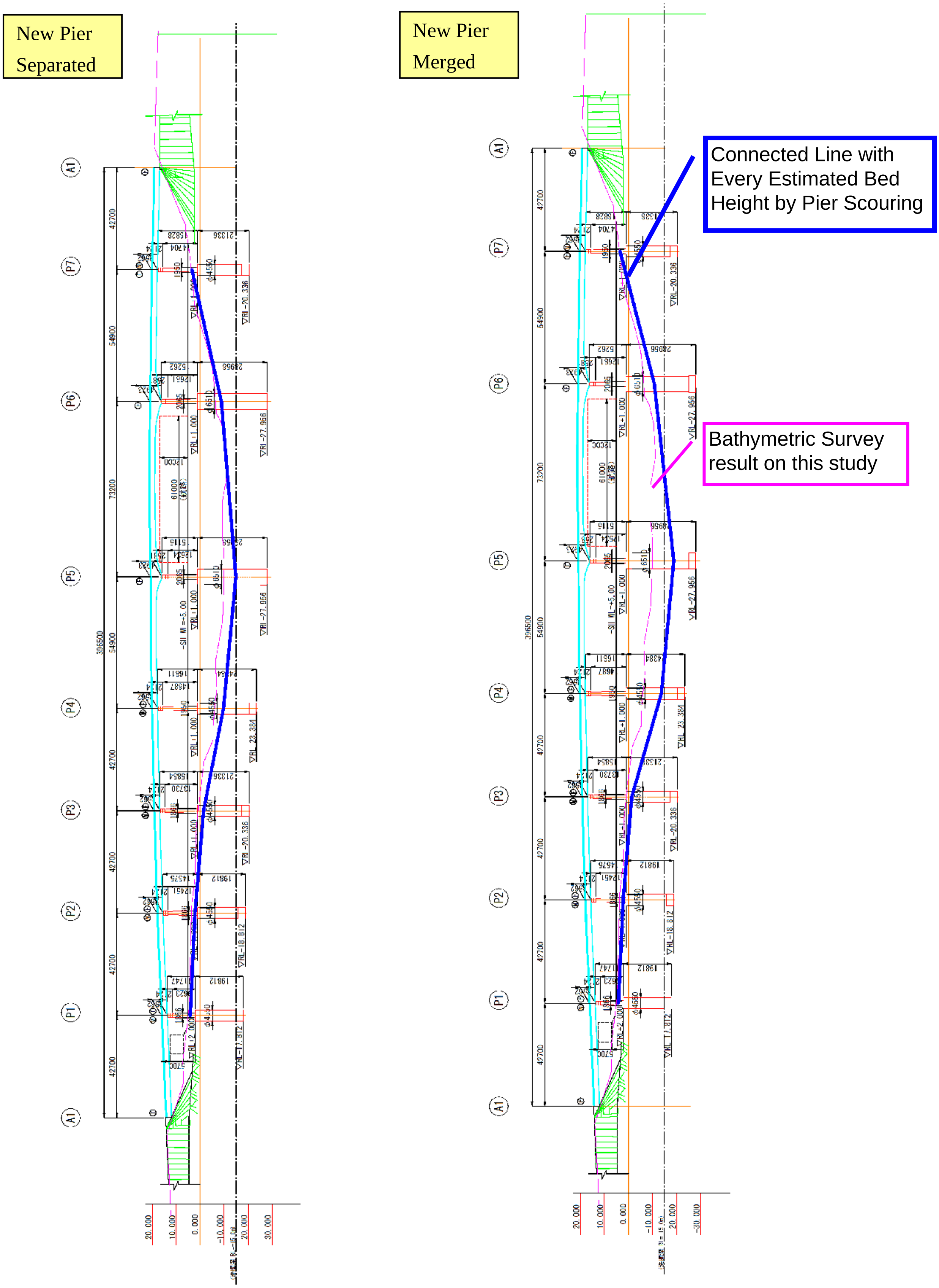
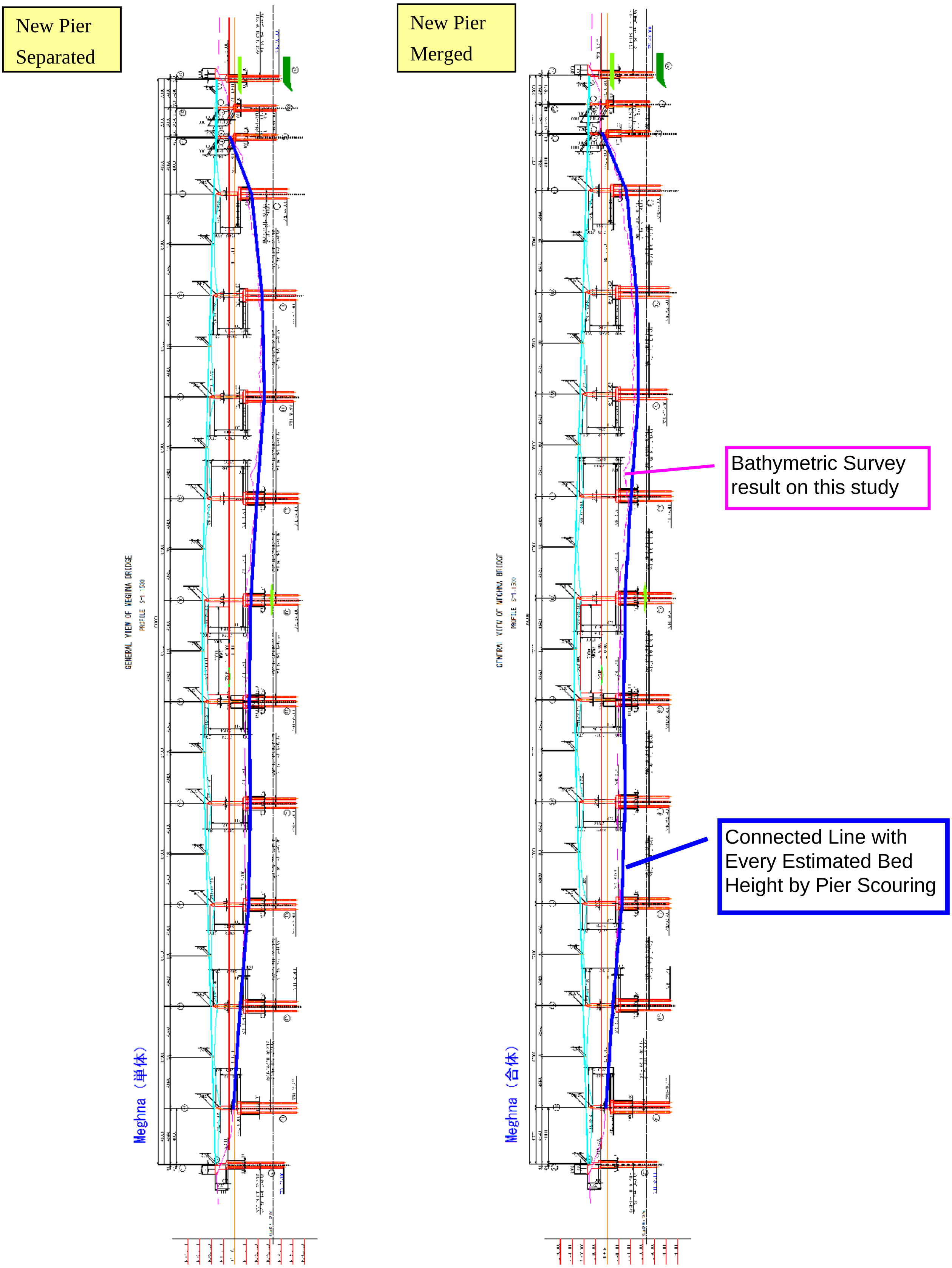


Figure 5.4.7 Bridge Size for Local Scour Estimation



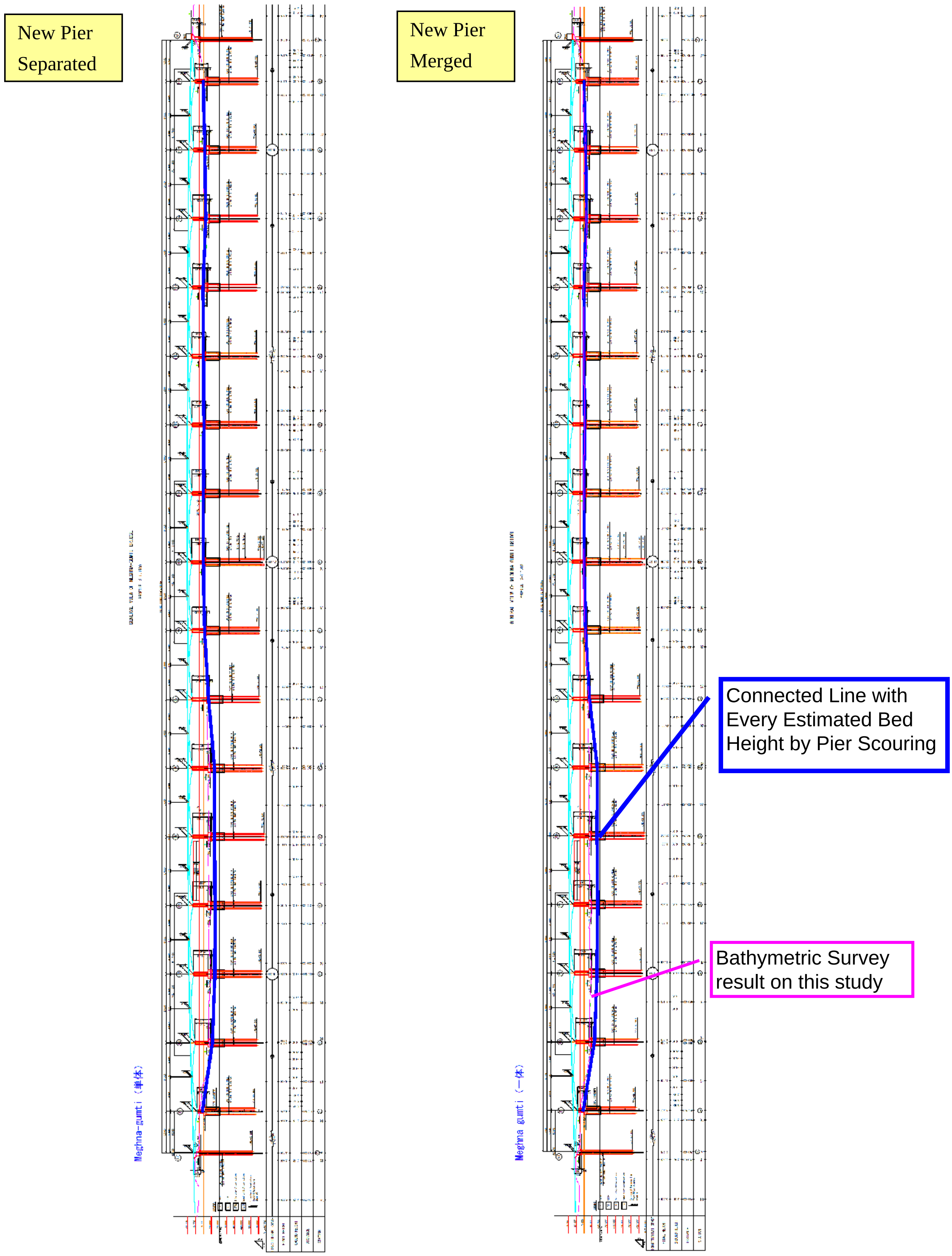
Source: Estimated by the study team

Figure 5.4.8 Estimated Bed Profile with Local Scouring at Kanchpur Bridge



Source: Estimated by the study team

Figure 5.4.9 Estimated Bed Profile with Local Scouring at Meghna Bridge



Source: Estimated by the study team

Figure 5.4.10 Estimated Bed Profile with Local Scouring at Gumti Bridge

Table 5.4.2 Local Scour in 100-Year Return Period Flood at Kanchpur Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	Reference
Pier Width		m	1.89	1.89	1.89	1.95	2.07	2.07	1.95	
Foundation Width		m	4.55	4.55	4.55	4.55	6.15	6.15	4.55	
Foundation Exposed / Coveried by Present bed condition			covered	covered	covered	exposed	exposed	exposed	covered	
Pier Width (foundation width included)	D	m	1.89	1.89	1.89	4.55	6.15	6.15	1.95	
Water Level in 100-year return period flood		MSL.m	6.25	6.24	6.24	6.23	6.24	6.25	6.26	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	4.00	0.87	-6.04	-9.09	-6.36	3.65	Surveyed in this study
Water Depth	h0	m	3.47	2.24	5.36	12.27	15.33	12.61	2.61	
Current Velocity	V	m/s	0.62	0.89	1.22	1.33	1.23	0.77	0.28	From Hydraulic Analysis
Froude Number	Fr	-	0.11	0.19	0.17	0.12	0.10	0.07	0.06	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.42	0.80	1.20	0.80	0.80	0.40	0.10	Read from Diagram
h0/D		-	1.84	1.19	2.84	2.70	2.49	2.05	1.34	
h0/dm		-	20774	13436	32123	73473	91807	75516	15606	
Estimated Scour Depth	Z	m	0.79	1.51	2.26	3.64	4.92	2.46	0.20	
Estimated Scour Width from Pier Edge	R	m	1.70	3.24	4.85	7.81	10.55	5.28	0.42	
Estimated Bed Level after Scouring		MSL.m	1.99	2.49	-1.39	-9.68	-14.01	-8.82	3.46	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	Reference
Pier Width		m	1.89	1.89	1.89	1.95	2.07	2.07	1.95	
Foundation Width		m	9.55	9.55	9.55	9.55	11.15	11.15	9.55	
Foundation Exposed / Coveried by Present bed condition			covered	covered	covered	exposed	exposed	exposed	covered	
Pier Width (foundation width included)	D	m	1.89	1.89	1.89	9.55	11.15	11.15	1.95	
Water Level in 100-year return period flood		MSL.m	6.25	6.24	6.24	6.23	6.24	6.25	6.26	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	4.00	0.87	-6.04	-9.09	-6.36	3.65	Surveyed in this study
Water Depth	h0	m	3.47	2.24	5.36	12.27	15.33	12.61	2.61	
Current Velocity	V	m/s	0.62	0.89	1.22	1.33	1.23	0.77	0.28	From Hydraulic Analysis
Froude Number	Fr	-	0.11	0.19	0.17	0.12	0.10	0.07	0.06	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.42	0.80	1.20	0.80	0.80	0.40	0.10	Read from Diagram
h0/D		-	1.84	1.19	2.84	1.28	1.38	1.13	1.34	
h0/dm		-	20774	13436	32123	73473	91807	75516	15606	
Estimated Scour Depth	Z	m	0.79	1.51	2.26	7.64	8.92	4.46	0.20	
Estimated Scour Width from Pier Edge	R	m	1.70	3.24	4.85	16.38	19.13	9.56	0.42	
Estimated Bed Level after Scouring		MSL.m	1.99	2.49	-1.39	-13.68	-18.01	-10.82	3.46	

Source: Estimated by the study team

Table 5.4.3 Local Scour in 100-Year Return Period Flood at Meghna Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Reference
Pier Width		m	2.70	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	2.70	1.50	1.50	
Foundation Width		m	11.20	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.20	7.20	7.20	
Foundation Exposed / Coveried by Present bed condition			Covered	Covered	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Covered	Covered	
Pier Width (foundation width included)	D	m	2.70	3.20	11.91	11.91	11.91	11.91	11.91	11.91	11.91	11.20	1.50	1.50	
Water Level in 100-year return period flood		MSL.m	6.49	6.44	6.46	6.47	6.48	6.49	6.48	6.47	6.45	6.47	6.48	8.64	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-4.56	-10.78	-9.83	-8.94	-10.78	-16.63	-22.80	-20.60	-10.48	5.68	6.16	Surveyed in this study
Water Depth	h0	m	3.71	11.01	17.24	16.30	15.42	17.27	23.12	29.27	27.05	16.94	0.80	0.20	
Current Velocity	V	m/s	0.32	0.13	0.72	1.28	1.28	1.17	1.17	1.32	1.49	1.39	1.07	0.00	From Hydraulic Analysis
Froude Number	Fr	-	0.05	0.01	0.06	0.10	0.10	0.09	0.08	0.08	0.09	0.11	0.38	0.00	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.10	0.01	0.10	0.30	0.30	0.25	0.20	0.20	0.25	0.35	1.05	#N/A	Read from PWRI Diagram
h0/D		-	1.37	3.44	1.45	1.37	1.29	1.45	1.94	2.46	2.27	1.51	0.53	0.13	
h0/dm		-	22229	65920	103216	97593	92315	103420	138424	175289	162005	101458	4770	1198	
Estimated Scour Depth	Z	m	0.27	0.03	1.19	3.57	3.57	2.98	2.38	2.38	2.98	3.92	1.58	#N/A	
Estimated Scour Width from Pier Edge	R	m	0.58	0.07	2.55	7.66	7.66	6.39	5.11	5.11	6.39	8.41	3.38	#N/A	
Estimated Bed Level after Scouring		MSL.m	2.51	-4.60	-11.97	-13.40	-12.51	-13.76	-19.01	-25.19	-23.58	-14.40	4.11	#N/A	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Reference
Pier Width		m	2.70	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	2.70	1.50	1.50	
Foundation Width		m	16.20	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.20	12.20	12.20	
Foundation Exposed / Coveried by Present bed condition			Covered	Covered	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Exposed	Covered	Covered	
Pier Width (foundation width included)	D	m	2.70	3.20	16.91	16.91	16.91	16.91	16.91	16.91	16.91	16.20	1.50	1.50	
Water Level in 100-year return period flood		MSL.m	6.49	6.44	6.46	6.47	6.48	6.49	6.48	6.47	6.45	6.47	6.48	8.64	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-4.56	-10.78	-9.83	-8.94	-10.78	-16.63	-22.80	-20.60	-10.48	5.68	6.16	Surveyed in this study
Water Depth	h0	m	3.71	11.01	17.24	16.30	15.42	17.27	23.12	29.27	27.05	16.94	0.80	0.20	
Current Velocity	V	m/s	0.32	0.13	0.72	1.28	1.28	1.17	1.17	1.32	1.49	1.39	1.07	0.00	From Hydraulic Analysis
Froude Number	Fr	-	0.05	0.01	0.06	0.10	0.10	0.09	0.08	0.08	0.09	0.11	0.38	0.00	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.10	0.01	0.10	0.30	0.30	0.25	0.20	0.20	0.25	0.35	1.05	#N/A	Read from PWRI Diagram
h0/D		-	1.37	3.44	1.02	0.96	0.91	1.02	1.37	1.73	1.60	1.05	0.53	0.13	
h0/dm		-	22229	65920	103216	97593	92315	103420	138424	175289	162005	101458	4770	1198	
Estimated Scour Depth	Z	m	0.27	0.03	1.69	5.07	5.07	4.23	3.38	3.38	4.23	5.67	1.58	#N/A	
Estimated Scour Width from Pier Edge	R	m	0.58	0.07	3.63	10.88	10.88	9.07	7.25	7.25	9.07	12.16	3.38	#N/A	
Estimated Bed Level after Scouring		MSL.m	2.51	-4.60	-12.47	-14.90	-14.01	-15.01	-20.01	-26.19	-24.83	-16.15	4.11	#N/A	

Source: Estimated by the study team

Table 5.4.4 Local Scour in 100-Year Return Period Flood at Gumti Bridge

Existing and New Piers Separated

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	Reference
Pier Width		m	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Foundation Width		m	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	11.41	
Foundation Exposed / Coveried by Present bed condition			covered	exposed	exposed	exposed	exposed	exposed	exposed	exposed	covered	covered	covered	covered	covered	covered	covered	covered	
Pier Width (foundation width included)	D	m	4.90	11.41	11.41	11.41	11.41	11.41	11.41	11.41	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Water Level in 100-year return period flood		MSL.m	6.58	6.59	6.60	6.60	6.60	6.58	6.58	6.59	6.60	6.59	6.59	6.59	6.58	6.57	6.57	6.56	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-7.32	-9.87	-9.34	-7.91	-8.01	-5.86	-1.02	0.33	0.58	-0.20	0.58	1.21	-2.36	-1.06	2.09	Surveyed in this study
Water Depth	h0	m	3.80	13.91	16.47	15.94	14.51	14.59	12.44	7.61	6.27	6.02	6.79	6.01	5.37	8.93	7.62	4.46	
Current Velocity	V	m/s	1.01	1.29	1.48	1.62	1.71	1.65	0.48	0.27	0.17	0.49	0.46	0.43	0.54	0.46	0.59	0.75	From Hydraulic Analysis
Froude Number	Fr	-	0.17	0.11	0.12	0.13	0.14	0.14	0.04	0.03	0.02	0.06	0.06	0.06	0.07	0.05	0.07	0.11	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.73	0.35	0.40	0.47	0.53	0.53	0.06	0.04	0.02	0.10	0.10	0.10	0.15	0.08	0.15	0.35	Read from Diagram
h0/D		-	0.78	1.22	1.44	1.40	1.27	1.28	1.09	0.67	1.28	1.23	1.39	1.23	1.10	1.82	1.56	0.91	
h0/dm		-	22754	83275	98601	95432	86865	87388	74479	45546	37545	36028	40668	36011	32162	53488	45651	26729	
Estimated Scour Depth	Z	m	3.58	3.99	4.57	5.36	6.05	6.05	0.68	0.46	0.10	0.49	0.49	0.49	0.74	0.39	0.74	1.72	
Estimated Scour Width from Pier Edge	R	m	7.67	8.57	9.79	11.50	12.97	12.97	1.47	0.98	0.21	1.05	1.05	1.05	1.58	0.84	1.58	3.68	
Estimated Bed Level after Scouring		MSL.m	-0.80	-11.32	-14.44	-14.70	-13.96	-14.06	-6.54	-1.47	0.23	0.08	-0.69	0.08	0.48	-2.75	-1.79	0.38	

Existing and New Piers Merged

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	Reference
Pier Width		m	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Foundation Width		m	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	16.41	
Foundation Exposed / Coveried by Present bed condition			covered	exposed	exposed	exposed	exposed	exposed	exposed	exposed	covered	covered	covered	covered	covered	covered	covered	covered	
Pier Width (foundation width included)	D	m	4.90	16.41	16.41	16.41	16.41	16.41	16.41	16.41	4.90	4.90	4.90	4.90	4.90	4.90	4.90	4.90	
Water Level in 100-year return period flood		MSL.m	6.58	6.59	6.60	6.60	6.60	6.58	6.58	6.59	6.60	6.59	6.59	6.59	6.58	6.57	6.57	6.56	From Hydraulic Analysis
Bed Elevation at Pier Position		MSL.m	2.78	-7.32	-9.87	-9.34	-7.91	-8.01	-5.86	-1.02	0.33	0.58	-0.20	0.58	1.21	-2.36	-1.06	2.09	Surveyed in this study
Water Depth	h0	m	3.80	13.91	16.47	15.94	14.51	14.59	12.44	7.61	6.27	6.02	6.79	6.01	5.37	8.93	7.62	4.46	
Current Velocity	V	m/s	1.01	1.29	1.48	1.62	1.71	1.65	0.48	0.27	0.17	0.49	0.46	0.43	0.54	0.46	0.59	0.75	From Hydraulic Analysis
Froude Number	Fr	-	0.17	0.11	0.12	0.13	0.14	0.14	0.04	0.03	0.02	0.06	0.06	0.06	0.07	0.05	0.07	0.11	
Bed Material Diameter dm	dm	mm	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	
Z/D		-	0.73	0.35	0.40	0.47	0.53	0.53	0.06	0.04	0.02	0.10	0.10	0.10	0.15	0.08	0.15	0.35	Read from Diagram
h0/D		-	0.78	0.85	1.00	0.97	0.88	0.89	0.76	0.46	1.28	1.23	1.39	1.23	1.10	1.82	1.56	0.91	
h0/dm		-	22754	83275	98601	95432	86865	87388	74479	45546	37545	36028	40668	36011	32162	53488	45651	26729	
Estimated Scour Depth	Z	m	3.58	5.74	6.57	7.71	8.70	8.70	0.98	0.66	0.10	0.49	0.49	0.49	0.74	0.39	0.74	1.72	
Estimated Scour Width from Pier Edge	R	m	7.67	12.32	14.08	16.54	18.66	18.66	2.11	1.41	0.21	1.05	1.05	1.05	1.58	0.84	1.58	3.68	
Estimated Bed Level after Scouring		MSL.m	-0.80	-13.07	-16.44	-17.05	-16.61	-16.71	-6.84	-1.67	0.23	0.08	-0.69	0.08	0.48	-2.75	-1.79	0.38	

Source: Estimated by the study team

5.4.6 Countermeasures Against Scouring

It is recommended that highway bridge should be structurally taking into account the estimated potential scour at bridge, piers and abutment. The potential scour is estimated for both contraction and local scour based on HEC-18. In addition, the allowance for long term degradation is also provided where necessary referring to the river profile and its cross sections.

According to HEC-18, piles should not be exposed under 100-year return period floods. Therefore, riprap scour protection is provided for those piers in which piles are exposed under local scour (100-year return period) [Details are given in Table 5.4.5 to Table 5.4.7; "Dimension of Riprap Protection"]. The sizing of riprap stone and protection width and thickness are shown below according to the recommendations given in HEC-18 and also taking into consideration of the engineering and economical aspects.

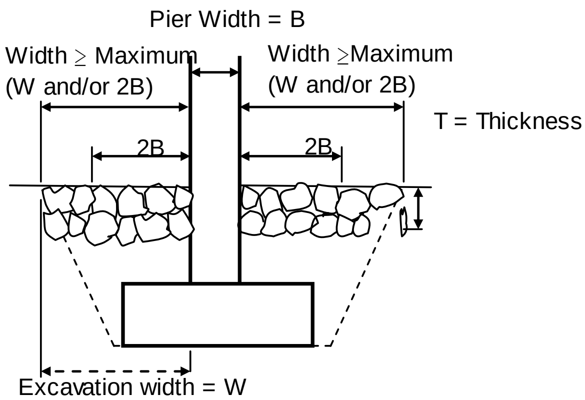


Figure 5.4.11 Schematic Diagram for Scour Countermeasure.

(1) Size of Rip-rap stone at piers

HEC-18 recommends stone diameter D50 of riprap using the rearranged Ishbash equation as given below.

$$D_{50} = \frac{0.692(KV)^2}{2 * g * (S_s - 1)}$$

(Reference HEC 18- Federal Highway Administration, USA)

Where;
D_{50} = Median stone diameter of riprap (m)
K = Coefficient for pier shape
V = Velocity on pier, m/s
Ss = Specific gravity of riprap (normally 2.65)
g = 9.81 m^2/s
K = 1.5 for round-nose pier
K = 1.7 for rectangular pier

(2) Protection width

According to the recommendations given in HEC-18, riprap mat should be extend horizontally at least two times the pier width, measured from the pier face and also the top of a riprap mat is placed at the same elevation as the streambed. The deeper riprap is placed into the streambed; it is less likely to be moved. It is not proper to place the mat bottom of a riprap i.e. on top of the streambed. It is a disadvantage to bury riprap so that the top of the mat will be under the streambed.. This is because it is difficult to monitor whether some or all of the riprap has been moved during the flood when monitoring of the bridge is conducted after a flood event. Therefore, it is recommended to place the mat top of a riprap at the same elevation as the streambed.

- Width of riprap mat >= 2.0 * Pier Width (B) or Excavation width from the pier face.

(3) Thickness of Rip-rap

The thickness of the riprap mat should be three times of stone diameters (D50) or more. The maximum size rock should be no greater than twice the D50 size.

- Thickness of riprap mat >= 3.0 * D50 of stone size

As of HEC-18, piles, in principle, should not be exposed due to scouring at 100-year return period flood event. In the design, top of pile cap is set below the general scouring depth and piles are generally protected by pile cap. However, if total scour exceeds the certain depth, whole pile cap will be exposed and then piles will also be exposed due to scour hole. In such cases the piles are to be designed as exposed ones. Therefore, it is reasonable to provide scour countermeasure with riprap protection only for pile caps under severe scouring conditions.

The extent to be covered in horizontal layer at the level of pile cap has already been explained before. Pile caps that should be protected with riprap are examined not only by total scour depth at the bottom levels of pile caps but also by investigating the actual site conditions.

The necessity of riprap protection, size of riprap stone and minimum width and thickness to be applied in the design are shown in the table below. Although, the minimum width is 3.0 m, it has been decided that riprap width for piers that are located at the main stream and abutments shall be extended to excavation width of pile caps.

Table 5.4.5 Dimension of Riprap Protection around Meghna Bridge

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Reference
Current Velocity	V	m/s	0.32	0.13	0.72	1.28	1.28	1.17	1.17	1.32	1.49	1.39	1.07	0.00	
Water Depth	h0	m	3.71	11.01	17.24	16.30	15.42	17.27	23.12	29.27	27.05	16.94	0.80	0.20	
Riprap Stone size caluculated D50 by HEC for Piers		m	0.01	0.00	0.03	0.10	0.10	0.09	0.09	0.11	0.14	0.12	0.07	0.00	
Riprap Stone size caluculated D50 to be applied		m	0.30												
Minimum Protection width from Pier Face		m	2B and/or Excavation Width												
Minimum Thickness for Piers		m	0.9												

Table 5.4.6 Dimension of Riprap Protection around Gumti Bridge

Pier No.			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Current Velocity	V	m/s	1.01	1.29	1.48	1.62	1.71	1.65	0.48	0.27	0.17	0.49	0.46	0.43	0.54	0.46	0.59	0.75
Water Depth	h0	m	3.80	13.91	16.47	15.94	14.51	14.59	12.44	7.61	6.27	6.02	6.79	6.01	5.37	8.93	7.62	4.46
Riprap Stone size caluculated D50 by HEC for Piers		m	0.06	0.10	0.14	0.16	0.18	0.17	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.03
Riprap Stone size caluculated D50 to be applied		m	0.30															
Minimum Protection width from Pier Face		m	2B and/or Excavation Width															
Minimum Thickness for Piers		m	0.9															

Table 5.4.7 Dimension of Riprap Protection around Kanchpur Bridge

Pier No.			P1	P2	P3	P4	P5	P6	P7	Reference
Current Velocity	V	m/s	0.62	0.89	1.22	1.33	1.23	0.77	0.28	
Water Depth	h0	m	3.47	2.24	5.36	12.27	15.33	12.61	2.61	
Riprap Stone size caluculated D50 by HEC for Piers		m	0.02	0.05	0.09	0.11	0.09	0.04	0.00	
Riprap Stone size caluculated D50 to be applied		m	0.30							
Minimum Protection width from Pier Face		m	2B and/or Excavation Width							
Minimum Thickness for Piers		m	0.9							

The Riprap protection is usually adapted against scouring problems. However, the Riprap protection method isn't adopted in this project because the stability of SPSP foundation is enough for the scouring according to the foundation design study.

CHAPTER 6

DESIGN CRITERIA

6. DESIGN CRITERIA

6.1 Design Criteria for Roads

6.1.1 Design Standards

Design standards to be used for the road design shall be the Bangladeshi Standards or, as required, American Association of State Highway and Transportation Officials (AASHTO) Standards/Guidelines.

(1) Road geometry design

- Geometric Design Standards for RHD(2001)
- Geometric Design Guidelines by AASHTO

(2) Pavement design

- Pavement Design Guide RHD 2005
- AASHTO Pavement Design 1993

(3) Retaining wall design

- AASHTO LRFD (Load-and-Resistance Factor Design) Bridge Design Specifications (2010, 5th edition)

6.1.2 Standard for Roads in Bangladesh

The roads in Bangladesh are regulated by the functional road classifications of RHD. The classifications are described below;

a) Road Class

The roads in Bangladesh are divided into the following 3 classifications.

Table 6.1.1 Functional Road Class

Class	Roads	Function
N	National	Roads the connecting the national capital with divisional headquarters, old district headquarters, port cities and international highways
R	Regional	Roads connecting different regions with each other, which are not connected by the national highways
Z	Zilla	Roads connecting Thana headquarters to the arterial network

Source: RMMS database, RHD

b) Design Classes

The roads in Bangladesh are divided into six design types.

Table 6.1.2 Road Design Types

Design Type	Design Year Traffic Volume [PCU/peak hr.]	Maximum Design speed kph			Functional Classification		
		Plain	Rolling	Hilly	N	R	Z
1	4500 - 8500	80-100	80	-	√		
2	2100 – 4500	80-100	80	-	√	√	
3	1600 – 2100	80	65	50	√	√	
4	800 – 1600	65	50	40	√	√	√
5	400 – 800	50	40	30		√	√
6	< 400	50	40	30			√

Source: Road geometric design standard by RHD

c) Project Roads

According to the classifications mentioned above, the project road is classified as a National Highway with Design Type 1.

(2) Design Criteria for Project Road

a) Basic Policy

The project bridges connect Dhaka to Daudkandi and also the Chittagong corridor. Traffic volume in the target year in peak hour is over 4500 PCU/hr. Therefore, the connecting road clearly falls under the National Highway and is to be designed under Design Type 1. Based on the above views, the following factors need to be considered;

- The design speed of 80 km/h is specified as the design criteria for National Highway, Type 1.

- The approach roads of the 2nd bridges will be extended to the existing highways; therefore, a design speed of 80 km/hr will be set as standard design criteria.

Taking into account the aforesaid factors, the design criteria ensuring a high level of service is recommended for the bridge connecting roads regardless of their locations in urban or rural areas. This leads to the following criteria as mentioned in Table 6.1.3.

Table 6.1.3 The Geometric Design Standard for Main Line

Items	Unit	Requirement of Criteria Applied	RHD Standard	AASHTO 2010	Japanese Standard	Remarks
Design Speed	Km/h	80	80	80	80	
Height Clearance	m	5.7	5.7	5.1	5.0	
Sight Distance						
Stopping Sight Distance	m	120	120	130	110	
Intermediate Sight Distance	m	250	250	-	-	
Passing Sight Distance	m	500	500	245	350	
Cross Section Elements						
Lane Width	m	3.65	3.65	3.6	3.5	
Outer Shoulder	m	1.8	1.8	3	1.25	
Inner shoulder	m	0.3	0.3	1.2	0.75	
Median Width including Inner Shoulder	m	1.25	1.25	3	2.25	
Cross fall of Travel Way	%	3.0	3.0	2.0	2.0	
Cross fall of Outer Shoulder	%	5.0	5.0	2.0-6.0	4.0	
Max. Super Elevation	%	7.0	7.0	10.0	10.0	
Super Elevation	%	R=500: 5 %	R=500: 5 %	R=538: 6 %	R=450: 6 %	
	%	R=1000: 3 %	R=1000: 3 %	R=670: 5 %	R=540: 5 %	
	%			R=1190: 3 %	R=1240: 2 %	
Horizontal Elements						
Min. Radii	m	250	250	280	280	
Min. Curve Length including Transition Curve	m	-	-	-	140	
Min. Transitional Curve Length	m	*	*	38	70	
Min. Radius not requiring Travel Way Widening	m	201	201	-	280	
Min. Radius not requiring Transition Curve	m	-	-	-	2000	
Min. Radius not requiring Super Elevation	m	2000	2000	2500	3500	
Vertical Elements						
Max. Grade-Standard Max	%	5.0	5.0	4.0	4.0	Rolling area
Min. Vertical Curve K Value	m	35	35	26 (Crest) 30 (Sag)	-	

b) Design Speed

The design speed of 80 km/h, which is the most important factor for road design, is recommended. This falls under the same condition of design type 1 in the plain area.

c) Lane Width

Based on the design policy and design speed, a lane width of 3.65 m is introduced for the following reasons;

- Heavy traffic of semi-trailers and full trailers can be adopted as the design vehicle
- Existing lane width of the corridor is 3.65 m, which is also used in the 4-lane Dhaka-Chittagong highway project.

d) Minimum Radius

In accordance with design speed 80 km/h, the minimum radius shall be 250 m.

e) Other Components

Regarding other design components, the criteria that will meet the design speed of 80 km/h shall be used.

6.1.3 Example of Typical Cross Section

(1) Typical Cross Section

As explained in the preceding section, the bridge connecting roads are categorized as the Road Class "N" (National Highway) and Design Type 1. Accordingly, the typical cross section pertinent to the Geometric Design Standards (RHD) is shown in Figure 6.1.1.

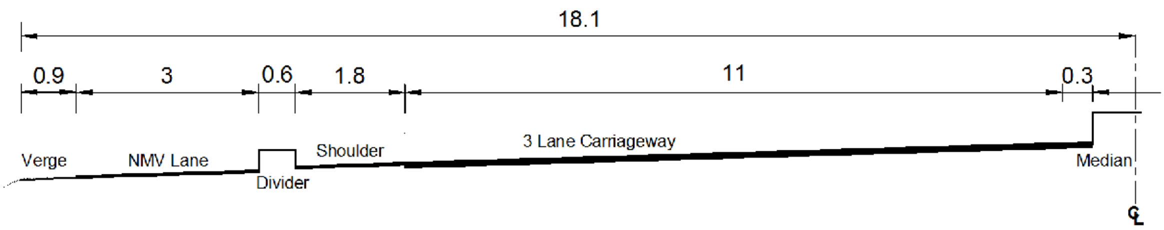


Figure 6.1.1 Typical Cross-Section of Road Proposed by Geometric Design Standard (RHD)

(2) Proposed Typical Cross Section

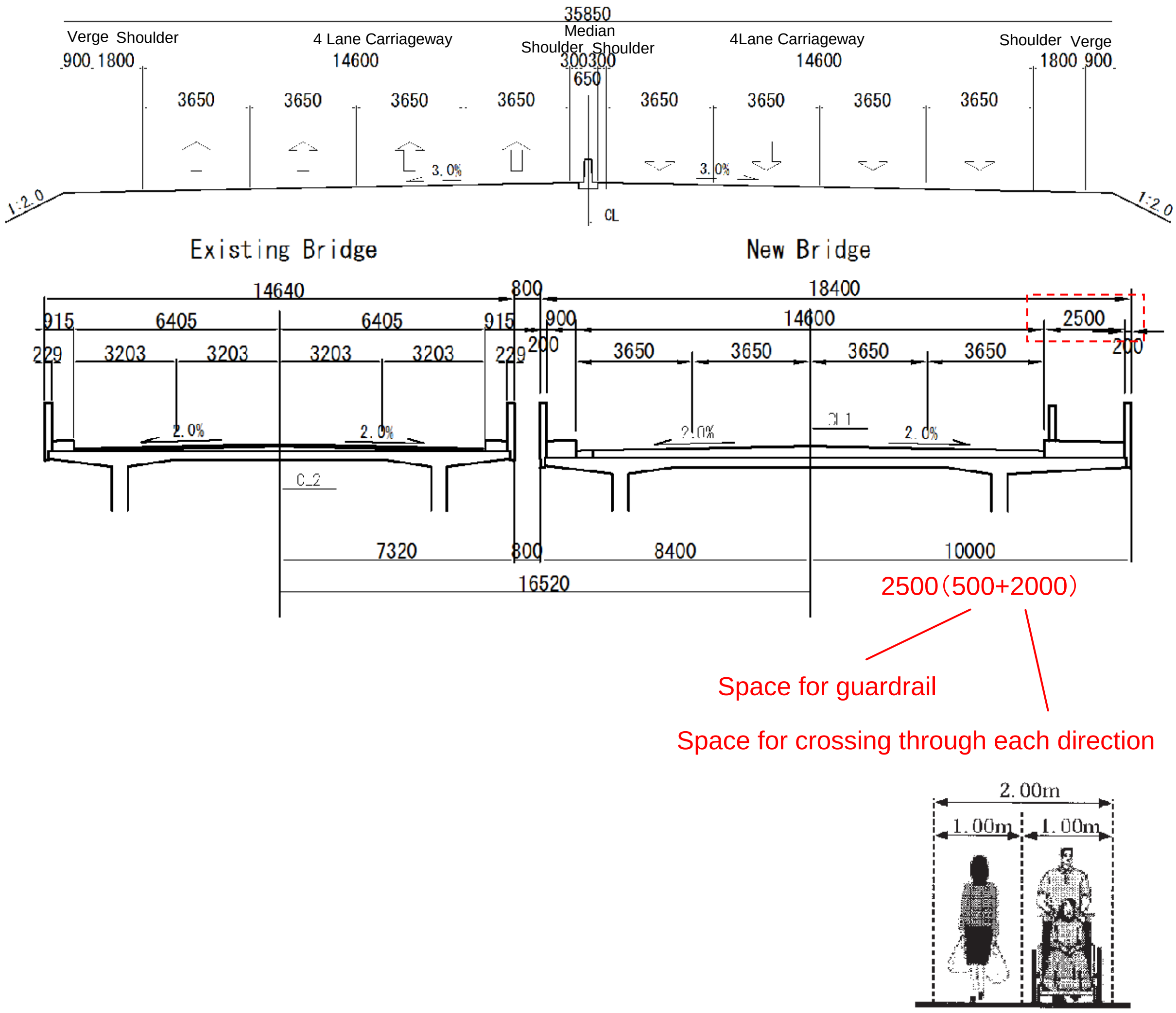
Taking the above into account, the typical cross section shown in Figure 6.1.1 might need some modifications in order to meet the existing as well as future situations of the project area. In this regard, the median width along with the necessity of a Non-Motorized Vehicle

(NMV) lane has been discussed with RHD personnel. Some of the discussion outcomes are listed below.

- Median width: median width is 0.65 m to provide space for a Safety Barrier
- NMV Lane and footway: As the study area is not in an urban area, the inclusion of a NMV Lane is not necessary. But there are many pedestrians passing and gathering at Kanchpur site which is assumed to be the entrance of Dhaka city. Therefore, a footway widened to 2.5 m seems to be necessary so as to ensuring that the pedestrians can smoothly cross in each direction at Kanchpur Bridge site.

In accordance with the above discussions, the typical cross section of the approach road is being finalized, which is schematically shown blow.

a) Kanchpur Bridge



As per RHD evaluation, the existing Kanchpur Bridge shall be considered as a 4- lane bridge.

Figure 6.1.2 Typical Cross Section for Kanchpur Bridge

b) Meghna Bridge

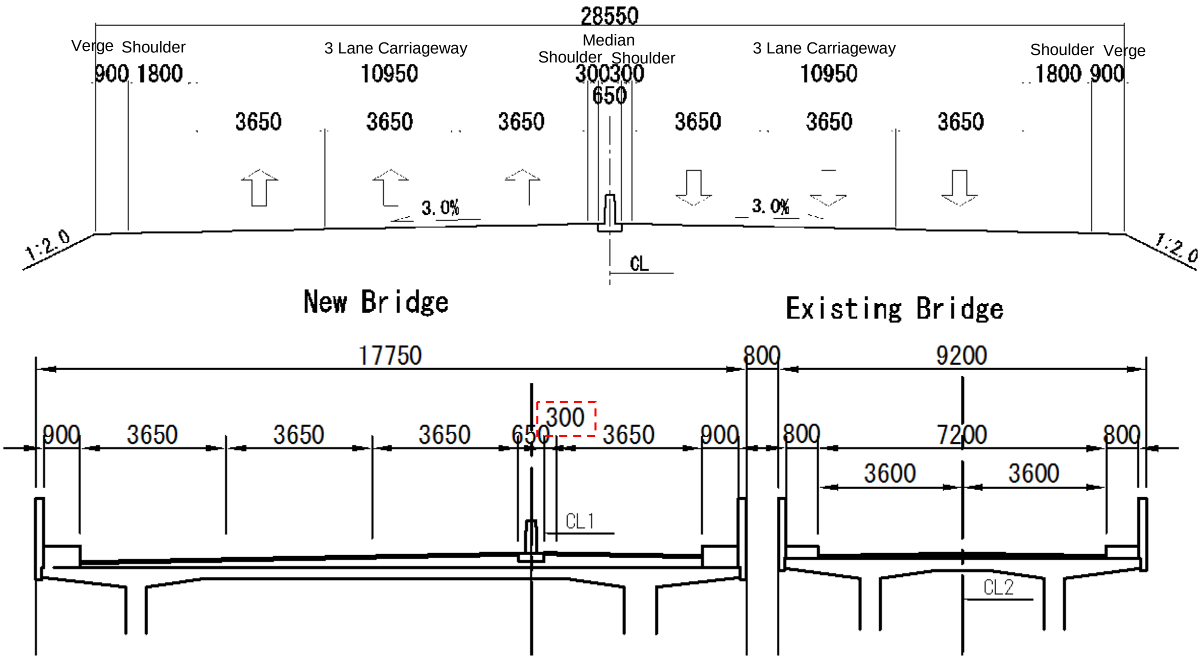


Figure 6.1.3 Typical Cross Section for Meghna Bridge

RHD road design standard has provision on carriageway width of 3,650 mm but no specific provision on shoulder design along the bridge. Moreover, in case of one way single carriageway, the carriage width of 3,650 mm seems to be narrow to pass through and inadequate to provide side clearance. To overcome this constraint for 2nd Meghna Bridge, a shoulder of 300 mm width is recommended to add at the median side, which is schematically shown in Figure 6.1.3.

c) Gumti Bridge

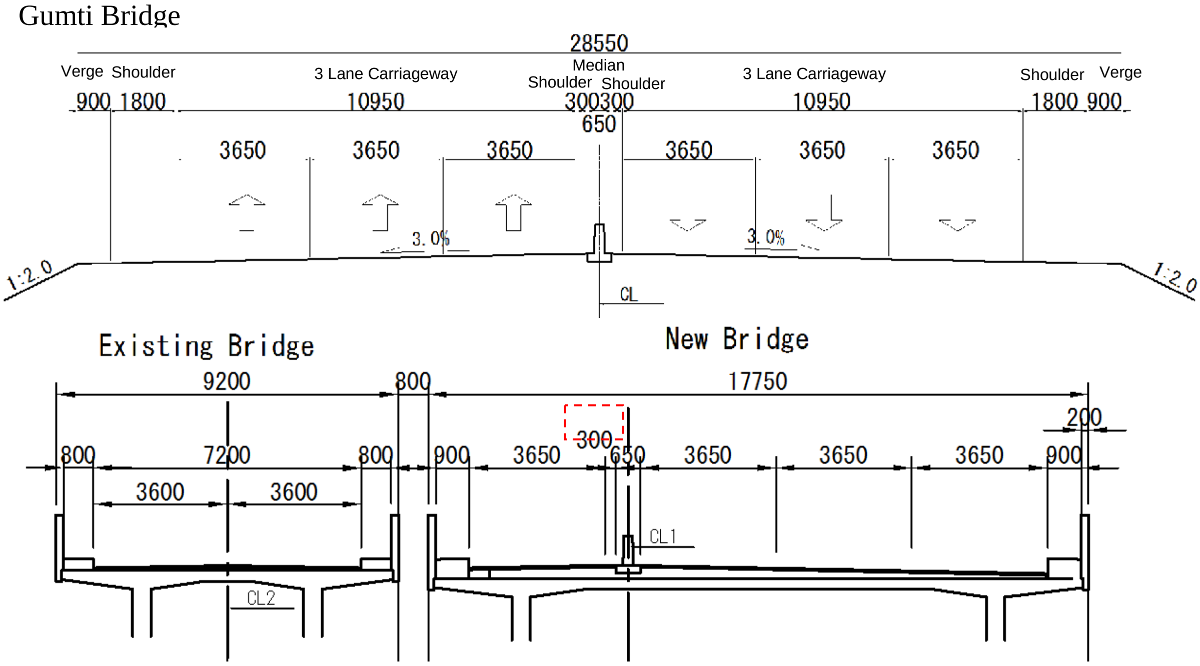


Figure 6.1.4 Typical Cross Section for Gumti Bridge

In case of 2nd Gumti bridge, a shoulder of 300 mm width is also recommended to add at the median side (Figure 6.1.4), which is same as 2nd Meghna Bridge.

(3) Benches

Benches of 2.0 m width shall be installed where the height of the embankment exceeds 5.0 m.

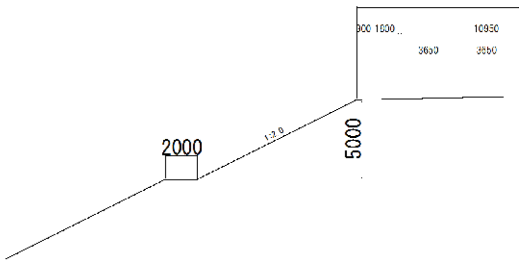


Figure 6.1.5 Benches

(4) Service road

a) Kanchpur Bridge

Service road width shall be equal to that of the existing service road. From site survey results, it is found that the width of the service road is 8.0 m.

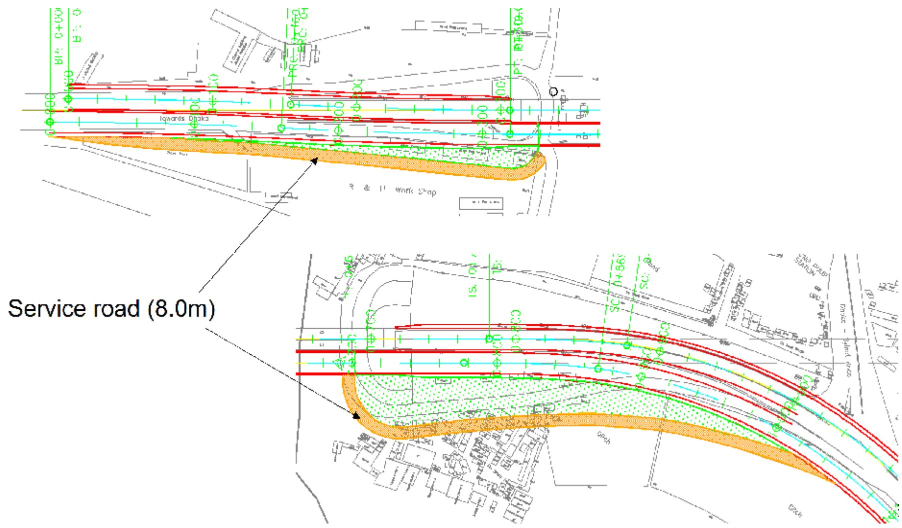


Figure 6.1.6 Service Road at Kanchpur Bridge

b) Meghna Bridge

Service road width shall be equal to the existing road width (8.0 m)

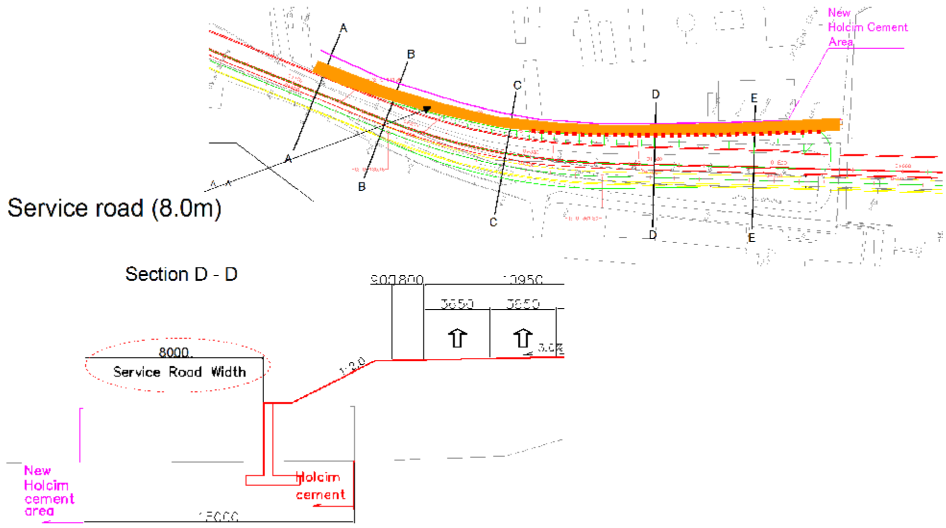


Figure 6.1.7 Service Road at Meghna Bridge

(5) Pavement design

a) Approach road

The thickness of approach road shall be determined based on traffic volume forecasted.

b) 2nd bridges

In accordance with Japanese pavement design guideline (2006), the pavement should be designed with thickness of 60 mm~80 mm. For this project, the thickness of carriageway for 2nd bridges shall be designed as 80 mm, which is maximum value recommended by Japanese standard. The reason behind the selection of maximum value is that the project bridges are now accommodating with high traffic volume. Therefore, selection of maximum thickness for pavement design will be safe side.

6.2 Design Criteria for Bridge

6.2.1 Design Standards to be followed in Bangladesh

(1) Design Standards

With due consideration for the design standards followed by several bridge projects under the Roads & Highways Department in recent years, the design standards to be used for design of the 2nd bridges and retrofitting of the existing bridges scoped in the present project have been selected as follows;

- Bridge Design Standards By Roads & Highways Department (2004)
- Bangladesh National Building Codes (BNBC)-1993 (Gadget 2006)
- Geometric Design Standards for Roads & Highways Department (2001)
- Standard Tender Documents – Section-7: Technical Specifications, RHD, 2011
- AASHTO LRFD Bridge Design Specifications (2010, 5th edition)
- AASHTO Guide Specifications for LRFD Seismic Bridge Design (2011, 2nd edition)
- Standard Specifications and Code of Practice for Road Bridges Section :II (Indian Road Congress (IRC), 2010)
- Specifications for Highway Bridges-Japan Road Association (JRA) (2002)

(2) Combination of design standards for bridge design

The design of the floor slab system of the steel narrow box girder bridge shall be done in accordance with JRA specification. This is because the live load specified by JRA is higher than that by AASHTO. This specification will provide additional safety from direct impact of heavy loaded vehicles passing over the bridge. Moreover, the live load specification by the Japan Road Association-JRA (2002) will also be used in the rehabilitation of the floor slab system of the existing Kanchpur Bridge.

The live load specification by AASHTO shall be followed to design the bridge girder and substructure (pier and foundation), whereas the seismic load calculation for the entire bridge structure shall be done by AASHTO standards along with BNBC for site information. The design standards to be followed for design of the 2nd bridge components and rehabilitation of existing bridges are listed in Table 6.2.1.

Table 6.2.1 Design Standards for Design of 2nd Bridges and Rehabilitation of Existing Bridges

Load	Structural components	Design standards
Live load	Floor slab system	JRA
	Girder/Substructure/ Foundation	AASHTO
Seismic load	Entire structure	AASHTO, BNBC

6.2.2 Number of Lanes

The 2nd bridges shall be designed as 4-lane bridges.

6.2.3 Bridge Alignment

The 2nd bridge alignment shall be planned to be parallel to and next to the existing bridge. That means the 2nd bridges shall be straight bridges. The vertical and horizontal alignments are schematically shown in Chapter 4.

6.2.4 Restrictions on Bridge Planning

(1) Navigation Clearance

There is a navigation route underneath the center span of the existing bridges. Therefore, the navigation clearance under the 2nd bridges shall also be secured in their detailed drawings. The navigation clearance of the 2nd bridges should be the same as the existing so that it will secure geometric conformity without deterioration of the aesthetic view and ensure the smooth vessel movement without any hindrance.

In accordance with the general view of the existing Meghna and Gumti Bridges, the span between piers P5-to-P6 of Meghna Bridge has a navigation clearance of 18.0 m height and 75.0 m width, while the span between piers P4-to-P5 of Gumti Bridge has a navigation clearance of 7.5 m height and 75.0 m width. The span between piers P5-to-P6 of the existing Kanchpur Bridge has a navigation clearance of 12.2 m height and 61.0 m width, which is cited in a Japanese research paper. The present status of navigation clearance under the existing bridges is summarized in Table 6.2.2.

Table 6.2.2 Present Status of Navigation Clearance under Existing Bridges

Bridge name	Navigable space	Present status	
		W (m)	H (m)
Kanchpur	Pier P5-to-P6	61.0	12.2
Meghna	Pier P5-to-P6	75.0	18.0
Gumti	Pier P4-to-P5	75.0	7.5

The same navigation clearance shown in Table 6.2.2 shall be secured for the 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges i.e. the navigation clearance under the center span of the 2nd bridge shall be the same as the present status of the existing bridge.

Before construction of 2nd bridges, the navigation clearance defined above should be confirmed by Bangladesh Inland Water Transport Authority (BIWTA). Therefore, at the time of detailed design, RHD needs to obtain the 'Navigation Clearance Certificate' from BIWTA.

(2) Overhead Clearance

Up to now, there has been no disturbance observed over the existing bridges. According to the Road Geometric Design Standard by RHD, the overhead clearance is supposed to be set at 5.7 m.

The aviation height is based on international aviation code which is found to be 300 m, and if the structure height exceeds 60 m, aviation indicators will be installed at the top of the structure.

6.2.5 Design Loads

There are several loads to be considered for the bridge design.

(1) Dead Load

Dead load shall include the weight of all components of the structure, utilities attached, pavement wearing surface and future overlays. In absence of precise information, the unit weights prescribed by AASHTO can be used to calculate the dead load of the structure.

Table 6.2.3 Unit Weight of Bridge Materials for Dead Load Calculation

Material	Unit weight (kN/m^3)
Steel	77.0
Plain Concrete	23
Reinforced Concrete	24.5
Prestressed Concrete	24.5
Asphalt mix	22.5

JICA study team inquired to RHD whether they have any plans to install utilities (gas pipes, water supply pipes etc.) along the 2nd bridges in the future. Accordingly it was confirmed that currently, RHD has no specific plan to install utilities along the 2nd bridges. Therefore, dead load of utilities shall not be considered for the 2nd bridge design.

(2) Live loads

According to AASHTO LRFD, live loads on the roadways of the bridges shall consist of the;

- Design truck or design tandem, and
- Design lane load

a) Design Truck

The weights and spacing of axles and wheels for the design truck shall be as per the specification shown in Figure 6.2.1.

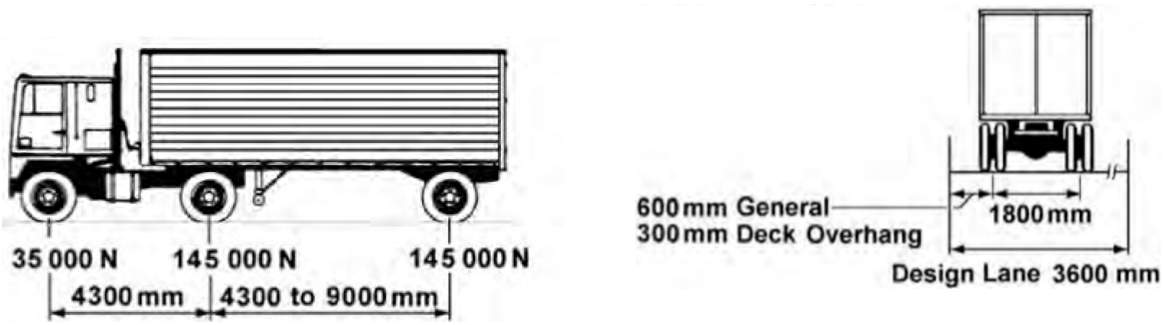


Figure 6.2.1 Characteristics of Design Truck (HS20-44)

The available report on existing Meghna and Gumti Bridges conveys that they are in a vulnerable situation due to the damage to the bearing shoes and expansion joints. The bearing shoes and expansion joints are damaged due to improper periodic maintenance and movement of overloaded trucks/trailers on the bridges. Therefore, it may be necessary to pay special attention to design the floor slab system of the three 2^{nd} bridges for heavy loaded vehicles.

i. Truck load comparison

The bridge floor slab system shall be designed in accordance with the live loads specified by a design code other than AASHTO. This is because the live load specification by AASHTO is relatively smaller than that by other specifications widely used in the world. As a reference, a comparison among live load specifications by AASHTO, Indian Road Congress (IRC)-class, Euro code and JRA is shown in Table 6.2.4. Based on the comparison and considering the application of live loads on the bridges in Bangladesh, the JRA-specification is selected, which will be used as a design criterion for floor slab system design of the three 2^{nd} bridges as well as the existing Kanchpur Bridge. The JRA-specification is comparable with the live load provision widely preferred in the bridge design world.

Table 6.2.4 Truck Load Comparison

Design code	Special vehicle	Number of Axles	Load/axle (tf)
AASHTO	HS 20-44	3	14.4
JRA (Japan)	B-type	2	20.0
Euro code	600 kN	4	14.7
	1200 kN	6	19.6
	3600	15	23.5
IRC (India)	Class A	2	20.0

ii. Restoration design for existing Kanchpur Bridge

◆ Truck load for slab restoration design

The truck load HS20-44 specification by AASHTO (1973) is shown in Table 6.2.5 and compared with that by AASHTO LRFD (2010). The former one will be used for restoration design for the existing Kanchpur Bridge and to determine which loading combination was used when the bridge was designed. This is because no as-built drawings are available for the existing Kanchpur Bridge. This will provide the current state of stress in the structural components.

Table 6.2.5 Truck Load Specification by AASHTO and JRA for Floor Slab System Design

Live load specification	Axle load (kN)	Slab to tire contact area (mm^2)	Impact (IM)	Remarks
HS20-44 (AASHTO LRFD 2010)	145 Wheel load 73	250×500	33 % (does not depend on span length)	-
HS20-44 (AASHTO 1973)			$\mathrm{IM} = 15.24/(38+L)$ L= Span length (m)	-
B-type load (JRA-2002)	200 Wheel load 100	200×500	$\mathrm{IM} = 20/(50+L)$ L= Span length (m)	Recommended for slab design

◆ Lane load for girder and substructure restoration design

The lane load specification by AASHTO (1973) in accordance with HS20-44 is shown in Figure 6.2.2. The design lane load consists of a uniform load of 9.3 kN/m with a combination of the concentrated load of 80 kN for moment or 115 kN for shear. This lane load combnation shall be used to carry out restoration design of the girders and substructure of the existing Kanchpur Bridge.

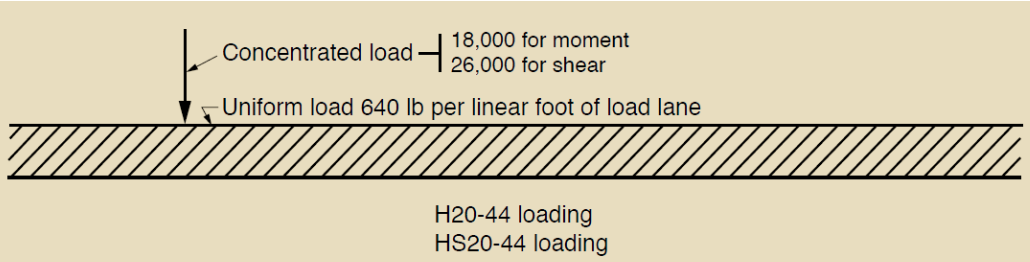


Figure 6.2.2 Lane Load for Restoration Design of Girders and Substructure (Existing Kanchpur Bridge)

iii. Truck load for floor slab system design

As is said above, the floor slab system of existing Kanchpur along with the three 2nd bridges shall be designed on the basis of truck load specified by JRA. The truck load specifications by JRA are shown in Table 6.2.5 and compared with that by AASHTO. This comparison shows that both the magnitude of axle load and the Impact (IM) provision by JRA are higher than that by AASHTO.

b) Design lane load for the girder and substructure design to be applied with a combination of the truck load.

The lane load specification for girder and substructure design of the 2nd bridges is summarized in Table 6.2.6. It consists of a uniform load of 9.3 kN/m that is distributed along the longitudinal direction and spreads over a lane with 3 m width. The lane load shall not be subjected to dynamic load allowance.

Lane load shall not be interrupted to provide space for the design truck or tandem (concentrated load), except where interruption in a patch loading pattern produces an extreme value for certain force effects.

Table 6.2.6 Lane Load Specification for Girder and Substructure Design

Live load specification	Truck load per lane (concentrated load)	Design load over 3 m lane width (uniformly distributed)	Multiple presence factor for 4-lane bridge	Impact (IM)
HS20-44 (AASHTO LRFD 2010)	325 kN	9.3 kN/m	65 %	33 % but for truck load only

(3) Earthquake Load

To calculate the earthquake load, necessary input parameters include the zone coefficient, site coefficient for soil and design Response Spectrum (RS). In this regard, BNBC (2006) will be used as a supporting document to derive the design RS with respect to Bangladesh.

a) Zone coefficient

In order to compute the earthquake load, firstly it is necessary to select the seismic zone in which the bridges will be built. The seismic zones are defined in the Bangladesh seismic zoning map (Figure 6.2.3). Based on the severity of the probable intensity of seismic ground motion and damages, Bangladesh is divided into three seismic zones, i.e. Zone 1, Zone 2 and Zone 3. These three zones along with their zone coefficients are shown in Table 6.2.7. The existing and 2nd bridges of this project are located in zone 2 and accordingly, the zone coefficient Z in accordance with zone 2 is determined as 0.15, which means the bridges are to be designed under moderate severe earthquake load.

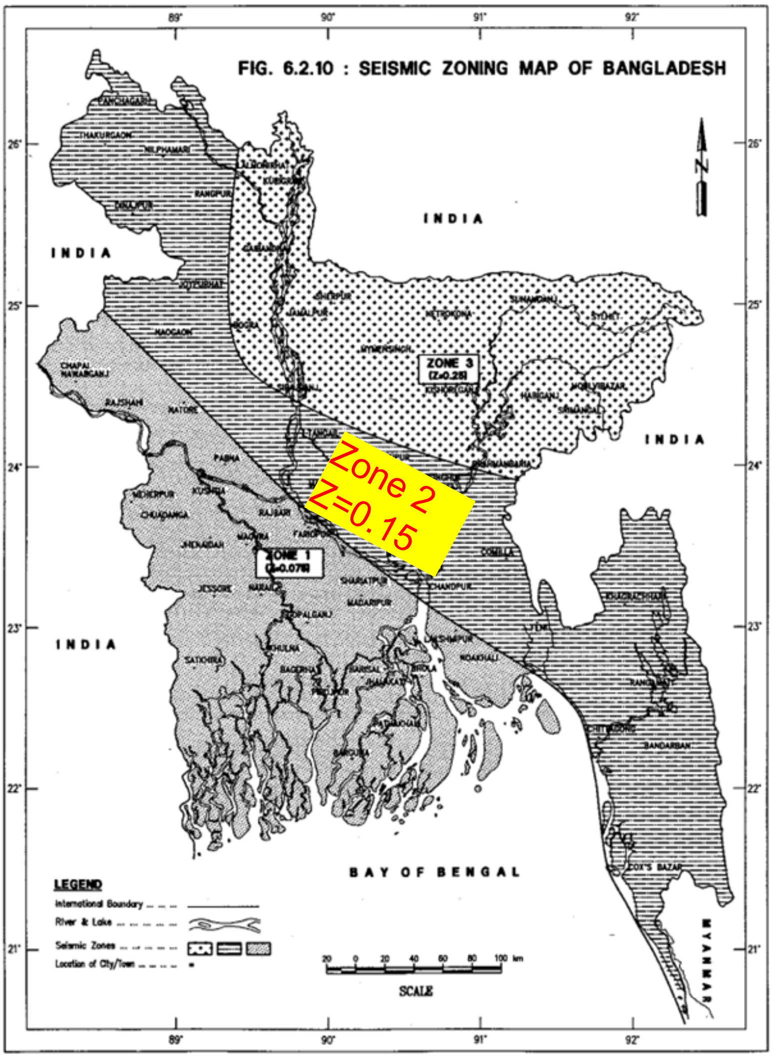


Figure 6.2.3 Seismic Zoning Map (BNBC)

Table 6.2.7 Zone Coefficient Z (BNBC)

Seismic zone	Zone coefficient
1	0.075
2	0.15
3	0.25

b) Site coefficient S

The parameter site coefficient shall be determined based on site soil characteristics. According to BNBC, there are four types of soil such as S1, S2, S3 and S4 that are classified based on the depth of the soil, shear wave velocity and soil type. The coefficients are specified in Table 6.2.8. In accordance with geological data surveyed for this project, the soil profile under the three bridges sites can be classified as soil type S3. Accordingly, the value of S3 shall be determined as 1.5.

Table 6.2.8 Site Coefficient S for Seismic Lateral Forces (BNBC)

Site soil characteristics		Coefficient S
Type	Description	
S1	A soil profile with either: A rock like material characterized by shear wave velocity greater than 762 m/s or by other suitable means of classification or, stiff or dense soil condition where the soil depth is less than 61 m.	1.0
S2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 61m.	1.2
S3	A soil profile 21 m or more in depth and containing more than 60 m of soft to medium stiff clay but not more than 12 m of soft clay.	1.5
S4	A soil profile containing more than 12 m of soft clay characterized by shear wave velocity less than 152 m/s.	2.0

c) Design Response Spectrum (RS)

Generally, a design Response Spectrum shall be developed based on geologic, seismologic and soil characteristics associated with the specific site. In this regard, BNBC has a provision on design Response Spectra (RS) whose magnitude is almost equal to the magnitude of the response spectra proposed by AASHTO LRFD (2007). The design Response Spectra are formulated in Eq. (4.2.1) and schematically shown in Figure 6.2.4.

$$C_{sm} = \frac{1.2ZS}{T_m^{2/3}} \leq 2.5Z \qquad 4.2.1$$

where,

T_m = Periodic time of m^{th} mode vibration,

C_{sm} = Elastic response coefficient

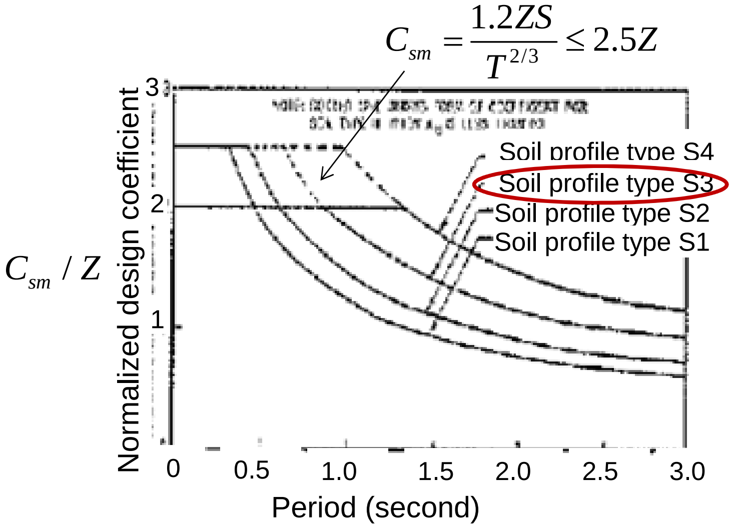


Figure 6.2.4 Design Response Spectrum

The RSs shown in Figure 6.2.4 were derived based on the return period of 475 years as the specification of AASHTO. The design of the 2nd bridges as well as retrofitting of the existing bridges shall be conducted in accordance with the Response Spectrum (RS) corresponding to soil type S3. The RS corresponding to S3 shall be used to carry out multimodal dynamic analysis.

(4) Wind Load

The project bridge sites are in a cyclone prone area of Bangladesh. Therefore, the calculation of wind load acting on the bridge superstructure and substructure will be necessary. Design wind load calculation according to BNBC (2006) and JRA is shown in the following steps.

a) Basic wind speed

The basic wind speed represents the fastest wind speed at 10 m above ground for the terrain Exposure B with a 50-year recurrence interval. Basic wind speeds for selected locations are provided in Appendix-1. From which the basic wind speed for the locality, i.e. at the project site Narayanganj is taken as V_b=195 km/hr.

b) Sustained wind pressure

BNBC specifies the sustained pressure q_z on a surface at any height z above a water surface to be calculated by

$$q_z = C_C V_b^2 \cdot C_I C_z \qquad 4.2.2$$

where,

q_z = Sustained wind pressure at height z, kN/m^2

C_c = Velocity-to-pressure conversion coefficient = $47.2x10^{-6}$

C_I = Structure importance coefficient

C_z = Combined height and exposure coefficient

V_b = Basic wind speed in km/hr

JRA specifies the wind pressure to be calculated by

$$p = 1/2\rho U_d^2 \cdot C_d G \qquad 4.2.3$$

where,

p = Wind pressure (N/m^2),

ρ= Density of the air (1.23 kg/m^3),

U_d = Basic wind speed (m/s),

C_d = Static wind force coefficient

G = Gust response coefficient

In the above two formula, $C_I, C_z, C_d,$ and G are the values to be given in each code depending on the situations, whereas $C_C V_b^2$ and $1/2\rho U_d^2$ are the basic pressure values.

In the Eq. (4.2.2), $C_C V_b^2 = 47.2x10^{-6} V_b^2$ kN/m^2.

U_d in m/s is equivalent to 1000/3600 V_b = 1/3.6 V_b, thus in the Eq. (4.2.3), $1/2\rho U_d^2 = 1/2 \text{ x } 1.23 \text{ x } (1/3.6\ V_b)^2 = 0.0475\ V_b^2\ N/m^2 = 47.5 \text{ x}10^{-6}\ V_b^2\ kN/m^2$.

Through these it should be noted that BNBC and JRA are based on the same theory to calculate the wind pressure. In addition, it should also be noted that in terms of the resultant design wind pressures to be adopted, BNBC only gives those for building structures using the relevant values of C_I, C_z and so on, but nothing for bridge structures.

c) Design wind pressure

From the above consideration, the design wind pressures shall be given based on JRA code as follows. The effects of C_d, G and so on have been considered in the formula. For simplicity only a case without live loadings shall be considered.

The design wind pressure on the superstructure shall be;

for $1 \leqq B/D < 8$, $p = [4.0 - 0.2\ (B/D)]\ D \geqq 6.0$ in kN/m, 4.2.4

for $8 \leqq B/D$, $p = 2.4D \geqq 6.0$ in kN/m. 4.2.5

where

p = the design wind pressure to be applied horizontally on the superstructure in kN per longitudinal linear meter of the bridge structure,

B = the overall bridge width.

D = the overall bridge girder height including the overall height of the solid parapet or the overall height of the open parapet minus 40 cm.

The design wind pressure on the substructure shall be;

for circular or oval sections, $q = 1.5$ kN/m^2, 4.2.6

for rectangular sections, $q = 3.0$ kN/m^2 4.2.7

where, q = the design wind pressure to be applied horizontally on the substructure in kN per projected square meter area of the substructure.

d) Parallel effect

As the 2nd bridges will be built adjacent to the existing bridges with a minimal air gap, the parallel effect shall be taken into account using modification factors as follows.

The modification factor to multiply the design wind pressure to be applied on the **superstructures** located in parallel shall be;

for the windward and leeward structures 1.3 4.2.8

The modification factor to multiply the design wind pressure to be applied on the **substructures** supporting the superstructures located in parallel shall be;

for the windward structure 1.3 4.2.9

for the leeward structure 1.0 4.2.10

(5) Thermal Load

a) Design temperature range

i) Existing Prestressed Concrete bridges

The information on design temperature is necessary for the design of the floor slab system which is directly subjected to the thermal pressure. According to a general note cited in Meghna and Gumti Bridge design, the design temperature was considered as $26^{\circ}C \pm 17^{\circ}C$ in which $26^{\circ}C$ is the average temperature and $17^{\circ}C$ denotes the thermal gradient in the concrete structure. This time the average temperature is also verified by temperature data (year 1998 to 2008) at Dhaka station collected from Bangladesh Meteorological Department (BMD), which is shown in Table 6.2.9. It shows that the average temperature data recently collected also coincides with the data considered for the existing bridge design. Therefore, for the rehabilitation, the floor slab system of the existing concrete bridges shall be designed in accordance with the design temperature of $26^{\circ}C \pm 17^{\circ}C$ which ranges from $9^{\circ}C$ to $43^{\circ}C$.

Table 6.2.9 Ambient Temperature at Dhaka Site

Location	Average Temp. (°C)	Max Temp. (°C)	Min Temp. (°C)
Dhaka	26.2	36.1	12.0

Source: Data from Bangladesh Meteorological Department edited by study team

ii) 2nd Bridges (Steel bridge narrow box girder bridges)

In order to conduct design for the floor slab system of the steel narrow box girder bridges (2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges), the design temperature used shall be $10^{\circ}C$ to $50^{\circ}C$, which is a recommended range for steel material.

b) Thermal gradient

The thermal gradient has a significant effect on the bridge slab and girder design, which is firstly generated in the interface between the tires-to-slab top and then distributed over the thickness. This means that the temperature gradient forms the basis for calculating the change in temperature with depth in the cross-section. As is described in the preceding section, the bridge floor slab system shall be designed in accordance with JRA; therefore the design thermal gradient is determined in accordance with the JRA-code which shall be stated as follows;

Thermal gradient between concrete slab-to-concrete girder : 5 °C

Thermal gradient between concrete slab-to-steel girder : 15 °C

(6) Load combinations

Several load combinations such as permanent load, transient load, live load, wind load, earthquake load and stream pressure are needed for detailed design of bridge structures. These combinations along with respective load factors are listed in to Table 6.2.10-to-Table 6.2.11.

Table 6.2.10 Load Combinations and Load Factors by AASHTO

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

DD = down-drag

DC = dead load of structural components and non-structural attachments

DW = dead load of wearing surfaces and utilities

EH = horizontal earth pressure load

EL = accumulated locked-in force effects resulting from the construction process, including the secondary forces from post-tensioning

ES = earth surcharge load

EV = vertical pressure from dead load earth fill

CR= Force effect due to creep

PS= Secondary forces from post tensioning

BR = vehicle braking force

CE = vehicular centrifugal force
CT = vehicular collision force

CV = vessel collision force

EQ = earthquake

FR = friction

IC = ice load

IM = vehicular dynamic allowance

LL = vehicular live load

LS = live load surcharge

PL = pedestrian live load

SE = settlement

SH = shrinkage

TG = temperature gradient

TU = uniform temperature

WA = water load stream pressure

WL = wind on live load

WS = wind load on structure

Table 6.2.11 Permanent Load Factors γ_p by AASHTO

Types of Load, Foundation Type, and Method used to calculate Down-drag		Load Factor γ_p	
		Maximum	Minimum
DC: Component and Attachments		1.25	0.90
DC: Strength IV only		1.50	0.90
DD: Down-drag	Piles, α Tomlinson Method	1.40	0.25
	Piles, λ Method	1.05	0.30
	Drilled shafts, O'Neill and Reese (1999) Method	1.25	0.35
DW: Wearing Surfaces Utilities		1.50	0.65
EH: Horizontal Earth Pressure			
	Active	1.50	0.90
	At-Rest	1.35	0.90
	AEP for anchored walls	1.35	N/A
EL: locked-in-Erection Stresses		1.00	1.00
EV: Vertical Earth Pressure			
	Overall Stability	1.00	N/A
	Retaining Wall Abutments	1.35	1.00
	Rigid Buried Structures	1.30	0.90
	Rigid Frames	1.35	0.90
	Flexible Buried Structures other than Metal Box Culverts	1.95	0.90
	Flexible Metal Box Culverts	1.50	0.90
ES: Earth Surcharge		1.50	0.75

Load factor γ_{EQ}

AASHTO LRFD considers the earthquake load only under “EXTREME EVENT I”. Under this extreme event loading case, the coefficient γ_{EQ} will be taken as 1.0. The reason behind this is based on an assumption that the live load multiplied by γ_{EQ} =1.0 will result a critical condition when applied to the superstructure.

Load factor γ_{TG}

The load factor for the temperature gradient γ_{TG} should be considered on a project specific basis. In lieu of project specific information to the contrary, γ_{TG} may be taken as;

- 0.0 at strength and extreme event limit state
- 1.0 at service limit state when live load is not considered
- 0.50 at service limit state when live load is considered

6.2.6 Design of Seismic Anti-collapse Device

There is no clear guideline for prevention of bridge collapse by earthquake in Bangladesh. The devices for resistance against seismic force will be designed based on the results obtained from the seismic analysis and the stability of anti-collapse devices will be verified by the criteria defined by JRA.

6.2.7 Seismic Analysis

The selection of the method for seismic analysis depends on the regularity and the number of bridge spans. For a multi-span bridge structure, the minimum requirements for seismic analysis shall satisfy the requirements shown in Table 6.2.12 in which;

ESA = Equivalent Static Analysis

EDA = Elastic Dynamic Analysis

Table 6.2.12 Minimum Analysis Requirements for Seismic Effects

Single span bridge	Regular bridges with 2 through 6 spans	Not regular bridges with 2 or more spans
No analysis required	ESA or EDA	EDA

'Regular bridges' are taken as those having fewer than seven spans, no abrupt or unusual changes in weight, stiffness or geometry; and no major changes in these parameters from span to span or support. Any bridge not satisfying the requirements of Table 6.2.13 shall be considered 'Not Regular'. The number of spans of the existing and 2nd bridges of this project is more than six; therefore, the project bridges are considered to be not regular bridges and Elastic Dynamic Analysis (EDA) is the minimum requirement for seismic evaluation.

Table 6.2.13 Regular Bridge Requirements

Parameter	value				
Number of spans	2	3	4	5	6
Maximum subtended angle for a curved bridge	30°	30°	30°	30°	30°
Maximum span length ratio from span to span	3	2	2	1.5	1.5
Maximum bent/pier stiffness ratio from span to span excluding abutments	–	4	4	3	2

6.2.8 Design Rainfall

The hourly rainfall data is a key parameter for drainage design. In accordance with available data collected from Bangladesh Meteorological Department (BMD), the average rainfall data at Dhaka station over several years is found to be 430 mm/month, whereas rainfall data at Dhaka station is recorded up to the present to maximum as 341 mm/day. Therefore, collected data basically expresses the monthly or daily rainfall which seems to be cumbersome to convert into hourly rainfall. In this regard, neither AASHTO guideline nor the 'RHD Bridge Design Hand Book' recommends any specific design value. For sake of drainage design works, a general procedure is followed herein to determine the hourly rainfall which amounts to 1/3 of daily rainfall. In view of this consideration and applying some engineering judgements, the design rainfall is determined as 120 mm/hr.

6.2.9 Technical Specifications for Construction Materials

(1) For design of 2nd bridges and rehabilitation of existing bridges

a) Concrete

In accordance with RHD practice, the values for 28-day-compressive strength of concrete cylinders for various structural components (RC bored piles, abutments, piers) shall be 25 MPa, whereas the concrete strength of prestressed deck slabs shall be 50 MPa as per JIS specification. The concrete strength values according to bridge components are listed in Table 6.2.14.

Table 6.2.14 Strength Requirements of Concrete for Bridges

Bridge Components	28-days compressive strength of concrete cylinder, σ_{ck} (MPa)
Prestressed concrete deck slabs (JIS)	50
RCC Piles and abutments and their foundations, piers; Other structural components (RHD)	25

b) Reinforcing steel bar

Reinforcing steel bars shall be deformed, except that plain bars or plain wire may be used for spirals, hoops, and wire fabric. Two types of reinforcing steel bars: Grade-40 and Grade-60 are available in the Bangladesh market and their strengths are specified by American Society for Testing Materials (ASTM). The ASTM specifications for the said two grades are shown in Table 6.2.15.

Table 6.2.15 Nominal Stress of Reinforcing Steel Bars for Bridges

Steel grade	Yield stress σ_y (MPa)	Tensile strength σ_u (MPa)
Grade-40	280	420
Grade-60	420	620

c) Prestressing steel

Uncoated low relaxation seven-wire strands and prestressing bar shall be used as prestressing steel in order to achieve continuity in the box girder sections of the existing bridges. Among them, prestressing bar shall be used as external cable. Both forms of prestressing steel shall conform to the JIS specifications shown in Table 6.2.16.

Table 6.2.16 Nominal Stress of Prestressing Steel

Prestressing steel	Grade	Yield stress σ_y (MPa)	Tensile strength σ_u (MPa)
Strand (7-wire)	SWPR7BL	1583	1860
Bar	SBPR930	930	1180

d) Steel narrow box girder

As per JIS specification, the grades SM400A/SM400B or SM490A/SM490B will be used as steel material for steel narrow box girders. The tensile strength and yield stress of the respective grades are stated in Table 6.2.17.

Table 6.2.17 Nominal Stress of Steel

Steel grade ($16 < t \leq 40$ mm)	Yield stress σ_y (MPa)	Tensile strength σ_u (MPa)
SM400A/SM400B	235	400 to 510
SM490A/SM490B	315	490 to 610

e) Steel pipe pile for SPSP foundation

The grades SKY 400 or SKK 400 and SKY 490 or SKK 490 are commonly used as steel pipe material for foundation design in Japan. The numerical value followed by capital letters of each grade denotes the tensile strength of steel pipe material. The tensile strength and yield stress of the respective material grades are stated in Table 6.2.18.

Table 6.2.18 Nominal Stress of Steel Pipe Pile for SPSP Foundation

Material grade	Yield stress σ_y (MPa)	Tensile strength σ_u (MPa)
SKY 400 or SKK 400	235	400
SKY 490 or SKK 490	315	490

(2) For prediction of the existing capacity of the existing bridges

The material information obtained from as-built drawings available for the existing Meghna and Gumti Bridges is summarized in Table 6.2.19, whereas for the existing Kanchpur Bridge pier, the concrete strength is considered as 21.0 MPa which is cited in a Japanese report published by 'Journal of Concrete Engineering'. In order to verify this magnitude, the JICA study team conducted the Schmidt hammer test on each pier and confirmed the concrete compressive strength to be within a range of 28-40 MPa. Therefore, concrete strength of 21.0 MPa shown in Table 6.2.20 will be on the safer side, and will be considered to evaluate the existing capacity of Kanchpur Bridge piers.

Table 6.2.19 Concrete Strength for Existing Meghna and Gumti Bridges

28-day-compressive strength of concrete cylinders, σ_{ck} (N/mm^2)		
Piers	Foundation	Girder
24	30	35

Table 6.2.20 Concrete Strength for Kanchpur Bridge Pier

Concrete strength σ_{ck}						
P1	P2	P3	P4	P5	P6	P7
21.0 (MPa)						

Table 6.2.21 Steel Nominal Stress Used for Meghna and Gumti Bridges

Steel bar	Yield stress σ_y (MPa)	Tensile strength σ_u (MPa)
Deformed bar	295	485
PC-strand	1470	1715
PC-bar	930	1080

6.2.10 Technical Specifications for Paintings

The steel bridges should be protected against corrosion by paintings. The long life and durable paint system is regulated by the specifications proposed by Ministry of Land, Infrastructure, Transport and Tourism (MILTT), Japan. The paint system is divided into 5 categories for each part of the bridge as shown in Table 6.2.22. The stepwise each paint system is briefly explained in Table 6.2.23.

Table 6.2.22 Paint system categories

Name	Application place	Note
C-5	Steel girder outer surface	
D-5	Box girder inner surface	
T	Splice plate and attached member surface	
F-11	High tension Bolt splice outer surface	Applied for C-5 paint system
F-12	High tension Bolt splice inner surface	Applied for D-5 paint system

Table 6.2.23 Steel girder outer surface painting C-5

Step		Paint name	Standard paint volume (g/m^2)	Paint method	Standard thickness (μm)	Paint interval
Pre-treatment	First base plate conditioning	Primitive plate blasting	-	-	-	
						Below 4 hour
	Primer	Inorganic zinc primer	160	Spraying	(15)	
						Below 6 month
Factory paint	Secondary base plate conditioning	Assembled member blasting	-	-	-	
						Below 4 hour
	Under coating	Inorganic zinc paint	600	Spraying	75	
						2 day-10 day
	Mist coating	Mist coating	160	Spraying	-	
						1 day-10 day
	Under coating	Under coat epoxy resin paint	540	Spraying	120	
						1 day-10 day
	Intermediate coat	Intermediate fluororesin paint	170	Spraying	30	
						1 day-10 day
	Top coat	Top coat fluororesin paint	140	Spraying	25	

Table 6.2.24 Steel girder inner surface painting D-5

Step		Paint name	Standard paint volume (g/m^2)	Paint method	Standard thickness (μm)	Paint interval
Pre-treatment	First base plate conditioning	Primitive plate blasting	-	-	-	Below 4 hour
	Primer	Inorganic zinc primer	160	Spraying	(15)	Below 6 month
Factory paint	Secondary base plate conditioning	Power tool	-	-	-	Below 6 month
	Under coating	Inorganic zinc paint	600	Spraying	75	2 day-10 day
	Mist coating	Mist coating	160	Spraying	-	1 day-10 day
	First layer	Inner surface modified epoxy resin paint	410	Spraying	120	1 day-10 day
	Second layer	Inner surface modified epoxy resin paint	410	Spraying	120	

Table 6.2.25 Splice plate and attached area painting T

Step		Paint name	Standard paint volume (g/m^2)	Paint method	Standard thickness (μm)	Paint interval
Pre-treatment	First base plate conditioning	Primitive plate blasting	-	-	-	Below 4 hour
	Primer	Inorganic zinc primer	160	Spraying	(15)	Below 6 month
Factory paint	Secondary base plate conditioning	Assembled member blasting	-	-	-	Below 4 hour
	First layer	Inorganic zinc paint	600	Spraying	75	

Table 6.2.26 High Tension Bolt splicing F-11

Step		Paint name	Standard paint volume (g/m²)	Paint method	Standard thickness (μm)	Paint interval
Site paint	Secondary base plate conditioning	Power tool	-	-	-	Below 4 hour
	Mist coating	Under coat modified epoxy resin paint	130	Paint bulash	-	1 day-10 day
	Under coating	Ultra thick modified epoxy resin paint	500	Paint bulash	300	1 day-10 day
	Under coating	Ultra thick modified epoxy resin paint	500	Paint blush		1 day-10 day
	Intermediate coat	Intermediate fluororesin paint	140	Paint blush	30	1 day-10 day
	Top coat	Top coat fluororesin paint	120	Paint blush	25	

Table 6.2.27 High Tension Bolt splicing F-12

Step		Paint name	Standard paint volume (g/m²)	Paint method	Standard thickness (μm)	Paint interval
Site paint	Secondary base plate conditioning	Power tool	-	-	-	Below 4 hour
	Mist coating	Under coat modified epoxy resin paint	130	Paint blush	-	1 day-10 day
	Under coating	Under coat modified epoxy resin paint	200	Paint blush	60	1 day-10 day
	Under coating	Under coat modified epoxy resin paint	200	Paint blush	60	1 day-10 day
	Under coating	Under coat modified epoxy resin paint	200	Paint blush	60	1 day-10 day
	Under coating	Under coat modified epoxy resin paint	200	Paint blush	60	

When the steel members are damaged due to the faults generated at the time of transportation or erection stage, the paint surface should be repainted and restored to the original paint system by touch up works. The touch-up works as per the painting systems are briefly explained in Table 6.2.28.

Table 6.2.28 Touch-up works

Paint system	After factory paint or site paint Bridge member ※(damages due to transportation or erection bad treatment)		
	Damages reached to the base metal and rusted		Damages until paint layers
C-5 F11	First base plate conditioning	Power tool, Handy tool	Repaint to the original paint system after removed the damaged paint film and surroundings by sand paper for smoothing surface
	Under coat	Under coat modified epoxy resin paint 4 times	
	Intermediate coat	Fluororesin paint for intermediate coat	
	Top coat	Fluororesin paint for top coat	
D-5 F-12	first base plate conditioning	Power tool, Handy tool	
		Under coat modified epoxy resin paint 4 times	

The steel bridge members should be painted at factory and transported to the bridge sites. At the time of transportation, the steel bridge members should be packed by sheet awning and protectors. After assemblage and bolting, the splice plates are to be painted at the bridge site. Next to the assembling yard, the paint shop will be placed for interval of erection cycle. The surroundings of the site paint shop should be covered in order to avoid dust accumulation and also to control temperature and humidity. This is because the paint standards specify the painting environmental condition as shown in Table 6.2.29, which should be thoroughly followed when the bridge surface will be painted.

Table 6.2.29 Limit of paint works

Paint	Temperature (℃)	Humidity (RH %)
inorganic zinc primer	Below 0	Under 50
inorganic zinc paint	Below 0	Under 50
Inner modified epoxy resin paint	Below 10	Over 85
under coat modified epoxy resin paint	Below 10	Over 85
Intermediate coat Fluororesin paint	Below 5	Over 85
Top coat Fluororesin paint	Below 0	Over 85
Ultra thick epoxy resin paint	Below 5	Over 85

CHAPTER 7

SELECTION OF BRIDGE TYPES OF 2ND BRIDGES

7. SELECTION OF BRIDGE TYPES OF 2ND BRIDGES

7.1 General

In letter No.35.033.014.00.00.015.2011 (Part-1)-115 issued by Ministry of Communication (MoC) of Bangladesh on 24th June, 2012, the following two points are clarified.

- The alignment of 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges shall be next to and parallel to the existing bridges
- The said 2nd bridges would be 4-lane Bridges.

Therefore, the 2nd bridges shall be designed in accordance with the above clarification letter. Accordingly, this chapter studies and examines the bridge type selection for the 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges. The bridge types of the 2nd bridges are studied and examined in accordance to several factors such as (1) type of foundation and their integrity with the existing one, (2) applicable bridge types along with their applicability in accordance with the environmental effect and (3) comparison studies among applicable bridge types.

(1) The type of foundation for the 2nd bridges is studied in this chapter taking into consideration several factors such as foundation scale, construction method, riverbed scouring and overall costing for construction. Moreover, the construction of the 2nd bridge foundations should follow the retrofitting of the existing. Therefore, the new foundation type along with their integrity to the existing is studied in detail in the following section.

(2) The applicable bridge types for the 2nd bridges are selected based on general span length configuration, avoiding foundations in medium to severe riverbed scouring zones and bridge superstructure material, for instance prestressed concrete and steel.

(3) Comprehensive comparison studies among the applicable bridge types for the 2nd bridges are included in this chapter. This comparison mainly includes structural performance,

constructability, environmental impact due to scouring and change of river hydrology, and frequency of periodic maintenance after bridge construction.

The factors quoted above mainly govern the selection of bridge type for the 2^{nd} bridges. These are fully described with relevant information in the subsequent sections.

7.2 Preconditions of Bridge Type Selection

In Chapter 4, the alignments of the 2^{nd} bridges were studied and determined, the alignments of the 2^{nd} Kanchpur and 2^{nd} Gumti Bridges are planned downstream next to the existing Kanchpur and existing Gumti Bridges while the alignment of the 2^{nd} Meghna Bridge is planned upstream next to the existing Meghna Bridge.

In the context of the above decision, the 2^{nd} bridges are close to the existing bridges, therefore, the span configuration of the 2^{nd} bridge is required to be the same as the existing bridge. In case of modification of span configuration of the 2^{nd} bridge, the span length of the 2^{nd} bridge should be expanded as double or triple of existing bridge span by deleting one or two piers and foundations.

The three existing bridges were designed and constructed based on an outdated seismic design standard with the seismic acceleration coefficient of 0.05 and the deepest riverbed -20.7 m (PWD) was observed in a bathymetric survey along the Meghna Bridge, meanwhile, the new seismic design standard with increased acceleration value 0.15 was established by BNBC (2006). With the application of the new standard of BNBC (2006), the seismic stability of the structure was a concern under the condition of exposure of the foundation due to scouring.

New seismic design standard of BNBC (2006) should be applied to retrofit the existing bridges and to design the 2^{nd} bridges. In case of retrofitting the existing bridges, the necessity of integration of the foundations of the existing bridge and 2^{nd} bridge is investigated.

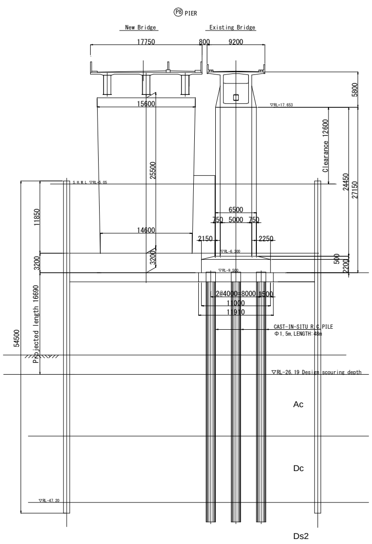
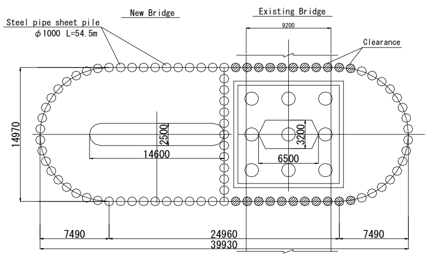
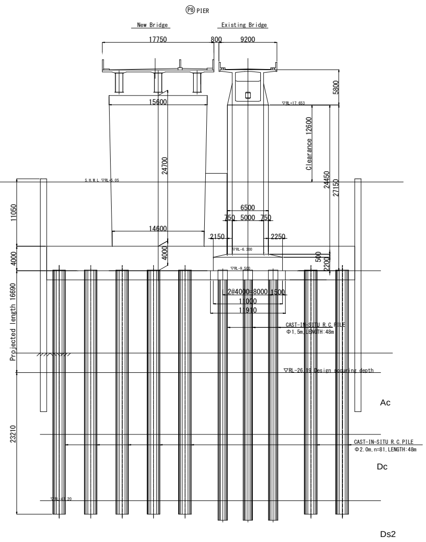
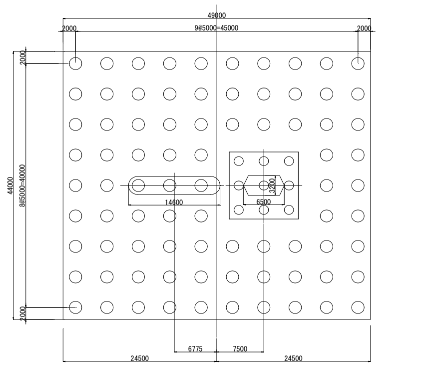
7.3 Selection of Foundation

The foundation type of the existing Kanchpur Bridge is open caisson and the foundation type of the existing Meghna and Gumti Bridges is cast-in-place concrete pile, and these foundations were designed in accordance with the outdated seismic design standard.

Two types of foundations are chosen as applicable foundation types for the 2^{nd} bridges and retrofitting the existing bridges, one is Steel Pipe Sheet Pile (SPSP) and the other is cast-in-place concrete pile. The comparison of applicability of the two types for the integrated foundation P8 of the 2^{nd} Meghna Bridge and the existing Meghna Bridge is shown in Table 7.3.1. The cast-in-place concrete pile foundation needs a huge plane section, a long period for construction, a huge construction cost and a cofferdam to build the pile cap, while the SPSP foundation is able to be constructed with a smaller plane section, a shorter period and less cost and also needs no cofferdam because of the cofferdam function of the SPSP. In accordance with the result of the above comparison, the application of SPSP was proposed and decided for the integrated foundations of the 2^{nd} bridge and the existing bridge.

As alternative ideas for foundation type there are steel pile type and caisson type foundation, however, they were not adopted for the comparison candidates because of higher cost of steel pile and necessity of artificial island for caisson construction.

Table 7.3.1 Selection of Foundation Type for Pier P8 (Meghna Bridge)

		A plan: Steel pipe sheet pile		B plan: Additional RC pile	
Image		 		 	
Structural aspect					
	Record	A little	△	A little	△
	Foundation scale	Small in size	◎	Large in size	△
Erection aspect					
	Erection	No need cofferdam	◎	Need cofferdam (cofferdam by Steel pipe sheet pile)	△
	Navigation clearance	Adequate	△	Adequate	△
	Erection time	Six months (Only Steel pipe sheet pile)	◎	Over one year (RC pile + Steel pipe sheet pile)	△
Natural environment					
	Effect on acquatic environment	Small (foundation is small)	◎	Large (foundation is large)	△
	River bed scouring	Small (foundation is small)	◎	Large (foundation is large)	△
Cost		Only pier P8 1.00	◎	Only pier P8 2.56	△
Evaluation		◎		△	

Legend: ◎excellent, ○good, △poor

7.4 Remarks on Bridge Types for 2nd Bridges

7.4.1 Applicable Bridge Types

The existing Kanchpur Bridge has 8 spans with a longest span of 73.2 m and shortest one of 42.7 m, and most of the span lengths of the existing Meghna and Gumti Bridges are 87.0 m. Under restricting condition of considering the span configuration of the existing bridges, the applicable bridge types for the 2nd bridges are listed in Table 7.4.1.

PC T-beam type bridge is very popular, however, the span length is usually limited up to 45 m. Continuous PC box girder bridge is also very popular and applicable to the three 2nd bridges. In these days a number of continuous PC box girder bridges with corrugated steel web are used in Japan, they have the merit of reducing dead load and the site works are not so complex. Steel box girder bridge is typically used for the bridges with span length about 90.0 m. And also recently the steel narrow box girder bridges are used in Japan, they have the merit of reducing the erection period.

Table 7.4.1 Applicable Bridge Types

Bridge type	General applicable span length (m)	Remarks
PC T-beam	25 – 45	Same span configuration of existing bridges
Continuous PC box girder (including corrugated steel web)	45 - 100	Ditto
Steel narrow box girder	50 - 120	Ditto
PC extradosed	150 - 240	In case of adopting double span length of existing bridges
PC cable-stayed	150 - 400	In case of adopting triple span length of existing bridges

Some foundations, especially P6, P7, P8 and P9 of Meghna Bridge, are suspected to be scoured, so PC extradosed and PC cable-stayed type bridges which are able to expand span length are applicable to avoid the scoured locations.

In addition to the listed bridge types in Table 7.4.1, steel truss type bridge and tied arch type bridge are applicable for bridges with span length of around 90.0 m, however, these bridge types do not harmonize with the existing bridges, so they are not listed for comparison candidates.

7.4.2 Application of Bridge Types for Each Bridge for Comparison

Based on Table 7.4.1 comparison candidates to select the most suitable bridge type for Kanchpur, Meghna and Gumti Bridges are described in Table 7.4.2.

Table 7.4.2 Application of Bridge Types for 2nd Bridges

Bridge type	2nd bridges			Remarks
	Kanchpur	Meghna	Gumti	
PC T-beam	○	-	-	
Continuous PC box girder	○	○	○	
Continuous PC box girder with corrugated steel web	-	○	○	
Steel narrow box girder	○	○	○	
PC extradosed	○	○	○	To avoid one scoured foundation of Meghna and Gumti Bridges
PC cable-stayed	-	○	-	To avoid four scoured foundations of Meghna Bridge. Study is conducted as a reference

Note: ○ means comparison candidate bridge type for each bridge

(1) 2nd Kanchpur Bridge

1) Option-1

PC T-beam bridge + continuous PC box girder bridge

((4x42.7) + (54.9+73.2+54.9+42.7) = 396.5 m)

Option-1 has the same span configuration as the existing bridge, and is planned as a similar bridge type of the existing bridge. Figure 7.4.1 shows the side view and section of Option-1, and Figure 7.4.2 shows Computer Graphics (CG) of the completed bridge from the Dhaka side. A discontinuous web shape between T-beam girder and box girder appears. The selection of T-beam that makes discontinuous web shape at Chittagong end would result in cost minimization.

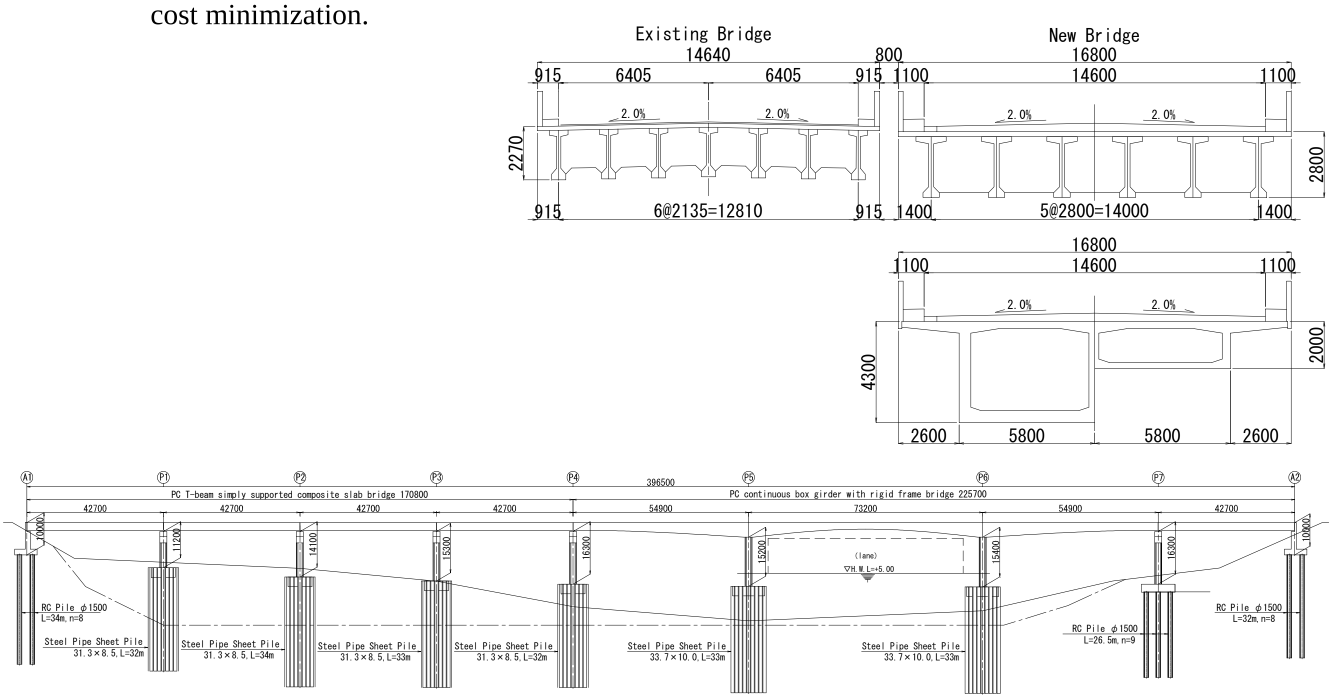


Figure 7.4.1 Cross-Section and Side View of Option-1 (Kanchpur Bridge)

Figure 7.4.2 Computer Graphics of Kanchpur Bridge (Option-1) from Dhaka Side

2) Option-2

Continuous PC box girder bridge

(42.7+85.4+97.6+73.2+54.9+42.7 = 396.5 m)

Option 2 is planned as continuous PC box girder bridge by deleting the 2 piers, P2 and P4. Figure 7.4.3 shows the side view and section of Option-2. The bridge floor elevation of the 2nd bridge and the existing bridge results in a difference of 1.5 m because of ensuring the navigation clearance. Figure 7.4.4 shows a CG of completed bridge from the Dhaka side.

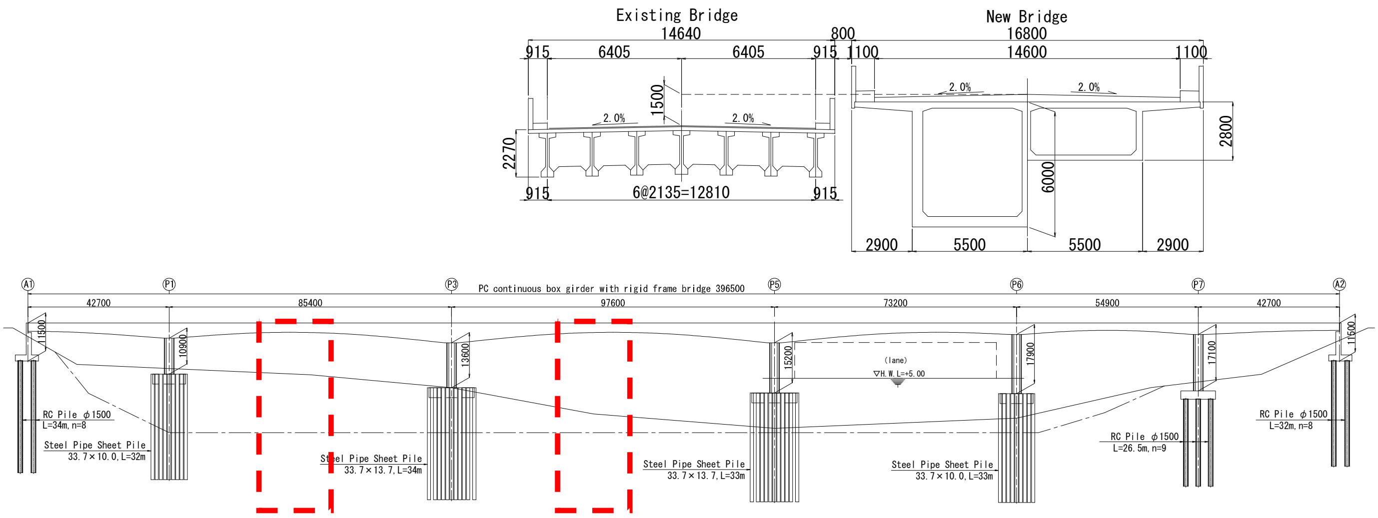


Figure 7.4.3 Cross-Section and Side View of Option-2 (Kanchpur Bridge)

Figure 7.4.4 Computer Graphics of Kanchpur Bridge (Option-2) from Dhaka Side

3) Option-3

Steel narrow box girder bridge

(42.7+85.4+97.6+73.2+54.9+42.7=396.5 m)

Option-3 is planned as a steel narrow box girder bridge with the same span configuration as Option-2 and superstructure weight is decreased. Figure 7.4.5 shows the side view and section of Option-3, and Figure 7.4.6 shows a CG of the completed bridge from the Dhaka side.

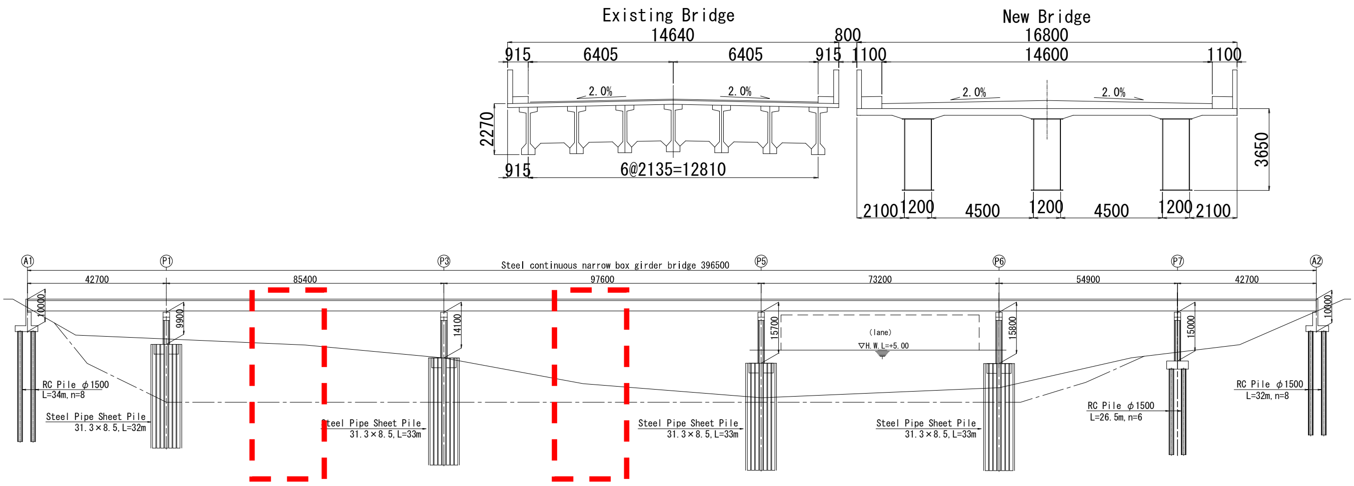


Figure 7.4.5 Cross-Section and Side View of Option-3 (Kanchpur Bridge)

Figure 7.4.6 Computer Graphics of Kanchpur Bridge (Option-3) from Dhaka Side

4) Option-4

PC extradosed bridge

(42.7+85.4+170.8+97.6 = 396.5 m)

Option-4 is planned as a PC extradosed bridge by deleting 4 piers, P2, P4, P5 and P7. Figure 7.4.7 shows the side view and section of Option-3. The bridge floor elevation of the 2nd bridge and the existing bridge results in a difference of 1.2 m.

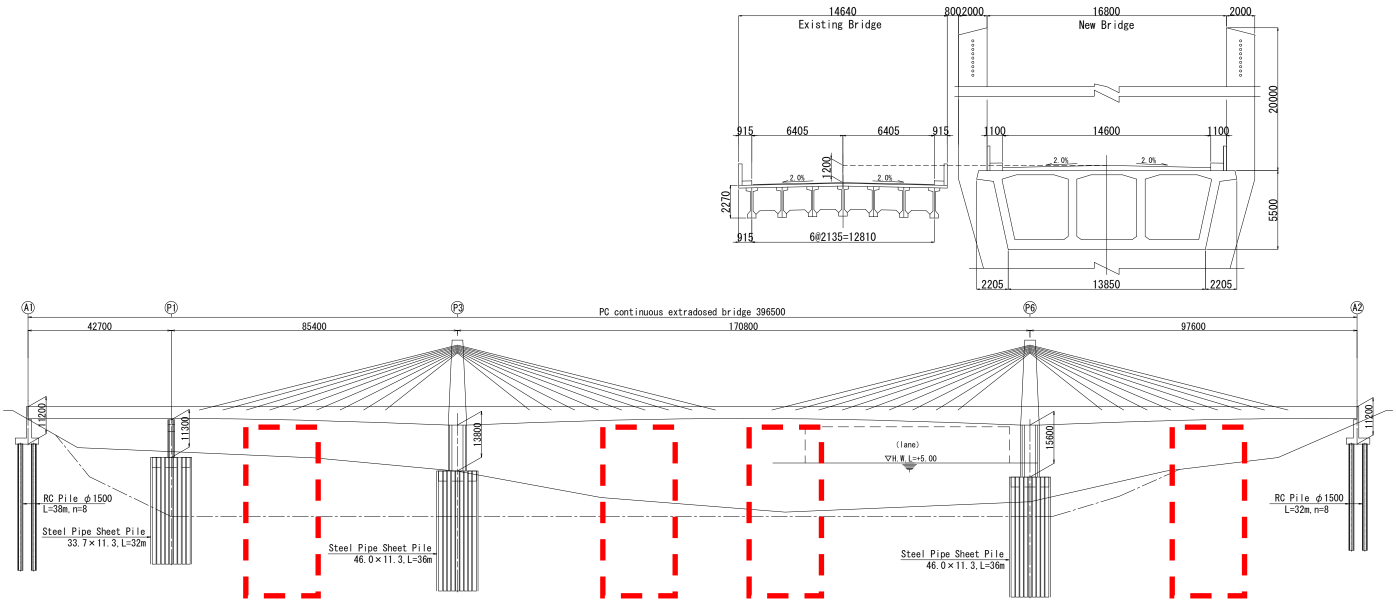


Figure 7.4.7 Cross-Section and Side View of Option-4 (Kanchpur Bridge)

Figure 7.4.8 Computer Graphics of Kanchpur Bridge (Option-4) from Dhaka Side

(2) 2nd Meghna Bridge

1) Option-1

Continuous PC box girder bridge

((48.5+ 5 x 87) + (4 x 87+73.5+25) = 930m)

Option-1 has the same span configuration as the existing bridge, and is planned as a similar bridge type of the existing bridge. Option-1 consists of 2 parts of 483.5 m and 446.5 m continuous bridge. Figure 7.4.9 shows the side view and section of Option-1, and Figure 7.4.10 shows a CG of the completed bridge from the Chittagong side.

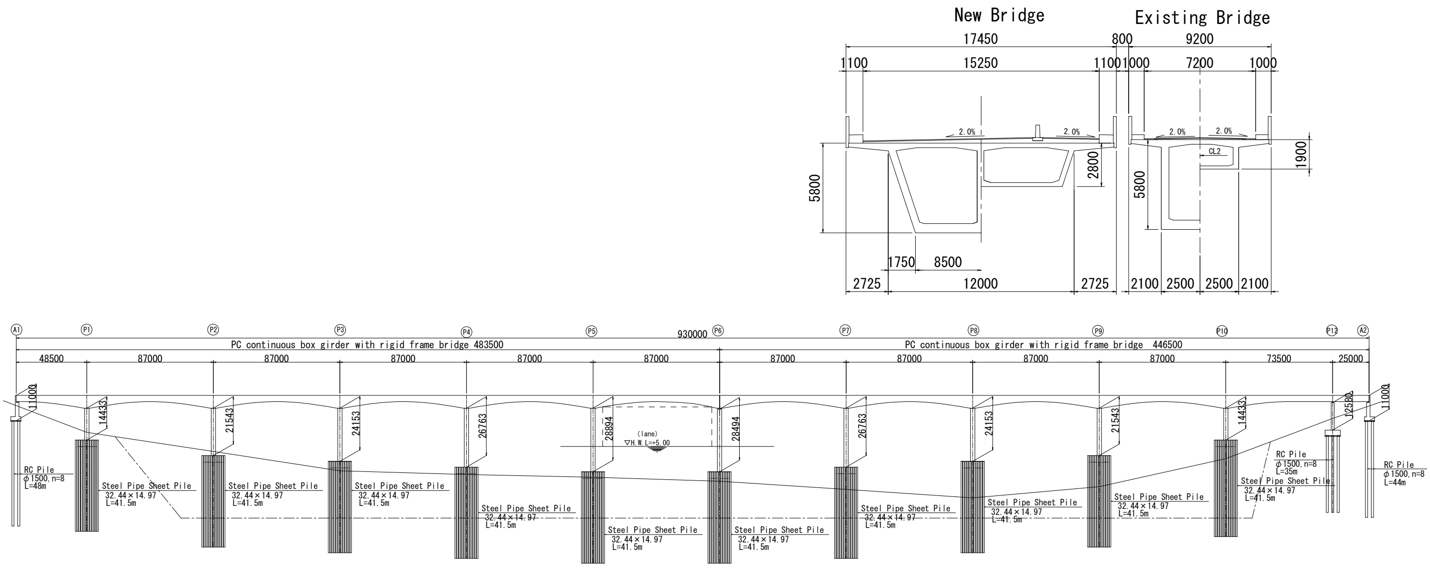


Figure 7.4.9 Cross-Section and Side View of Option-1 (Meghna Bridge)

Figure 7.4.10 Computer Graphics of Meghna Bridge (Option-1) from Chittagong Side

2) Option-2

Continuous PC box girder bridge with corrugated steel web

((48.5+ 5 x 87) + (4 x 87+73.5+25) = 930 m)

Option-2 has the same span configuration as Option-1 and corrugated steel web is used in order to decrease the superstructure weight so as to increase the earthquake resistance. Figure 7.4.11 shows the side view and section of Option-2, and Figure 7.4.12 shows a CG of the completed bridge from the Chittagong side.

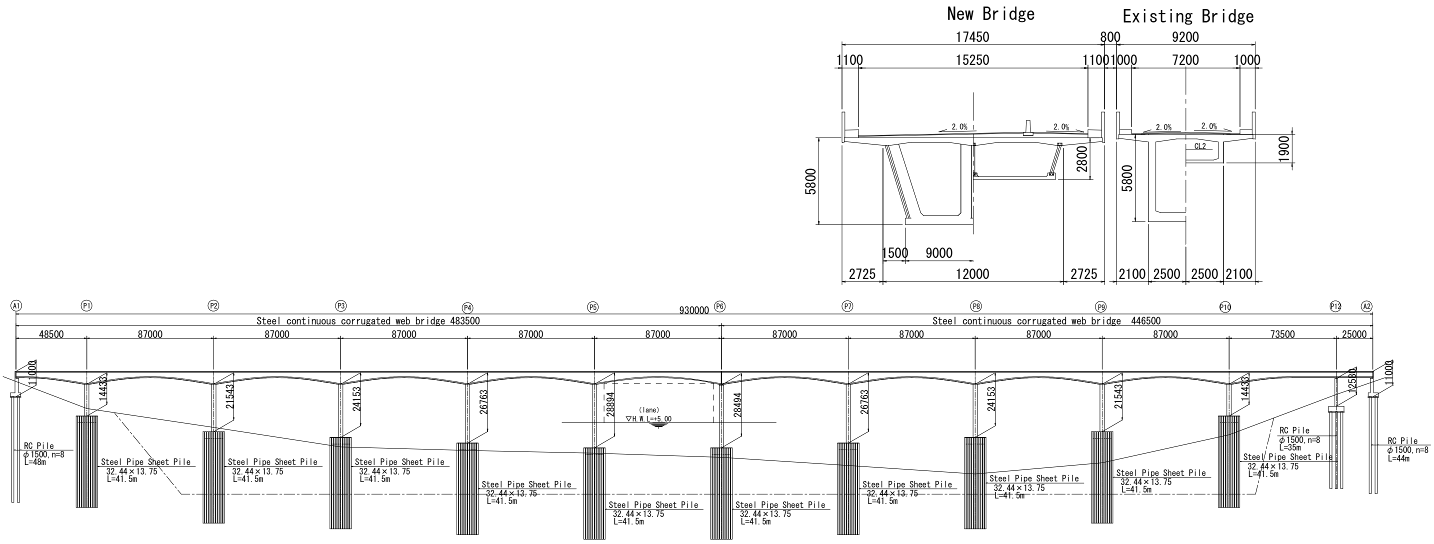


Figure 7.4.11 Cross-Section and Side View of Option-2 (Meghna Bridge)

Figure 7.4.12 Computer Graphics of Meghna Bridge (Option-2) from Chittagong Side

3) Option-3

Steel narrow box girder bridge

(48.5+ 9 x 87+73.5+25 = 930 m)

Option-3 has the same span configuration as the existing bridge and is planned as a completely continuous girder bridge in order to decrease the superstructure weight and thereby increase the earthquake resistance, and a narrow steel box girder is used. The narrow box girder is fabricated with steel, and the outer surface of the steel girder can be protected from severe corrosive action by paint. Figure 7.4.13 shows the side view and section of Option-3, and Figure 7.4.14 shows a CG of the completed bridge from the Chittagong side.

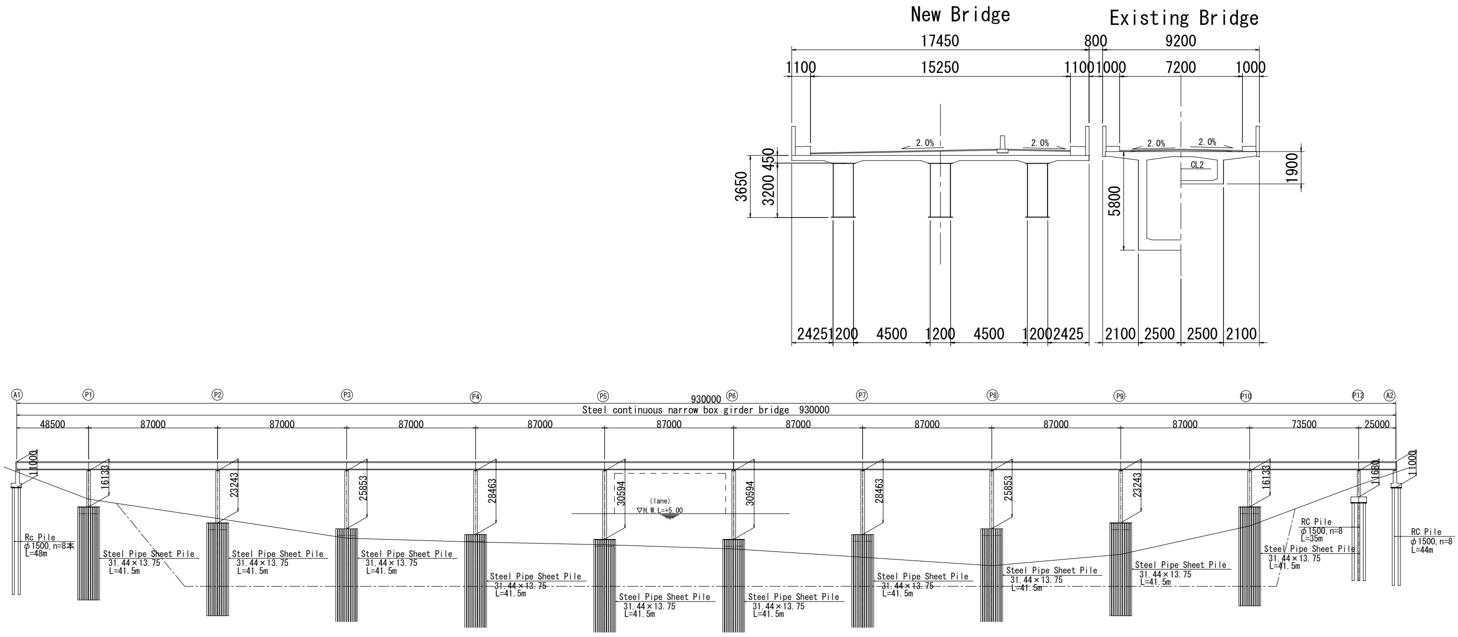


Figure 7.4.13 Cross-Section and Side View of Option-3 (Meghna Bridge)

Figure 7.4.14 Computer Graphics of Meghna Bridge (Option-3) from Chittagong Side

4) Option-4

Continuous PC box girder bridge + PC extradosed bridge

((48.5+ 4 x 87+ 58.0)+ (29.0+87.0+174.0+ 87.0+48.5+50.0) = 930 m)

Option-4 is planned as a PC extradosed bridge by deleting pier P8 which is located under severe riverbed scouring. Figure 7.4.15 shows the side view and section of Option-4, and Figure 7.4.16 shows a CG of the completed bridge from the Chittagong side.

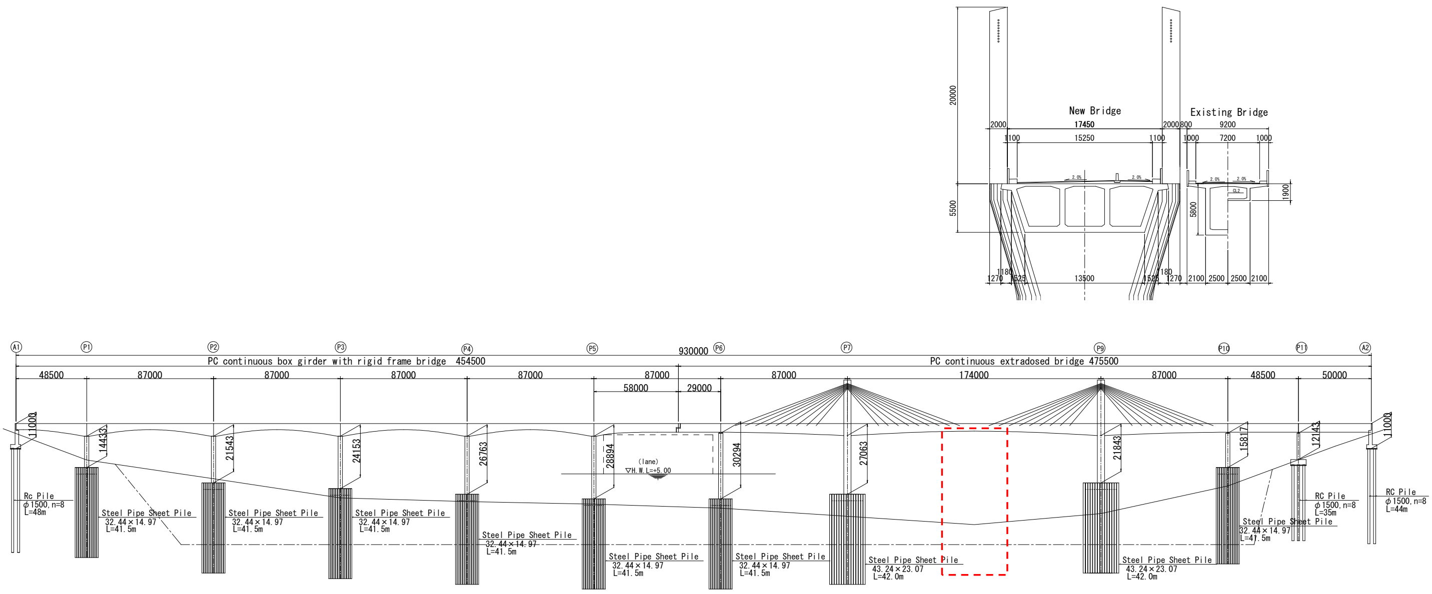


Figure 7.4.15 Cross-Section and Side View of Option-4 (Meghna Bridge)

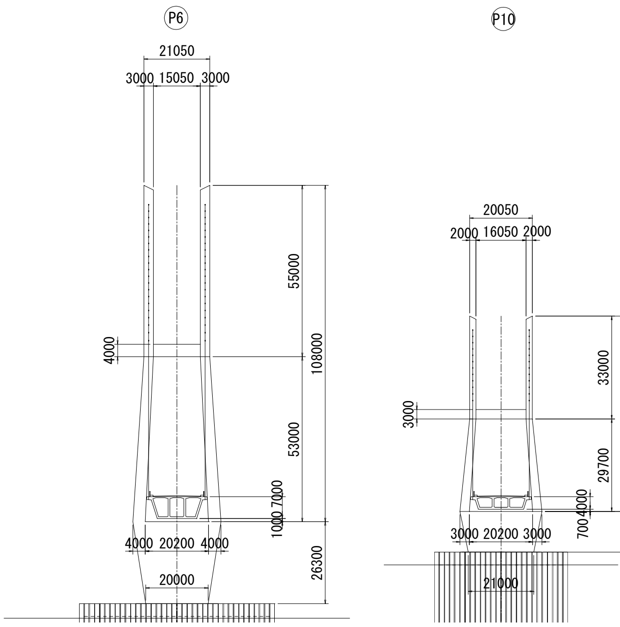
Figure 7.4.16 Computer Graphics of Meghna Bridge (Option-4) from Chittagong Side

5) Reference option

Continuous PC box girder bridge + PC cable-stayed bridge

(48.5+2x 87+58.0) + (29.0+174.0+348.0+98.5) = 930 m)

The reference option is planned as a PC cable-stayed bridge by deleting five piers, P5, P7, P8, P9 and P11. The piers, excluding P5 and P11, are located in a medium to severe riverbed scouring zone. This study is conducted as a reference option and compared to Option-4. The side view and section of the Reference option are shown in Figure 7.4.17.



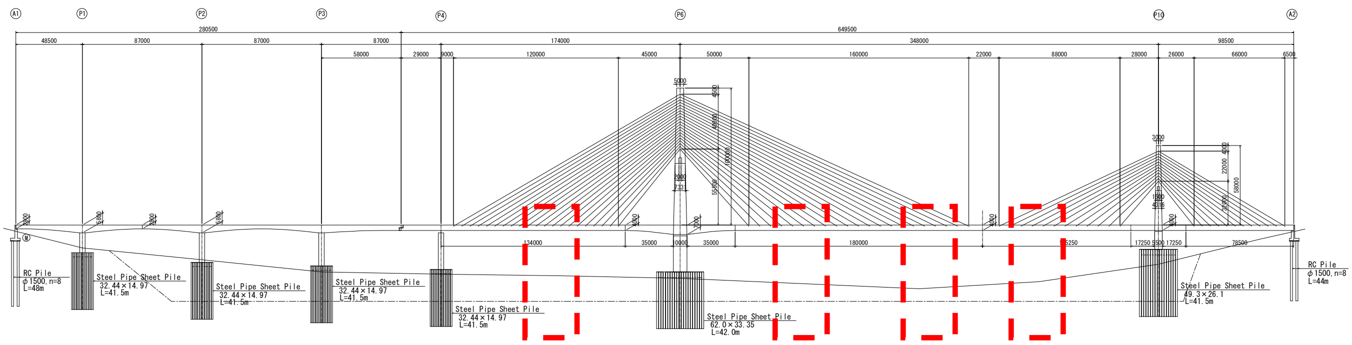


Figure 7.4.17 Cross-Section and Side View of Reference Option (Meghna Bridge)

(3) 2nd Gumti Bridge

1) Option-1

Continuous PC box girder bridge

((52.5+5 x 87) + (5 x 87) + (5 x 87+52.5) = 1,410 m)

Option-1 has the same span configuration as the existing bridge, and is planned as a similar bridge type of the existing bridge. Option-1 consists of 3 parts of 487.5 m, 435 m and 487.5 m continuous bridge. Figure 7.4.18 shows the side view and section of Option-1.The landscape of Option-1 is similar to that of the 2nd Meghna Bridge; therefore no CG for Option-1 of Gumti Bridge is included herein.

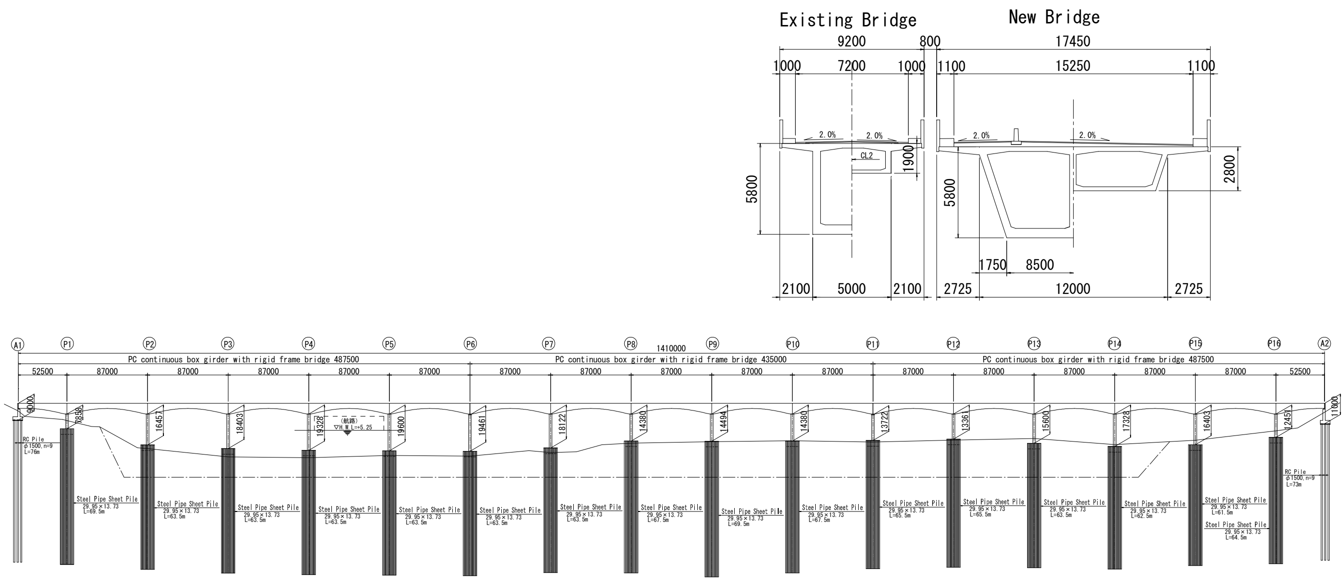


Figure 7.4.18 Cross-Section and Side View of Option-1 (Gumti Bridge)

2) Option-2

PC box girder bridge with corrugated steel web

((52.5+5 x 87) + (5 x 87) + (5 x 87+52.5) = 1,410 m)

Option-2 has the same span configuration as Option-1 and corrugated steel web is used in order to decrease the superstructure weight so as to increase the earthquake resistance. Figure 7.4.19 shows the side view and section of Option-2. The landscape of Option-2 is similar to that of the 2nd Meghna Bridge; therefore no CG for Option-2 is included herein.

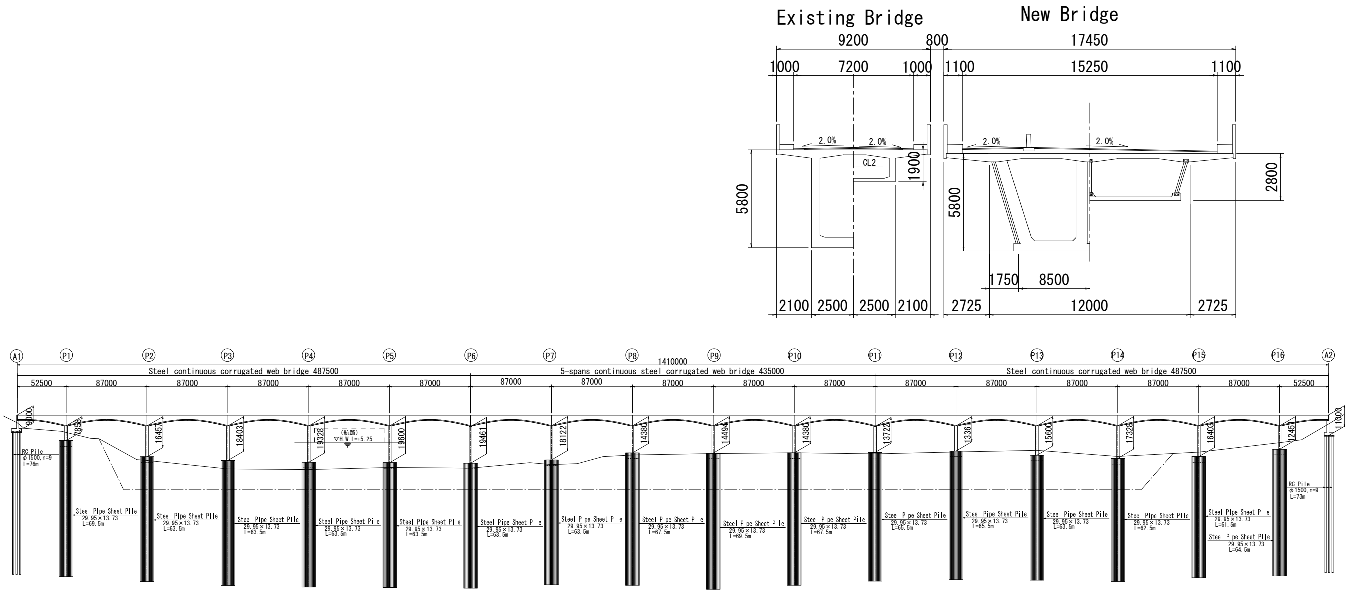


Figure 7.4.19 Cross-Section and Side View of Option-2 (Gumti Bridge)

3) Option-3

Steel narrow box girder bridge

((52.5+8 x 87) + (7 x 87+52.5) = 1,410 m)

Option-3 has the same span configuration as the existing bridge and a narrow box girder is used in order to decrease the superstructure weight so as to increase the earthquake resistance. The narrow box girder is fabricated with steel, and the outer surface of the steel girder can be protected from severe corrosive action by paint. Option-3 consists of 2 parts of 748.5 m and 661.5 m continuous bridge. Figure 7.4.20 shows the side view and cross section of Option-3. Although the landscape of Option-3 is similar to that of 2nd Meghna Bridge included in the preceding section, a CG for Option-3 (Gumti Bridge) is further included herein in order to get the real scenario of Gumti Bridge. Figure 7.4.21 shows the CG of the completed 2nd Gumti Bridge from the Dhaka side.

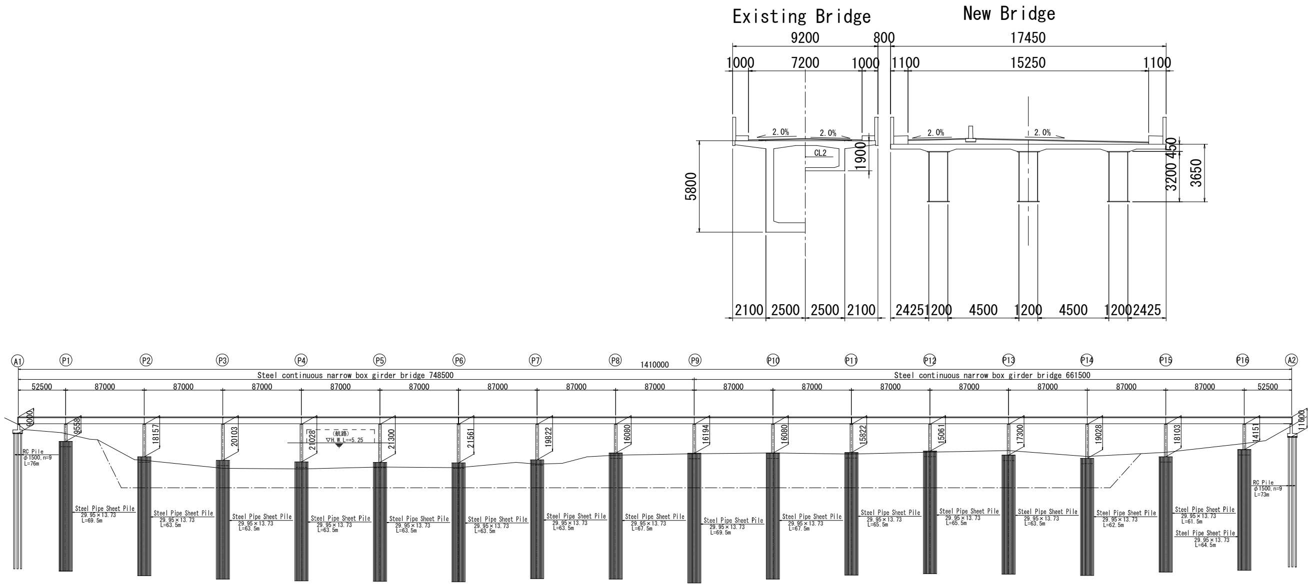


Figure 7.4.20 Cross-Section and Side View of Option-3 (Gumti Bridge)

Figure 7.4.21 Computer Graphics of Gumti Bridge (Option-3) from Dhaka Side

4) Option-4

PC extradosed bridge + Continuous PC box girder bridge

((52.5+87.0+174.0+87.0+29.0) + (58.0+5 x 87) + (5 x 87+52.5) = 1,410 m)

Option-4 is planned as a PC extradosed bridge by deleting pier P3 which is located in a severe riverbed scouring zone. Option-3 consists of 3 parts of 429.5 m extradosed bridge, 493 m and 487.5 m continuous PC box girder bridge. Figure 7.4.22 shows the side view and section of Option-4. The landscape of Option-2 is similar to that of the 2nd Meghna Bridge; therefore no CG for Option-2 is further included herein.

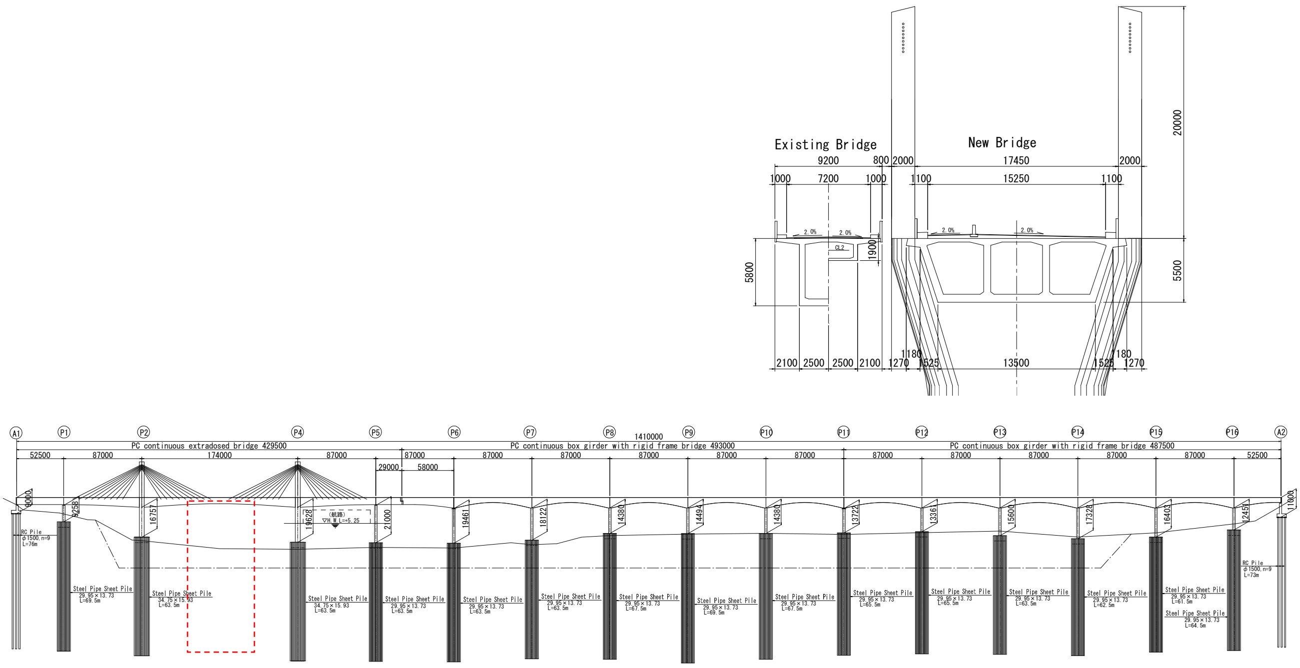


Figure 7.4.22 Cross-Section and Side View of Option-4 (Gumti Bridge)

7.5 Comprehensive Evaluation of Selection of Bridge Type for 2nd Bridges

7.5.1 Evaluation Items

The evaluation items and their interpretation are described in Table 7.5.1 and also evaluation criteria are explained.

Table 7.5.1 Evaluation Items

Evaluation items		Description
Structural performance	Record of usage	Corresponds to the number of existing bridges in operation. The limited numbers represent that the application of their construction technologies are still in the initial stage. Number of more than 200 usages is evaluated as "◎", number of more than 100 is evaluated as "○".
	Durability	Corresponds to the durability of the structure with respect to so-called RC structures. Basically, the durability of bridges is governed by the floor slab. PC floor slab is evaluated as "◎", RC floor slab is evaluated as moderate, that is, as "○".
	Earthquake resistance	Largely depends on the weight of the bridge superstructure. Theoretically, relatively lighter superstructure is advantageous to earthquake resistance. PC girder is evaluated as moderate, that is, as "○", steel girder is evaluated as advantageous, that is, as "◎" because of lighter superstructure.
Constructability	Construction method	Basically depends on level of difficulties encountered due to construction method to be adopted. It largely depends on girder erection time or concrete formwork preparation. Cantilever and launching method are evaluated as moderate, that is, as "○", cable suspended structure type is evaluated as slightly difficult, that is, as "△".
	Quality control	Corresponds to the level of difficulties arising from bridge assemblage, for example site welding of girders, cable adjustment or shape control. Cantilever and launching method are evaluated as moderate, that is, as "○", suspended structure type is evaluated as slightly difficult, that is, as "△".
	Construction period	Depends on time to complete one cycle. Total time period required for construction shall be integrated with site constraints (rainy season), national holidays and weekend holidays. Construction period of PC girder type bridge is evaluated as moderate, that is, as "○", in case of shorter period than moderate it is evaluated as "◎", in case of longer period it is evaluated as "△".
Maintenance	Painting /Carbonation	Repainting is necessary for steel bridges. If the steel is adopted, it should be repainted for surface treatment after 30 years. A process where CO_2 diffuses in the concrete and reacts with the calcium hydroxide in the presence of water to form carbonate and thus reduces the pH value of the hardened concrete. Once this process reaches the reinforcement, corrosion will initiate. Therefore, surface treatment is required to restrain the progress of aggressive corrosion action. Repainting (coating) of the concrete structure is needed for preventing carbonation every 30 years is evaluated as moderate, that is, as "○", repainting of steel surface at every 30 years is also evaluated as "○".

Evaluation items		Description
	Periodic maintenance	Periodic maintenance covers pavement surface work and expansion joint replacement. It mainly depends on the number of bearings (number of piers with bearings) and expansion joints used in the superstructure. Zero (0) of intermediate expansion joint number is evaluated as "◎", one (1) or two (2) is evaluated as "○". Zero (0) of number of piers with bearings is evaluated as "◎", two (2) to four (4) is evaluated as "○", more than five (5) is evaluated as "△".
	Replacement of cable sheath	Depends on action to be taken as countermeasures in whole lifespan of the bridge. Basically, this maintenance includes the cable cover (sheath) treatment to be done once every 75 years. No requirement of cable sheath replacement is evaluated as" ◎ ", requirement of cable sheath replacement is evaluated as "△".
Landscape (aesthetic view)		Usually it depends on the feelings of human beings and the structure seems to be symbolic. Towers and diagonal cables of such symbolic structure are attractive and impressive. Cable suspended bridge type is evaluated as "◎", normal girder type bridge is evaluated as moderate, that is, as "○".
Environmental impact	River hydrology	Depends on disturbance that enforces the diversion of river flow. Basically, the number of bridge piers on the riverbed greatly affects the river hydrology. Least number of piers is evaluated as "◎", most numbers are evaluated as "△".
	Scouring	Depends on stream flow diversion around the bridge piers. Therefore, the number of bridge piers in the main stream is a governing factor for scouring. Least number of piers is evaluated as "◎", most numbers are evaluated as "△".
	Noise /vibration	Depends on numbers and conditions of expansion joints. Total number of expansion joints used in superstructure is a vital factor. Least number of expansion joints is evaluated as "◎", most numbers are evaluated as "△".
Life cycle cost		Comprised of construction cost and maintenance cost.

"Six major items" such as "Structural performance", "Constructability", "Maintenance", "Landscape", "Environmental impact" and "Life cycle cost" are chosen, and each major item consists of some sub-items. "Structural performance" consists of "Record of usage", "Durability" and "Earthquake resistance". "Constructability" consists of "Construction method", "Quality control" and "Construction period". "Maintenance" consists of "Painting/Carbonation", "Periodic maintenance" and "Cable". "Landscape" means "Aesthetic view". "Environmental impact" consists of "River hydrology", "Scouring" and "Noise/Vibration". And "Life cycle cost" comprised of construction cost and maintenance cost is evaluated by the ratio of each option to the lowest cost option.

Each sub-item is evaluated subject to evaluation criterion described in Table 7.5.1. Each major item is analysed by integrating the evaluation results of the sub-items.

Major item is evaluated as "◎" based on whether most sub-items are evaluated as "◎" along with remaining sub-item evaluated as "◯", or more than two (2) sub-items are evaluated as "◎".

Major item is evaluated as "◯" if most sub-items are evaluated as "◯" even if a remaining sub-item is evaluated as "◎" or "△".

Major item is evaluated as "△" if most sub-items are evaluated as "△".

Life cycle cost item is evaluated as "◎" in case of lowest or very nearest lowest value. It is evaluated as "△" in case of highest and "◯" in case of a value between lowest and highest.

Finally, the order of options is ranked subject to the total number of "◎" of major items.

7.5.2 Results of Evaluation

(1) 2nd Kanchpur Bridge

Table 7.5.2 shows the comparison results of the 4 options in accordance with the evaluation items and criteria specified in Table 7.5.1.

Regarding record of usage, “Steel narrow box girder bridge” (Option-3) is evaluated as “○” because of 111 actual construction achievements in 2009 in Japan, and other options are evaluated as “◎” as to “Structural performance”.

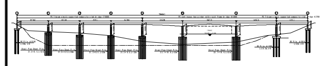
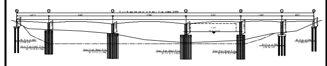
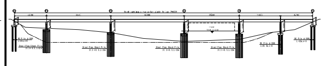
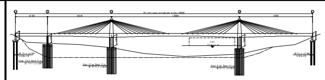
Regarding “Constructability”, most options are evaluated as “○” except “Option-4”. Moreover, construction period of “Option-3” is expected to be the shortest.

Regarding “Maintenance”, “Option-2” is evaluated as “◎” because it has no intermediate expansion joints, bearings or cable, and also “Option-3” is evaluated as “◎” while “sub-item for pier with bearings” is evaluated as “△”. The life span of rubber bearings to be adopted for “Option-3” is expected to be 100 years according to recent research.

Only “Option-4” is evaluated as “◎” regarding “Landscape” because of the suspended structure. And also “Option-4” is evaluated as “◎” regarding “Environmental impact” because the number of piers in the river are decreased by applying longer span. However, “Option-4” needs the highest cost for construction, which is 1.43 times “Option-1”.

Therefore, in accordance with the above evaluations, finally “Option-3” is ranked as “1st order” by comprehensive comparison procedure, and it is proposed for the most appropriate bridge type of the 2nd Kanchpur Bridge.

Table 7.5.2 Bridge Type Evaluation for 2nd Kanchpur Bridge

			Option-1			Option-2			Option-3			Option-4		
Bridge type			PC T-beam bridge + PC box girder bridge			Continuous PC box girder bridge			Steel narrow box girder bridge			PC extradosed bridge		
Bridge shape														
Strctural performance	Record of usage		Many	◎	◎	Many	◎	◎	Moderate	○	◎	Moderate	○	○
	Durability	Durability of floor slab	Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎	
	Earthquake resistance	Weight of superstraucture	Moderate	○		Moderate	○		Advantageous	◎		Moderate	○	
Constructability	Construction method	Difficulty level of constructuction	Normal	○	○	Normal	○	○	Normal	○	○	Slightly difficult	△	△
	Quality control	Difficulty level of quality control	Normal	○		Normal	○		Normal	○		Slightly difficult (Camber adjustemnt)	△	
	Construction period		3.0 years	○		3.0 years	○		2.5 years	◎		3.5 years	△	
Maintenance	Painting / Carbonation	Necessity of painting / Surface treatment	Painting once in 30 years	○	○	Painting once in 30 years	○	◎	Painting once in 30 years	○	○	Painting once in 30 years	○	○
	Periodic maintenace	Intermidiate joint numbers	1 point	○		Nothing	◎		Nothing	◎		Nothing	◎	
		Pier with bearings	5 points	△		Nothing	◎		5 points	△		1 point	○	
	Cable	replacement of cable sheath	Not required	◎		Not required	◎		Not required	◎		replacement once in 75 years	△	
Landscape	Aesthetic view		Straight + Slender arch shape	○	○	Slender arch shape	○	○	Straight	○	○	Monumental appearance	◎	◎
Environmental impact	River Hydrology	Depends on no. of bridge piers in riverbed	7 piers	△	○	5 piers	○	○	5 piers	○	○	3 piers	◎	◎
	Scouring	number of piers in main stream	2 piers	○		2 piers	○		2 piers	○		1 pier	◎	
	Noise / vibration	No.and conditions of expansion joints	3 points	○		2 points	◎		2 points	◎		2 points	◎	
Construction cost			1.00	◎		1.07	○		1.03	◎		1.43	△	
Evaluation			2			3			1			4		

Legend: ◎ Excellent, ○ Good, △ Poor

(2) 2nd Meghna Bridge

In accordance with the evaluation items and criteria specified in Table 7.5.1, comparison results for the 4-options for the 2nd Meghna Bridge are shown in Table 7.5.3.

Regarding record of usage, "Steel narrow box girder bridge" (Option-3) is evaluated as "○" because of 111 actual construction achievements in 2009 in Japan. This evaluation is the same as Option-2 (PC-box girder with corrugated steel web). The other two options are evaluated as "◎" as to this sub item. Moreover, Option-3 including Option-1and 4 is evaluated as "◎" as to "Structural performance".

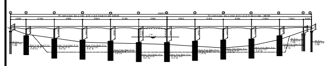
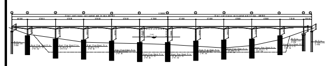
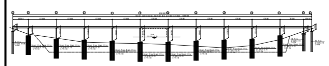
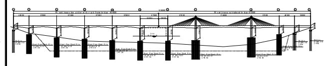
Regarding evaluation item "Constructability", most options are evaluated as "○" except "Option-4". Moreover, the sub item construction period of "Option-3" is expected to be the shortest.

Regarding "Maintenance", only "Option-3" is evaluated as "◎" because it has no intermediate expansion joints or cable needed to be replaced. But sub-item "pier with bearings" for Option-3 is evaluated as "△". The life span of the rubber bearings to be adopted for "Option-3" is expected to be 100 years in accordance with research conducted up to the present. The other options are evaluated as "○" as to "Maintenance".

Only "Option-4" is evaluated as "◎" regarding "Landscape" because of the suspended structure. The other options are evaluated as "○". And also "Option-4" is evaluated as "◎" regarding "Environmental impact" because the number of piers in the riverbed are decreased by applying longer span. However, "Option-4" needs the highest cost for construction, which is 1.17 times "Option-1".

Therefore, in accordance with the above evaluations, finally "Option-3" is ranked as "1st order" by the comprehensive comparison procedure, and it is proposed for the most appropriate bridge type of the 2nd Meghna Bridge.

Table 7.5.3 Bridge Type Evaluation for 2nd Meghna Bridge

Bridge type			Option-1			Option-2			Option-3			Option-4		
			PC box girder bridge			PC box girder bridge with corrugated steel web			Steel narrow box girder bridge			PC extradosed bridge + PC box girder bridge		
Bridge shape														
Strctural performance	Record of usage		Many	◎	◎	Moderate	○	○	Moderate	○	◎	Moderate	○	○
	Durability	Durability of floor slab	Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎	
	Earthquake resistance	Weight of superstraucture	Moderate	○		Slightly advantageous	○		Advantageous	◎		Moderate	○	
Constructability	Construction method	Difficulty level of constructuction	Normal	○	○	Slightly difficult	△	○	Normal	○	○	Slightly difficult	△	△
	Quality control	Difficulty level of quality control	Normal	○		Normal	○		Normal	○		Slightly difficult (Camber adjustemnt)	△	
	Construction period		4 years	○		4 years	○		3 years	◎		4 years	○	
Maintenance	Painting / Carbonation	Necessity of painting / Surface treatment	Painting once in 30 years	○	○	Painting once in 30 years	○	○	Painting once in 30 years	○	○	Painting once in 30 years	○	○
	Periodic maintenance	Intermidiate joint numbers	1 points	○		1 points	○		Nothing	◎		1 points	○	
		Pier with bearings	2 points	○		2 points	○		11 points	△		3 points	○	
	Cable	replacement of cable sheath	Not required	◎		Not required	◎		Not required	◎		Replacement once in 75 years	△	
Landscape	Aesthetic view		Slender arch shape	○	○	Slender arch shape	○	○	Straight	○	○	Monumental appearance	◎	◎
Environmental impact	River Hydrology	Depends on no. of bridge piers in riverbed	11 piers	○	○	11 piers	○	○	11 piers	○	○	10 piers	◎	◎
	Scouring	number of pier in main stream	5 piers	○		5 piers	○		5 piers	○		4 piers	◎	
	Noice/vibraton	No.and conditions of expansion joints	3 Points	○		3 Points	○		2 Points	◎		3 Points	○	
Construction cost			1.00		◎	1.00		◎	1.00		◎	1.17		△
Evaluation			2			3			1			4		

Legend: ◎ Excellent, ○ Good, △ Poor

(3) 2nd Gumti Bridge

In accordance with the evaluation items and criteria specified in Table 7.5.1, comparison results of 4-options for the 2nd Gumti Bridge are shown in Table 7.5.4.

Regarding record of usage, “Steel narrow box girder bridge” (Option-3) is evaluated as “○” because of 111 actual construction achievements in 2009 in Japan. This evaluation is the same as Option-2 (PC-box girder with corrugated steel web). The other two options are evaluated as “◎” as to this sub item. Moreover, Option-3 including Option-1and 4 is evaluated as “◎” as to “Structural performance”.

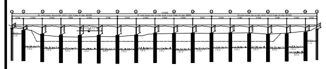
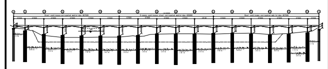
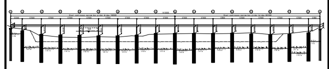
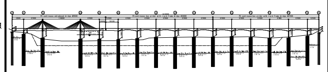
Regarding the evaluation item “Constructability”, most options are evaluated as “○” except “Option-4”. Moreover, the sub item construction period of “Option-3” is expected to be the shortest.

Regarding “Maintenance”, only “Option-3” is evaluated as “◎” because it has no intermediate expansion joints or cable needed to be replaced. But the sub-item “pier with bearings” for Option-3 is evaluated as “△”. The life span of the rubber bearings to be adopted for “Option-3” is expected to be 100 years in accordance with researches conducted up to the present. The other options are evaluated as “○” as to “Maintenance”.

Only “Option-4” is evaluated as “◎” regarding “Landscape” because of the suspended structure. The other options are evaluated as “○”. And also “Option-4” is evaluated as “◎” regarding “Environmental impact” because the numbers of piers in the riverbed are decreased by applying longer span. However, “Option-4” needs the highest cost for construction, which is 1.07 times “Option-1”.

Therefore, in accordance with the above evaluations, finally “Option-3” is ranked as “1st order” by the comprehensive comparison procedure, and it is proposed for the most appropriate bridge type of 2nd Gumti Bridge.

Table 7.5.4 Bridge Type Evaluation for 2nd Gumti Bridge

Bridge type			Option-1			Option-2			Option-3			Option-4		
			PC box girder bridge			PC box girder bridge with corrugated steel web			Steel narrow box girder bridge			PC extradosed bridge + PC box girder bridge		
Bridge shape														
Strctural performance	Record of usage		Many	◎	◎	Moderate	○	○	Moderate	○	◎	Moderate	○	○
	Durability	Durability of floor slab	Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎		Enough (PC floor slab)	◎	
	Earthquake resistance	Weight of superstraucture	Moderate	○		Slightly advantageous	○		Advantageous	◎		Moderate	○	
Constructability	Construction method	Difficulty level of constructuction	Normal	○	○	Slightly difficult	△	○	Normal	○	○	Slightly difficult	△	△
	Quality control	Difficulty level of quality control	Normal	○		Normal	○		Normal	○		Slightly difficult (Camber adjustemnt)	△	
	Construction period		4 years	○		4 years	○		3 years	◎		4 years	○	
Maintenance	Painting / Carbonation	Necessity of painting / Surface treatment	Painting once in 30 years	○	○	Painting once in 30 years	○	○	Painting once in a 30 years	○	○	Painting once in 30 years	○	○
	Periodic maintenance	Intermidiate joint numbers	2 points	○		2 points	○		1 point	◎		2 points	○	
		Pier with bearings	2 points	○		2 points	○		16 points	△		4 points	○	
	Cable	replacement of cable sheath	Not required	◎		Not required	◎		Not required	◎		replacement once in 75years.	△	
Landscape	Aesthetic view		Slender arch shape	○	○	Slender arch shape	○	○	Straight	○	○	Monumental appearance	◎	◎
Environmental impact	River Hydrology	Depends on no. of bridge pier in riverbed	16 piers	○	○	16 piers	○	○	16 piers	○	○	15 piers	◎	◎
	Scouring	Number of piers in main stream	6 piers	○		6 piers	○		6 piers	○		5 piers	◎	
	Noise/vibraton	No.and conditions of expansion joints	4 points	◎		4 points	◎		4 points	◎		4 points	◎	
Construction cost			1.00	◎		1.01	◎		1.01	◎		1.07	△	
Evaluation			2			3			1			4		

Legend: ◎ Excellent, ○ Good, △ Poor

7.5.3 Remarks on Bridge Type Evaluation

In accordance with the preceding sections, finally Option-3 (Steel narrow box girder bridge) is selected as bridge type for 2nd Kanchpur, 2nd Meghna and 2nd Gumti Bridges. The selection of this bridge type is governed by several factors such as adequate durability, advantageous to earthquake resistance, least construction period and less impact on environment, compared with the other options.