terminals and expansion of existing ferry terminals are very difficult. Therefore, improvement of existing ferry operations in without project case is unrealistic. As to the alternative “2):do nothing situation”, waiting time at ferry ghats is about one hour for buses/light vehicles and two hours for trucks even now.

In addition above, there is urgent need to replace existing dangerous ferry/launch operations between Dhaka and the Southwest region by more safety and reliable surface transport system. Overloaded vessels frequently sink in this waterway route passing through near the risky-prone zone of turbulent confluence of the Padma and Meghna rivers.

About 4,000 lives were lost in some 270 launch accidents since 1976 (average 9 vessels sunk or capsized every year, and about 140 deaths per year). These situations have not been improved for the past 30 years. Under the situation, an option of augmentation of existing ferry/ launch operations was not considered as an alternative in the case of “Without Project”.

From the above mentioned situation, it was concluded that from the technical difficulty of expanding ferry facilities and from the aspect of providing the safety all-weather transport mean (with 100 year project life), as well as from the point of view of efficiency in the investment, ferry operation shall be replaced with the Bridge in the future optimum timing

It should be noted that local traffic, such as small boats crossing the River today, will continue, as is the case for Jamuna Bridge. Furthermore, the study did not assume the all ferry services crossing the Padma River are stopped after construction of the Bridge. At present, about 70% - 85% of river crossing traffic is using the Patruria – Goalundo ferries and this most dominant ferry service remains even after the bridge is constructed. This ferry route (Patruria – Goalundo) will be used as an alternative transport mean for travelers of goods transporters who do not want to use the new bridge.

3.2 SCREENING OF BRIDGE LOCATION ALTERNATIVES

The main objectives of this section are to conduct a river characteristic study, transport study, a preliminary bridge and highway engineering study, and to make preliminary environmental and social assessments to select two preferable site options from the four alternative locations originally chosen in the preceding Section 3.1.

3.2.1 Traffic Demand Projection

(1) Approach and Methodology

Based on the future socio-economic framework, the existing transport profile and the traffic survey analysis, future traffic demand of the Padma Bridge was forecast. The target year is set at the year 2025. The year 2015 is also considered as the intermediate target year.

(a) Traffic Type

In order to forecast future demand, traffic types are classified as normal traffic, diverted traffic, induced traffic and development traffic. Normal traffic is the traffic which currently uses the existing Paturia – Goalundo and Mawa – Charjanajat ferry services to cross the Padma River, and would be expected to grow regardless of whether the Padma Bridge is constructed or not. Diverted traffic is the traffic which currently travels by other modes or via other routes, and would be diverted to use the Padma Bridge. It is expected that some passengers and freight traffic would be diverted from inland water transportation, depending on travel or transport time, cost and commodity type. And some road traffic may be diverted to the Padma Bridge from the Jamuna Bridge, depending on the bridge location, which is determined by the traffic assignment procedure. Induced traffic is defined as the traffic which will be newly generated due to shorter travel time and greater convenience resulting from the construction of the Padma Bridge and on-going and future projects nearby the Padma River such as the Southwest Road Network Development Project and so on. Induced traffic is expected to be generated local and long-distance passenger and freight traffic. Developed traffic will be generated by an increase of activities of regional development or people movements due to effect of the infrastructure investment. In this Study, developed traffic has been defined to be included in induced traffic which is estimated by a change of accessibility.

(b) Vehicle Types

In this Study, the vehicle types are categorized as follows:

- Light Vehicles
- Buses
- Trucks

The light vehicles and the buses are considered as passenger transport vehicles, and the trucks are commodity transport vehicles. The light vehicles consist of cars, utility vehicles, and microbuses. Buses consist of mini buses and large buses. Trucks are small trucks, medium trucks and articulated trucks. Each vehicle type is categorized by RHD. Auto rickshaws and non-motorized vehicles are not included in vehicle types in this Study, because they are only used to access and egress to launch ghats, and their percentage is very low of all vehicles across the Padma River.

(c) Zoning

For the purposes of traffic demand forecasts, the study area has been divided into 75 traffic zones in Bangladesh and neighboring countries. Each district in Bangladesh is considered as one zone. The traffic zones are shown in Figure 3.2.1 and Table 3.2.1.

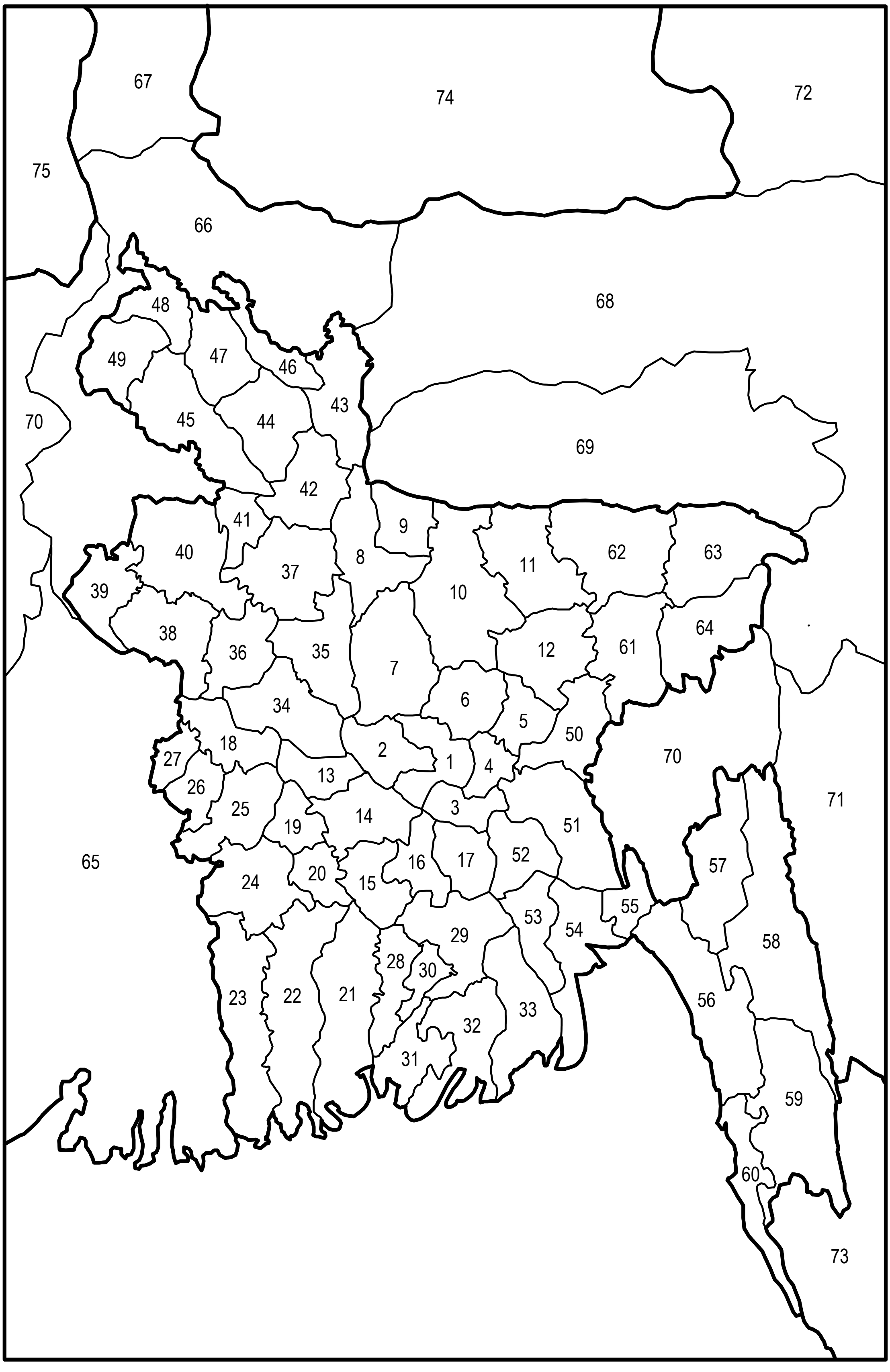


Figure 3.2.1 Zoning Map

Table 3.2.1 (1) Traffic Zones

Zone	Country	Division	Zila (District)	Region
1	Bangladesh	Dhaka	Dhaka	North East Region
2	Bangladesh	Dhaka	Manikganj	
3	Bangladesh	Dhaka	Munshiganj	
4	Bangladesh	Dhaka	Narayanganj	
5	Bangladesh	Dhaka	Narsingdi	
6	Bangladesh	Dhaka	Gazipur	
7	Bangladesh	Dhaka	Tangail	
8	Bangladesh	Dhaka	Jamalpur	
9	Bangladesh	Dhaka	Sherpur	
10	Bangladesh	Dhaka	Mymensingh	
11	Bangladesh	Dhaka	Netrokona	
12	Bangladesh	Dhaka	Kishoreganj	
13	Bangladesh	Dhaka	Rajbari	South West Region
14	Bangladesh	Dhaka	Faridpur	
15	Bangladesh	Dhaka	Gopalganj	
16	Bangladesh	Dhaka	Madaripur	
17	Bangladesh	Dhaka	Shariatpur	
18	Bangladesh	Khulna	Kushtia	
19	Bangladesh	Khulna	Magura	
20	Bangladesh	Khulna	Narail	
21	Bangladesh	Khulna	Bagerhat	
22	Bangladesh	Khulna	Khulna	
23	Bangladesh	Khulna	Satkhira	
24	Bangladesh	Khulna	Jessore	
25	Bangladesh	Khulna	Jhenaidah	
26	Bangladesh	Khulna	Chuadanga	
27	Bangladesh	Khulna	Meherpur	
28	Bangladesh	Barisal	Pirojpur	
29	Bangladesh	Barisal	Barisal	
30	Bangladesh	Barisal	Jhalakhati	
31	Bangladesh	Barisal	Barguna	
32	Bangladesh	Barisal	Patuakhali	
33	Bangladesh	Barisal	Bhola	
34	Bangladesh	Rajshahi	Pabna	North West Region
35	Bangladesh	Rajshahi	Sirajganj	
36	Bangladesh	Rajshahi	Natore	
37	Bangladesh	Rajshahi	Bogra	
38	Bangladesh	Rajshahi	Rajshahi	
39	Bangladesh	Rajshahi	Nawabganj	
40	Bangladesh	Rajshahi	Naogaon	
41	Bangladesh	Rajshahi	Joypurhat	
42	Bangladesh	Rajshahi	Gaibandha	
43	Bangladesh	Rajshahi	Kurigram	
44	Bangladesh	Rajshahi	Rangpur	
45	Bangladesh	Rajshahi	Dinajpur	
46	Bangladesh	Rajshahi	Lalmanirhat	
47	Bangladesh	Rajshahi	Nilphamari	
48	Bangladesh	Rajshahi	Panchagarh	
49	Bangladesh	Rajshahi	Thakurgaon	

Table 3.2.1 (2) Traffic Zones

Zone	Country	Division	Zila (District)	Region
50	Bangladesh	Chittagong	Brahmanbaria	East Region
51	Bangladesh	Chittagong	Comilla	
52	Bangladesh	Chittagong	Chandpur	
53	Bangladesh	Chittagong	Laksmipur	
54	Bangladesh	Chittagong	Noakhali	
55	Bangladesh	Chittagong	Feni	
56	Bangladesh	Chittagong	Chittagong	
57	Bangladesh	Chittagong	Khagrachhari	
58	Bangladesh	Chittagong	Rangamati	
59	Bangladesh	Chittagong	Bandarban	
60	Bangladesh	Chittagong	Cox's Bazar	
61	Bangladesh	Sylhet	Habiganj	
62	Bangladesh	Sylhet	Sunamganj	
63	Bangladesh	Sylhet	Sylhet	
64	Bangladesh	Sylhet	Maulavi Bazar	
65	India	West Bengal (South Area)		Outside Bangladesh
66	India	West Bengal (North Area)		
67	India	Sikkim		
68	India	Assam		
69	India	Meghalaya		
70	India	Tripura		
71	India	Mizoram		
72	India	Other Divisions		
73	Myanmar			
74	Bhutan			
75	Nepal			

(d) Procedure of Traffic Demand Forecast

Future traffic volume crossing the Padma Bridge was forecast by dividing all the traffic into normal traffic, diverted traffic, and induced traffic. The procedure for the traffic demand forecast is illustrated in Figure 3.2.2 and summarized below:

- Normal traffic in 2003 was prepared in the form of origin-destination (OD) matrices by vehicle type, using results of traffic surveys and existing data,
- Normal traffic demand was forecast through conventional methods, namely, trip production, trip generation/attraction, and trip distribution based on the past trend of traffic volumes across the Padma River and the Jamuna River, GDP and the future GRDP growth rates by each zone and by vehicle type,
- Diverted traffic from inland water transportation is forecast by applying modal split models for passenger traffic and freight traffic, respectively,
- Induced traffic is forecast by applying a gravity model which can reflect the change of accessibility between the cases with and without on-going and future projects and the Padma Bridge in the future. Induced traffic is estimated without the steps of estimation of trip production, trip generation/attraction applying forecast future OD matrices of normal traffic,
- Future OD matrices by vehicle type were prepared by summing normal traffic, induced traffic, and diverted traffic, and
- Future traffic volumes across the Padma Bridge are forecast by assigning the OD matrices by vehicle type to the future network reflecting future road and bridge construction and improvement plans. The future traffic volumes are estimated by each bridge crossing site (Paturia-Goalundo (Site-1), Dohar-Charbhadrasan (Site-2), Mawa-Janjira (Site-3), and Chandpur-Bhedarganj (Site-4)).

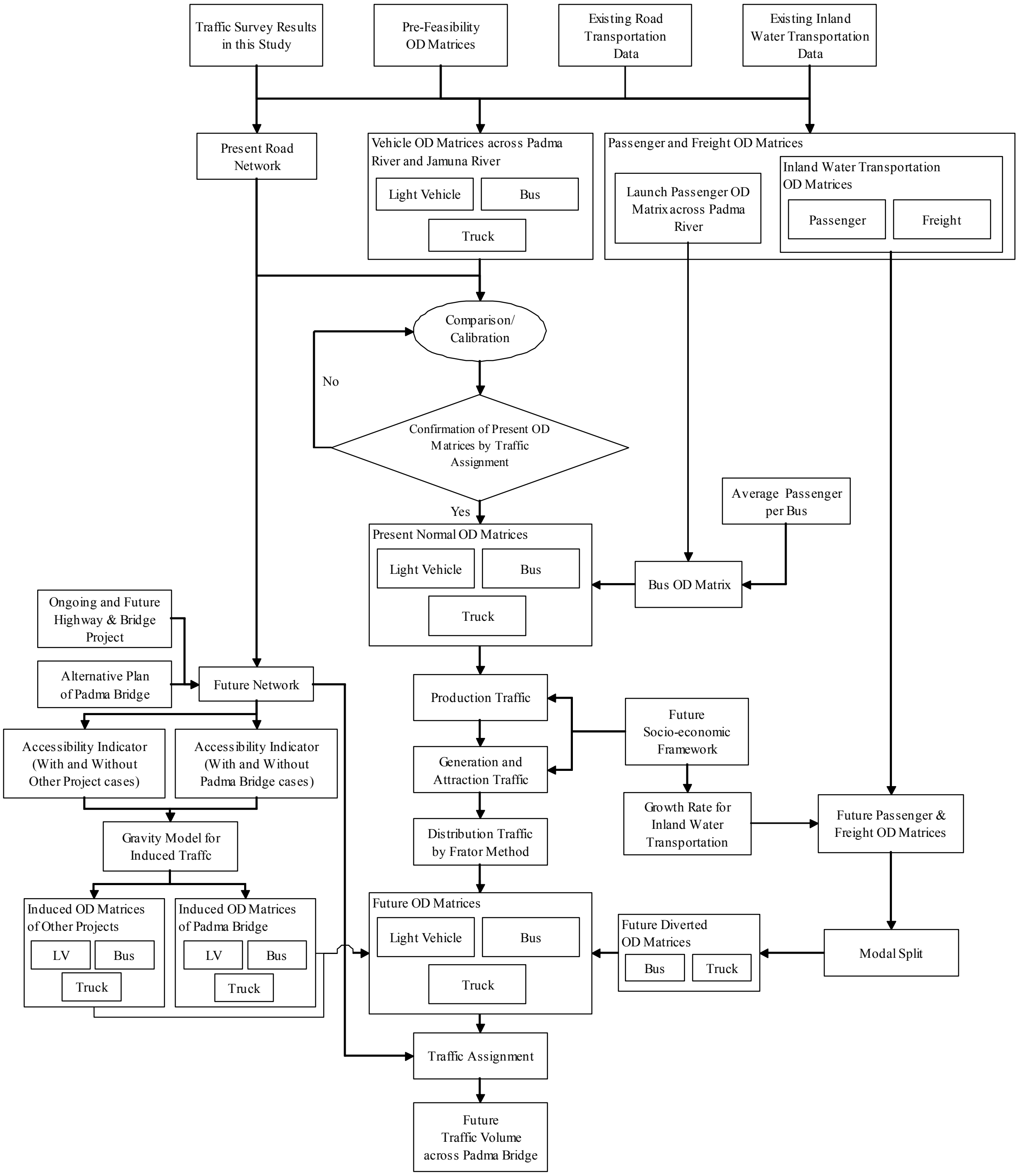


Figure 3.2.2 Procedure for the Traffic Demand Forecast

(2) Estimation of AADT, OD Matrix and Road Network Model in 2003

(a) Annual Average Daily Traffic in 2003

Annual average daily traffic (AADT) crossing the Padma River and Jamuna River has been estimated based on the results of the traffic survey and weekly and monthly traffic records by BIWTC and JOMAC. Weekly and monthly conversion factors to calculate AADT are estimated at each station and survey location, generally. However, traffic volume across the Padma River and Jamuna River fluctuates depending on the locations of ferry terminals due to diversion of traffic from Paturia-Protappur ferry to Jamuna Bridge and detoured traffic from Mawa-Charjanajat ferry to Paturia-Goalundo ferry because of on-going improvement works of National Highway N8 route between Dhaka and Mawa. Therefore, the conversion factors to grasp neutral fluctuations are estimated by each river, as shown in Table 3.2.2 and Table 3.2.3.

Table 3.2.2 Weekly Factors by Vehicle Type

Month	Padma River Crossing			Jamuna River Crossing		
	Light Vehicles	Buses	Trucks	Light Vehicles	Buses	Trucks
Mon	0.93	0.95	0.85	1.13	1.00	0.91
Tue	1.07	1.01	0.97	1.05	1.03	0.98
Wed	1.11	1.04	0.88	1.09	1.01	0.92
Thu	0.88	1.00	0.98	0.92	0.94	1.00
Fri	0.97	0.98	1.01	0.83	0.99	1.05
Sat	0.99	1.02	1.46	1.01	1.01	1.23
Sun	1.11	1.01	1.04	1.04	1.03	0.98

Source: JICA Study Team
Note: Above factor was estimated based on BIWTC and JOMAC data.

Table 3.2.3 Monthly Factors by Vehicle Type

Month	Padma River Crossing			Jamuna River Crossing		
	Light Vehicles	Buses	Trucks	Light Vehicles	Buses	Trucks
Jan	0.93	1.02	0.92	0.95	1.04	0.92
Feb	0.67	0.91	1.11	0.81	0.89	1.17
Mar	1.06	1.03	0.99	0.99	0.98	0.98
Apr	1.03	1.02	0.94	1.07	1.03	0.94
May	1.00	0.96	0.92	0.95	0.98	0.93
Jun	1.10	0.89	1.00	0.95	0.98	0.94
Jul	1.09	1.10	1.05	1.04	1.10	1.08
Aug	1.14	1.08	1.02	1.07	1.05	1.11
Sep	1.17	1.05	1.10	1.18	1.08	1.06
Oct	1.16	0.99	1.06	1.06	1.03	0.90
Nov	1.15	1.07	0.90	1.28	1.15	0.97
Dec	0.79	0.91	1.02	0.83	0.80	1.07

Source: JICA Study Team
Note: Above factor was estimated based on BIWTC and JOMAC data.

The AADT volumes of across the Padma River and the Jamuna River have been estimated applying the above factors and estimated AADT is shown in Table 3.2.4. The location of each site is illustrated in Figure 3.2.3.

Table 3.2.4 AADT Across Padma River and Jamuna River

	Padma River Crossing			Jamuna River Crossing		
	Paturia-Daulatdia	Mawa-Charjanajat	Total	Jamuna Bridge	Paturia-Protappur	Total
Light Vehicles	635	152	787	652	22	674
Buses	770	251	1,021	1,560	0	1,560
Trucks	1,204	81	1,285	2,275	307	2,582
Total	2,609	484	3,093	4,487	329	4,816

Source: JICA Study Team

Note: BIWTC ferry service crossing the Jamuna River was changed to Paturia-Protappur from Aricha-Nagaribari, recently. Protappur is nearby Nagarbari in Northwest region.

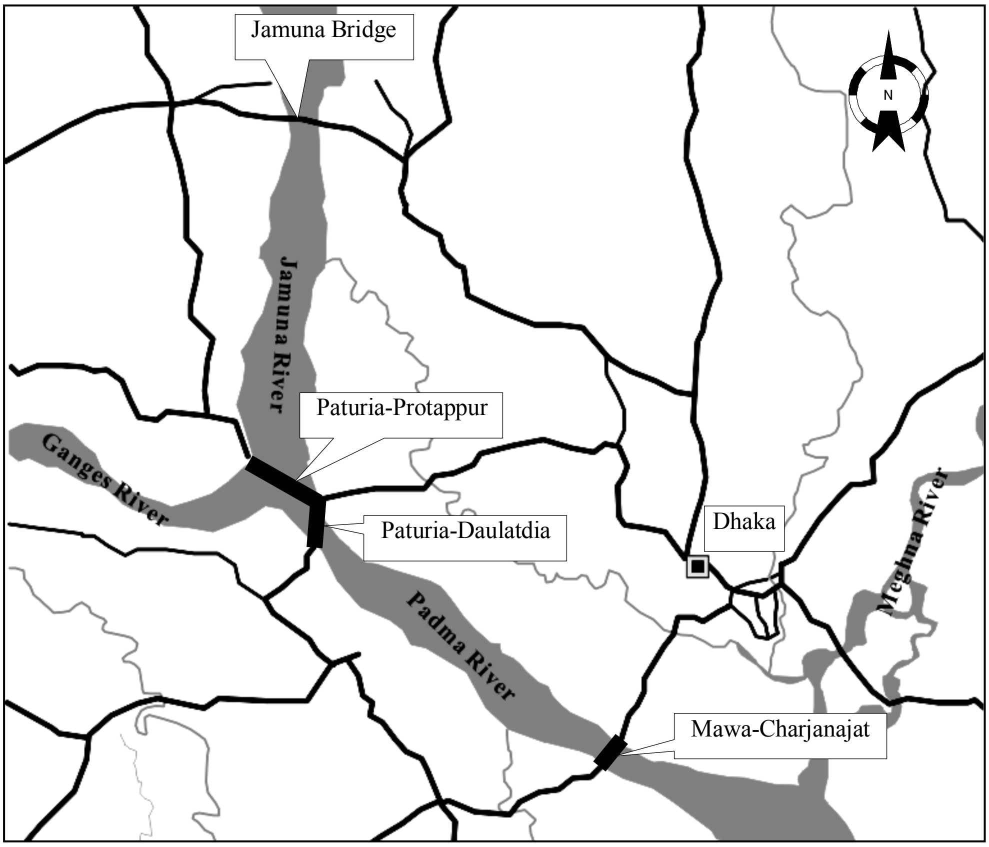


Figure 3.2.3 Locations of AADT Across Padma River and Jamuna River

(b) Present OD Matrices and Network Model

i) Present OD Matrices

Present OD (Origin/Destination) matrices by vehicle type are established applying the results of traffic surveys and AADT described above. Origin and destination patterns of present OD matrices are derived from the results of OD interview surveys at Paturia-Goalundo, Mawa-Charjanajat and Jamuna Bridge. For the Paturia-Protappur OD matrices, those are derived and supplemented by the results of Pre-Feasibility Study (2000). Present OD matrices are expanded by adjusting AADT to total volumes of OD matrices by vehicle type. Present OD matrices for Padma River and Jamuna River are illustrated by the form of desired lines in Figure 3.2.4. It is clear that traffic movements are divided into Dhaka-Southwest at the Padma River and Dhaka-Northwest at Jamuna River. Some traffic movements between Bangladesh and India are observed in the traffic crossing the Padma River.

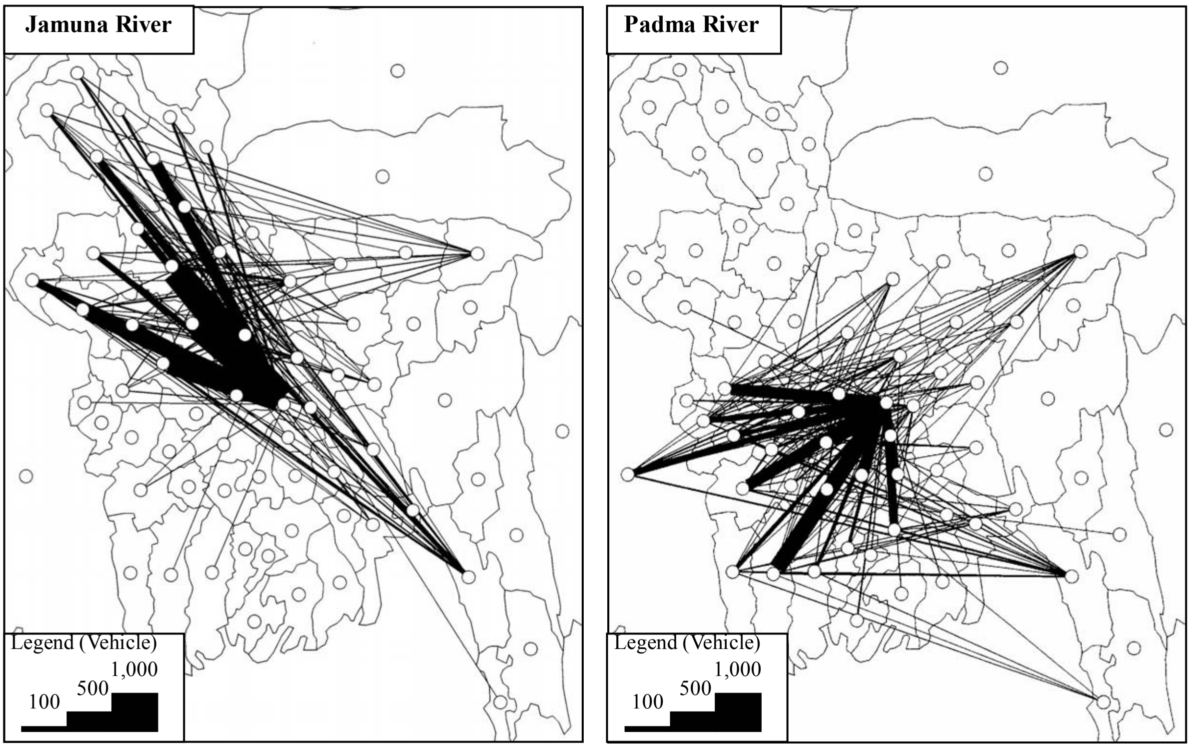


Figure 3.2.4 Present OD at Padma River and Jamuna River

ii) Present Network Model

The present network model was established on the basis of "RHD Road Network Database Annual Report 2002, March 2003" and the Pre-feasibility Study. The network model consists of national, regional, and feeder roads as shown in Figure 3.2.5. The feeder roads are taken into account only for surrounding areas of the Padma River. The link information includes of distance between nodes, travel speed and fares, as explained below:

- Bridge tolls and ferry fares on national and regional highways in Dhaka and the Southwest Region are attached as link information to the present network model,
- RHD ferry crossing times are set at 30 minutes including waiting time,
- Waiting times and fares for BIWTC ferries across Paturia-Goalundo and Mawa-Charjanajat are set as the impedance by vehicle type which were obtained from the traffic surveys
- Link speed is set at 60 km/h on national highways and 50 km/h on regional highways, based on the free flow speed according to RHD and the Pre-Feasibility Study, and assumed as 30 km/h on feeder roads,
- Link distance was taken from RHD Road Network Database and the Pre-Feasibility Study data, and
- Time penalty of 30 minutes was imposed on links through Dhaka City.

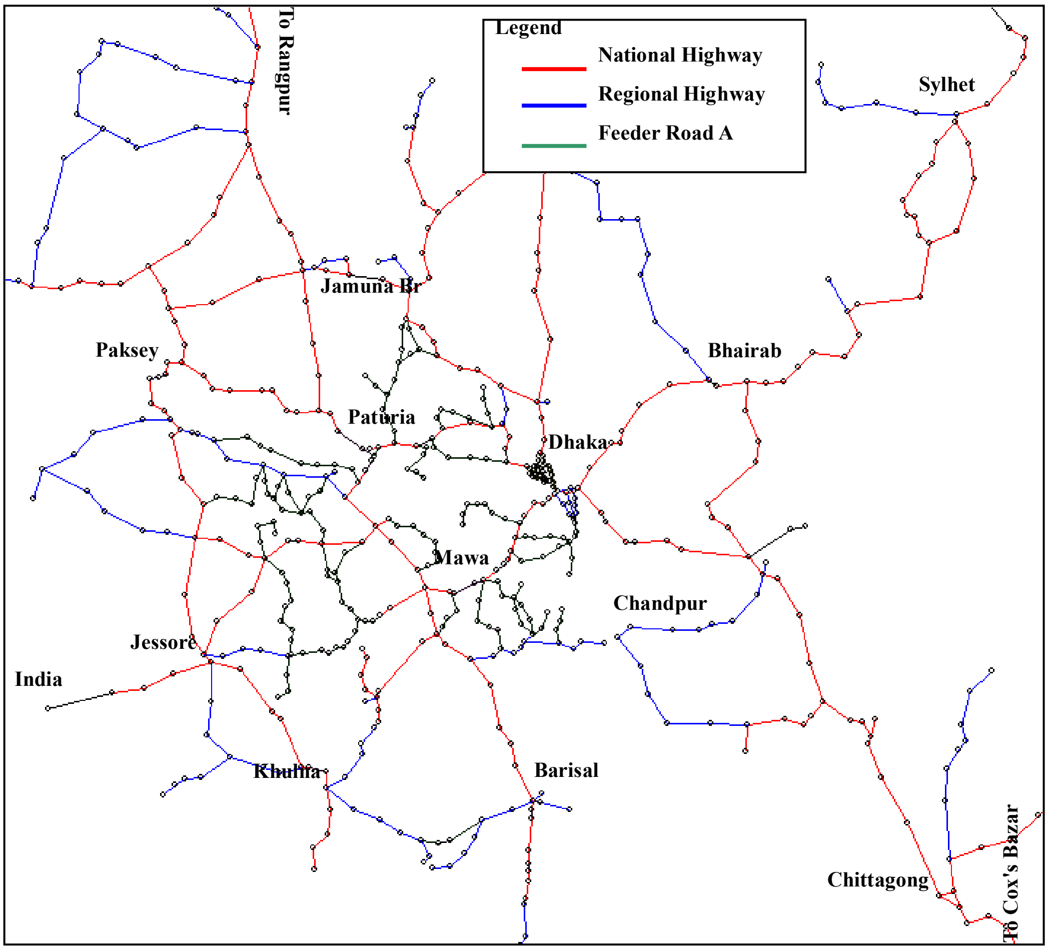


Figure 3.2.5 Present Network Model

(c) Validation of Present OD Matrix and Present Network Model

For the future traffic demand forecast, present OD matrices and network model are basic input. It is important to confirm the consistency between the model results and observed AADT volumes. The present OD matrices and network model are calibrated with iterations of traffic assignment until the simulated traffic volumes approximately match with the AADT volumes across the Padma River and the Jamuna River which were defined as a screen line in this Study. Chandpur-Bhedarganj crossing was not considered as the screen line, because of low traffic volumes of about 50 vehicles per day according to the traffic records by BIWTC. The assigned traffic on the network model is limited only to the traffic which is crossing the Padma River and the Jamuna River. Table 3.2.5 shows a comparison of actual AADT and simulated traffic volumes. As a result, present OD matrices and the network model are confirmed to reproduce the actual AADT, though there are some differences by vehicle type at Mawa-Charjanajat. It is confirmed that the present OD matrices and network model can be applied to forecast future traffic demand.

After the above process, launch passengers were converted into the bus OD matrix. The Launch passengers were estimated as 27,158 annual average daily passengers considering seasonal factors. These were converted into 667 buses, using the RHD average of 40.7 passengers per bus. At present, the launch passengers use various modes such as buses, non-motor vehicles, motorcycles and auto rickshaws for access and egress to/from the Paturia-Goalundo and Mawa-Charjanajat launch ghats, according to the results of the traffic survey. However, they would be diverted from present modes to buses after opening of the Padma Bridge.

Table 3.2.5 Results of Validation Across Padma River and Jamuna River

Screen Line		Traffic Volumes (vehicle/day)			
		Light Vehicles	Buses	Trucks	Total
Paturia-Daulatdia	AADT	635	770	1,204	2,609
	Simulated Traffic	684	784	1,146	2,614
	Ratio	1.08	1.02	0.95	1.00
Mawa-Charjanajat	AADT	152	251	81	484
	Simulated Traffic	109	255	144	508
	Ratio	0.72	1.02	1.78	1.05
Total of Padma River Crossing	AADT	787	1,021	1,285	3,093
	Simulated Traffic	793	1,039	1,290	3,122
	Ratio	1.01	1.02	1.00	1.01
Total of Jamuna River Crossing	AADT	674	1,560	2,582	4,816
	Simulated Traffic	668	1,542	2,577	4,787
	Ratio	0.99	0.99	1.00	0.99

Source JICA Study Team
Note: Above ratio is Simulated Traffic / AADT.

(3) Forecast of Normal Traffic

(a) Produced Traffic

In order to forecast produced traffic which is used as the control total of OD matrices by vehicle type for normal traffic, regression models were developed to explain the relationship between GDP and annual number of vehicles crossing the Padma River and Jamuna River applying the past five years data. The regression models were shown as below:

$Pi = \alpha * GDP + \beta$

Where: Pi : Annual number of vehicles across river (Thousand Vehicles)
GDP : GDP at constant prices (Billion Taka)
α and β : Coefficients

		α	β	Correlation Coefficient
Padma River	Light Vehicles	0.287	-364.438	0.983
	Buses	0.389	-609.952	0.997
	Trucks	0.285	-228.609	0.999
Jamuna River	Light Vehicles	0.036	135.777	0.694
	Buses	0.502	-641.763	0.993
	Trucks	0.464	-294.510	0.958

Note: In terms of light vehicles across Jamuna River, the regression model was developed from Jamuna Bridge records in the past four years only, due to unstable trend in opening year of Jamuna bridge.

The future produced traffic was forecast by adopting growth rates of the future annual number of vehicles obtained from the above regression models and future GDP established in future socio-economic framework. Table.3.2.6 shows the future traffic growth rates by vehicle type.

Table 3.2.6 Future Traffic Growth across Padma River and Jamuna River

		2003-2015	2015-2025
Padma River	Light Vehicles	9.89%	7.12%
	Buses	11.63%	7.68%
	Trucks	7.42%	6.39%
Jamuna River	Light Vehicles	1.79%	3.21%
	Buses	9.65%	7.13%
	Trucks	6.97%	6.16%
GDP		5.42%	5.44%

Source: JICA Study Team

(b) Forecast of Generated and Attracted Traffic by Traffic Zone

For the purpose of obtaining future generated and attracted traffic at each zone, the following method was applied:

- Firstly, the tentative future volume of each zone's generated and attracted traffic in 2015 and 2025 were calculated, applying GRDP growth rates to the present volumes of generated and attracted traffic, and
- Secondly, the tentative generated and attracted traffic volumes by each zone calculated above were adjusted proportionally so as to be equal to the pre-determined produced traffic because the sum of the generated and attracted traffic should be equal to the number of control total as produced traffic.

Future GRDP growth rates by each traffic zone were calculated from the estimated future economic framework. In addition, 5.64% of average GDP growth rate of India estimated by ADB for 1994-2000, was applied to zones in India. Growth rates for zones in Myanmar, Bhutan and Nepal were not applied because those traffic volumes were not caught in the traffic survey (OD interview survey) and, therefore, not included in the present OD matrices.

(c) Distributed Traffic

Future distributed traffic was obtained based on the present OD pattern and future generated and attracted traffic determined above, using the "present pattern method" through the convergence calculation of the Frator method. After that process, OD matrices of normal traffic for the Padma River and the Jamuna River in 2015 and 2025 were added. Future O-D movement patterns of normal traffic crossing the Padma and Jamuna Rivers are illustrated by the form of desired lines in Figure 3.2.6.

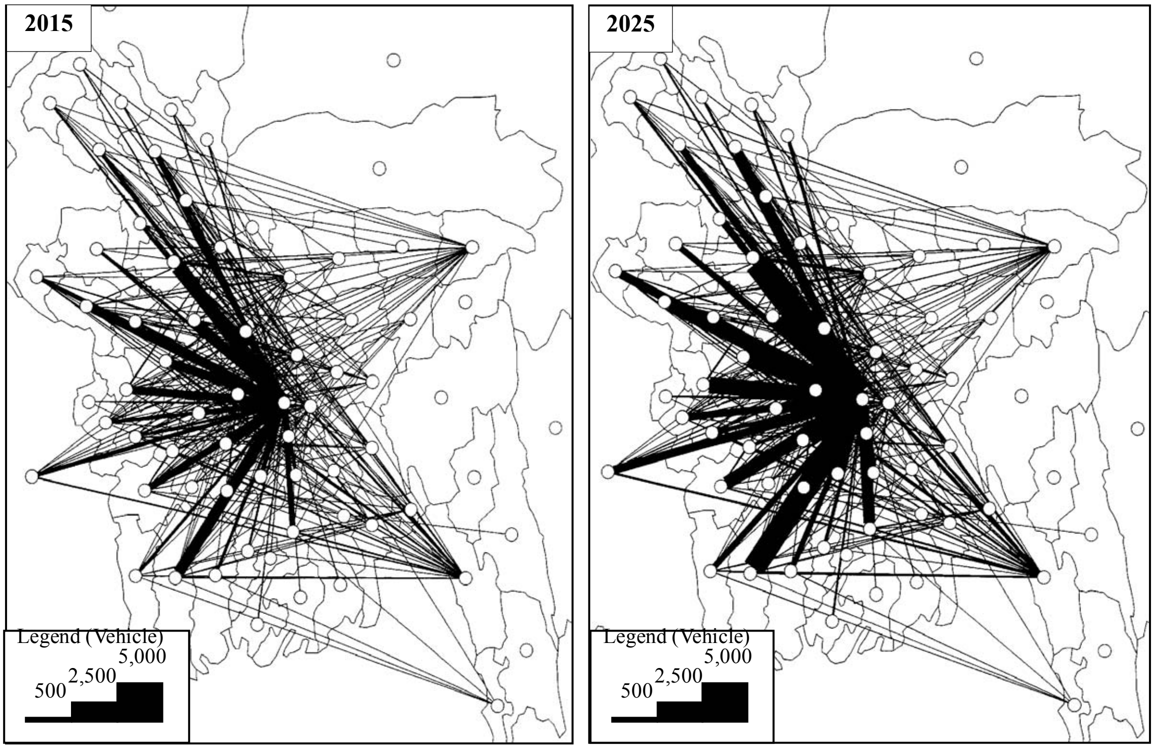


Figure 3.2.6 Desired Line of Normal Traffic in 2015 and 2025

(4) Forecast of Induced Traffic

(a) Definition of Induced Traffic

Induced traffic arises when a trip becomes more attractive by virtue of a reduction in cost or time as a consequence of the construction of a bridge, roads or regional development. Induced traffic is expected to be generated from shops and houses located along the road in the short term and by commercial centers and EPZ (Export Processing Zones) located in the surrounding area due to a change of land use induced by the regional development plan in the long term. In the areas surrounding the Padma River, there are development projects not only the Padma Bridge project but also other on-going and planned projects. Therefore, induced traffic was estimated by the following types:

- Induced Traffic from projects other than Padma Bridge
- Induced Traffic from Padma Bridge

To consider local traffic around the Padma River, traffic will be affected by the developments such as new markets or improvement of feeder roads planned by LGED. The future developments are classified into “future developments without the Padma Bridge” and “future developments which will be realized by opening of the Padma Bridge”. Regarding the “future developments without the Padma Bridge”, the future demand of local traffic is expected to grow regardless whether or not the Padma Bridge is constructed. Therefore, this type of traffic is included in normal traffic and the future GRDP growth rates were applied for forecasting the future generated and attracted traffic because the future GRDP growth is estimated based on past GRDP growth rates which have been achieved with past developments. The future demand of local traffic from “future developments which would be realized by opening of the Padma Bridge” is included in induced traffic which is determined by a reduction ratio of travel time as explained below.

(b) Estimation of Induced Traffic

Induced traffic was estimated by a factor of change in the accessibility indicator between “with” and “without” project cases. In this Study, the accessibility indicator was defined as travel time for each zone pair and it was obtained by assigning normal traffic to the network model. The bridge tolls and ferry fares were substituted by time and included into the travel time. The following gravity model was applied using the data of population and GRDP by each zone as explanatory variables, and adopted for the estimation of induced traffic:

<u>*Gravity Model for Light Vehicles and Buses*</u>

$$T_{ij} = \alpha \frac{P_i^{\beta} \times P_j^{\gamma}}{D_{ij}^{\delta}}$$

Where: Tij : Theoretical traffic volume between Zone i and j

Pi : Population of Zone i

Pj : Population of Zone j

Dij : Travel Time between Zone i and j

$\alpha, \beta, \gamma, \delta$: Coefficients

		α	β	γ	δ	Multiple Correlation Coefficient
Light Vehicles	Coefficient	0.0144	0.7639	0.6690	0.9284	0.64
	t-value	2.71	5.30	4.63	3.94	
Buses	Coefficient	0.0013	1.6324	1.5270	1.2809	0.76
	t-value	8.31	12.67	11.90	5.48	

Note: The coefficients were estimated from present OD matrices and present network model.

Gravity Model for Trucks

$$T_{ij} = \alpha \frac{G_i^{\beta} \times G_j^{\gamma}}{D_{ij}^{\delta}}$$

Where: *Tij* : Theoretical traffic volume between Zone *i* and *j*
Gi : GRDP of Zone *i*
Gj : GRDP of Zone *j*
Dij : Travel Time between Zone *i* and *j*
$\alpha, \beta, \gamma, \delta$: Parameters

		α	β	γ	δ	Multiple Correlation Coefficient
Trucks	Coefficient	0.0775	0.7094	0.7707	0.9109	0.70
	t-value	6.00	12.67	13.40	8.23	

Note: The coefficients were estimated from present OD matrices and present network model.

The theoretical traffic volumes are calculated by applying each travel time of “with” and “without” project cases to the above equations by vehicle types. Induced traffic is obtained by applying the theoretical traffic volumes to the following equation:

$$T_{ij}^{Induced} = T_{ij}^{Normal} \times \left(\frac{T_{ij}^{with}}{T_{ij}^{without}} - 1 \right)$$

Where: $T_{ij}^{Induced}$: Induced traffic volume between Zone *i* and *j*
T_{ij}^{Normal} : Normal traffic volume between Zone *i* and *j*
T_{ij}^{With} : Theoretical traffic volume between Zone *i* and *j* calculated by gravity model, under “with” project case
$T_{ij}^{Without}$: Theoretical traffic volume between Zone *i* and *j* calculated by gravity model, under “without” project case

In order to estimate induced traffic from other projects and from the Padma Bridge, the travel time of each zone pair was calculated for the following cases:

Induced Traffic from Other Projects

- “with” project case : Future network model without the Padma Bridge
- “without” project case : Present network model

Induced Traffic from Padma Bridge

- “with” project case : Future network model with the Padma Bridge
- “without” project case : Future network model without the Padma Bridge

Table 3.2.7 Type of Network Model for Induced Traffic

Network Model		Present	Other Projects	Padma Bridge
Induced Traffic from Other Projects	With	O	O	×
	Without	O	×	×
Induced Traffic from Padma Bridge	With	O	O	O
	Without	O	O	×

The future network model without Padma Bridge includes all on-going and planned projects such as the "Southwest Road Network Development Project" together with the Arialkhan Bridge on National Highway N8, "Rupsa Bridge Construction Project", "Paksey Bridge Construction Project", "Third Road Rehabilitation and Maintenance Project (RRMP-III)" and "Road Improvement and Maintenance II". Induced traffic from other projects in 2015 and 2025 was estimated as common traffic volume with alternative bridge locations so that it is not affected by alternatives of the Padma Bridge location. Different traffic volumes were estimated for induced traffic from Padma Bridge in 2015 and 2025 for the alternative bridge locations due to difference in reduced travel time for each bridge location, and illustrated by desired lines in Figure 3.2.7. As shown in Figure 3.2.7, induced traffic from Padma Bridge will largely be generated between Dhaka and Faridpur at Site-2, and between Dhaka and all zones in the Southwest Region at Site-3, which shows strong interactions between districts divided by the Padma River. On the other hand, Site-1 and Site-4 would have a little induced traffic compared to the other two alternative bridge locations.

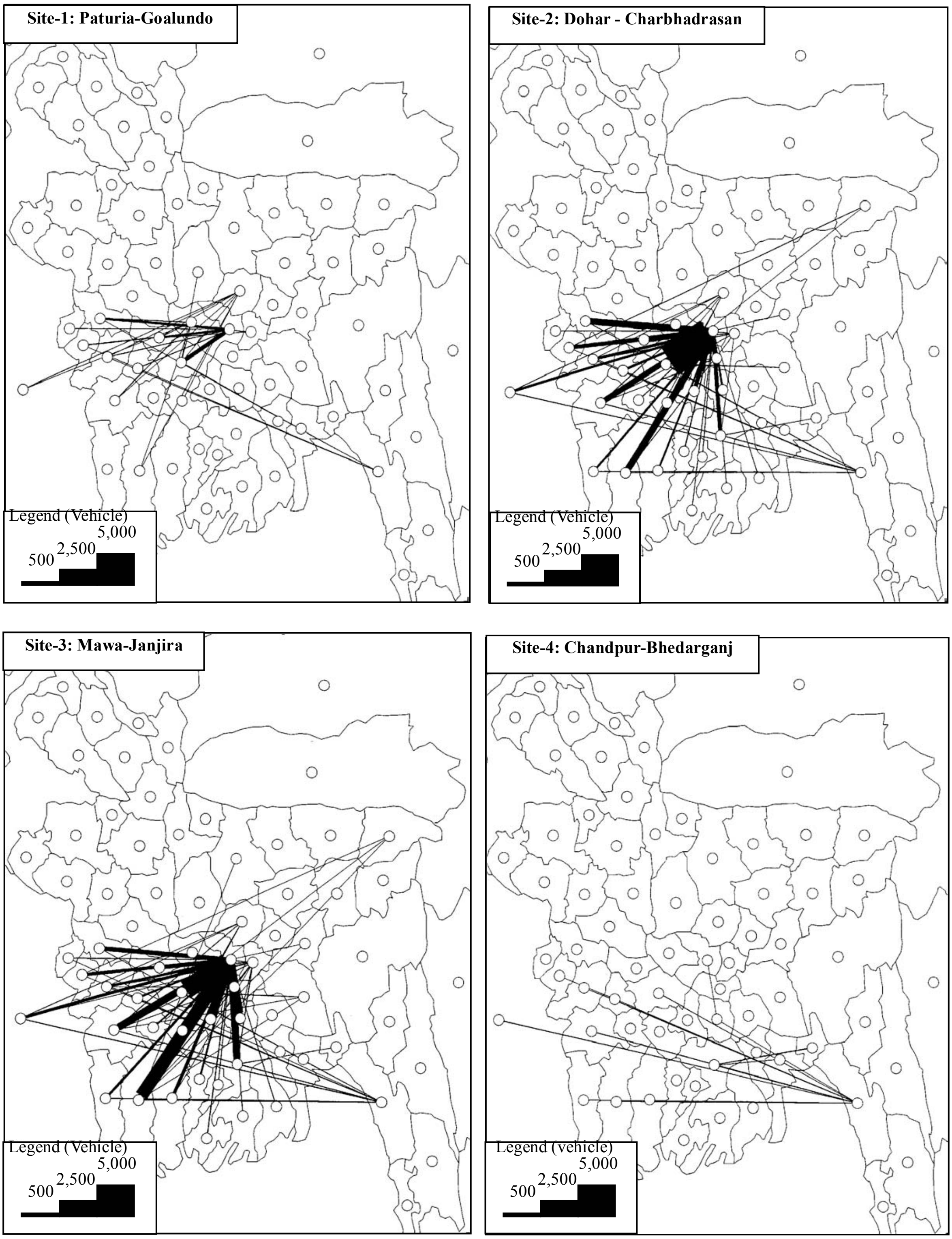


Figure 3.2.7 Induced Traffic from Padma Bridge by Alternative Bridge Location in 2025

(5) Forecast of Diverted Traffic

Traffic presently using the Inland water transportation (IWT) between Dhaka/Sylet/Chittagong divisions and the southwest region is likely to change mode from inland water to roads. In this Study, diverted traffic from the IWT for passengers and freight is estimated by applying diversion models. Diverted traffic is forecast for the passengers between Dhaka and southwest region, and freight between Dhaka/Sylet/Chittagong divisions and the southwest region.

(a) Growth Rates for IWT

The future growth rates of traffic by IWT were forecast for both passengers and freight by inland water applying future GDP to the regression models developed from the relationship between GDP and the annual number of passengers by motor-launch and steamer, and relationship between GDP and the annual tonnage of cargo by IWT using past traffic data for 1990-1999. The regression models are shown in the following equations:

Inland Water Passengers

Pi = 109.324*LN(GDP) - 746.269 ($R^2 = 0.874$)
Where: Pi : Annual number of passengers by IWT (Million passengers)
GDP : GDP at constant prices (Billion Taka)

Inland Water Freight

Pi = 5.3564*LN (GDP) - 34.183 ($R^2 = 0.867$)
Where: Pi : Annual tonnage of cargo by IWT (Million ton)
GDP : GDP at constant prices (Billion Taka)

The growth rates for passengers and freight traffic by inland water obtained by the above models are shown in Table.3.2.8. The growth rates of IWT were estimated to be lower in comparison with normal traffic. This is because passengers and freight transfer from IWT to roads year by year, due to improvement of roads in the southwest region.

Table 3.2.8 Growth Rates for IWT

	Passenger	Freight
2003-2015	4.49%	3.24%
2015-2025	2.99%	2.39%

Source: JICA Study Team

(b) Diverted Traffic from IWT

Traffic volumes of passengers and freight per day using IWT are difficult to estimate accurately, because their trips require a few days, in general. According to the results of traffic survey, it was confirmed that all freight vessels and about 70% of passenger vessels departing from the Sadargat Port usually took a few days to arrive at their destinations. In order to estimate the volume of passengers and freight using IWT per day, the data of average traffic volume obtained from BIWTA were adopted as present volumes and OD pattern and used in the traffic demand forecast.

Passengers using IWT were assumed to be diverted to buses if they divert to roads. Regarding the freight presently using IWT, their commodity types are classified into “construction material” and “other goods” which are assumed to be diverted to medium trucks if they divert to roads. The methodology for estimating the volume of diverted traffic from inland water to roads was based on modal split models. The equations applied travel cost and travel time for passengers and transport time for freight as explanatory variables. The modal split models calculate different shares by OD pair and each alternative bridge location because of different reductions in time and cost depending on the bridge sites.

The parameters of the modal split models for passengers and freight using IWT are estimated by present traffic via road and via IWT. Future passenger and freight volumes using IWT can not be directly estimated from the modal split models because different growth rates for normal traffic and for IWT traffic are assumed. Therefore, future diversion rates were assumed as the difference of the theoretical road shares between with and without bridge cases obtained from the modal split models.

Inland Water Passengers

$$P_{ij} = \frac{1}{1+e^{\alpha+\beta(t_{ij}^{Road}-t_{ij}^{IWT})+\gamma(c_{ij}^{Road}-c_{ij}^{IWT})}}$$

$$D_{ij} = P_{ij}^{With} - P_{ij}^{Without}$$

Where: P_{ij} : Theoretical road share between zone *i* and *j*
t_{ij}^{Road} : Road travel time between zone *i* and *j*
t_{ij}^{IWT} : IWT travel time between zone *i* and *j*
c_{ij}^{Road} : Road travel cost between zone *i* and *j*
c_{ij}^{IWT} : IWT travel cost between zone *i* and *j*
D_{ij} : Diversion rate from passenger using IWT zone *i* and *j*
P_{ij}^{With} : Theoretical road share between zone *i* and *j,* under "with" bridge case
$P_{ij}^{Without}$: Theoretical road share between zone *i* and *j,* under "without" bridge case

	α	β	γ	Multiple Correlation Coefficient
Coefficient	3.0581	0.6851	0.02315	0.82
t-value	2.11	2.68	2.83	

Note: The coefficients were estimated from present data.

Inland Water Freight

$$F_{ij} = \frac{1}{1+e^{-8.911+29.11\times\left(t_{ij}^{Road}/t_{ij}^{IWT}\right)}} \quad \text{(Construction Materials)}$$

$$F_{ij} = \frac{1}{1+e^{4.600+0.149\times\left(t_{ij}^{Road}-t_{ij}^{IWT}\right)}} \quad \text{(Other Goods)}$$

$$D_{ij} = F_{ij}^{With} - F_{ij}^{Without}$$

Where: F_{ij} : Theoretical road share between zone *i* and *j*
t_{ij}^{Road} : Road transport time between zone *i* and *j*
t_{ij}^{IWT} : IWT transport time between zone *i* and *j*
D_{ij} : Diversion rate from freight using IWT zone *i* and *j*
F_{ij}^{With} : Theoretical road share between zone *i* and *j*, under "with" project case
$F_{ij}^{Without}$: Theoretical road share between zone *i* and *j*, under "without" project case

		α	β	Multiple Correlation Coefficient
Construction Materials	Coefficient	-8.911	29.112	0.92
	t-value	-4.07	3.27	
Other Goods	Coefficient	4.600	0.149	0.56
	t-value	2.10	2.11	

Note: The coefficients were estimated from present data.

After estimating the diversion rates, diverted passengers and freight were converted into vehicles at the rates of 40.7 passengers per bus and 8 ton per truck. The results of the forecast of diverted traffic are illustrated with desired lines in Figure 3.2.8.

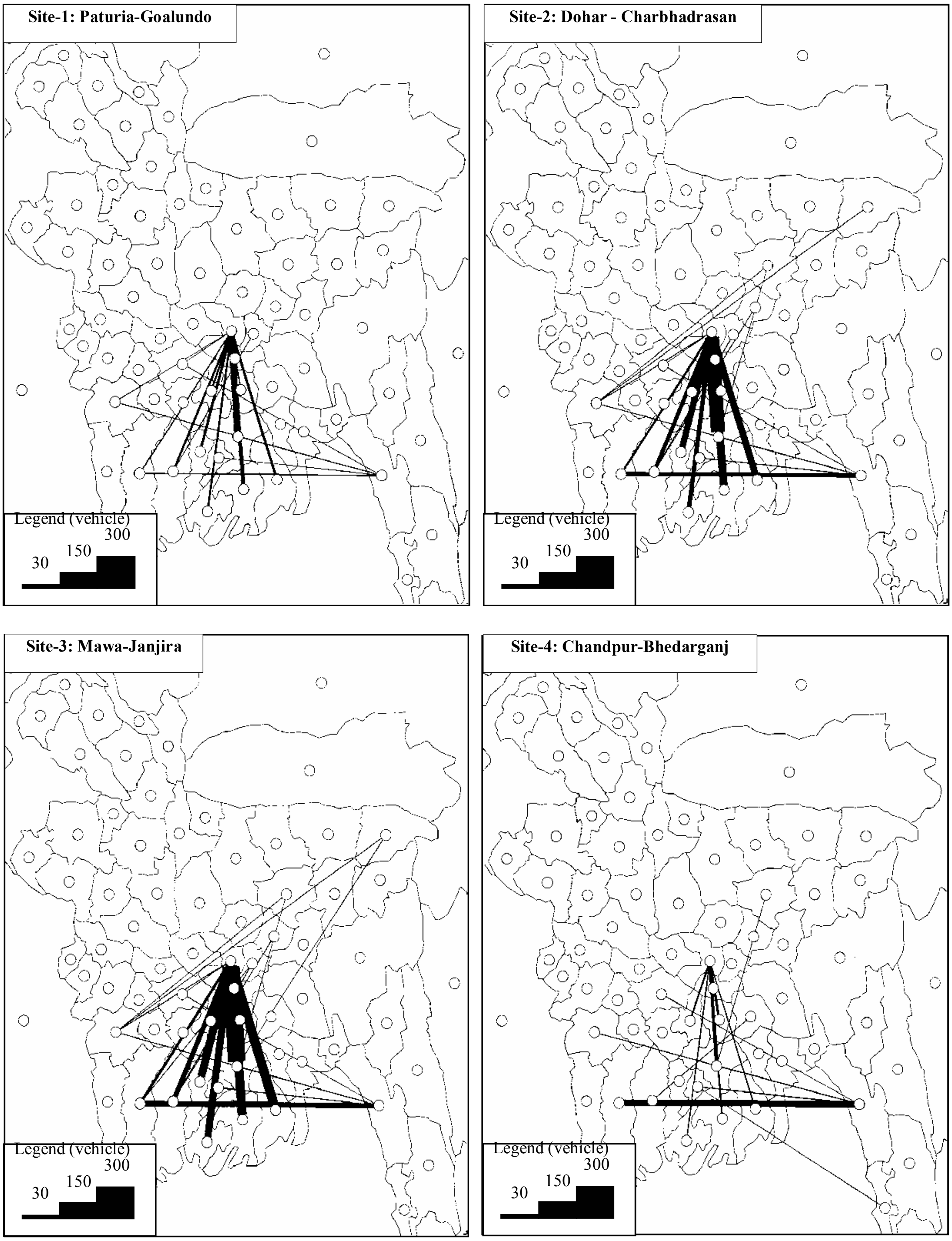


Figure 3.2.8 Diverted Traffic from IWT by Alternative Bridge Location in 2025

(6) Future Traffic Assignment

Future traffic volumes at the alternative bridge locations were determined applying the traffic assignment methodology, which requires input data consisting of the complete modeling of the future network and future OD matrices. Based on the present network model, the future network model was established considering major highway & bridge projects. The future OD matrices consist of normal traffic, induced traffic from other projects, induced traffic from the Padma Bridge and diverted traffic by vehicle type (light vehicle, bus and truck). In this Study, an "Incremental Assignment Procedure" was adopted using JICA STRADA, which is generally used for traffic assignment on the future network model. Each OD pair was divided by the number of calculation steps and the traffic of each step was assigned on the minimum path considering travel speed of all links. If a link is levied tolls, it was converted into equivalent travel time using the travel time costs (TTC) and added to the travel time of the tolled link. In this Study, travel time costs for light vehicles and buses were estimated based on the financial travel time costs established by RHD, using average occupancy rates as shown in Table 3.2.9. The travel time cost for trucks were assumed at 533 taka/hr obtained from the average tariff and fare of a truck by RHD.

Table 3.2.9 Financial Travel Time Costs for 2002-2003 (National Average)

Vehicle Category	Occupancy	TTC per passenger Taka/hr	TTC per vehicle Taka/hr
All Buses	40.7	18.3	745.3
Car/Utility	4.0	32.9	118.6

Source: RHD Road User Cost Annual Report for FY 2002/2003

(7) Traffic Forecast Results for 2015 and 2025

(a) Study Scenarios

In order to forecast future traffic volumes by alternative crossing location, four alternative bridge locations were set as follows plus the "Without bridge case":

- Case 1: Bridge at Paturia-Goalundo (Site-1)
- Case 2: Bridge at Dohar-Charbhadrasan (Site-2)
- Case 3: Bridge at Mawa-Janjira (Site-3)
- Case 4: Bridge at Chandpur-Bhedarganj (Site-4)
- Case 5: Without bridge

Present ferry services at Paturia-Goalundo and Mawa-Charjanajat across the Padma River are provided to handle the present traffic demand. If an additional ferry improvement plan is not carried out, future traffic demand will exceed ferry capacity and ferry waiting time will increase enormously, Case 5 (without bridge case).

The toll rates by vehicle type on the Padma Bridge for case 1 to case 4 are assumed at 400 taka for light vehicles, 800 taka for buses and 1,000 taka for trucks. These are the same levels as the Jamuna Bridge. The toll rates for buses and trucks are lower than the present ferry charges at Paturia-Goalundo and Mawa-Charjanajat.

(b) Traffic Forecast Results for 2015 and 2025

Future traffic volumes on the Padma Bridge in four cases in 2015 and 2025 were forecast by assigning the OD matrices by vehicle type (light vehicle, bus, truck) and by traffic type (normal traffic, two types of induced traffic and diverted traffic), separately, to the future network model. From the results of the forecasts, the following characteristics in future traffic can be stated regarding the "with" and "without bridge" cases, respectively:

i) With Bridge cases

The assignment results in 2015 and 2025 for "with bridge cases" are summarized in Table 3.2.10 and 3.2.11 and illustrated in Figure 3.2.9 and 3.2.10. Comparisons of normal traffic by each bridge location for the year 2025 are shown in Figure 3.2.11.

Case 1: Bridge at Paturia-Goalundo (Site-1)

Future traffic volumes in Case 1 will be 10,300 vehicles/day in 2015 and 19,850 vehicles/day in 2025. In this case, 30% of total traffic across the Padma River will use the Mawa-Charjanajat ferry on National Highway N8 improved by the "Southwest Road Network Development Project".

Case 2: Bridge at Dohar-Charbhadrasan (Site-2)

In Case 2, the future traffic volumes are forecast at 18,120 vehicles/day in 2015 and 34,880 vehicles/day in 2025, requiring construction of a longer approach road between National Highway N8 and a point near Faridpur.

Case 3: Bridge at Mawa-Janjira (Site-3)

The highest future traffic volumes are forecast in Case 3, with 21,260 vehicles/day in 2015 and 41,550 vehicles/day in 2025. It is indicated that most of the total traffic across the Padma River will pass through the bridge at Mawa-Janjira.

Case 4: Bridge at Chandpur-Bhedarganj (Site-4)

The future traffic volumes are 2,560 vehicles/day in 2015 and 5,040 vehicles/day in 2025. In this case, movements between Chittagong and southwest region are significant. However, this case has the lowest future traffic volume forecast among the four cases, because Paturia and Mawa ferries are still attractive for the movements between Dhaka and southwest region.

ii) Without Bridge case

As shown in Figure 3.2.12, in the "without bridge case", Paturia ferry will have higher traffic volume than Mawa ferry similar to the present situation. While present shares between Mawa and Paturia ferries are 19% and 81% according to present AADT, it will change to 40% and 60% in 2025 due to improvement of road condition on N8 as noted earlier.

(c) Influence to Jamuna Bridge

To grasp the influence of traffic on the Jamuna Bridge in case of the construction of the Padma Bridge, normal traffic volumes on the Jamuna Bridge by each case are shown in Figure 3.2.13. The Padma Bridge at Chandpur-Bhedarganj will not affect the traffic on the Jamuna Bridge, compared to the "without bridge case". While if the Padma Bridge is constructed at other locations, the traffic volumes on the Jamuna Bridge will decrease by about 8% due to the traffic diversion from the Jamuna Bridge to the Padma Bridge.

(d) Cross Border Traffic via Padma Bridge

The future cross border traffic between Bangladesh and India across the Padma River via Padma Bridge (through Benapole) was also forecast. The cross border traffic should be treated carefully because the conditions at border crossings are changeable not only by infrastructure improvement projects, but also affected by political factors. The forecast in this Study did not consider the clearance condition and waiting time at borders.

Table 3.2.10 Traffic Assignment Results by Alternative Bridge Location in 2015

Unit: vehicle/day

		Site-1	Site-2	Site-3	Site-4
Normal Traffic	Light Vehicles	1,990	2,020	2,340	80
	Buses	3,720	5,350	6,300	1,150
	Trucks	2,430	2,350	2,580	670
	Total	**8,140**	**9,720**	**11,220**	**1,900**
Induced Traffic from Other Projects	Light Vehicles	200	230	240	10
	Buses	620	1,110	1,210	230
	Trucks	340	340	360	110
	Total	**1,160**	**1,680**	**1,810**	**350**
Induced Traffic from Padma Bridge	Light Vehicles	220	1,310	1,270	30
	Buses	420	3,990	5,270	70
	Trucks	210	1,030	1,140	120
	Total	**850**	**6,330**	**7,680**	**220**
Diverted Traffic	Buses	120	300	430	30
	Trucks	30	90	120	60
	Total	**150**	**390**	**550**	**90**
Total	Light Vehicles	2,410	3,560	3,850	120
	Buses	4,880	10,750	13,210	1,480
	Trucks	3,010	3,810	4,200	960
	Total	**10,300**	**18,120**	**21,260**	**2,560**
Vehicle-km of Normal Traffic		5,400,888	5,240,067	5,081,482	5,405,938
Vehicle-hours of Normal Traffic		110,964	100,975	92,664	111,970

Source: ICA Study Team
Note: Site-1: Paturia – Goalundo Site2: Dohar – Charbhadrasan Site3: Mawa – Janjira
Site-4: Chandpur - Bhedarganj

Table 3.2.11 Traffic Assignment Results by Alternative Bridge Location in 2025

Unit: vehicle/day

		Site-1	Site-2	Site-3	Site-4
Normal Traffic	Light Vehicles	3,830	3,790	4,450	160
	Buses	7,650	10,870	12,880	2,430
	Trucks	4,350	4,220	4,690	1,320
	Total	**15,830**	**18,880**	**22,020**	**3,910**
Induced Traffic from Other Projects	Light Vehicles	360	430	460	20
	Buses	1,260	2,260	2,470	470
	Trucks	580	570	610	160
	Total	**2,200**	**3,260**	**3,540**	**650**
Induced Traffic from Padma Bridge	Light Vehicles	420	2,430	2,430	50
	Buses	850	8,010	10,820	130
	Trucks	350	1,780	2,020	200
	Total	**1,620**	**12,220**	**15,270**	**380**
Diverted Traffic	Buses	160	400	580	30
	Trucks	40	120	140	70
	Total	**200**	**520**	**720**	**100**
Total	Light Vehicles	4,610	6,650	7,340	230
	Buses	9,920	21,540	26,750	3,060
	Trucks	5,320	6,690	7,460	1,750
	Total	**19,850**	**34,880**	**41,550**	**5,040**
Vehicle-km of Normal Traffic		10,451,259	10,192,696	9,830,143	10,484,861
Vehicle-hours of Normal Traffic		220,536	203,077	184,259	223,149

Source: JICA Study Team
Note: Site-1: Paturia - Goalundo Site2: Dohar – Charbhadrasan Site3: Mawa – Janjir
Site-4: Chandpur – Bhedarganj

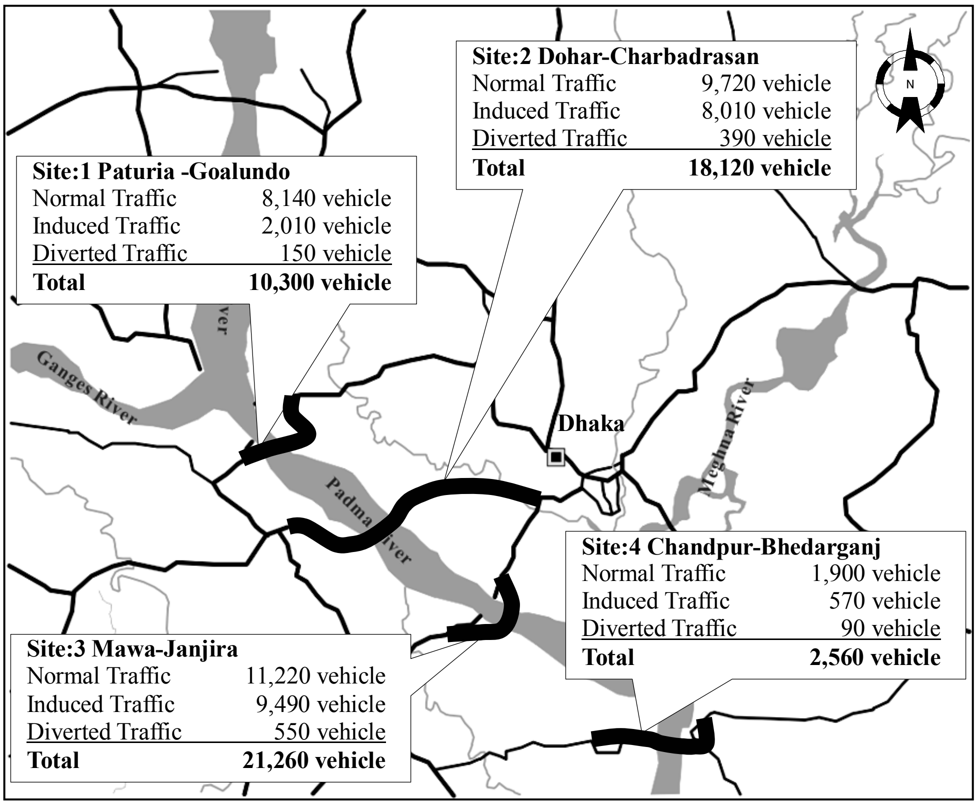


Figure 3.2.9 Traffic Volume by Alternative Bridge Location in 2015 (Vehicles/day)

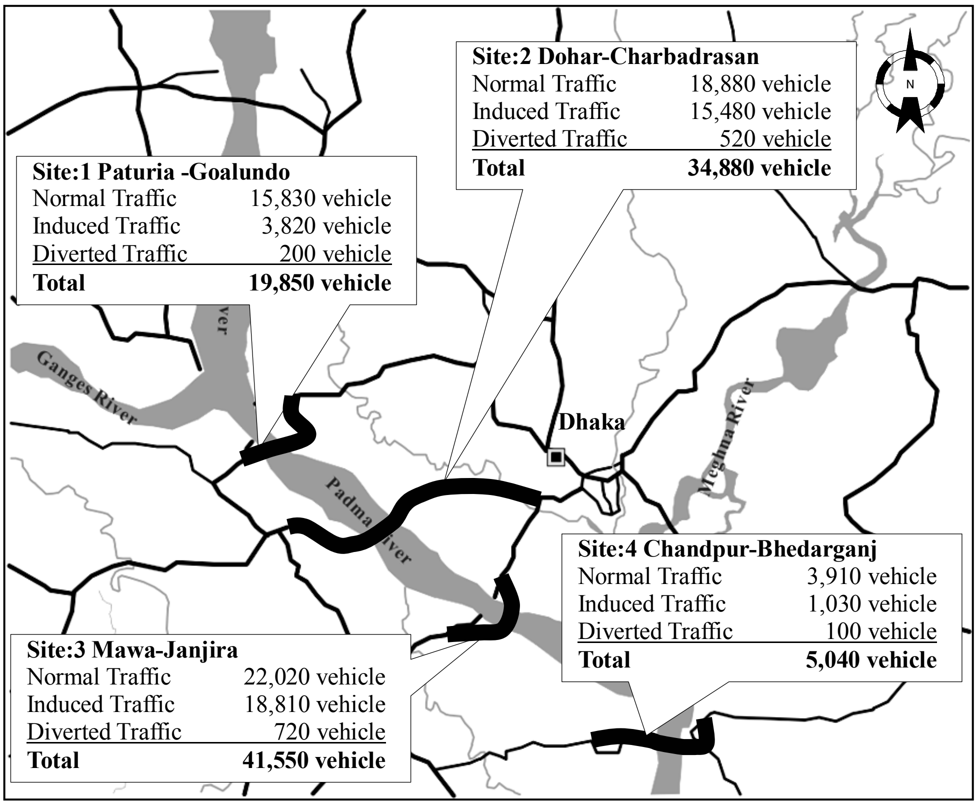


Figure 3.2.10 Traffic Volume by Alternative Bridge Location in 2025 (Vehicles/day)

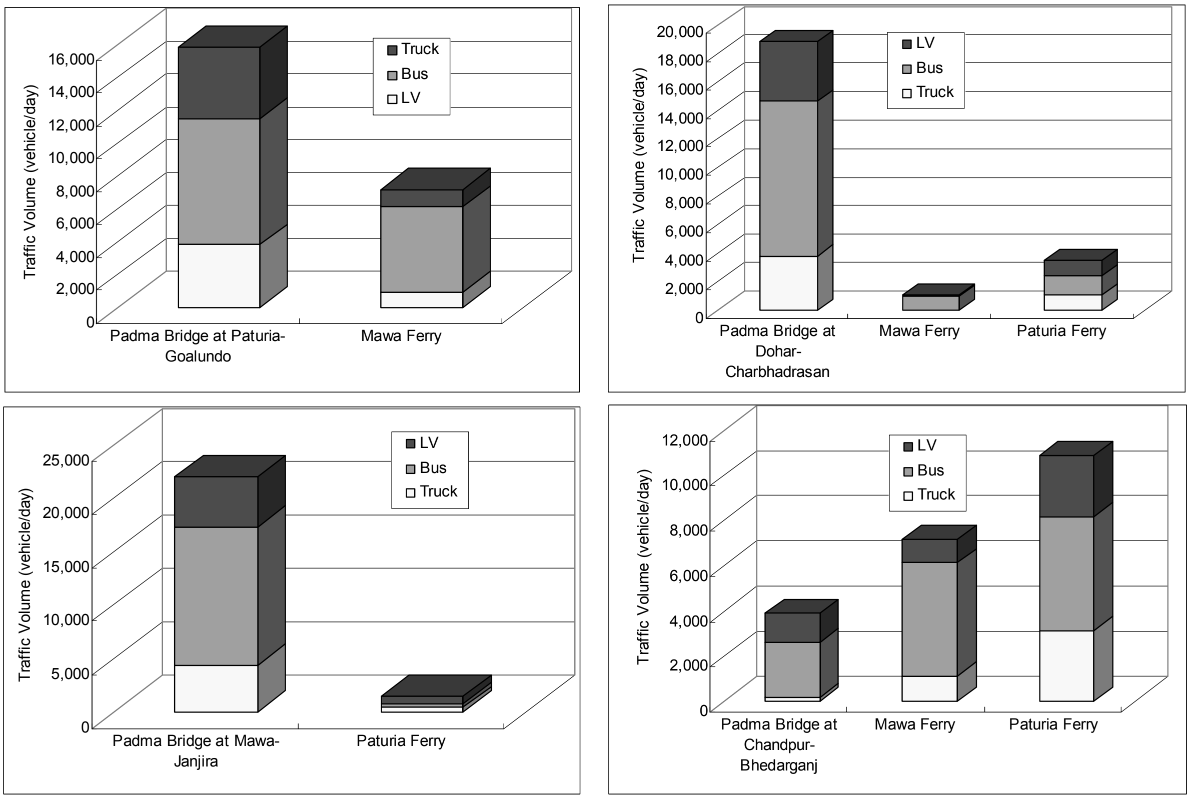


Figure 3.2.11 Normal Traffic Volume at Padma River Crossing by Alternative Bridge Location in 2025

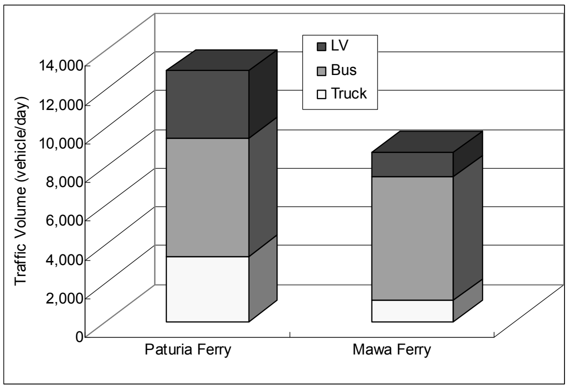


Figure 3.2.12 Normal Traffic Volume at Padma River Crossing of Without Bridge Case in 2025

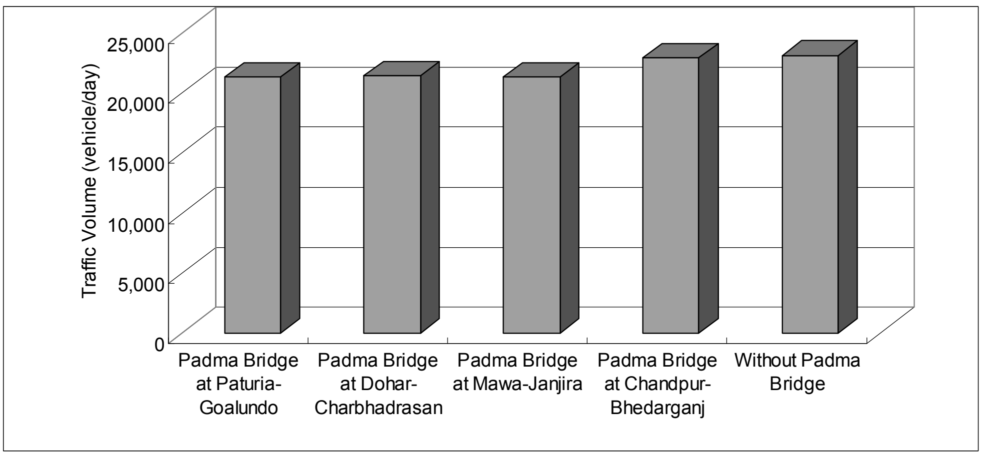


Figure 3.2.13 Normal Traffic Volume on Jamuna Bridge in 2025

3.2.2 Technical Considerations for River Engineering

In order to select two preferable locations out of four, the advantages and disadvantages of each location are discussed mainly based on the data available at the initial stage.

In this section, the following items are discussed:

1) General river conditions
2) Stability of the river
3) River works
4) Evaluation from river perspective

(1) General River Conditions

According to the latest satellite images and site reconnaissance from land and air, general conditions of the Padma River and the conceivable crossing locations were summarized below.

Padma River: The Padma River from the Ganges-Jamuna confluence (Goalundo) to the Padma-Meghna confluence (Chandpur) takes a straight course as a whole toward the southeast, having swollen plan-forms with islands in three reaches. Flood plain on the left bank seems relatively old and consolidated in comparison with that on the right bank where numerous vestiges of recent river channels are left.

Site-1 (Paturia-Goalundo Site): The crossing site is located immediately downstream of the confluence of the Ganges and the Jamuna rivers. The site forms a complete nodal section. Present river width measured on the satellite images (Jan. 2003) is about 4.8 km including attached sandbar. On the right bank distributaries from the right bank of the Ganges bypass the site. The ferry ghat (port) of Goalundo is located at one of those outlets. Attached sandbar is seen along the right riverbank.

Site-2 (Dohar-Charbhadrasan Site): The site is sandwiched between the first and second swollen river sections from the uppermost point. On both banks of the crossing section, low-lying flood plains develop. These low-lying plains could become a part of the river channel to convey flood water. The site forms a nodal section but seems incomplete. Present river width measured on the satellite image (Jan. 2003) is about 4.4 km. From the right bank downstream of the crossing location, the Arial Khan River bifurcates.

Site-3 (Mawa-Janjira Site): The crossing site forms a complete nodal section just downstream of the second swollen river section of which the right side channel seems to be diminishing. Present river width measured on the satellite image (Jan. 2003) is about 4.9 km including attached sandbar. According to the Pre-feasibility Study of Padma Bridge, a thick clayey layer exists on the left bank at this site.

Site-4 (Chandpur-Bhedarganj Site): The crossing section forms a very narrow section immediately downstream of the confluence of the Padma and the Meghna rivers. Present river width is only 2.7 km on the satellite image (Jan. 2003). But it has a wide low-lying flood plain on the right bank where some bypass channels from the Padma are found. Reflecting the narrow river section and probably the tidal influence, river flow is said dangerously fast and river depth was surveyed as deep as 65 m PWD at Chandpur (May 2002). The left river bank is now suffering from severe erosion.

(2) Stability of River

As discussed in APPENDIX-5, the stability of the river channel and river banks at the conceivable crossing locations was preliminarily evaluated based on the satellite images in the past 30 years as follows:

Site-1 (Paturia-Goalundo): Stable

- Change in river width (W_{min} to W_{max}) : 2.44 to 5.00 km
- Average river width (W_{ave}) : 4.27 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.61
- Maximum river extent during 30 years : 5.20 km

Site-2 (Dohar-Charbhadrasan): Less Stable

- Change in river width (W_{min} to W_{max}) : 3.56 to 8.48 km
- Average river width (W_{ave}) : 5.25 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.94
- Maximum river extent during 30 years : 8.88 km

Site-3 (Mawa-Janjira): Stable

- Change in river width (W_{min} to W_{max}) : 2.00 to 4.92 km
- Average river width (W_{ave}) : 3.81 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 0.60
- Maximum river extent during 30 years : 5.24 km

Site-4 (Chandpur-Bhedarganj): Less Stable

- Change in river width (W_{min} to W_{max}) : 2.68 to 9.60 km
- Average river width (W_{ave}) : 5.31 km
- Coefficient of variation = $(W_{max}-W_{min})/W_{ave}$: 1.30
- Maximum river extent during 30 years : 9.60 km

(3) Expected River Works

Main river works expected for the Padma Bridge are guide bund works, additional river training works and channel works on the flood plain. From the river works, Site-1 and Site-3 apparently have advantages over the remaining sites owing to the following reasons:

Guide Bund Works: At the present stage of study, there is no reason to mark an advantage or disadvantage for any of the crossing sites. Additional River Training Works: Because of instable river conditions at Site-2 and Site-4 these sites would require more works to train the river course and flows.

Channel Works on Flood Plain: Site-2 and Site-4 require longer approach roads because of no national highway with which to be connected. The longer approach road traversing the flood plain would require more works for the treatment of minor river channels and drainage in the plain area.

(4) Evaluation from River Perspective

The above discussions on the four crossing locations are summarized in Table 3.2.12.

Table 3.2.12 Evaluation of Crossing Locations from River Perspective

	Site-1	Site-2	Site-3	Site-4
River Scale				
River width	4.8 km	4.4 km	4.9 km	2.7 km
Max. depth surveyed	21 m	22 m	30 m	65 m
Low-lying flood plain	-	3.8km in total on both banks	-	7.4km on right bank
Stability (1973-2003)				
Change in river width	2.44 to 5.00km	3.56 to 8.48km	2.00 to 4.92km	2.68 to 9.60km
Average river width	4.27 km	5.25 km	3.81 km	5.31 km
Coefficient of variation	0.61	0.94	0.60	1.30
Max. river extent	5.20 km	8.88 km	5.24 km	9.60 km
River banks	Left bank fairly stable	-	Left bank fairly stable	Left bank fairly stable
River Work				
Guide bund works	No significant difference	No significant difference	No significant difference	No significant difference
Additional RTW	-	More works anticipated because of less stable channel	-	More works anticipated because of less stable channel
Flood plain works	-	More works anticipated because of longer approach road.	-	More works anticipated because of longer approach road.

From river perspective, Site-1 (Paturia-Goalundo) and Site-3 (Mawa-Janjira) are by far more favorable to the crossing location comparing to the other sites.

3.2.3 Technical Considerations for Highway and Bridge Engineering

(1) Highway Engineering

(a) Road System of Bangladesh and Functional Requirements for the Project Highway

The road system of Bangladesh, its classification and definitions comprising the National Highway, Regional Highway, Zila Roads, Upazila Roads, Union Roads, Village Roads and Municipal Roads, responsible administrative organizations, regional distribution are as shown in the table below. Based on the present status of road administration and the objective of the Project, it is concluded that the Project highway should be connected at the both ends to a National Highway, or at least to a Regional Highway.

Table 3.2.13 Road System of Bangladesh

Domain	Classification	Primary Connection	Length (km)	
RHD	National Highways	National Capital to Divisional headquarters, Sea/Land ports and Asian Highways	3,086	20,799
	Regional Highways	Between District headquarters, Main river/land ports, not connected by National Highways	1,751	
	Zila Roads	District headquarters to Upazila headquarters, or between Upazila headquarters, by a single main connection with National/Regional Highway, through shortest distance/route	15,962	
LGED in collaboration with Local Government Institutions (LGI)	Upazila Roads	Upazila headquarters to Growth Center(s), or between Growth centers by a single main connection, or Growth Center to Higher Road System (National Highways, Regional Highways and Zila Roads), through shortest distance/route	23,434	201,738
	Union Roads	Union headquarters to Upazila headquarters, Growth Cneters or Local markets, or Between Union headquarters	68,624	
	Village Roads	Villages to Union headquarters, Local markets, Farms and Ghats, or between Villages, and within a Villages	114,126	
Municipal bodies like City Corporations and Pourashavas	Municipal Roads	Within specified Urban areas	4,300 as of 1997	

(b) Characters of Initial Project Location Alternatives and their Evaluation from Highway Planning Aspects

As described earlier, four locations which were preliminarily selected prior to the start of the Study; *viz,*

Site-1, Paturia-Goalundo,
Site-2, Dohar-Char Bhadrasan,
Site-3, Mawa-Janjira, and
Site-4, Chandpur-Bhedarganj,

are also dominantly justified as alternative Padma crossing locations by evaluation from the physical aspects above. They are as shown in Figure 3.2.14.

Evaluation of each of the four location alternatives from the aspect of highway planning was conducted and summarized as in Table 3.2.14.

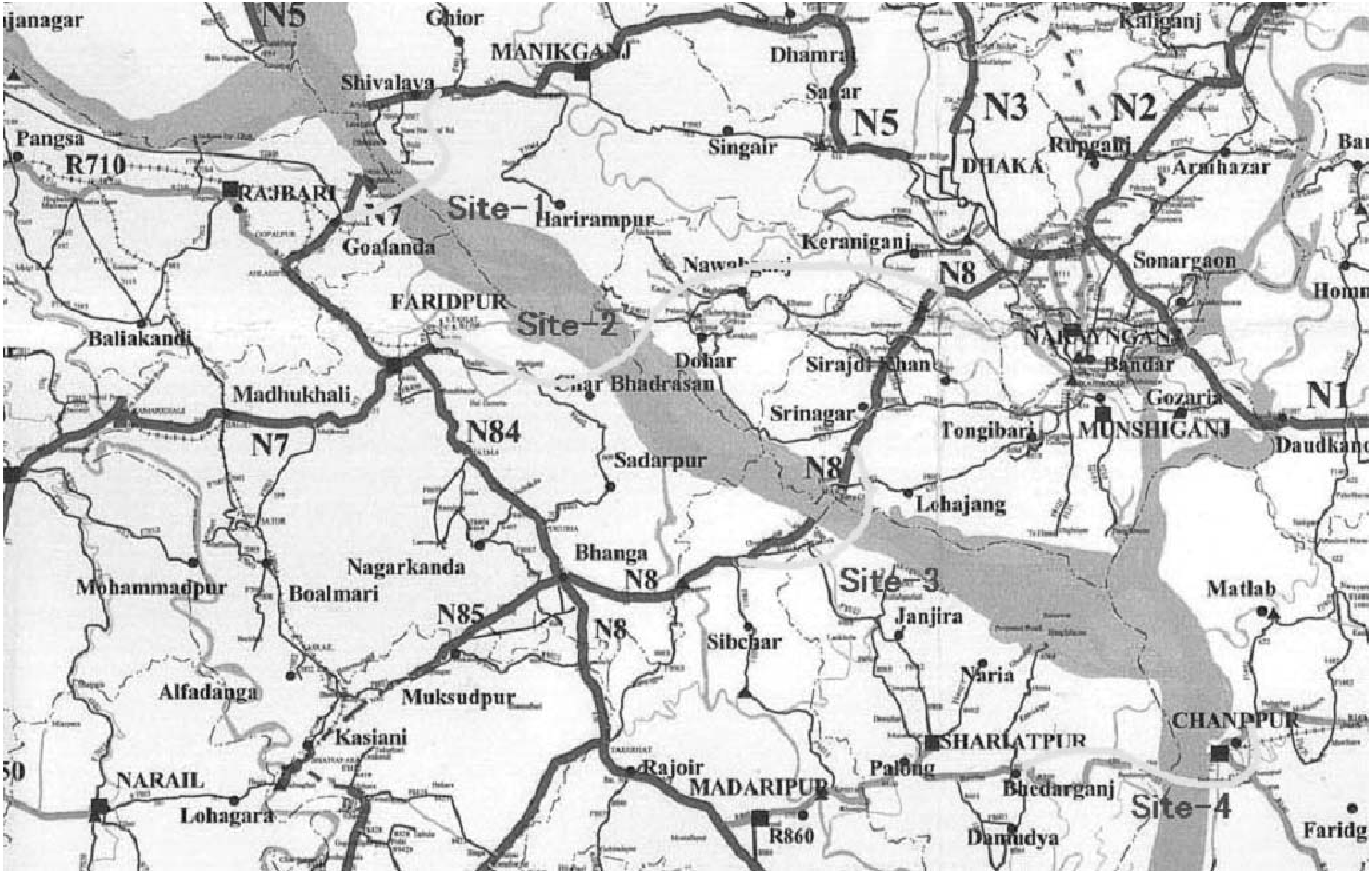


Figure 3.2.14 Alternative Project Location for the Padma Crossing

Table 3.2.14 Comparison of Alternative Project Locations from Highway Planning Aspect

Aspects	Paturia-Goalundo Site-1	Dohar-Char Bhadrasan Site-2	Mawa-Janjira Site-3	Chandpur-Bhedarganj Site-4
Highway Planning				
Project Length	17 km Bridge: 6.1 km Approach Roads: LBS 8 km RBS 3 km Total 11 km	58 km Bridge: 9.6 km Approach Roads: LBS 32 km RBS 16 km Total 48 km	19 km Bridge: 6.1 km Approach Roads: LBS 4 km RBS 9 km Total 13 km	33 km Bridge: 10.8 km Approach Roads: LBS 7 km RBS 15 km Total 22 km
Connecting Roads	N5 and N7	N8 and N84	Both N8	R140 and R360
Particulars	Moderate project length, moderate bridge length Connects arterial National Highways presently being linked by ferry services Improvement of connecting roads not required Less favorable to Dhaka-Southwest connection More favorable to Dhaka-Northwest connection Somewhat competitive with Jamuna Bridge	Project length too long due to too long approach roads and relatively longer bridge Improvement of connecting roads not required, but construction of new, long approach roads in the flood plain on both sides required Presently no traffic due to lack of arterial approach roads and ferry linkage Moderately favorable to Dhaka-Southwest connection Significantly competitive with N8 to be upgraded	Moderate project length, moderate bridge length Completes an arterial National Highway link presently missing and ferry services being provided Improvement of the connecting road, N8 between Dhaka and Noapara, in progress to be completed by the end of 2004 More favorable to Dhaka-Southwest connection	Longer project length, longest bridge length Connects arterial Regeonal Highways presently being linked by ferry services Improvement and upgrading of connecting roads considerably required Least favorable to Dhaka-Southwest connection due to ralizing no direct linkage between the two Regions but indirect one partially via the East Region compelling a long detour or use of low standard local roads
Comparative Advantage	**	*	***	*

(2) Bridge Engineering

The major task in this paragraph is to select two prospective sites from the four alternative sites for bridge crossings. The technical assumptions adopted for this preliminary planning stage for the bridge are:

- Recent river opening need to be maintained.
- Guide bunds would be constructed on both riverbanks at all the alternative sites.
- Although no subsoil exploration has been conducted yet by the Study Team, foundation type and sizes could be predicted by using available subsoil data in the vicinity of the respective alternative sites.

Indicative bridge lengths and foundation types and sizes are main factors for selecting prospective sites from the four alternative crossing sites. Detailed discussions of this paragraph are referred to Appendix 9 Bridge Engineering.

(a) Indicative Bridge Length

Indicative bridge lengths are used for a comparison of the alternative crossing sites. As with the Bangabandhu Bridge (Jamuna Bridge), sufficient distance from the recent riverbanks in low water seasons would be required for construction of the guide bunds whichever alternative bridge site is considered.

Indicative bridge lengths are determined by summing:

a) The maximum river width in low water seasons in the past 30 years.
b) The space required for construction of the protection bunds allowing for excavation of side slopes assuming the guide bunds would have a profile of 1:6 to predicted scour depth and a 1:4 side slope to the ground forming the temporary dam to the river that will be 170 m wide at water level.
c) Viaduct length from guide bund to abutment, which should be determined based on stability of the approach road embankment, but assumed to be 60 m at this time.

As a result, the following indicative bridge lengths are estimated.

a)	Site-1: Patria-Goalundo	Indicative Bridge Length = 6.1 km
b)	Site-2: Dohar-Charbhadrasan	= 9.6 km
c)	Site-3: Mawa-Janjira	= 6.1 km
d)	Site-4: Chandpur-Bhedarganji	= 10.8 km

(b) Possible foundations of the Padma Bridge

As the foundations are to be constructed in extremely deep layers, conceivable types of the foundations are limited to the following:

i) Site-1: Paturia-Goalundo

Foundation Depth: 90m or more

Foundation Type:
a) Large diameter cast-in-place RC piles, which are popular world-wide for deep foundations.
b) Large diameter tubular steel pipe driven piles, which were used for the Bangabanndhu (Jamuna) Bridge.
c) RC open caissons by jack-down method with cable anchors. This method, developed in Japan, was adopted on the New Nizammudin Bridge over the Yamuna River in Delhi, and is

now often used in India.

ii) Site-2: Dohar-Charbadrasan

Foundation Depth: 70m or more
Foundation Type:
a) Large diameter cast-in-place RC piles
b) RC open caissons by jack-down method with cable anchors.
c) Large diameter tubular steel pipe driven piles.

iii) Site-3: Mawa-Janjra

Foundation Depth: 80m or more
Foundation Type:
a) Large diameter cast-in-place RC piles
b) Large diameter tubular steel pipe driven piles
c) RC open caissons by jack-down method with cable anchors.

iv) Site-4: Chandpur-Bhedarganji

Foundation Depth: 100m or more – records from the BWDB indicate channel depths of up to 65m in this area (BWDB measurements made in 2002). No suitable foundation has been identified for these conditions.

Accordingly, Site-1 and Site-3 are regarded as preferred bridge sites because of the shorter bridge length and variety of applicable foundation types. At Site-4 the channel depth, which could affect the foundation, is considered to present an unacceptable risk to construction and stability of a structure at that location

3.2.4 Environmental and Social Considerations

Introduction

The environmental and social issues were given due consideration in the study of the bridge location alternatives. This section provides a comparative overview of the environmental and social dimensions of the four alternatives aimed at developing guidelines for initial screening to select two "preferred" locations. Section 2.2.4.1 presents the environmental aspects, followed by the social considerations (Section 3.2.4 (2)) for selection of two alternative locations.

(1) Environmental Aspects

(a) Steps of the Environmental Study

The steps of the environmental study implemented for the Padma Bridge Feasibility Study are as follows:

- Environmental assessment of the Padma river eco-system in relation to the initial screening,
- Initial Environmental Examination (IEE),
- Environmental Impact Assessment (EIA), and
- Preliminary Environmental Management Plan (EMP) to counteract the negative impacts.

For the Padma River crossing, four alternate sites were conceived as explained in previous sections. Initial environmental assessment for four alternative sites and Padma River eco-system was conducted between May and July, 2003 and was presented in the Chap 1 of APP – 11. A brief summary is given here.

(b) Objective of the Initial Assessment

The environmental assessment for initial screening was undertaken during the study stage to select 2 preferred sites out of the 4 sites conceived. The main issues are,

1) To identify critical issues like ecological park, ethnic minorities, habitat of endangered species, etc.
2) To identify difference in environmental settings among the 4 sites.
3) To estimate difference in anticipated impacts among the 4 sites.

(c) Approaches to the Environmental Studies

Environmental impacts due to the construction of the bridge can be classified into two major groups, natural and socioeconomic. Some of these impacts are positive and some are negative. There are two conventional ways of impact assessment. One is to identify the activities and try to find out their impacts. The other is to identify different environmental issues and try to find out which activity would influence each issue and to what extent. In this Study, both approaches will be used.

In this Study, mainly Bangladesh guidelines and JICA guidelines will be followed. However, other guidelines will be consulted.

(d) Environmental Laws and Guidelines

At the onset of the environmental study, relevant environmental laws and guidelines were studied. These include,

- Environmental Pollution Control Ordinance (1977)
- Environmental Policy (1992)
- Environmental Conservation Act (1995)
- Environmental Conservation Rules (1997).
- Environmental Quality Standards (EQS),
- Emission standards,
- EIA requirements of Bangladesh.
- JICA guidelines, and
- JBIC guidelines.

(e) Reconnaissance survey

In the beginning of the Study, four possible river crossing locations were conceived on technical grounds. Districts and Upazilas involved with these four sites are shown in the following table along with the area and population of the concerned Upazilas.

Site	River Bank	District	Upazila	Area (Sq. Km)	Population
Paturia –Goalundo	Left	Manikganj	Shibaloy	199.07	143,842
	Right	Rajbari	Goalundo	149.03	91,675
Dohar – Charbhadrasan	Left	Dhaka	Dohar	161.49	175,842
	Right	Faridpur	Charbhadrasan	141.59	69,876
Mawa – Janjira	Left	Munshiganj	Lauhaganj	130.12	153,433
	Right	Shariatpur	Janjira	239.53	157,316
Chandpur – Bhedarganj	Left	Chandpur	Chandpur Sadar	?	396,872
	Right	Shariatpur	Bhedarganj	267.28	207,258

Source: Bangladesh Population Census 1991 – Community Series

The Study Team members in charge of Environmental Issues made extensive field investigations in all four sites and adjacent areas. In addition, all relevant secondary data was analyzed. Details are given in Chap-1 of App-11.

Padma is a braided river. Its width varies from 5 to 15 km. The general topography of the area in the vicinity of Padma River is flat. The soil of the Project area consists mainly of recent Holocene alluvial deposits. The materials are mostly sediments transported by the river. The Project area is located in a sub-tropical monsoon fed region. Most of the vegetation is secondary forest and cultivated crops. A significant number of people live in the Project influence area. The main economic activities are agriculture, fisheries, small trading and day labor. There are many chars within the river and some of them are habited. Overall landscape features along the Padma River watershed are monotonous.

The environmentally influenced zone of the proposed Padma Bridge is set at approximately 10,000 sq km. The strip is about 100 km long along the Padma River. The starting point of the strip is the confluence of the Jamuna River and the upper Padma near Aricha ghat and continues downstream to the confluence with Meghna River at the Chandpur near Haimchar. The width of the influence strip is 100 km, 50km perpendicularly from the center of the Padma River. The influence zone is shown in the Figure 3.2.15. This influence zone covers 16 districts partially or fully. These districts are Manikganj, Dhaka, Munshiganj, Chandpur, Tangail, Gazipur, Narshindi, Narayanganj, Comilla, Shariatpur, Madaripur, Faridpur, Rajbari, Magura, Narail, and Gopalgonj.

Members of the Study Team made field reconnaissance of the influence zone a number of times to anticipate the environmental scenario of the area. The survey concentrated on the proposed four crossing sites of the bridge. Information on land use patterns, such as land type, trees and vegetation, cropping patterns, settlement patterns, mosques/temples, institutions, cultural values, including flooding occurrence, riverbank stability and its tributaries, associated channels, etc. within the study area were collected during the field observation.

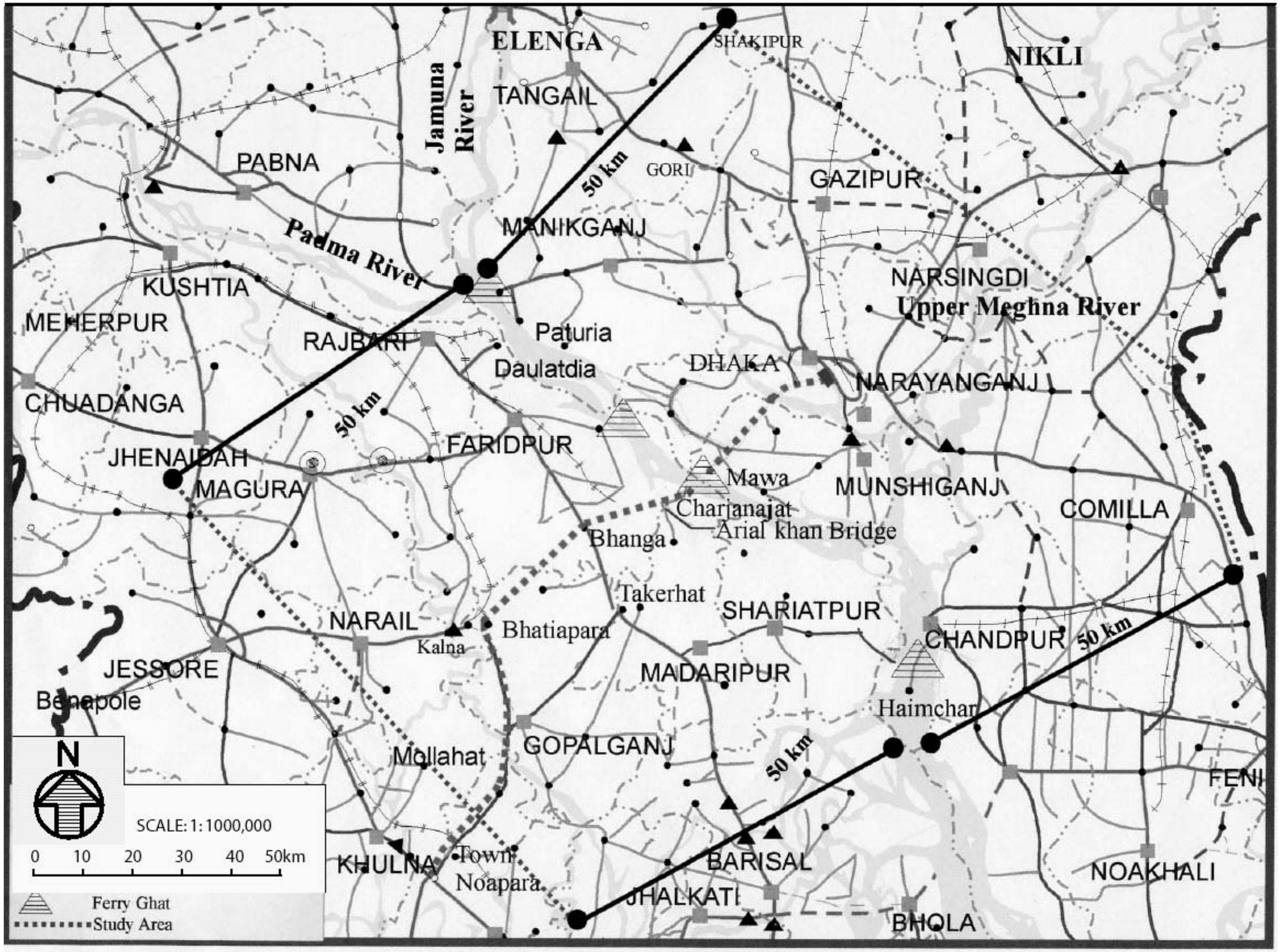


Figure 3.2.15 Environmentally Influence Zone of the Proposed Padma Bridge

The Padma River originates from the southern slopes of Himalayas with the name Ganges and after crossing from India to Bangladesh, it is known as the Upper Padma River. About 200km downstream from the Indian boarder, it joins with the Jamuna River. From this confluence the river changes its direction and joins with the Meghna River at Chandpur. This 120 km stretch is named the Padma River. Generally, the Padma River has high current and velocity during monsoon season and becomes very ferocious and wild. Riverbank erosion and accretion are taking place on the Padma River watershed as a common phenomenon. From the main stream of the river, a number of tributaries, channels and canals are developed. Arial khan is one of the biggest distributaries on the right bank of the Padma River at Shibchar thana in Madaripur District.

A number of chars have developed along the main stream of the Padma River. Settlement and secondary vegetation have started to develop in many of the aged chars such as Char Daulatdia, Chra Bhadrasan, Shibchar, Char Janajat, etc. Seasonal flooding is a common phenomenon in the char lands and floodplains adjacent to the banks of the Padma River. Tidal influence on the Padma River varies from upstream to downstream of the mainstream. Tidal flow in the upstream is comparatively lower than downstream. Field investigation indicated that tidal influence is 3-6 inches at Goalando and Charbadrasan. At Bhederganj and Ibrahimpur, tidal flow difference is about 2-3 feet. Maximum tidal difference of about 4-6 feet was noticed at Chandpur ferryghat site.

Vegetation along both the banks is mainly of agricultural crops and homestead vegetation, which includes fruit trees, timber, bamboo bushes and dhoincha bushes. Field investigation indicated that afforastation or/community plantation has been partly started by the Department of Forest and some NGOs in Janjira Upazila. Major cropping patterns in the char area are paddy, nuts, potatoes, jute, chilies, onions, sugarcane etc. Paddy cultivation is mainly IRRI rice and boro rice. Huge amounts of onions and chilies are cultivated on the char lands and floodplain lands in Janjira. Jute and sugarcane are mainly grown in Bhedarganj and Chnadpur sites. In addition to these, rabi crops such as green vegetables, pulse, mustard, etc. are also grown in the floodplain lands along the Padma watershed.

The economic condition of the people of the left bank is more prosperous than those of the right bank of the Padma River. During the field visit it was noticed that Chandpur site is rich compare to other sites of the proposed bridge locations. The majority of the houses are of corrugated iron sheet for roof and walls. The people of Bhedarganj site and Chrabhadrasan site in Shariatpur and Faridpur districts respectively are poor and a large majority of houses are thatched/huts.

Four crossing sites for the Padma Bridge are proposed at the narrow width sections of the main stream of the Padma River within the study area. A detailed description of the landscape pattern of the four proposed crossing sites of the Padma Bridge is given in Chap-1 of APP-11.

(f) Initial Evaluation of Four Alternatives

Bangladesh is a densely populated country and the natural terrestrial ecosystem is mostly lost by the exploitation of this huge population. Therefore, the impacts related to the construction and operation of the bridge primarily affect the conditions and livelihood of the people in the direct vicinity. The bridge will also certainly affect the natural environment, especially river morphology and drainage conditions. The aquatic fauna may be affected to some extent, mainly during the construction phase. Other impacts due to the proposed bridge will be associated with the construction works. This implies that they are generally of limited spatial extent and of limited duration.

For all the four locations, the areas that may be affected are rural in character. Generally, more commercial activities are found on the left bank. People are having various economic activities, namely, agriculture, day labor, small trade and fisheries, agriculture being the dominant. It was found that in Chandpur and Goalundo sites, non-farm activities are significant. It is apparent that the economic activities are highest in site-4 followed by site -1.

According to the pre FS (JMBA, 2000), there are neither any ecologically sensitive area, nor any archeologically or culturally important sites.

The project might cause backwater effects during flood conditions, combined with increased scour at and near the bridge crossing and increased sedimentation further downstream. These impacts require further analysis along with cross drainage of the floodplain.

The impact on the terrestrial ecosystem will remain limited to the removal of the current vegetation, mostly agricultural crops, trees, and homestead vegetation, from the project area. Agricultural product and practice must be investigated. During the construction, residential and migratory birds that use char land as feeding and breeding ground, may temporarily driven away. A wildlife baseline survey is required to assess the impact.

To assess the impact on the aquatic ecosystem due to dredging and dredge spoil disposal; and the behavior of riverine fish affected by the pilling works requires further investigation. Fishing practice and catches should be investigated.

The anticipated environmental impacts during the construction phase are,

- Noise pollution
- Air pollution
- Surface and ground water pollution
- Hindrance of river transport
- Problems in road transport
- Occupational health and safety
- Social disruption
- Waste disposal, and
- Operation of work site and labor camp.

From the above basic analysis on the anticipated impacts, it appears that no site has a relative advantage or disadvantage over others as the general environmental setting is very similar in all 4 cases. However, due to the nature of the anticipated impacts, it is expected that environmental impact would be more for a longer approach road and greater river training activities. As explained in the technical assessment, site 1 and 3 would require shorter approach roads and also these two sites indicate more stable river sections requiring less river training works. Therefore, it can be expected that environmental impact would be less for site 1 and site 3.

(2) Social Issues and Dimensions

(a) Objectives and Methods of Inquiry

The materials under social issues and dimensions provide an overview of the socioeconomic characteristics of the four crossing locations or corridors. An initial social assessment (ISA) of the four corridors was carried out to develop some broad criteria for project screening purposes for the selection of two alternatives. The scope of investigations included land acquisition resettlement issues, taking into consideration the demographic, socioeconomic, housing/settlement, and livelihoods sources of the people in each alternative location. The Study team carried out extensive field visits to the four locations and used various methods for data collection including focus group discussion (FGD) at the *Upazila* (sub-district) level, participatory rapid appraisal (PRA), selective interviews of key of local experts, and available census data. The availability of data at times dictated the scope of inquiries and the nature of analysis presented here. Thus, the analysis derived from the initial assessment is only indicative of the socioeconomic characteristics of the Padma floodplain.

(b) Description of the Four Crossing Sites

The four alternative sites involve eight districts, of which four (Manikganj, Dhaka, Munshiganj, and Chandpur) are located on the left bank of the Padma; the remaining four districts (Rajbari, Faridpur, Shariatpur, and Madaripur) are on the right bank. In all four sites, riverbank erosion is endemic affecting literally hundreds and thousands of people annually. The rate of erosion is more on the left bank in all four sites. In the floodplain, the eroded lands typically re-appear in the form of *chars* (mid-channel islands), which are used by the poorer people for crop cultivation during the winter or dry season. The rate and extent of erosion and accretion of *chars* depends on the migration of the meandering bends of the Padma River. The lands in all four sites are classified into *char* and mainland, with characteristic features of risk and uncertainty associated with the use of *char* land as a resource for survival and sustenance. Thus, the forces of riverine ecology, including annual flooding, largely shape the general socioeconomic conditions of the local populations. A brief description of the four sites is in order. Detailed comparative socio-demographic and economic characteristics of the four sites are presented later in this section.

Site – 1: Paturia-Goalundo

Paturia-Goalundo is located at the upstream of the four sites. Paturia on the left bank belongs to Shibalaya *Upazila* in Manikganj district. In the recent past, the area experienced massive erosion, particularly the right bank. As a result, nearly 45% (89.12 sq. km) of the total area (199 sq. km) are riverine area. This also necessitated the relocation of ferry terminals and the railway station as well. Goalundo is a historic river port with railways and road network with the northeastern zone. As a meandering river, the main channel of the Padma has moved off towards the east of the present ferry *ghat* passed what is now known as the dead Padma. Paturia *ghat* is now located in a rural area, close to many large village settlements. On the other hand, Goalundo is an urban municipal area. This river port was once the gateway to Kolkata during the British period. The urban character is reflected by the industrial and commercial activities in the area. There are several textile mills, hatcheries, and poultry farms. The expanding commercial and industrial activity of this port town will benefit form a fixed link over the Padma River.

Site –2: Dohar-Charbhadrasan

Dohar-Charbhadrasan site is located in a fairly remote area with very little road network of national standards. The active channel of the Padma is more to the right bank. The area is low floodplain with many *chars* in between the riverbank. The width of the river is huge – an estimated 10 to 12 km wide – with long island *chars*. One such *char* has a large settlement on it. Many of the *chars* are covered by vegetation and are fairly stable. The *chars* are used to grow winter crops and vegetables, which remain as important sources of cash income for the char settlers. There are, however, several *chars* consisting of new accretion sands and still not ready for cultivation. Since it is a *char* area, the settlement on the Charbhadrasan site is thinner compared to Dohar on the left bank. Settlement and cultivation in Charbhadrasan is constrained by the instability of *chars*, erosions and flood hazards. In addition the road network on the Charbhadrasan is practically non-existent.

Site – 3: Mawa-Janjira Site

Mawa is located on the left bank. It is an important river port and transportation hub for the southwestern part of the country. Janjira on the left bank is a rural area – located about 2 km down stream from the existing ferry *ghat* in Shariatpur. There are no visible island *chars* at the site; however, a cluster of *chars* slightly upstream from Mawa has fairly old dense village settlements. While the left bank still experiences erosion annually, the right bank area is gradually gaining more and more accretioned or *char* lands. The extent and size of *char* land area would be clearer after the flood season. However, unlike other sites, the *chars* on the right bank are fairly stable. Settlements and density of population are lower on the right bank. The likely landing area on the Janjira site has several small and scattered village settlements.

Mawa is well placed from the point of national road network. It is on N8 connecting Dhaka with the Southwestern region. This road section is present being widened into an improved two-lane under ADB assistance and expected to complete in May 2005. The Janjira-end will require construction of an approach road to connect with N8 on the other side of the river. Several local villages will be affected by the construction of the bridge and river training work.

Site – 4: Chandpur-Bhedarganj

Chandpur is an old and historic river port of national importance. The site is downstream from the port area – located in the lower reach of the Padma. Like Dohar-Charbhadrasan, the site is remote and constrained by lack of good road network with national highways system. The width of the river at the confluence is wider compared to other sites. The island *chars* between the banks are reportedly of different age and elevation. According to local villagers, over 50 percent of the *char* areas are flooded during normal flood year. The attached *chars* in this site are vegetated better than the island *chars*, allowing better agricultural production. The settlements on the right bank are very sparse and scattered, which typically characterize *char* settlement in the floodplain.

(c) Demography and Socioeconomic Aspects: Comparative Overview

Table 3.2.15 presents socio-demographic characteristics of the four sites. The four sites cover nine *upazilas*. The population as well as density in the *upazilas* on the right bank is consistently lower compared to the *upazilas* on the left bank. Similarly, the literacy rate is also on the lower side compared to left bank *upazilas.* The level of urbanization is uneven – from 1.31 percent in Janjira to 30 percent in Charbhadrasan (1991 Census). It is intriguing that Charbhadrasan, being a rural upazila, has urban population higher than Goalundo (13 percent) and Dohar (15 percent). Available data on the annual urban growth rate is about 10 percent or over in upazilas on the left bank. Shibchar on the right bank has a growth rate of seven percent. Goalundo experienced negative growth rate due to loss of commercial and market areas to erosion in the 1980s and early 1990s.

Table 3.2.15 Socio-demographic Characteristics of the Project Area

Site	Upazila	Location	Total Population	Sex ratio M/F	Density Sq km	Literacy %		Urban Population %	Annual urban growth rate %
						M	F		
1. Paturia - Goalundo	Shibaloy	Left bank	143,842	110/100	723	36.5	20.8	2.51	9.64
	Goalundo	Right bank	91,675	109/100	615	27.5	13.0	12..67	(-) 0.69
2. Dohar-Charbhadrasan	Dohar	Left bank	175,842	98/100	1,089	36.3	29.6	15.26	12.72
	Charbhadrasan	Right bank	69,876	106/100	494	26.5	14.2	30.0	-
3. Mawa-Janjira	Lauhaganj	Left bank	153,433	100/100	1,179	40.0	34.2	7.61	12.96
	Janjira	Right bank	157,316	105/100	657	24.8	11.3	1.31	-
	Shibchar	Right bank	306,082	104/100	934	40.0	24.9	7.95	7.22

4. Chandpur-Bhedarganj	Chandpur	Left bank	396,872	-	1,193	-	-	8.65	-
	Bhedarganj	Right bank	207,258	103/100	775	27.4	17.4	2.11	-

Source: Community Series Data, 1991 (Bangladesh Bureau of Statistics)

Housing and Settlement Patterns

Upazilas on the right bank have generally smaller number of households – for example, Goalundo, Charbhadrasan, and Janjira. However, the average household size is almost same (5 persons/household) in all four sites (Table X2). The Table shows that the roof of the residential structure is predominantly made of tile/C.I. sheet. Also, a large number of residential dwellings are made of straw/bamboo. Such types of houses are found more on the right bank.

Table 3.2.16 Household Size and Types of Construction Materials for Residential Structures

Site	Upazila	Total Households	Household Size/person	Construction materials used (%)		
				Straw/Bamboo	Tile/CI Sheet	Cement
1. Paturia-Goalundo	Shibaloy	26,334	5.4	14.85	84.17	0.98
	Goalundo	15,694	5.8	43.56	55.94	0.50
2.Dohar-Charbhadrasan	Dohar	31,645	5.6	23.58	75.92	0.59
	Charbhadrasan	12,415	5.7	59.78	39.84	0.38
3. Mawa-Janjira	Lauhagnaj	26,570	5.7	15.49	83.59	0.92
	Janjira	28,716	5.5	48.38	51.38	0.24
	Shibchar	58,085	5.3	43.44	56.17	0.39
4.Chandpur-Bhedarganj	Chandpur	350,200	5.7	-	-	-
	Bhedarganj	36,550	5.7	41.08	58.64	0.28

Source: Community Series Data, 1991 (Bangladesh Bureau of Statistics)

Local Economy – Key Indicators

Selected indicators are presented in this section to illustrate the pattern of local economy and livelihood sources. Table 3.2.17 presents the pattern of ownership of agricultural land in the project area. As evident, nearly half of the households in some cases do not own any agricultural land. The incidence of households without agricultural lands appears to be higher in Shibalaya, Goalundo, Dohar, and Lauhajang – areas that have been heavily affected by erosion in recent years.

Table 3.2.17 Households with/without Cultivable Land

Site	Upazila	Households with Cultivable land %	Households without Cultivable land %
1. Paturia-Goalundo	Shibaloy	48.71	51.29
	Goalundo	49.84	50.16
2. Dohar-Charbhadrasan	Dohar	33.40	66.60
	Charbhadrasan	62.36	37.64
3. Mawa-Janjira	Lauhagnaj	44.34	55.66
	Janjira	77.81	22.19
	Shibchar	66.25	33.75
4. Chandpur-Bhedarganj	Chandpur	64.60	35.33
	Bhedarganj	64.36	35.64

Source: Community Series Data, 1991 (Bangladesh Bureau of Statistics)

Livelihood and income sources include a variety of economic activities. Table 3.2.18 contains available data on sources of household income and employment patterns. The principal source of income is agriculture, followed by agricultural wage labor, business and employment. There are very limited options for non-farm activities, particularly in *upazilas* on the right bank such as Shibchar, Janjira, and Bhedarganj.

Table 3.2.18 Livelihood and Sources of Income (%)

Site	Upazila	Cultivation	Livestock, forestry/ fishery	Pisci-culture	Agricultural Wage labor	Non-farm wages	Business	Employ-ment
1. Paturia-Goalundo	Shibalaya	36.40	2.82	0.08	23.13	3.87	14.74	6.93
	Goalundo	35.14	1.60	0.05	20.52	4.95	15.91	6.90
2. Dohar-Charbhadrasan	Dohar	17.15	1.51	0.04	11.45	5.08	14.08	18
	Charbhadrasan	46.95	2.74	0.07	20.97	2.82	7.38	5.06
3. Mawa-Janjira	Lauhagnaj	21.93	3.33	0.22	19.25	2.20	27.83	8.29
	Janjira	63.90	0.80	0.01	19.23	2.12	6.06	2.22
	Shibchar	47.74	1.27	0.14	23.98	2.49	9.33	3.94
4. Chandpur-Bhedarganj	Chandpur	35.13	3.48	0.16	20.04	3.15	12.0	11.68
	Bhedarganj	46.01	3.59	0.13	26.24	2.80	8.19	4.12

Source: Community Series Data, 1991 (Bangladesh Bureau of Statistics)

The income sources and livelihood data do not give any indication of the incidence of poverty in the project area. However, field visits and PRA data indicate that nearly half of the rural people are poor. According to the Household Expenditure Survey (1995/96) 47% of the rural households are below the poverty line in terms of intake of less than 2122 kcal and 24.6% are below hardcore poverty line measured in terms of intake of less than 1805 kcal. Beside this, the Survey also used the cost of basic needs methods and measured poverty at upper and lower levels. Accordingly, the study found 36% population at the lower level (i.e., hard-core poor) and 53% at the upper level (i.e., poor) on a national basis. Recent statistics indicate that the poverty situation between 1996 and 1999 has marginally improved.[1] However, the poverty situation among populations at the project sites is likely to be above the national average due to loss of livelihood sources through frequent flooding, erosion, and displacement.

Review of Preliminary Project Data

According to the preliminary technical works, the bridge length as well as approach roads are likely to be longer in the case of Site 2 - Dohar-Charbhadrasan and Site 4 - Chandpur-Bhedarganj (Table 3.2.19). Site 2 will involve longer project length due to long approach roads and a relatively longer bridge. Similarly, Site 4 in Chandpur-Bhedarganj has longer project length and the longest bridge length of the four alternatives.

Table 3.2.19 Potential Impacts of Alternative Sites

Site	Estimated bridge length/km	Length of approach road/km	River Training	Project impacts
1. Paturia-Goalundo	5.4	14	Guide bund with minor river works	Moderate impacts
2. Dohar- Charbhadrasan	9.5	57	Guide bund with significant river training work	Severe impacts – more land, more displacement, more disruption
3. Mawa-Janjira	5.8	20	Guide bund with minor river works	Moderate impacts
4.Chandpur- Bhedarganj	10.5	33	Guide bund with significant river training work and treatment of minor river channels	Severe impacts – more land, more displacement and resettlement

Source: Alternative Crossing Locations of Padma Bridge, Draft Report, Padma Feasibility Study (August 2003)

Social Impacts - Summary

The proposed bridge over the Padma at any of the locations would bring benefits to the local communities, reduce erosion through river training protection and provide

[1] *Bangladesh (2001-2003): Country Assistance Plan*, Asian Development Bank, December 2000.

opportunities for business, industries, and regional development. It will also help reduce poverty in the project zone of influence by providing access to income and employment and induce economic growth and development in the relative backward southwestern region. However, the associated adverse impacts of the bridge caused by land acquisition will substantially differ from one site to another. It is too early for any estimates for land acquisition and resettlement impacts. Key facilities that would require land acquisition include (i) approach roads on both sides; (ii) bridge end facilities; (iii) river training works; and (iv) the construction of the bridge itself involving char lands. In addition, given the potential for large number of displaced families, further land acquisition would be required for development of resettlement sites for the affected people.

At this point of the study, no design was available except of some basic design criteria such as length of the bridge at individual locations, the extent of approach road and river structures required. The primary purpose was to develop broad screening guidelines. As evident from the description of the project locations and the socioeconomic characteristics, the four sites have similar characteristics. However, it was clear that impacts would significantly vary on the project length. This means that the longer the length, more land would be required that would involve more displacement and disruption, and require need for resettlement of the affected households. Massive land acquisitions will cause hardship among those affected. Typical assets to be affected would involve land, housing, shops/businesses, and religious/community structures and services. As a result, income sources and livelihood may also be lost. There is a risk of impoverishment of those affected unless adequate steps are not taken to properly assess the impacts and identify the affected households for compensation of lost assets and resettlement assistance.

(d) Selection of Two Alternatives – Screening Criteria

The discussion presented earlier establishes various dimensions of project impacts with regard to land acquisition and resettlement. Therefore, the screening for two alternatives must consider the social issues and select sites that would reduce or minimize acquisition of land and displacement of people. Given this, Site-1 (Paturia-Goalundo) and Site–3 (Mawa-Janjira) are more suited as two alternatives for further investigations at this stage of project preparation.

3.2.5 Screening of Alternatives

These four alternative locations were examined from the view points of existing transport profile of the Project Area, traffic demand forecast, preliminary river study, technical considerations in highway planning, preliminary bridge planning, and environmental and social considerations as discussed in the preceding subsections.

The four alternatives were compared, taking physical, technical, environmental and social aspects into consideration. The summary of Screening is given in Table 3.2.20.

From the points above, Site-1 Patria-Goalundo and Site-3 Mawa-Janjira are recommended as prospective bridge sites being studied for the selection of final bridge site in the subsequent Section 3.3.

Table 3.2.20 Comparison Summary for Alternative Crossing Locations of Padma Bridge

Comparative Items		Site Descriptions	Site-1: Paturia-Goalundo	Site-2: Dohar - Charbhadrasan	Site-3: Mawa-Janjira	Site-4: Chandpur-Bhedarganj
			Narrow river section located just d/s of the Jamuna-Ganges jct. at Paturia ferry port to connect N7 (left bank) and N5 (right bank).	Narrow river section located about 35 km d/s of Site-1. Ferry to cross the Padma is now not available but proposed.	Narrow river section at Mawa ferry port to connect N8 on the both banks. Ferry crossing is now available.	Narrow river section located just d/s of the Meghna-Padma jct. at Chandpur to connect R140 (left bank) and R860 (right bank).
1. Physical Aspects	1.1 River Scale	River width Max. depth surveyed	4.8 km 21 m (☆☆☆)	4.4 km 22 m (☆)	4.9 km 30 m (☆☆☆)	2.7 km 65 m (☆)
	1.2 River Stability ('73-'03)	Average river width Coefficient of variation Max. river extent[Note-1]	4.27 km 0.61 5.20km	5.25 km 0.94 8.88 km	3.81 km 0.6 5.24 km	5.31 km 1.3 9.60 km
		(Comparative Advantage)	**Advantage**(☆☆☆)	Disadvantage(☆)	**Advantage**(☆☆☆)	Disadvantage(☆)
2. Technical Aspects	2.1 Transportation Planning (Network Efficiency)	Trip Length (TL) [Note-3] Vehicle kilometer of normal traffic in 2025 (vkm/day)	10,451,259	10,192,696	9,830,143	10,484,861
		Travel Time (TT) [Note-4] Vehicle hour of normal traffic	220,536	203,077	184,259	223,149
		Distance of route from Dhaka to Mongla Sea Port (Khulna) [Note-5] to Benapole Land Port (Jessore)	312km 253km (☆☆)	284km 225km (☆☆)	211km 199km (☆☆☆)	290km 317km (☆)
	2.2 Bridge Planning	Bridge length (indicative) Depth of Bearing Strata (assumed)	Approx.6.1 km with guide bunds 90 m or more (☆☆☆)	Approx.9.6 km with guide bunds 70 m or more (☆)	Approx.6.1 km with guide bunds 80 m or more (☆☆☆)	Approx10.8 km with guide 80 m or more (☆)
	2.3 Highway Planning	Approach Road Length [Note-2] Connecting Roads	11 km N5 and N7 (☆☆)	48 km N8 and N84 (☆)	13 km Both N8 (to Asian Highway A1) (☆☆☆)	22 km R140 and R360 (☆)
	2.4 River Work.	Guide bund works Additional RTW Flood plain works	No significant difference Less works participated Less works participated	No significant difference More works anticipated More works anticipated	No significant difference Less works participated Less works participated	No significant difference More works anticipated More works anticipated
		(Comparative Advantage)	**Advantage(☆☆☆)**	Disadvantage(☆)	**Advantage(☆☆☆)**	Disadvantage(☆)
3. Environmental and Social Aspects		3.1 Natural environmental impact	(☆☆)	(☆)	(☆☆)	(☆)
		3.2 Social impact	(☆☆)	(☆)	(☆☆)	(☆)
		(Comparative Advantage)	**Advantage**	Disadvantage	**Advantage**	Disadvantage
		OVERALL EVALUATION	**Advantage**	**Disadvantage**	**Advantage**	**Disadvantage**
		Project Cost (reference only)	Less costly	Much costly	Less costly	Much costly

(NOTES)

1. Evaluation: Evaluation was made first with marks "*** (very good)", "** (good)", and "* (fair)" for respective items under each aspect. Then, the evaluation with terms of "Advantage" or "Disadvantage" for respective aspects was given based on the marks given to each item. Finally two alternative sites for further study were selected as a result of overall evaluation based on the evaluation results by aspects. The site marked as "Disadvantage" is judged relatively disadvantageous among the four sites, but this does not mean the site is not appropriate for the bridge crossing.
2. Definitions and explanations of terms:
   1) Max. river extent (Rext): Width between extra limit of left and right banks during past 30 years.
   2) Approach road: Road to be constructed to connect the existing access road and bridge abutment to the national network.
   3) Trip length (TL) is the total length of road that vehicles must travel to reach their final destination when routed through a particular bridge location. The product of the total distance and the number of vehicles using the routes provides the weighted vehicle kilometer (vkm) value. The higher values of vkm are disadvantageous as they mean comparatively longer traveling distances are necessary.
   4) Travel time (TT) is the time to reach final destinations when routed through a particular bridge location, and the higher values represent longer times to reach destinations.
   5) For reference information: Distance from Dhaka to Chittagong Sea Port is 264 km (source: RHD)
3. Abbreviations: d/s: downstream, jct.: confluence, LBS: left bank side, RBS: right bank side, N and R given to the road numbers indicate national and regional highways, respectively.

3.3 SELECTION OF FINAL BRIDGE SITE

3.3.1 Preliminary River Study

Studies were made for Patria-Goalundo site (PG-site) and Mawa-Janjira site (MJ-site), in order to compare river and river morphologic features to select a final crossing location for the Padma Bridge.

(1) Displacement of Left and Right Banks

Displacement of riverbanks at PG-site and MJ-site was studied based on the old topographic maps of 1926 and 1960; and satellite images taken in 1973, 1984, 1993 and 2003. Locations of historical bank-lines were superimposed and shown in Figure 3.3.1. In the Figure, left bank-lines are shown in white lines and right bank-lines in yellow lines. Approximate crossing locations are also shown in the Figure.

Probably due to the eastward shifting, the left bank of the Padma River seems to stick to the eastern land where the Padma River has not flowed yet. Especially near Paturia and Mawa the bank-lines of the various years were superimposed on single line, which indicates that the bank-lines did not made visible movement at least during the data period of 78 years. The left banks at these sites are markedly stable.

On the other hand, the right bank of the Padma River is changeable as a whole located on the unconsolidated past river course of the Padma River. It seems that the right bank moves to absorb the river width changes due to fluctuation of water and sediment flow conditions of the Padma River.

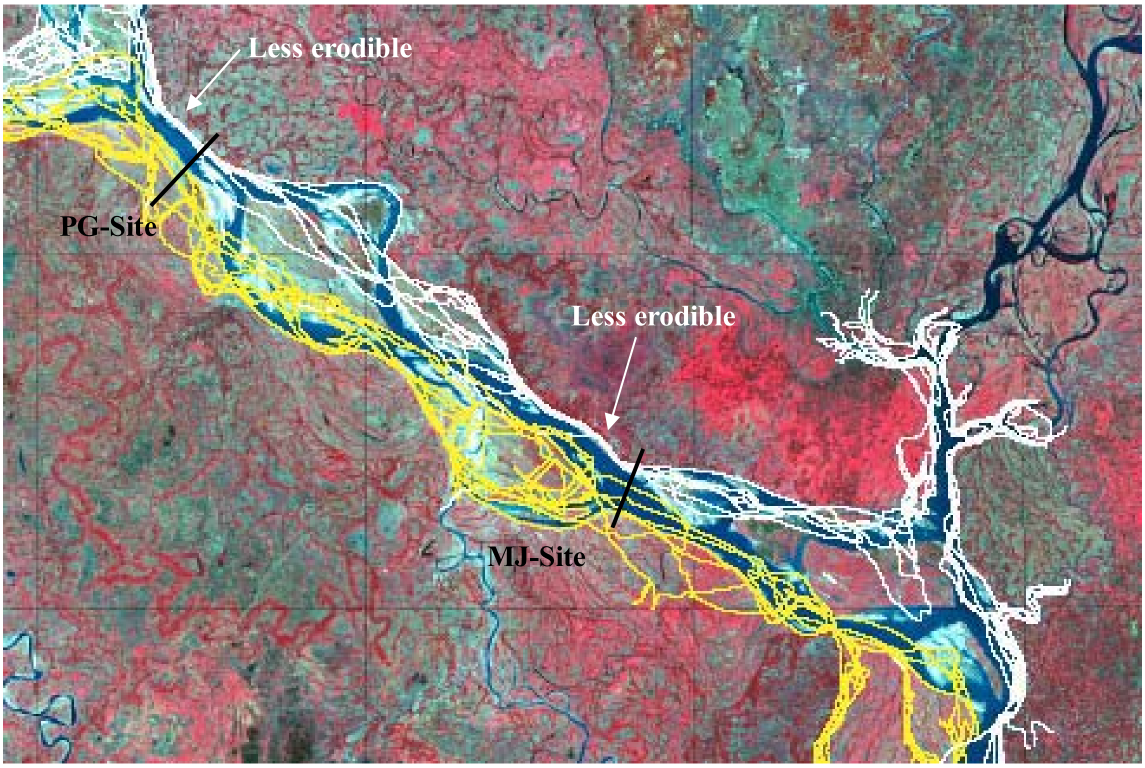


Figure 3.3.1 Displacement of Riverbanks along Padma River

(2) Identification of Erosion Resistant Banks

The bank line shift of the Padma River is very active and its erosion rate is high as a whole. However, the erosion rate of the bank line is not uniform for its entire 100 km long stretch. In some locations the bank erosion rates are relatively low (5 to 20 m/year), and further there are a few locations where the bank erosion is markedly low (1 to 5 m/year) as mentioned earlier. The locations of low erosion rate are found even where the main flow of the Padma is along the bank.

In order to identify erosion resistant banks, the Asian Institute of Technology (AIT, Bangkok) conducted a study under sub-contract of the JICA Study Team. The study was carried out jointly with AIT and the Center for Environmental and Geographic Information Services (CEGIS, Dhaka). The result of the AIT-CEGIS study is summarized below.

1) The soil materials of the floodplain and riverbank along the right bank are nearly uniform and composed of recently deposited unconsolidated sediments mostly consisting of fine sand and silt. The right bank is highly erodible while any channel of the Padma River attacks the bank. The rate of bank erosion often reaches in the range of one hundred meters per year.
2) Unlike the right bank, the floodplain along left bank of the river was not uniform in terms of erodibility. Most of the floodplain is composed of Atria-Gur and 'Tippera Surface' sediments, the ages of which are probably several hundred to several thousand years old. Borehole data show that the sediments are consisting of clay, silt and fine sand. The left floodplain near Harirampur which was formed recently and suffer from high erosion rate in the scale of hundred meters per year.
3) The left floodplain downstream of the Mawa, although it appears to be composed of 'Tippera Surface', is found susceptible to erosion, the average rate of bank erosion has been 20 to 40 m/years during the last three decades, which is between the observed erosion rates in the recently formed and the older floodplains upstream of Mawa.

As a result of the AIT-CEGIS study, Figure 3.3.2 was prepared to show the extent of the different categories of erodibility levels in consideration of bank materials and their distributions.

In the Figure, all the riverbanks of the Padma River are divided into three categories of erodibility levels: highly erodible, moderately erodible and less erodible. When the main channel of the Padma River attacks the bank, the erosion rate would be more than one hundred meters per year along the highly erodible bank (red line), 20 to 50 m/year along the moderately erodible bank (yellow line), and 0 to 15 m/year along the less erodible bank (green line). It should be mentioned that even a moderately erodible bank can act as erosion resistant bank for a number of decades due to having a thin patch of clay deposits or if the bank is not attacked by an aggressive bend.

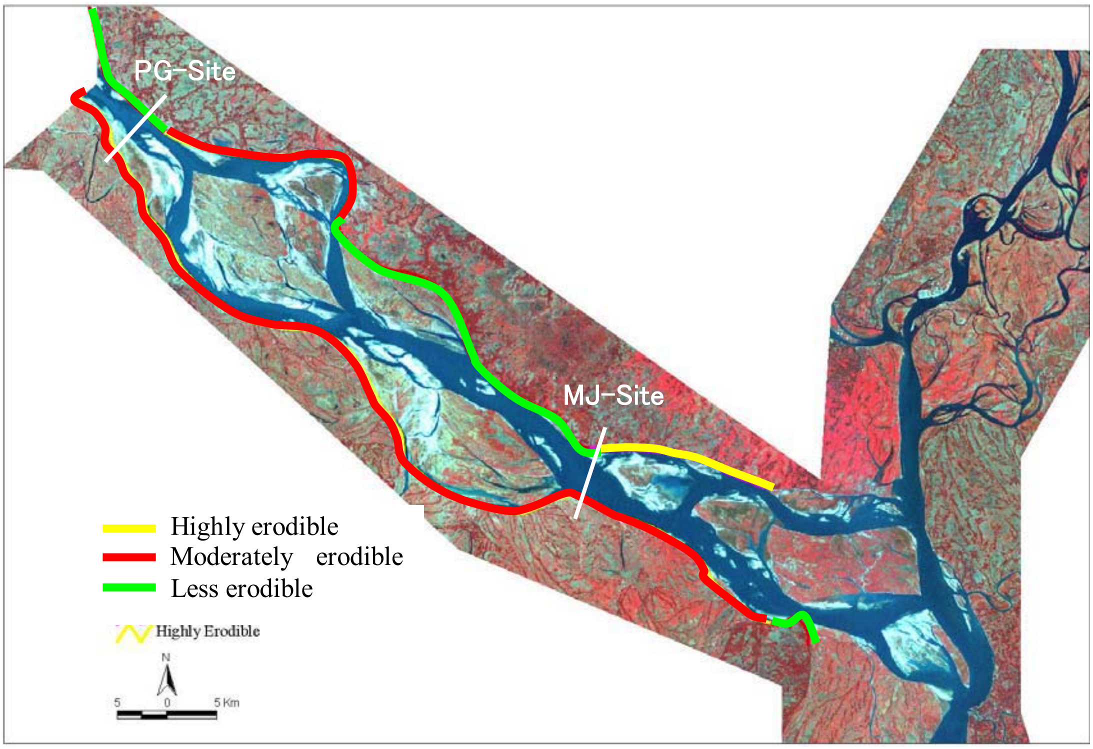


Figure 3.3.2 Distribution of Erodibility Levels of Riverbanks

(3) River Channel

(a) Longitudinal Profile

Based on the cross sections surveyed in 1998/99, longitudinal profiles of the lowest riverbed, left and right riverbanks, and mean riverbed were prepared along the Padma River as shown in Figure 3.3.3.

Since the mean riverbed generally represents the hydraulic sectional characteristics of the river, riverbed slope was delineated on the profile of the mean riverbed. The riverbed slope is 1/15,800 (or 6.3 cm/km) from Hardinge bridge of the Ganges River to about 1.3 km downstream of MJ-site of the Padma River. Within the stretch, PG-site and MJ-site are included. In the downstream reaches of the stretch, the Padma and the Lower Meghna rivers have very gentle bed slope as 1/50,200 (or 2.0 cm/km).

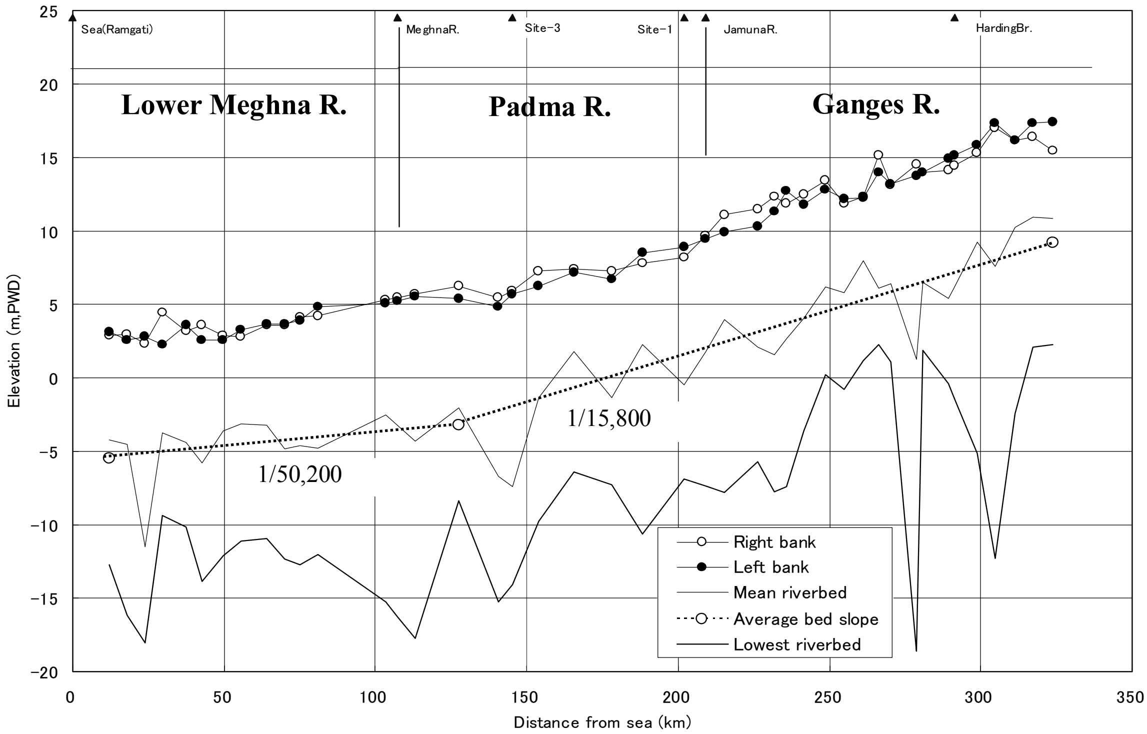


Figure 3.3.3 Longitudinal Profile of Meghna-Padma-Ganges River: 1998/99

(b) Study on River Section Data

The BWDB river section survey data nearest to the PG-site is CS-P7 about 4 km downstream of the PG-site, and that nearest to the MJ-site is CS-P2.1, which is almost on the MJ-site. Historical changes and hydraulic characteristics of there river sections were studied as presented below.

Historical Changes of CS-P7 near PG-site: Section data are available for 33 years from 1969 to 2001 for CS-P7. The maximum extent of the river is about 8.0 km during the data period. The left bank of the main stream stayed at almost the same location during the past 33 years, and the river sections could be divided into three periods of similar sectional patterns mainly depending on the location of the right bank. Considering its proximity to the PG-site, the river section at the crossing location would be similar to CS-P7 but with a little narrower width.

Historical Changes of CS-P2.1 near MJ-site: River sections at CS-P2.1 could be divided into four periods of similar sectional patterns, according to the BWDB data available covering 32 years from 1968 to 1999. Although the locations of the perennial channel move to the left and right within the maximum extent of the river of about 6.5 km, the river remains relatively narrow ranging from 3.5 to 4.5 km in width.

The left riverbank stayed almost at the same location during the data period. It is noted that the sections from 1993 to 95 showed markedly different sectional patterns from others with extremely deep water depth close to the left bank. During this period, the main flow of the Padma River took almost along the present south channel behind Char Kawrakandi. The sectional pattern of the MJ-site would be the same as those of CS-P2.1, since the locations are close each other.

Hydraulic Characteristics: Hydraulic channel characteristics of CS-P7 near PG-site and

CS-P2.1 near MJ-site were analyzed using the same data discussed above. Results of the analysis are shown in Table 3.3.1 for CS-P7 and Table 3.3.2 for CS-P2.1.

Table 3.3.1 Hydraulic Channel Characteristics (CS-P7 near PG-Site)

Y·M·CS	Bankfull m PWD	MeanBed m PWD	LowestB m PWD	Area m^2	Width m	Dmean m	Dmax m	Qlow m^3/s	Qtotal m^3/s	hx/hm
6902P7	7.56	0.28	-8.03	56,386	7,744	7.282	15.590	112,000	112,000	2.14
7003P7	7.56	-0.03	-8.20	59,080	7,779	7.595	15.764	121,000	121,000	2.08
7012P7	7.56	1.39	-5.25	47,191	7,653	6.166	12.813	84,000	84,000	2.08
7202P7	7.56	-0.64	-8.34	63,779	7,775	8.203	15.905	138,000	138,000	1.94
7301P7	7.56	0.51	-7.98	54,325	7,710	7.046	15.539	106,000	106,000	2.21
7312P7	7.56	1.28	-6.48	48,534	7,728	6.280	14.042	88,000	88,000	2.24
7412P7	7.56	1.33	-4.61	47,633	7,650	6.227	12.170	86,000	86,000	1.95
7512P7	7.56	-0.28	-8.79	41,608	5,310	7.836	16.347	87,000	88,000	2.09
7707P7	7.56	-1.63	-13.20	49,179	5,351	9.191	20.764	114,000	115,000	2.26
7712P7	7.56	-0.27	-7.06	42,095	5,379	7.826	14.624	88,000	88,000	1.87
7911P7	7.56	-1.31	-10.45	47,334	5,339	8.865	18.005	108,000	108,000	2.03
8104P7	7.56	0.62	-8.80	37,829	5,453	6.937	16.362	73,000	73,000	2.36
8202P7	7.56	0.78	-6.05	36,297	5,352	6.783	13.612	69,000	69,000	2.01
8311P7	7.56	-0.16	-12.91	41,372	5,360	7.718	20.465	86,000	86,000	2.65
8412P7	7.56	-0.63	-9.52	44,544	5,440	8.188	17.075	96,000	96,000	2.09
8702P7	7.56	0.30	-5.73	41,566	5,727	7.259	13.290	83,000	83,000	1.83
8904P7	7.56	-1.07	-9.37	48,876	5,663	8.631	16.929	109,000	109,000	1.96
9208P7	7.56	0.46	-6.67	43,330	6,102	7.101	14.227	85,000	85,000	2.00
9305P7	7.56	1.49	-8.62	37,428	6,163	6.072	16.181	66,000	66,000	2.66
9501P7	7.56	2.86	-1.95	29,362	6,250	4.698	9.509	44,000	44,000	2.02
9602P7	7.56	0.04	-12.14	45,872	6,104	7.515	19.700	93,000	93,000	2.62
9711P7	7.56	0.91	-7.92	42,107	6,330	6.652	15.480	79,000	79,000	2.33
9802P7	7.56	-0.88	-8.06	53,490	6,340	8.437	15.620	118,000	118,000	1.85
9812P7	7.56	0.52	-6.88	44,420	6,310	7.040	14.440	87,000	87,000	2.05
0001P7	7.56	0.27	-7.94	47,446	6,510	7.288	15.500	95,000	95,000	2.13
0201P7	7.56	0.81	-8.51	39,847	5,900	6.754	16.070	76,000	76,000	2.38
Ave	7.56	0.27	-8.06	45,805	6,324	7.292	15.616	91,962	92,038	2.15

Table 3.3.2 Hydraulic Channel Characteristics (CS-P2.1 near MJ-Site)

Y·M·CS	Bankfull m PWD	MeanBed m PWD	LowestB m PWD	Area m^2	Width m	Dmean m	Dmax m	Qlow m^3/s	Qtotal m^3/s	hx/hm
6812P21	5.71	-3.37	-14.39	28,952	3,187	9.083	20.103	67,000	71,000	2.21
7001P21	5.71	-5.24	-10.56	32,917	3,005	10.952	16.274	86,000	89,000	1.49
7102P21	5.71	-4.66	-10.89	33,966	3,274	10.373	16.597	86,000	89,000	1.60
7205P21	5.71	-3.65	-10.24	27,917	2,982	9.362	15.948	66,000	66,000	1.70
7303P21	5.71	-3.67	-12.68	31,652	3,376	9.376	18.393	75,000	75,000	1.96
7402P21	5.71	-4.74	-15.09	26,175	2,505	10.450	20.798	66,000	67,000	1.99
7504P21	5.71	-6.16	-13.21	31,317	2,638	11.869	18.923	86,000	87,000	1.59
7602P21	5.71	-6.01	-9.17	32,805	2,800	11.717	14.878	90,000	91,000	1.27
7704P21	5.71	-4.05	-12.54	30,850	3,161	9.759	18.250	75,000	76,000	1.87
7802P21	5.71	-3.08	-14.28	32,879	3,741	8.790	19.990	74,000	74,000	2.27
7912P21	5.71	-3.91	-9.83	29,893	3,108	9.618	15.536	72,000	73,000	1.62
8102P21	5.71	-4.03	-12.05	35,354	3,631	9.736	17.765	85,000	86,000	1.82
8203P21	5.71	-1.59	-10.21	28,665	3,924	7.304	15.920	57,000	57,000	2.18
8403P21	5.71	-2.47	-14.42	33,209	4,061	8.178	20.131	71,000	72,000	2.46
8501P21	5.71	-2.75	-10.18	39,075	4,621	8.455	15.887	86,000	87,000	1.88
8905P21	5.71	-1.51	-5.13	22,068	3,057	7.219	10.835	44,000	45,000	1.50
9301P21	5.71	-2.48	-21.74	35,700	4,361	8.187	27.445	77,000	77,000	3.35
9401P21	5.71	-4.66	-28.31	35,908	3,464	10.366	34.022	91,000	92,000	3.28
9510P21	5.71	-1.21	-4.70	21,859	3,161	6.916	10.412	42,000	43,000	1.51
9703P21	5.71	-6.23	-21.66	47,331	3,965	11.937	27.370	131,000	132,000	2.29
9803P21	5.71	-5.29	-15.09	44,361	4,032	11.002	20.800	116,000	117,000	1.89
9907P21	5.71	-4.91	-14.10	44,371	4,178	10.619	19.810	114,000	115,000	1.87
Ave	5.71	-3.89	-13.20	33,056	3,465	9.60	18.91	79,864	80,955	1.98

River Sections Surveyed by Study Team: The JICA Study Team conducted a leveling survey in August 2003 along the proposed routes of the approach roads and bridge sites across the Padma River at PG-site and MJ-site. The survey results are shown in Figures 3.3.4 and 3.3.5 for PG-site and MJ-site, respectively.

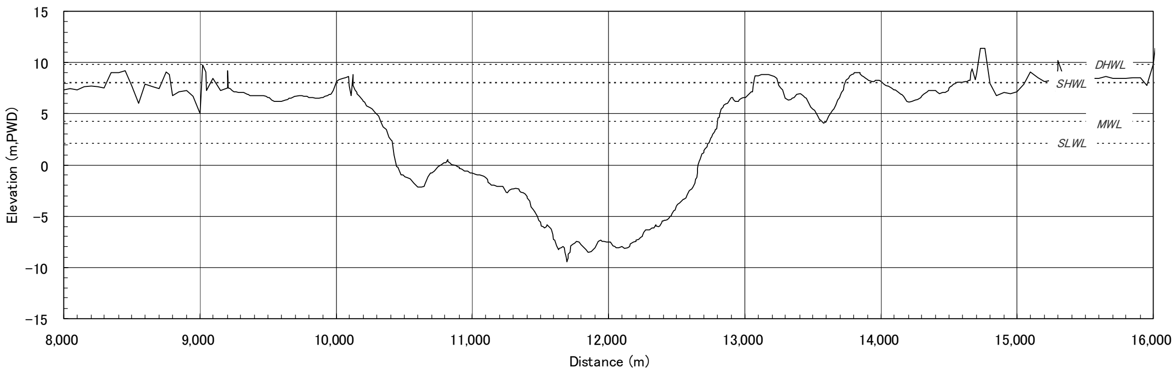


Figure 3.3.4 Cross Sectional Survey across PG-site

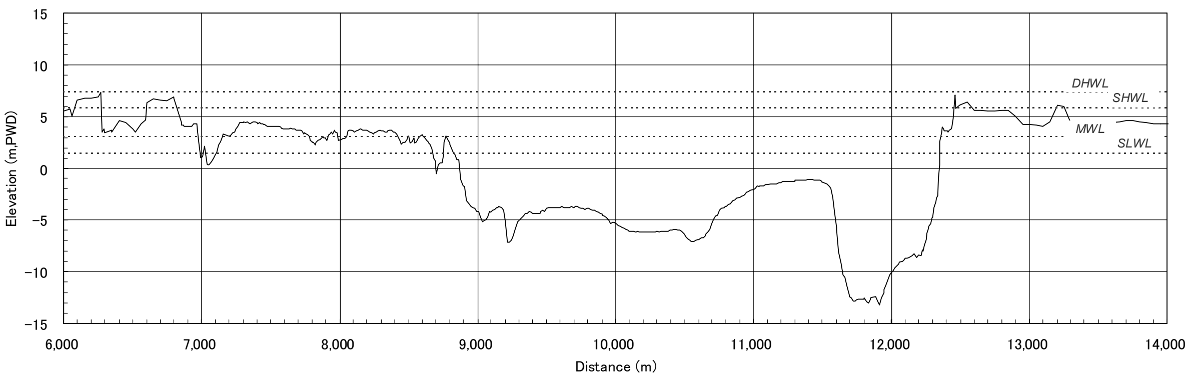


Figure 3.3.5 Cross Sectional Survey across MJ-site

(4) Preliminary Estimate of Maximum Scour Depth

Maximum scour depths were estimated preliminary for the facility design to select an optimum crossing location. The same method and standards adopted for the design of Jamuna Bridge and pre-feasibility study of Padma Bridge were applied tentatively, taking account of the confluence acour, bend scour and local scour around river works and bridge piers. The maximum scour depths estimated by the empirical formulas are summarized in Table 3.3.3.

Table 3.3.3 Estimated Maximum Scoured Depth

Location	Items	PG-Site Q_{100} = 151,400 m^3/s H_{100} = 9.72 m PWD		MJ-Site Q_{100} = 134,400 m^3/s H_{100} = 7.35 m PWD	
		Depth (m)	El. (m PWD)	Depth (m)	El. (m PWD)
Near bank	Scour due to bend & BPW	43.5	-33.8	44.9	-37.5
	Scour due to pier (Φ3m)	49.0	-39.3	50.4	-43.0
Middle river	Scour due to confluence	32.8	-23.1	33.7	-26.4
	Scour due to pier (Φ3m)	38.3	-28.6	39.2	-31.9

(Remarks) Depth: Water depth below DHWL; EL: Scoured riverbed elevation

The scour depths estimated in this sub-section are to be used for the initial study on the facilities for selection of a final site only.

3.3.2 Topographic and Geotechnical Characteristics

(1) Topography

(a) General

Topographic surveys and bathymetric surveys were carried out along the two following planed areas,

- Paturia – Goalundo, and
- Mawa – Janjira.

The locations are shown in Figure3.3.6 and Figure3.3.7.

These Surveys have two major activities, one is Field Topographic Survey Works of the approach road and another one is Bathymetric Survey of the river of the proposed area.

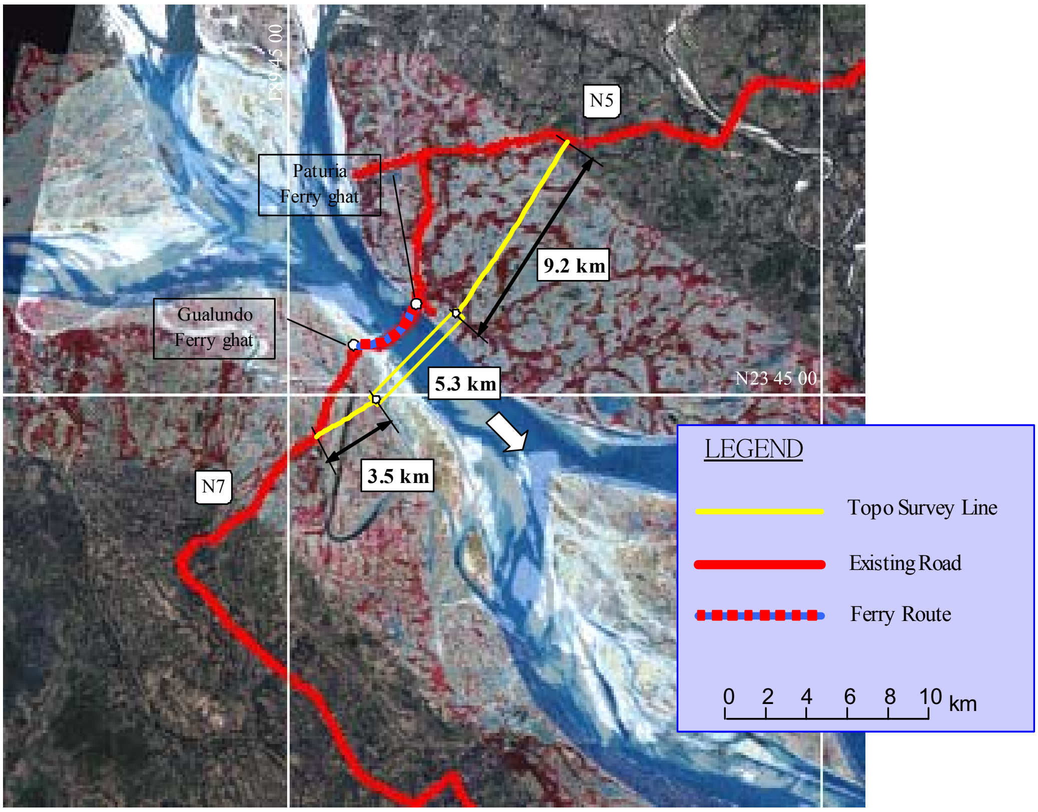


Figure 3.3.6 Topographic Survey Area (Paturia-Goalundo)

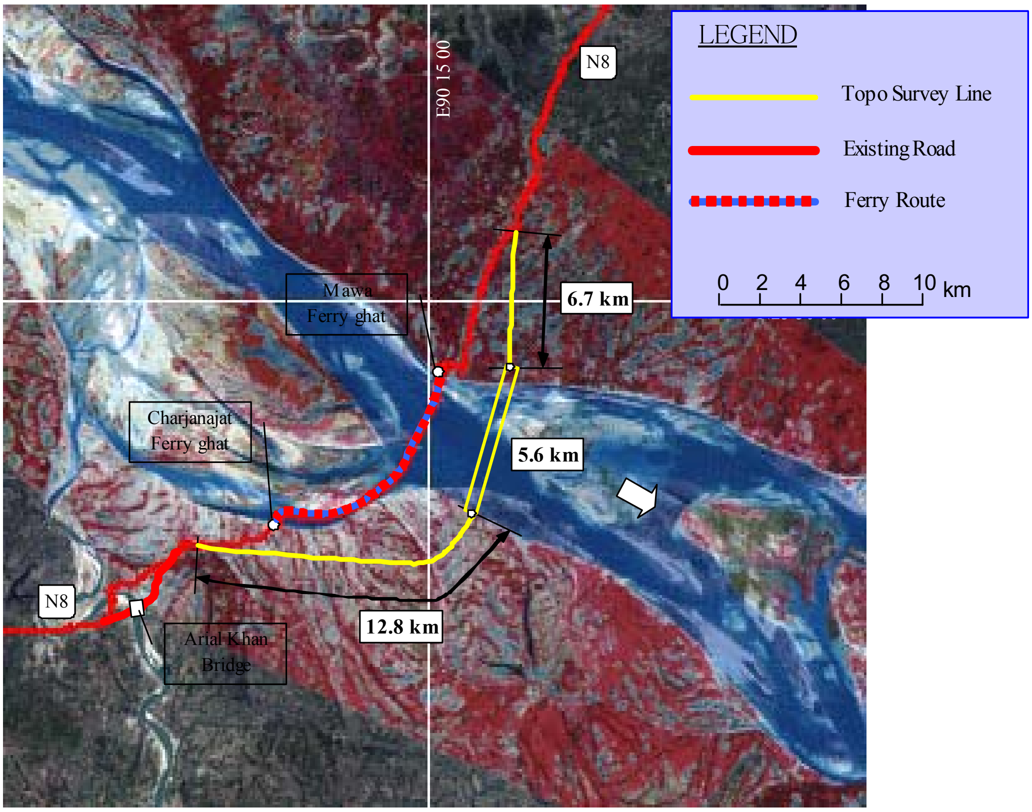


Figure 3.3.7 Topographic Survey Area (Mawa-Janjira)

(b) Topography

The alignment passes through the mature delta of the Ganges flood plain. The Padma receives flood water from the Ganges and the Jamuna. The area does not receive extensive silt deposits any more, nor is it subjected to much diluvion. (Geography of Bangladesh, Haroun Er Rashid, 1991). Land types are Medium High Land and Medium Low Land (The Geography of the Soils of Bangladesh, Hugh Brammer, 1996). The topography of the active flood plain of the Ganges River and its adjoining meander flood plain comprises a low ridge and basin relief crossed by channels and creeks. Local differences in elevation are generally less than 1m. The flood plains are studded with swamps. The areas are inundated up to a depth of about 2m every year. Houses, markets, roads etc are constructed on built up lands. The annual inundation occurs due to rise in Ganges water; which starts rising in May and usually reaches peak by late-August / early September.

(c) Location of Site

The proposed Paturia- Goalundo area takes off near the 76th km of N5 Highway (Dhaka Aricha Highway), near Mahadebpur Market, Mahadebpur union, Shibaloy P.S. of Manikganj district: Then it passes through Ulail and Sharisha bari village of Ulail union, and Darikandi village of Aroa Union of Shibaloy P.S. of Manikganj district. Then it crosses the Padma River and reaches Uttar Daulatdia village, Daulatdia union, Goalundo P.S. of Rajbari district. Then it crosses Nazim Uddin Fakir Para, Daulatdia union, Goalundo P.S. of Rajbari district. Finally it meets the N7 Highway (Faridpur- Daulatdia Highway) about 4 km from Daulatdia.

The proposed Mawa- Janjira area takes off from Dhaka-Mawa Highway (N8 Highway) from a place about 30 km from Dhaka at Bejgaon village, Patabhog union, Sreenogar P.S. of Dist. Munshiganj. Then it passes through Kazir Pagla village, Medini Mandol union; Mochua village, Haldia Union and Wari village, Kumerbhog union of Louhajong P.S of Dist Munshiganj. Then the alignment crosses the Padma River and reaches Majhikandi village, Naoduba union, Janjira P.S. of Shariatpur district. Then it crosses Latif Fakir's village, Dhali Kandi and Majid Dhali's Kandi villages of Naoduba union, Janjira P.S. of Shariatpur district. Then it meets the under construction N8 Highway at Sikderkandi village, Matbor Char union, Shibchar P.S. of Madaripur District.

(d) Methodology

i) Scope of Works

The scope of works covers the following activities in each study area (Paturia-Goalundo and Mawa-Janjira).

- Installation of Concrete Control Points
- Installation of Bench Mark
- Longitudinal Profile Leveling and Centerline Survey
- Topographic Survey
- Bathymetric Survey for the Padma River Section

ii) Coordinates System and Datum Level

The local coordinates system was adopted and was related to the coordinates system of the relative civil construction project and existing road.

The datum level also was related to the hydrological data, which is used to analyze the high water level for the bridges of this project.

The horizontal and vertical control data in the vicinity of the proposed bridge crossing was collected from the Survey of Bangladesh (SOB).

The survey charts have been prepared on Bangladesh Transverse Mercator (BTM) Projection. The parameters used for conversion of WGS-84 data into BTM coordinates are as shown in Appendix-3.

iii) Topographic Survey

The topographic Survey was carried out for a 100m wide strip along the proposed line. The topographic Survey was carried out with reference to traverse stations established earlier. All details were picked up such as Landmarks, structures and topographic features such as houses, buildings, bridges, culverts, electricity poles, telephone poles, land use boundaries, water courses, road shoulders edges, pavement edge, rails, ponds, rivers, embankments, depressions and spot heights etc.

iv) Bathymetric Survey

For position fixing, a Differential Global Positioning System (DGPS) was used, the data was received from satellites in World Geodetic System- 84 (WGS-84) and transmitted differential corrections from the Reference Station. The position fixing on the cross-section line was done by mobile GPS set on board the Survey boat and radio link that receives positional data from the satellites and corrections from the Reference Station. The WGS-84 data received at the mobile GPS set onboard and at the Reference Station ashore were converted (on line) into Bangladesh Transverse Mercator (BTM) co-ordinates by using hydro software.

The positions and depths on the cross section were obtained simultaneously by GPS Receiver and Echo Sounder fitted on board the survey boat.

The positional and the sounding data collected were backed up on a floppy, which was subsequently brought to the office for processing purposes.

The soundings were taken for the proposed line at an interval of 50m and measurements of depths/soundings on the line were made by using an MS-26 Echo Sounder. The depths/soundings shown on the charts are reduced to PWD level in the area. Therefore, in order to know the actual depth at any spot of the chart the following calculation was done.

Actual depth at any spot of the chart = Water Level (from the gauge) + Reduced depth

The level of tide was also recorded with appropriate time intervals and used for correction for the depth reading.

(e) Result of Topographic and Bathymetric Surveys

The quantities of activities which have been done in each study area are shown in the following table.

Table 3.3.4 Quantities of Activities for Each Study Area

Paturia – Goalundo

	Control Points (pts)	Longitudinal Profile Leveling (km)	Topographic Survey (ha)	Bathymetric Survey (km)
Left Bank Side	2	9.2	20	
Right Bank Side	2	3.5	20	
In the River				5.3
Total	4	12.7	40	5.3

Mawa – Janjira

	Control Points (pts)	Longitudinal Profile Leveling (km)	Topographic Survey (ha)	Bathymetric Survey (km)
Left Bank Side	2	6.7	67	
Right Bank Side	3	12.8	128	
In the River				5.6
Total	5	19.5	195	5.6

All topographic survey data were properly processed by using SDR Mapping & Design; and Bathymetric Survey Data was processed by Hydro Pac software output by Auto CAD 2002 format. The survey drawings were made to scale H 1:1000 & V 1:200.

(2) Geotechnical Characteristics

(a) General

The geotechnical studies and Investigations for the feasibility study of Padma Bridge were carried out for the following purposes:

1) Investigation for bridges
   To provide the design engineers with information on the engineering properties of the natural soils, which will permit the determination of the foundation type and foundation structure.
2) Investigation for approach roads
   To provide the design engineers with information on the foundation of minor bridges over channels and embankment for approach roads.

The geotechnical investigation consists of core drilling, Standard Penetration Tests, Pressure meter Tests, laboratory tests for soils and laboratory tests for groundwater for bridges and approach roads at the Mawa Janjira and Paturia Goalundo sites.

(b) Outline of Geotechnical Investigation

The geotechnical investigation consists of core drilling, Standard Penetration Tests, Lateral Loading Tests, undisturbed soil sampling, groundwater sampling, laboratory tests for soils and laboratory tests for groundwater at both the Mawa Janjira site and the Paturia Goalundo site.

At the Mawa Janjira site, four boreholes were conducted. A 40m deep borehole (JMBH1) and a 120m deep borehole (JMBH2) were drilled on the left bank. On the right bank, a 40m deep borehole (JMBH4) and a 120m deep borehole (JMBH3) were drilled. At the Paturia Goalundo site, four boreholes were also conducted. A 40m deep borehole (PDBH1) and a 103m deep borehole (PDBH2) were drilled on the left bank. On the right bank, a 57m deep borehole (PDBH4) and a 120m deep borehole (PDBH3) were drilled. The locations of the boreholes are shown in Figures 3.3.8 and 3.3.9.

The Standard Penetration Tests and Split-Barrel Sampling of soils (ASTM D 1586) were carried out at an interval of one meter and disturbed sampling was conducted for laboratory tests.

The Lateral Loading Test was conducted in four boreholes, comprising three depths at JMBH2, five depths at JMBH3, four depths at PDBH2 and four depths at PDBH3.

For cohesive soils, undisturbed samples were taken for laboratory tests using a thin wall sampling tube.

Sampling of groundwater was taken after 24 hours from the drilled boreholes for investigating the groundwater quality.

Laboratory tests for soil consist of natural water content, specific gravity, unit weight, Atterberg limit, grain size analysis, triaxial compression test, consolidation test, mica content, pH, total sulfate content, soluble sulfate content and total chloride content.

On the other hand, laboratory tests for groundwater consist of pH, sulfate content and chloride content.

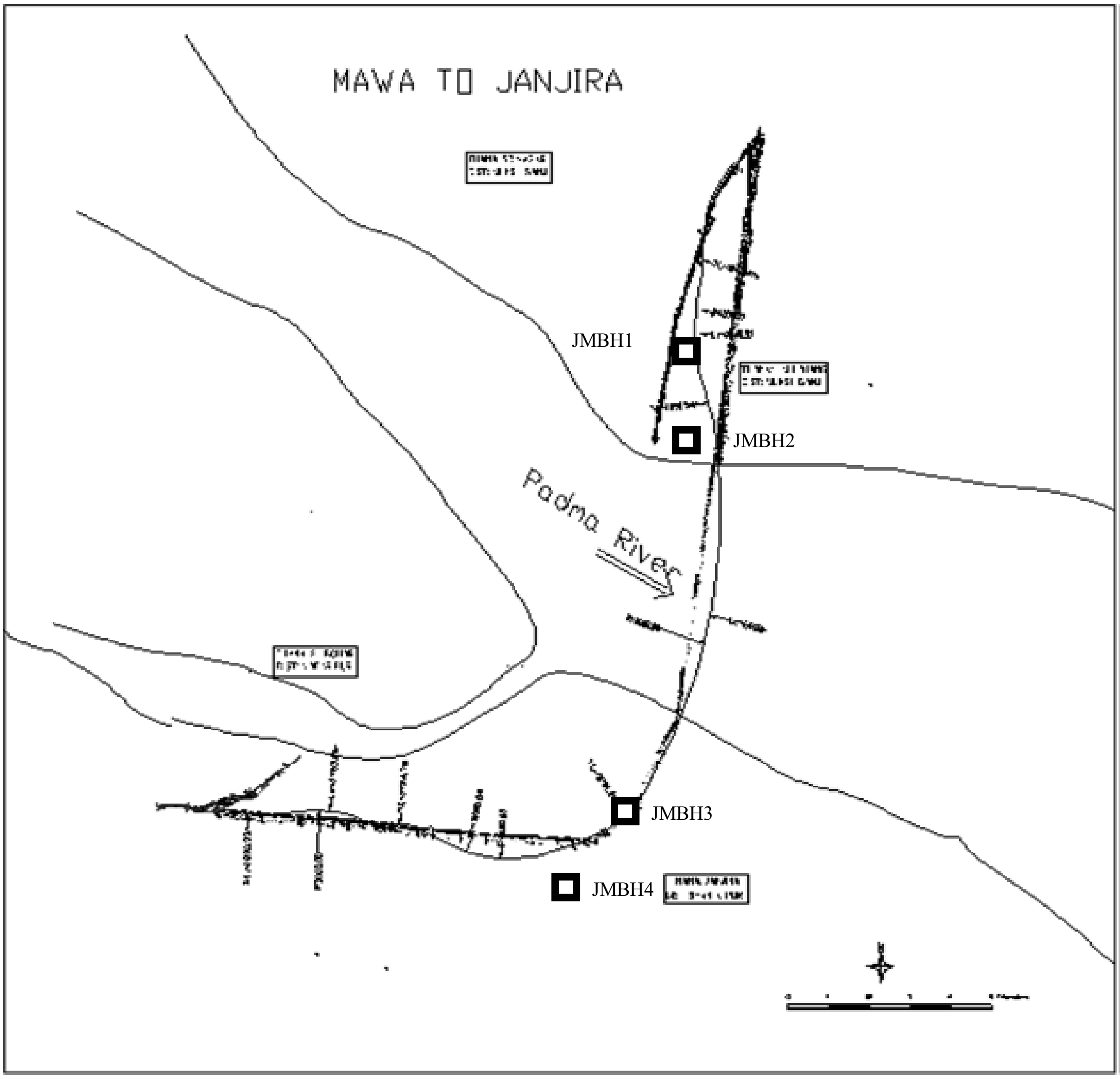


Figure 3.3.8 Location Map of Boreholes (Mawa – Janjira site)

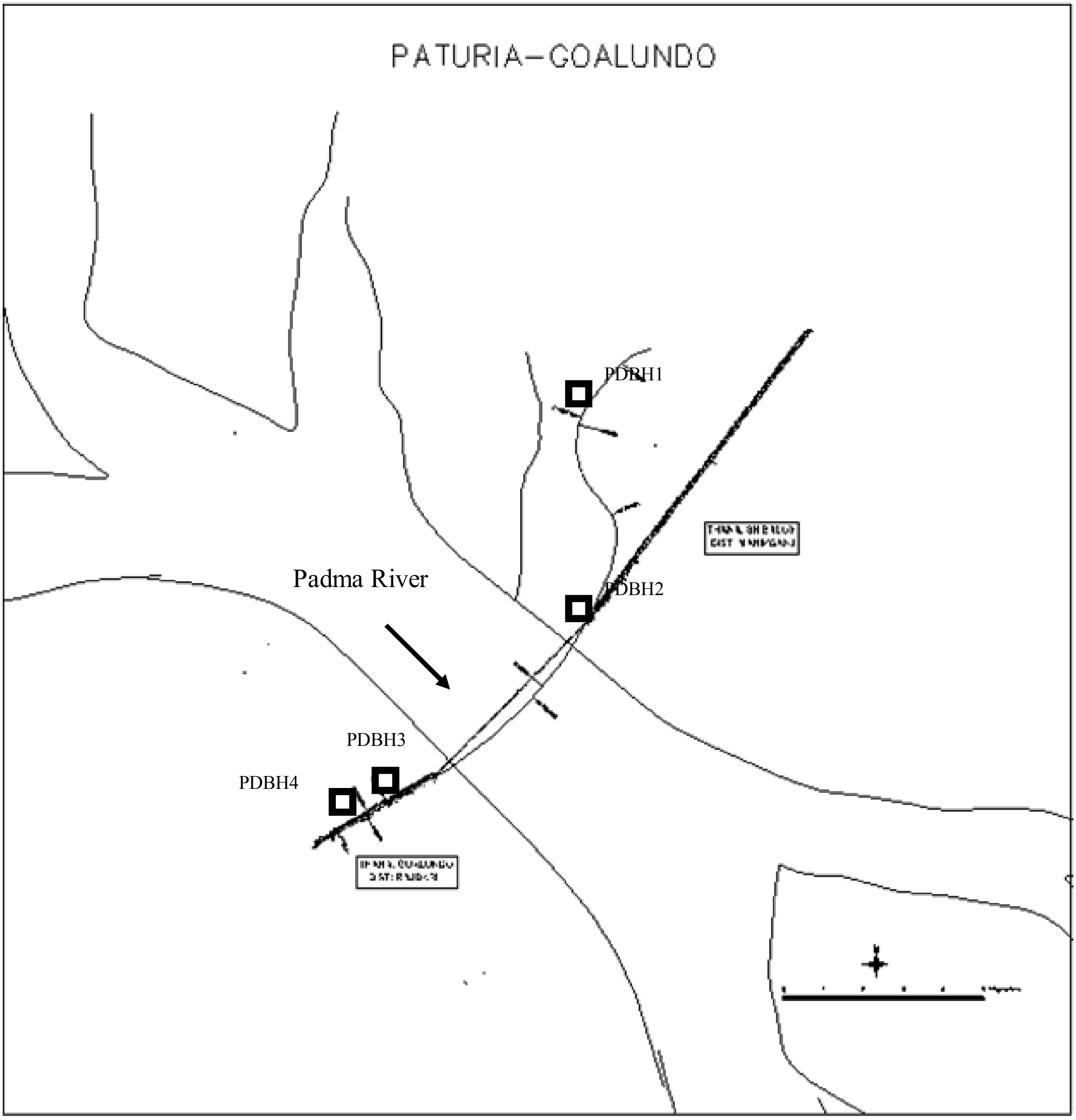


Figure 3.3.9 Location Map of Boreholes (Paturia – Goalundo site)

(c) Ground Conditions

Geological Profile

The following chronological and stratigraphical classification was used for drawing the geological profiles of Mawa Janjira site and Paturia Goalundo site. Based on the results of grain size analysis, the following classification is proposed:

Stratum	Criteria
Unit-1a	Clay + Silt ≥ 50%
Unit-1b	20% ≤ Clay + Silt < 50%
Unit-2	Clay + Silt < 20% and Medium Sand < 10%
Unit-3	Clay + Silt < 20% and Medium Sand ≥ 10%

Gradation curves of each stratum are shown in Figure 3.3.10. From these gradation curves, each stratum can be characterized as follows:

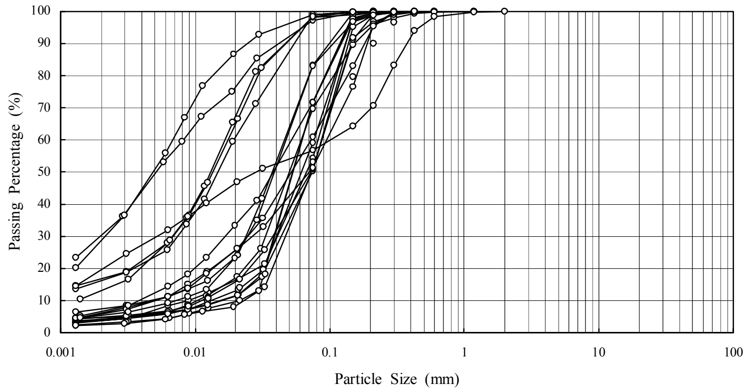
Stratum	Description
Unit-1a	CLAY or SILT with fine sand
Unit-1b	very silty fine SAND
Unit-2	silty fine SAND
Unit-3	slightly silty fine and medium SAND

As the gradation curve of Unit-2 is steep and the uniformity coefficient is very small, the soil of Unit-2 is evaluated to be poorly graded. Therefore, the soil of Unit-2 is estimated to be looser than that of Unit-1b and Unit-3.

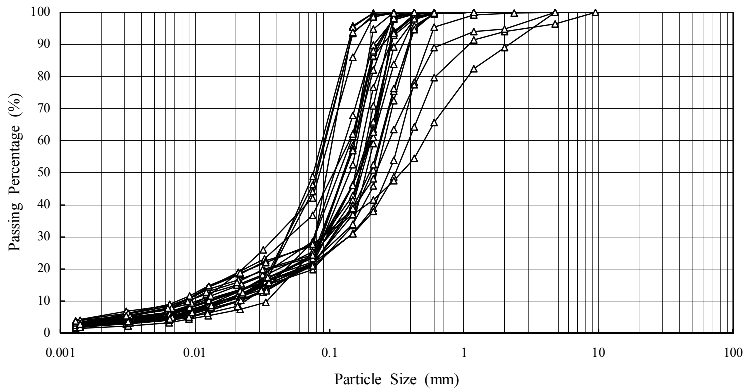
Geological profiles of Mawa Janjira site and Paturia Goalundo site are shown in Figures 3.3.11 and 3.3.12 respectively. These geological profiles are drawn up, based on the results of grain size analysis and visual observation of the disturbed split spoon samples obtained from the Standard Penetration Tests.

Based on the result of drilling JMBH1 and JMBH2 on the left bank at Mawa Janjira site, Unit-1a was found in the upper part to El. -10.293m ~ -15.397m, CLAY or SILT with fine sand. In the lower part below Unit-1a, Unit-1b was found, very silty fine SAND. At the borehole site of JMBH2, Unit-2 lies between Unit-1a and Unit-1b from El. -10.293m to El. -19.293m, silty fine SAND.

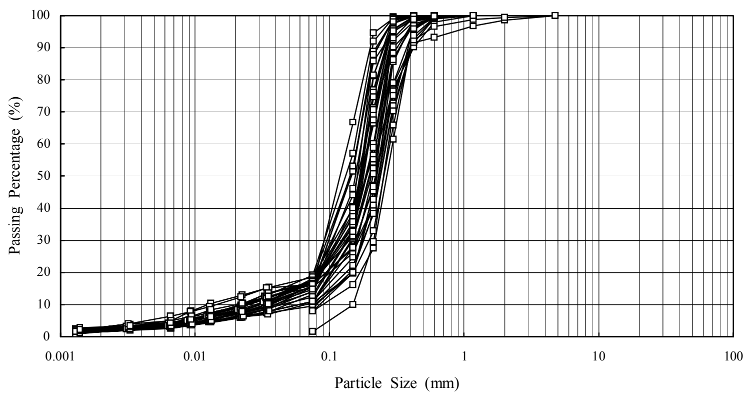
(Unit – 1a)



(Unit – 1b)



(Unit – 2)



(Unit – 3)

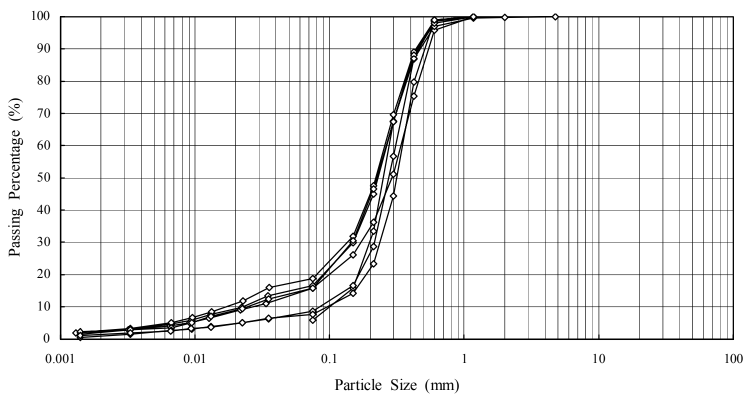


Figure 3.3.10 Gradation Curves of Each Stratum

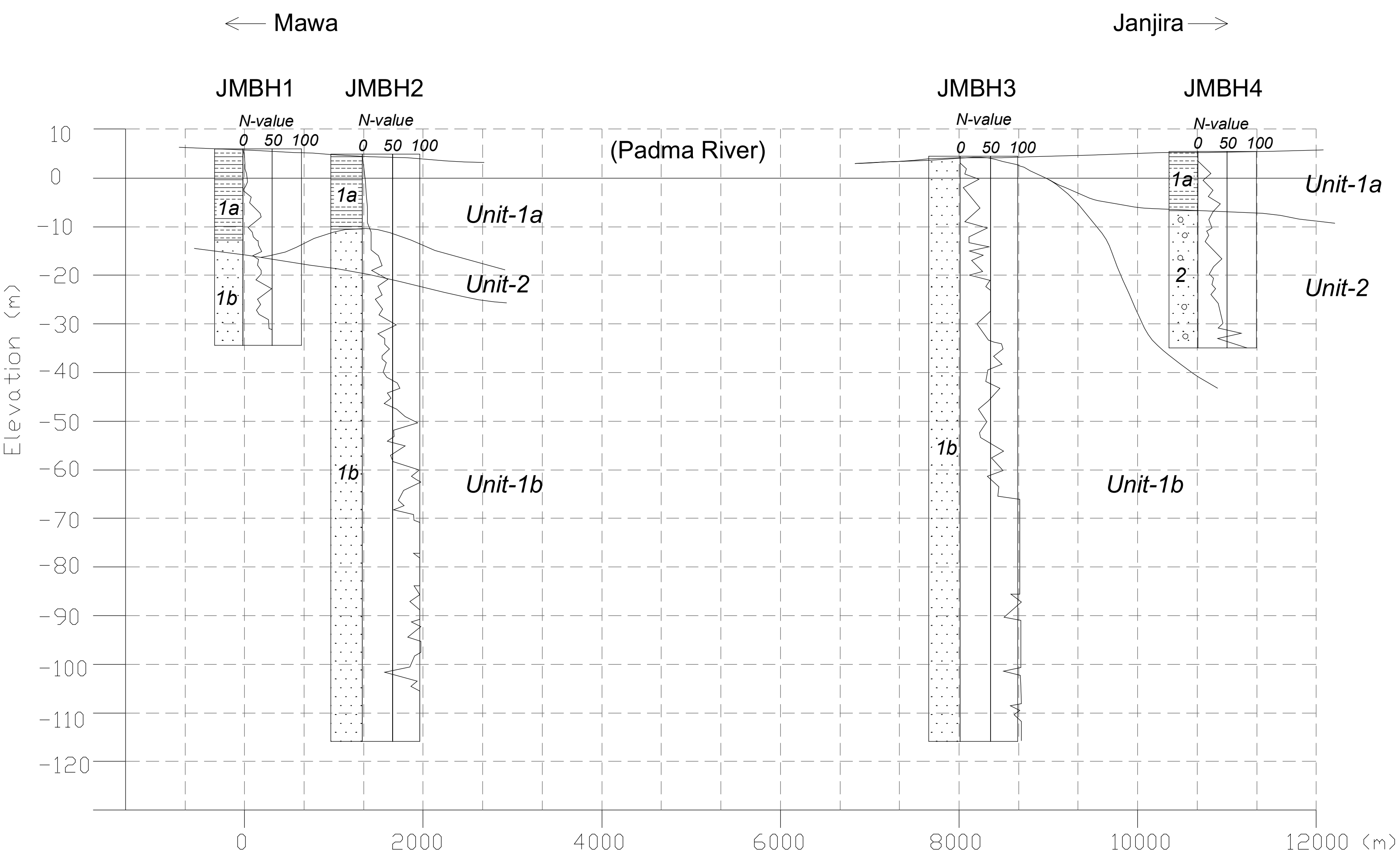


Figure 3.3.11 Geological Profile (Mawa Janjira site)

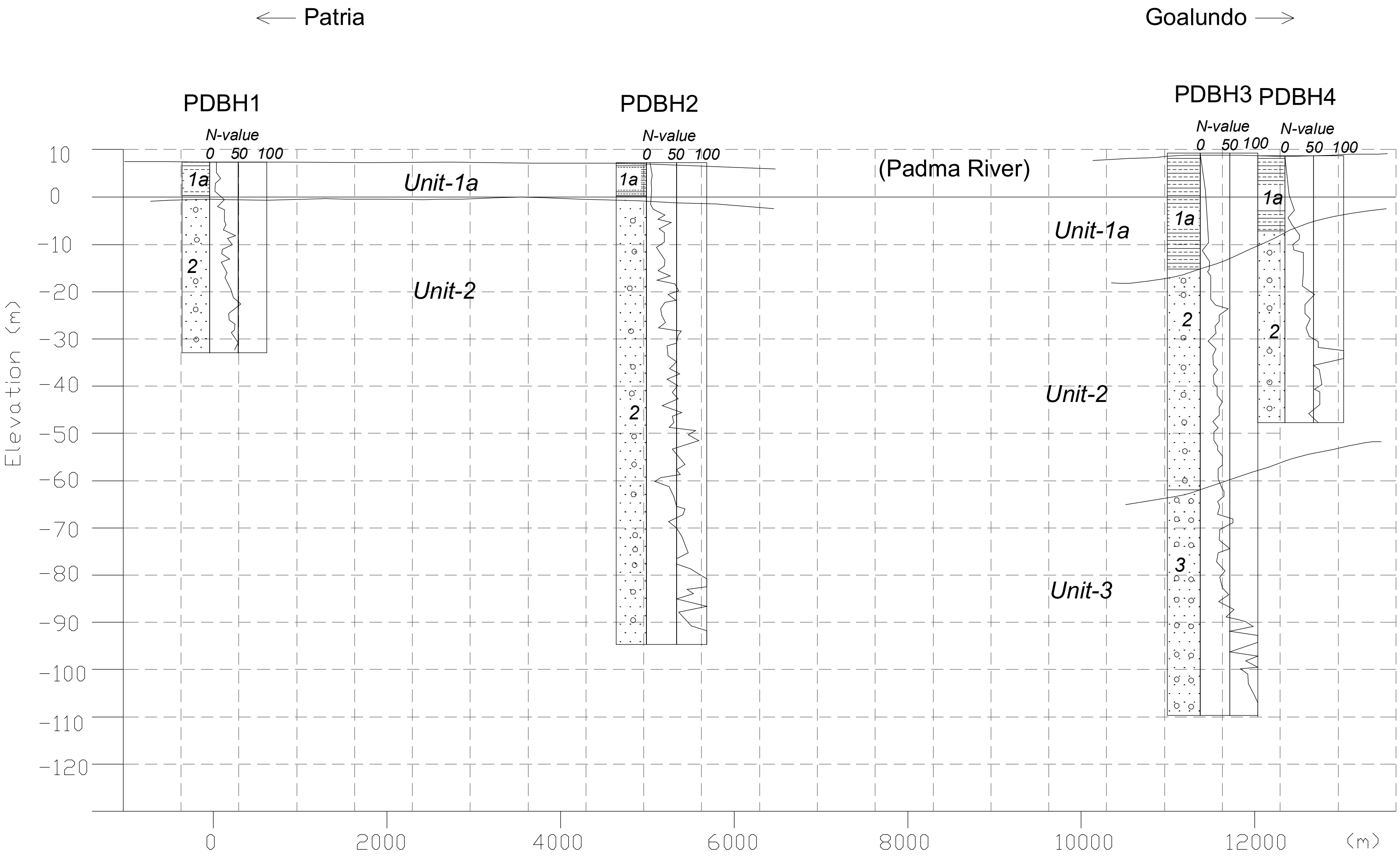


Figure 3.3.12 Geological Profile (Paturia Goalundo site)

On the right bank at Mawa Janjira site, at the borehole site of JMBH3, Unit-1b was found from the ground surface through 120m in depth, very silty fine SAND. On the other hand, at the borehole site of JMBH4, Unit-1a was found in the upper part to El. -6.496m, CLAY or SILT with fine sand. In the lower part, Unit-2 was found, silty fine SAND.

Based on the result of drilling PDBH1 and PDBH2 on the left bank at Paturia Goalundo site, Unit-1a was found in the upper part to El. -0.595m ~ -0.847m, CLAY or SILT with fine sand. In the lower part below Unit-1a, Unit-2 was found, silty fine SAND.

On the right bank, based on the result of drilling PDBH3 and PDBH4, Unit-1a was found in the upper part to El. -7.199m ~ -15.752m, CLAY or SILT with fine sand. In the middle part, Unit-2 was found, silty fine SAND. In the lower part, Unit-3 was found below El. -62.752m, slightly silty fine and medium SAND.

There is a remarkable difference of geological profile between Mawa Janjira site and Paturia Goalundo site, that is, Unit-1b predominates at Mawa Janjira site while Unit-2 predominates at Paturia Goalundo site.

(d) N-value

The Standard Penetration Test was carried out at an interval of one meter for the full depth of each borehole. The measured N-values have a problem because blow energy has losses on the way to the bed in very deep holes, which produces imperfect results.

A number of study results have been provided by Terzaghi - Peck (1948), Ikeda (1959), Thornburn (1963), Uto (1974) and others on the correction of such measured N-values.

In this study, considering that the highest is the loss of blow energy caused on its transmission to the bottom of a bore, the loss-error of the measured N-value was corrected by the formula of Uto (1974). That is the way the corrected N-values were evaluated for the comparison between Mawa Janjira site and Paturia Goalundo site, and the proposal of design value.

The following formula (Uto, 1974) was applied for N-value correction:

$N = N'$ $(L < 20m)$

$N = (1.06 - 0.003 \times L) \times N'$ $(L \geq 20m)$

where,

N: corrected N-value

N': measured N-value

L: length of drill rods (m)

The distributions of corrected N-value at Mawa Janjira site and Paturia Goalundo site are shown in Appendix-4. Further, lower design line and average design line of corrected N-value distribution are proposed for design of the bridge substructure at both sites. At Mawa Janjira site, there is no marked difference between the left bank and the right bank. On the other hand, at Paturia Goalundo site, there is some difference between the left bank and the right bank below El. -40m. In a word, the N-value on the left bank is larger than that on the right bank below El. -40m.

The comparison of corrected N-values between Mawa Janjira site and Paturia Goalundo site is shown in Figure 3.3.13. It is clear that there is a remarkable difference between Mawa Janjira site and Paturia Goalundo site below El. -40m. In short, the N-value at Mawa Janjira site is much larger than that at Paturia Goalundo site below El. -40m. However, there is not a clear difference from the surface to El. -40m.

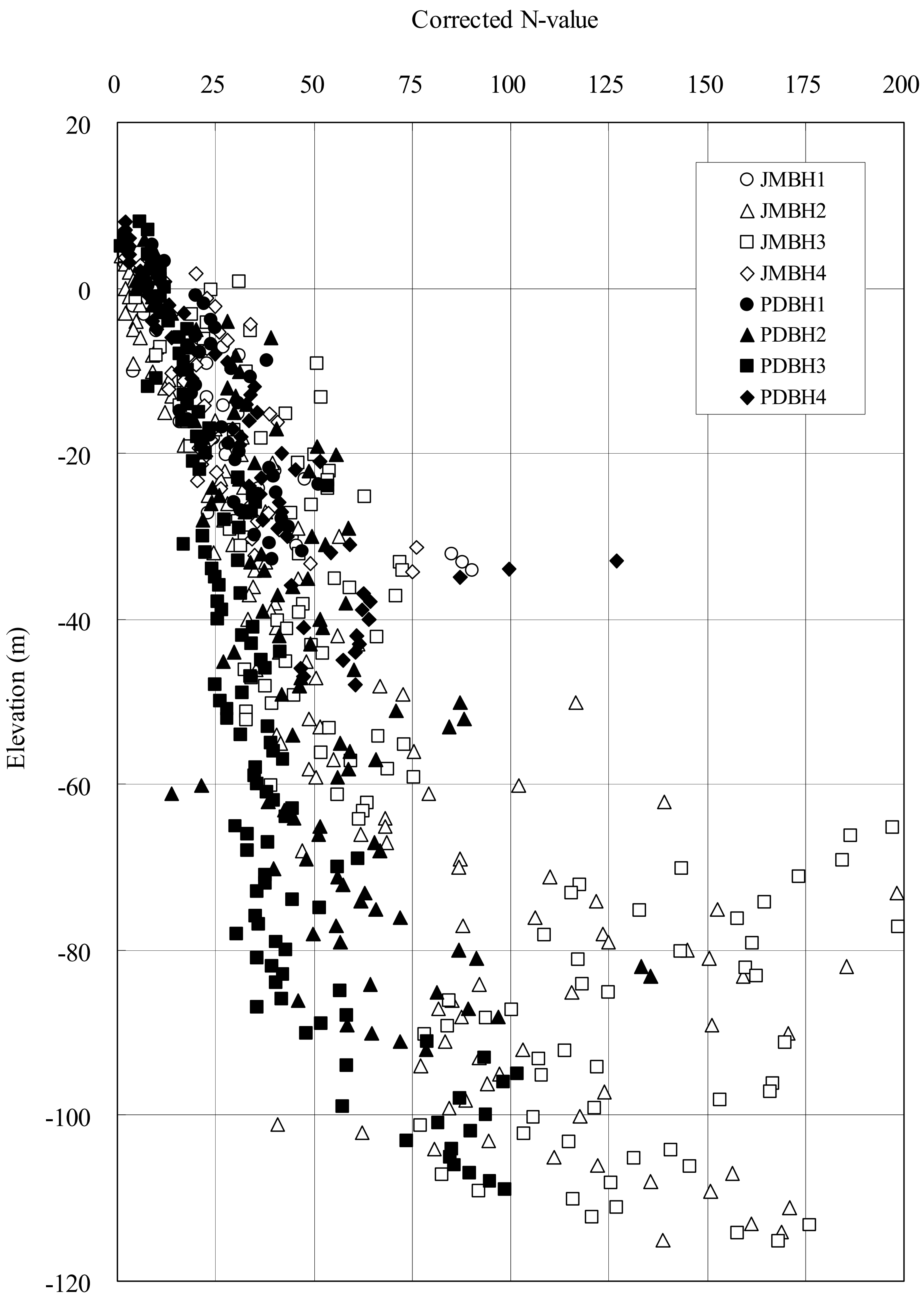


Figure 3.3.13 Comparison of Corrected N-value between Mawa-Janjira site and Paturia - Goalundo site

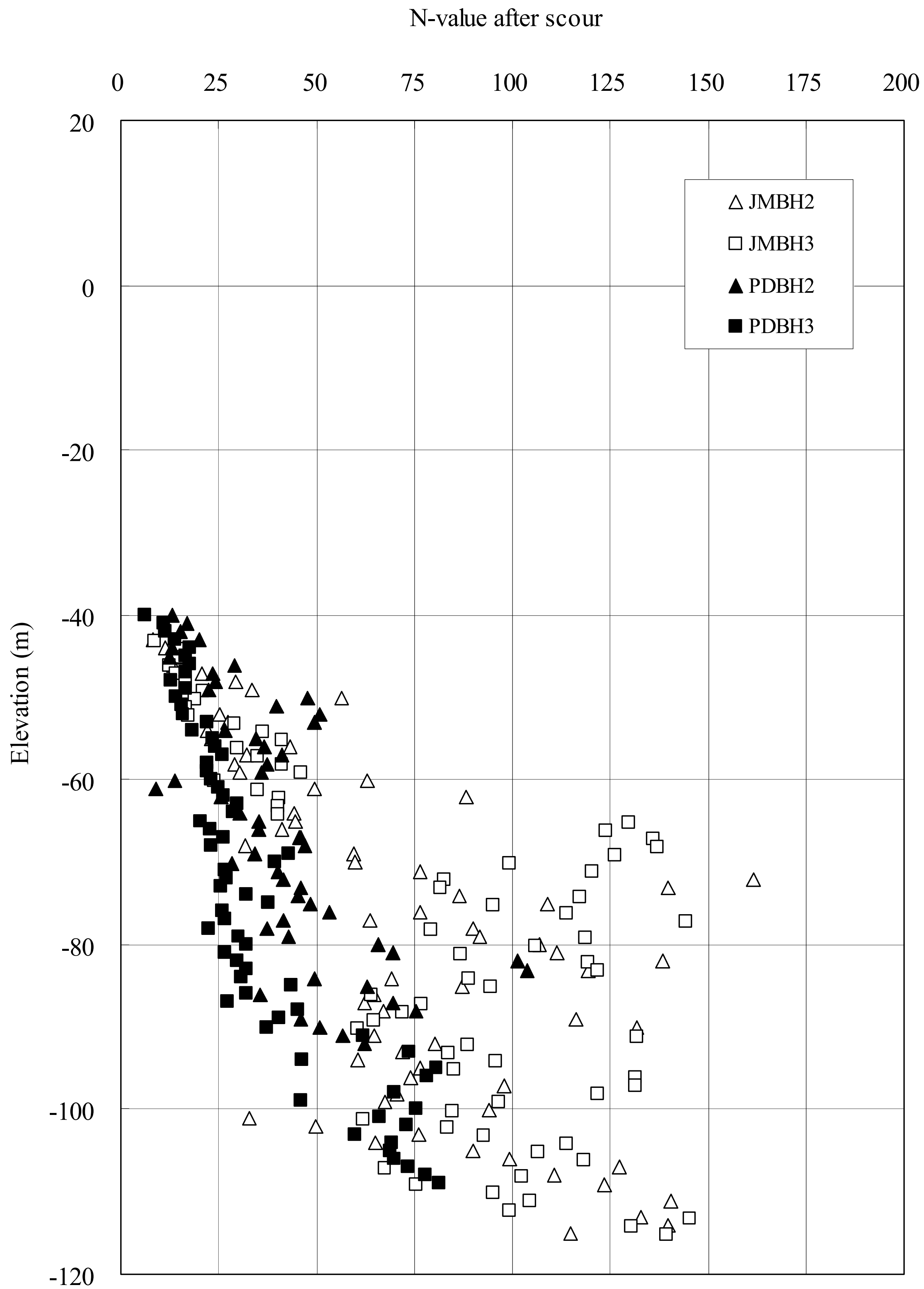


Figure 3.3.14 Comparison of N-value after Scour between Mawa-Janjira site and Paturia-Goalundo site

(e) Results of Lateral Loading Test

To determine the lateral reaction of soil, there are several methods as follows:

1) empirical calculation from N-value,
2) measurement by loading on bore wall with rubber tube,
3) measurement by plate load test, and
4) measurement with test pile.

For the rubber tube method 2), the DOKEN (Public Works Research Institute under the government of Japan) system, the lateral loading test system and the pressio-meter system are generally used in Japan. In this study, the lateral loading test was adopted.

The results of lateral loading test are Appendix-4. Based on the above test results, the correlation between corrected N-value and modulus of elasticity (Em) obtained from lateral loading test is shown in Figure 3.3.15. There is a definite tendency that Em is increasing gradually with an increase of N-value. From the above tendency, the formula of N to Em relation, Em = 4.52 N, was obtained for the design of substructure.

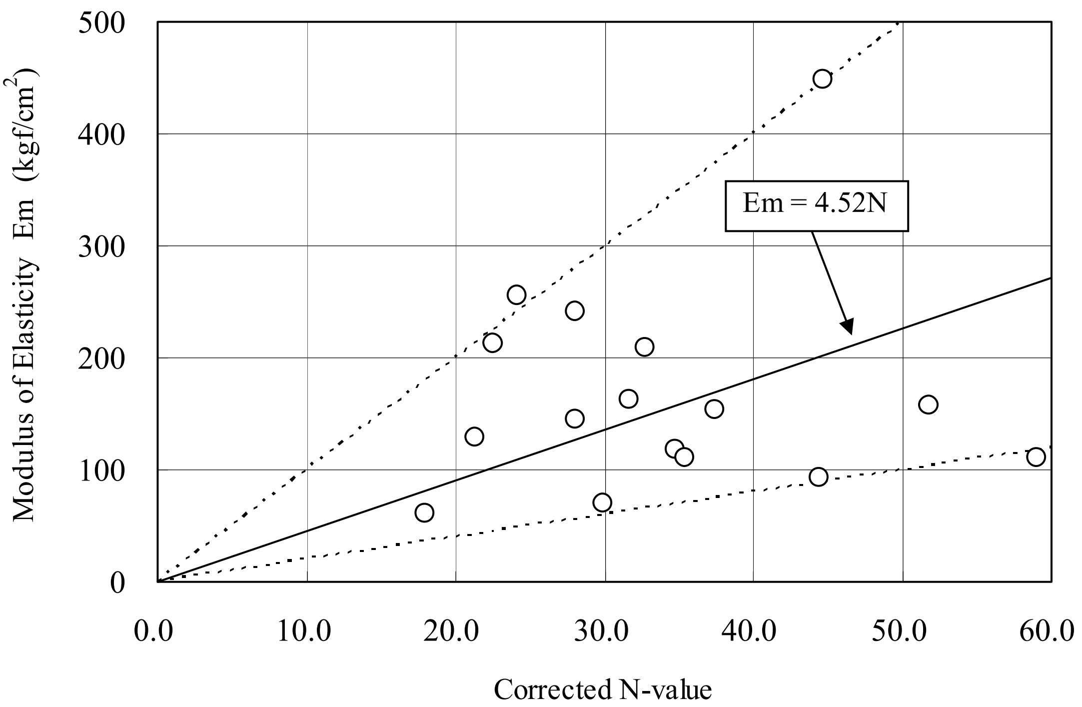


Figure 3.3.15 Correlation between N-value and Modulus of elasticity

(f) Results of Laboratory Test

i) Chemical Properties of Soil Samples

Chemical property tests consisting of mica content, pH, total chloride content, soluble sulfate content and total sulfate content were carried out employing the SPT samples.

The results of chemical property tests are summarized in Appendix-4.

Reported mica content ranges widely from 3.5% to 66.6%. However, the mica proportions reported for JMBH1, JMBH4 and PDBH1 are judged to be much too large according to the visual observation and the previous investigation. Therefore, mica content is evaluated to range from 3.5 to 17.2%. In Jamuna Bridge Project, it is reported that some flow sliding occurred during excavation works for guide bund foundation of which the soil contains some mica. Judging from these failure accidents, also in Padma Bridge Project, great attention needs to be paid to excavation works for guide bund construction.

The value of pH ranges from 6.9 to 8.4 and the soil is nearly neutral.

Total chloride content, soluble sulfate content and total sulfate content range from 0.0238 to 0.0341%, from 0.0120 to 0.0170% and from 0.1114 to 0.1749% respectively.

ii) Chemical Properties of Groundwater

Chemical property test results of groundwater are summarized in Appendix-4. Chemical properties of groundwater consist of pH, chloride content and sulfate content.

The value of pH ranges from 7.0 to 8.9 and the groundwater is nearly neutral. Chloride content and sulfate content range from 11.0 to 275.0 mg/L and from 1.0 to 125.0 mg/L respectively.

(g) Laboratory Test Results of Undisturbed Samples

Laboratory tests consisting of natural water content, specific gravity, grain size analysis, Atterberg limit, triaxial compression test and consolidation were carried out employing undisturbed samples.

The laboratory test results of undisturbed samples are in Appendix-4.

The shear strength of cohesion and internal friction angle is 30.0 kN/m^2 and 15.8 degrees at Mawa Janjira site. On the other hand, the shear strength of cohesion and internal friction angle is 26.0 kN/m^2 and 14.6 degrees at Paturia Goalundo site.

Compression index (Cc) ranges from 0.081 to 0.642 and is characteristic of silt soil.

(h) Design Values

Table 3.3.5 Estimated Parameters from N-value

Stratum			Unit - 1a	Unit - 1b	Unit - 2	Unit - 3
N-value			11	49	39	58
Saturated Density	γt (tf/m³)		-	-	-	-
Submerged Density	γsub (tf/m³)		-	-	-	-
Strength Parameter						
Cohesion	C (tf/m²)	*1	11.0	0	0	0
Internal Friction Angle	ϕ (degree)	*2	0	42	39	44
Modulus of Elasticity	Em (kgf/cm²)	*3	50	221	176	262

*1: Cu = N for Unit - 1a and Cu = 0 for Unit - 1b, 2 and 3

*2: f = 0 for Unit - 1a and f = 15 + $\sqrt{15N}$ for Unit - 1b, 2 and 3

*3: Em = 4.52N

Table 3.3.6 Proposed Design Values

Stratum		Unit - 1a	Unit - 1b	Unit - 2	Unit - 3
N-value		11	49	39	58
Saturated Density	γt (tf/m³)	1.80	1.95	1.90	2.00
Submerged Density	γsub (tf/m³)	0.80	0.95	0.90	1.00
Strength Parameter					
Cohesion	C (tf/m²)	11.0	0	0	0
Internal Friction Angle	ϕ (degree)	0	38	35	40
Modulus of Elasticity	Em (kgf/cm²)	50	220	170	260

(i) Liquefaction Potential Analysis

Liquefaction potential has been evaluated using the Seed method (ref. Seed and Idriss, 1971) and the Iwasaki method (ref. Iwasaki and Tatsuoka, 1978). The method consists of evaluating the cyclic stress ratio (L) in an element of soil resulting from an earthquake acceleration and comparing it with the cyclic resistance ratio (R). The liquefaction resistance (F_L) is defined as $F_L = R / L$. If F_L is less than 1.0, liquefaction may occur.

The liquefaction resistance (F_L) is conventionally determined from the following:

$$F_L = R / L$$
$$R = R_1 + R_2 + R_3$$
$$L = 0.65 \times \alpha_{max} \times \gamma d \times \sigma v / \sigma v'$$
$$R_1 = 0.0882 \times \sqrt{\frac{N}{\sigma v' + 0.7}}$$

$R_2 = 0.19$ $(0.02mm \le D_{50} \le 0.05mm)$

$0.225 \times \log_{10}(0.35 / D_{50})$ $(0.05mm < D_{50} \le 0.6mm)$

-0.05 $(0.6mm < D_{50} \le 2.0mm)$

$R3 = 0.0$ $(0\% \leq FC \leq 40\%)$
$0.004 \times FC - 0.16$ $(40\% < FC \leq 100\%)$
$\gamma d = 1.0 - 0.015x$
where,
- F_L: liquefaction resistance
- R: cyclic resistance ratio
- L: cyclic stress ratio
- α_{max}: maximum horizontal acceleration coefficient
- γd: stress reduction coefficient
- σv: total vertical stress (tf/m^2)
- $\sigma v'$: effective vertical stress (tf/m^2)
- N: N-value
- D_{50}: diameter at which 50% of the soil is finer (mm)
- FC: fine particle content (%)
- x: depth (m)

The estimated maximum horizontal accelerations for the bridge design have been assessed at 0.125g at Mawa Janjira site and 0.15g at Paturia Goalundo site in pre-feasibility study of Padma Bridge, 2000. Therefore, the above maximum horizontal accelerations were adopted for the liquefaction potential analysis in this study.

The liquefaction potential analysis was carried out on four borehole sections of JMBH2, JMBH3, PDBH2 and PDBH3 in two cases of before scour and after scour.

The results of liquefaction potential analysis are shown in Appendix-4. As a result of analysis, the following conclusions have been obtained:

1) At Mawa Janjira site of JMBH2 and JMBH3, there is no potential for liquefaction both in cases of before scour and after scour.
2) At Paturia Goalundo site of PDBH2 and PDBH3, there is some potential for liquefaction in some depths both in cases of before scour and after scour. As a result of the above analysis, some countermeasures against liquefaction are judged to be needed for guide bund and bridge substructure at Paturia Goalundo site.

(j) Conclusions and Recommendations

As a result of geotechnical investigation, the following are concluded and recommended for the design of bridge substructure.

- The classification of four strata consisting of Unit-1a, 1b, 2 and 3 was recommended for drawing the geological profiles of Mawa Janjira site and Paturia Goalundo site.
- As the gradation curve of Unit-2 is steep and the uniformity coefficient is very small, the soil of Unit-2 is evaluated to be poorly graded and estimated to be looser than that of Unit-1b and Unit-3.
- There is a remarkable difference of geological profile between Mawa Janjira site and Paturia Goalundo site, that is, Unit-1b predominates at Mawa Janjira site while Unit-2 predominates at Paturia Goalundo site.
- N-value at Mawa Janjira site is much larger than that at Paturia Goalundo site below El. -40m.
- N-value after scour at Mawa Janjira site is much larger than that at Paturia Goalundo site.
- The mean N-value of Unit-2 is lower than that of Unit-1b and Unit-3, because the soil of Unit-2 is poorly graded and is estimated to be looser than that of Unit-1b and Unit-3.
- There is a definite tendency that Em is increasing gradually with an increase of N-value.

From the above tendency, the formula of N to Em relation, Em = 4.52 N, was obtained for the design of substructure.

- The reported mica content ranges widely from 3.5 to 66.6 %. However, the proportions of mica reported for JMBH1, JMBH4 and PDBH1 are judged to be much too large according to the visual observation and the previous investigation. Therefore, mica content is evaluated to range from 3.5% to 17.2 %. In the Jamuna Bridge Project, it is reported that some flow sliding occurred during excavation works for guide bund foundation of which the soil contains some mica. Judging from these failure accidents, also in Padma Bridge Project, great attention needs to be paid to excavation works for guide bund construction.
- The proposed design values are summarized below.

Stratum		Unit - 1a	Unit - 1b	Unit - 2	Unit - 3
N-value		11	49	39	58
Saturated Density	γt (tf/m^3)	1.80	1.95	1.90	2.00
Submerged Density	γsub (tf/m^3)	0.80	0.95	0.90	1.00
Strength Parameter					
Cohesion	C (tf/m^2)	11.0	0	0	0
Internal Friction Angle	ϕ (degree)	0	38	35	40
Modulus of Elasticity	Em (kgf/cm^2)	50	220	170	260

- The above design values of ϕ are proposed by reducing the estimated values a little in consideration of the effect of mica content to the shear strength of sand. In the next step, therefore, it is recommended that the relationship between mica content and shear strength of sand shall be investigated in detail by means of laboratory testing.
- At Mawa Janjira site of JMBH2 and JMBH3, there is no potential for liquefaction both in cases of before scour and after scour.
- At Paturia Goalundo site of PDBH2 and PDBH3, there is some potential for liquefaction at some depths both in cases of before scour and after scour. As a result of the above analysis, some countermeasures against liquefaction are judged to be needed for guide bund and bridge substructures at the Paturia Goalundo site.

3.3.3 Initial Studies on River Facilities, Bridge and Highways

3.3.3.1 Initial Studies on River Facilities

(1) Principles for Facility Plan

River works were planned and designed preliminarily for Paturia-Goalundo site (PG-site) and Mawa-Janjira site (M-J site) for the selection of an optimum crossing site for Padma Bridge. The following considerations and principles were introduced for the planning and preliminary design of the river works in consideration of the purpose of the present study:

Large Scale River Shifting: Considering the active river shifting in the past, the possibility of large scale changes such as activation of the Old Brahmaputra River and northeastward transmigration of the Padma River cannot be denied. Such large scale changes, however, would progress gradually for a long time far beyond the project life of the bridge. The bridge plan under consideration will not handle the issue of large scale river shifting, and the study will focus on crossing the Padma River under the present condition.

Stable Riverbank: The left bank of the Padma River is relatively stable as a whole. Especially near Paturia and Mawa, the left bank has been markedly stable at least in these past 78 years. According to the investigation on the erodibility of the riverbank, the left banks at the proposed crossing locations were evaluated as relatively erosion resistant with annual erosion rates ranging from 0 to 15 m/year, consisting of relatively old geological formations made of silty and clayey soil. The stable or less erodible left river bank near the alternative crossing locations can be effectively used for the river works.

Waterway Opening: In order to maintain the present river regime of the Padma at the crossing locations, it is desirable to keep the waterway opening at least 4.7 km wide for PG-site and 4.4 km wide for MJ-site, assuming Lacey's coefficient C = 12 (m-sec units). It should also be considered that the bridge abutments and river works for them are to be located on the riverbanks owing to the difficulty in execution of reliable works in the river flows.

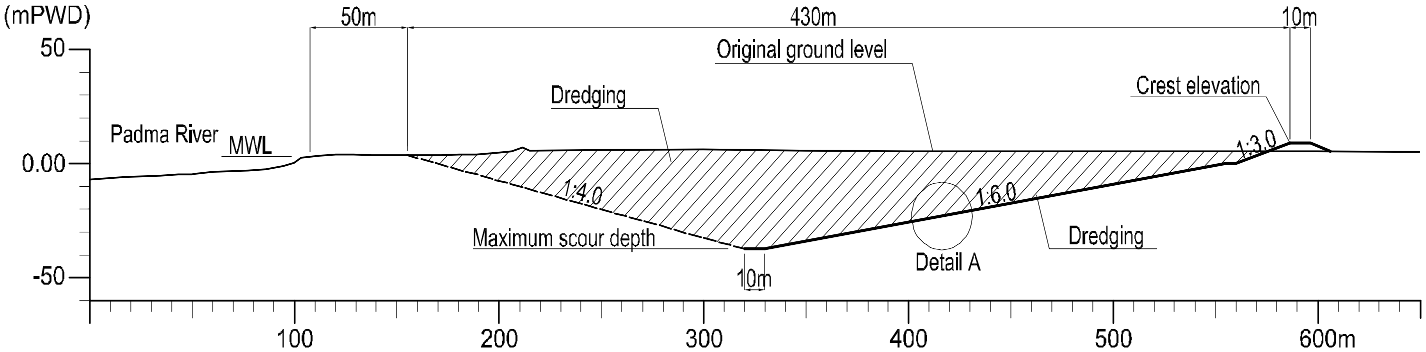
River Works: Guide bund works (GBW), abutment protection works (APW) and bank protection works (BPW) are considered as major river works for the alternative study of the crossing location. The GBW aims to guide river flow to the bridge opening and to protect bridge abutments and approach roads from erosion. The APW aim to protect the bridge abutment from erosion. The BPW aim to ensure the function of the GBW and APW by protecting riverbank from erosion and maintaining present flow conditions around the crossing location of the bridge.

(2) Design Criteria for River Works

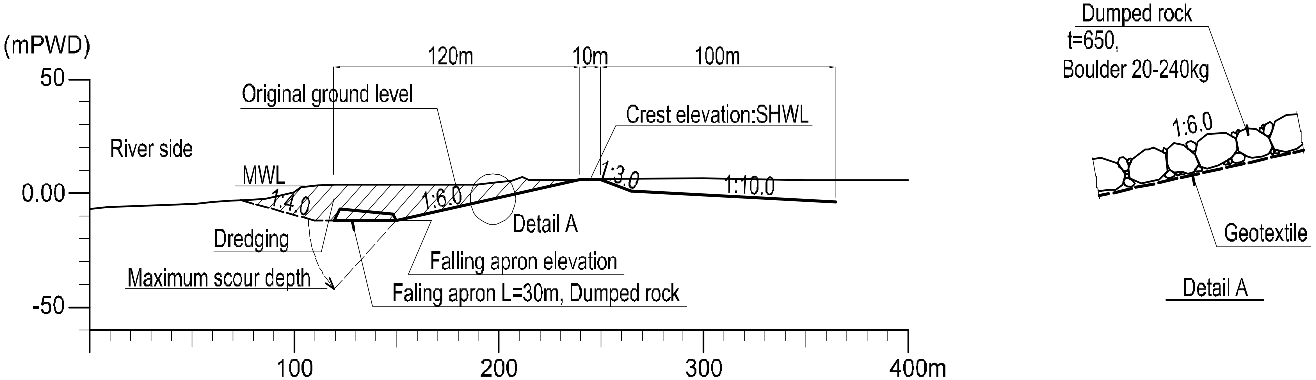
Besides, with the principles set forth in the above, design standards and criteria applied to previous works were reviewed and major bridge sites in Bangladesh were visited to see the actual situation of the river works for bridges. Technical standards for the river works in Bangladesh and India were also reviewed. The river works for PG-site and MJ-site were preliminarily designed based on the following criteria, applying the results of the reviews, among others the standards and practice introduced for Jamuna Multipurpose Bridge Project and Pre-feasibility study of the Padma Bridge. Typical sections of river works for the alternative study are shown in Figure 3.3.16.

Guide bund

		Patria-Goalundo	Mawa-Janjira
Crest elevation	(mPWD)	11.22(=9.72+1.50)	8.85(=7.35+1.50)
Maximum scour depth	(mPWD)	-33.8	-37.5
Original ground level	(mPWD)	8	6



Bank protection



		Patria-Goalundo	Mawa-Janjira	Remarks
Crest elevation(SHWL)	(mPWD)	7.94	5.81	SHWL:Standard High Water Level
Mean Watel Level(MWL)	(mPWD)	4.21	3.02	
Falling apron elevation	(mPWD)	-11	-12	MWL-15

Figure 3.3.16 Typical Section of River Works

(a) Guide Bund Works (GBW):

- Length: 3,200 m based on Gale's empirical relation considering the head and tail loops
- Crest elevation: DHWL (Design High Water Level) + 1.50m (Free board)
- Crest width: 10 m, considering the transportation of materials for construction and maintenance.
- Slope = 1:6.0, following the designs of Jamuna bridge and other existing works
- Toe elevation: Maximum scour depth of the Padma River
- Material: Dumped rock and boulders (20-240 kg)
- Construction method: Works on bank and in stilling water area dredged

(b) Abutment Protection Works (APW):

- Length: 500 m considering plan-form of the abutment and head and tail loops.
- Crest elevation: DHWL (Design High Water Level) + 1.50m (Free board)
- Slope = 1:3.0
- Toe elevation: Variable depending on the site conditions.
- Material: Concrete cube (450x450x450)
- Construction method: On the bank.

(c) Bank Protection Works (BPW):

- Length: Variable depending on the site conditions
- Crest elevation: SHWL (Standard High Water Level)
- Crest width: 10m, considering the transportation of materials for construction and maintenance.
- Slope = 1:6.0, following the designs of Jamuna bridge and other existing works
- Toe elevation: Mean Water Level – 15m, considering the dredging depth of dredgers available in Bangladesh.
- Material: Dumped rock and boulders (20-240 kg)
- Construction method: Works on bank and in stilling water area dredged

(3) Preliminary Design of River Works for PG-site

General Site Conditions

General location of Paturia-Goalundo site (PG-site) is shown in Figure 3.3.17. The left bank of the Padma River closely follows the stable left bank. Historically the width of the low-water channel and the location of thalweg vary broadly depending on the fluctuations of water and sediment flows of the Ganges and Jamuna rivers.

The permanent bank so-called "Khadir" is identified on the right bank at around 8 km away from the left riverbank. This permanent bank is said to be the old riverbank of the Ganges River. The main stream of the Padma River takes a route close to the stable left bank, and a high-water channel or flood plain extends on the right side bank of the main stream.

Some anabranches from the Ganges flow on the high-water channel. Goalundo ferry ghat is located at the outlet of one of such anabranches. Development of these anabranches may adversely affect the crossing section of Padma Bridge. Behind the stable bank on the left bank, the Ichamati River flows in parallel to the Padma River. The Ichamati River, a distributary from the Jamuna River, is a source of floodwater and a main drainage of the surrounding area as well. Careful treatment is necessary for the Ichamati River in relation with river works and approach road works.

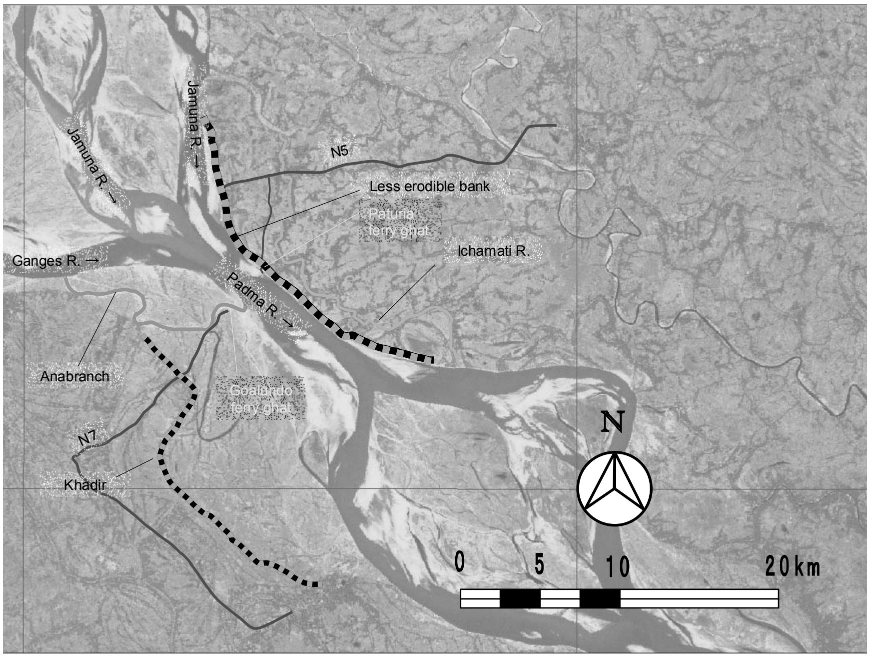


Figure 3.3.17 General Location of PG-site

<u>**Alternative Schemes**</u>

Planning Considerations: The following considerations were given in planning the river works for the PG-site:

1) **River Works:** Bridge abutment is to be protected by guide bund works (GBW) or abutment protection works (APW). The GBW aim to guide river flow to the bridge opening and to protect the bridge abutment and approach road from erosion. The APW aim to protect the bridge abutment from erosion. Bank protection works (BPW) aim to ensure the function of the GBW and the APW, maintaining present river flow conditions.
2) **Works for Left Bank Abutment:** GBW and APW can be considered as alternative schemes. The GBW (3,200 m) is to be proposed on the riverbank directly facing the main flow of the Padma River. The APW (500 m) for the left abutment is to be located at least 1 km behind the stable riverbank. The distance was chosen so that the works would be free from erosion of the Padma, considering the past erosion rate of the left bank. The depth of foundation of the APW can be designed shallower depending on the local conditions.
3) **Works for Right Bank Abutment:** According to the results of the study and investigation on historical plan-form changes and the erodibility of the riverbank, it was judged that the right bank abutment should be protected by the GBW or the equivalent to secure the safety of the abutment, even if it was located at the permanent riverbank (Khadir). Therefore, the GBW (3,200 m) is to be planned on the right riverbank directly facing the main flow of the Padma River to minimize bridge length.
4) **Bank Protection Works:** Bank protection works (BPW) such as groins and other works to protect the riverbank are necessary to ensure the functions of the GBW and APW discussed above for maintaining present flow conditions at the Ganges-Jamuna confluence, and checking activation of anabranches from the Ganges River. The factor of safety for these works can be planned lower than the GBW and APW.
5) **Ichamati River:** If GBW is planned on the left bank, the Ichamati River should be joined with the Padma upstream of the GBW, but if APW is planned the abutment should be located on the left (east) bank of the Ichamati River about 1.5 km inland from the existing riverbank.

Alternative River Work Schemes: Two schemes can be considered in combination of the GBW and APW discussed above. These alternative schemes are outlined in Figures 3.3.18 and 3.3.19.

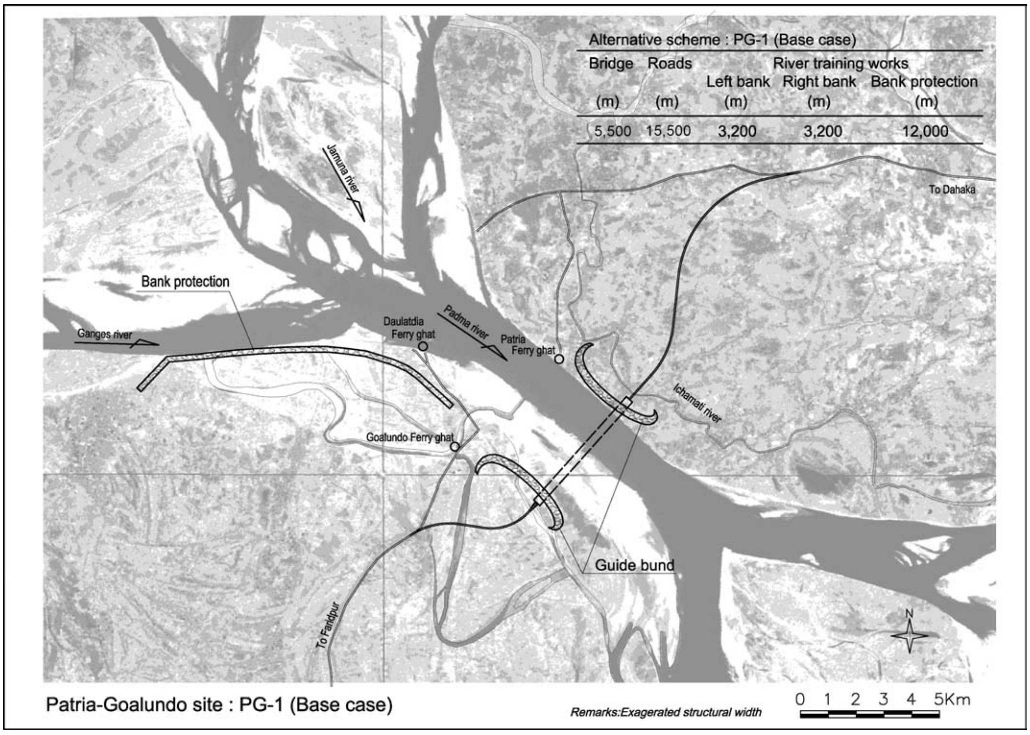


Figure 3.3.18 Alternative Scheme: PG-1

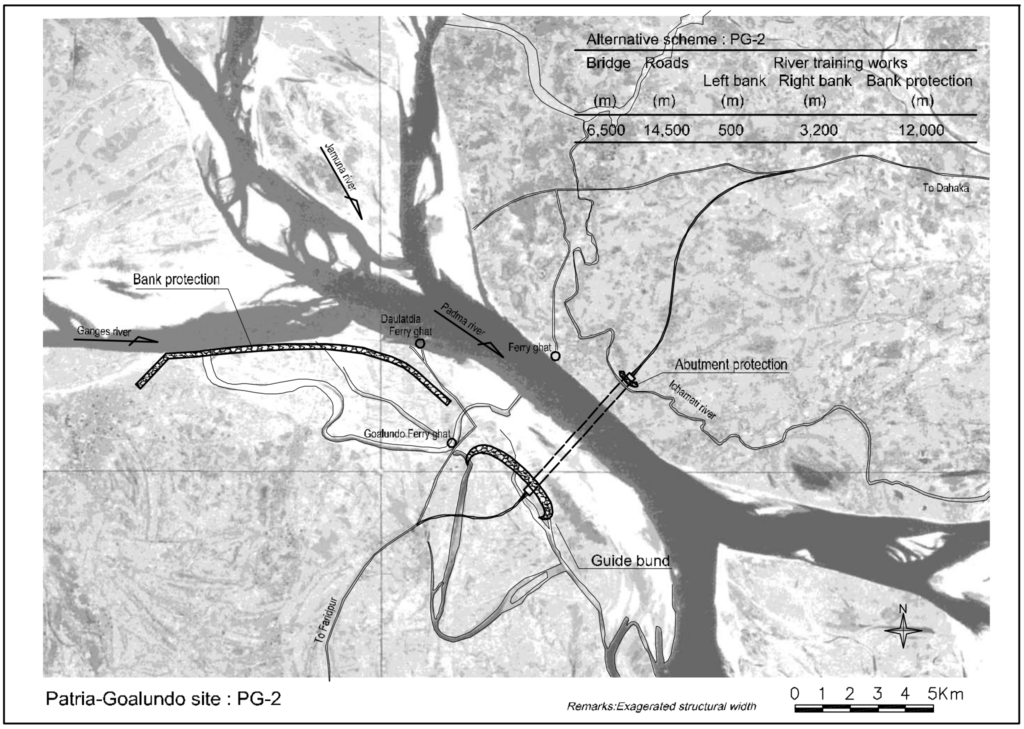


Figure 3.3.19 Alternative Scheme: PG-2

Selection of Optimum Scheme for PG-site

Based, in principle, on the unit work cost of the Jamuna Bridge, direct construction cost of each scheme was preliminarily estimated. According to the result of estimates, scheme PG-2 costs 91% of PG-1. Besides the cost, GBW on the left bank as in scheme PG-1 bring a risk of disturbing the presently stable riverbank.

The scheme PG-2 with APW for the left bank, GBW for the right bank and BPW along the right bank of the Ganges River is proposed for the PG-site.

(4) Preliminary Design of River Works for MJ-site

General Site Conditions

General location of Mawa-Janjira site (MJ-site) is shown in Figure 3.3.20. Historically the low-water channel and the thalweg were, in general, located in the right side or center of the river at the MJ-site. When the southeastern channel of Char Kawrakandi becomes active, the thalweg is pushed to the stable left bank and causes deep scour. Evolution of Char Kawrakandi and the southeastern channel behind the Char is an important factor to the stability of the river section at the MJ-site.

On the right bank near the Arialkhan River, the permanent riverbank (khadir) is identified at around 12 km away from the left bank. From the right riverbank some minor channels divert from the Padma River taking a route along the old river courses. Some of them return to the Padma River and others flow into the Arialkhan River. These diversion channels are dried up during the dry season.

On the left bank, the Srinagar River flows into the Padma River downstream of the MJ-site. The Srinagar River functions as a main drainage canal of the marshy lands on the left bank.

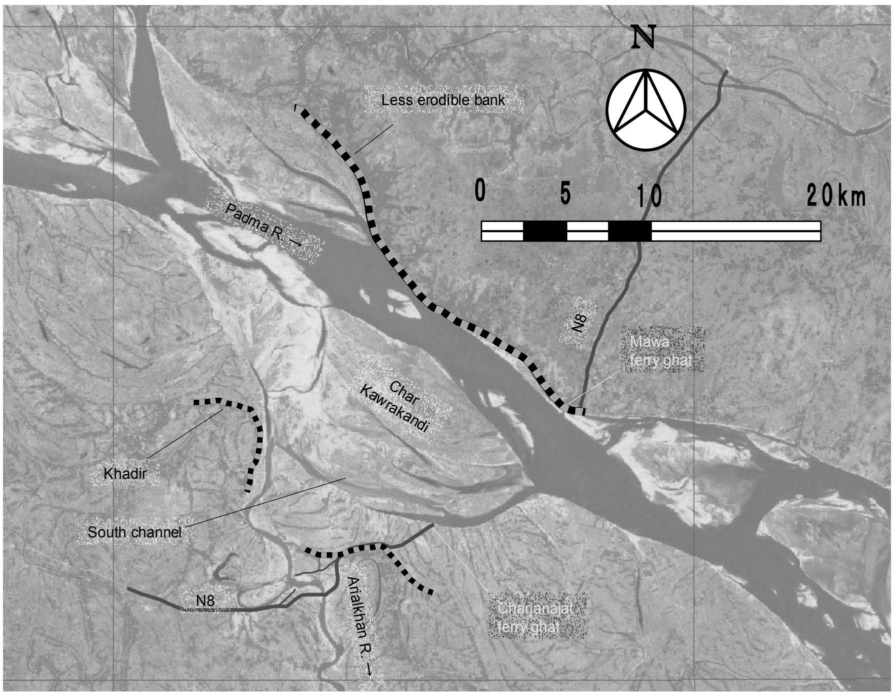


Figure 3.3.20 General Location of MJ-site

Alternative Schemes

Planning Consideration: In planning river works for the MJ-site, the following considerations were given:

1) **River Works:** The bridge abutment is to be protected by guide bund works (GBW) or abutment protection works (APW). The GBW aims to guide river flow to the bridge opening and to protect bridge abutments and the approach road from erosion. The APW aims to protect the bridge abutment from erosion. Bank protection works (BPW) aim to ensure the function of the GBW and the APW, maintaining present river flow conditions.
2) **Works for Left Bank Abutment:** The GBW (3,200 m) is to be proposed on the left riverbank facing the main flow of the Padma River, and the APW with shallower foundation is proposed about 1 km behind the stable left riverbank. The distance of 1 km was chosen considering the erosion rate of the left riverbank in the past.
3) **Works for Right Bank Abutment:** According to the study and investigation results on historical plan-form changes and the erodibility of the riverbank, it was judged that the right bank abutment should be protected by the GBW or the equivalent even if it was located at the permanent riverbank (Khadir) to secure the safety of the abutment. Therefore, the GBW (3,200 m) is to be planned on the right riverbank directly facing the Padma to minimize the bridge length.
4) **Bank Protection Works:** Bank protection works (BPW) such as groins and other works to protect the riverbanks would be necessary in case the guide bund is planned on the right bank of the south channel of Char Kawrakandi, to ensure the function of the GBW and to protect the right approach road from the erosion by the southeastern channel.

Alternative River Work Schemes: Two schemes can be considered in combination of the GBW and APW. Outlines of these alternative schemes are shown in Figures 3.3.21 and 3.3.22.

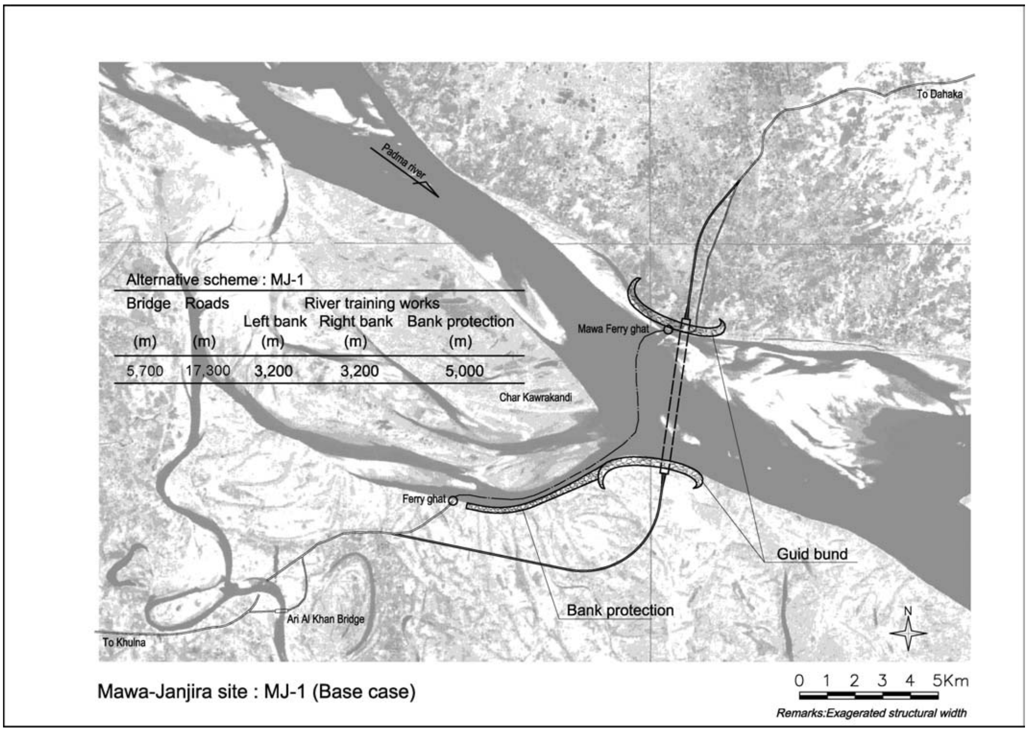


Figure 3.3.21 Alternative Scheme: MJ-1

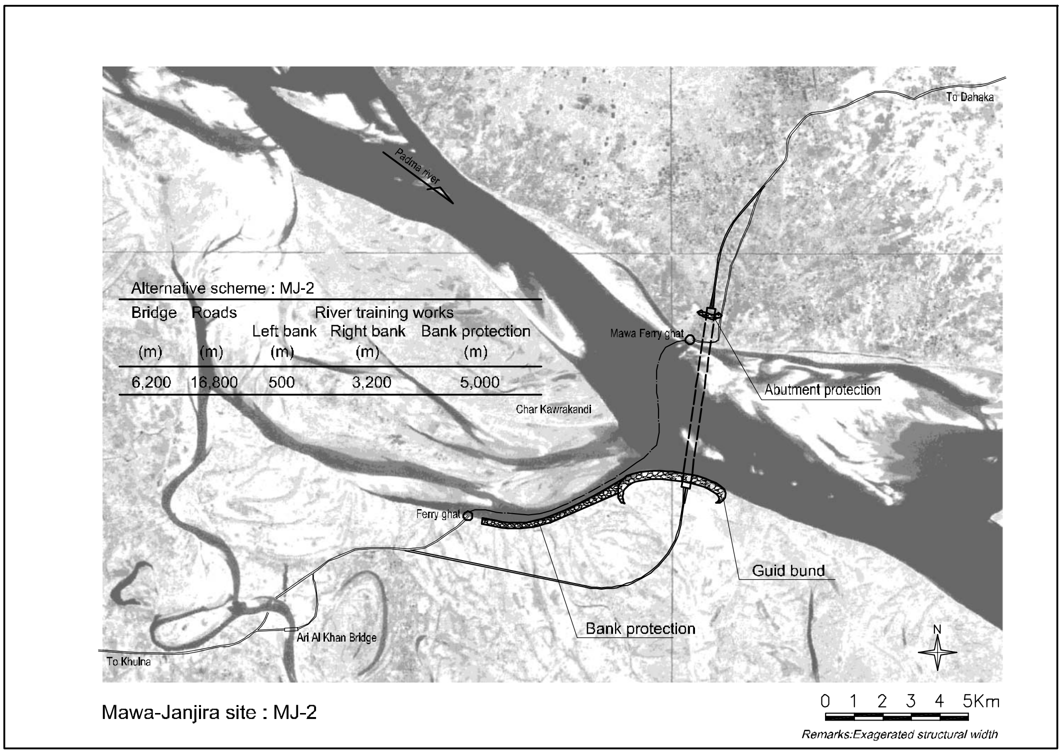


Figure 3.3.22 Alternative Scheme: MJ-2

Selection of Optimum Schemes for MJ-site

Based, in principle, on the unit work cost of the Jamuna Bridge, direct construction cost of each scheme was estimated preliminarily. According to the result of these estimates, scheme MJ-2 costs 86% of MJ-1. Besides the cost, GBW on the left bank as in scheme MJ-1 bring a risk of disturbing the presently stable riverbank.

Scheme MJ-2 with APW for the left bank, GBW for the right bank and BPW along the southwestern channel of Char Kawrakandi is proposed for the MJ-site.

3.3.3.2 Initial Studies on Padma Bridge

(1) Policy of Initial Study

The initial study follows the policy mentioned below.

1) 4-lane configuration without railway provision is adopted for both Paturia-Goalundo and Mawa-Janjira sites to cope with the future traffic volumes.
2) Span lengths must be longer than 100 meters to ensure smooth and safe navigation.
3) The Padma River will shift the main flow over the entire width for the long design life of the bridge, and thus the navigation span cannot be fixed, therefore all the spans over the river must satisfy the navigation limit and be navigable.
4) Foundations must be designed so as to be suitable to characteristics of the subsoil obtained from the geotechnical investigations for the PG and MJ sites, and the structures must be selected taking into account scour and liquefaction. Careful consideration must be given to abnormal horizontal loads such as ship impact and earthquake.
5) An electric power cable with a huge capacity, greater than ever installed, a gas pipeline and telecom cables are expected to cross along the bridge. The bridge design must consider not only the load, but also the location and the installation details.

(2) Methodology

The initial study aims at presuming an appropriate range of span lengths, and then recommending a superstructure and foundations in consideration of the said preconditions.

(a) Superstructure

In selecting an appropriate superstructure type under specific conditions, span length and major materials are essential factors affecting construction cost. Whether the supporting system is continuous or simply supported affects not only the cost, but the constructability, drivability and maintainability. There are various superstructure types, but each type has a suitable possible range of span lengths appropriate to apply in terms of economics.

i) Minimum span length

In order to keep the navigation limit of the Padma River, the span length must be greater than 100 meters as seen in the following Figure 3.3.23.

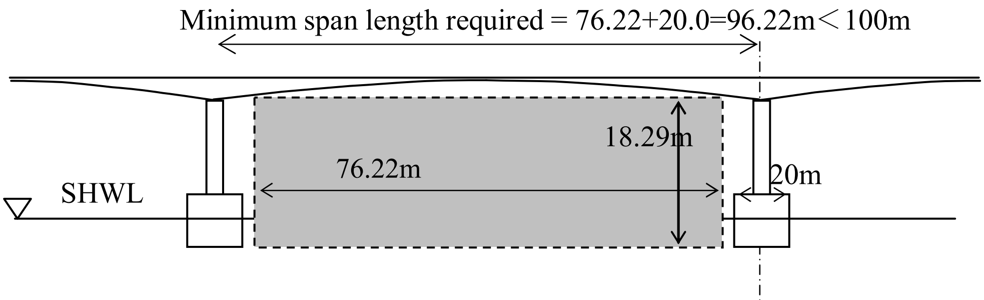


Figure 3.3.23 Navigation Clearance

ii) Superstructure types applicable to span longer than 100m

Table 3.3.7 shows the superstructure types and applicable range of span lengths for concrete and steel superstructures. These types are usually applicable to the span ranges in terms of economics.

Table 3.3.7 Superstructure Types and Applicable Span Length

Superstructure Type	Applicable Span Length (m)	Remarks
Prestressed Concrete Type Bridge		
1) Continuous Box Girder	50 < L < 110	e.g. Jamuna, Paksey Br
2) Rigid Frame Box Girder	40 < L < 140	
3) Box Girder with Central Hinge	60 < L < 180	e.g. Meghna, Meghna-Gumti Br
4) Extradosed Girder	100 < L < 200	
5) Cable Stayed Girder	150 < L < 250	
Steel Type Bridge		
1) Continuous Box Girder	30 < L < 150	
2) Continuous Truss Girder	60 < L < 110	
3) Langer Girder (Arch Bridge)	50 < L < 120	Simply supported structure
4) Lohse Girder (Arch Bridge)	80 < L < 150	Simply supported structure
5) Nielsen Girder (Arch Bridge)	100 < L < 170	Simply supported structure
6) Cable Stayed Girder	130 < L < 500	

iii) Selection of materials

Usually concrete and steel are utilized for major elements of a superstructure.

To be brief, steel is strong and light-weight compared with concrete, but some countermeasures must be taken against corrosion. Concrete is cheaper and easier to obtain in most countries. Details of advantages and disadvantages of these materials are discussed in Appendix-8.

iv) Continuous vs. simply supported construction

Continuous and simply supported construction of superstructures have different characteristics in regards to safety against catastrophes, differential settlement, constructability and so on. Out of the superstructure types shown in Table 3.3.4.1, the three arch types are simply supported, and all others are continuous. In terms of maintenance of the Padma Bridge in the future, rigid frame type bridges are the best, and continuous supported type is better than simply supported type.

v) Characteristics of Each Superstructure Types

Concrete Bridges

Box Girder Bridges

This type can be classified into three categories. They are Continuous Box Girder Bridge, Continuous Rigid Frame Girder Bridge and Hinged Box Girder Bridge, having similar appearances and structural characteristics. But their connecting details provide different structural characteristics. These types can be applied to a span length of up to 180m, but most are less than 150m. Most major bridges in Bangladesh belong to this type.

Extradosed Girder Bridges

In appearance the extradosed girder bridges are similar to cable stayed girder bridges, but they differ in the following two respects. Typically the tower height to span length ratio is approximately 1/10, and the optimum girder depth is 1/30 to 1/35 of the main span length.

The applicable span ranges between 100m and 200m.

Cable Stayed Girder Bridges

This is more suitable for longer spans than other concrete bridges. Usually they are applied for a span up to 250m. The tower is as high as one fifth of the span length, which is much higher than that of extradosed girder bridges. Furthermore it enables the girder to be less deep and thus provide spacious navigation clearance beneath the bridge by the use of sharply inclined stayed cables. Girders and towers for cable stayed girder bridges can be constructed of both concrete and steel.

Steel Bridges

Box Girder Bridges

Steel box girder bridges have similar appearance and characteristics to those of concrete. For the Jamuna Bridge project the consultants developed a steel box girder scheme in the bidding documents. Steel has different maintenance requirements from concrete such as repainting.

Continuous Truss Bridges

If the configuration includes a railway, either at day one or for future provision, then this type can be planned as a double decked continuous truss arrangement. Particular weaknesses are corrosion due to the vast surface area, the large number of slender elements and the complex structure of the nodes, thus careful maintenance is required.

Arch Bridges

Langer arch, Lohse arch and Nielsen arch belong to a tied arch family. They are simply supported structures and applied mostly up 170m. Its relative lack of popularity lies in the difficulty of its erection due to the structural characters of the simple support system and the complex structure with a good number of elements, which might cause local corrosion.

Cable Stayed Girder Bridges

Steel cable stayed bridges can be used for spans in the range between 200m and 800m. They are most often used in situations where high and wide navigation clearances are required or where an owner decides that a "landmark" structure is justified. They are invariably relatively expensive, often costing in the region of 25 to 50 percent more than girder bridges.

vi) Candidate superstructure types

Among the above-mentioned superstructure types, some are deleted from a list of candidates for the subsequent cost estimating due to crucial disadvantages of constructability and/or maintainability.

Table 3.3.8 shows disadvantages of each type, where "X" indicates the disadvantage of the type in constructability or maintainability.

Table 3.3.8 Disadvantages of Bridge Type

	Type	Constructability	Maintainability
PC Bridge	Box Girder		X
	Extradosed		
	Cable Stayed		
Steel Bridge	Continuous Box		
	Continuous Truss		X
	Arch	X	X
	Cable Stayed		

Note*: Future maintenance will be difficult if prestressing cables are encased in conduits of the concrete girders.

Thus the steel continuous truss and steel arch are excluded from the succeeding procedure. The remaining five types are usually applied within the span ranges shown in Table 3.3.9.

Table 3.3.9 Applicable Span Length of Candidate Types

	Type	Applicable Span (100m – 150m – 200m – 250m)
PC Bridge	Box Girder	150m (frequently applied); 180mm (applicable span)
	Extradosed	200m
	Cable Stayed	250m
Steel Bridge	Continuous Box	150m
	Cable Stayed	500m

▬▬ : Frequently applied span length, - - - - : Applicable span

(b) Substructure/Foundation

i) Loading

As the primary stage of the foundation design it is necessary to identify the loading and circumstances that will cause adverse conditions that the foundations must be designed to resist.

The loading may be divided into one of four general categories.

- Structural Loads: Weight of the structure, surfacing and effects from structural behavior.
- Live Loads: The loads from traffic on the deck.
- Environmental Loads: Wind loads, loads from the river (stream flow, buoyancy, wave forces).
- Abnormal Loads: Ship impact or earthquake loads.

ii) Scour and Flow

Scour influences the following aspects of substructure and foundation design;

- The design height of the substructure: That is the distance from scour riverbed level to bearing level.
- Overturning effects of the foundation: As scour increases the lever arm at which

forces act increases.

- Loads from water flow increases.
- The stiffness of the substructures becomes important: For slender members vibration and buckling must be checked.

iii) Subsoil

The subsoil conditions along the river are described in Chapter 6.

Below the scour depths projected at the preferred bridge sites the soil is fine to medium sand with traces of mica. It is the engineering properties of these strata that will govern the foundation design for vertical and particularly horizontal load capacity. The resistance of the ground to lateral loads and movement will be the most important design consideration. The presence of mica can have a marked effect on the soil properties.

iv) Types of Piles

The three main issues of loading from ship impact, depth of scour and the capacity of the ground to resist horizontal loading will govern the design of the foundations. The foundations will have to be strong enough to carrying the loads and suitably distribute the loads through the ground to ensure the soil strength is not exceeded.

Four types of foundation have been identified as potentially suited for use for the Padma Bridge.

Driven steel tubular piles

One option for the construction of pile foundations for the Padma Bridge would be to use tubular steel piles, which is the same foundation type as used for the Jamuna Bridge. Using steel piles would be the quickest way to construct a foundation and the piles could be installed in a raked or vertical orientation. One advantage of steel piling is the strength of the pile section and that steel will work equally well in tension and compression. For the Padma Bridge it is expected that piles will subject to tension loading.

Insitu concrete piles

Large diameter bored reinforced concrete piles could be adopted for the Padma Bridge foundations. This option would limit the foundation to a vertical pile arrangement only. Bored pile construction uses a sequence of operations. This method is slower than driven steel pile installation and concrete piles will be weaker under the tensile loading expected on the piles of this bridge.

Concrete caissons

Two types of caissons have been considered for primary design purposes, a tube (well) caisson and a large diameter caisson. Both types were assessed for their suitability as foundations in the Padma bridge environment.

Tube caissons (or Well foundations)

A tube or well caisson could be used to provide the foundation beneath each bridge pier. During the works on Aricha Power Conveyor where caissons were installed, one caisson suffered a blow out during sinking operations, this would be a risk if this type of foundation were adopted for the Padma Bridge.

Well caissons are suitable to carry the loading and distribute it into the ground. However the large deflections at bearing level under ship impact load and the works required to install such caissons make them a costly form of construction.

Large diameter caissons

Use of large diameter caissons was considered to check if a shorter caisson height could be used to provide the bridge foundations. For this case it was assumed bearing capacity under the base would resist the vertical loads and horizontal loads would be resisted by base friction. Outline calculations show it is not a suitable foundation unless taken to a considerable depth due to the nature of the supporting ground.

v) Foundation type in preparatory study

As a result of the examination of each type described above, a foundation using "Driven Steel Tubular Piles" is considered as representing the best foundation type for the selection of a final bridge site.

(c) Selection of Target Ranges of Span Lengths

i) Methodology

In order to grasp the tendency of the relationship between span lengths and the construction costs, outline estimates were carried out for both concrete and steel bridges. The methodology taken for the estimate is as follows.

- The span ranges from 100m through 250m. Estimate was made in increments of 25m within the above range, in other word, seven cases of 100, 125, 150, 175, 200, 225 and 250m for both materials.
- Cross Section
  The cross-section used for selecting a final bridge site is shown in Figure 3.3.24, which was proposed by the Pre-feasibility Study of the Padma Bridge as a 4-lane configuration. This cross Section will be changed after review in the course of preliminary design stage in Chapter 5.

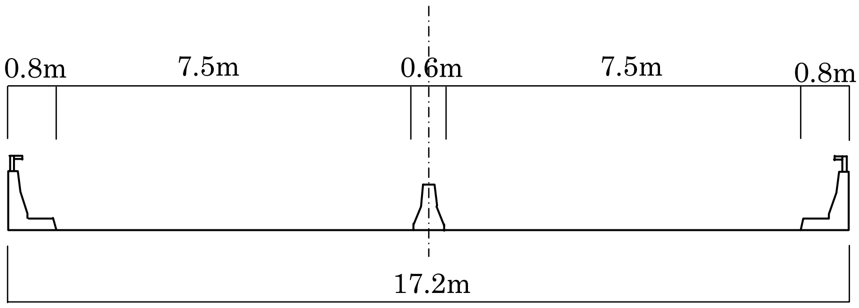


Figure 3.3.24 Lane Cross-section

- Superstructure types for each span of each material were taken as shown below.

PC Superstructures

Type	Continuous Box		Extradosed		Cable Stayed		
Span (m)	100	125	150	175	200	225	250

Steel Superstructures

Type	Steel Deck Continuous Box				Cable Stayed Girder		
Span (m)	100	125	150	175	200	225	250

Typical views of a Continuous Box Girder Bridge, Extradosed Girder Bridge and Cable Stayed Girder Bridge are shown in Figure 3.3.25 as samples for a span length of 150m.

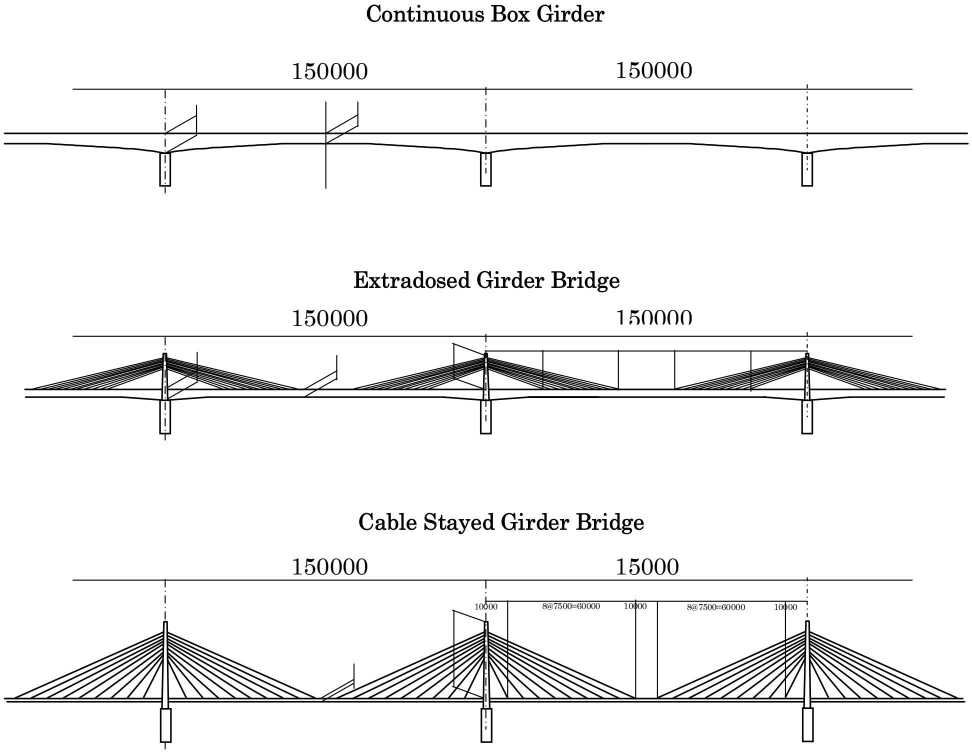


Figure 3.3.25 Side Views by Bridge Types (Example span length = 150m)

- Substructure/foundations for estimating indicative costs in selecting a final bridge site were as shown in Figure 3.3.26.

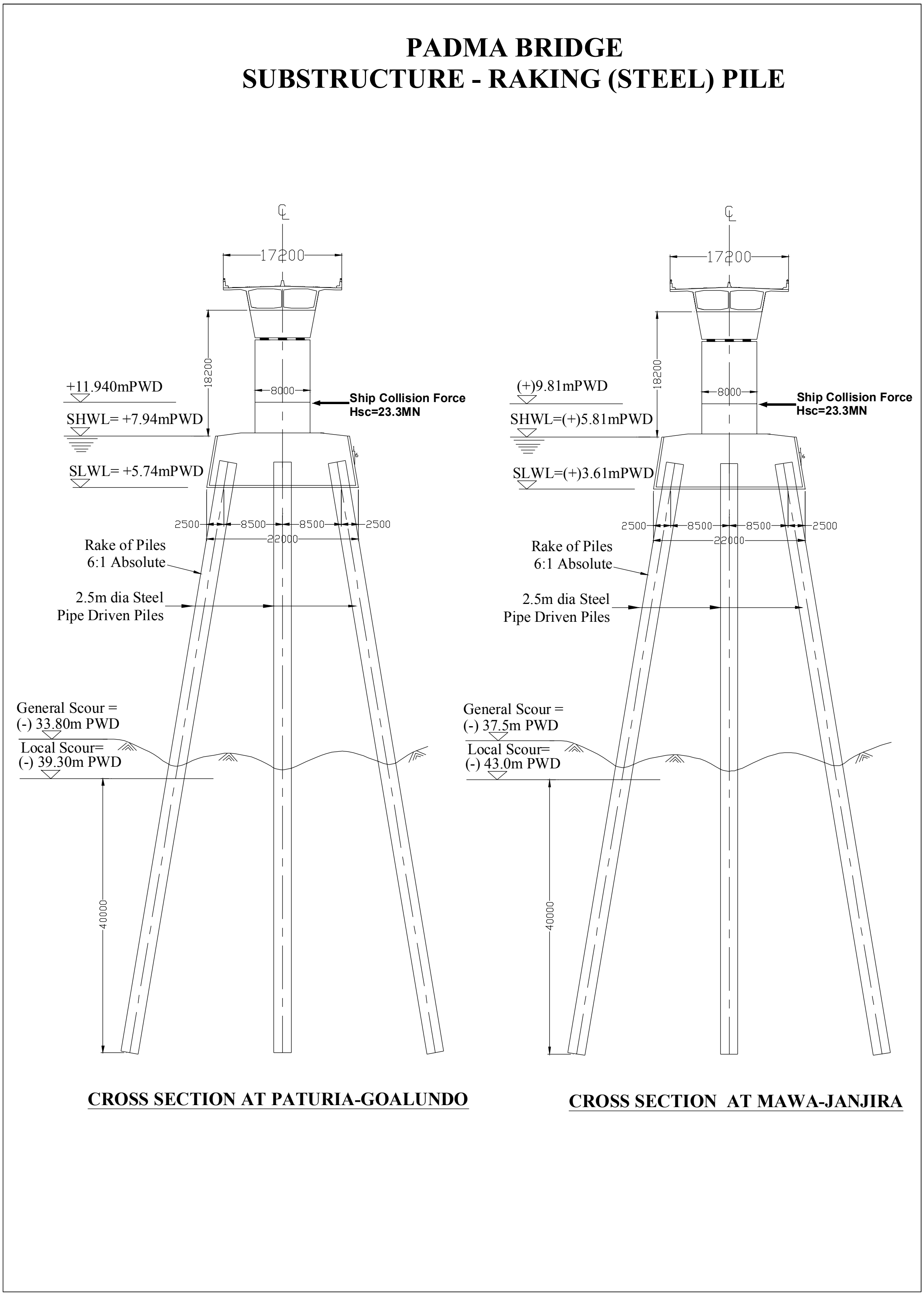


Figure 3.3.26 Substructure and Foundation considered in Indicative Cost

ii) Results of Indicative Bridge Costs

Costs per meter including superstructures, piers and foundations were estimated based on the following:

- Quantities of superstructures, substructures and foundations are estimated in the preceding sub-paragraphs.
- Unit prices of materials such as concrete, PC tendons, re-bars, etc. are based on those experienced in Paksey Bridge, and that of steel tubular driven piles is based on the Jamuna Bridge.

Prestressed Concrete Bridges

a) Superstructure Type by Span Length
   From 100m to 125m Span: Continuous Box Girder
   From 150m to 175m Span: PC Extradosed Girder
   From 200m to 250m Span: PC Cable Stayed Girder

b) Pier and Foundation
   Reinforced concrete piers supported by steel tubular driven piles were considered. The quantities of piles were calculated based on the external forces transmitted from the superstructures, ship collision force, seismic force and the subsoil data from the geotechnical investigation for the Paturia-Goalundo and Mawa-Janjira sites.

Steel Bridges

a) Superstructure Type by Span Length
   From 100m to 150m Span: Steel Deck Continuous Box Girder
   From 175m to 250m Span: Steel Cable Stayed Girder

b) Pier and Foundation: Same as i) b) of the above.

As a result, the relationship between span length and indicative costs per meter is shown in the following figure.

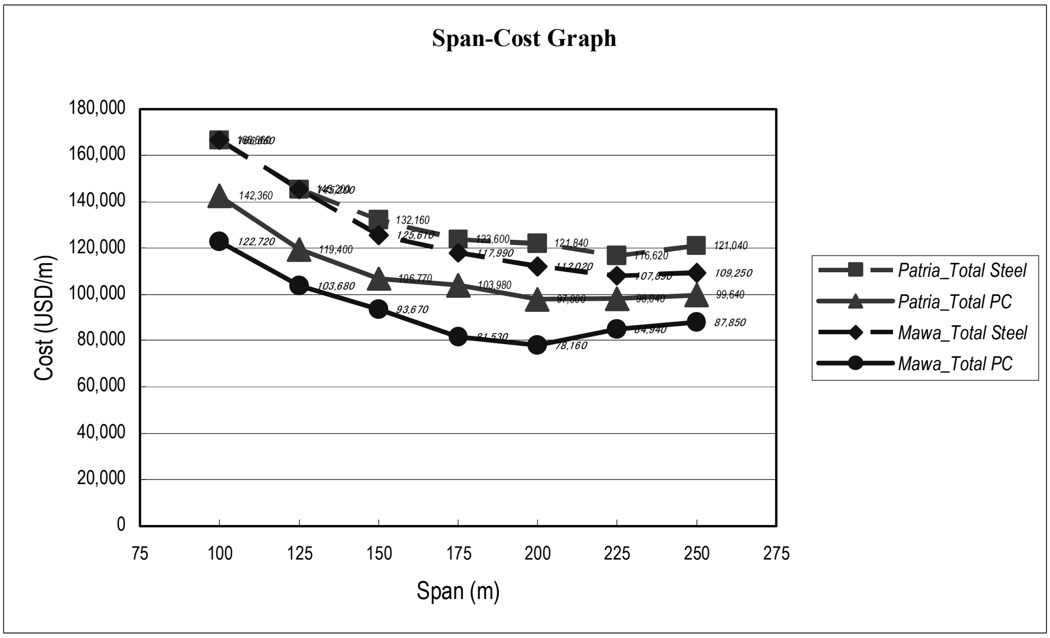


Figure 3.3.27 Span-Cost Relation

3.3.3.3 Basic Condition Analysis for Highway Design

On top of the first-stage study and evaluation, some in-depth analysis and comparison of the conditions and prospective features of the highway between the two alternative locations was conducted from the highway planning aspect.

(1) Connecting Roads

<u>Site-1 (Paturia)</u>

The Project Highway will be connected to the N5 Highway on the Paturia side and the N7 Highway on the Goalundo side, respectively. Presently, the connecting roads at the assumed connecting sections are two-way, two-lane highways with a fair condition of the surface pavement. The existing road embankments of these highways have a 1:1.5 to 1:3.0 slope gradient with turf or grass protection. The existing ground surface condition is cultivated or swampy land, and the embankments at the connecting sections are assumed to be about 3m to 5 m high above the ground.

<u>Site-3 (Mawa)</u>

The Project Highway will be connected to the N8 Highway on both river banks (Mawa and Janjira). The N8 Highway is being improved up to an arterial highway with two-lane asphalt concrete surface under a road improvement project financed by ADB. The Project Highway will be connected to this improved N8 project road alignment.

The proposed road structure of the N8 highway project is composed of a 7.3m carriageway plus 2.7m shoulders and 1:2.0 embankment slopes on both sides. The design height of the N8 embankment near the connecting points will be about 3m to 5 m high above the cultivated or swampy ground in the vicinity.

(2) Traffic Demand Forecast

Future traffic in the years of 2015 and 2025 is estimated by the Study Team as follows:

Table 3.3.10 Future Traffic Forecast

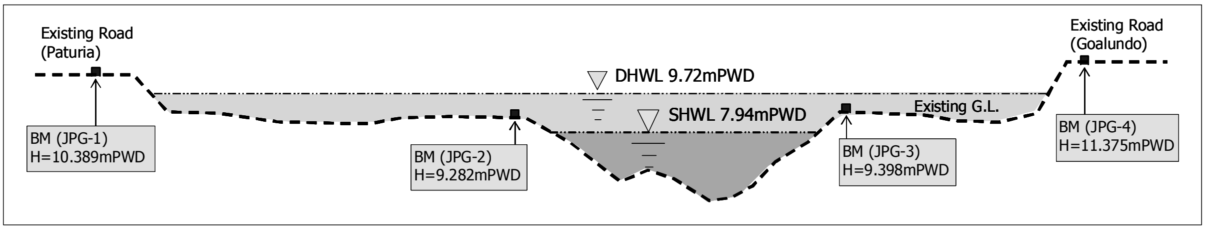
Description		Site-1 Payuria-Goalundo		Site-3 Mawa-Janjira	
		Vehicles per day	Composition %	Vehicles per day	Composition %
Year 2015	Light Vehicle	2,410	23.4	3,850	18.1
	Bus	4,880	48.7	13,210	62.1
	Truck	3,010	28.0	4,200	19.8
	Total	10,300	100.0	21,260	100.0
Year 2025	Light Vehicle	4,610	23.2	7,340	17.7
	Bus	9,920	50.0	26,750	64.4
	Truck	5,320	26.8	7,460	18.0
	Total	19,850	100.0	41,550	100.0

Note: Average Composition ratio 2015-2025 Site-1=Light Vehicle 23.3%, Bus 48.7%, Truck 28.0%
Site-3=Light Vehicle 17.9%, Bus 63.3%, Truck 18.9%

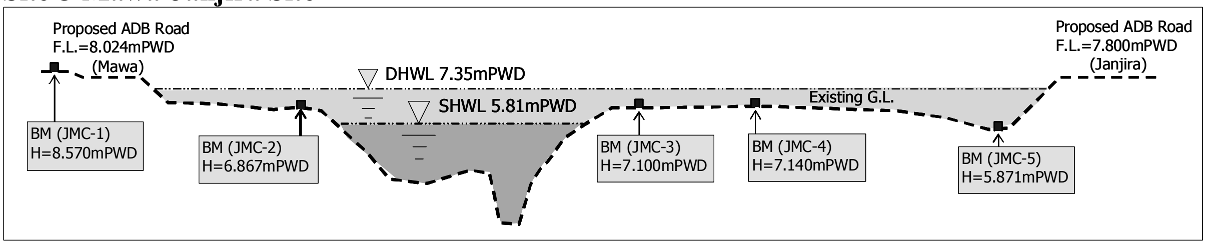
(3) Height of Project Highway

Topographic surveys were conducted with the Bench Marks established along the assumed survey lines at the two sites. The surveys provide the heights of the existing ground and the connecting points of the existing roads to the survey line for both sites, as in Figure 3.3.28.

Site-1 Paturia-Goalund Site



Site-3 Mawa-Janjira Site



Note: Not to Scale
DHWL=Design High Water Level, SHWL=Standard High Water Level , BM=Bench Mark

Figure 3.3.28 Project Height

(4) Potential Highway Routes for Second-Stage Project Location Alternatives

Based on the site conditions and the results of the initial inventory study, the features of the alignment of the two alternative project sites are compared. Generally, no big difference is observed between the two alternative sites in terms of highway design.

(5) Evaluation of Second-Stage Project Location Alternatives

Though evaluation from the highway planning aspect has detected no distinct advantage or disadvantage between the two, except for the contribution to the smooth development of the Dhaka-Southwest Region traffic corridor, the Mawa-Janjira site is selected as the final Project location, as a result of the overall evaluation.

3.3.4 Initial Environmental Examination

(1) Introduction

The Initial Environmental Examinations (IEE) was conducted for the two preferred sites during the period August to December, 2003 and the details are given in Chapter 2 of APP – 11. A brief summary is given here.

The main objective of the IEE study is to identity the significant environmental impacts for the two bridge sites of the project by following the requirements of the environmental guidelines prepared by JICA, JBIC, GoB and other donor agencies, and to assess the scope of the EIA for the proposed project. Another major objective is make a comparison between the two sites from an environmental point of view as an input for the technical team to assist in the final site selection.

The scope of works of an IEE includes:

- Project description from the environmental aspect
- Data collection and analysis to describe the natural environment, social environment and environmental pollution;
- Screening to identify significant environmental impacts;

- Identification of mitigation measures;
- Prepare the scope of the EIA for the project

(2) Approach adopted in IEE Study

The IEE was conducted through tailor made project specific templates. Project specific IEE/EIA templates have been prepared comprising a number of steps and these steps are presented in Figure 3.3.29. Selection of environmental parameters for the IEE and EIA of the Padma bridge construction along with their selection rational, impact sources, frequency of occurrence, and nature of impacts were made based on various guidelines. In total, 40 environmental parameters were identified and these are classified into natural environment, ecological parameters, environmental pollution and social environment. The weight values of the environmental parameters are decided in the context of Padma bridge construction and their importance to the national development and environmental conservation. The rationalities of putting the weight values for different environmental parameters are presented. In the process of selecting the weight values, the "Guidelines on Environmental Issues Related to Physical Planning" prepared by LGED and "Preliminary Activities related to Project Environmental Assessment" prepared by REB with WB assistance were consulted. It may be mentioned here that values proposed in LGED guideline were prepared based upon extensive input from a number of national environmental experts. A project specific guideline for mitigation measures / supporting strategies was prepared, which provides a basis for the mitigation measures and/or strategy for each identified screening parameter.

For the screening purpose, three templates are prepared. The first template allows analysis of all screening parameters based on the background information, field investigation, consultation with local stakeholders and worldwide experience with similar projects. This provides an in-depth focus of the type of impacts (direct, indirect or both), temporal extent (during or after construction or both), spatial extent (local or widespread), ease of mitigation (fully or partial), and monitoring possibility (fully or partially). Once the analysis of the impacts was clear, the second template was used for identifying the positive and negative impacts of the project with impact rating. This template can identify the key issues, namely the parameters having negative impacts. The purpose of identification of the key issues is to focus on those environmental parameters that need careful attention for ensuring sustainable environment friendly development of the country in the long run. The possible mitigation measures for the key issues can be formulated based on the guideline prepared. The third template is for assessing the overall benefit from implementation of the mitigation measures. This is a Leopold Graded Matrix where the graded values are obtained for both the "without mitigation case" and the "with mitigation" case. It may be mentioned here that such grading matrix is usually not a part of an IEE, rather it is done in the EIA stage. For this project, to facilitate the final site selection, such grading matrix was used based on very preliminary ideas of mitigation measures indicated.

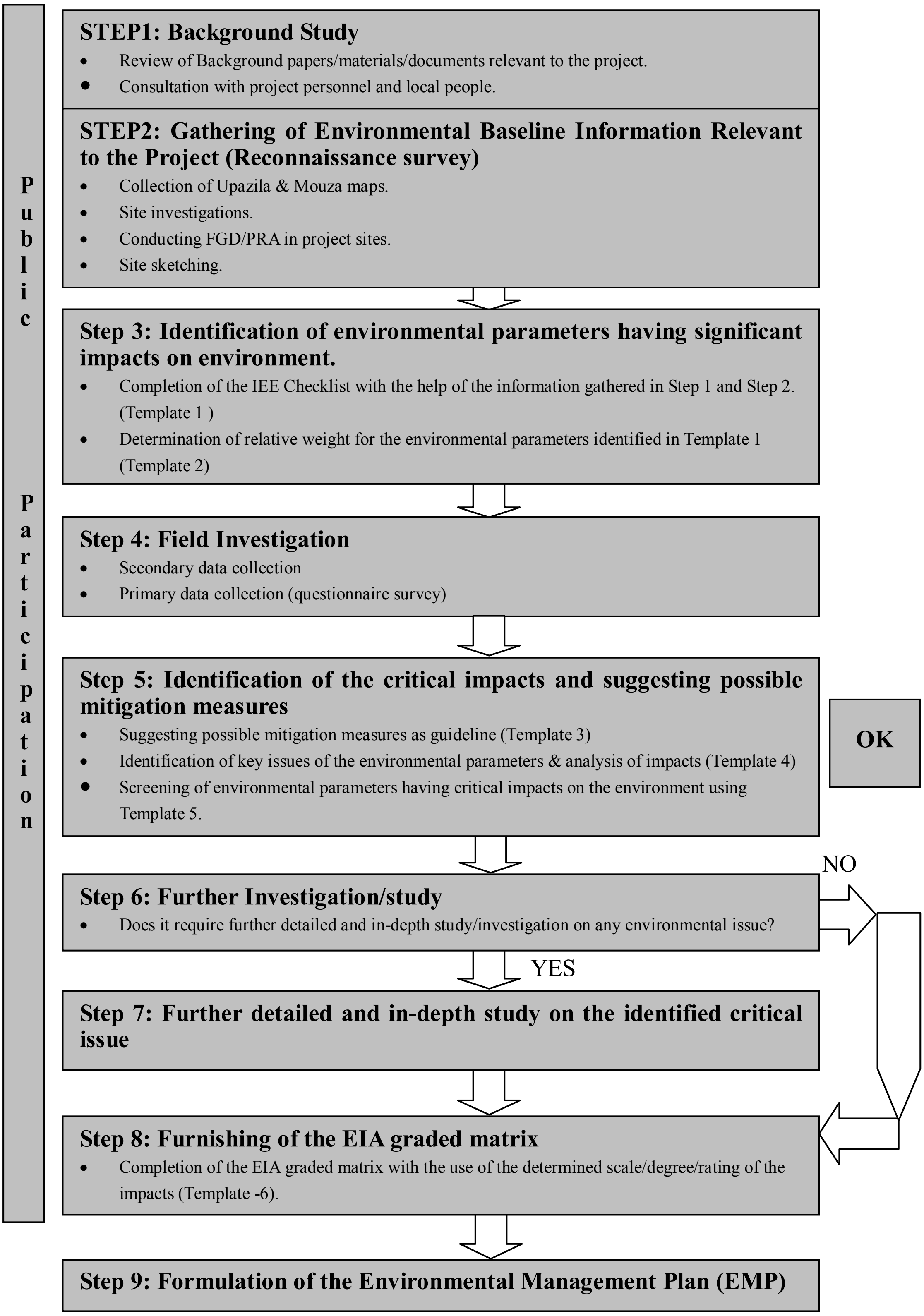


Figure 3.3.29 Procedural Steps in the Environmental Study of the project

(3) Methodology

The methodology used for the IEE study included the following steps

- Secondary data collection to establish environmental baseline
- Primary data collection (environmental reconnaissance, stakeholders meeting, land use survey, and questionnaire survey)
- Project site descriptions from environmental point of view
- Identification of environmental impact study area
- Analysis of project activities from environmental point of view
- Environmental baseline analysis (natural environment, ecological environment, social environment and environmental pollution)
- Screening through custom made project specific templates
- Impact analysis for both sites
- Impact rating for both the sites, and
- Grading Matrix for two cases, with mitigation measures and without mitigation measures, to compare the 2 sites in order to assist the process of final site selection.

Details of the IEE are given in the Chapter 2 of Appendix 11.

(4) Environmental Impact Study Area

Since the environmental impact of a major project is not necessarily confined to the project vicinity area, the overall environmental impact study area of the Padma Bridge Project is considered to cover the entire Padma River and its tributaries and associated channels. The impact study area is considered as a 100 km strip with the Padma River at the centre. The starting point of the strip is the confluence of the Jamuna and Ganges Rivers near at Aricha and continues downstream (d/s) of Chandpur District near Haimchar Upazila. The area of the strip is approx. 10000 km2.

(5) Environmental Baseline

Environmental baseline was established for the 2 sites from both secondary and primary data. The details are given in Chap-2 of App-11. Some important features are given below.

<u>Drainage interference due to the Project</u>

The possible drainage interferences due to the Bridge approach road are as follows:

- At Paturia site, a proposed approach road about 17 km long runs mainly on the floodplain of the Padma River. It crosses a Khal at Village Amdala and runs almost parallel to the Ichamati River.
- At Goalundo site, about 7 km long proposed road mainly crosses the dead river of Padma and passes through the floodplain of the Padma River.
- At Mawa site, about 8 km proposed road runs over the floodplain of Padma River and crosses a Khal at Village Dogachi.
- At Janjira site, the 21 km long proposed road passes through the floodplain of Padma and crosses the Azra River at Mouza Karali.

<u>Landscape</u>

A detail landscape survey was conducted along the river banks for a 400m strip on both banks. The general landscape along the Padma River stream from the Jamuna-Ganges downstream to the confluence at Maghna River is mostly floodplain. Dominant landscape types are agricultural land and char land. In addition some housing, homestead trees, orchards, commercial structures, rural roads, schools, religious institutions (such as mosques, temples, etc) and water bodies are also present.

Forest and vegetation

There is no designated forest in the vicinity of the 2 proposed sites. The main forms of vegetation are road side plantation and homestead plantation, in addition to the agricultural vegetation.

Wildlife

There is no exclusive habitat for any endangered species near the 2 proposed project sites.

Environmentally Protected and Sensitive Areas

There is no environmentally protected area near the 2 proposed sites.

(6) Screening

Screening was carried out by custom made project specific templates as explained before. The first template provides the basis of the impact analysis, while the second template helps in determining the impact rating. The second template gives the identification of key issues. A key issue is an issue that requires detailed and in-depth further investigation and main focus in the project activities. A preliminary idea of the mitigation measures for the key issues is provided. The tailor made third template is a Leopold graded matrix to be used for the EIA. An attempt was made to complete this matrix to get the comparison between two sites. This also gives an indication of impact reduction due to mitigation measures to be employed.

The first template of impact analysis was used for both the sites. In this template, impact type is divided into direct, indirect and cumulative; temporal extent is analyzed as impact during construction or impact after construction; spatial extent is characterized as local impact or widespread impact; feasibility of mitigation is categorized as impacts that can be fully mitigated or partially mitigated; and finally, monitoring possibility is distinguished as fully monitorable and partially monitorable. Comparing the two tables, it can be inferred that impact characteristics for both the sites are completely the same.

(7) Impact Rating

The second template of impact rating was also applied for both the sites. In this template, Impacts are principally divided into 3 categories, namely, positive, negative and no impact. Positive and negative impacts are further classified into severe, moderate and low impacts with impact ratings vary between 1 and 3.

From the two tables, it can be noted that most of the impacts are similar for the two sites. There are 8 positive impacts, 8 no impacts and 24 negative impacts.

The ‘positive impacts’ as identified in the IEE Study are as follows:

Natural Environment

- Flood Control

Ecological Parameters

- Tree Plantation

Social Environment

- Employment
- Women Empowerment
- Health & Nutrition
- Infrastructure Development
- Industries
- Road Transport

The ‘no impacts’ as identified in the IEE Study are as follows:

Natural Environment

- Meteorology
- Land Subsidence

Ecological Parameters

- Wet lands
- Forest
- Endangered Species
- Environmentally Protected and Sensitive Areas

Social Environment

- Water Rights
- Ethnic Minorities and Indigenous People

The ‘negative impacts’ as identified in the IEE Study are as follows:

Natural Environment

- Topography
- Soil erosion and siltation
- Hydrology / flooding
- Drainage congestion
- Landscape

Ecological Parameters

- Fisheries
- Vegetation / Agricultural loss
- Water bodies loss
- Plant cutting
- Wildlife

Environmental Pollution

- Air pollution
- Noise and Vibration
- Water pollution
- Soil Contamination
- Waste Disposal

Social Environment

- Land Acquisition
- Homestead Loss
- Income Loss
- Historical and Cultural Loss
- Navigation and Water Transport
- Health and Safety
- Split of Communities
- Road Accidents
- Land Use

(8) Comparison between the Two Sites

From the environmental screening, it can be concluded that impact types and their degrees are very similar for the two sites. However, the following slight differences are observed:

- Erosion and siltation might poise a greater threat at the PG site.
- Impact on fisheries is expected to be more at the PG site.
- Water body losses will be more at the PG site.
- Homestead losses will be more at the MJ site.
- Income loss is expected to be more at the MJ site.
- Split of communities might be more at the MJ site.

Hence, it can be said that there is no relative advantage of one site over the other in terms of environmental impact.

3.3.5 Social Impact Assessment and Resettlement Issues

(1) Introduction

Construction of large infrastructure projects like the Padma Bridge generally involves adverse social impacts arising out of land acquisition and displacement of project affected persons. A social impact assessment was carried out in the two preferred sites – (i) Paturia-Goalundo and (ii) Mawa-Janjira – to ascertain the likely project impacts, local responses to the project and resettlement needs of the potentially affected persons. An immediate purpose of the SIA was to develop broad guidelines for the selection of the final bridge site. This section presents the nature of social and economic impact due to loss of agricultural land and displacement. A set of criteria is presented for final site selection followed by potential mitigation measures, based on the existing legal framework, best practice examples from ongoing and/or completed projects in Bangladesh and donors' requirements.

(2) Field Surveys and Data Collection

Two separate teams were dedicated for socioeconomic study of the two alternative sites. The objective was to gather a broader overview of project impacts and mitigations, based on local knowledge and practices. Two hundred potential affected households (100 hundred from each site) were randomly selected representing cross-section of occupational groups. Other methods for data collection such as PRA and FGDs with stakeholders were held at the two alternative sites. The primary purpose of the meetings was to explain preliminary work plan for project preparation, screening for final site selection, and the potential impact of the bridge to assess local responses to the project. The team also explained mitigation measures adopted in the case of the Jamuna Bridge Project, particularly compensation for assets at replacement rate, resettlement of the displaced families, civic amenities at replacement sites, and common property resources in host communities and that similar and/or improved measures would be undertaken to assist those to be affected by loss of land and displacement.

(3) Characteristics of the Alternative Sites

The two alternative corridors – Mawa-Janjira and Paturia-Goalundo – are characterized as deltaic floodplain with many common physical and socioeconomic features. First, riverbank erosion is an endemic problem at both sites, affecting literally hundreds and thousands of people annually. The rate of erosion is more on the left bank along the entire delta plain. As a result, many homes are destroyed every year, making people homeless and temporary in-migrants (*nadibashi*) in the existing villages along the riverbanks.[2] However, as a natural process of erosion (*sikosti*) and accretion (*payasti*), new *chars* (mid-channel islands) appear and disappear annually in the floodplain. These *char* lands are used during the low water season for winter cultivation, particularly by the poor and landless people. If newly emerged *chars* become stable overtime and remain above the annual normal flood level, they are either settled by previous owners or by poor people under a system of local patronage.[3] Secondly, the area, the right bank in particular, is generally single cropped – mainly rice – and in some areas on the left bank, people grow a second crop like potato and/or mustard. In the project area, nearly 71 percent of the people are engaged in agriculture (national average 66 percent). Third, besides agriculture, the populations are engaged in horticulture, cattle/goat rearing, and poultry for cash income. Capture fisheries is also a common source of income for people along the bankline. Table 10.1 presents the size and incidence of landless and agricultural farm laborers to the total population of the five districts – Munshiganj, Shariatpur and Madaripur in Mawa-Janjira, and Manikganj and Rajbari in Paturia-Goalundo sites. Over one-fifth of the households in the project area are farm laborers.

(4) Findings of the Survey

As indicated earlier, questionnaire survey was conducted for primary data collection. A total of 200 respondents were interviewed from the two alternative crossing sites. The questionnaire used aimed at eliciting key socio-economic data both at household and community levels. The tables provide a comparative view of the potential impacts. The detail analysis and mitigation measures are discussed separately.

(a) Impact of Land Acquisition

The estimated amount of land acquisition required is almost same in both sites (Table 3.3.11). However, the impacts vary substantially. For example, the number of affected households/persons is almost twice in the case of Mawa-Janjira site compared to Paturia-Goalundo (also called Daulatdia) crossing. This is due to significant difference in population density locally, which is 1,042 and 707, respectively in Mawa-Janjira and Paturia-Goalundo. In both sites, the density on the left bank is much higher than the right bank.

[2] See, C. E Haque and M.Q. Zaman, "Coping with Riverbank Erosion Hazard and Displacement in Bangladesh," *Disasters*, Vol. 13(4), 1989.

[3] M. Q. Zaman, "Social Structure and Process in *Char* Land Settlement in the Brahmaputra-Jamuna Floodplain," *Man* (N.S.), Vol. 26(4), 1991.

Table 3.3.11 Impact of Land Acquisition

Nature of Impact	Mawa-Janjira	Paturia-Goalundo
Affected area (includes approach roads, bridge end facilities, construction site/services	1,272 ha	1,239 ha
Number of affected households on the ROW corridor	2,635	1,842
Number of affected persons	13,204	8,732
Average household size	5.0	4.8

Source: Field Survey (Nov-December 2003)

The impact in terms of number of affected persons includes only those likely to be affected by loss of houses/structure and would require relocation. At this time, it has not been possible to estimate the number of affected households/person likely to be affected by loss of agricultural land (without need for relocation). Experience suggests that the number of those affected by loss of agricultural plots only is likely to be three to four times than the number of displaced households.[4] As a result, the impact would be quite significant at both crossings – an estimated 10,000 households (50,000 persons) or more in the case of Mawa-Janjira and 6,000 households (29,000 persons) or more in Paturia-Goalundo site. Furthermore, there will also be temporary and permanent impacts of the construction of the bridge on *char* lands, including loss of land and livelihood. This can be ascertained only after the selection of the bridge site and preliminary design of the bridge structure.

(b) Impact on Land Area/Settlement

During the survey, an assessment of the project impact on the village settlement/*mouza*[5] area was made based on consultation with the local villagers and community leaders. The survey team used a preliminary drawing indicating a route for the approach roads, right-of-way, bridge start location/landing area, construction site, tool gates and other bridge-end facilities that would require acquisition of land. The results are presented in Table 3.3.12. The assessment presented here is very speculative to say the least due to absence of any specific design, precise alignment/ROW for the approach roads, and final location of the bridge site.

Table 3.3.12 Land Area/Settlements Likely to be affected

Site	Number of Mouza/ Village	Proportion of Mouza/Village Area (%) Likely to be Affected by Project Intervention				
		Up to 20%	21-50 %	51-80%	81-90%	91-100%
Mawa-Janjira	46	18	12	01	5	10
Paturia-Goalundo	29	13	05	04	-	07

Source: Field Survey (November-December 2003)

The number of villages to be affected in Mawa-Janjira crossing is higher than one would expect through visual survey of the area. This is due to the presence of many smaller and scattered "social" villages, which often are *para* (neighborhoods) or kin groups known after the head or senior elder of the group – for example, Hasan Mollar Gram or Jabbar Sikder Kandi. Nearly all of the 36 villages (in Janjira end) out of 46 listed in Mawa-Janjira crossing are such type of small "social" villages. This also is a result of fragmentation of villages due to erosion, displacement and migration of people overtime from their "original" villages. In Paturia-Goalundo crossing, 11 (in Goalundo end) of the 29 villages

[4] Jamuna Multipurpose Bridge Project (Total number of households affected was 16,000 out of which only 4,000 required relocation. The rest lost agricultural land only and did not require relocation.)

[5] A *mouza* is a local land-revenue unit as defined by the cadastral survey. Any reference to land in Bangladesh is mouza-based, which generally covers one to two-square km area. Typically, villages are named after the specific *mouza*, but there may be more than one village (bearing a separate name) in one mouza, the latter is recognized as "social" village usually named after an influential person like a village *matabbar* (leader) – for example, Hasan Mollar Gram. In some instances, a *mouza* may contain only cultivable land and no settlements.

are similar kin-based small settlements. The extent of loss of land area is likely to be significant. Among the villages likely to be affected, about one-fourth would lose 100% of the area. These villages are mainly from the proposed bridge location/construction and landing areas from both sides of the river. In a land scarce situation, any amount of loss – even 20% of the current holding by farmers – would mean severe impacts on the productivity and output of the affected farm families.

(c) Types of Structures

A very preliminary estimate of the number of structures likely to be affected has been prepared. The various types of structures to be affected are categorized into three broad types, based on the construction materials used: (a) katcha (straw and bamboo roof); (b), semi-pucca (CI sheet/tile roof); and (iii) pucca (brick/cement). The number of structure affected will be more in the Mawa-Janjira site. In each site, over 80 percent of structures are either katcha and/or semi-pucca, which can easily be dismantled and moved, should they be affected. Table 3.3.13 presents the distribution of structures by types. Mawa has the highest number (18 percent) of permanent/*pucca* structures, which indicates in general better socio-economic conditions of the people.

Table 3.3.13 Types of Structures Likely to be affected

Site	Location	Affected structures (total)	Katcha	%	Semi-Pucca	%	Pucca	%
Mawa –Janjira	Mawa	1,454	232	16	959	66	263	18
	Janjira	1,181	165	14	1,016	86	-	-
Paturia -Goalundo	Paturia	978	293	30	547	66	138	14
	Goalundo	864	311	36	466	54	87	10

Source: Field Survey (Nov-December 2003)

An inventory of the community/civic amenities likely to be fully and/or partially affected has also been prepared. The inventory includes local *hat* (market), mosques, temples, schools, and graveyards/cremation sites. Estimates of the number of affected community and civic structures are: (a) Mawa/Janjira – 60, and (b) Paturia/Goalundo – 18.

(d) Resettlement Options

The survey included questions with regard to resettlement choices and preferred options by the respondents. Two hundred potentially affected heads of households were asked to state their preferred options for resettlement, provided they are affected by the construction of the bridge. The responses are listed in Table 3.3.14.

Table 3.3.14 Preferred Options (%) for Resettlement

Sl. no	Location	Self-relocation on own land	Resettled on purchased land elsewhere through own efforts	Resettle with project assistance	Project sponsored resettlement village
1	Mawa	32	36	20	12
2	Janjira	36	46	12	6
3	Paturia	6	90	2	2
4	Goalundo	20	76	0	4
	Mawa-Janjira average	34	41	16	9
	Paturia-Goalundo average	13	83	1	3

Source: Field Survey (Nov-December 2003)

In Mawa, 75 percent of those interviewed preferred relocation on their own initiatives (i.e., self-relocation). In Paturia-Goalundo crossing site, 96 percent indicated their preferences for self-relocation on their own and/or purchased lands. The survey findings indicate that there will be very limited demand for project-assisted resettlement site(s) development.

(e) Awareness and Response to the Project

The local people appeared to be fairly aware of land acquisition, displacement and consequent resettlement associated with bridge project implementation, particularly from the Jamuna Bridge resettlement experience. During PRA and FGD in Mawa-Janjira site, many indicated their awareness about donor policies and comprehensive resettlement packages offered by the ADB-funded Southwest Road Network Development Project under implementation. The survey team also explained the nature of project interventions, likely impacts on properties, livelihoods and socioeconomic conditions, and potential mitigative measures (based on the Jamuna experience) and the administration of the resettlement processes.

In Mawa-Janjira and Paturia-Goalundo, several lobby groups and associations have been formed to placate demands for the construction of the bridge at their respective area. Indeed, local politicians and interest groups met the JICA Study Team in the field as well in the office to present arguments, supported by their own "studies" justifying selection of their favored site.6 The Study Team experienced opposition to the project in only one meeting in Mawa site during the early stage of the feasibility study when a 6-km approach road was proposed for the Mawa site at an alignment (later abandoned) – about 3 km downstream from the selected site. The opposition was more due to difficulties associated with land titles and payments of compensation by the DCs. Many along that abandoned alignment live on land considered "vested" or government property and/or have titled which are disputed as the "original" owners migrated to India in the 1970s or earlier. No opposition to the present alignment in Mawa was noticed during the study.

During the survey, key respondents in the two project sites were asked to list their observations as to why and for what reasons they favor the construction of the bridge project. Table 3.3.15 presents the responses to and perceived benefits of the project. There is a strong support to the project in both sites. The survey team members explained likely compensation packages and resettlement assistance citing examples from the Jamuna Bridge Project. In general, people at both sites are fully aware of the likely losses and disruptions that may cause the construction of the bridge project. Despite this, they showed willingness to part with their lands and structures if adequately compensated and assisted in resettlement.

Table 3.3.15 Responses (%) to the Project

Reason	Mawa	Janjira	Paturia	Goalundo
Improved communication	75	100	100	100
Improved access to healthcare facilities	-	20	50	50
New and improved business opportunities	75	20	50	50
Bring improvements in quality of life	25	20	-	50
Sources of income will increase	-	20	50	50
Bring new employment opportunities	50	40	50	100
Capital flow and new industrial development	75	40	50	100
Land value will appreciate	25	60	50	50
Riverbank erosion will be controlled	100	60	100	100
Travel time will be reduced	25	60	50	50
Tourism will develop	6	-	-	-
National economic development will occur	8	4	6	2

Source: Field Survey (Nov-December 2003)

[6] *Biswa Moitry Setu* (in Bangla) by Daulatdia Padma Setu Bastobayan Parishad, 2003; *Memorandum* submitted by the Mawa Padma Setu Bastobayan Andolon, November 2003.

(5) Review and Analysis of the Findings

The SIA data should be treated as indicative of the potential impacts. For Mawa-Janjira, the results are generally in line with the estimates prepared by the Pre-Feasibility Study[7], which indicated that the directly and indirectly affected persons could run into 50,000. The Prefeasibility Report recorded higher impacts (68,400 persons) in the case of Goalundo crossing. This difference is primarily due specific location considered (i.e., Aricha-Goalundo site) unlike more rural Paturia-Goalundo site.

Experience in Bangladesh[8] and elsewhere indicate that involuntary resettlement in large infrastructure projects often give rise to severe risks of a social, economic, cultural, and environmental nature. Production systems are dismantled and people are impoverished unless appropriate measures to restore people's livelihoods are carefully planned and implemented.[9] A more extensive census survey, to be carried out for the final selected site, will provide comprehensive, up-to-date, and reliable details on various characteristics of the displaced population (e.g., description of production systems, labor and household organization, standard of living, formal and informal/home-based economic activities, inventory of assets, gender-based impacts, information on disadvantaged/vulnerable groups, etc.).

(6) Cost Estimates

The cost estimates for the two alternative site is presented in Table 3.3.16. At this stage, only a rough estimate of the total costs can be provided. At Mawa site, LA and resettlement cost will be about $39 million dollar while Paturia site will require $24 million. These figures should be treated as preliminary, based on locally available and reported value.

Table 3.3.16 Land Acquisition and Resettlement Cost Estimates (Taka/Million)

Item	Mawa-Janjira	Paturia-Goalundo
Compensation for LA and other assets (land, trees, crops, and structures)	2000.00	1200
Resettlement Measures (Site development, shifting costs, resettlement assistance, training/income restoration, planning and administrative costs)	250.00	175
Total (*Taka 58=$1)	Tk 2250 ($38.79)*	Tk 1375 ($23.70)

Source: Field Survey (Nov-December 2003)

(7) Criteria for Final Site Selection

The preliminary results show greater impacts in Mawa-Janjira over the Paturia-Goalundo/Daulatdia site. Likewise, land acquisition and resettlement costs will be higher in the case of Mawa-Janjira. The impacts of alternative sites are based on a preliminary crossing location and a broadly identified corridor for approach roads in both cases. The project alignments may likely change in the course of final site selection. Therefore, the impacts can vary significantly depending on the alignment and design to be adopted.

[7] *Padma Bridge Study – Phase I Prefeasibility Study Report* (Chapter 5 – Initial Resettlement Evaluation), RPT, February 2000.
[8] M. Q. Zaman, "Development and Displacement in Bangladesh: Toward a Resettlement Policy," *Asian Survey*, Vol. 36(7), 1996.
[9] Michael M. Cernea, "Risks, safeguards, and reconstruction: a model for population displacement and resettlement." In Michael M. Cernea and Christopher McDowell (edited), *Risks and Reconstruction: Experiences of Resettlers and Refugees*. The World Bank, Washinton, D.C., 2001.

(8) Land Acquisition and Resettlement Issues

(a) Acquisition Ordinance of 1982: An Overview

In Bangladesh, the current legislation governing land acquisition for public purposes is the *Acquisition and Requisition of Immovable Property Ordinance* (Ordinance II of 1982) and its subsequent amendments in 1993 and 1994. The 1982 Ordinance governs all cases of acquisition and requisition by the government of immovable property (i.e., land, crops, and built structures) for any public purpose or in the public interest.

The 1982 Ordinance covers only titled owners and used to exclude other interests in land such as sharecroppers/tenants. An amendment in 1994 made provisions for payment of crop compensation to the tenant cultivators. The Ordinance, however, does not cover project-affected persons without titles or ownership records such as squatters, non-farm workers, landless laborers or indirectly affected people. Moreover, it does not take into account the adverse impact of dislocation, including resettlement and economic rehabilitation of the affected households. In sum, the existing legal framework offers limited assistance to people affected by development projects and resettlement of affected persons is not considered an integral part of the development process.

(b) Resettlement in Donor-funded Projects

Bangladesh does not have a national policy for resettlement of project-affected persons. As a result, in recent years, *ad hoc* project-specific improved measures have been adopted in many projects (for instance, Jamuna Bridge Project, Bhairab Bridge Project, Paskey Bridge Project, Rupsa Bridge, and Jamuna Rail Link Project, and Southwest Road Network Project) to comply with donor requirements. These measures are over and above the requirements set by the Land Acquisition Ordinance of 1982. The measures are now considered standard "best practices" in resettlement management in development projects in the country. They include: (a) comprehensive resettlement plan to counter adverse project impacts; (b) provision for replacement value of assets (land and housing) – this is over and above the payments by district commissioners in accordance to law; (c) consultation and community participation in the planning and implementation of resettlement plans; (d) resettlement sites with basic civic amenities like roads, drainage, water, power, schools, and community centres; (e) provisions for civic amenities in "host" communities to enhance carrying capacity due to new resettlers; (f) training for alternative skills and income restoration in post-resettlement period; and (g) special attention to women and vulnerable groups in the relocation and rehabilitation processes.

(c) Lessons from Resettlement Experience

Despite "best practices" in donor-funded projects, the challenge of resettlement still persists. Recent evaluations of donor-funded projects [10] reported various inadequacies and weaknesses in the planning and implementation of resettlement.

First, more land was acquired than necessary in the case of the Jamuna Bridge Project due to uncertainty caused by river erosion.

Second, delays in the payments of compensation have been widely reported in several projects, particularly payment by DC office. This also caused delay in the payments of additional grants as per the project entitlement matrix and approved framework.

Third, the record in income restoration has been at best mixed as many reported lack of

[10] *Evaluation of Resettlement Experience in Selected Projects*, cited earlier.

employment opportunities in resettlement sites. As a result, about one-third of those resettled by the Jamuna project claimed that they were "worse-off" than the pre-project standard of living. However, many poor and vulnerable families benefited from free allocation of house plots in resettlement sites and other housing assistance.

Finally, there was no community capacity building measure for maintenance of civic amenities in post-resettlement period in the Jamuna Bridge and River Bank Protection Projects.

The "lessons learned" from the selected projects would be instructive in the planning of the Padma resettlement. The experience of the Jamuna in particular will be invaluable due to strikingly similar context and riverine situation. It is expected that many of the features of the Jamuna can be tailored to the needs of the Padma Project. A detailed resettlement framework will be prepared during the feasibility study, based on further studies of the selected site.

3.3.6 Indicative Cost Estimate

Indicative construction cost of alternative PG-3 (Patria-Goalundo) and alternative MJ-3 (Mawa-Janjira) which were selected in Chapter 2 was estimated referring to the construction cost of the Jamuna Bridge. The estimation result was used for the economic evaluation in this Project.

(1) Alternative PG-3 (Patria-Goalundo)

Approximate quantities and indicative construction costs in the crossing site of the alternative PG-3 (Patria-Goalundo) were estimated on the basis of the following project formation. The following table shows the indicative construction costs of alternative PG-3.

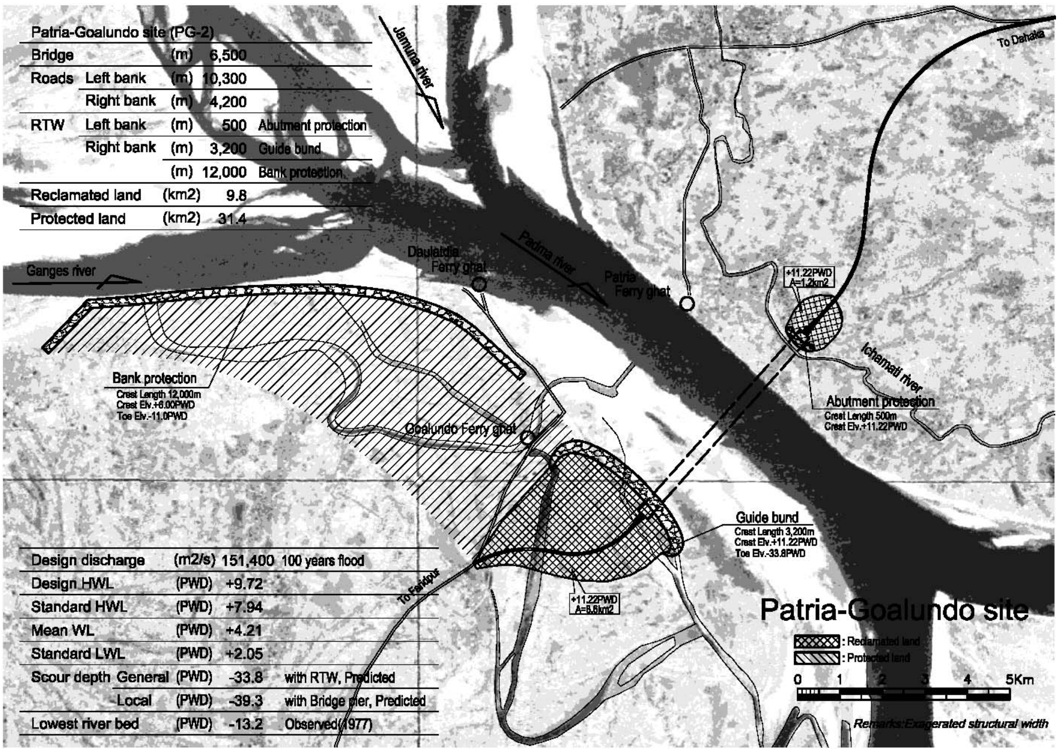


Figure 3.3.30 Project Formation of Alternative PG-3 (Patria-Goalundo)

Table 3.3.17 Indicative Construction Cost of Alternative PG--3 (Patria-Goalundo)

Item	Amount		Total Amount	Remarks
	Local (Taka)	Foreign(USD)	(USD)	
Main Bridge	8,340,584,000	447,834,100	639,763,000	6,500m
Approach Road	251,364,000	13,451,300	17,766,000	14.5km
Box Culvert & Minor Bridge	284,652,000	15,395,900	20,282,000	
Guide Bund	8,215,703,000	329,070,000	470,100,000	
Electric & Utilities	596,788,000	23,903,600	34,148,000	
Road Widening (Dhaka-Mawa)	0	0	0	
Subtotal 1	17,689,091,000	829,654,900	1,185,233,000	
General	3,537,818,00	165,931,000	237,046,600	20% of Subtotal 1
Subtotal 2	21,226,909,000	995,585,900	1,422,279,600	
Engineering Service	1,061,345,000	49,779,000	71,114,000	5% of Subtotal 2
Total	22,288,254,000	1,045,364,900	1,493,393,600	

Exchange rate as of January 2004: 1USD = 58.25Taka

(2) Alternative MJ-3 (Mawa-Janjira)

Approximate quantities and indicative construction costs in the crossing site of the alternative MJ-3 (Mawa-Janjira) were estimated on the basis of the following project formation. The following table shows the indicative construction costs of alternative PG-3.

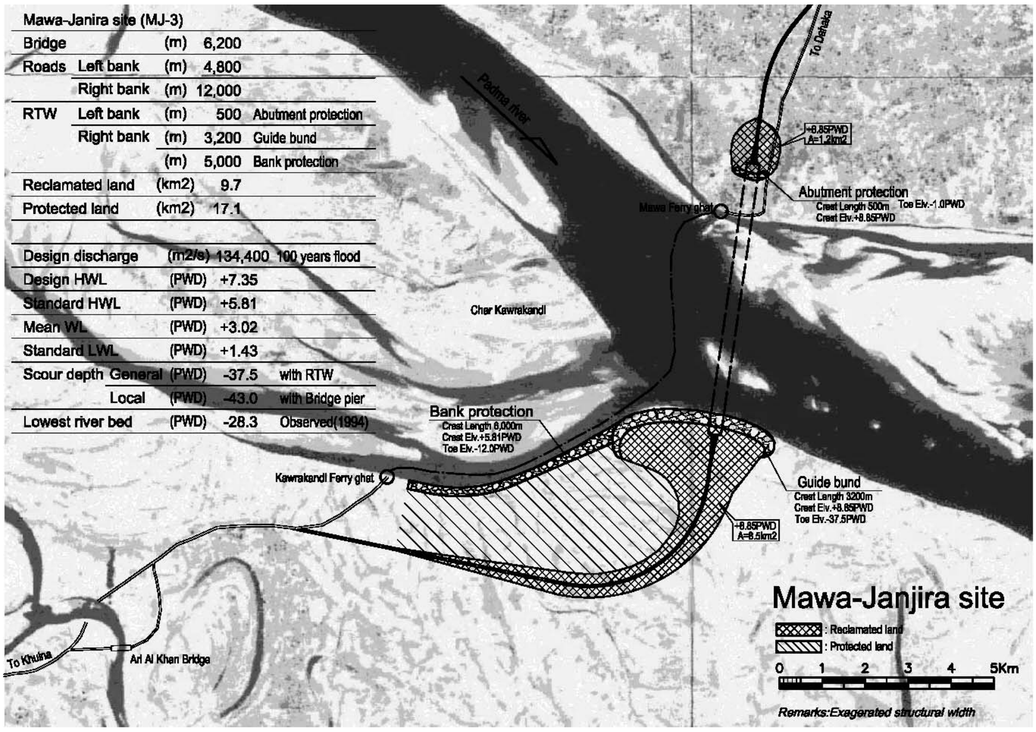


Figure 3.3.31 Project Formation of Alternative MJ-3 (Mawa-Janjira)

Table 3.3.18 Indicative Construction Cost of Alternative MJ-3 (Mawa-Janjira)

Item	Amount		Total Amount	Remarks
	Local (Taka)	Foreign(USD)	(USD)	
Main Bridge	6,384,450,000	341,906,800	488,439,000	6,200m
Approach Road	299,649,000	15,964,500	21,108,000	16.8km
Box Culvert & Minor Bridge	249,348,000	13,418,200	17,698,000	
Guide Bund	5,421,210,000	217,140,000	310,200,000	
Electric & Utilities	733,943,000	29,397,200	41,996,000	
Road Widening (Dhaka-Mawa)	370,153,000	18,849,500	25,204,000	
Subtotal 1	13,458,753,000	636,676,200	910,086,000	
General	2,691,751,000	127,335,200	182,017,200	20% of Subtotal 1
Subtotal 2	16,150,504,000	764,011,400	1,092,103,200	
Engineering Service	807,525,000	38,201,000	54,605,000	5% of Subtotal 2
Total	16,958,029,000	802,212,400	1,146,708,200	

Exchange rate as of January 2004: 1USD = 58.25Taka

3.3.7 Indicative Economic Effect and Preliminary Examination of Feasibility

(1) Economic Feasibility

(a) Direct Economic Benefits

The following direct benefits are estimated for the economic evaluation of the Padma Bridge:

1) Vehicle Operation Cost (VOC) saving Benefit
2) Travel Time Cost Saving Benefit
3) Freight Value Deterioration Saving Benefit
4) Ferry Operation and Maintenance Cost Saving
5) Traffic Accident Saving
6) Air Pollution Reduction Benefit (reduction of CO_2 and NO_X
7) Benefit from Provision of Utility Facilities (such as gas pipelines, electric cables and telecommunication cables)
8) Land Enhancement Benefit such as land value to be enhanced at reclaimed and protected land)

(b) Project Costs

Projects costs consist of the following items:

1) Construction cost of main bridge and approach roads
2) Box culvert and minor bridge
3) Guide bund
4) Electric and utilities
5) Road widening (in case of Dhaka – Mawa)
6) Engineering services
7) Land acquisition and resettlement
8) Operation and maintenance costs after opening

(c) Economic Evaluation

For the economic evaluation, the following three indicators were calculated trough benefit cost cash flow analysis.

1) Economic Internal Rate of Return (EIRR)

2) Net Present Value (NPV)
3) Benefit/ Cost Ratio (B/C Ratio)

The evaluation results are summarized below:

	Paturia - Goalundo	Mawa - Janjira
EIRR	9.6 %	16.9 %
NPV (Million TK)	- 9,857	23,140
B/C	0.71	1.81

Therefore, Mawa – Janjira route is more preferable than Paturia – Goalund.

(2) Indirect Economic Effect from the Project

(a) Main Factors Taken into Account

The following factors were taken into account for the analysis and comparison of indirect economic effects.

1) Improvement of Accessibility
2) Formation of International Road Network
3) Contribution to Regional Economic Development
4) Relationship with Regional Development Projects

(b) Results of Comparison

Comparisons between the two candidate sites were made from various aspects and conclusions are summarized as follows:

Item	Paturia Route	Mawa Route
Traffic Demand (2025)	19,850 vehicles/day	41,550 vehicles/day
Economic Feasibility	EIRR = 9.6 %	EIRR = 16.9 %
Financial Project Cost	1,493 Million US$	1,147 Million US$
Improvement of Accessibility	(Travel time) Dhaka – Mongla 4.5 hours Dhaka- Benapole 4.6 hours (Beneficiary Population) Within 3 hours from Dhaka 2,791,000 (9%) Within 4 hours from Dhaka 12,738,000 (42%)	(Travel time) Dhaka – Mongla 3.6 hours Dhaka – Benapole 3.6 hours (Beneficiary Population Within 3 hours from Dhaka 10,417,000 (35%) Within 4 hours from Dhaka 22,247,000 (74%)
Density of Feeder Roads	No big difference	
Formation of International Road Network		Asian Highway A-1 Short distance to Benepole Land Port and Mongla Sea Port
Contribution to Regional Economic Development	GDP of Southwest Region will increase by 18% (1.2% per year)	GDP of Southwest Region will increase by 35% (2.3% per year)
Growth Centers around the bridge sites	No big difference	

3.3.8 Selection of Final Bridge Site

(1) Evaluation of Paturia-Goalundo Site and Mawa-Janjira Site

As a result of the previous discussions, evaluation criteria for selecting a final bridge site are summarized in the following table.

Evaluation Criteria		Paturia - Goalundo	Mawa - Janjira
Future Traffic Demand	Year = 2015 Year = 2025	10,300 vehicles/day 19,850 vehicles/day	21,260 vehicles/day 41,550 vehicles/day
Economic Feasibility	EIRR	9.6 %	16.9 %
	B/C Ratio	0.71	1.81
	NPV (Million TK)	- 9,857	23,140
Financial Project Cost (Indicative)		1.49 billion US$	1.15 billion US$
Improvement of Accessibility	Travel Time Dhaka – Mongla Dhaka - Benapole	 4.5 hours 4.6 hours	 3.6 hours 3.6 hours
Density of Beneficiary population	Population from Dhaka Within 3 hours Within 4 hours	 2,791,000 (9%) 12,738,000 (42%)	 10,417,000 (35%) 22,247,000 (74%)
Formation of International Road Network			Asian Highway Route No. A-1. Short distance to Benapole Land Port and Mongla Sea Port.
Regional Economic Development	Increase of GRDP of Southwest Region	18% up (1.2% per year)	35% up (2.3% per year)
Growth Centers around the Bridge Site		No big difference	
Environmental Impact	Result of IEE	No advantage of one site over other	
Social Impact and Resettlement Issues	Households requiring relocation	1,842	2,635
	Community structures affected	18	60
	Total population affected (both direct and indirect)	40,000 – 45,000	70,000 – 80,000
	Preliminary RAP cost	23.7 million US$	38.79 million US$

(2) Recommended Final Bridge Site

From the economic feasibility including the costs for social and resettlement issues and future effects on the GRDP growth, the bridge site at Mawa-Janjira is recommended.

Despite higher adverse social impacts in Mawa-Janjira, the site was favored due to higher traffic forecasts, reduced travel time to major destinations in the Southwest, higher EIRR and geotechnical considerations. It was considered that the impact could be reduced or minimized by adopting technical/engineering options, particularly with regard to land acquisition. Once the site is selected, various technical options and alternatives will be considered in consultation with the affected people and communities, including appropriate resettlement matters.

3.3.9 Improvement of Ferry Operations

(1) Effects of Capacity Increase of Ferry Operations

An additional study was undertaken in order to check the effects of improvement of ferry operations as explained below:

(a) Calculation of Capacity of Existing Ferry Operations

The ferry cycle time for one crossing is summarized as follows:

Ferry Cycle Time for One Crossing

(Unit: minutes)

Route	Loading	Crossing	Unloading	Total
Paturia - Daulatdia	20	35	10	65
Mawa - Charjanajat	20	122	10	152

Number of (possible) ferry crossings per day per ferry is calculated as below as the ferry operation hour is 24 hours a day:

No. of Possible Ferry Crossings per day

Per Ferry

Route	No. of possible ferry crossings per day per ferry
Paturia - Daulatdia	22.1 (rounded to 20)
Mawa - Charjanajat	9.4 (rounded to 9)

At the same time, BIWTC (Bangladesh Inland Water Transport Corporation) provided the information about the assigned ferry vessels on these two routes with their capacity (expressed in Truck Unit) as shown below (excluding ferries under repair):

Calculation of Existing Ferry Operation Capacity by Route

Route	Capacity in Truck unit per ferry (A)	No. of ferries assigned (B)	Total Truck unit (A) * (B)
Paturia – Daulatdia (P-D)	27	1	27
	25	6	150
	20	2	40
	14	1	14
	13	1	13
	Sub total		**244**
	Total capacity of route per day in Truck unit		**244*20=4880**
Mawa – Charjanajat (M-C)	17	1	17
	13	4	52
	8	2	16
	3	3	9
	Sub total		**94**
	Total capacity of route per day in Truck unit		**94*9=846**

Original Source: BIWTC

Therefore, ferry operation capacity of existing ferry services were calculated at 4,880 truck units for Paturia – Daulatdia and 846 truck units for Mawa – Charjanajat per day respectively.

(b) Comparison of Operation Capacity and Future Traffic Demand of Ferry

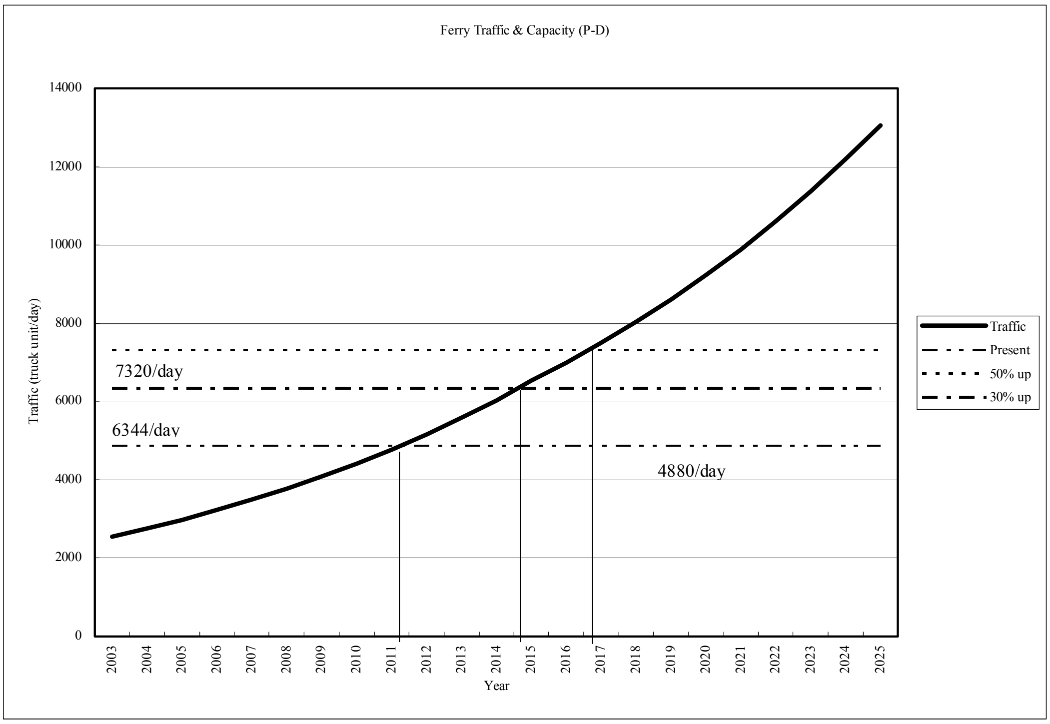
The year of saturation was estimated comparing future traffic demand with the various improved levels of capacity as shown below:

i) Paturia – Daulatdia Route

- Under the existing capacity: saturation will be appeared around in 2011.
- 30% of capacity increase (by increasing assigned vessels and expanding ferry terminals): saturation will be in 2014.
- 50% of capacity increase: saturation year will be in 2017.

Therefore, in Patiria Route, even if the operation capacity is expanded by 50%, saturation year will come before the year 2017.

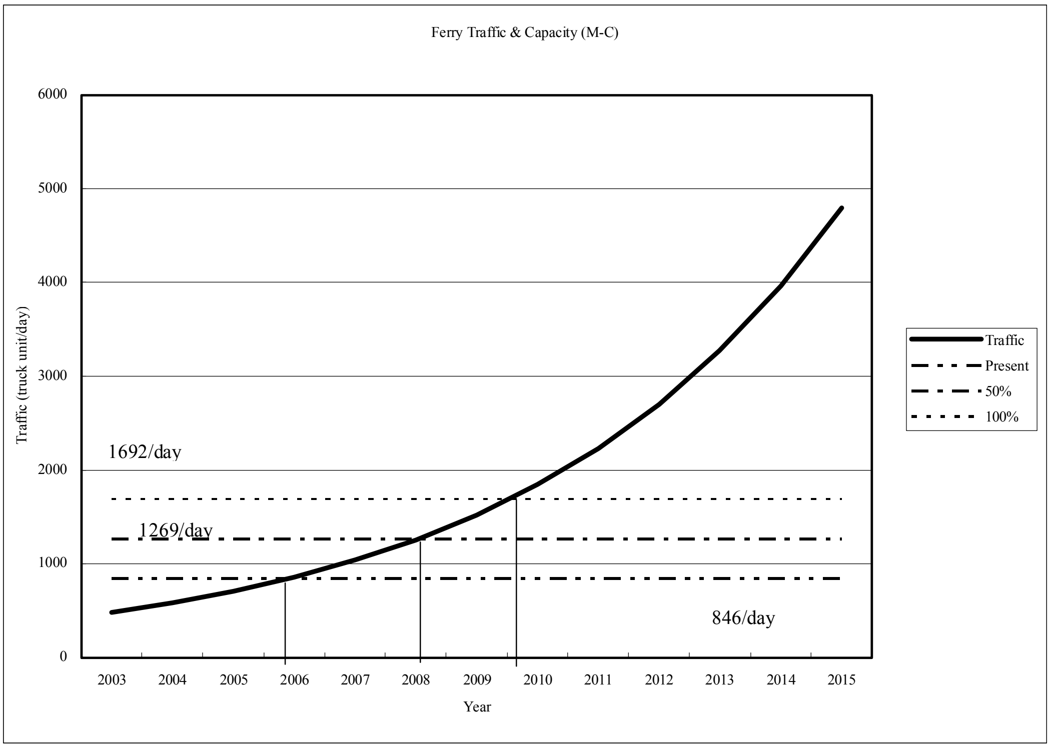
It is also noted that the Paturia – Daulatdia ferry is assumed to be operated continuously even after the Padma Bridge at Mawa is constructed and it is used as an alternative route of the Padma Bridge.



Comparison of Operation Capacity and Traffic Demand (Paturia – Daulatidia)

ii) Mawa – Charjanajat Route

In case of Mawa Route, even if capacity is increased by 100%, traffic demand will exceed the operation capacity in 2010.



Comparison of Operation Capacity and Traffic Demand (Mawa – Charjanajat)

(2) Conclusions

It is concluded that from the technical difficulty of expanding ferry facilities and from the aspect of providing the safety all-weather transport mean (with 100 year project life), as well as from the point of view of efficiency in the investment, Mawa – Charjanajat ferry operation shall be replaced with the Bridge in the future optimum timing