CHAPTER 11

FORMULATION OF TRANSPORT MASTER PLAN

CHAPTER 11 FORMULATION OF TRANSPORT MASTER PLAN

11.1 Background of the Plan

11.1.1 Roles and Functions of Rupsa Bridge

Rupsa Bridge is planned to be located on National Highway No. 7 and to cross over the Atai/Rupsa River and its tributaries. This river severs the South-western region of Bangladesh and disrupts community of Khulna Division with 12.7 million population in regional as well as Khulna Former District with 5.3 million in local as shown in Fig. 11.1.1.
National Highway No. 7 forms the north-south backbone of arterial road network to connect Mongla Port to Khulna, Jessore and the North-western Region of Bangladesh, and sustains socio-economic activities and development along the road.
The roles and functions of the Bridge have been deliberated for a long span of time. However, it becomes clear and distinct that the Bridge should play roles and functions pertaining to them as shown in Fig. 11.1.2, considering circumstances of formulation of on-going Khulna Development Master Plan and progress of Paksey Bridge Construction Project.

(1) Alleviate Traffic Congestion of Rupsa Ferry
Congestion taken place daily at Rupsa Ferry is so serious and grave that traffic movement in the region may be discouraged and decline to bring adverse effects to under-utilize infrastructures such as Khulna - Mongla road and Mongla Port. Considerable ferry users of not only motorized vehicular traffic but also pedestrian and non-motorized vehicles suffer economical loss from long journey in terms of not distance but time. Bridge is only one fundamental solution to alleviate traffic congestion.

(2) Strengthen Khulna - Mongla Road by Non-River Interruption
Existing ferry makes Khulna - Mongla Road unstable transport means and restricts loading capacity of trucks. All-weather and reliable land link strengthens arterial road network in the region, especially Khulna - Mongla Road.

(3) Promote Khulna Bypass
Existing National Highway No. 7 passes the downtown of Khulna city where traffic congestion takes place very often. Heaviest traffic in the region is observed in the section of Khulna - Jessore, and they are always caught by traffic congestion due to no availability of alternative route. Khulna Bypass is planned under such circumstances to bypass through traveled traffic to downtown of Khulna as well as to strengthen road network of Khulna city. Rupsa Bridge and its approach roads are designated as a part of Khulna Bypass to encompass Khulna Urbanized area including Rupsa.

(4) Stimulate Mongla Port to Induce Freight Demand

It is incredible that neither road nor railway transport container in the region. All container cargoes imported are opened at the port and transferred to trucks, while the exported are carried by trucks and packed at the port. Small capacity and congested ferry surely discourage to transport cargoes by container.

Khulna - Mongla Road will stimulate Mongla Port to induce freight demand as well as sustain large-scale development at the port area if no river interruption exist. Container cargoes will be encouraged according to worldwide tendency of containerization.

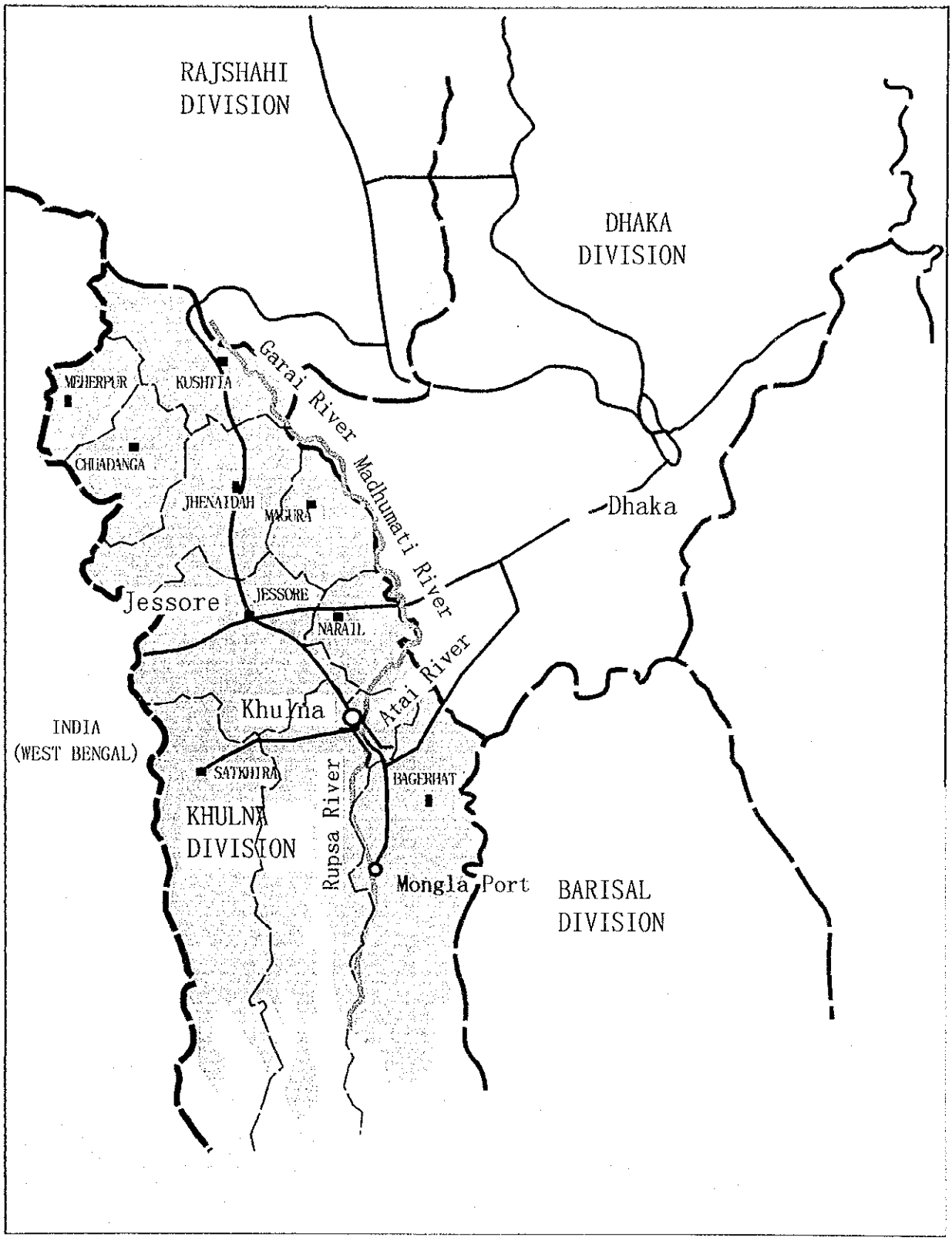


Fig. 11.1.1 Rupsa Bridge and its Location in Khulna Division

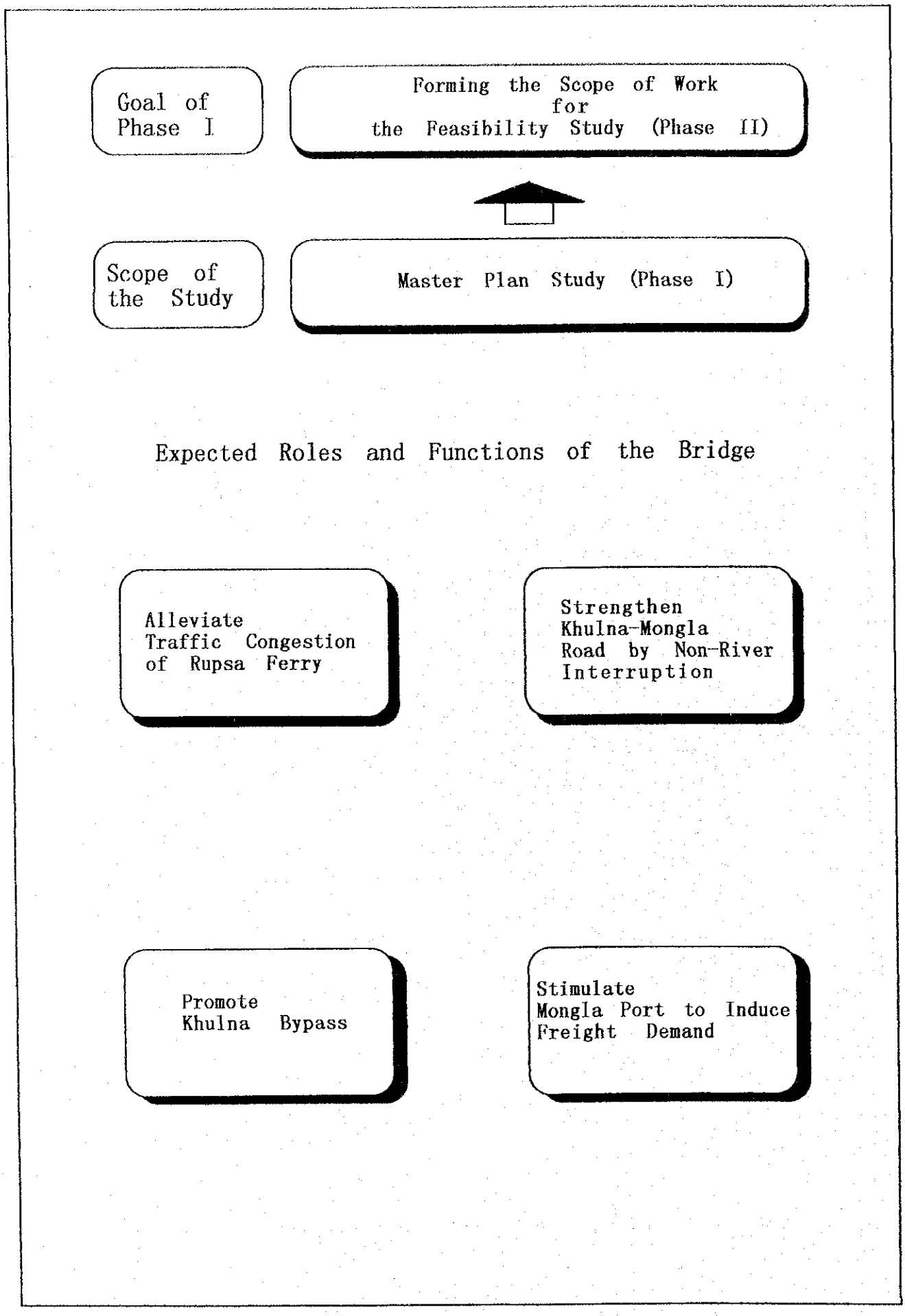


Fig.11.1.2 Scope of the Study and Expected Roles and Functions of the Bridge

11.1.2 Categorization of Five Traffic Movements

A Transportation Master Plan shall be formulated for the Bridge and its related transport facilities, taking into consideration following five (5) categorized traffic movements as shown in Fig. 11.1.3;

Traffic-1 : Passenger and Non-motorized Vehicle Movement

Almost all traffic move within Khulna and Rupsa. Considerable passenger volume occupy the ferry capacity and motorized vehicles may reach to full capacity on the assumption that present operating system should be kept, and they make level of service at Rupsa Ferry get deteriorated.

Traffic-2 : Motorized Vehicular Movement within Khulna

Khulna, the third biggest city of Bangladesh and the hub of commercial and administrative activities in the Division, mainly attracts and generates regional traffic.

This traffic is always caught by traffic jam at the ferry terminal of Rupsa Ghat as well as traffic congestion prone area in downtown of Khulna.

Traffic-3 : Motorized Vehicular Movement beyond Khulna

Through traveled traffic of which origin/destination are outside Khulna passes Khulna and Rupsa Ferry such as bound for Jessore, for the Northwestern region and even Nepal.

Traffic-4 : Cargo Movement within Khulna - Mongla

Predominant inland water transport accommodates cargo movement handled at either mooring buoys or anchorage areas in the river which 94% of cargo handled at Mongla Port presently rely upon. Inland water transport may keep advantageous position in terms of cost.

Traffic-5 : Cargo Movement beyond Khulna

Combined inland water transport and land transport accommodate cargo movement beyond Khulna.

Nepal transit cargoes transferred from inland water transport to land transportation at Khulna port were transported partially by railway in 1997. The remaining were estimated that present road transportation from Khulna interweaves them because of no Nepal transit cargo from the jetty at Mongla port.

These five traffic movements will have substantial implication to transport facilities related to the formulation of Transport Master Plan according to their volume and extent.

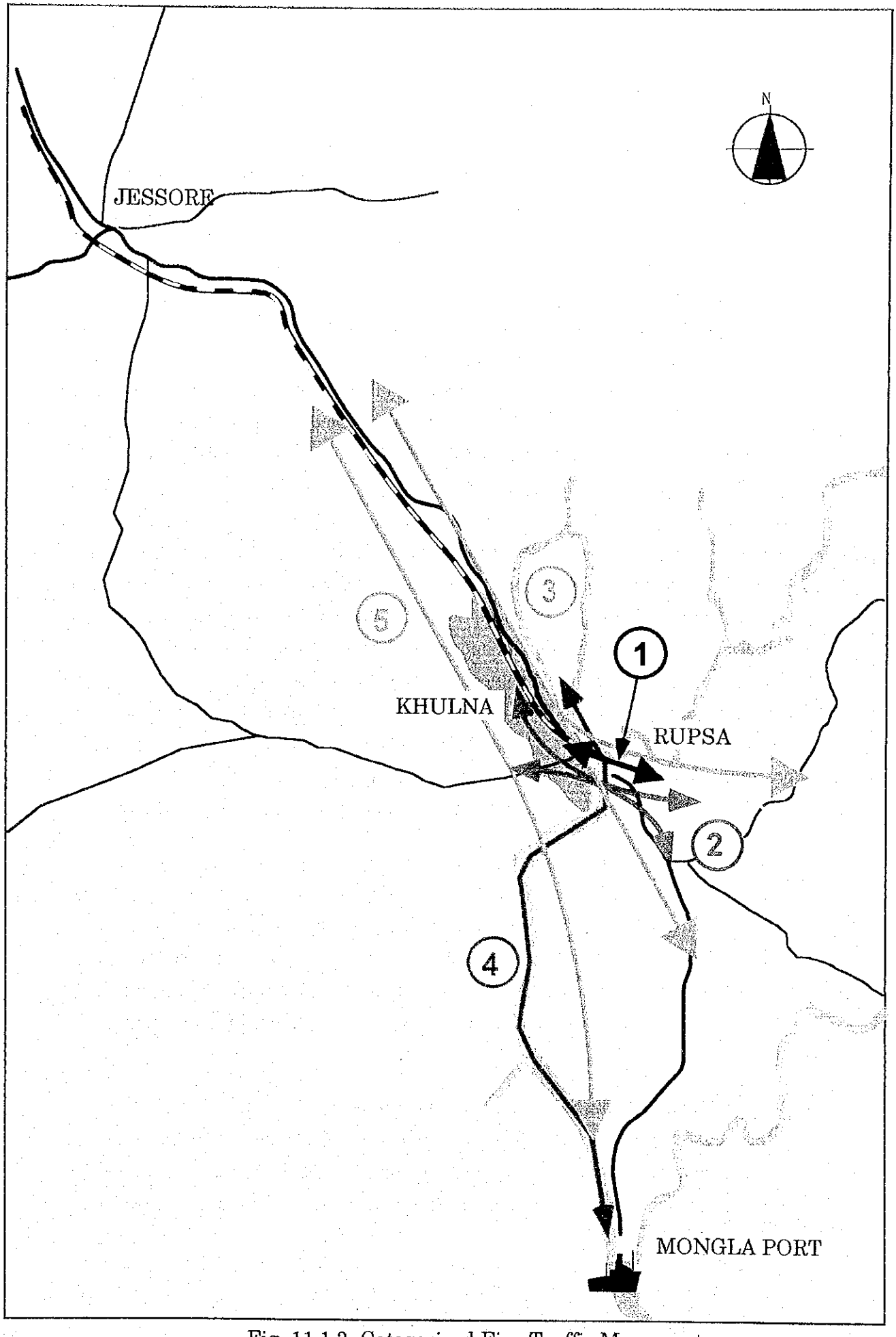


Fig. 11.1.3 Categorized Five Traffic Movements

11.1.3 Related Transport Facilities

Traffic demand forecasts in Chapter 8 are carried out, having assumptions that following transport facilities related to the Bridge are to be improved in order to sustain future traffic demand systematically and comprehensively. The location of these transport facilities is shown in Fig. 11.1.4.

(1) Khulna Bypass

Rupsa Bridge is designated to be a part of Khulna Bypass and to cross the Atai/Rupsa river and its tributaries on National Highway No. 7.

There are four (4) possible bridges involved in the Study. Every bridge is named referring to river name at river crossing point, namely Rupsa Bridge on ADB's Alignment-A (the Western Route) and Bhairab Bridge/Atai Bridge/Atherobaki Bridge on ADB's Alignment-B (the Eastern Route) as shown in Fig. 11.1.4.

The Bridge, so-called "Rupsa Bridge ", is referred as a bridge or a group of bridges on Khulna Bypass that Mongla Port Area Development Project (the MPADP) financed by ADB has studied to solve underutilization of Khulna-Mongla Road, resulted in underutilization of Mongla Port. The MPADP examined two routes to solve traffic bottlenecks in Khulna including congested Rupsa Ferry, Alignment-A in the western side of the Rupsa River and Alignment-B in the eastern side.

An appropriate type and location of the Bridge will be selected in the course of the Study within the corridor covering Alignment-A & B studied by ADB, examining possibility of railway extension up to Mongla Port.

However, following background has been found prior to commencing the Study.

1) Recommendation of the MPADP

Immediate concern of the MPADP was to find the way how to solve congested National Highway No. 7 in downtown Khulna including over-capacity Rupsa Ferry.

The MPADP recommended Alignment-A on the assumption that two-lane Rupsa Road Bridge would be viable and appropriate modal share by road transport would be achieved in lieu of standing and dominant inland waterway transport linkages to the Port.

2) Khulna Bypass proposed by the Khulna Development Master Plan

Khulna Development Authority has intention to formulate the Khulna Development Master Plan, and Khulna Bypass is being studied in the western side of the Rupsa River to cope with strengthening road network in Khulna as well as alleviating congested Rupsa ferry.

Accordingly, Khulna Bypass in the Khulna Development Master Plan is proposed in the same side as the recommendation (Alignment-A) of the MPADP as shown in Fig. 11.1.4.

Table 11.1.1 summarizes the comparison of salient features and differences revealed in association with route location of which Khulna Bypass is located either in the eastern side of the river or in the western side.

(2) Railway Extension to Mongla Port

The MPADP have studied it on the assumption that Railway Extension to Mongla Port should run parallel to Khulna Bypass and existing Khulna - Mongla Road, taking into account scheme of rail-cum-road bridge. However, the Railway Extension to Mongla Port is planned in the Study to connect existing railway to Mongla Port only to accommodate future cargo demand by its own route.

Bangladesh Railways (BR) had studied the railway extension to Mongla Port in the past. The southern part of the extension was almost similar to Khulna-Mongla Road in the section between Rupsa East and Mongla Port, but its northern part was different from that of the MPADP. The eastern route (B) diverts Khulna City in order to evade a high clearance bridge at the Rupsa river, while the western route (A) goes in the suburbs of Khulna City. The railway extension is approximately 40 km in length, of which the land in 15 km long stretch was reported to have been acquired and owned by the BR.

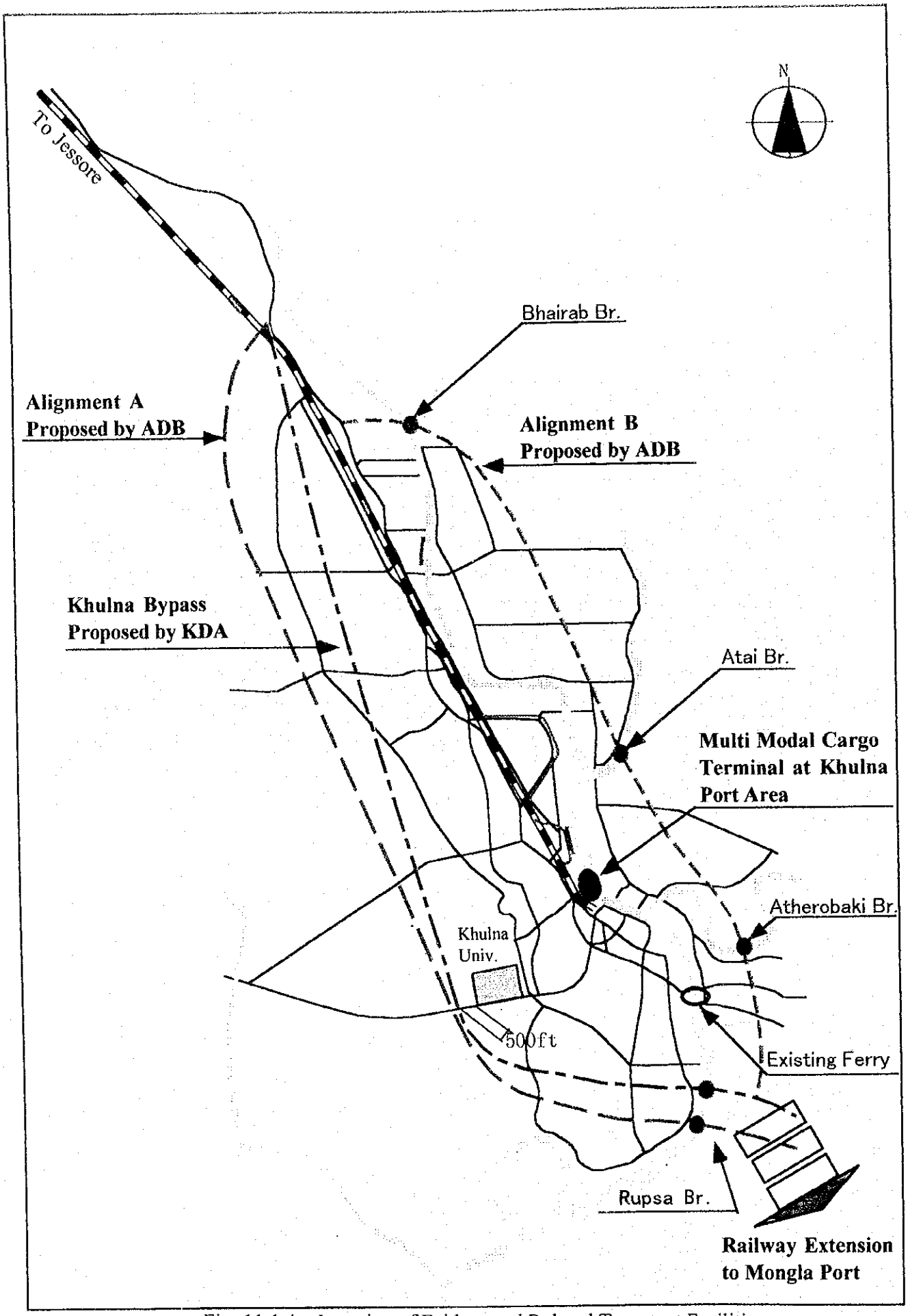


Fig. 11.1.4 Location of Bridges and Related Transport Facilities

Table 11.1.1 Comparison of Salient Features of Bridge and Approach Road on Alignment-A and B

Items	Alignment - A (in the western side of the Rupsa river)	Alignment - B (in the eastern side of the Rupsa river)
Outline of Bridge and Approach Road		
Road Length	10 km Between Khulna-Satkhira Road and Khulna-Mongla Road	20 km Between Cantonment in Siromoni on Khulna - Jessore Road and Khulna-Mongla Road
Bridge Length & Navigation Clearance	Rupsa Bridge : 1,385 m with H=76.22 m, V=18.3 m	Bhairab Brdige : 823 m with H=76.22 m, V=12.2 m Atai Bridge : 923 m with H=76.22 m, V=12.2 m Atherobaki Bridge : 488 m with H-30.48 m, V=7.62 m Total Bridge Length : 2,234 m
General Conditions of Land Use	1) Arable lands spread widely in the western side of the river and shrimp farms exist in the eastern side. 2) Affected villages will be limited.	1) Villages have been densely developed along the river and scattered villages are also found in arable lands. 2) Affected villages will be considerable due to passing through the suburbs.
1. Land Availability	1) **Very high** because the route is located in the periphery of urbanized area. 2) The northern part of the Bypass is planned by KDA and acknowledged by Ministry of Land.	1) **Uncertain** because the routes have to pass in the suburbs with scattered villages. No commitment is made.
2. Future Traffic Demand	1) **Very high** to accommodate traffic demand to/from Khulna and its surroundings as well as to let present traffic at Rupsa Ferry divert.	1) **Low** because the route will serve only through traffic bound for beyond Khulna and hardly contribute to alleviate traffic congestion at Rupsa Ferry.
3. Social Impacts	1) **Lesser degree** because loss of cultivated lands with certain productivity will be limited to road right-of way acquisition due to few resettlements.	1) **Considerable** because cultivated lands with certain productivity will be acquired for road right-of way acquisition and resettlements for affected inhabitants.
4. Construction Economy	1) **Smaller** because of one bridge of totaling 1,390 m in length including 590 m main spans just in case of 60ft navigation clearance with 3% grade. 2) One construction site will be able to make works more economical yet shorter.	1) **Bigger** because of three bridges of totaling 2,230 m in length including 870 m main spans even in case of 40 ft and 25 ft navigation clearance with 3% grade. 2) Three construction sites will make works inefficient yet longer.
5. River Morphology	1) **Sound** because the western bank of the Rupsa river is comparatively stable in spite of high current velocity. 2) A conventional river training is required.	1) **Changeable** because the Atai river moves considerably and the Atherobaki river meanders sharply. 2) Intensive river trainings will be required.

Note : Lengths of road and bridge are estimated on the assumptions that the grade is 3% and the maximum embankment height is 5 m high.

(3) Multi Modal Cargo Terminal at Khulna Port Area

The cargo throughput of Mongla Port is expected to dramatically increase up to the year 2015, though the detailed projection is presented in Chapter 7. In particular, container transport will develop into the major transportation means for exported goods and other general cargo at Mongla Port, taking into account the latest trend at Mongla Port as well as development of containerization in the maritime transportation.

Although it is presumed that most of these container cargo would be transported by land transport means through the improved future land-transportation-networks in the hinterland of Mongla Port, the major portion of the inland transport of the port cargo would be still performed by inland water vessels. This is the most suitable transportation system for Mongla Port, which has lots of anchorage space with the limited number of jetty berths, and is also environmentally friendly means of transportation with the best energy efficiency.

According to the possible increase of port cargo movement to/from Mongla Port by inland water, the necessary considerations should be given to the development of inland water transportation system in the future, especially to that of Khulna Port, which currently handles approximately a third to a quarter of cargo volume to/from Mongla Port by inland water.

Khulna Port has been currently developed in a proper manner, however, it has some problems such as efficiency of connection between different modes and lack of jetty at the Roosevelt terminal. An appropriate development, including that of Multi Modal Cargo Terminal at Khulna Port area, will be required.

11.1.4 Potential Rail Cargo at Mongla Port

The cargo handled at the jetty is subject to transshipped by land transport and is estimated approximately 2 million tons, which is to increase remarkably as compared with 0.16 million tons in 1997/98. Almost of all cargoes, however, are assumed containers.

Containerization is a worldwide tendency of freight transportation.

Its merits are,

① door to door,
② easy to handle,
③ quick and accurate at departure and at arrival,
④ safety of freight, etc.

Taking into account handling costs and time at railway station, these merits may exert at the remotest end from the conventional system of rail transport in the western zone.

Out of 2 million tons, 0.76 million tons is estimated long-trip cargo such as Dhaka, North-western Region and Nepal. It is theoretically true that rail transport has advantage to share it, but it is hard to predict 100% of the long-haul cargo would be transshipped by rail because road transport still keep high modal share in Bangladesh at present and in future. Moreover, status quo of freight transport in the Broad Gauge section is so poor that considerable investment would be required accompanied with a comprehensive plan to cope with containerization.

Under such circumstances, potential rail cargo at Mongla Port may be estimated 0.48 million tons at most in case of the railway extension to Mongla Port, which is the remotest portion of cargo handled at the jetty, mainly comprising North-western Region and Nepalese Transit Cargo.

11.2 Development Scenario

Following three (3) development scenarios are contemplated in association with potential traffic on the Bridge.

(1) Scenario-1 : the Bridge with Railway Extension to Mongla Port

Land transport shall be enhanced to access to/egress from Mongla Port to accommodate long-trip cargo demand in this case, providing that the hinterland of Mongla Port will extend considerably to the North-western region. This traffic movement which comprises mainly Traffic-3 and Traffic-5 will support the possibility of railway extension plan to Mongla Port in case that long-trip cargoes such as Nepalese transit cargo become dominant in future. It will also examine the possibility of Khulna Bypass in the eastern side of the Rupsa river.

(2) Scenario-2 : the Bridge with Multi Modal Cargo Terminal

Incremental container cargoes handled at jetties will be transported by land transport network in the hinterland of Mongla Port, and Multi Modal Cargo Terminal will become necessary at Khulna Port area to build inland links between railway, road and waterway.

This scheme is deliberated as a practical solution from managerial viewpoints of present railway because container base/bases at an arrival side is indispensable in the western inland area if container trains should run on the western zone from Mongla port. Simultaneously, it might become a good chance to renew the freight system by rail in the western zone, including the introduction of the airbrake and automatic coupling to the freight cars.

This traffic movement which comprises mainly Traffic-2 and Traffic-3 will support the possibility of Khulna Bypass in the western side of the Rupsa river.

(3) Scenario-3 : Only the Bridge

This case forms remarkable contrast with the former two scenarios regarding degree of traffic movement beyond Khulna, namely significantly low traffic movement beyond Khulna. On the contrary, local traffic will become dominant demand pertaining to the Bridge.

This traffic movement which comprises mainly Traffic-1 and Traffic-2 will badly require Rupsa Bridge itself to cross the Rupsa river, and it will not support the possibility of railway extension plan to Mongla Port.

11.3 Evaluation and Recommendations

11.3.1 Evaluation on Alternatives of Development Scenarios

The followings are pointed out as due considerations to evaluate alternatives from the planning viewpoints.

1) Present Rupsa Ferry will become serious traffic bottleneck to sustain Mongla Port and future development at the port area if no bridge exists to cross the Rupsa river.
2) Khulna Bypass located in the eastern side of the Rupsa river will force vehicles to make detour and hardly meet traffic demand so that existing National Highway No. 7 in Khulna city will suffer traffic congestion to attract and generate traffic at downtown of Khulna. It is very sure that Rupsa Ferry should be maintained for local traffic if Khulna Bypass is located in the eastern side of the Rupsa river.
3) Rupsa Bridge to cross the Rupsa river on Khulna Bypass located in the western side of the Rupsa river has advantages in the aspects of;
   a) to alleviate traffic congestion at Rupsa Ferry as well as to serve majority of present ferry users.
   b) to keep consistence with the proposed route of Khulna Development Master Plan and to strengthen road network in Khulna City.
   c) to strengthen not only north-south road network but also the east-westward road link of Satkhira - Khulna - Mollahat/Gopalganj
   d) to provide good access to Multi Modal Cargo Terminal at Khulna Port area in case of its realization
4) At most 478,000 tons/year cargo traffic demand for the year 2015 will be generated and attracted at Mongla Port through railway, if Railway is extended to Mongla

Port. Although the possibility of the extension plan will be examined in the course of the Study on the basis of this demand forecast, it is as a matter of fact that this demand is a half of freight in present Khulna - Jessore section.

5) Traffic assignment of Case 1 supported by development Scenario-2 is evaluated as the optimum alternative for the Study from the following aspects;
   a) Although it is presumed that most of these container cargo would be transported by land transport means through the improved future land transportation networks in the hinterland of Mongla Port, the major portion of the inland transport of the port cargo would be still performed by inland water vessels. This is the reason why it is the most suitable transportation system for Mongla Port and is also environmentally friendly means of transportation with the best energy efficiency.
   b) Although on-going Paksey Bridge will be completed and future land transportation network will be improved toward the north as the hinterland of Mongla Port such as North-Western Region and Nepal, Cargo Movement beyond Khulna subject to rail transport is estimated 478,000 tons/year at most, that is medium.

CHAPTER 12

PRELIMINARY ENGINEERING DESIGN

CHAPTER 12 PRELIMINARY ENGINEERING STUDY

12.1 Highway Design

12.1.1 Outline of Road Planning

The Study contains the Bridge and other related components such as passengers and freight transportation by road, railway and inland water that would pass through the Rupsa Bridge. Railway Extension to Mongla Port and Multi Modal Terminal in Khulna Port Area were described in the Chapter 11. They aim at deeply augmenting the roles and functions of the proposed Rupsa Bridge, strengthening the traffic network of Khulna City and its surroundings, and also improve the prospects of Mongla Port further more.

(1) Khulna Bypass

The Bridge is assumed to be a road bridge that is located on the Khulna Bypass, and to cross the Rupsa River either on the east or west side of the Study Area as shown in Fig.12.1.1.

In case the Khulna Bypass takes the east route the project will consist of three bridges viz. Bhairab, Atai and Atherobaki Bridges. On the other hand, there will be only the Rupsa Bridge, if the west route is considered. Moreover, other important aspects such scope of road-cum-railway bridge, costs comparison and navigation clearances for each bridge, changes in costs and resultant social impact derived from slope changes, and cross section at configuration of different components such as number of lanes and extra lanes for slow moving vehicles, need to be addressed.

Basic examination of bridge types for each bridge will be discussed in section 12.2.

(2) Multi Modal Terminal

In and around Khulna City, there exist a well developed inland water transportation network, which is advantageous from the viewpoint of transportation, economics and environment.

Meanwhile 94% of the cargo throughput at Mongla Port is handled at either mooring buoys or anchorage areas, and is charged/discharged to/from riverboats or barges. Even after the Rupsa Bridge and the land transportation facilities are completed, this suitable inland water transportation means in Khulna is expected to last.

The Khulna Port, under the control of the BIWTA, is a river port, extends north- and southwards along the Rupsa River, and their facilities are scattered over. At the BIWTA terminal, located almost in the center of Khulna City and adjacent to the National

Highway No.7, there are not only facilities of BIWTA but also Roosevelt Jetty of Mongla Port Authority, and a marshalling yard and Khulna Railway.

The Multi Modal Terminal is planned as a development project of the area of 80 ha near the existing BIWTA facilities centering on a point where railway, roadway and inland water traffic meet and connect mutually, as the south section of the Khulna Bypass including the Rupsa Bridge are developed and therefore the road network in the area be will strengthened as shown in Fig.12.1.2.

As development of the Multi Modal Terminal concerns to several departments of the Bangladesh Government, it is essential to regulate the situation in the aspects of the system and management. Accordingly only the scope of the works of the feasibility study is prepared just in case that the Multi Modal Terminal would carry out in the Phase II.

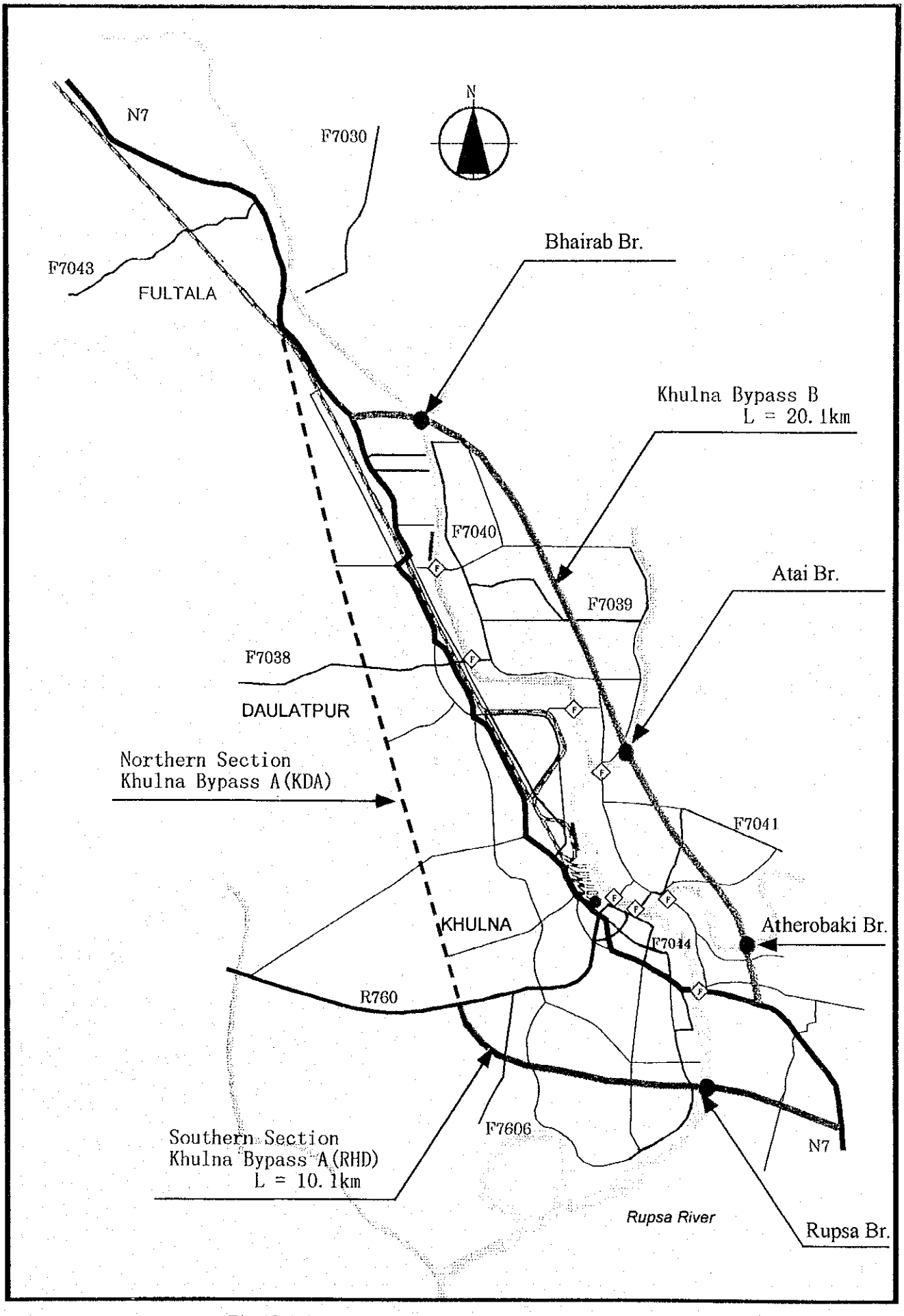


Fig.12.1.1 Road Network Proposed by Khulna Master Plan

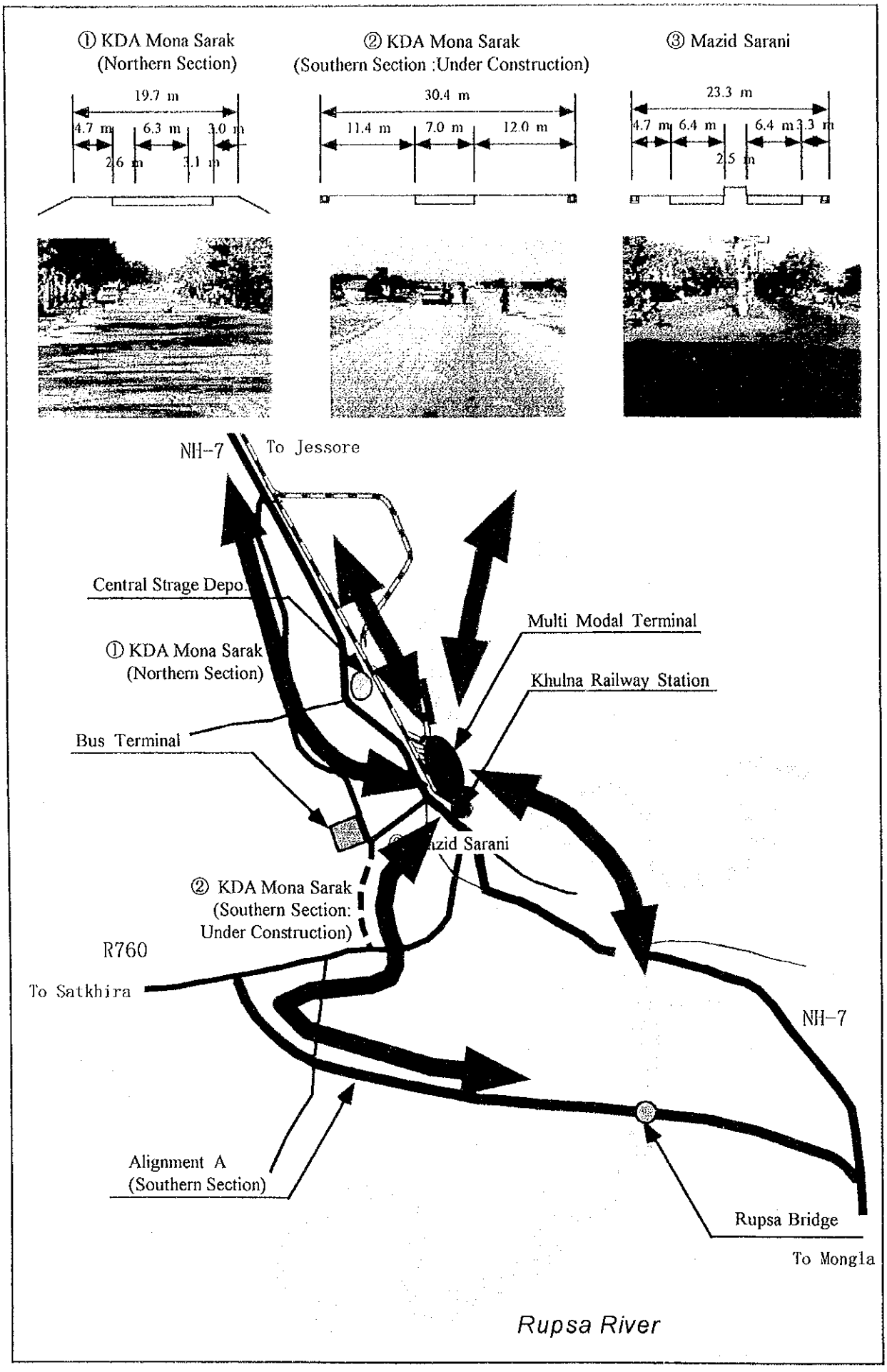


Fig.12.1.2 Fright Transportation in Southern Khulna City

12.1.2 Basic Case of Project Road and Alternatives of Road Planning

(1) Concept and Methodology for economic analysis of Road

i) As shown in Fig. 12.1.1, KDA Master Plan proposes extension of 115 kilometers including the north section of Khulna Bypass Western (A) route in addition to the existing 100 kilometers section, totaling 215 kilometers. Accordingly it is expected that the road development will be implemented continually until 2015. In particular the Khulna Bypass Western (A) route has a high priority and is scheduled to commence construction works in 1998/99. The study is conducted on the assumption that the north section of Khulna Bypass would be completed until 2015.

ii) The benefit estimate of road is worked out in such a manner that the case without the project (Case-0) is assumed as a base case, and then indices of difference of vehicle-hour and vehicle-km between Case-0 and Case-1, 3 are calculated from the results of assignment for the cases with the project, namely the south section of Khulna Bypass Western (A) route (Case-1: without railway extension) and the Khulna Bypass Eastern (B) route (Case-3: without railway extension).

iii) The case without the project signifies that none of the four bridges in the project is not yet realized while the road network in 2015 is completed, and therefore the Rupsa River is crossed only by ferry. The traffic assignment in 2015 will be calculated for the road network obtained by adding the road network plan proposed by Khulna Master Plan including the north section of the Khulna Bypass Western (A) route to the existing network.

iv) Meanwhile the case with the project means that the road network in 2015 and the bridges have been completed. Therefore, in case of Case-1 : Khulna Bypass takes Western (A) route, the project road is 10.1 kilometers of the south section under the jurisdiction of RHD between Khulna-Satkhira Road and Khulna-Mongla Raod. On the other hand, in case of Case-3 : Eastern (B) route, the project road is 20.1 kilometers between Cantonment in Siromony and Khulna –Mongla Road. In either cases, it is assumed in relation with the benefit estimate that 17.6 kilometer of the north section under the jurisdiction of KDA would have been open to traffic prior to the south section.

v) Table 12.1.1 indicates the indices used for future traffic volume and benefit estimate of each basic case and the bridges.

Indicated below are the basic cases for the economic analysis;

The Western Route (A Route)

ALT 1-1: Demand Forecast = Case-1, Cost Estimate = The Southern Section of Khulna Bypass (Undivided 2-lane with Sidewalks)

The Eastern Route (B Route)

ALT 3-1: Demand Forecast = Case-3, Cost Estimate = The Eastern Route of Khulna Bypass (Undivided 2-lane with Sidewalks)

vi) An analysis is made assuming a route shown in Fig.12.1.3 just in case that 17.6 kilometers of the north section under the jurisdiction of KDA should not be completed prior to the south section. It is supported that this assumption is functionally satisfied, vehicle-km which 100% count in the benefit is scarcely affected , vehicle-hour which 15% count in the benefit increase 20% a little over.

Table 12.1.1 Required Data for Economic and Financial Analysis

Case	Type of Vehicle	Traffic Volume on Bridge or Ferry		Average Trip Length (km)	Benefit Factors			
		PCU/Day	Veh/Day		PCU-kms x 1,000	Veh-kms x 1,000	PCU-hrs	Veh-hrs
0	Motorcycle	238	793	49.2	78.4	261.3	2,916.3	9,721.0
	Autorickshaw	1,849	1,849		437.0	437.0	18,736.7	18,736.7
	Passenger Car	814	814		319.9	319.9	11,404.2	11,404.2
	Bus	6,118	2,447		1,633.0	653.2	65,231.2	26,092.5
	Truck	4,225	2,113		1,627.6	813.8	58,550.7	29,275.4
	Total	13,244	8,016		4,095.9	2,485.2	156,839.1	95,229.8
1	Motorcycle	335	1,117	53.5	63.6	212.2	1,673.5	5,578.3
	Autorickshaw	2,536	2,536		335.4	335.4	9,245.9	9,245.9
	Passenger Car	1,120	1,120		268.8	268.8	7,095.9	7,095.9
	Bus	8,663	3,465		1,240.2	496.1	33,640.1	13,456.0
	Truck	5,829	2,915		1,370.7	685.3	35,989.9	17,995.0
	Total	18,483	11,153		3,278.7	1,997.8	87,645.3	53,371.1
3	Motorcycle	290	967	68.5	68.0	226.7	1,877.3	6,257.7
	Autorickshaw	2,279	2,279		344.5	344.5	11,047.2	11,047.2
	Passenger Car	1,012	1,012		285.7	285.7	7,829.5	7,829.5
	Bus	7,255	2,902		1,380.2	552.1	40,034.6	16,013.8
	Truck	5,274	2,637		1,451.2	725.6	39,475.2	19,737.6
	Total	16,110	9,797		3,529.6	2,134.6	100,263.8	60,885.8

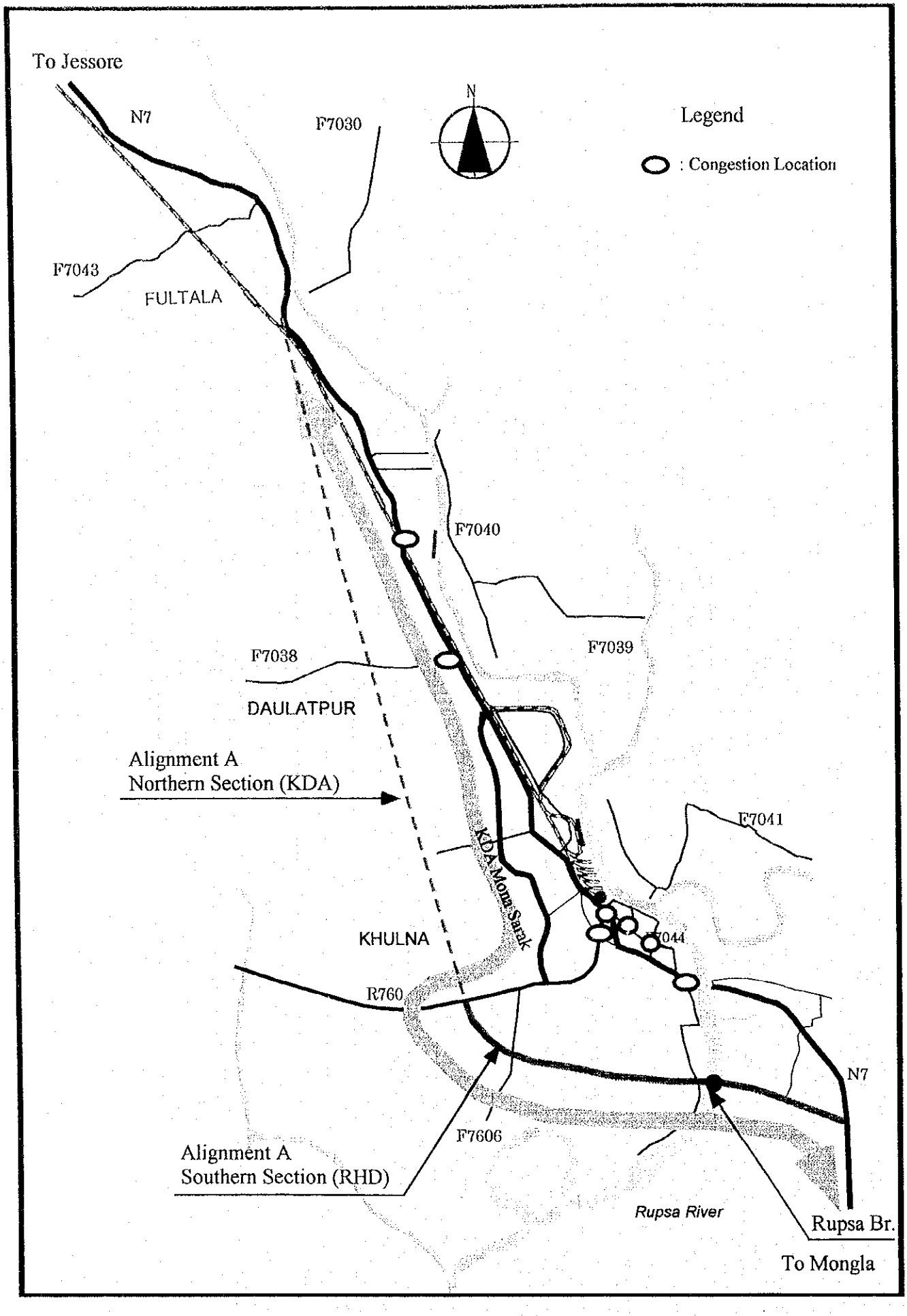


Fig.12.1.3 Substitution of Northern Section of Alignment A

12.1.3 Highway Design

(1) Traffic Capacity and Required Number of Lanes

To determine the required number of traffic lanes, the capacity of project road must be determined based on future traffic characteristics and proposed cross section shown in Fig.12.1.9.

The concept and methodology used for the analysis are based on the "Highway Capacity Manual" of the Highway Research Board, USA and "Road Design Standard" of Japan. And it was confirmed that the design capacity calculated using both methodologies is larger than the traffic volume of future demand forecast.

The design capacity is presented in Table 12.1.2.

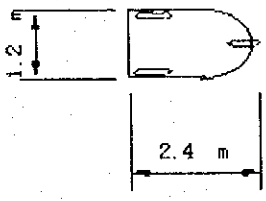
The traffic volume of Case-1 was adopted for the analysis of traffic demand forecast, as it is the highest among these Cases at the target year 2015.

Fig.12.1.4 shows the traffic volume of Case-1 in 2015 and Fig. 12.1.5 presents relationship between traffic capacity of the planned cross section and the traffic volume in Alignment A. Judging from the figure, it is obvious that the 2-lane carriageway has enough capacity for the traffic in 2015.

(2) Consideration of Slow-moving Vehicles

i) One of the salient features of the traffic characteristics in the Study Area is a large number of slow-moving vehicles such as motor-bikes and auto rickshaws. As the mixture with these slow moving vehicles may reduce the traffic capacity as well as traffic safety, it is preferable to separate them. Therefore, the lane for the slow moving vehicles is recommended.

ii) Fig.12.1.6 demonstrates dimensions of auto-rickshaw, which is 1.2m wide. Therefore, width of slow-moving lane is set to be 3.0m in undivided 2-lane of both directions for slow moving vehicles.



Auto Rickshow

Fig.12.1.6 Design Vehicle for Slow-moving Lane

iii) In case of one lane, it is desirable that a slow moving lane is at least 2.5m wide to secure a space for the traffic when a breakdown vehicle stops at roadside. However, it is generally required to reduce the width on the bridge from a viewpoint of economy. And the width of 2.0 m was decided considering that it is located far from the city center, not so many pedestrians pass at a time, and a breakdown vehicle may be allowed to encroach on a footpath temporally.

iv) The slow-moving lanes are basically provided each one (1) on both sides for the use by auto rickshaws and motorbikes. In case it is only two (2) lanes on one side on bridge, consideration is given so that these slow moving vehicles can be distributed to both lanes through box culverts installed in the embankment behind the abutments in the embankment, as shown in Figs.12.1.7 and 12.1.8.

Table 12.1.2 Traffic Capacity Analysis

		Daily Future Traffic Volume						K-factor	Hour Future	Flow rate	Capacity
		Motorcycle	Autorickshaw	Car	Bus	Truck	Total	%	Traffic Volume		
PCU Ratio		0.3	1.0	1.0	2.5	2.0		8.0			
PCU conversion	Without Railway	335	2,536	1,120	8,663	5,829	18,483		1,479		
	With Railway	336	2,536	1,120	8,779	5,112	17,883		1,431		1,687
Vehicle conversion	Without Railway	1,117	2,536	1,120	3,465	2,915	11,152		892	959	
	With Railway	1,120	2,536	1,120	3,512	2,556	10,844		867	933	1,292

*PCU: Passenger Car Unit

**K-factor: The rate of the 30th highest hourly volume during the year to the AADT.

Japanese Standard			
Ideal capacity (2-lanes)		pcu/h	2,500
Level of service (level-2)			0.9
Adjustment factors	Narrow lanes		1.00
	Restricted shoulder width		1.00
	Roadside condistion of development		0.90
	Grade and presence of heavy vehicles		0.90
	Presence of Motorcycle		0.93
Possible traffic volume		pcu/h	1,874
Design traffic volume		pcu/h	1,687

AASTHO			
Ideal capacity (2-lanes)		pcu/h	2800
Level of service			D
Ratio of flow rate to ideal capacity for level of service			0.64
Adjustment factors	Directional distribution		0.94
	Narrow lanes and restricted shoulder width		0.85
	Presence of heavy vehicles		0.903
Service flow rate		vehicle/hour	1,292
Full-hour volume		vehicle/hour	892
Peak hour factor			0.93
Flow rate		vehicle/hour	959

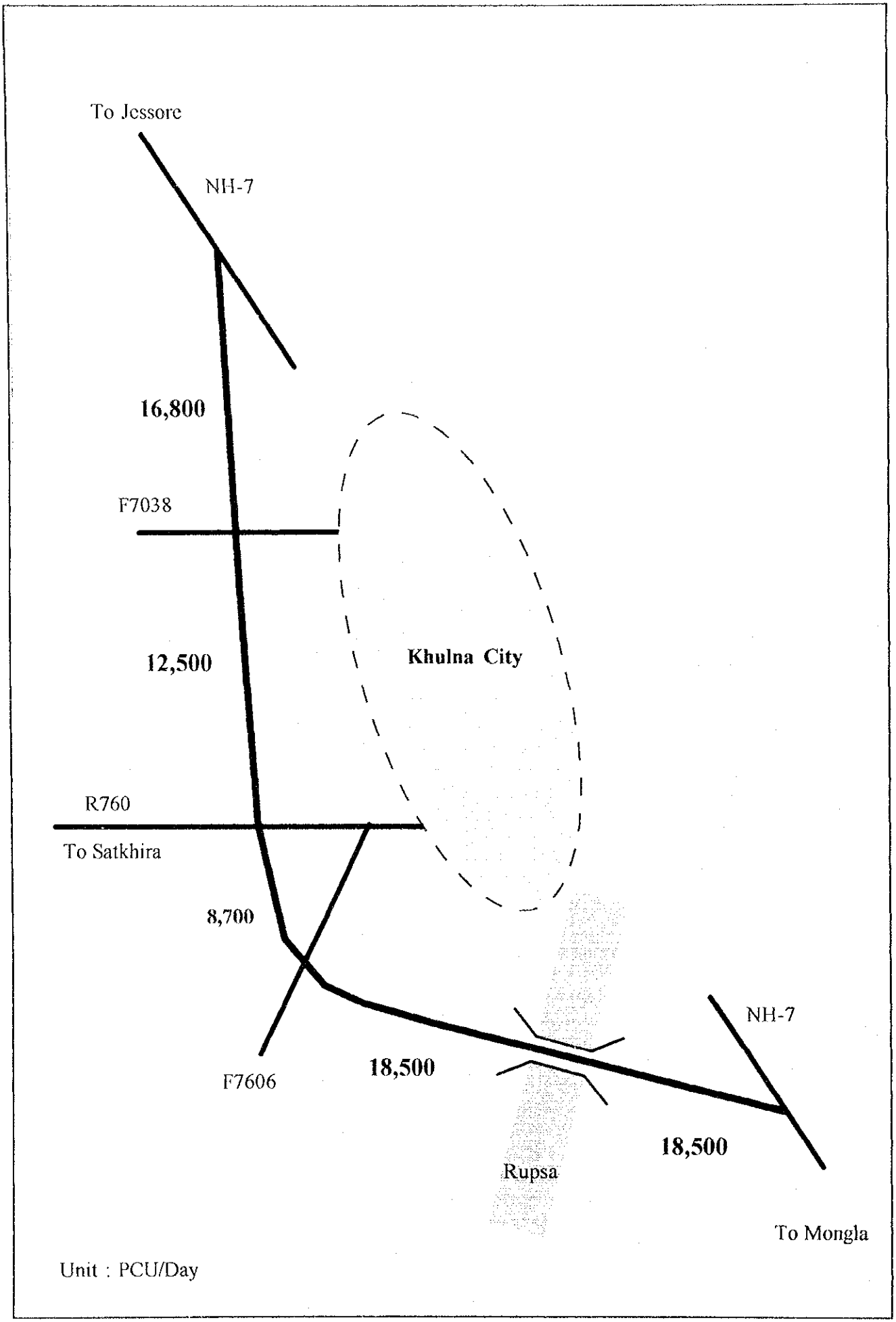


Fig.12.1.4 Traffic Volume of Case-1

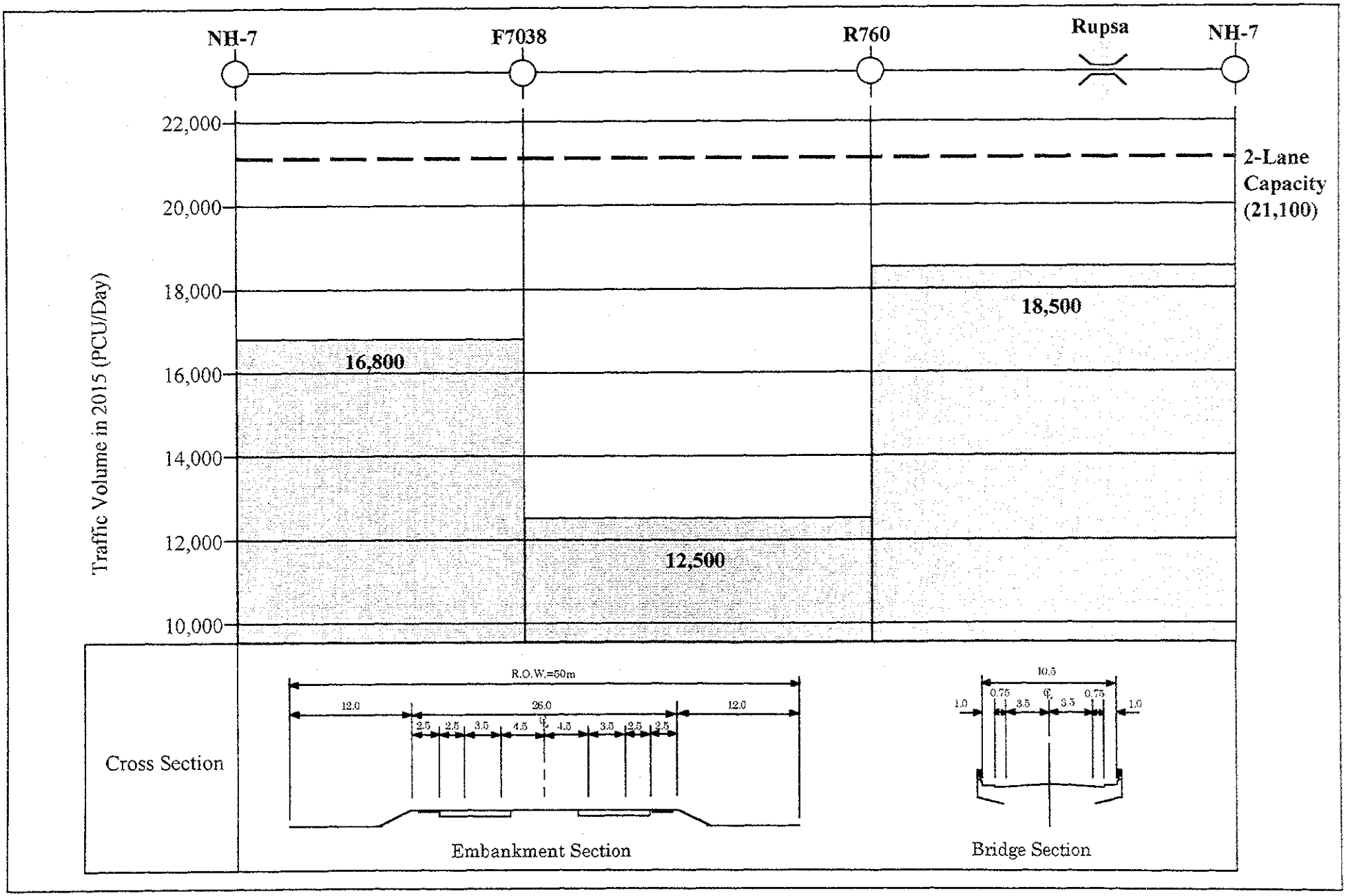


Fig.12.1.5 Comparison with Traffic Capacity and Traffic Volume of Alignment A

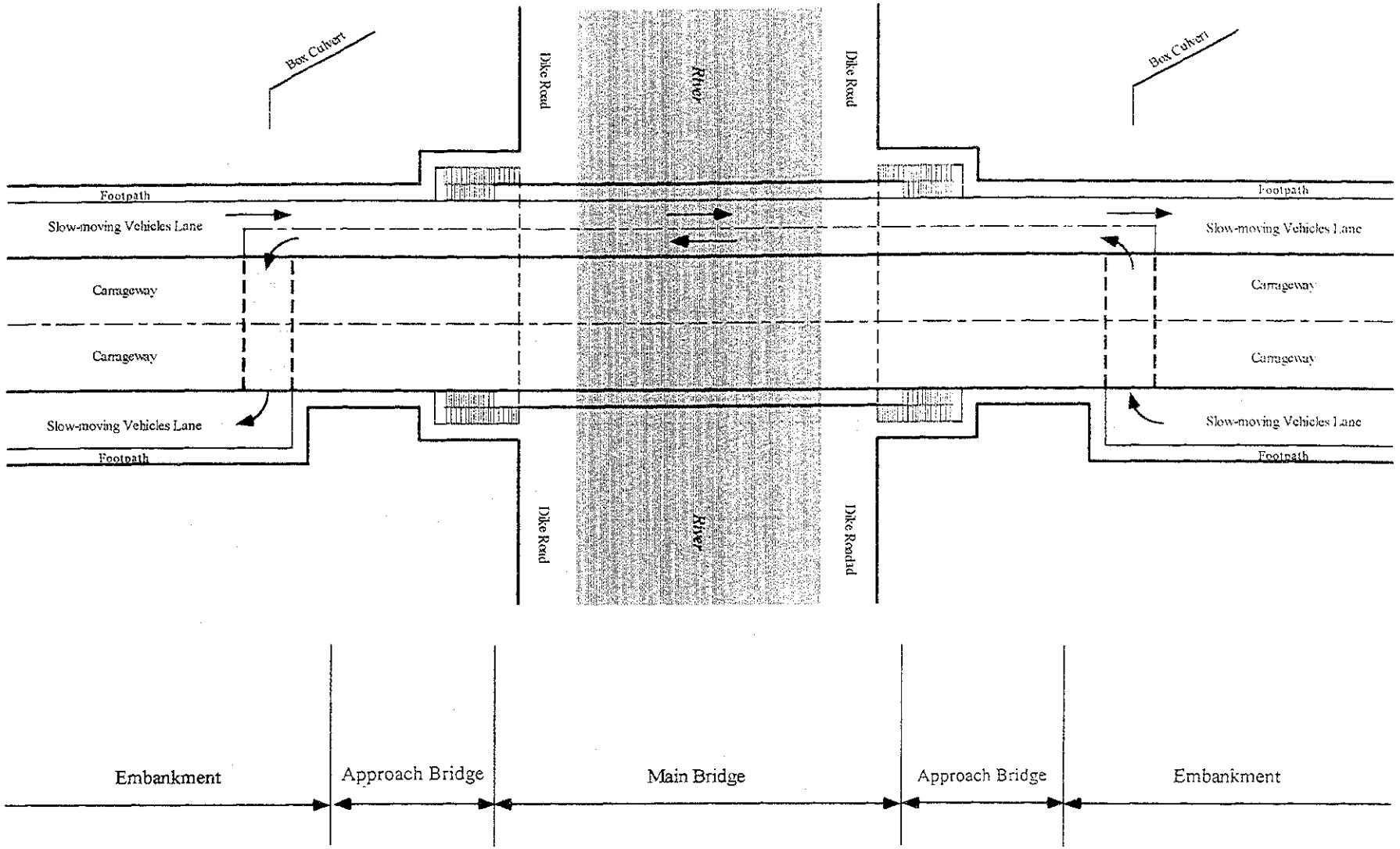


Fig.12.1.7 Connection of Slow Moving Lane (One Side)

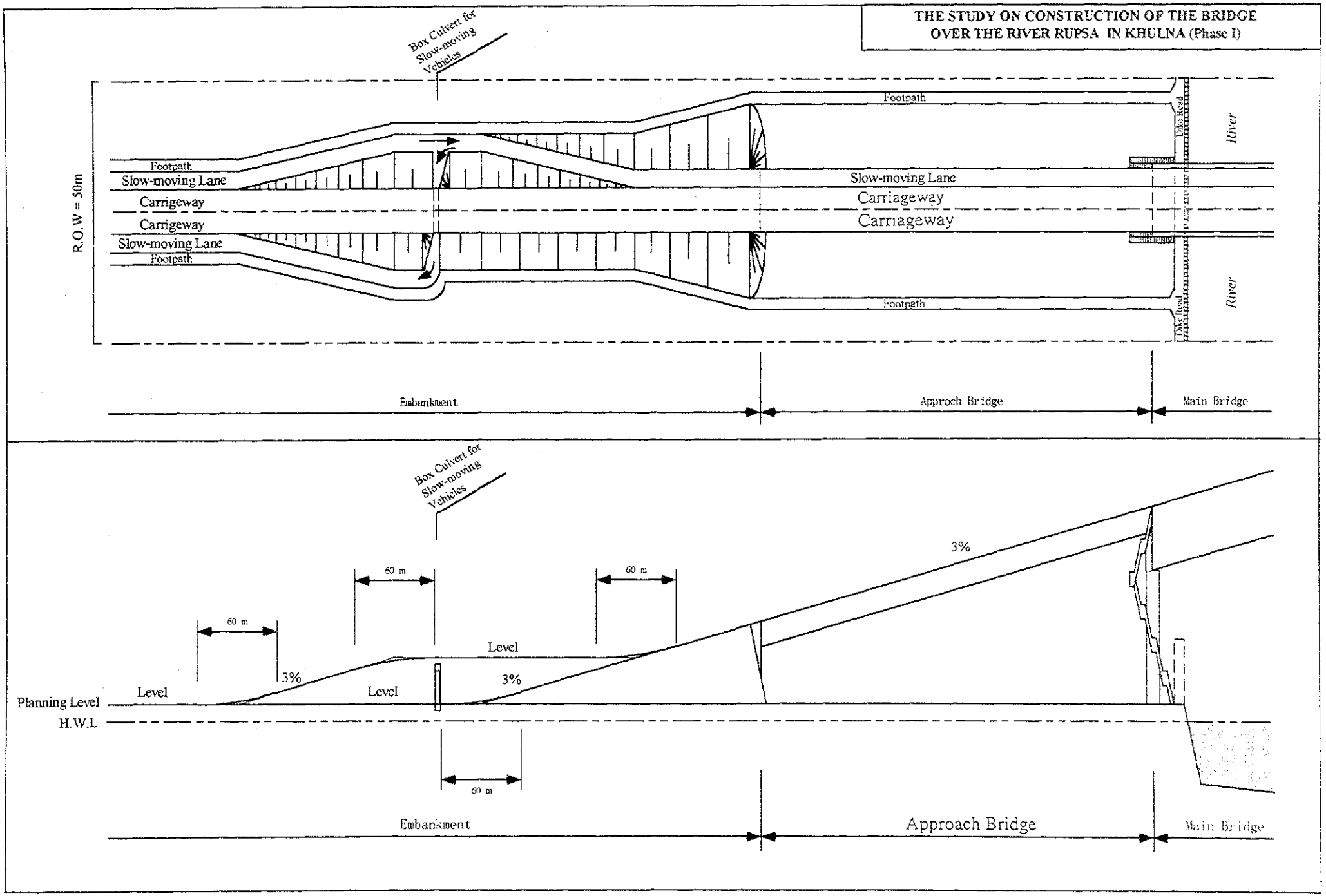


Fig.12.1.8 Details of Connection of Slow Moving Lane (One Side)

(3) Alternative Cross Sections

The cross sections are examined by establishing alternatives separately for the embankment portion and the bridge portion.

1) Bridge portion

i) The undivided 2-lane was decided to be a basic idea of the roadway in the Study, as described in "12.1.3 (1) Traffic Capacity and Required Number of Lanes". Therefore, the basic cross section for each alternative is taken as undivided 2-lane with footpath on both sides.

ii) 8.5 m is given to throughway for an undivided 2-lane, which enables a vehicle passing by a breakdown car stopping at a shoulder.

iii) A large number of slow-moving vehicles such as motorbikes and auto-rickshaws are expected to pass the four bridges in the Study, because they are located in Khulna City, and used mainly by commuters, in other words, the trip is short. Therefore, Alternatives ALT 1-2/3-2 consisting of basic cross-section with two way slow moving lane on one side and Alternatives ALT 1-3/3-3 consisting of basic cross-section with one way slow moving lane on each side are selected.

iv) Alternatives ALT 1-4/3-4 are for rail-cum-road bridge, which consists of basic cross section and a single truck of railway.

v) Alternatives ALT 1-5/3-5 for divided 4-lane also examined in order to compensate the uncertainty that the future demand forecast may have. The cross section of ALT 1-5/3-5 is almost same scale of Paksey Bridge.

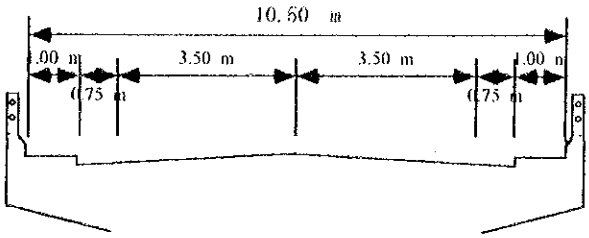
vi) The five alternatives of cross section are shown in Fig.12.1.9, of which whole width is 10.5m, 14.0m, 15.5m, 16.5m and 18.0m respectively.

2) Embankment portion

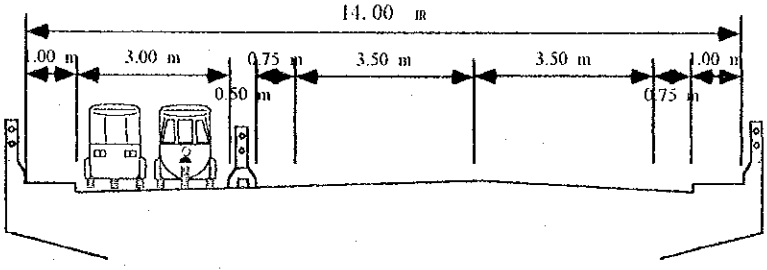
i) It is desirable that cross-section in embankment section has certain allowances, because road in embankment is cheaper than that in bridge. Two types of cross-sections in the embankment section are provided, they are divided 2-lane and divided 4-lane as shown in Fig.12.1.10.

ii) A median of 4.0m wide is provided to a divided 4-lane cross section, which may be used as an auxiliary lane for right-turn.

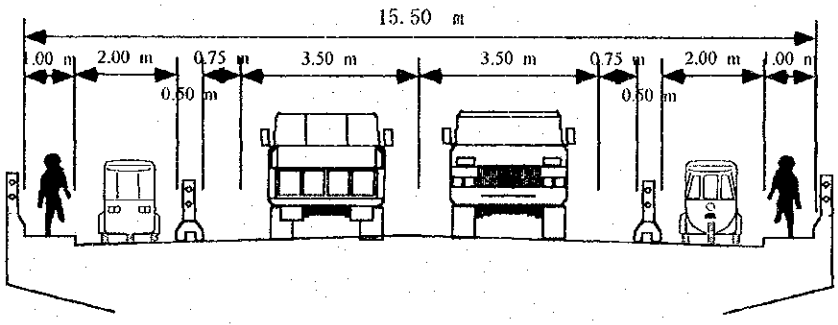
iii) A median of 9.0m wide is provided to a divided 2-lane road, which may be used as a right-turn lane and also may be modified to a divided 4-lane road in the future. Besides, an open space is secured in the middle so that it can avoid an illegal occupation of the right of way may make it difficult to widen the road in the future.



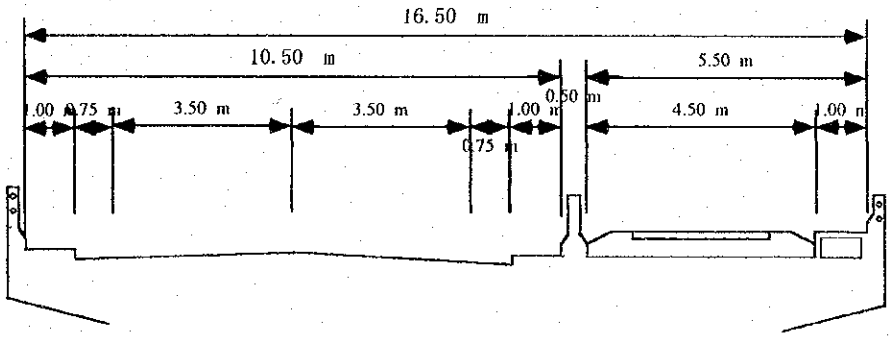
ALT 1-1 / 3-1



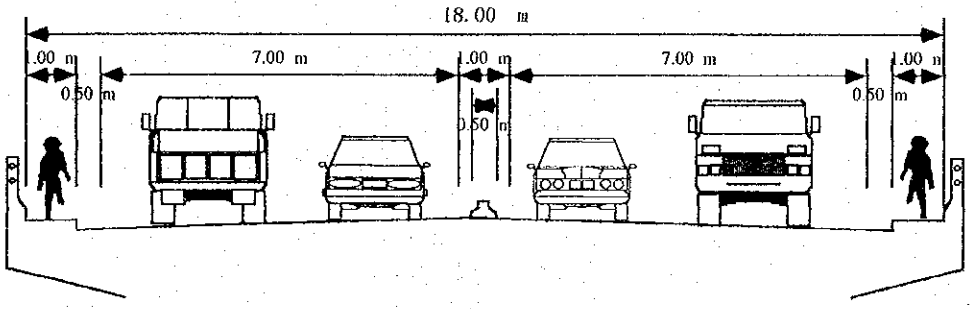
ALT 1-2 / 3-2



ALT 1-3 / 3-3

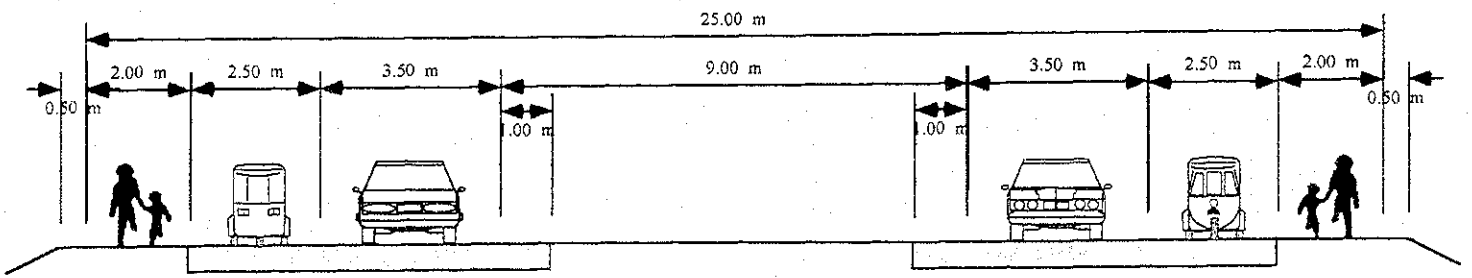


ALT 1-4 / 3-4

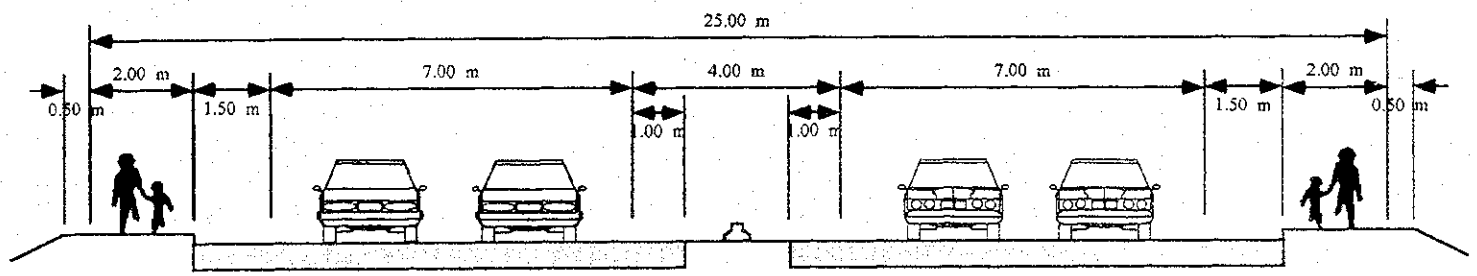


ALT 1-5 / 3-5

Fig.12.1.9 Cross Section of Each Alternative Plans on Bridge



2-Lane



4-Lane

Fig.12.1.10 Cross Section of Each Type on Embankment

(4) Grade

Maximum grade for the bridge portion is taken as 3.0% for the project. Japanese Road Design Standard specifies the maximum grade to be 5% for the design speed of 60km/h. If less grade such as 3% or4% is taken, the bridge length will increase by 470m or 170m respectively compared with that of 5%, as shown in Fig.12.1.10.

The reason for adopting the less grade of 3% is that the traffic characteristics in the Study Area is a traffic by a large number of vintage, over-loaded trucks and buses, and also slow moving vehicles.

(5) Design Speed

Design speed of 60km/h in the Study is adequate, as described in Chapter 10. And both design speed and bridge length is closely connected with sight distance. If a design speed is assumed as 60km/h, 80km/h or 100km/h for the Rupsa Bridge, the vertical curve radius must be taken as 2000m, 4500m or 10000m respectively in order to secure the required sight distance. Keeping the grade to 3%, if the design speed is increased from 60 to 80km/h, or from 60 to 100km/h, the bridge length will increase by 55m or 210m respectively, as shown in Fig.12.1.11.

Because the grade of 3% has been already adopted with consideration of traffic characteristics, which is flatter for design speed 60km/h in the Study. On the viewpoint of economy, design speed and vertical curve length are respectively applied 60km/h and 2000m for Road Bridge.

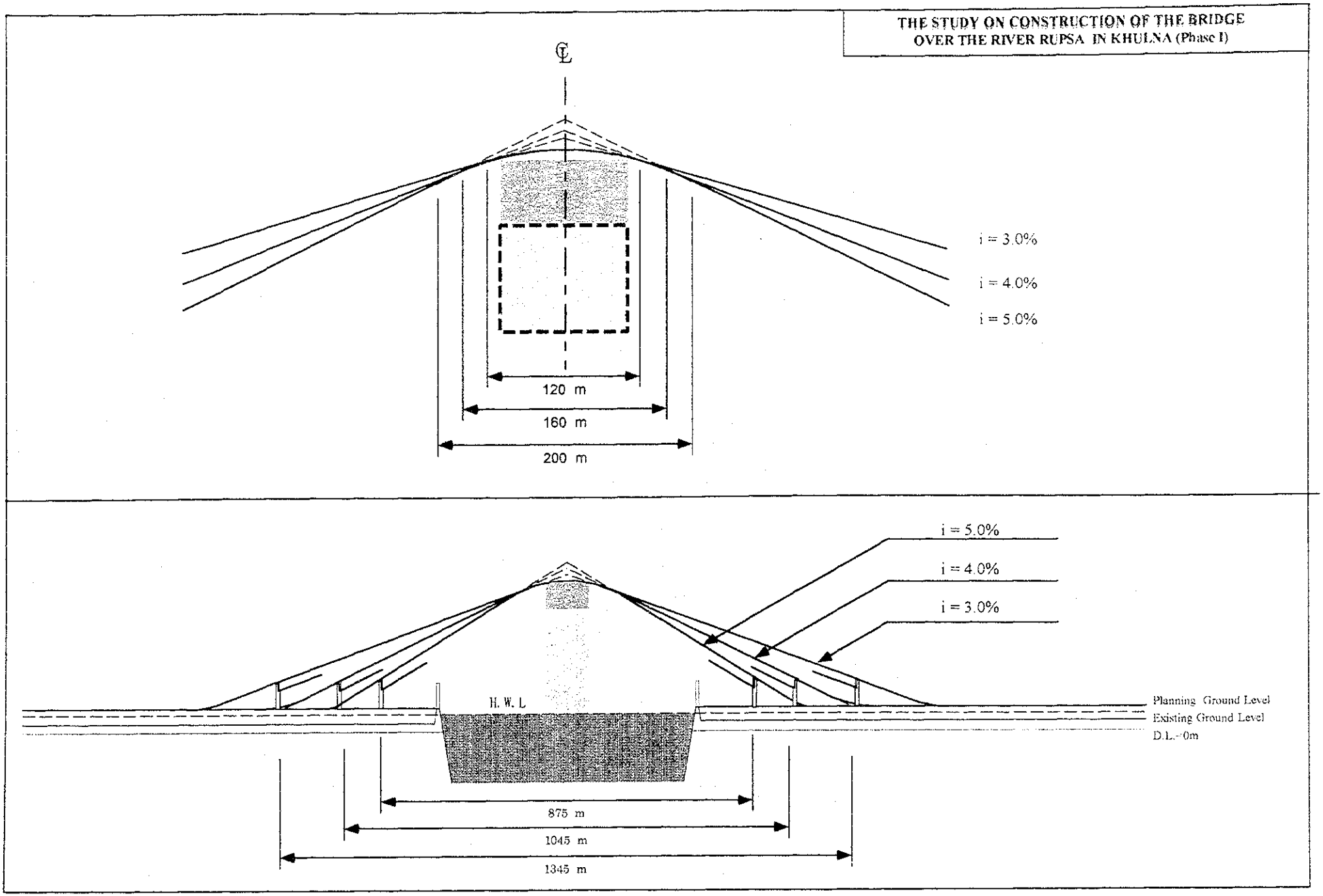


Fig.12.1.10 Bridge Length by Gradient (3%, 4% and 5%)

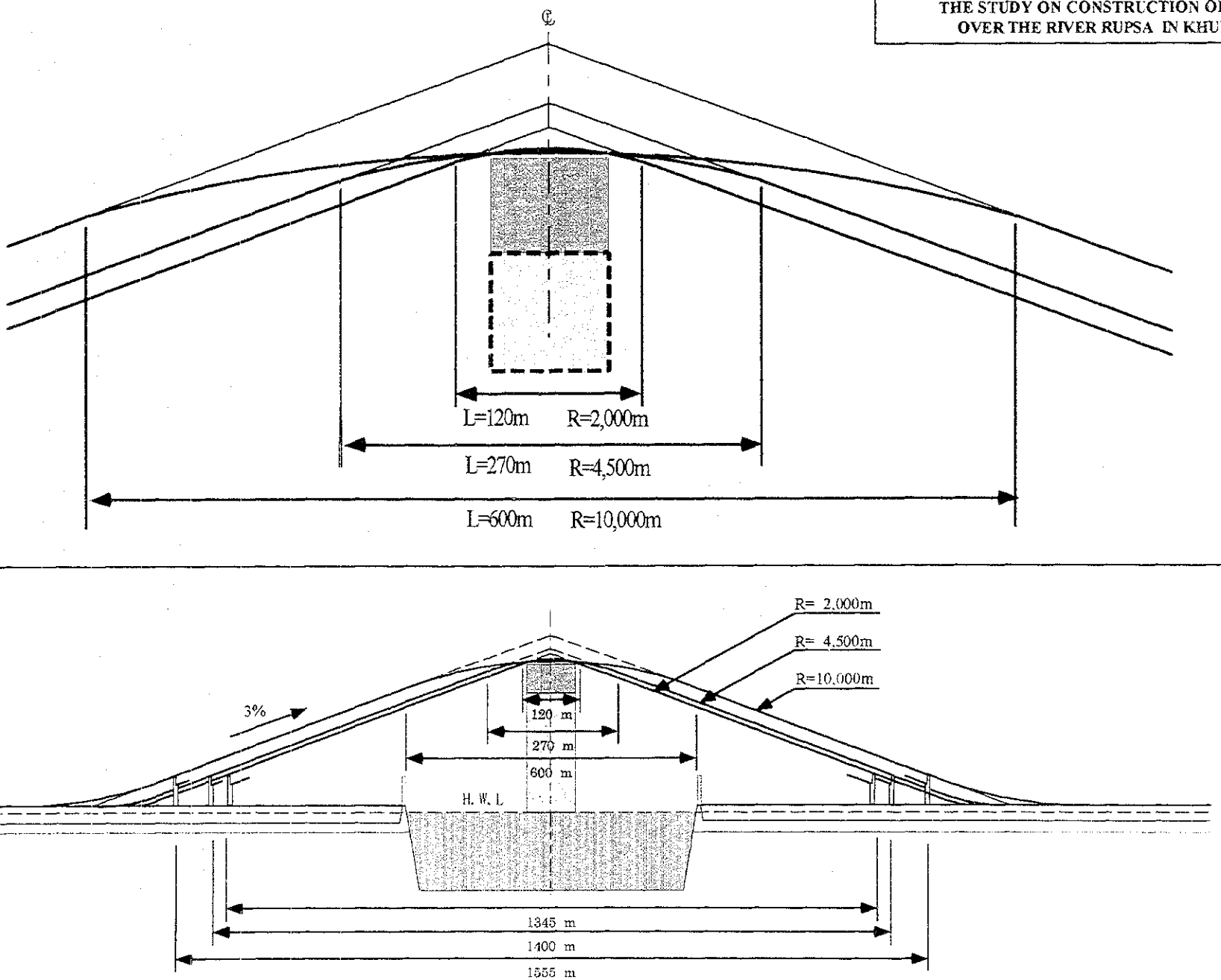


Fig.12.1.11 Bridge Length by Vertical Curve Radius (2000m, 4500m, 10000m; Grade 3%)

12.1.4 Alternatives for Rail-cum-Road Bridge

(1) Policies on comparison

i) In determining the vertical alignment of a rail-cum-road bridge, the railway and roadway have to hold the alignment in common, in other words, flatter vertical alignment of the two must be taken as the common alignment, that is of the railway. On the contrary if the bridge keeps the common vertical alignment of the flatter through the whole bridge length, it will be less economical, because the roadway portion has to be longer than necessary. Therefore, two schemes of the rail-cum-road alignment are studied, one of which is that only the portion of the Main Bridge holds the superstructure in common and the Approach superstructures for the rail part and the road have separate grades, they are 1% and 3% respectively (ALT 1-4). The other is that the rail-cum-road bridge has the bridge structure in common totally through the whole length of the bridge (ALT 1-6).

ii) For the purpose of comparison, it is assumed that the common structures between the rail and road part is to be built at once when the road bridge is constructed, and the cost for the common structures are borne by the road bridge.

iii) Two alternatives of the rail-cum-road bridges, ALT 1-4 and ALT 1-6, are compared with the alternative bridge (ALT 1-1) only for a roadway purpose on the assumption that they are used as roadway bridge initially until the railway facilities are completed, and then later are made use as rail-cum-road bridges. This aims at verifying the degree to which the road bridge will bear the burden of the initial investment from the aspect of investment efficiency.

(2) Basic Conditions

i) Maximum grade for Road Bridge is 3%.

ii) Minimum vertical curve radius for road bridge is 2000m.

iii) Maximum grade for rail-cum-road bridge is 1% considering relationship between traction power of locomotive and length of a freight train.

iv) Minimum vertical curve radius for rail-cum-road bridge is 3000m in accordance with the railway standards.

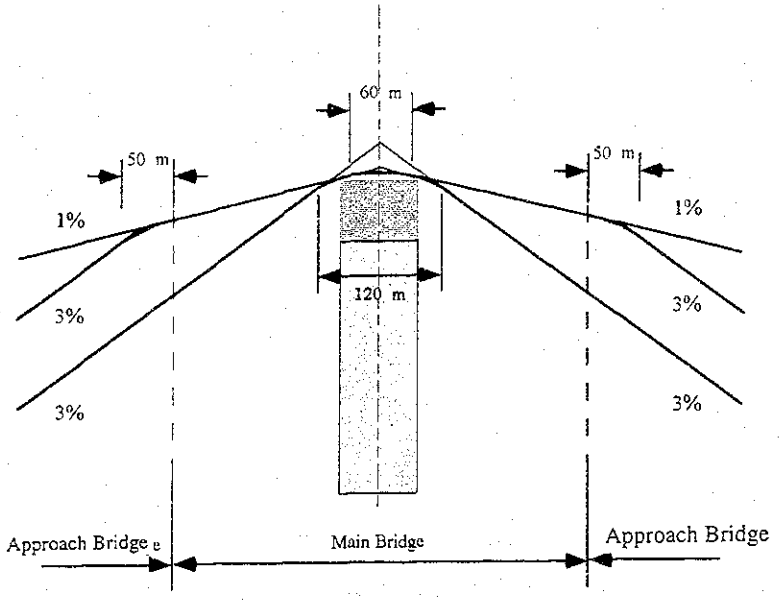
(3) Evaluation and Conclusion

i) Fig.12.1.12 shows the comparison of bridge length among the alternatives taking Rupsa Bridge as an example.

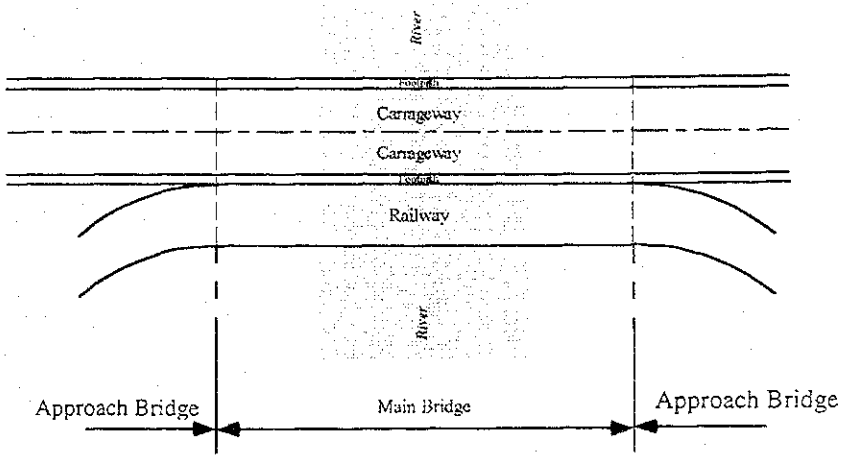
ii) Table 12.1.3 shows the comparison of direct construction cost among the alternatives. It is revealed that the costs of ALT 1-4 and ALT 1-6 are1.6 times and 3.8 times as that of ALT1-1.

iii) Fig.12.1.13 indicates the comprehensive comparison. Examining the result, "the alternative of the rail-cum-road bridge through the whole length (ALT 1-6)" is set aside from the alternatives study hereinafter by following reasons;

- It is not reasonable that the vertical alignment of road should comply with considerably flatter grade of that of railway only to share the space of bridge to result in huge increase of bridge cost.
- There's a physical problem that the initial 4-lane road bridge has to be modified to a rail-cum-road bridge with a single track and 2-lane. It may be a serious problem for RHD to invest in such an inefficient manner.



Details of Vertical Curves



Plan

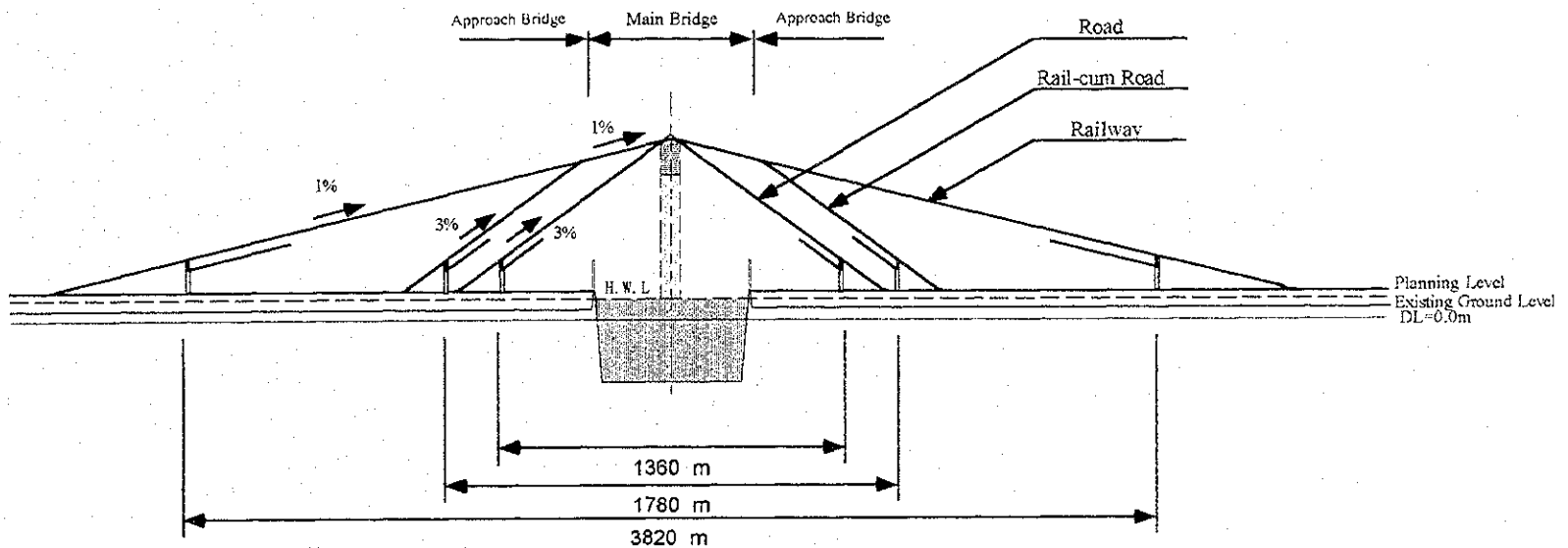


Fig.12.1.12 Comparison for Bridge Length (Road, Rail-cum-Road, Railway)

Table 12.1.3 Comparison among Road Br. (i=3%), Rail-cum-Road Br. (i=3% & i=1%) and Rail-cum-Road Br. (i=1%)

Alternative	Studied Bridge				Direct Bridge Cost (M. Tk.)	Remarks
	Name	Main (m)	Approach (m)	Total (m)		
Road Bridge 2-Lane with Sidewalk No Slow-Track	Rupsa	640	720	1, 360	ALT 1-1 1, 341. 1 100%	3% of road grade Simple road bridge
Rail-cum-Road Br. 2-Lane with Sidewalk No Slow-Track	Rupsa	640	1, 140	1, 780	ALT 1-4 2, 126. 9 159%	3% of road grade and 1% of rail grade Rail-cum-road bridge
Rail-cum-Road Br. 2-Lane with Sidewalk Single Line	Rupsa	640	3, 180	3, 820	ALT 1-6 5, 131. 8 383%	1% of road grade and 1% of rail grade Rail-cum-road bridge

Note:

1) Direct construction cost of bridge covers costs between abutments and excluding 10 % contingency.
2) In road-cum-railway bridge, direct construction cost of Approach Bridge for railway is not included.
3) 100 m span continuous PC box girder with cast-in-situ concrete pile for Rupsa Bridge.
4) 30 m span composite PC I-girder with cast-in-situ concrete pile for Approach Bridge.

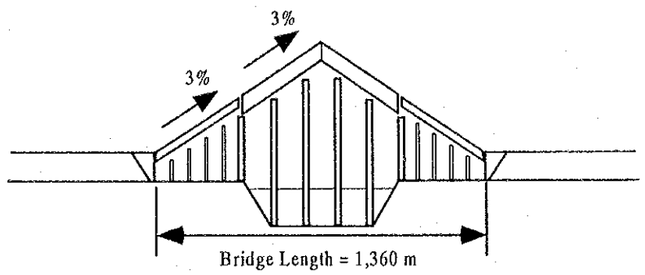
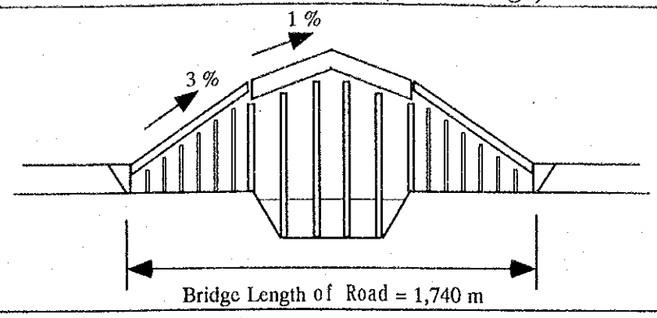
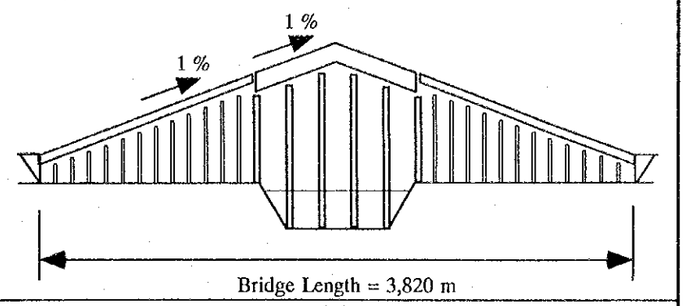
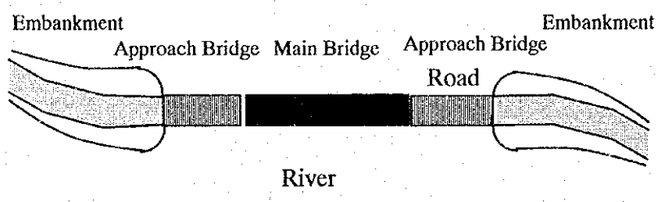
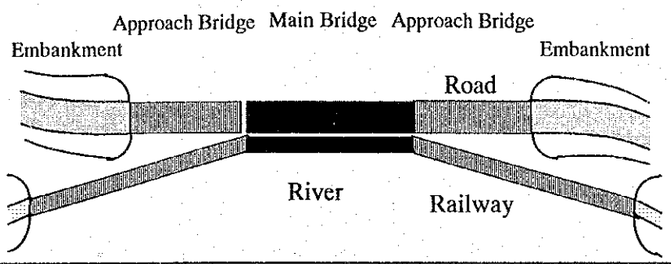
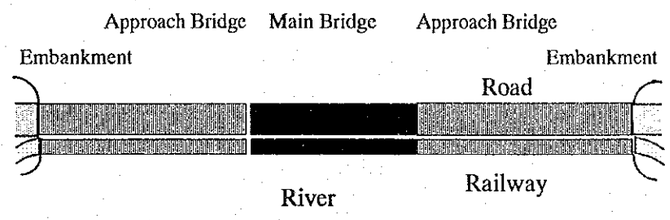
	Simple Road Bridge	Rail-cum-Road Bridge (Main Bridge)	Rail-cum-Road Bridge (Main + Approch Bridge)
Road Profile			
Plan			
Outline of Scheme	1) The scheme of Simple Road Bridge with 3% grade. 2) Total bridge length of 1,360 m with 640 m Main Br. & 720 m Approach Br. 3) Direct cost of bridge of 1,341 M. Tk. in case of ALT 1-1.	1) The scheme of Rail-cum-Road Bridge with only Main Bridge. 2) Total bridge length of 1,780 m with 640 m Main Br. & 1,140 m Approach Br. 3) 1.59 times as high as that of direct cost of bridge compared to ALT 1-1. 4) Slim chance in use of the space for railway on Main Bridge.	1) The scheme of Rail-cum-Road Bridge with Main plus Approach Bridges. 2) Total bridge length of 3,820 m with 640 m Main Br. & 3,180 m Approach Br. 3) 2.41 times as high as that of direct cost of bridge compared to ALT 1-1. 4) Excessively flat grade of 1% applied due to railway.
Return on Investment	High IRR is expected due to no excessive cost.	IRR still remains acceptable just in case earlier realization of railway extension.	IRR becomes marginal level due to excessive cost.
Road User's Benefits	Reasonable in all aspects even in case of toll bridge.	Not acceptable if toll should cover additional cost for railway space.	Unreasonable for excessively long bridge even though railway be extended.
Land Use along Road	Good in land use because of the shortest approach bridge section.	Fair in land use in spite of railway occupation taken place in one side.	Very poor because of long approach bridge and parallel railway.
Social Impacts	Shortest stretch of community disruption by viaduct and embankment.	Impairment of development impacts brought by road because of unfavorable elevated railway.	Longer stretch of community disruption by parallel and elevated railway.
Evaluation	**Superior.** Fulfillment of expected roles and functions of Rupsa Bridge.	Further study on the possibility of railway extension to Mongla Port is necessary.	**Inferior.** It is not acceptable that the grade of road becomes excessively flat due to railway and it results in very high construction cost.

Fig. 12.1.13 Comparison of Schemes of Road Bridge and Rail-cum-Road Bridge

12.1.5 Alternatives for Road Bridge

(1) Approach of Alternatives and Comparison

i) The four bridges are examined here only as road bridges on the east or west route. As for rail-cum-road scheme, the space for future railway is regarded as road portion.

ii) The railway extension plan is studied so that it independently extends the railway from Khulna to Mongla Port. It is assumed that the railway bridges at four locations will be installed parallel to those of the road bridge, when the extension is considered.

iii) The scheme "the rail-cum-road bridge through the whole length (ALT 1-6)" is set aside from the alternatives study. However, the alternative of rail-cum-road bridge is studied as "rail-cum-road bridge of only main bridge (ALT 1-4)". And then, road and railway have individual grade in approach bridge section.

iv) At all locations of the four bridges, some improvements of the river protection, mainly bank protection on upstream and downstream, may be required. A road for maintenance purpose will be built on top of the banks, and a clearance for the roads are secured.

(2) Alternatives for locations of Khulna Bypass

1) Route Description

i) Two routes are examined, the east route and the west route.

ii) When the east route is taken, Khulna city is bypassed by bridging the three rivers, Bhairab, Atai and Atherobaki. On the other hand, if the west route is taken, there will be only one bridge, although there should be a discussion on the matter of navigation clearances for each river.

iii) In case of the west route, length of Rupsa Bridge is only 1,360 m, while those of Bhairab, Atai, Atherobaki are1,040m, 1,040m and 570m respectively. Total of these three on the east route is 2,650 m, and is 1.9 times as that of the west route.

iv) Route of Alignment A is shown in Figs.12.1.14 through 12.1.19. And route of Alignment B is shown in Figs.12.1.20 through 22, and the ending point is shown in Fig.12.1.18.