DEPARTMENT OF ROADS
MINISTRY OF WORKS AND HUMAN SETTLEMENT
THE KINGDOM OF BHUTAN

DATA COLLECTION SURVEY ON ROAD CONNECTIVITY IN THE KINGDOM OF BHUTAN

FINAL REPORT

SEPTEMBER 2014

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS CO., LTD.
INGÉROSEC CORPORATION

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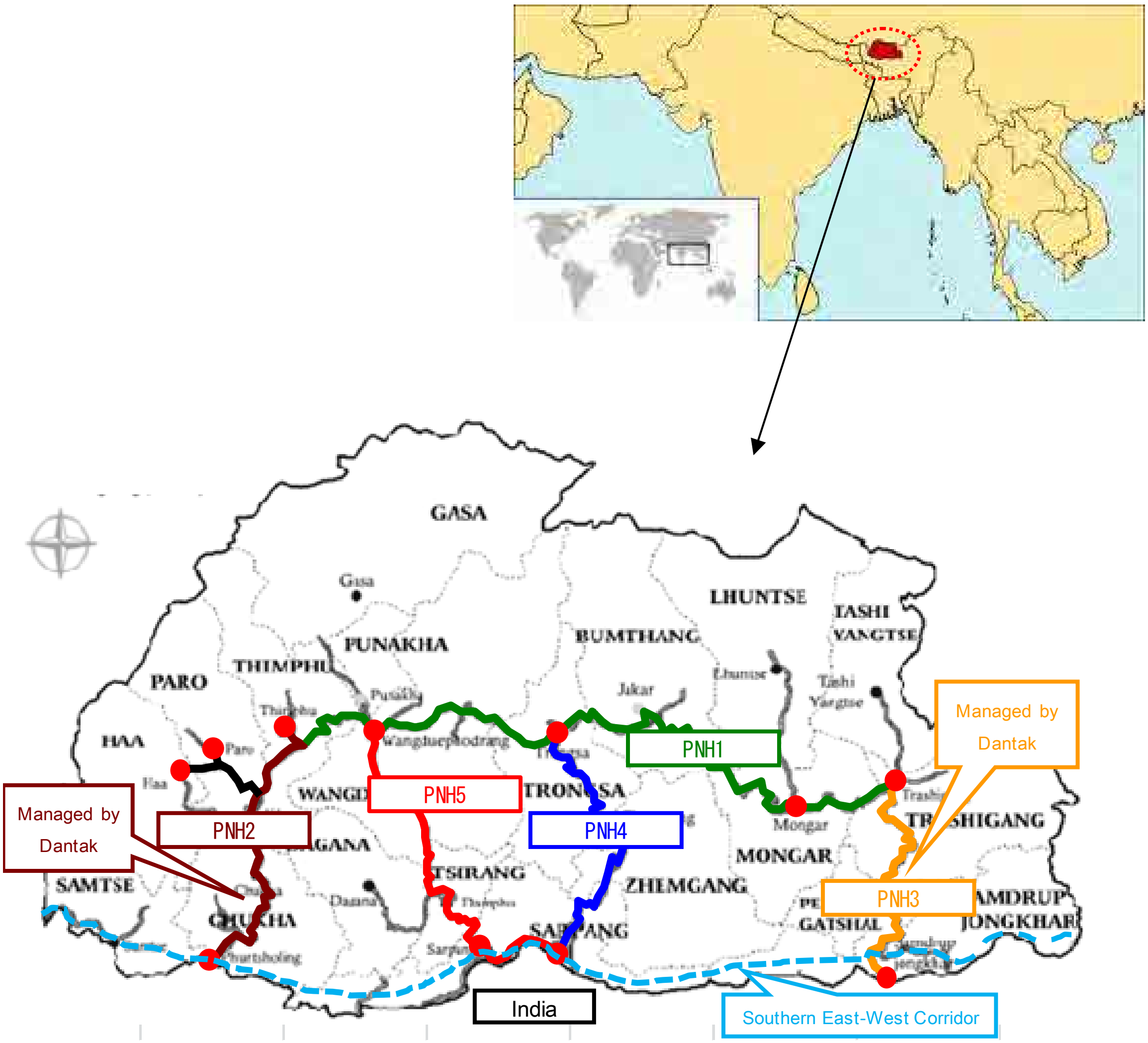

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
ADIF	Agricultural Development International Fund
AH	Asian Highway
BBS	Bhutan Broadcast Service
BTL	Bhutan Telecom Limited
CDCL	The Construction Development Corporation Limited
CPS	Country Partnership Strategy
DANTAK	Indian Border Roads
DGM	Department of Geology and Mines, Ministry of Economic Affairs
DLAAC	Dzongkhag Land Acquisition and Allotment Committee
DoA	Department of Agriculture, Ministry of Agriculture
DoE	Department of Energy, Ministry of Economic Affairs
DoR	Department of Roads, Ministry of Works and Human Settlement
DPA	Department of Public Account, Ministry of Finance
DPT	Peace and Prosperity Party
DRAP	Dzongkhag Rural Access Planning
EIA	Environmental Impact Assessment
F/S	Feasibility Study
FDI	Foreign Direct Investment
FS	Feasibility Study
GDP	Gross Domestic Product
GLOF	Glacial Lake Outburst Flood
GNH	Gross National Happiness
GNP	Gross National Product
GOI	Government of India
GPS	Global Positioning System
H.W.L.	High Water Level
IBRD	International Bank for Reconstruction and Development
ICB	International Competitive Bidding
IDA	International Development Agency
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IRC	Indian Road Congress
IS	Indian Specification
JICA	Japan International Cooperation Agency
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDG	Millennium Development Goal
MIGA	Multilateral Investment Guarantee Agency
MoAF	Ministry of Agriculture and Forests
MoEA	Ministry of Economic Affairs
MoF	Ministry of Finance
MoWHS	Ministry of Works and Human Settlement
MW	Megawatt
NATM	New Austrian Tunneling Method
NEC	National Environmental Commission
NGI	Norwegian Geotechnical Institute
NGO	Non-Governmental Organization
NLC	National Land Commission
Nu	Bhutanese Currency or Ngultrum

Abbreviations

ODA	Official Development Assistance
PC	Prestressed Concrete
PCT	Pre-stressed Concrete T type
PCU	Project Coordination Unit
PDP	People's Democratic Party
PMU	Project Management Unit
PNH	Primary National Highway
RAP1	Rural Access Project
RAP2	Second Rural access Project
RC	Reinforced Concrete
RCSC	Royal Civil Services Commission
RGoB	Royal Government of Bhutan
ROW	Right of Way
RSTA	Road Safety and Transport Authority
SASEC	South Asia Sub regional Economic Cooperation
TA	Technical Assistance
WB	World Bank

Chapter 1. Survey Outline

1-1. Survey Background and Objectives

1-1-1. Survey Background

The Kingdom of Bhutan (Bhutan) is a mountainous landlocked country located at the eastern end of the Himalayan mountain range. Since most land areas in the country consist of steep mountains, roads are the main means of transportation. Therefore, efficient development of road and bridge networks is essential to the socio-economic development of Bhutan. However, the number of highways is small, and highway standards do not impose sufficient restrictions due to topographic constraints.

The Government of Japan will provide assistance for the development of the road network and bridges so as to secure efficient and stable transport/traffic and promote economic revitalization in the region through the road network development program in the country assistance policies for Bhutan. To date, Japan International Cooperation Agency (JICA) has provided grant aid 4 times for the replacement of bridges, and 3 times for the provision of road construction equipment. JICA County Analytical Work also regards rectifying the great regional disparities between urban and rural areas as a development issue, and it has evaluated the construction of roads and bridges, which provide improved access in rural areas, as a key issue.

In the 11th Five-Year Plan (2013 to 2018) of Bhutan, “Strategic Development of Infrastructure” is prioritized, and a commitment to the development of transportation infrastructure (including national highways) for the promotion of inclusive socio-economic development is declared. As the development of the road network and bridges is of high priority, the current state of the domestic transportation network, including the traffic bottlenecks, will be examined, and upon the consideration of future loans, grant aid assistance and technical cooperation, the collection of the necessary information will be conducted in this Survey in order for JICA to carry out effective project formulation in this field.

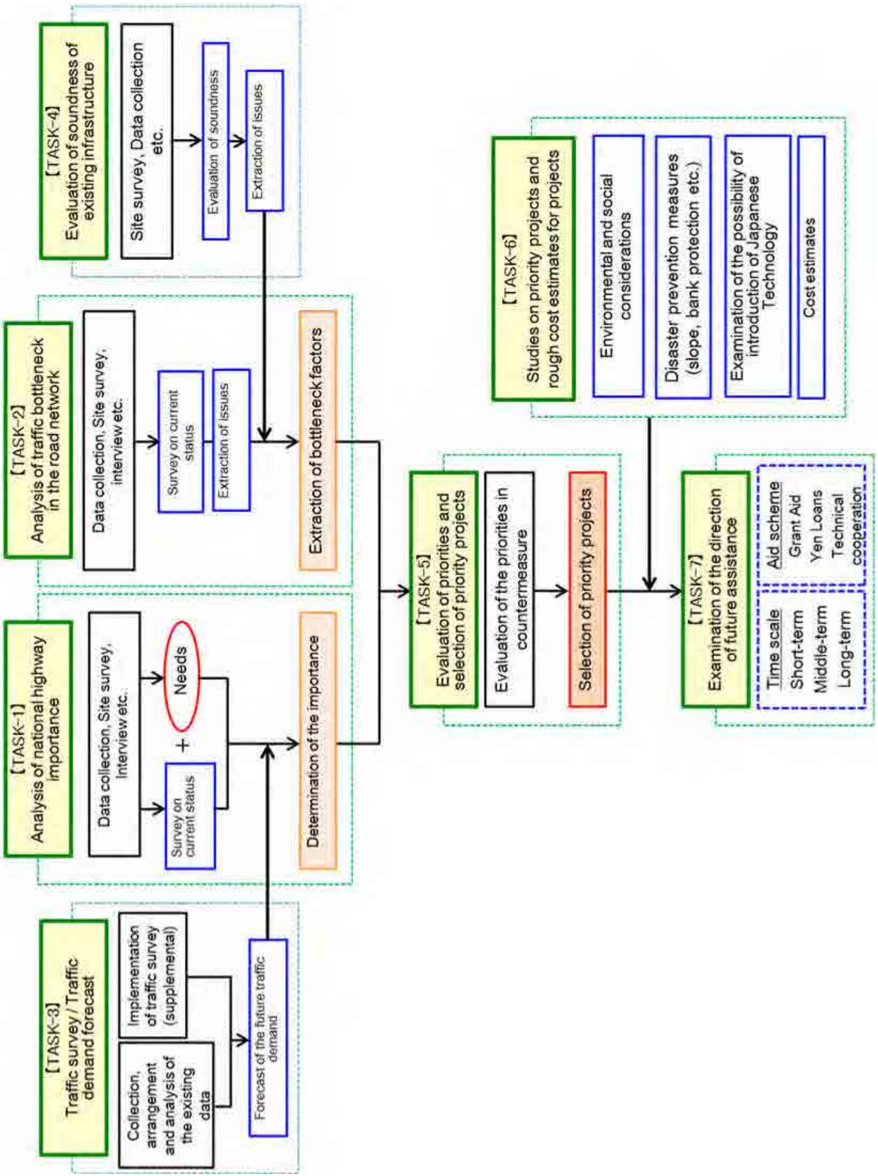
1-1-2. Survey Objectives

The objective of the survey is to examine the direction of future assistance in the transport/traffic field. In order to achieve this objective, traffic bottlenecks in the road network will be investigated, and road/bridge projects which require significant action will be selected upon consideration of the Bhutanese government’s plans, existing survey results, etc.

1-2. Survey Approach

In the Survey, the following 7 tasks will be implemented by the flowchart shown in Figure 1.1.

【TASK－1】　Analysis of national highway importance
【TASK－2】　Analysis of traffic bottlenecks in the road network
【TASK－3】　Traffic survey/Traffic demand forecasts
【TASK－4】　Evaluation of soundness of existing infrastructure
【TASK－5】　Evaluation of priorities and selection of priority projects
【TASK－6】　Studies on priority projects and rough cost estimates for projects
【TASK－7】　Examination of the direction of future assistance



Source: JICA Study Team

<Figure1-1>Survey flow chart

1-3. Survey Organization

In order to achieve the objectives of the survey efficiently and effectively, this project is composed of the following survey team.

<Table1-1>Survey Organization

Assignment	Name	Company
Team Leader/Road and Transport Engineer	Keigo KONNO	Oriental Consultants Co., Ltd.
Deputy Team Leader/Road, Transport and Bridge Engineer	Yasuhisa SUGANUMA	Oriental Consultants Co., Ltd.
Bridge Engineer	Shinichi NII	INGÉROSEC Corporation
River Engineer	Yoshiteru SHUTTA	Oriental Consultants Co., Ltd.
Environmental and Social Considerations Specialist	Masahiro YOSHIZAWA	INGÉROSEC Corporation
Slope Protection Engineer	Tetsuya SANO	Oriental Consultants Co., Ltd.
Coordinator/Environmental and Social Considerations Specialist	Mizuki TAKAHASHI	Oriental Consultants Co., Ltd.

Source: JICA Study Team

1-4. Survey Schedule

<Table1-2> Schedule of 1st Survey

Date		sum	Team Leader/Road and Transport Engineer Mr.Konno	Bridge Engineer Mr.Nii	River Engineer Mr.Shutta	Deputy Team Leader/Road, Transport and Bridge Engineer Mr.Suganuma	Coordinator/Environmental and Social Considerations Specialist Ms.Takahashi	Environmental and Social Considerations Specialist Mr.Yoshizawa	Slope Protection Engineer Mr.Sano	Stay in
7-Apr	Mon	1		Move:Narita⇒Bangkok	Move:Kansai⇒Bangkok	Move:Narita⇒Bangkok	Move:Narita⇒Bangkok			Bangkok
8-Apr	Tue	2	Move:Haneda⇒Bangkok⇒Paro	Move:Bangkok⇒Paro	Move:Bangkok⇒Paro	Move:Bangkok⇒Paro	Move:Bangkok⇒Paro			Thimphu
			14:00-DoR courtesy call, 15:30-JICA Office meeting, Health check-up							
9-Apr	Wed	3	Apprication of WP, ,Data/Information collection							Thimphu
10-Apr	Thu	4	,Data/Information collection, 16:00-JICA office meeting							Thimphu
11-Apr	Fri	5	Meeting with related agencies,Team meeting,Data/Information collection							Thimphu
12-Apr	Sat	6	Team meeting, Data/Information collection							Thimphu
13-Apr	Sun	7								Thimphu
14-Apr	Mon	8								Thimphu
15-Apr	Tue	9	Site investigation : Thimphu→Trongsa(NH1)				Safety management of the team member,Data/Information collection in Thimphu			Trongsa / Thimphu
16-Apr	Wed	10	Site investigation : Trongsa→Gelephu(NH4)			Site investigation : Trongsa→Mongar(NH1)				Mongar / Gelephu / Thimphu
17-Apr	Thu	11	Site investigation : Gelephu(Maukhola＆NH4)			Site investigation : Mongar→Bumthang(NH1)				Bumthang / Gelephu / Thimphu
18-Apr	Fri	12	Site investigation : Gelephu(Maukhola)			Site investigation : Bumthang→Thimphu(NH1)				Gelephu / Thimphu
19-Apr	Sat	13	Site investigation : Gelephu(Maukhola)			Site investigation : Thimphu&Paro				Gelephu / Thimphu
20-Apr	Sun	14	Site investigation : Gelephu→Thimphu(NH5＆NH1)			Data/Information collection				Thimphu
21-Apr	Mon	15	Team meeting, Data/Information collection							Thimphu
22-Apr	Tue	16	DoR Kick-off meeting, Data/Information collection							Thimphu
23-Apr	Wed	17	Meeting with related agencies,Team meeting, Data/Information collection							Thimphu
24-Apr	Thu	18								Thimphu
25-Apr	Fri	19								Thimphu
26-Apr	Sat	20	Team meeting,Data/Information collection							Thimphu
27-Apr	Sun	21								Thimphu
28-Apr	Mon	22	Move:Paro⇒Bangkok	Site investigation : Thimphu→P/ling(NH2)						P/ling / Bangkok
29-Apr	Tue	23	Move:Bangkok⇒Haneda	Site investigation : P/ling→Samtse→P/ling						P/ling
30-Apr	Wed	24		Site investigation : P/ling→Thimphu(NH2)						Thimphu
1-May	Thu	25		Meeting with related agencies,Data/Information collection						Thimphu
2-May	Fri	26								Thimphu
3-May	Sat	27								Thimphu
4-May	Sun	28								Thimphu
5-May	Mon	29								Thimphu
6-May	Tue	30								Thimphu
7-May	Wed	31								Thimphu
8-May	Thu	32						Move:Narita⇒Bangkok		Thimphu / Bangkok
9-May	Fri	33						Move:Bangkok⇒Paro		Thimphu
10-May	Sat	34		Team meeting,Data/Information collection	Move:Paro⇒Bangkok	Meeting with related agencies,Data/Information collection				Thimphu / Bangkok
11-May	Sun	35			Move:Bangkok⇒Kansai					Thimphu
12-May	Mon	36								Thimphu
13-May	Tue	37								Thimphu
14-May	Wed	38								Thimphu
15-May	Thu	39								Thimphu
16-May	Fri	40								Thimphu
17-May	Sat	41								Thimphu
18-May	Sun	42				Team meeting,Data/Information collection		Site investigation : Thimphu→Trongsa(NH1)		Thimphu / Trongsa
19-May	Mon	43				Meeting with related agencies,Data/Information collection		Site investigation : Trongsa→Mongar(NH1)		Thimphu / Mongar
20-May	Tue	44						Site investigation : Mongar(NH1)		Thimphu / Mongar
21-May	Wed	45						Site investigation : Mongar→Trongsa(NH1)		Thimphu / Trongsa
22-May	Thu	46						Site investigation : Trongsa→Thimphu(NH1)	Site investigation : Trongsa→Geylegph(NH4)	Gelephu / Thimphu
23-May	Fri	47	Move:Narita⇒Bangkok					Meeting with related agencies,Data/Information collection	Site investigation : Gelephu(NH4)	Gelephu / Thimphu / Bangkok
24-May	Sat	48	Move:Bangkok⇒Paro			Team meeting,Data/Information collection			Site investigation : Gelephu(Maukhola)	Gelephu / Thimphu
25-May	Sun	49	Team meeting,Data/Information collection						Site investigation : Gelephu→Thimphu(NH5＆NH1)	Thimphu
26-May	Mon	50	Site investigation : Thimphu→Bumthang(NH1)			Meeting with related agencies,Data/Information collection				Thimphu / Bumthang
27-May	Tue	51	Site investigation : Bumthang→Trongsa(NH1)							Thimphu / Trongsa
28-May	Wed	52	Site investigation : Trongsa→Gelephu(NH4)							Gelephu / Thimphu
29-May	Thu	53	Site investigation : Gelephu(Maukhola)							Gelephu / Thimphu
30-May	Fri	54	Site investigation : Gelephu→Thimphu(NH5＆NH1)							Thimphu
31-May	Sat	55	Team meeting,Data/Information collection			Team meeting,Data/Information collection				Thimphu
1-Jun	Sun	56								Thimphu
2-Jun	Mon	57	Meeting with JICA,Meeting with DoR and related agencies			Meeting with JICA,Meeting with DoR and related agencies				Thimphu
3-Jun	Tue	58								Thimphu
4-Jun	Wed	59	Move:Paro⇒Bangkok			Move:Paro⇒Bangkok				Bangkok
5-Jun	Thu	60	Move:Bangkok⇒Narita			Move:Bangkok⇒Narita				

Source: JICA Study Team

<Table1-3> Schedule of 2nd Survey

Date		sum	Team Leader/Road and Transport Engineer Mr.Konno	Deputy Team Leader/Road, Transport and Bridge Engineer Mr.Suganuma	River Engineer Mr.Shutta	Coordinator/Environmental and Social Considerations Specialist Ms.Takahashi	Stay in
2-Jul	Wed	1	Move:Narita⇒Bangkok			Move:Narita⇒Bangkok	Bangkok
3-Jul	Thu	2	Move:Bangkok⇒Paro			Move:Bangkok⇒Paro	Thimphu
4-Jul	Fri	3	Meeting with JICA,Meeting with DoR			Meeting with JICA,Meeting with DoR	Thimphu
5-Jul	Sat	4	Survey in Thimphu, Data/Information collection			Survey in Thimphu, Data/Information collection	Thimphu
6-Jul	Sun	5					Thimphu
7-Jul	Mon	6	Meeting with related agencies, Survey in Thimphu, Data/Information collection			Meeting with related agencies, Survey in Thimphu, Data/Information collection	Thimphu
8-Jul	Tue	7					Thimphu
9-Jul	Wed	8					Thimphu
10-Jul	Thu	9			Move:Kansai⇒Bangkok⇒Paro		Thimphu
11-Jul	Fri	10	Meeting with related agencies, Survey in Thimphu, Data/Information collection				Thimphu
12-Jul	Sat	11	Survey in Thimphu, Data/Information collection				Thimphu
13-Jul	Sun	12					Thimphu
14-Jul	Mon	13	Site investigation : Thimphu→Gelephu			Safety management of the team member,Data/Information collection in Thimphu	Thimphu / Gelephu
15-Jul	Tue	14	Site investigation : Maukhola Bridge				Thimphu / Gelephu
16-Jul	Wed	15	Site investigation : Gelephu→Thimphu				Thimphu
17-Jul	Thu	16	Meeting with related agencies, Survey in Thimphu, Data/Information collection				Thimphu
18-Jul	Fri	17					Thimphu
19-Jul	Sat	18	Survey in Thimphu, Data/Information collection				Thimphu
20-Jul	Sun	19					Thimphu
21-Jul	Mon	20	DoR meeting,Data/Information collection		Move:Paro⇒Bangkok	DoR meeting,Data/Information collection	Thimphu / Bangkok
22-Jul	Tue	21	Meeting with related agencies,Report writing, Explanation of final report		Move:Bangkok⇒Kansai	Meeting with related agencies,Report writing, Explanation of final report	Thimphu
23-Jul	Wed	22					Thimphu
24-Jul	Thu	23					Thimphu
25-Jul	Fri	24	JICA meeting, Data collection			JICA meeting, Data collection	Thimphu
26-Jul	Sat	25	Survey in Thimphu, Data/Information collection			Survey in Thimphu, Data/Information collection	Thimphu
27-Jul	Sun	26					Thimphu
28-Jul	Mon	27	Move:Paro⇒Bangkok			Move:Paro⇒Bangkok	Bangkok
29-Jul	Tue	28	Move:Bangkok⇒Narita			Move:Bangkok⇒Narita	Thimphu

Source: JICA Study Team

1-5. List of Major Contact Persons of Related Agency

(1) DoR,MoWHS

- Karma Galay: Director
- Kunzang Wangdi: Specialist, Planning Division
- M.N. Lamichaney: Specialist, Construction Division
- Jangchuk Yeshi: Chief Engineer, Design Division
- Karma Wangdi: Chief Engineer, Design Division
- Tshering Wangdi(A): Chief Engineer, Construction Division
- Tshering Paljare: Chief Engineer, Planning Division
- Tshering Wangdi(B): Chief Engineer, Maintenance Division
- Tougay Choedup: Chief Engineer, Head of Trongsa Regional Division
- Dorji Wangdi: Chief Engineer, Head of Phuentsoling Regional Division
- Karma Dorji: Chief Engineer, Head of Sarpang Regional Division
- Prabhat Rai: Chief Engineer, Head of Zhemgang Regional Division
- Karma Tenzin: Executive Engineer, Design Division (Road)
- Delip Thapa: Executive Engineer, Geotechnical Section and others

(2) JICA Bhutan Office

- Yumiko Asakuma: Chief Representative
- Hidetaka Sakabe: Representative
- Masanori Sunada: Project Formulation Adviser
- Masumi Ando: JICA Senior Volunteer

(3) Other related agencies

- Ugyen Wangda: Head of Geology Division, DGM, Ministry of Economic Affairs
- Karma Tshewang Chief Engineer, Hydropower Development Division, Department of Hydropower & Power System, Ministry of Economic Affairs
- Parsuram Sharma: General Manager (Operation), CDCL

Chapter 2. Current Conditions of the Road/Bridge Sector

2-1. Development of Road Network

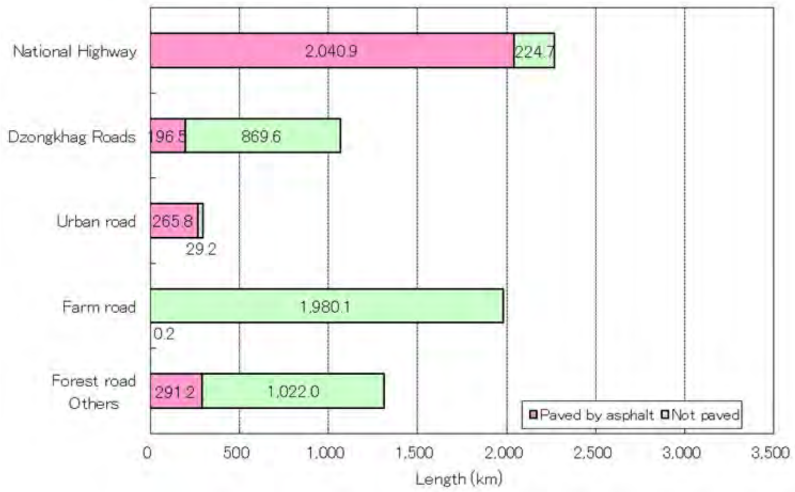
The development of roads in Bhutan is shown in Table 2-1. The first highway was constructed in 1961 between Phuentsholing and Thimphu, Paro through the assistance of the Indian Government. Ever since, the road network has been steadily expanding, resulting in a total length of about 10,600km at present (as of 2013). An expressway was constructed in the city of Thimphu which was opened for use in 2007, and the total length is 6.2km. The arterial roads (national highways) are called Primary National Highways (PNH), which have the highest standard in the country, and Secondary National Highways.

<Table2-1> Road length for the road network in Bhutan

Year	Expressway	Primary National Highway	Secondary National Highway	Dzongkhag Roads	Urban Road	Farm Road	Forest Road	Access Road	Others	Total
2004	–	1577.20	459.00	1213.21	117.42	244.27	542.60	Nil	Nil	**4153.70**
2005	–	1571.00	459.00	1278.26	125.11	388.54	570.60	Nil	Nil	**4392.50**
2006	–	1556.00	510.95	1246.91	130.22	525.85	574.80	Nil	Nil	**4544.73**
2007	6.2	1628.1	481.2	818.2	161.3	1012.3	559.6	534.7	148.1	**4946.6**
2008	6.2	1621.1	482.0	820.7	163.0	1045.6	528.9	554.2	140.8	**5362.4**
2009	6.2	1696.79	490.65	883.36	206.64	1395.62	536.80	562.64	203.60	**5982.31**
2010	6.2	1753.83	505.59	1066.09	295.00	1980.26	583.39	580.57	149.20	**6920.13**
2011	6.2	1757.19	516.35	1107.50	304.87	3236.41	630.75	619.87	134.90	**8314.04**
2012	6.2	1768.65	521.18	1050.94	326.91	4380.93	667.25	634.50	134.90	**9491.47**
2013	6.2	1860.12	578.26	1178.29	349.67	5255.19	667.25	563.18	120.10	**10578.26**
2014	6.2	1860.12	578.26	1178.29	349.67	5255.19	667.25	563.18	120.10	**10578.26**

Source: DoR

About 90% of the national highways are paved with asphalt, but other roads are partly not paved. Less than 30% of the roads are paved in the whole of Bhutan (See Figure2-1). The width of national highways is narrow, and the horizontal and vertical alignments of the road are bad, so dropping off cliffs and other traffic accidents are issues. However, it is not easy to widen the roads due to the necessity of slope measures for both the valley side and mountain side.



Source: DoR

<Figure2-1> Length of Road and pavement condition (2013)

2-2. Present Conditions of Bridges

(1) Number of Bridges

The number of bridges in Bhutan (the comparison of the number of bridges between 1994 and 2013) is shown in Table 2-2.

<Table 2-2> Number of bridges in Bhutan (1994 and 2013)

Type of superstructure	1994		2013	
	Number	Length(m)	Number	Length(m)
Reinforced concrete	46	996.03	70	1391.30
Pre-stressed concrete	3	226.22	14	721.00
RC Arch	0	0	3	265.00
Composite	0	0	20	376.06
Steel Arch	0	0	6	494.45
Bailey & Bailey Suspension	54	2,082.32	151	5,067.76
Steel Truss or Girder	7	628.05	17	964.60
Steel Hemilton	7	228.66	10	313.60
RCC slab of RSJ	22	212.80	34	578.25
Wooden deck/RSJ	3	97.56	0	0
UNIDO modular	17	253.05	0	0
Multi cell box culvert	0	0	5	216.00
RCC submersible	1	45.73	7	193.50
Total	**153**	**4,142.37**	**337**	**10,581.52**

Source: DoR

(2) DoR Implementing System

The Bridge Design Section, under Design Division of Department of Roads (DoR), is in charge of bridge planning and design in Bhutan. It has 4 local engineers and a JICA Senior Volunteer. The operation and maintenance of bridges are the responsibilities of Maintenance Division of DoR. Staff of regional offices take charge of actual works at the site.

(3) Bridge Design Standards, Design Documents

Bridges are designed in accordance with the Indian Design Standards (Indian Specifications: IS Codes and Indian Road Congress Specifications: IRC Codes), and American Association of State Highway and Transportation Officials (AASHTO) is used as a supplement.

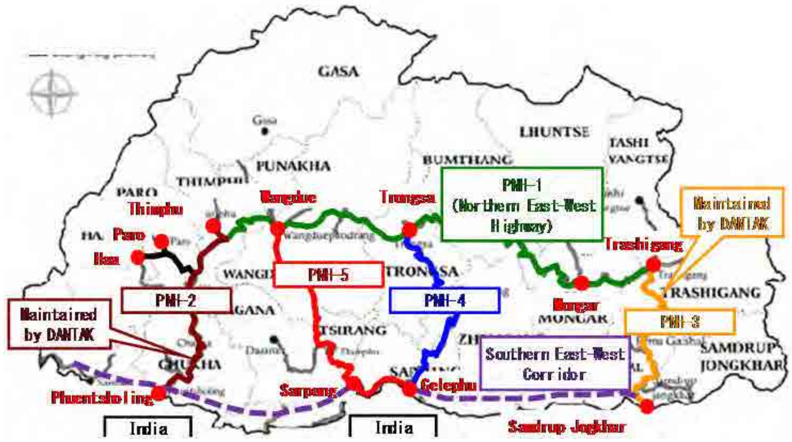
DoR keeps the design documents concerning the bridges designed and constructed by DoR after 2002. But most of the bridges were constructed by Indian Border Roads (DANTAK) before and the design documents were not kept. The bridges made by DANTAK are designed at a design load of 40R.

The bridges on PNH are expected to comply with the loading capacity in terms of IRC70R (single lane) or IRC Class A (double lane). Most of the existing bridges along PNH fall short of the requirements on such width and loading capacity, so that the goal to achieve here is to ensure the east - west and north – south connectivity in the country. From this viewpoint, it may be said that almost all of the existing bridges require reconstruction because of shortage of load capacity.

2-3. Current State of National Highways

(1) Current state of PNH

PNH network in Bhutan is shown in Figure 2-2 and total length of each PNH is shown in Table 2-3. The road network in Bhutan is mainly constituted by the network of PNH and there are 5 main PNHs which include one route for east-west direction (PNH-1) and 4 routes for north-south direction (PNH-2 to PNH-5). PNH-2 and PNH-3 were constructed by the Government of India and are currently maintained by DANTAK. PNH-1 is the only road that crosses from east to west and there are 5 sections of mountain pass of more than 3,000m altitude, therefore road blockage is frequent in winter and the rainy season. The construction of the Southern East-West Corridor is a critical issue in Bhutan since the route through India needs to be used in the case of a road block.



Source: JICA Study Team

<Figure2-2> PNH Network in Bhutan

<Table 2-3> Current status of PNH (as of May 2014)

Name	Total length (km)	Controlling agency (in charge of maintenance)
PNH-1	545	Trashigang - Simtokha: DoR
PNH-2	168	Phuentsholing - Thimphu: DANTAK
PNH-3	180	Gelephu - Trongsa: DoR
PNH-4	244	Samdrup Jongkhar - Trashigang: DANTAK
PNH-5	112	Gelephu - Wangdue: DoR

Source: DoR

Source: JICA Study Team

<Figure 2-3> Condition of PNH-1

(2) Existing Principal Issues of the National Highways

Existing principal issues and social/economic effects related to the national highways are summarized in Table2-4.

<Table2-4> Existing principal issues and social/economic effects related to national highways

Issues	Factors related to infrastructure	Social/economic effects
Landslide and flood disasters during rainy season	Road : Slope failure Bridge: Washing out of temporary bridge	Hindrance of persons and material flows due to roadblock
Lack of alternative route to the East – West Highway (PNH1)	Vulnerability of the road network	No alternative route exists when PNH1 is blocked
Bottleneck due to structural problems	Road : Narrow road width, poor alignment Bridge: Not compatible with traffic of heavy vehicles, insufficient strength	Poor traveling performance causes traffic bottle necks and hindrance to the flow. In case of disaster, slope failure or collapse of bridge may cause long-term disruption of traffic.
Traffic accidents and disasters due to structural problems of infrastructure	Road : Narrow road width, poor alignment Bridge: Not compatible with traffic of heavy vehicles, insufficient strength	Poor alignment and narrow sections cause traffic accidents, such as falling off the cliff side, collision with on-coming vehicles, etc.

Source: JICA Study Team

2-4. Traffic Volume Data

In order to grasp the traffic condition in each national highway, traffic data were obtained from DoR and organized. Further, the traffic survey shown in Table2-5 was conducted in order to grasp the latest traffic situation.

<Table2-5> Schedule of Traffic survey conducted by the Study Team

Route Name	Item	Content
PNH5	Date	28/April/2014
	Time	6:00am～18:00pm(12hours)
	Location	Hilley Check Post
PNH4	Date	29/April/2014
	Time	6:00am～18:00pm(12hours)
	Location	Geleg Zam (Aie Bridge) Check Post
PNH1	Date	05/05/2014
	Time	6:00am～18:00pm(12hours)
	Location	Dochula

Source: JICA Study Team

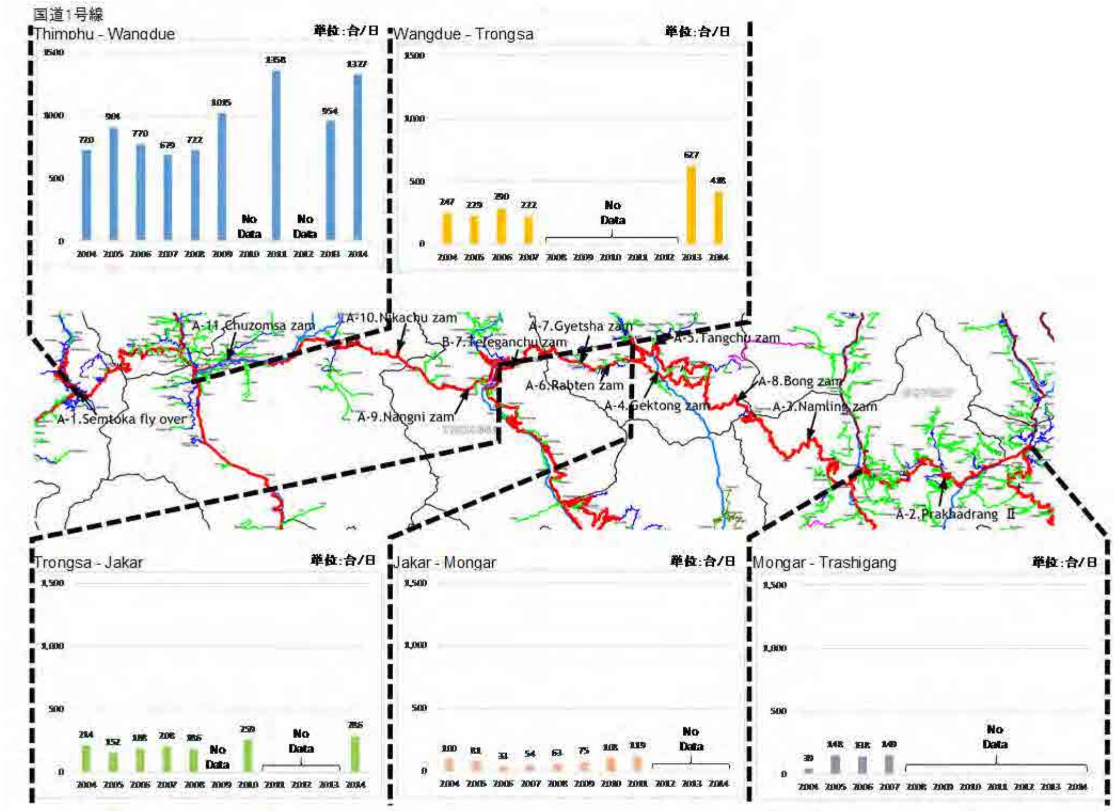
Traffic condition of each PNH is shown below.

(1) PNH-1

Traffic condition of PNH-1 is described in the figure below. PNH-1 connects between Thimphu-Trashigang and is the only route that crosses east to west in Bhutan. The traffic volume of PNH-1 is increasing or remains at the same throughout its entire length. The section which has particularly heavy traffic volume is between Thimphu – Wangdue. Since 2009 average traffic volume has been about 1,000 units per day to 1,300 units per day of which about 14% has been heavy vehicles and 75% is normal sized cars in 2014.

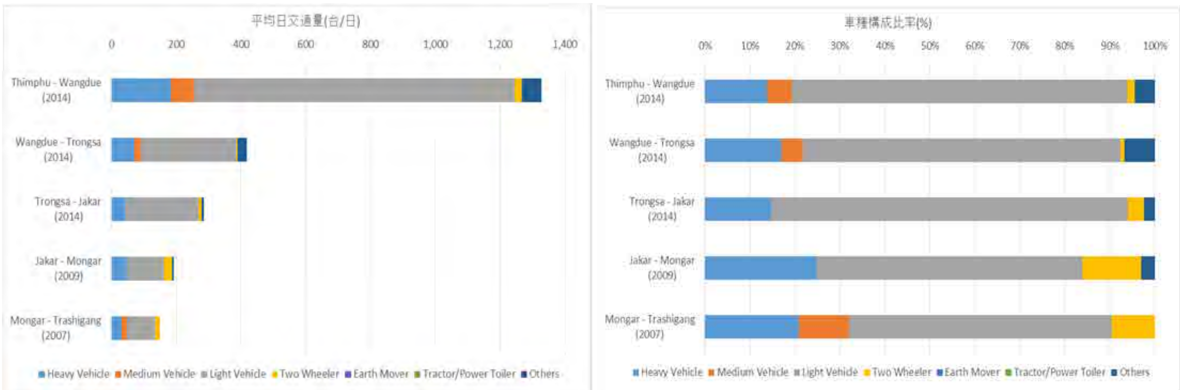
This section has the largest traffic volume on the national highways in Bhutan since it handles the traffic towards the area east of PNH-1 (Trongsa, Mongar, Trashigang) and the traffic towards the south side (Gelephu) through PNH-5 on the boundary of Wangdue.

There are variations in traffic volume of PNH-1 and PNH-5 on the east side of Wangdue depending on the year, however in the recent years the traffic towards PNH-5 tends to be increasing due to the influence of the Punatsangchhu Hydroelectric Project, and the traffic volume on the east side of PNH-1 as a boundary of Wangdue is under 1,000 units per day (approximately 200~300 units per day), about 20% is heavy vehicles and about 60-70% is normal sized cars.



Source: Prepared by JICA Study Team based on the data from DoR and the result of the traffic survey

<Figure2-4> Traffic condition of PNH-1



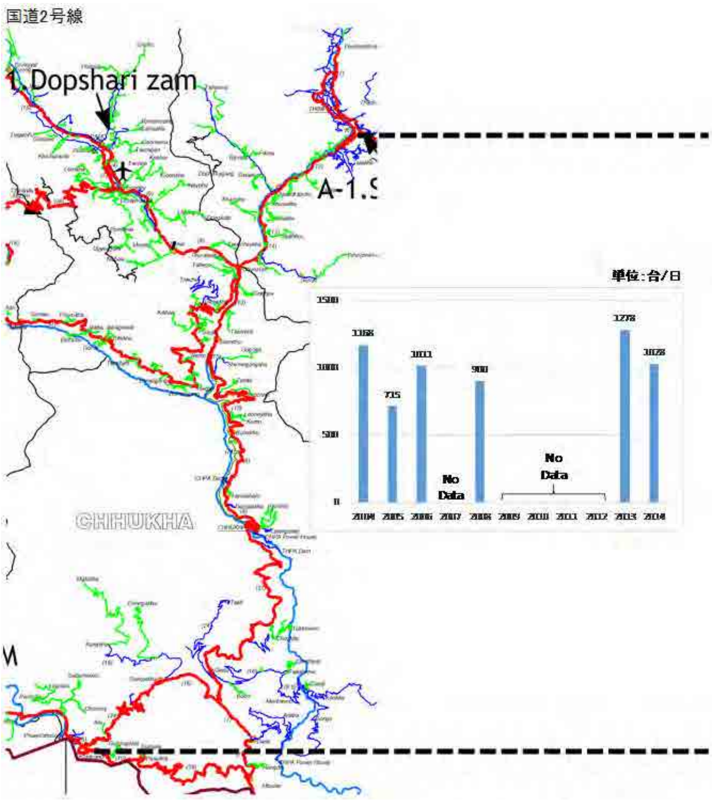
Source: Prepared by JICA Study Team based on data from DoR and the result of the traffic survey

(Result based on the latest data for each section (2007, 2009, 2014))

<Figure2-5> Type of vehicle passing PNH-1

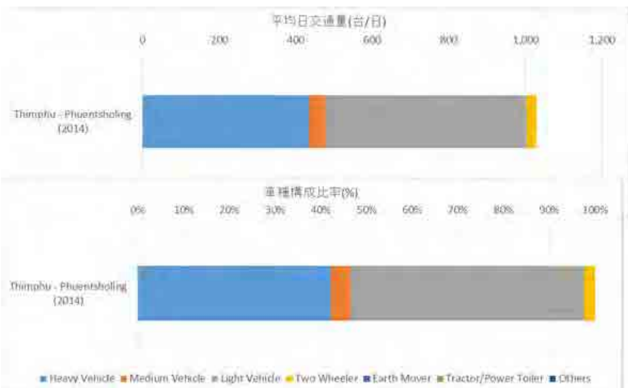
(2) PNH-2

PNH-2 is the route connecting Phuentsholing and Thimphu, which has 1,000 units to 2,000 units in daily traffic volume in average and is the route that has the second heaviest traffic after PNH-1. In vehicle type classification of traffic in 2014 is approximately 40% large vehicles and 50% normal cars and the heavy vehicles traffic is also heavy, consequently it plays a critical role as a route of transport.



Source: Prepared by JICA Study Team based on the data from DoR

<Figure2-6> Traffic condition of PNH-2

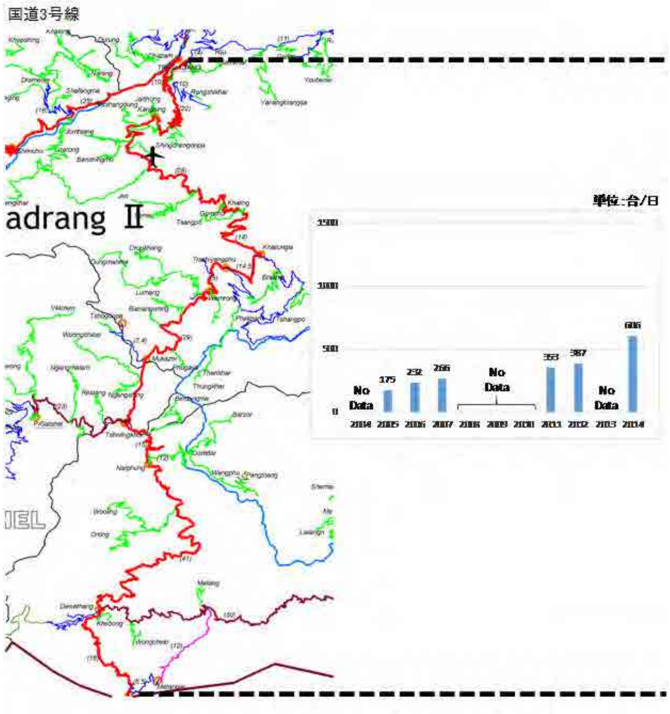


Prepared by JICA Study Team based on data from DoR (Data of 2014)

<Figure2-7> Type of vehicles on PNH-2

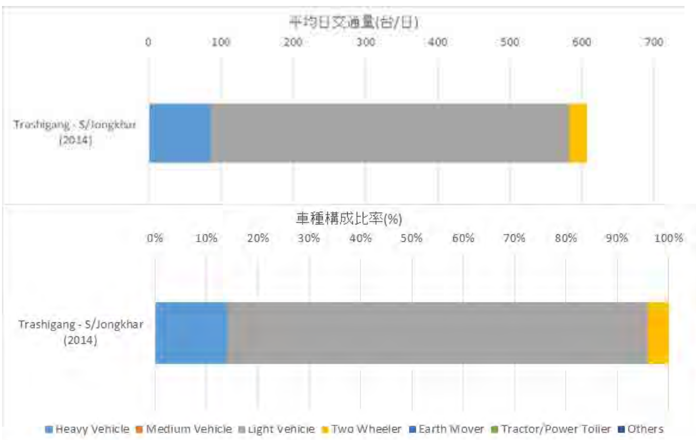
(3) PNH-3

PNH-3 is the route connecting Trashigang to Samdrup Jongkhar. Average daily traffic volume in 2014 is approximately 600 units per day and vehicle type classification is 14% heavy vehicles and 82% is normal sized cars, and tends to be increasing the percentage of normal cars is large. It is the route crossing from north to south similar to PNH-2, PNH-4 and PNH-5, however the traffic of heavy vehicles is small and it can be said that current major transport is based on PNH-2.



Source: Prepared by JICA Study Team based on the data from DoR

<Figure2-8> Traffic condition of PNH-3

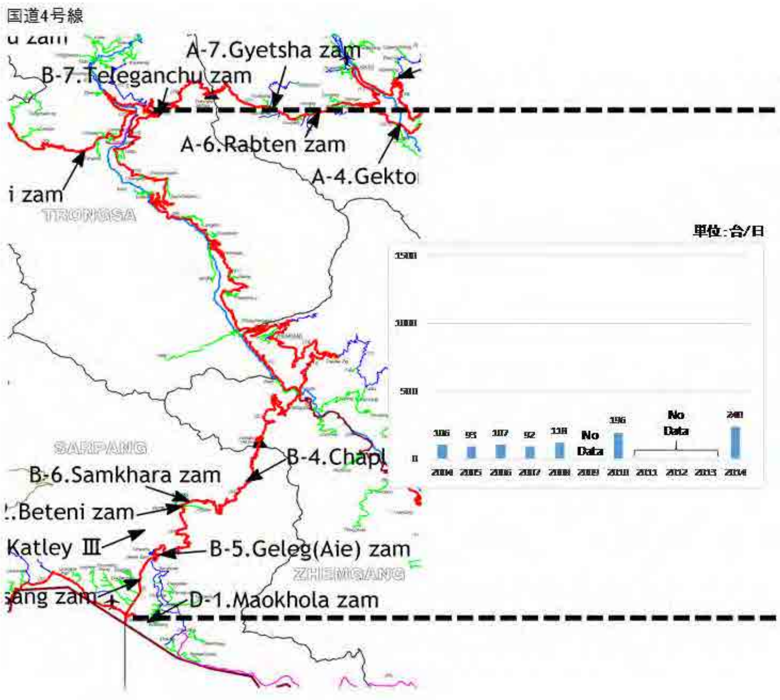


Prepared by JICA Study Team based on data from DoR（Data of 2014）

<Figure2-9> Type of vehicles on PNH-3

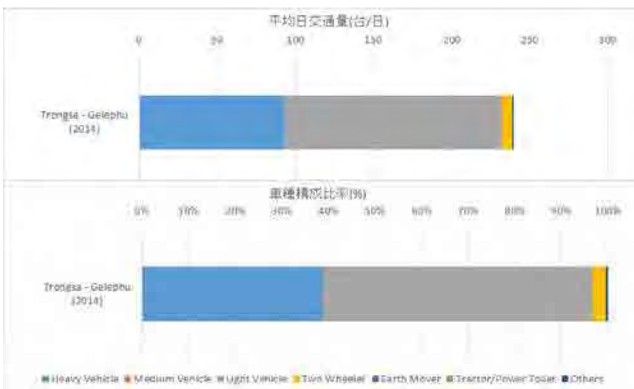
(4) PNH-4

PNH-4 is the route connecting Trongsa and Gelephu. Average daily traffic volume in 2014 is approximately 240 units per day and tends to be increasing. Vehicle type classification is 40% heavy vehicles and 60% normal sized cars, and the percentage of normal cars is large. As stated before, it is the route crossing from north to south similar to PNH2, PNH-3 and PNH-5, however the traffic flow of PNH-4 is smaller than the traffic to Wangdue on PNH-5.



Source: Prepared by JICA Study Team based on the data from DoR

<Figure2-10> Traffic condition of PNH-4

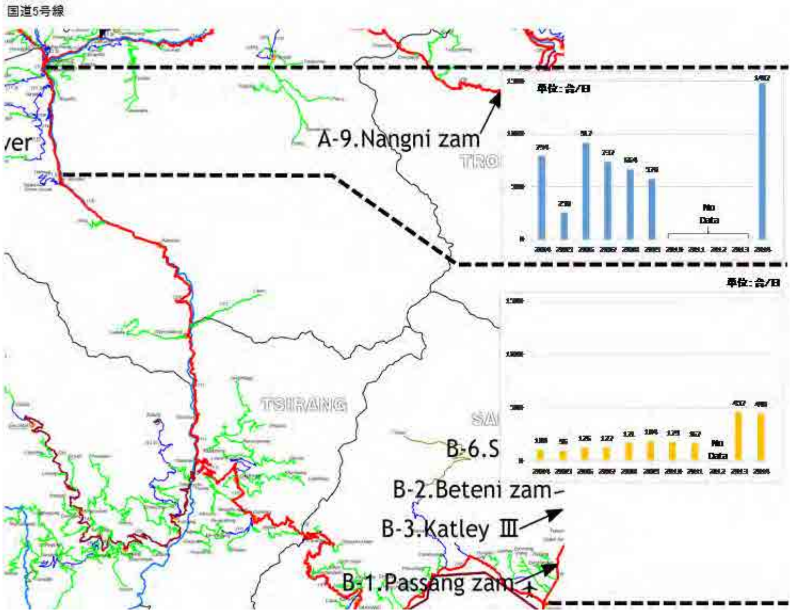


Prepared by JICA Study Team based on data from DoR and the result of the traffic survey（Data of 2014）

<Figure2-11> Type of vehicles on PNH-4

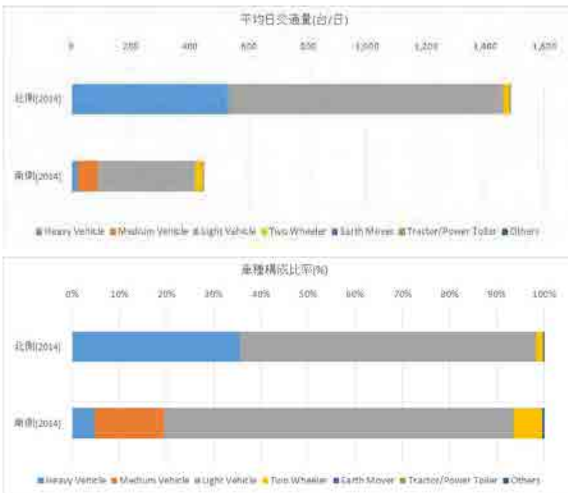
(5) PNH-5

PNH5 is the route connecting Wangdue and Gelephu and the extent of increase in average daily traffic volume on the Gelephu side (south side) is smaller compared to that on the Wangdue side (north side). This increase is due to the increase in construction vehicles associated with the Punatsangchhu Hydroelectric Project taking place in the north. Average daily traffic volume in 2014 is approximately 1,500 units per day in the north and 450 units per day in the south. Further, vehicle type classification is 35% heavy vehicles and 63% normal sized cars in the north and 5% heavy vehicles and 75% normal sized cars in the south. The traffic of large vehicles is greater in the north in terms of volume and composition ratio.



Source: Prepared by JICA Study Team based on the data from DoR

<Figure2-12> Traffic condition of PNH-5



Prepared by JICA Study Team based on data from DoR and the result of traffic survey

（Data of 2014）

<Figure2-13> Type of vehicles on PNH-5

2-5. Procurement of Construction Equipment and Materials

(1) Construction Materials

Table2-6 shows the current situation of procurement of major materials for construction in Bhutan. Cement, aggregates, rebars, etc. can be procured in Bhutan but PC steel wires and bearings which are mainly used in bridge construction should be imported from foreign countries (mainly from India).

There are the following two large cement plants in Bhutan.

- Gomtu：Penden Cement Authority Ltd（Government-affiliated company）
- Nganglam : Druk Dragon Cement（Government-affiliated company）、Lhaki Cement（Private company）

On the other hand, rebars made in a plant in Pasakha are generally used. The BRM PVT. LTD in Pasakha can manufacture deformed bars (D8, 10, 12, 16, 20, 25, 32) and round bars (R22, 25), and a laboratory is attached to the plant to check the quality of the rebars. Figure2-15 shows an example of strength test of rebars obtained from the BRM PVT.LTD.

<Table2-6> Classification of Major Materials according to Procurement Source

Material	Specifications	Procurement source		Remarks
		Bhutan	Foreign country	
Banking materials		○		
Asphalt	For mixing at the site	○		Imported from India
Asphalt emulsion		○		
Base course material	Ballast	○		
Cement	Regular Portland cement	○		
Admixture	Water-reducing admixture		○	
Fine aggregate	Sand	○		
Coarse aggregate	Ballast	○		
Split stone	20-25cm	○		
Steel reinforcement		○		
PC steel wire			○	
Sheath			○	
Railing	Made of steel		○	
Bearing	With bearing accessories		○	
Expansion device			○	
Bridge surface gully	With vertical drain pipes		○	

Material	Specifications	Procurement source		Remarks
		Bhutan	Foreign country	
Gabion		○		
Formwork plywood		○		
Support material	H steel material, tube pipe, etc.		○	
Scaffolding	Scaffolding, separators, etc.	○	○	Separators, etc. to be procured from foreign country
Timber	For formwork, temporary work, etc.	○		
Sand bag	For temporary work	○		Imported from India
Fuel		○		Imported from India

Source: JICA Study Team

Source: JICA Study Team

<Figure2-14> Rebar factory in Pasakha

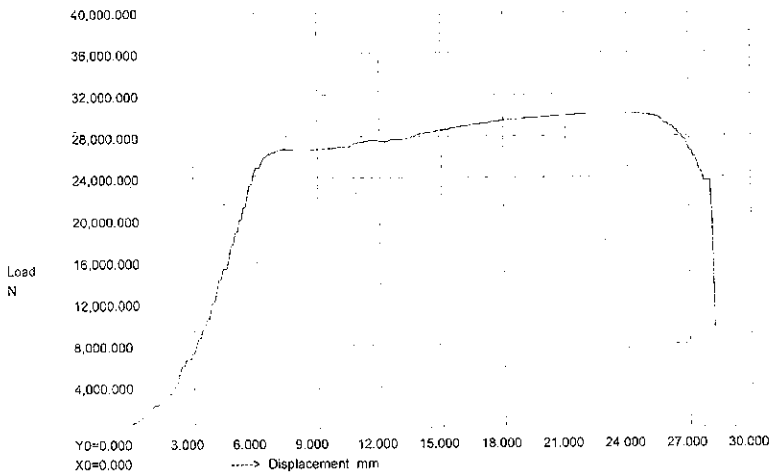
Test Certificate

Name of Company : BRM PVT. LTD.
Address : PASAKA
To : BRML
Sample Identification : 08mm
Machine : FIE Make Universal Testing Machine, UTE-100

Input Data : File Name : BR1504081779 , Record No. : 1 , Date : 15/04/2014
: Sample Type -- Other Area : 49.200 mm ²
: Sample Area = 49.200 mm ²
: Gauge Length : 40 mm Final Gauge Length: 48.4 mm
: Test Speed : 8 mm/min

Results of : Tension Test
Maximum Force (Fm) : 30,150.000 N
Max. Disp. : 28.200 mm
Tensile Strength (Rm) : 612.805 MPa
Elongation : 21.000 %
Yield Stress : 543.699 MPa
YS/[illegible] Ratio : ~~0.887~~ 1·127
* Note : Yield Calculated from graph

Graph : Load Vs Displacement



Source: BRM PVT.LTD

<Figure2-15> Example of result of strength test of rebar (deformed bar D8mm)

(2) Construction Equipment

Procurement of construction equipment at present is as shown below. In 2006, the Mechanical Division of DoR became independent and was renamed CDCL (the Construction Development Corporation Limited), which owned many types of equipment, but DoR does not own major construction equipment at present. Equipment is procured by competitive bids for private companies that own construction equipment. The bidding information is provided through television (BBS), a newspaper (Kuensel) and the website of Ministry of Works and Human Settlement (MoWHS). In addition to CDCL, many private companies, including Dungkar Hiring Agency, participate in the bids. However, the quality and quantity of equipment of private companies are low. When only CDCL has the equipment for paving, DoR awards a direct contract to CDCL.

<Table2-7> Classification of Major Construction Machinery according to Assumed Procurement Source

Equipment	Procurement source		Remarks
	Bhutan	Foreign country	
Bulldozer	○		Earthwork
Backhoe	○		Earthwork
Large breaker	○		Earthwork
Wheel loader	○		Material handling
Dump truck	○		Earthwork
Truck	○		Material handling
Rafter crane		○	Substructure work, superstructure work
Grout mixer		○	Foundation work, superstructure work (PC), temporary work (earth anchor)
Grout pump		○	
Boring machine		○	Temporary work (earth anchor)
Motor grader	○		Pavement work
Road roller	○		Pavement work
Tire roller	○		Earthwork, pavement work
Vibration roller	○		Earthwork, pavement work
Tamper	○		Earthwork, pavement work
Concrete mixer	○		
Air compressor	○		Earthwork
Air compressor	○		Temporary work
Generator set	○		
Materials and equipment for delivery		○	Superstructure work
Equipment for PC girder fabrication		○	Superstructure work
Equipment for PC girder construction		○	Superstructure work

Source: JICA Study Team

ADVERTISEMENT

Tuesday, May 13, 2014 | KUENSEL PAGE 11

INVITATION OF BIDS

MINISTRY OF WORKS AND HUMAN SETTLEMENT

Department of Roads, Regional OfficeTrashigang.

DoR/RO-Tg/2013-14/W-8/810

1. Department of Roads, Trashigang Regional Office, invites sealed bids from the eligible and qualified bidders for the following works.

Bid No.	Name of work	Bid Security (Nu.)	Last date of submission	Date of opening
DoR/RO-Tg/2014-2015/ Goods(01)	Hiring of vehicles & machinery for the Financial Year 2014-2015.	Refer Bid Document	June16, 2014 before 10.00am	June 16, 2014 at 10.30am

2. Bidding will be conducted through the National Competitive Bidding procedures specified in the RGoB Procurement Rules and Regulations, and are open to all bidders from Bhutan.
3. Interested eligible bidders may obtain further information from DoR, Trashigang Regional Office at Telephone No.**04-521135/521469** during office hours
4. A complete set of bidding document in English may be download from the website **www.mowhs.gov.bt**
5. Bids must be delivered to Office of Chief Engineer, DoR, Trashigang Regional Office on or before **10:00am on 16/06/2014**. Late Bids will be rejected. Bids will be opened physically in the presence of bidders/representatives who choose to attend in person at **10.30am on 16/06/2014** in the conference hall.
6. All bids shall be accompanied by a Bid Security as prescribed in the bidding document.

Offtg. Chief Engineer

Source: Kuensel (13 May 2014)

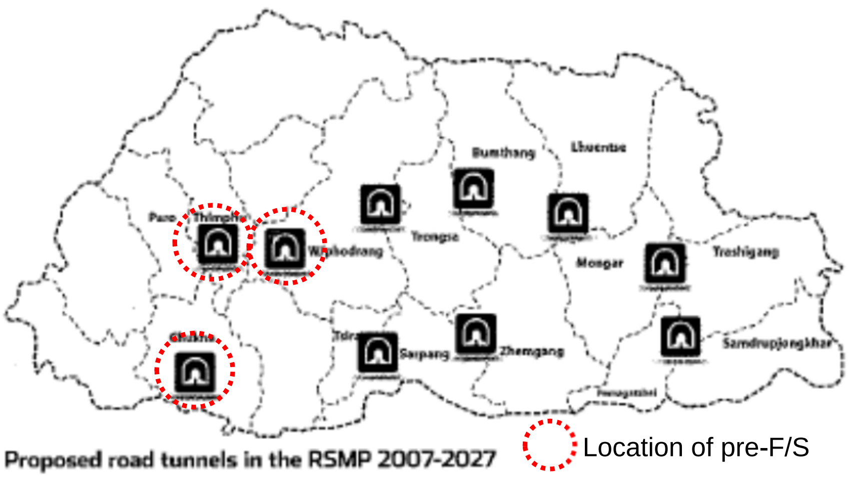
<Figure2-16> Tender information for the construction machinery that was published in the local newspaper

A list of construction machinery that belongs to CDCL is shown in Appendix-3. JICA has provided equipment three times under the grant aid program of Japan (Phase-1 in 1989, Phase-2 in 1997, Phase-3 in 2005). The equipment provided to the Mechanical Division of DoR at that time is owned and used by CDCL now.

The largest crane to suspend 25 tons was provided by JICA in phase 1 for bridge construction and stored in Hesothangkha but its aging is a problem. CDCL requested JICA to deliver grant aid equipment (Phase-4), but it was not approved.

2-6. Tunnel Plan

The local newspaper (Kuensel) announced on April 22, 2014 that DoR completed the pre-feasibility study on three candidate sites in the suburbs of the capital, from among the ten candidate sites for tunnel construction (see Figure2-17) described in the Road Sector Master Plan. There are three points, 1) PNH-2 (Gedu-Ganglakha section), 2) PNH-2 (Thimphu-Paro section), and 3) PNH-1 (Thimphu-Wangdue section), on which a pre-feasibility study financed by ADB was performed in 2011. That study covered positioning of the tunnel entrance, a comparative study of proposed routes, and an estimation of approximate construction costs. That estimation was done using the actual costs of construction of the 1.5 km tunnel in the Punatsangchhu-II Hydroelectric Project (construction cost of 720 million Nu.) and the 10.5 km tunnel construction project between Yusipang and Nabesa (construction cost 4.7 billion Nu.) by DGM and Norwegian Geotechnical Institute (NGI) and by taking into account the possible contingencies. The estimated amount was said to be about 600 million Nu./km. The result of the pre-feasibility study on each tunnel is shown in Table 2-8.



Source: Kuensel (22 April 2014)

<Figure2-17> Location map of candidate sites for tunnels

<Table2-8> Results of pre-feasibility study

Option	Total road Length (Km)	Reduction in Length (Km)	Tunnel Length (Km)	Net Present Value (NPV)
PNH-2				
A	175km	5.3km	0.77Km	868.56 Million Nu.
B		5.9Km	0.96Km	737.28 Million Nu.
PNH-2（Thimphu-Paro section）				
A	58km	26.0Km	18.3Km	3,952.80 Million Nu.
B		27.9Km	20.6Km	4,326.00 Million Nu.
C		13.8Km	8.2Km	2,115.60 Million Nu.
D		8.6Km	12.5Km	1,275.00 Million Nu.
PNH-1（Thimphu-Wangdue section）				
A	70km	30.1Km	10.3Km	7,539.60 Million Nu.
B		30.5Km	13.2Km	10,058.40 Million Nu

Source: Kuensel (22 April 2014)

DoR commented that among the three candidate sites, the site for which development is the most effective is the Gedu-Ganglakha section of PNH-2. Since this section runs through the Jumbja landslide area that has been infamous for 50 years or more, bypassing this section will prove highly effectively in securing safety. The next site proving effective in development is said to be the Thimphu-Wangdue section of PNH-1. However, the 10.5 km section between Yusipang and Nabesa under consideration by DGM and NGI includes a steep grade and presents problems in terms of safety management. Therefore, DoR proposes reduction of the grade to 3.5% by changing the section to be tunneled to the Semtokha- Nabesa section. For the remaining Thimphu-Paro section of PNH-2, a review is being made on four proposed routes. This section is already widened (two lanes) by DANTAK, and tunneling is considered to offer only limited economic effects in spite of the enormous cost requirement. DANTAK in charge of controlling PNH-2 considers it beneficial to shorten the required traveling time through increase in the number of lanes by widening the road because tunneling is extremely expensive.

Apart from three locations as above described, DoR places the priority on tunneling of the Gayzamchu-Sengor section of PNH-1. This section is to bypass the Thrumshing La Pass, which is located at the highest altitude along PNH-1, and a pre-feasibility study was performed on this section by NGI in 2007 to compare four proposed routes. The length of tunnel in the route shortest among them is about 2.2km, meaning that the route can be reduced by about 7 km. The study subsequently performed independently by DoR also reviewed the alternative plan of a 2.97 km long tunnel, which is expected to reduce the distance by about 12 km. When completed, this tunnel is expected to be highly effective in preventing road blockage by snow cover at the Thrumshing La Pass in the winter. The feasibility of tunnel construction for this section cannot be considered difficult when considering that the daily traffic of the section at present is small at about 100 vehicles. Even when the increase in the traffic related to construction of the Kuri-Gongri and Kholongchhu hydropower plants in the future is taken into account, the traffic expected ten years from now is estimated to be only 300 vehicles/day.

2-7. History of Disasters and Frequently Damaged Points on the National Highways

Table 2-9 shows information which was organized by DoR regarding the disasters in recent years. Figure 2-18 shows the locations of disasters.

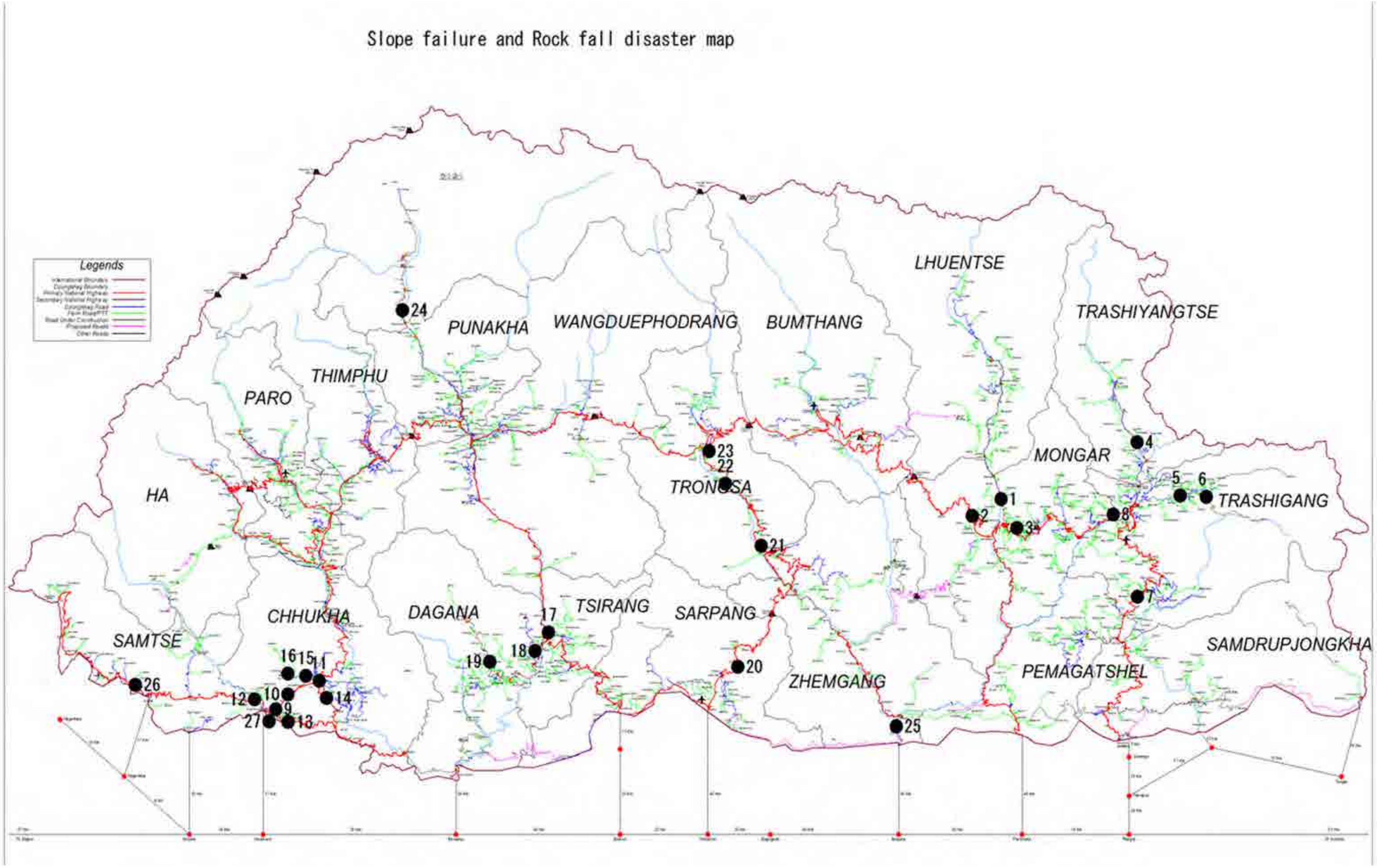
Almost all roads are constructed along rivers and on gentle slopes which have experienced landslides in the past, landslides on the steep slopes along rivers and re-collapse by cutting gentle grounds often occurs in the rainy season.

From the central part to the southern part, sediment disasters occur often due to the presence of rubbed fragile strata seen in a thrust fault and Baxa Group.

<Table2-9> Landslides and Rock Falls on National Highways (blank: unknown)

No.	Name of Slide	Name of highway/Roads	Location	Year	Type	status
1	Dorjieelung (Rotpashong)	Gangola-Lhuntse SNH	14.00-15.00 km	1970s	Land slide	active
2	Latongla	Trashigang-Semtokha PNH	167.10 km	2004	Rock slide	Stabilized
3	Trailing	Trashigang-Semtokha PNH	90.20 km	2004	Landslide	creeping
4	Koncholing	Chazam-Trashiyangtse SNH	23.00 km	2004	Land slide	active
5	Youdiri	Trashigang-Phongmey DR	29.50 km	2004	Landslide	active
6	Dungjuri	Trashigang-Phongmey DR	31.05 km	2004	Land slide	active
7	Moshi	S/jongkhar-T/gang PNH	-	-	Land slide	active
8	Yayung	Trashigang-Semtokha PNH	21.20 km	-	Landslide	-
9	Rinchending	P/ling – Thimphu PNH	5.00 km	-	Landslide	active
10	Sorchen	P/ling – Thimphu PNH	-	-	Landslide	Almost stabilized
11	Jumja	P/ling – Thimphu PNH	40.00 km	2000	Rock slide	active
12	Chamkhuna	P/ling – Samtse PNH	5.00 km	-	Landslide	active
13	Bhaijhora	Pasakha- Manitar Road	9, 15 & 23 km	-	Landslide	active
14	Bharkay	Tala- Manitar Road	5.20 km	-	Land slide	active
15	Raghubir	Ganglakha-Dungna Road	4.40 km	-	Rock slide	active
16	Tagona	Ganglakha-Dungna Road	13.00 km	-	-	active
17	Tintalay	Gelephu-Wangdue PNH	106-108 km	1998	Landslide	creeping
18	Chengala	Sunkosh-Daga SNH	9.00 km	2000	Landslide	active
19	Khagochen	Sunkosh-Daga SNH	23.00 km	1983	Landslide	active
20	Box cutting	Gelephu-Trongsa PNH	15.00 km	-	Land slide	active
21	At various places	Gelephu-Trongsa PNH	16, 21-22,28,-29, 36 & 49	-	Rockslide/ Landslide	active
22	Reotala	Gelephu-Trongsa PNH	158.00 km	-	landslide	active
23	Yurmo	Gelephu-Trongsa PNH	196.00 km	-	Landslide	active
24	Gathana	Punakha-Gasa SNH	45.00 km	-	Landslide	active
25	Mathanguri	Mathanguri-Panbang Road	-	-	landslide	-
26	Changmari	Samtse-Tendu Road	-	-	Landslide	active

Source: DoR

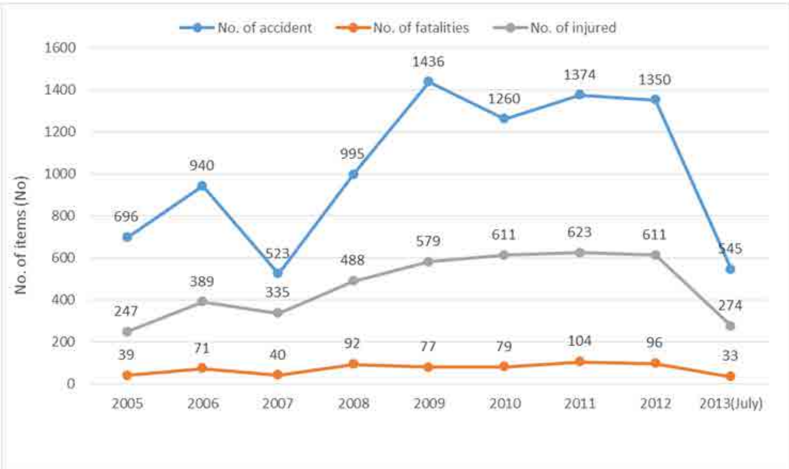


<Figure2-18> History of Disasters

Source: DoR

2-8. History of Traffic Accidents on National Highways

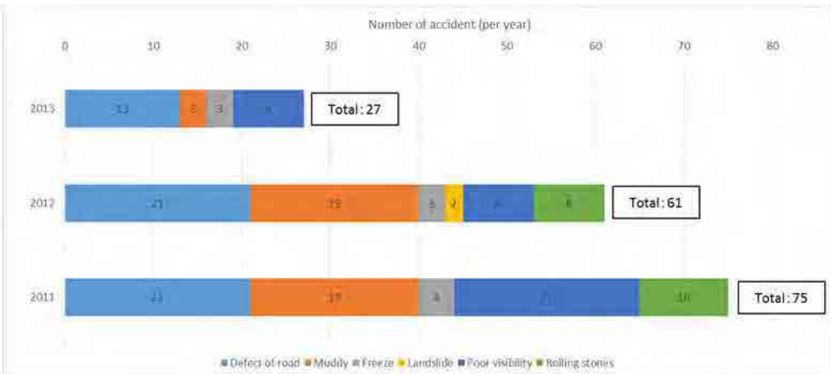
A record of traffic accidents in Bhutan is shown in Figure2-19. As shown in the figure, the traffic accidents increased rapidly from 2007 up to 2009. After 2009, the number of traffic accidents varies from 1,200 to 1,400. Traffic accident data is compiled by Road Safety and Transport Authority (RSTA) and its annual report stated that the number of fatal accidents was 14 per 10,000 vehicles in 2012. This probability is reported to be rather high in the South Asian area. Major details of accidents describe accidents caused by structural factors of roads, bad weather, poor visibility, etc.



Source: Road Safety and Transport Authority, Annual Report Financial Year 2012-2013

<Figure2-19> Record of the number of accidents (death, injury)

The data regarding accidents managed by police is shown in Figure 2-20. This data does not cover all accidents that occurred on Primary National Highways, however, the relationship between the cause of accident and the condition of roads can be understood using this data. According to this, many accidents are often caused by “a defect of the road”. This includes various types of defects, however the major defect is not clear. “Mud on the road surface” and “bad visibility on the road” are raised as other causes.



Source: Royal Bhutan Police

<Figure 2-20> Record of number of accidents by road condition

2-9. Operation and Maintenance of Roads and Bridges

(1) Maintenance Budget

According to the interview with the Chief Engineer of DoR regional office, annual maintenance budget to be allocated to each regional office is 26,000Nu/ bridge/ year for routine bridge inspection and maintenance (all types and routes are the same rate). In the case of road inspection and maintenance, 88,000Nu/km/year for PHN, 80,000Nu/km/year for Secondary National Highways and 44,000Nu/km/year for Feeder Roads is allocated. This budget is the same in all 9 regional offices. Regional offices, which are responsible for maintenance, actually select the point for repair and improvement uniquely in a limited budget to be allocated every year and carry out the construction work little by little.

In addition to the fixed amount budget allocated every year for normal inspection and maintenance, there is budget allocated for inspection and maintenance in abnormal times called "Monsoon Restoration". In September or October after the rainy season is over every year, staff from DoR headquarters, DPA (Department of Public Accounts) of MoF and staff from DoR regional office jointly check the route and identify the locations to be repaired and rehabilitated and thereafter cost for construction is estimated and a budget request is lodged. It is restoration construction for the damage caused by the monsoon, approval of the budgets is completed swiftly and construction can be started in the winter of the same year.

(2) Operation and Maintenance of Bridges

Bridges are basically operated and maintained by the staff of the regional offices of DoR. Table 2–10 shows the inspection method and frequency. As there is a technical and financial limit for them, inspection is made by simple visual observation only. For difficult operation and maintenance such as cracks and damage on bridges, in case of emergency, they request support from the headquarters of DoR or hire external consultants. In 2014 when the organization in DoR was changed, the Maintenance Division was established. The major role of the Maintenance Division is to technically support the staff of regional offices that are engaged in operation and maintenance at sites. The bridge inventory that was made by the guidance of JICA experts in 2006-2007 was delivered to each regional office after some renewal. It is unknown whether the staff of the head office of DoR is monitoring operation and maintenance by effective use of the ledger from each regional office. The relevant section is preparing a maintenance manual with reference to the Japanese operation and maintenance manual. Progress is yet to be made as there are a very limited number of persons in charge in the division.

It is desirable to prepare not only short-term (1 year) but also medium and long term operation and maintenance budget plan normally when calculating operation and maintenance cost and prioritizing certain bridges to be repaired. However, DoR does not prepare medium and long term operation and maintenance budget plans. In judging replacement of bridges, high priority is given to old bridges, those with heavy damage and temporary bridges (bailey bridges) for short-term use. However, no surveys or analysis to grasp the causes and extent of damages in detail are conducted at all. In this connection, the life of bailey bridges is about 10-15 years in Bhutan.

<Table2-10> Bridge inspection method and frequency

Kinds of Inspection	Frequencies	Implementation bodies	Inspection Points
Routine Check		Regional Office	Bridge deck, Beam, Bearing, Abutment, Piers
Periodic Check	Twice a year: Before and after rainy season	Regional Office	Erosion, scour of piers etc.
Unscheduled Check	Unscheduled As required	Regional Office & DoR HQ	Bridge defects and damages
Special Check	As required	DoR HQ	Subgrade in soft soil or sliding curb, Strength of Pavement, Bridge
Bridge Inspection	First-time inspection; to record initial status of structures before traffic operation.	Regional Office and/or DoR HQ	Whole bridge
	Following- inspection; 10 years later, then 5-7 year intervals	Regional Office and/or DoR HQ	Whole bridge

Source: Report from DoR

The contracts with private companies are generally made by competitive bids. For urgent cases such as restoration from disaster, direct contracting is used as an exception.

(3) Hybrid Routine maintenance

In 2011 DoR executed the Hybrid Routine Maintenance Contract with CDCL and another company (for a 3 year contract). The contents of the contract are as follows:

1. Performance-Based Routine Maintenance
2. Quantities-Based Routine Maintenance
3. Emergency Maintenance
4. Periodic Maintenance
5. Improvement Works

Hybrid Routine maintenance was introduced due to lack of human resources and funds. By entrusting private companies, it is intended to improve the issues and pursue high quality operation and maintenance through the competition among private companies.

The system was conducted on a trial basis for 3 years from 2011, and the second Hybrid Routine maintenance will start from July 2014, by changing the contract contents reflecting the results (the contract contents are being finally adjusted now). The improvement of the abilities of private companies is the key to the success of the Hybrid Routine maintenance.

The issue on Hybrid Routine maintenance is that the price that the contractor receives from DoR is reduced and the payments from DoR are delayed since the budget originally planned is not properly secured. According to the interview with the contractor, the budget was originally planned to be 81 million Ngultrum annually (243 million Ngultrum for 3 years), however it was reduced to 147 million Ngultrum for 3 years. Therefore, there was an opinion that it is difficult to obtain profit considering the actual volume of work. This happens because there seems to be the fact that DoR divert funds for Hybrid Routine maintenance to other construction work such as road widening work.

Source: JICA Study Team

<Figure2-21> Overlay at Pelela by CDCL

2-10. Japan's Policy of Assistance and Past Assistance in Bhutan

(1) Overview

Japan's assistance to Bhutan started with the activities of the late Kyoji Nishioka who was dispatched as an agricultural expert in 1964. Grant aid and technical cooperation were mainly conducted for infrastructure and agriculture development. In April 1987, an agreement for dispatching Japan Overseas Cooperation Volunteers (JOCV) was executed between the countries, and volunteers were dispatched beginning the next year. In 2007, ODA loans were started.

Japan has extended assistance as a major donor in Bhutan for many years. The high technology and functions/durability of granted facilities and materials/equipment are highly regarded. The king and people in general have expressed gratitude many times.

Bhutan has been friendly to Japan consistently since establishment of diplomatic relations with Japan. Bhutan is located in a geopolitically important area between the two superpowers, India and China. To promote democracy in Asia, the relationship between Japan and Bhutan is very important. Japan's ODA, which has produced steady fruits in various fields including agriculture, is highly evaluated by the Government of Bhutan and its people, and greatly contributed to maintenance and development of favorable relations between the two countries. It is thus important to continue assistance. To offset the shortage of human resources, many senior volunteers and JOCV have been dispatched to the core organizations of Bhutan, the activities of which are evaluated. This is a feature of our assistance in Bhutan.

(2) Basic Policy of Japan's Assistance to Bhutan: Country Data Book, Ministry of Foreign Affairs

Japan will assist Bhutan in building an independent and sustainable country with good balance between rural areas and cities. It will foster self-sustaining economic growth with reference to the basic idea of Gross National Happiness (GNH) and fixation of democracy, and assist revitalization of rural areas to achieve stable livelihood of farmers, and expansion of social infrastructure service there to improve the standard of living.

(3) Important areas

The Ministry of Foreign Affairs of Japan lists the following 4 important items in its "Plan for Deploying Projects in the Kingdom of Bhutan."

<Table2-11> The prioritized sectors in the “development plan in the Kingdom of Bhutan”

Important areas	Development issues
① Development of Agriculture/Rural Areas	Modernization, promotion and better access for agriculture
② Economic base development	Development of road network, electrification in the locality, promotion of information dissemination
③ Social development	Improved education service, health and medical service, and human resources development for job creation
④ Good governance	Strengthened decentralization and media functions

Source: Ministry of Foreign Affairs of Japan

(4) Japan’s Past Assistance

The results of Japan’s assistance in the immediately preceding 5 years are shown below. Regarding the form of assistance, grant aid has the largest share but technical cooperation has been offered constantly every year (see Table2-12).

As compared to the cooperation by other foreign countries, Japan’s assistance has been the largest, and 40% or more of the total assistance amount comes from Japan (see Table 2-13).

<Table 2-12> Japan’s assistance to Bhutan by Form (by fiscal year: FY)

(Unit: 100 Million Yen)

Fiscal Year	Yen Loan	Grant aid	Technical Cooperation
FY2008	-	10.45	6.94(6.76)
FY2009	-	10.38	8.56(8.41)
FY2010	-	11.27	7.82(7.60)
FY2011	21.87	21.59	7.24(7.19)
FY2012	-	5.09	6.59
Total	57.63	321.10	155.56

Note:

1. The fiscal year is based on the exchange of notes in principle for yen-loan and grant aid, and budget year for technical cooperation.
2. The amount of money is based on the exchange of notes for yen-loan and grant aid, and technical cooperation on actual JICA expense and actual technical cooperation expense by each ministry/agency or prefecture. Grassroots/human security grant aid, Japanese Non-Governmental Organization (NGO) coordination grant aid, and cultural grassroots grant aid are based on grant agreements.
3. The cumulative yen-loan does not include rescheduling and debt forgiveness.
4. The technical cooperation FY2008-2011 is an actual result of technical cooperation of all Japan, and figures in parentheses in the same fiscal years are the actual results of technical cooperation by JICA. The result in FY2012 for all Japan is under calculation, and only the JICA result is indicated. The cumulative figure is the total of actual results of technical cooperation performed by JICA.
5. Cumulative figures may not coincide due to rounding.

Source: Country Data Book, Ministry of Foreign Affairs of Japan

<Table 2-13> Results of Economic Cooperation to Bhutan by Various Foreign Countries

(Million US dollars)

Fiscal Year	1	2	3	4	5	Total
FY2007	Japan 18.07	Denmark 12.55	Switzerland 5.37	Austria 1.63	Canada 1.48	43.70
FY2008	Japan 20.34	Denmark 13.77	Switzerland 3.15	Netherlands 3.09	Austria 2.76	49.06
FY2009	Japan 23.92	Denmark 12.23	Switzerland 4.81	Netherlands 3.78	Austria 3.35	55.27
FY2010	Japan 43.23	Denmark 13.08	Australia 7.55	Austria 3.31	Netherlands 2.66	76.10
FY2011	Japan 31.88	Denmark 12.66	Australia 7.75	Switzerland 4.39	Austria 3.88	71.56

Source: OECD/DAC (Country Data book, Ministry of Foreign Affairs of Japan)

(5) Japan's Past Assistance in the Road and Bridge Sector

Assistance to economic infrastructure is the most important sector after agriculture and Japan has continuously assisted in this area since there are few other donors and the presence of Japan in Bhutan is high.

Particularly in the transport and traffic sector, Japan has assisted mainly the section of bridges and road construction equipment.

Based on this fact, Japan set the road network development program on the assistance plan to Bhutan as a priority area and is planning to provide aid to the road network and bridge maintenance in order to ensure efficient and stable traffic/transport and to promote the economic revitalization of the region.

Japan has assisted in the replacement of bridges 4 times and improvement of Equipment for Road Construction and Maintenance 3 times as grant aid to date.

<Table2-14> Japan's assistance in Road /Bridge sector

Year of Implementation	Project name	Amount	Implementing agency
1987	The project for improvement of the equipment for road construction and maintenance	412 million yen	MoWHS
1995	The project for improvement of the equipment for road construction and maintenance (phase 2)	557 million yen	MoWHS
2001-2003	The Project for Reconstruction of Bridges	1.713 billion yen	MoWHS
2003	The Project for Improvement of Equipment for Road Construction and Maintenance	603 million yen	MoWHS
2005-2007	The Project for Reconstruction of Bridges, Phase 2	1.302 billion yen	MoWHS
2009-2012	The Project for Reconstruction of Bridges, Phase 3	2.494 billion yen	MoWHS
2011-13	The Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster	1.019 billion yen	MoWHS

Source：JICA

2-11. Assistance by Other Organizations

The major assisting country and organizations other than Japan in the sector are the Government of India (GOI), Asian Development Bank (ADB) and World Bank (WB).

2-11-1. Government of India (GOI)

(1) Assistance Policy

Generally, in implementing a project for a five-year plan, the approved project cost is born 90% by GOI and the remaining 10% by the funds of Bhutan. GOI will internally examine the request of the Royal Government of Bhutan (RGoB) and decide whether to assist it. The governments of both countries hold a consultation called a Plan Talk twice a year concerning implementation of a five-year plan, and adjust the contents and the amount of assistance.

(2) Assistance Results

Table 2-15 shows the assistance by GOI during the term of the 10th Five-Year Plan (2007-2012). According to projects, spill-over is carried to the next fiscal year, but payments are completed at an early stage, which means favorable payments.

<Table2-15> Assistance by GOI Concerning the 10th Five-Year Plan

No	Name of project	Fiscal Year	Amount committed (Million Nu)	Amount actually paid (Million Nu)	Remarks
1	Gyalposhing – Nganglam Road construction	2008-2009	1,827.589	-	
		2009-2010		672.490	
		2010-2011		348.000	
		2011-2012		-	
		2012-2013		104.000	
	Total of the 10th period		1,827.589	1,124.490	703.099 (Spill-over)
	The 11th period	2013-2014	476.360	520.340	Completion in spill-over from the 10th period
		2014-		182.759	
	Total of the 11th period		476.360	703.099	
	Total		**2,303.949**	**1,827.589**	
2	Gomphu - Panbang Road construction	2008-2009	1,040.681	-	
		2009-2010		358.414	
		2010-2011		530.000	
		2011-2012		152.267	
		2012-2013		-	
	Total of the 10th period		1,040.681	1,040.681	No spill-over
	The 11th period	2013-2014	693.600	-	
		2014-		268.600	
	Total of the 11th period		693.600	268.600	
	Total		**1,734.281**	**1,309.281**	

No	Name of project	Fiscal Year	Amount committed (Million Nu)	Amount actually paid (Million Nu)	Remarks
3	Mandalpong-Digala Road construction	2008-2009	235.000	-	
		2009-2010		-	
		2010-2011		235.000	
		2011-2012		-	
		2012-2013		-	
	Total of the 10th period		235.000	235.000	No spill-over
	The 11th period	2013-2014	241.390	-	
		2014-		-	
	Total of the 11th period		241.390	0	
	Total		**476.390**	**235.000**	
4	Gelephu-Trongsa Road（NH4）widening/ improvement	2008-2009	484.700	-	
		2009-2010		168.600	
		2010-2011		-	
		2011-2012		151.100	
		2012-2013		-	
	Total of the 10th period		484.700	319.700	165.000 (Spill-over)
	The 11th period	2013-2014	0	116.530	
		2014-		48.470	
	Total of the 11th period		0	165.000	
	Total		**484.700**	**484.700**	
5	Galephu-Wangdue Road（NH5）widening/ improvement	2008-2009	1,096.600	-	
		2009-2010		159.000	
		2010-2011		-	
		2011-2012		578.363	
		2012-2013		168.000	
	Total of the 10th period		1,096.600	905.363	191.237(Spill-over)
	The 11th period	2013-2014	0	81.577	
		2014-		109.660	
	Total of the 11th period		0	191.237	
	Total		**1,096.600**	**1,096.600**	
6	Tingtibi-Praling Road widening/ improvement	2008-2009	277.164	-	
		2009-2010		-	
		2010-2011		116.000	
		2011-2012		161.164	
		2012-2013		-	
	Total of the 10th period		277.164	277.164	No spill-over
	The 11th period	2013-2014	116.720	-	
		2014-		-	
	Total of the 11th period		116.720	0	
	Total		**393.884**	**277.164**	

No	Name of project	Fiscal Year	Amount committed (Million Nu)	Amount actually paid (Million Nu)	Remarks
7	Refee-Khosela Bypass road construction	2008-2009	251.000	-	
		2009-2010		-	
		2010-2011		-	
		2011-2012		-	
		2012-2013		58.700	
	Total of the 10th period		251.000	58.700	192.300(Spill-over)
	The 11th period	2013-2014	358.974	192.300	
		2014-		-	
	Total of the 11th period		358.974	192.300	
	Total		**609.974**	**251.000**	

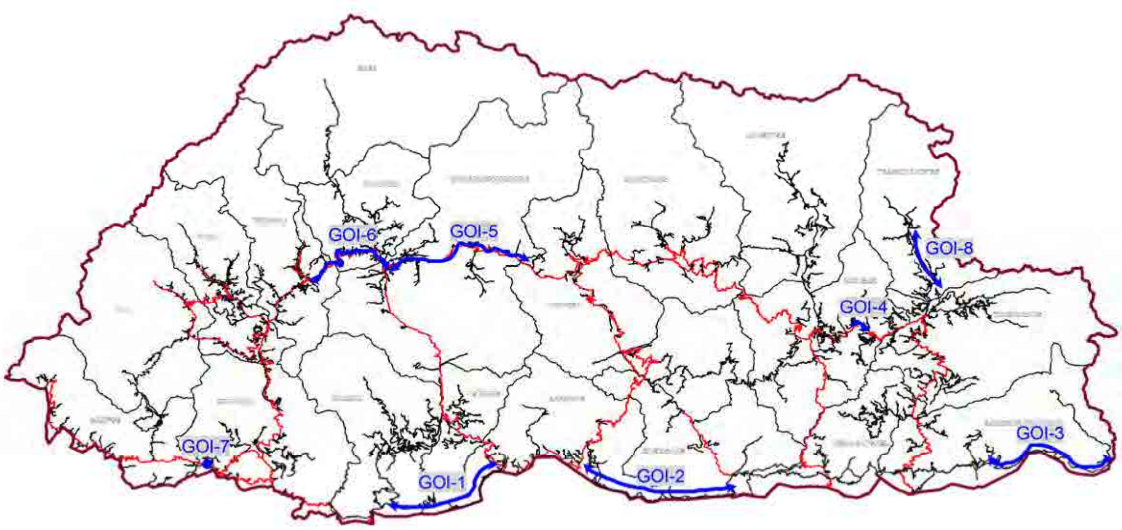
Source: DoR

Table 2-16 shows the assistance plan of GOI for the period of the 11th Five-Year Plan (2013-2018). Assistance to new projects is on hold. This is due to the general election in India currently being conducted. The government of Bhutan intends to get commitment from India by reconfirming the plan at the 3rd Plan Talk on the 11th Five-Year Plan between both governments in September 2014.

<Table2-16> Assistance of GOI to the 11th Five-Year Plan

No	Name of project	Physical Target (Km/Nos)	Budget approved by the 5 Year Plan (Million Nu)	RGoB Financing (10%)	GOI Financing (90%)	Amount received from GOI (as of May 2014)	Remarks
New Project (excluding the project carried over from 10th 5 Year Plan)							
1	Lhamoizingkha – Sarpang Road construction	87.5	1,366.710	136.671	1,230.039	0	Pending reply from GOI
2	Gelephu – Panbang Road construction	97.0	1,793.360	179.336	1,614.024	0	
3	Samrang – Jomotsangkha Road construction	85.2	1,221.340	122.134	1,099.206	0	
4	Kheri-Yadi Road improvement	15.0	343.300	34.330	308.970	0	May not be able to get support from GOI
5	Wangdue-Chuserbu Road improvement	10.0	131.330	13.133	118.197	0	Pending reply from GOI
6	Semtokha-Wangdue Road improvement	65.0	889.810	88.981	800.829	0	
7	Paachu Bridge construction	1.0	71.530	7.153	64.377	0	
8	Chazam-Trashi Yangtse Road improvement	33.0	725.930	72.593	653.337	0	
Total		359.7	6,543.310	654.331	5,888.979	0	

Source: DoR



Source: DoR

＜Figure2-22＞Location Map of GOI Projects

2-11-2. Asian Development Bank (ADB)

(1) Assistance Policy

The policy of cooperation by ADB in the south Asian area including Bhutan is described in the Regional Cooperation Strategy (2011-2015) (November 2011).

Bhutan's sober, careful approach to development has yielded a steady rise in its gross domestic product, a decrease in overall rates of poverty, and steady movement toward achievement of the Millennium Development Goals. The Asian Development Bank (ADB) has been a partner in the country's transition and development since 1982, and today ADB is Bhutan's largest multilateral development partner.

(2) South Asia Subregional Economic Cooperation (SASEC)

The South Asia Subregional Economic Cooperation (SASEC) Program is a project-based partnership between Bangladesh, Bhutan, India and Nepal that aims to strengthen regional economic cooperation by improving cross-border connectivity and facilitating trade among member countries.

The SASEC program strengthens road, rail, and air links in South Asia to cater to the needs of the region's growing economies. The priority areas for cooperation are transport, trade facilitation, and energy.

SASEC also supports initiative in the information and communication technology sector. There is a huge potential to increase mutually beneficial trade between the four SASEC countries and create access to distant Asian regional markets in the least economically integrated region in the world.

The shared vision of SASEC is to increase trade and cooperation within South Asia, create linkages to East and Southeast Asia, ensure effective and efficient cross-border movement of goods, people, and businesses, and improve the quality of life and opportunity of SASEC countries.

The Asian Development Bank serves as Secretariat to the SASEC Program. ADB supports SASEC countries in strengthening regional ties for growth and promoting cooperation; and provides financial and technical support to improve connectivity, strengthen institutions and trade links, and expand human capital.

1) Guiding Strategies of the SASEC Program

The Long-Term Strategic Framework of ADB 2008-2020 recognizes regional cooperation and integration as one of ADB's core development agendas to help achieve ADB's vision of an Asia and Pacific free of poverty. ADB's Regional Cooperation and Integration Strategy identifies four priority areas where ADB can work effectively with member countries to contribute to regional cooperation.

2-11-3. World Bank (WB)

(1) Assistance Policy

Bhutan became a member of the World Bank in 1981. Through the International Development Association (IDA), the World Bank's concessionary lending affiliate that provides low-interest or interest-free loans, the Bank began its program of assistance to Bhutan in the early 1980s. Bhutan joined the International Finance Corporation (IFC) in 2003. Bhutan has also submitted an application for membership in the Multilateral Investment Guarantee Agency (MIGA).

1) Country Partnership Strategy

The current joint World Bank/IFC-Bhutan Country Partnership Strategy (CPS) covers the period FY11-14 and is aligned with three key strategic frameworks:

- Principles of GNH
- Bhutan 2020 Vision
- Tenth Five-Year Plan (2008-2013)

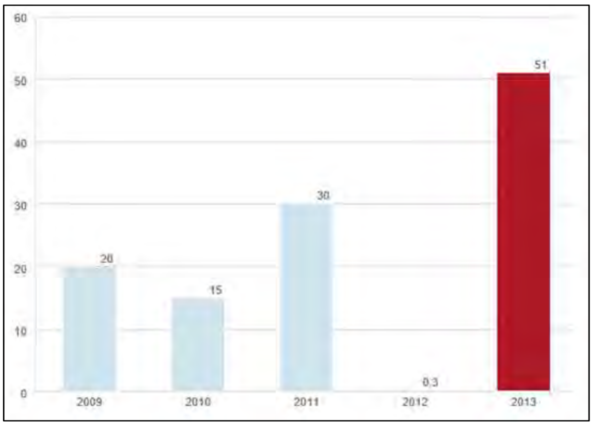
The CPS Results Framework is organized into two areas of engagement: (a) Economic Diversification, Job Creation and Financial Inclusion and (b) Spatial Planning and Public Services. The CPS also identifies two cross-cutting themes: (i) Capacity building for good governance; and (ii) Environmental sustainability. The CPS reflects Bhutan's GNH development philosophy, emphasizing economic and material growth in equal measure with the well-being of individuals, communities, and society.

The outcomes of the two areas of engagement focus on unleashing the potential for private-sector growth, ensuring that all members of society benefit from quality infrastructure and services tailored to the specific needs of both urban and rural populations while simultaneously ensuring that the country's remarkable gains in the social sectors of health and education continue apace. In addition, the CPS focuses on helping the government build human and institutional resource capacity. It acknowledges the central role of capacity for implementing development plans efficiently and effectively. The CPS also focuses on environmental stewardship and the application of environmental safeguards, disaster risk management, and adaptation to climate change.

The next CPS is scheduled to begin in July 2014, within 12 months of finalization of the next five-year national development plan. It is anticipated that many of the themes of the current CPS are likely to continue to resonate.

(2) Assistance Results

Assistance of World bank to Bhutan is shown in Figure 2-23. Assistance was stopped in 2012 however it resumed again in 2013.



Note: including the commitment of IBRD and IDA

<Figure2-23> Trends in commitment to Bhutan (Million dollars)

The major projects in the road sector are RAP1 and RAP2.

1) RAP1

The Rural Access Project for Bhutan aims to improve the access of rural communities to markets, schools, health centers, and other economic and social infrastructure in order to improve the quality of life and productivity of rural communities. The project will also help strengthen institutional capacity for implementing environmentally friendly approaches to improve rural access, community involvement in rural road selection and management, and improved infrastructure maintenance. There are three project components. The first builds new priority feeder roads and includes site preparation, earthworks, drainage construction, and road monitoring. The second component provides the DoR with necessary equipment, computers and accessories, survey equipment, and vehicles for immediate project implementation and supervision support, and in the long run to strengthen the technical and institutional capacity of DOR. The third component comprises six sub-components: Project management assistance and training; environmental and social assessment studies, which are required for all roads constructed under this project; the introduction of an LACI (Loan Administration Change Initiative) type format, and the funding of experts and related hardware and software; feeder road maintenance planning; the socio-economic evaluation of completed roads; and pre-investment studies for a follow-up project.

2) RAP2

The objective for the Second Rural Access Project is for residents of beneficiary Dzongkhags to utilize improved rural transport infrastructure and services. The target beneficiaries include about 12,000 rural residents in several geogs (blocks of villages) of Wangdue, Dagana, and Pemagtsel Dzongkhags, which have the highest demand for access in Bhutan. The dzongkhags and geogs were selected taking into account: (i) the development objectives set out in the Ninth Five-Year Development Plan; (ii) the demand for access in the area and the road prioritization; (iii) the exclusion of the selected geogs from projects supported by other donors; (iv) the cost-effectiveness of the individual road; and (v) the detailed geotechnical survey of the individual roads. The project includes 2 components: 1) The road access component which will include the following: (a) construction of new feeder roads of approximately 65 km length in total; (b) upgrading of about 24 km of existing roads to all-season, feeder road standards; (c) piloting low-cost sealing of feeder roads and performance based maintenance mechanisms using the national work force and/or community involvement or petty contracting; and (d) construction/upgrading of 8 bridges with a total approximate length of 116 meters; and 2) The capacity development and implementation support component which will comprise the following: (a) human resource development and training; (b) technical assistance to pilot performance-based maintenance mechanisms; (c) project implementation support for the Project Coordinating Unit (PCU) in Thimphu and the three Project Management Units (PMUs) at project sites; (d) socio-economic impact monitoring study; and (e) HIV/AIDS awareness of construction workers through the nation-wide program run by the Ministry of Health

3) Future Assistance Plan

WB, intends to shift their policy from rural road development to assisting in the development of the Southern East-West Corridor in the future.

2-11-4.Trends of Assistance by Foreign Countries in Recent Years

RGoB is strongly independent from foreign countries, limiting donors to India, Japan and European countries, and is careful in accepting international NGOs. Therefore, there are not many international donors active in Bhutan. As the country has accomplished steady economic growth, GTZ (Germany) withdrew in 2006, and Denmark expressed its intent to withdraw in 2013. As such, some other European donors are withdrawing.

The cooperation among donors is led by the Government of Bhutan. In the initial year and the middle year of the 5-year plan, a roundtable meeting is held for the assistance to Bhutan and all donors including Japan participate in it.

Bhutan selects the areas of assistance for each donor, and Japan mainly assists development of infrastructure (technically difficult bridges and roads) and agriculture. India is in charge of hydropower generation and infrastructure (relatively simple bridges and roads) and European countries are assisting them mainly in local administration. In recent years, assistance in human resources by Australia (mainly offering higher education to Bhutan students) is increasing.

Chapter 3. Environmental and Social Considerations

3-1. Organization, Laws and Procedures concerning Environmental Impact Assessments

3-1-1. Organization

The organizations for environmental administration in Bhutan seek to develop and transform themselves into simpler, more efficient and effective ones by reforming the traditional centralized system, largely expanding local autonomy, and delegating administrative authorities to the local government and ministries.

Major organizations for environmental administration in Bhutan are as follows:

(1) The National Environmental Commission (NEC)

The National Environmental Commission (NEC) was established in 1998 as an independent organ to deal with the environment-related issues of the country. It is given authority to request support from all governmental agencies and related organizations for its activities. As the supreme environment-related organ of the country, the Commission has legal authority not only to assess the environmental impact of development projects for sustainable development in the country, but also to control, enforce, and support all public and private activities involving the use of natural resources. The functions and roles of NEC include the coordination of agencies concerned in environmental activities and the development and implementation of environmental laws, regulations, and policies.

Source: NEC Website

<Figure3-1> Organization chart of the National Environmental Commission

(2) Environmental Units under the Ministries and Agencies

1) Environmental units under ministries and agencies

Each of the government offices running operations that might influence the environment has an environmental department. The mission of this environmental department is to assess the environmental impact of the office's projects.

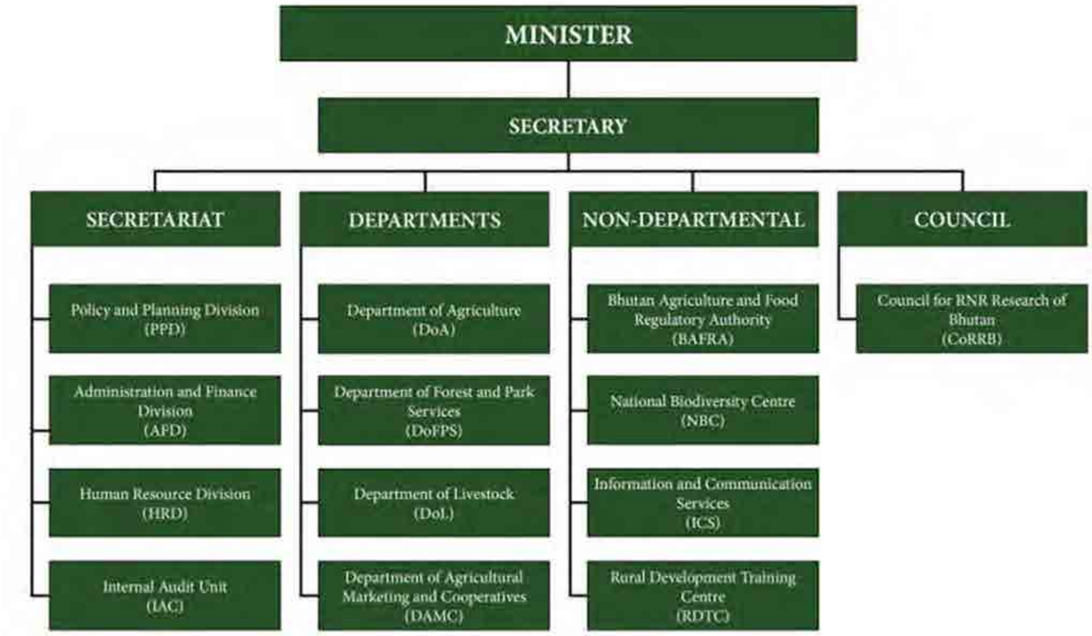
2) Environmental Units under the MoWHS

Infrastructures in the country are under the control of MoWHS. At MoWHS, principal bureaus each have an environmental unit. For instance, DoR has an environmental unit of its own and conducts environmental assessments for road and bridge projects.

Infrastructures to be constructed as projects, such as small-scale road repair and bridge construction, are listed in Regulation for the Environmental Clearance of Projects (See Annex 2, Regulation for the Environmental Clearance of Projects) by type of infrastructure. If a project is listed in the Annex 2, Regulation for the Environmental Clearance of Projects, the environmental assessment unit within each ministry and agency is delegated the authority to issue the environmental clearance at their discretion. At MoWHS, the Policy and Planning Division has an Environmental Section with authority to assess environmental impacts and issue environmental clearance. However, with regards to DoR projects, they can't get environmental clearance from this section because they are of the same ministry, and have to get all clearances from NEC.

(3) Department of Forest and Park Services (DFPS), MoAF

The Ministry of Agriculture and Forests (MoAF) governs not only agriculture and rural village development but also such other fields as forests, the environment, and natural protection. As services responsible for the management of natural resources, it has the Department of Forest and Park Services, and, further underneath: i) Forest Protection and Utilization Division, ii) Forest Resource Development Division, iii) Nature-Conservation Division, iv) Social Forestry Extension Division, v) Watershed Management Division, vi) Forest Information and Management Services, and vii) Nature Recreation and Eco-tourism Division. These divisions are in charge of all policies for the conservation of the natural environment; policies and plans for the protection of the natural environment including national parks and protected areas; and nature-related research and studies.



Source: Ministry of Agriculture and Forests

<Figure3-2> Organization chart of MoAF

3-1-2. Legal System and Procedures

(1) Legal System for Environmental and Social Considerations

The basic environmental law of Bhutan is called the National Environmental Protection Act of 2007. The act prescribes the basic guidelines for environmental protection, discharge control, etc. The act governing the environmental assessment system is the Environmental Assessment Act 2000, which prescribes Environmental Impact Assessment (EIA) and how it should be conducted. Based on this act, the Regulation for the Environmental Clearance of Projects 2002 was enacted as a guideline for EIA. Further, the Environmental Code of Practice has been enacted as a guideline for ministries concerned in carrying out their projects.

<Table3-1> List of laws and regulations for environmental and social considerations

No.	Relevant Environmental Legislation	Year
1.Environmental Assessment, Environmental Clearance and Environmental Standards		
1-1	National Environmental Protection Act	2007
1-2	Regulation for the Environmental Clearance of Projects	2002
1-3	Environmental Assessment Act, 2000	2000
1-4	Environmental Standards	2010
2. Natural Environment		
2-1	Biodiversity Act, 2003	2003
2-2	Forest and Nature Conservation Act of Bhutan, 1995	1995
2-3	Forest and Nature Conservation Rules, 2006	2006
3.Social Environment		
3-2	Land Act of Bhutan 2007	2007
3-3	Land Compensation Rates 2009	2009
3-4	Rules and Regulations for Lease of Government Reserved Forest Land and Government Land	2009

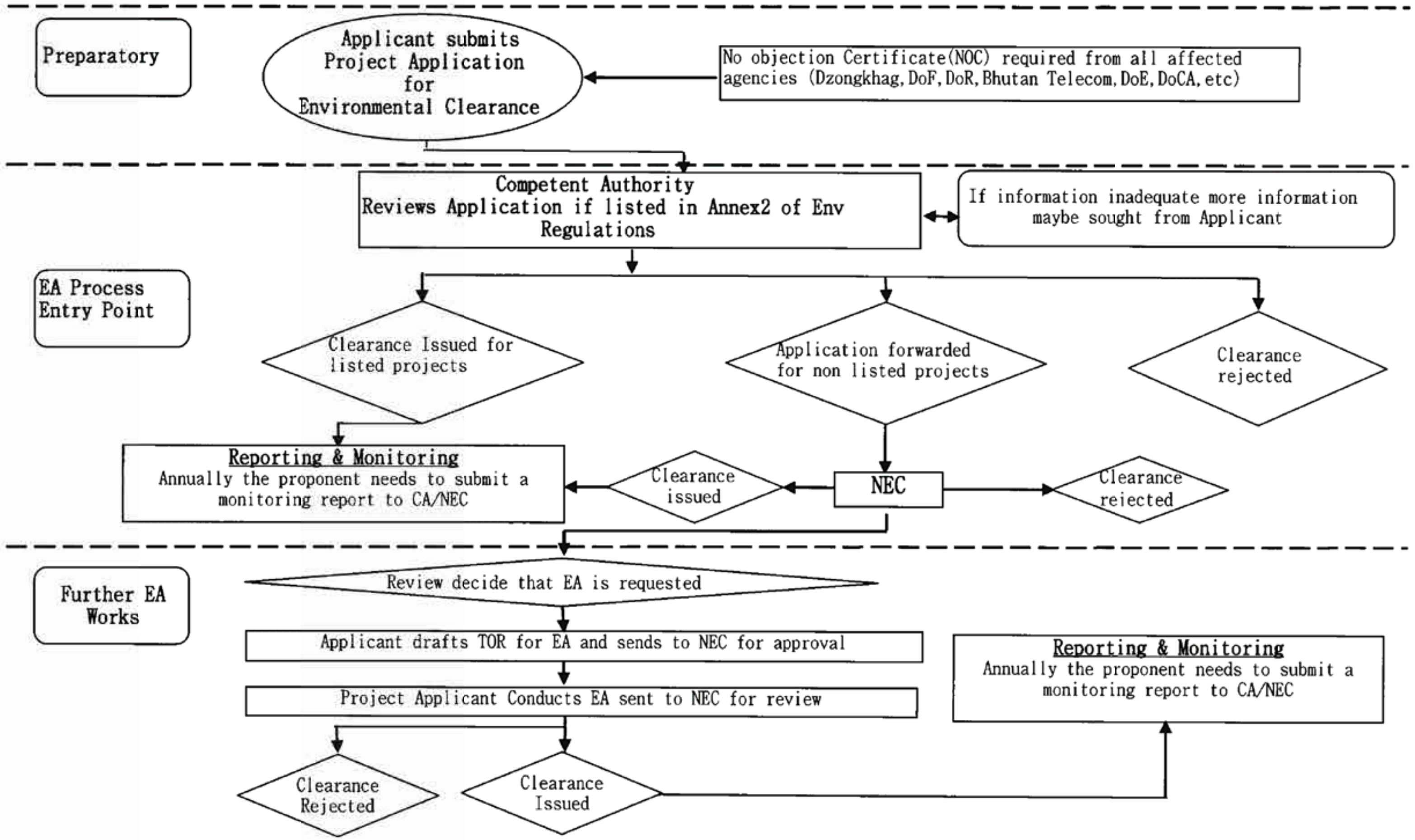
Source: Interview with DoR

(2) Guidelines for EIA

Legal grounds for EIA are provided by the Environmental Assessment Act 2000 enacted in 2000 and the Regulation for Environmental Clearance of Projects enacted in 2002. The Environmental Assessment Act 2000 establishes procedures for environmental impact assessment to be followed in implementing plans, policies, programs, and projects. The act prescribes that development projects that might have a negative impact on the environment should get environmental clearance. The Regulation for the Environmental Clearance of Projects 2002 defines procedures and responsibilities for the issuance of environmental clearance. When implementing a project, the developing entity has to conduct an Initial Environmental Examination (IEE) or EIA for an environmental report. According to the result of our interviews with environmental units, development projects that require EIA are only those within protected areas.

(3) Application for Environmental Clearance

As suggested by the guidelines, the developing entity must first get various permissions from organizations concerned if the project falls in a sensitive area. It is after that that it can apply for environmental clearance. In the case of DoR, DoR needs to apply to NEC even for projects that are listed in Annex2, Regulation for Environmental Clearance of Projects.



<Figure 3-3>Flowchart of the procedure in obtaining Environmental Clearance

Source: Application for Environmental Clearance Guideline for Highways and Roads

(4) Environmental Standards

As a standard for pollution control, the Environmental Standard (2010) issued in November 2010 is currently used. The standard defines criteria for discharge into the environment with regard to three parameters: water quality, air quality, and noise.

What might have the strongest impact on the environment in carrying out bridge replacement projects will be noise. The environmental discharge standard for noise is as shown in the table below.

<Table3-2> Noise discharge standard

Land Use Category	Max Leq		
	Day (6AM – 10PM)	Night (10PM – 6AM)	Unit
Industrial Area	75	70	dB (decibel)
Mixed Area	65	55	dB
Sensitive Area	55	45	dB

Source: Environmental Standards, November 2010, NEC

(5) National Park System

In Bhutan, about fifty percent of the national territory is designated as areas related to natural conservation, which are composed of five national parks, four wildlife sanctuaries, and one strict nature reserve. A characteristic of Bhutanese national parks is that they have biological corridors in place that connect these protected areas. These areas for natural conservation, including the biological corridors, were created under the Forest and Nature Conservation Act of Bhutan, 1995 and governed by DFPS, MoAF, which develops plans and policies for preservation of these areas and maintains, manages, and operates them.

<Table3-3> Protected Areas and Biological Corridors of Bhutan

Categories	Total Area(km2)
Total Area of Bhutan	38,394.00 km^2
National parks, Wildlife sanctuaries, Strict Nature Reserve	16,396.43 km^2 (42.7%)
Biological corridors	3,307.14 km^2 (8.6%)
Total Area of Protected Areas in Bhutan	19,703.57 km^2 (51.3%)

Source: Ministry of Agriculture and Forests

These protected areas are maintained in such a way that humans and wildlife freely move within them, with wildlife habitats neighboring human habitats and conserving the environment for ecosystems and wildlife to live and grow in according to local conditions. According to the Forest and Nature Conservation Rules, 2006, areas within national parks are classified into three zones according to their locations and the ecological importance of the wildlife, as shown in the table below:

<Table3-4> Zoning within national parks

Zone	Description
Core Zone	Areas where alteration or use of land is prohibited, giving top priority to wildlife conservation
Buffer Zone	Areas that neighbor protection areas, where only specified action is permitted.
Multiple-use Zone	Areas including human habitats. Implementing a project requires an EIA.

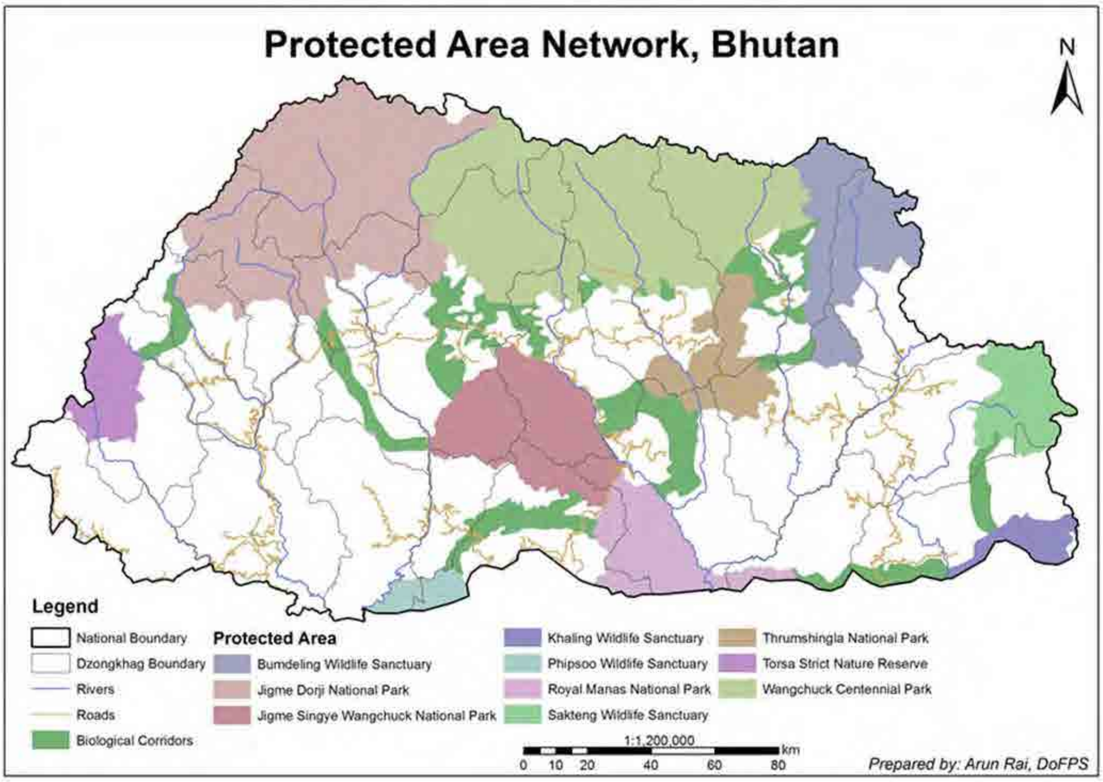
Source: Forest and nature Conservation Rules, 2006

The goals of a natural conservation area are to effectively use resources while conserving biodiversity and improve the living environment of local inhabitants and conserve the natural environment at the same time. As national parks and protected areas each have different natural environments and ecosystems, their subjects of conservation, objectives, and how to manage the natural environment are set forth separately for each one according to their local conditions. The status of national parks, wildlife protection areas, and natural conservation areas are as shown in the table below and their locations are as shown in the figure below.

<Table3-5> Status of national parks, wildlife protection areas, and natural conservation areas

Name of Protected areas	**Year of Establishment**	**Total Area (km^2)**	**Dzongkhags (Province)**
National park			
1.Wangchuck Centennial Park	2008 (gazetted)	4,914.00	Gasa, Wangdue, Bumthang, Trongsa & Lhuentse
2.Jigme Dorji National Park	1995	4,316.00	Punakha, Gasa, Thimphu & Paro
3.Jigme Singye Wangchuck National Park	1995	1,730.00	Trongsa, Wangdue, Sarpang, Tsirang & Zhemgang
4.Royal Manas National Park	1996	1,057.00	Sarpang & Zhemgang
5.Thrumshingla National Park	2000	905.05	Bumthang, Lhuentse, Mongar & Zhemgang
Wildlife Sanctuaries			
6.Bumdelling Wildlife Sanctuary	1998	1520.61	Trashiyangtse, Lhuentse & Mongar
7.Sakten Wildlife Sanctuary	2003	740.60	Trashigang & Samdrupjongkhar
8.Phibsoo Wildlife Sanctuary	Not established	268.93	Sarpang & Dagana
9.Khaling Wildlife Sanctuary	Not established	334.73	Samdrupjongkhar
Strict Nature Reserve			
10.Toorsa Strict Nature Reserve	Not established	609.51	Haa
Total protected area		16396.43	-
Biological Corridor			
Biological Corridors	Under process (1999 gazetted)	3307.14	Haa, Paro, Thimphu, Punakha, Wangdue, Sarpang, Tsirang, Trongsa, Zhemgang, Bumthang, Mongar, Lhuentse, Trashigang & Samdrupjongkhar
Recreational Park			
Royal Botanical Park	2004	47.00	-
Total		19,750.57	-

Source: Ministry of Agriculture and Forests Website



Source: Department of Forest and Park Services, MoAF

<Figure3-4> Locations of national parks, wildlife protection areas, and natural conservation areas

3-2. Organization, Laws and Procedures on Social Impacts

As for social considerations, we conducted surveys mainly on land acquisition and resettlement.

3-2-1. Organization

Procedures for land acquisition are the responsibility of the National Land Commission (NLC). Up until 2007, land ownership in Bhutan was controlled by the MoAF, but they have since been controlled by NLC which was created based on the Land Act 2007. NLC is authorized to issue land ownership certificates (lagthram), register land ownership, revise ownership certificates, etc. and, further, to expropriate land, allocate substitute land, and approve guarantees. As for title deeds and cadastral data in the special cities such as Thimphu and Phuentsholing, they are controlled by the Development Control Division of each city.

3-2-2. Legal System and Procedures

(1) Legal System

The legal system governing land is the Land Act 2007. In most cases of bridge replacement projects, the bridge construction site is only slightly changed; therefore it can be within the existing Right of Way (ROW). In that case it doesn't require any new land acquisition, unless the change requires significant re-routing.

The Road Act 2013 stipulates that ROW be secured for 50 feet on either side of the road from centerline.

(2) Procedure for Land Acquisition and Resettlement

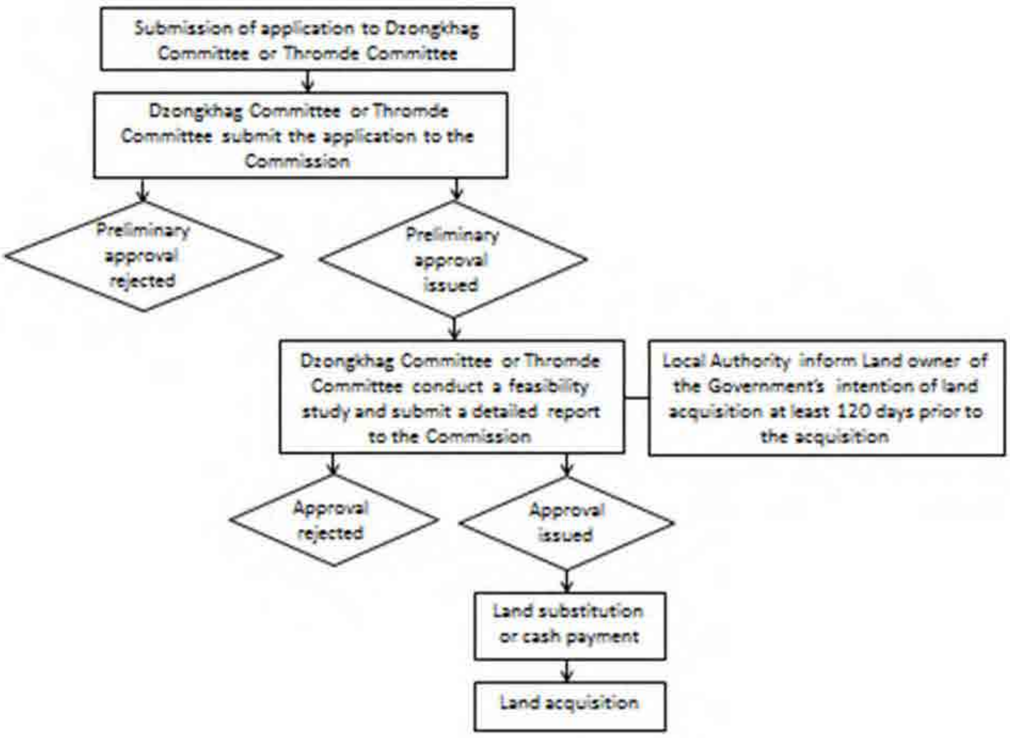
Land acquisition is conducted according to the Land Act 2007 and the Land Rules and Regulations of the Kingdom of Bhutan 2013. The acts grant the government authority to acquire land in exchange for money and/or substitute land. The organ that examines and approves each case of land acquisition is NLC. The value of the land is assessed by PAVA, an agency under MoF. PAVA is supposed to revise land compensation rates every three years, but, to date, the rates have not been revised from those in the Land Compensation Rates 2009. PAVA rates are regarded as not matching real market prices, but compensation is still being paid based on LCR 2009.

To acquire a parcel of land, the central or local government seeking expropriation first files an application with Dzongkhag Land Acquisition and Allotment Committee (DLAAC). DLAAC files an application with NLC for preliminary permission of land acquisition. After getting the preliminary permission, DLAAC notifies the owners at least three months prior to the planned date of expropriation, and conducts a detailed survey for scope of impact. The detailed survey includes calculation of land price and assessment of structures. DLAAC submits a report to NLC that summarizes where to relocate the inhabitants, amounts of compensation, necessary permission, etc. After getting the approval of NLC, the government can register substitute land

and expropriated land, but the law prescribes that the government cannot carry out the land acquisition unless the owners are compensated with cash money or substitute land, or both.

For the time being, there is no legislation governing resettlement. The Environmental Assessment Guideline, however, requires the establishment of a population relocation plan, which should include the following:

1) Details of compensation: substitute land, employment, compensation cost, availability of facilities at the new site (houses, infrastructure, education, etc.).
2) Relocation schedule and budget (responsibility for relocation; response to problems arising from relocation).
3) Consideration for disadvantaged people risking unemployment, such as female inhabitants or those who don’t own any land.
4) Detailed compensation plan for inhabitants who risk losing their livelihoods.



Source: JICA Study Team based on Land Act of Bhutan 2007

<Figure3-5>Flowchart of Land acquisition

Chapter 4 Analysis of National Highway Importance

4-1.Viewpoint and Method of Analysis

Related data and the detailed information of various plans are collected through interviews with DoR, the Ministry of Economic Affairs (MoEA), Ministry of Agriculture and Forest (MoAF), and other local authorities concerned, and then the priority among PNHs is analyzed from the viewpoints listed below:

1) Roles and features of routes
2) Traffic volume
3) Policies of the Government of Bhutan (priority in the five-year plan)
4) Physical distribution
5) Benefit to the poor
6) Contribution to promotion of national projects either currently in progress or under planning along PNHs, such as construction of hydropower plants, etc.

Each highway is assessed (scored) in terms of the above items to determine the priority of the highways. In addition to their priorities, the necessity of improvement by means of Japan's aid is also summarized separately on the basis of the result of a site survey and information collected. The viewpoint for such analysis as well as the results of the review are described later in section 4-8.

4-2.Summary of Site Reconnaissance Results

4-2-1.PNH-1

PNH-1 is the only highway running east to west in the northern part of Bhutan. This is a vital route, whose traffic volume is the largest (about 1,700 vehicles/day) and which has the principal cities connecting to the south-bound national highways. In spite of large traffic volume, the national highway includes many narrow sections whose road width is less than the 6.5 m as specified in the national highway guideline. At present, DoR is undertaking widening of the road (see Figure 4-1). Actually, widening is done a small amount at a time where possible within the limited budget available for use by DoR. The work is performed while giving priority to the Thimphu - Wangdue section that has the large traffic volume. Specifically, the national highway to the central and eastern parts east of Wangdue has many steep sections, so that only the pavement width for one lane can be secured because of the road geometric structure. Since the present traffic volume is relatively small, however, the lack of traffic capacity is not enough to cause congestion. However, it is evident from the report from DoR that rock falls and slope failures occur frequently in both the dry and wet seasons.

Existing bridges include some sound bridges reconstructed under Japan's grant aid, but others are so old (mostly constructed in 1980s) as to have deterioration and damage to the bridge main body. Similar to the roads, these bridges are evidently narrow in the roadway width for currently traveling vehicles and suffer deficient load bearing capacity. In addition, the abutment foundations are often scoured by river water. In order to ensure their safety, bridge surveys and inspections are needed urgently.

In winter, DoR has reported cracking of the pavement structure (particularly the asphalt surface course) especially in the 5 km section on the northern slope of Thrumshing La pass). It is also reported that the road has been blocked repeatedly because of snow.

Focusing on the national projects on PNH-1, on the other hand, it is known that the Phunatshangchu-I and II, and the Mangdechhu Hydroelectric Project are under way at present in Wangdue and Trongsa. Equipment and materials imported mainly from India are carried to the construction site via PNH-1 through Thimphu. Upgrading according to the 11th Five-Year Plan is planned for PNH-1, so that the plan of upgrading the road along with construction of the hydropower plants is an important national project.

It is evident from the reports from DoR and from collected data that the above described situation exists on and by the national highway and there are many factors that produce traffic bottlenecks on the trunk road.


Source: Photos taken by JICA Study Team

<Figure4-1> Road widening by DoR (PNH-1)

4-2-2.PNH-2

PNH-2 is the national highway running north south in the western part of Bhutan and has the second highest traffic volume (about 1,000vehicles/day) next to PNH-1. Phuentsholing is located in the south and is an economic center connecting with India, and it is no exaggeration to say that most of the physical flow passes through on PNH-2.

For PNH-2, road maintenance works are done under the control of DANTAK. Most of its sections comply with the guideline for national highways the road is in relatively satisfactory condition. According to the report from DoR, the tunneling plan by DANTAK will be put into practice for large-scale rock fall and failure locations. The "Road Sector Maser Plan (2007～2027)" developed by DoR in 2006 includes the Damchu – Chukha bypass plan of DANTAK.

Source: Photos taken by JICA Study Team

<Figure4-2> Jumbja landslide

4-2-3.PNH-3

PNH-3 runs from Trashigang, the eastern terminal of PNH1 down south to Samdrup Jongkhar located on the border with India. The traffic volume (about 600 vehicles/day) is more than 1/3 of that of PNH-1. Cargoes from Assam, India are transported through the border here to Trashigang in the north.

Similar to the case of PNH-2, road maintenance works are done under control of DANTAK. According to the report from DoR, road widening is currently under way by DANTAK. For the poor people living in Trashigang and Samdrup Jongkhar and along the national highway, the direct benefit provided by this national highway is considered great.

At present, in Trashi Yangtse, the hydropower plant (Kholongchhu) is being constructed as one of the national development projects. PNH-3 is also used for the transportation of construction equipment and materials, however, the main route for that is the route over PNH-1.


Source: Photos taken by JICA Study Team
(Left) Section being widened, (Right) Widened section
<Figure4-3> Condition of PNH3

4-2-4.PNH-4

PNH-4 is the one running from Trongsa, located at the approximate midpoint of PNH-1, down south to the relatively wealthy city of Gelephu on the border with India. The traffic volume here is the smallest (about 430 vehicles/day) among the national highways. However, there is a great deal of physical transportation between Gelephu and the Assam of India, with incoming/outgoing vehicles to/from India increasing since 2011 (about 25,000 or more vehicles/year), achieving growing economic effects.

The road has failure points on both the mountain and valley sides, and may be said to be barely held on to the unstable colluvial deposit. Therefore, the road includes many narrow points and has limited portions available for widening. In particular, there are two and three slope failure locations respectively in the Trongsa - Zhemgang section and Zhemgang - Gelephu section. The road is maintained moving new colluvial deposits occurring in the wet season from the mountain side of the road to the valley side.

Source: Photos taken by JICA Study Team

<Figure4-4> Slope failure condition (PNH4)

Existing bridges are old (constructed in 1960s to 1980s), with many deteriorations and damages observed. The bridge width is mostly 4.5 m or less except for one bridge (with the width of 7.5 m) in Gelephu. Besides, most of the bridges suffer insufficient loading capacity. Since the number of vehicles traveling this road is small as described above, most of them can keep functioning with the existing configuration. DoR places high priority on this national highway, which means that it is highly valuable. In this context, this highway proved beneficial to the poor in Zhemgang and Trongsa.

As a national project, construction of the Mangdechhu Hydroelectric Project is under way in the direct neighborhood of Trongsa. It is evident, therefore, that the national highway itself is highly important.

4-2-5.PNH-5

PNH-5 runs west from Gelephu to Sarpang, another city on the border, connecting to Wangdue of PNH-1. The traffic volume here is about 450 vehicles/day. At present, construction of the Phunatshangchu I/II Hydroelectric Project is in full swing. Note that this national highway is used in combination with the construction road, including many damaged and narrow sections.

There are some bridges constructed under Japan’s grant aids on the route of this national highway. The bridge was washed away recently by the heavy rain of Cyclone Aila that struck Southern Asia in May, 2009. The washed-off bridge was reconstructed under the “The Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster” in 2013, the last year. Though residents along the national highway include a relatively large proportion of the poor, this national highway is the most critical and beneficial route from the southern area to the capital and vice versa.


Source: JICA Study Team

<Figure 4-5> Present condition of PNH-5

4-2-6. Southern East-West Corridor

The Southern East-West Corridor plays an important role as an alternative to PNH-1 and runs east-west in the southern part of Bhutan. At present, financing for this corridor is provided by ADB and the Government of India. For the bridge crossing the Maukhola River, there is no aid agency. The reasons for this are the large scale of construction, the construction cost expected to increase, requirement of technical capacity enabling construction even during the rainy season to reduce the work period, and the request for Japanese technology.

For the relatively large number of poor people of Dzongkhags, the continuous route is expected to bring about substantial benefits.

This is included in the 11th Five-Year Plan of national development projects, and its importance is evident. Details are provided in Chapter 4-7.

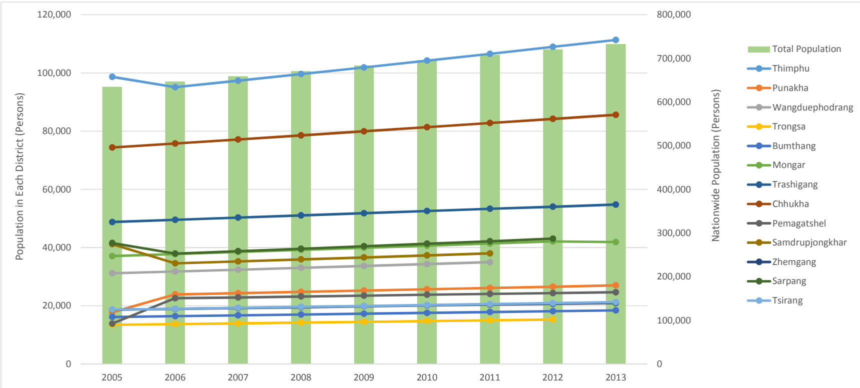
Source: Photos taken by JICA Study Team

<Figure4-6> Present condition of the Southern East-West Corridor

4-3.Traffic Demand Forecast

(1) Method of Forecast

This survey aims to forecast traffic demand using population data based on future prospects. The traffic demand forecasting formula is obtained by performing a regression analysis. It uses data provided by DoR shown in "2-4. Traffic Volume Data", traffic volume data on each PNH obtained by traffic volume surveys carried out by this survey, and population data on each district obtained from "Annual Dzongkhag Statistics", as basic data. Data on demographic change in the country and each district located along PNH used in this survey are as shown in Figure4-7. Future population for each district is determined using the population growth rate calculated based on future nationwide population which has already been estimated through to 2030.



Source: Annual Dzongkhag Statistics and Statistical Year Book 2013

<Figure 4-7> Demographic change in the country and each district located along PNH

<Table4-1> Districts located along each PNH

PNH Name	District Name
PNH-1	Thimphu
	Punakha
	Wangduephodrang
	Trongsa
	Bumthang
	Mongar
	Trrshigang
PNH-2	Thimphu
	Chhukha
PNH-3	Trashigang
	Pemagatshel
	Samdrupjongkhar
PNH-4	Trongsa
	Zhemgang
	Sarpang
PNH-5	Wangduephodrang
	Tsirang
	Sarpang

Source: JICA Study Team

(2) Forecast Results

Considering the prediction that the population will grow slowly as a whole and such a slow growth trend will continue until 2030, it is expected that traffic volume will also increase slowly. The forecast results for each PNH are shown below. For details about forecast results, refer to Appendix-1.

1) PNH-1

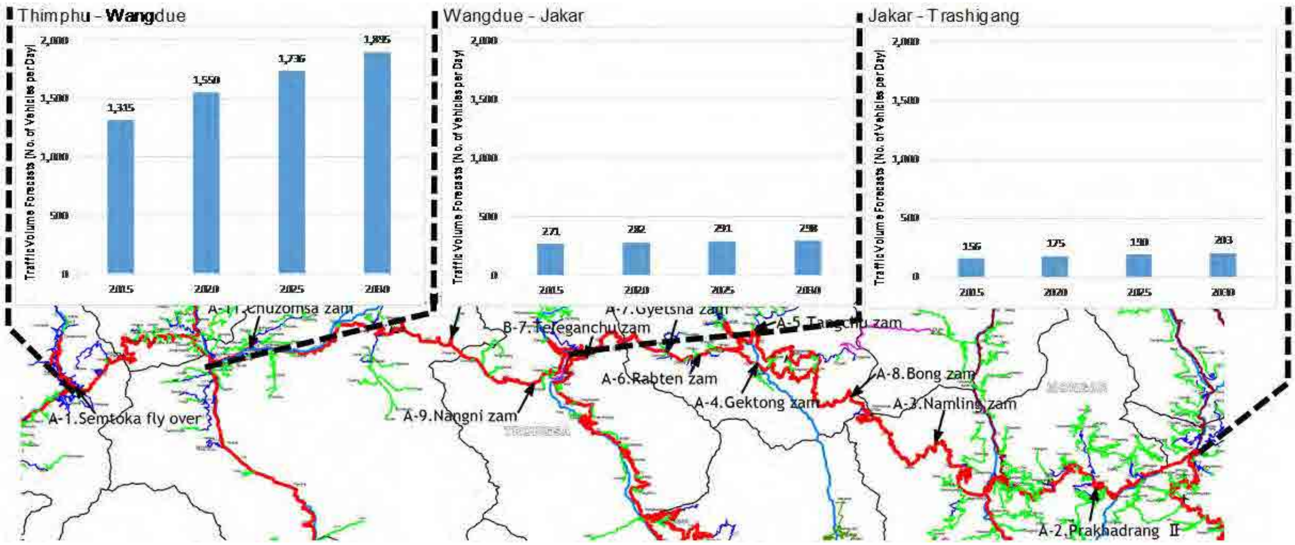
Changes in existing traffic volume show that rural areas have less volume than urban areas in the sections between Thimphu and Wangdue, Wangdue and Jakar, and Jakar and Trashigang. Therefore, the analysis for the forecasting survey is conducted separately for the above three sections.

Figure4-8 shows the forecast results of traffic demand on PNH-1. We forecast that the traffic volume during the period 2015-2030 will maintain an upward trend, starting at a level of 1,300 vehicles per day in 2015 and reaching1,900 vehicles per day in 2030 in the section between Thimphu and Wangdue, from 270 vehicles per day in 2015 to300 vehicles per day in 2030 in the section between Wangdue and Jakar, and from 150 vehicles per day in 2015 to 200 vehicles per day in 2030 in the section between Jakar and Trashigang.

As shown in Chapter 2, the traffic volume in the section between Thimphu and Wangdue ranged from 680 to 1,350 vehicles per day during the period 2004-2014. In recent years, it often exceeded 1,300 vehicles per day partly due to the impact of the construction of the Punatsangchhu Hydropower Project, but the average volume is about 940 vehicles per day. Because the road in this section passes through mountains and hills, and there are only a few villages dotted along it, the population is not expected to grow rapidly in those areas. In view of the average volume of 940 vehicles per day, it seems reasonable to forecast a traffic volume of 1,300 vehicles per day in 2015 to 1,900 vehicles per day in in 2030 in this section.

In the section between Wangdue and Jakar, the traffic volume ranged from 150 to 600 vehicles per day during the period 2004-2014, and the average volume was about 270 vehicles per day. Like the above section, the road in this section also passes through mountains and hills, and there are only a few villages dotted along it, so the population is not expected to grow rapidly in these areas either. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 270 vehicles per day in 2015 to 300 vehicles per day in 2030 in this section.

In the section between Jakar and Trashigang, the traffic volume ranged from 33 to 150 vehicles per day during the period 2004-2014, and the average volume was about 90 vehicles per day. Like the above two sections, the road in this section also passes through mountains and hills, and there are only a few villages dotted along it, so the population is not expected to grow rapidly in these areas either. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 150 vehicles per day in 2015 to 200 vehicles per day in 2030 in this section.



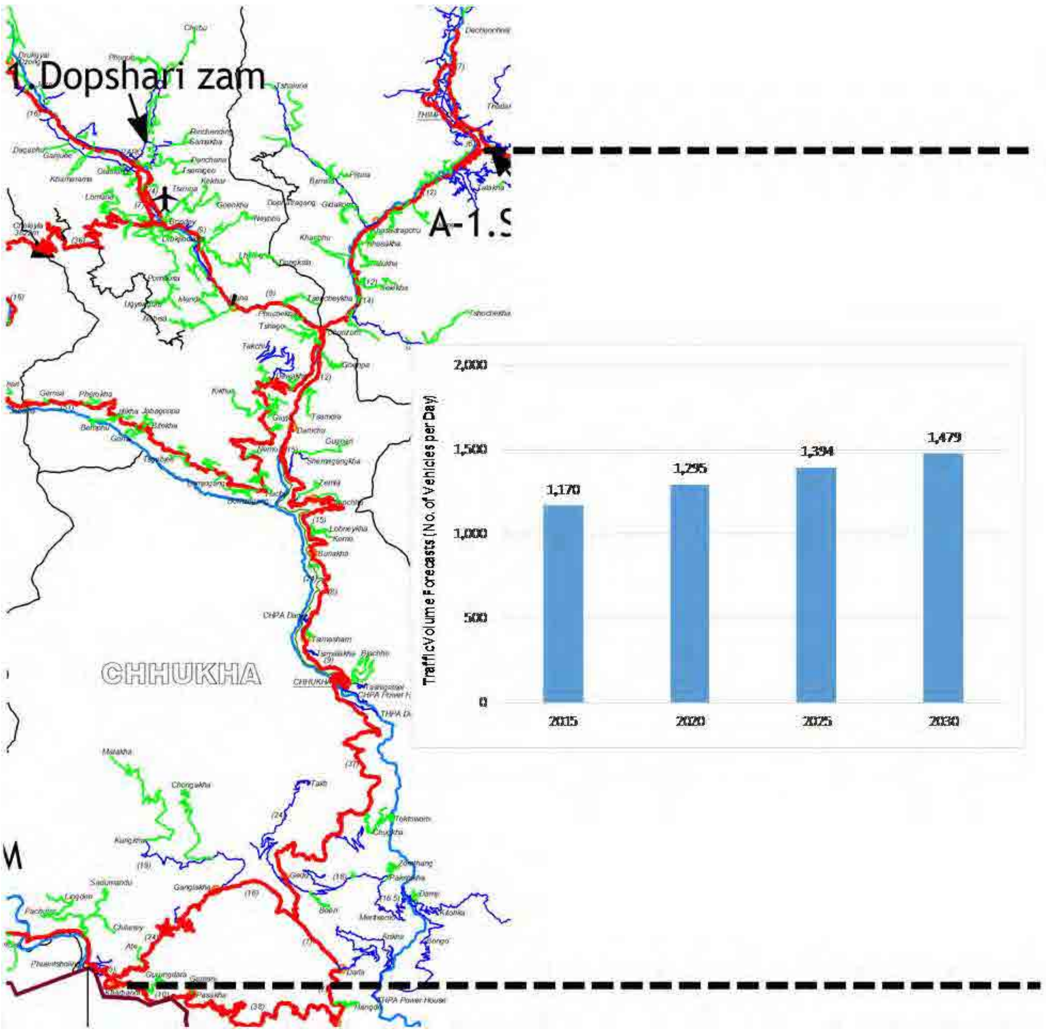
Source: JICA Study Team

<Figure 4-8> Forecast of traffic demand on PNH-1

2) PNH-2

Figure4-9 shows the forecast of traffic demand on PNH-2. We forecast that the traffic volume during the period 2015-2030 will maintain a slight upward trend at a level of 1,200 vehicles per day in 2015 to 1,500 vehicles per day in 2030.

The traffic volume ranged from 700 to 1,300 vehicles per day during the period 2004-2014. Though it has varied greatly from year to year, the average volume was about 1,000 vehicles per day. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 1,200 vehicles per day in 2015 to 1,500 vehicles per day in 2030.



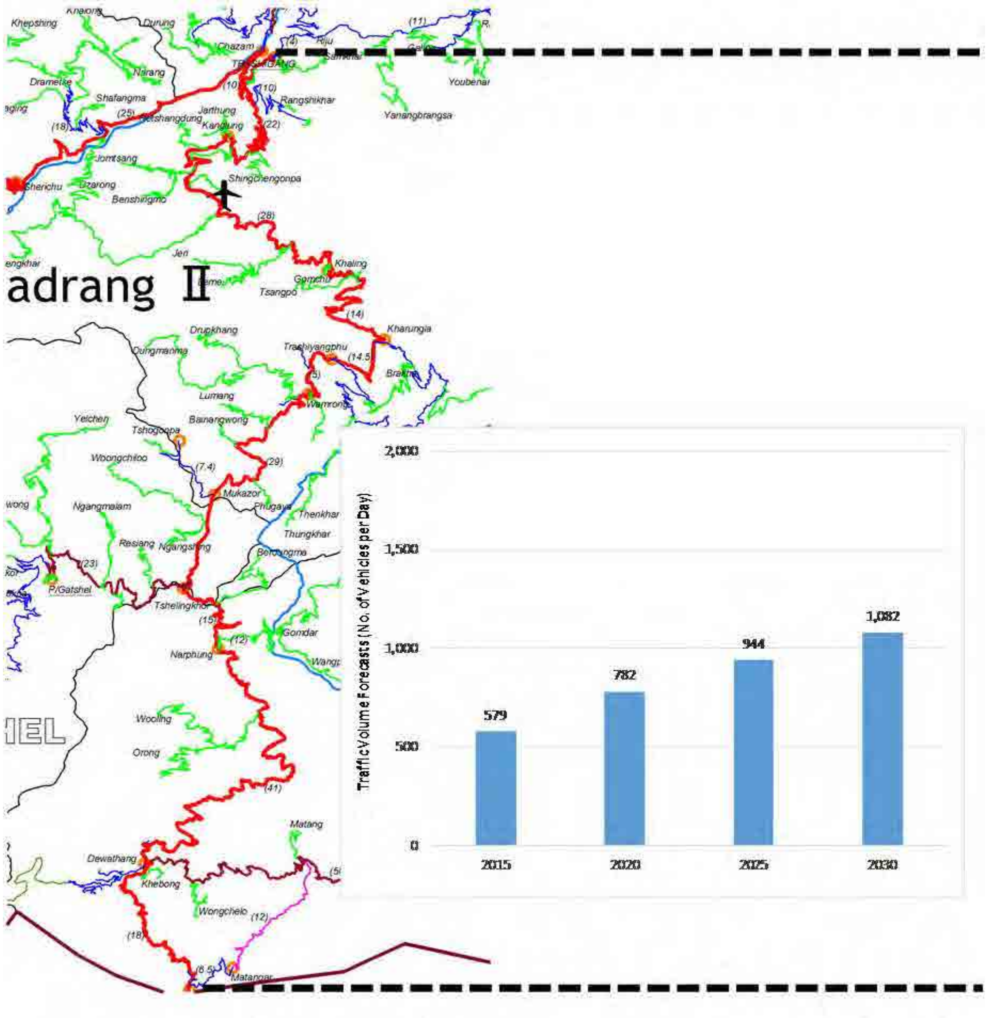
Source: JICA Study Team

<Figure 4-9> Forecast results for traffic demand on PNH-2

3) PNH-3

Figure4-10 shows the forecast results of traffic demand on PNH-3. We forecast that the traffic volume during the period 2015-2030 will maintain a slight upward trend at a level of 580 vehicles per day in 2015 to 1,100 vehicles per day in 2030.

The traffic volume ranged from 170 to 600 vehicles per day during the period 2004-2014, and the average volume was about 300 vehicles per day. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 580 vehicles per day in 2015 to 1,100 vehicles per day in 2030.



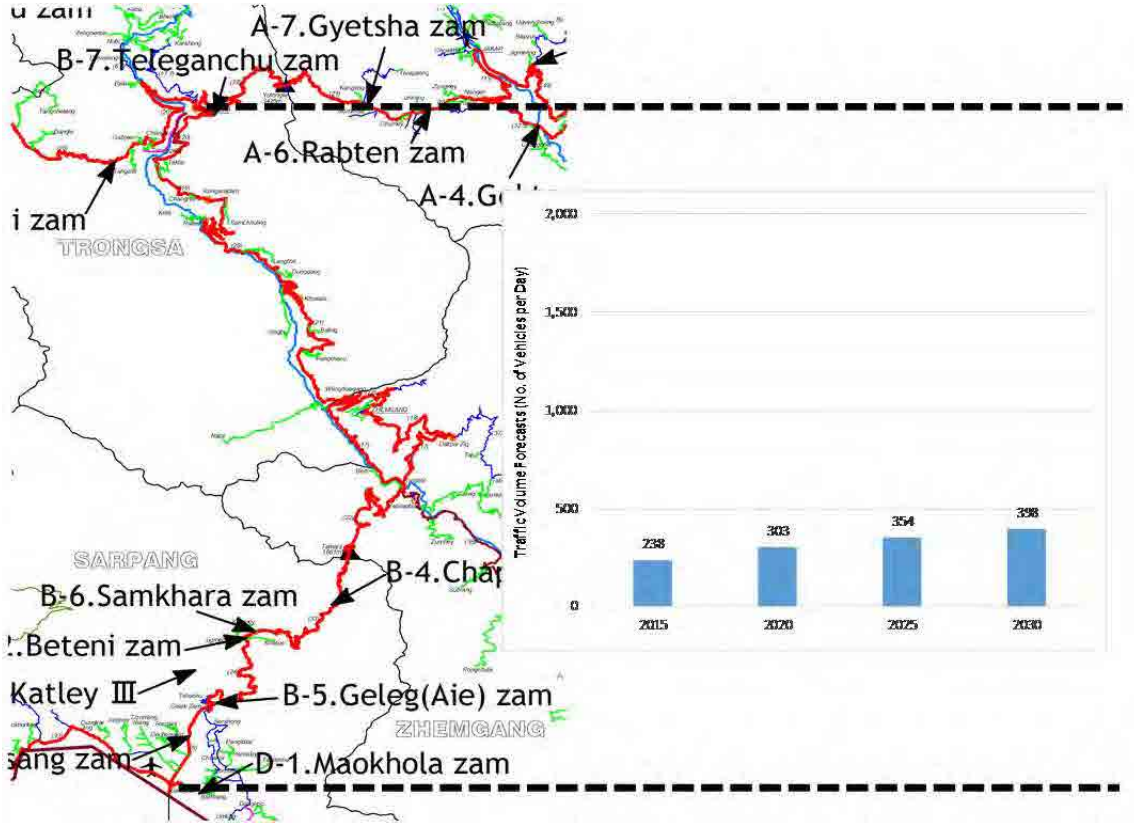
Source: JICA Study Team

<Figure 4-10> Forecast results of traffic demand on PNH-3

4) PNH-4

Figure4-11 shows the forecast results of traffic demand on PNH-4. We forecast that the traffic volume during the period 2015-2030 will maintain a slight upward trend at a level of 240 vehicles per day in 2015 to 400 vehicles per day in 2030.

The traffic volume ranged from 90 to 240 vehicles per day during the period 2004-2014, and the average volume was about 140 vehicles per day. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 240 vehicles per day in 2015 to 400 vehicles per day in 2030.



Source: JICA Study Team

<Figure 4-11> Forecast results of traffic demand on PNH-4

5) PNH-5

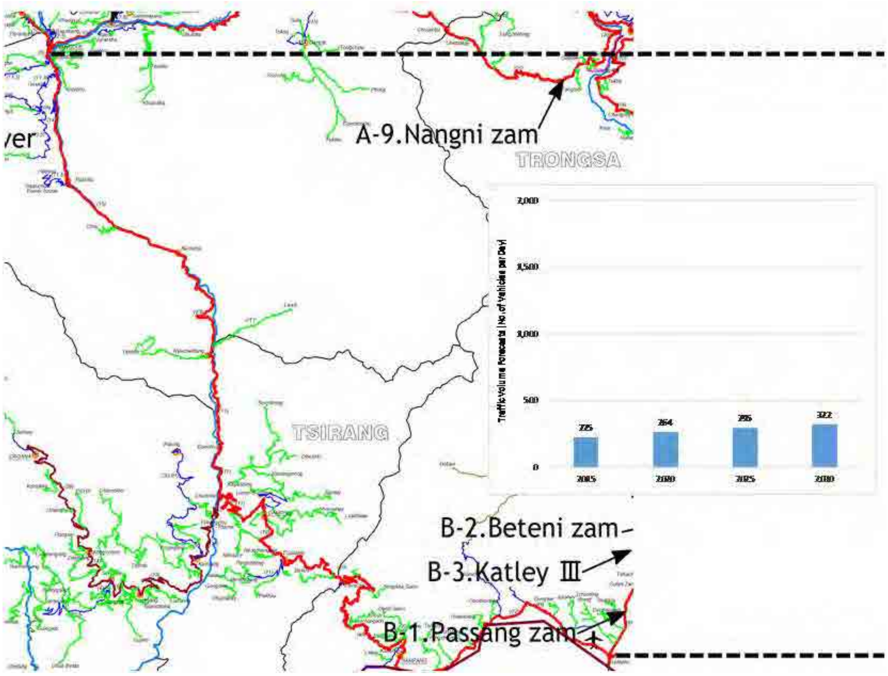
Figure4-12 shows the forecast results of traffic demand on PNH-5. We forecast that the traffic volume during the period 2015-2030 will maintain a slight upward trend at a level of 230 vehicles per day in 2015 to 320 vehicles per day in 2030.

Trends in traffic volume in the past reveal that there is a significant gap in traffic volume between the northern section (on the Wangdue side) and the southern section (on the Gelephu side).

In the northern section (on the Wangdue side), the traffic volume ranged from 250 to 1,500 vehicles per day during the period 2004-2014, and the average volume was about 780 vehicles per day. In 2014, it is 1,400 vehicles per day partly due to the impact of the construction of the Punatsangchhu Hydropower Project, but the average volume had decreased from 900 vehicles per day in 2006 to 580 vehicles per day in 2009. The volume has varied greatly from year to year, and the traffic situation is not stable.

In the southern section (on the Gelephu side), the traffic volume ranged from 100 to 450 vehicles per day in the past, and the average volume was about 200 vehicles per day. Unlike the northern section, it is unaffected by construction vehicles for the construction of the Punatsangchhu Hydropower Project, so the traffic volume varied little from year to year.

In order to grasp the steady-state traffic situation on PNH-5, we decided to use the data on the southern section which was unaffected by such factors as the construction of the Punatsangchhu Hydropower Project. The average volume in the southern section was about 200 vehicles per day. In view of past traffic situations, it seems reasonable to forecast a traffic volume of 230 vehicles per day in 2015 to 320 vehicles per day in 2030.

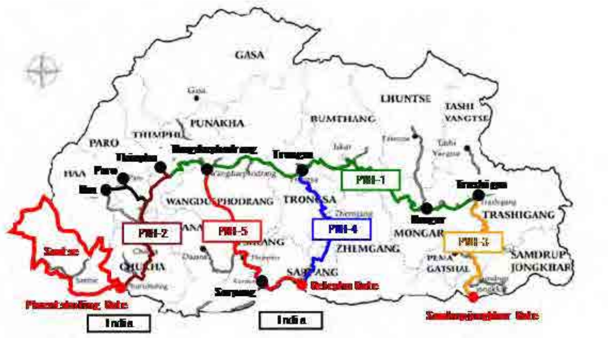


Source: JICA Study Team

<Figure 4-12> Forecast results of traffic demand on PNH-5

4-4. Situation of Physical Distribution

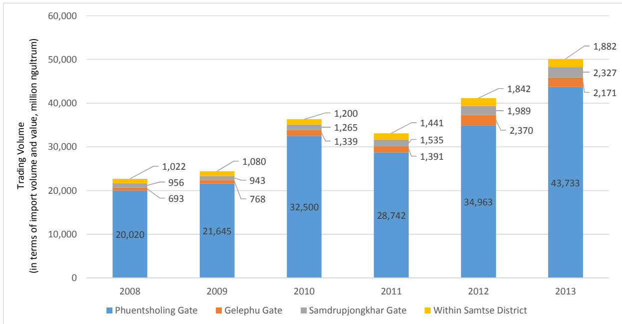
Looking at the situation of physical distribution, the main export and import partner is India, and major export items include ferrosilicon, iron/ non-alloy steel, and cement, while major import items include light oil, gasoline, metal products, and automobiles. That means large freight vehicles are the main mode of transport for these items.



Source: Department of Revenue and Custom, Ministry of Finance

<Figure 4-13> Locations of customs clearance gates on the border with India

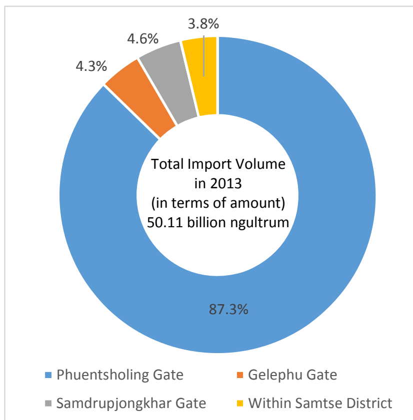
With regard to exports to and imports from India, products, including those manufactured in third countries other than India, are exported to and imported from Bhutan mainly by way of land transportation via India. As shown in Figure4-13, export/import transport routes go through three main customs clearance gates on the border with India (Phuentsholing, Gelephu, and Samdrupjongkhar) and seven minor customs clearance gates in Samtse District (Bindoo, Bhimtar, Gomtu, Jitty, Pugli, Samtse, and Trashijong).



Source: Department of Revenue and Custom, Ministry of Finance

<Figure 4-14> Trading Volume at each customs clearance gate (import amount)

As for trading volume, the import volume (in terms of amount) has been on the increase, as shown in Figure4-14. The import amount of about 23 billion ngultrum in 2008 nearly doubled to about 50 billion ngultrum in 2013. Most imported products have been handled at the Phuentsholing Gate, and about 90% of them were actually allowed to pass through the gate in 2013. In Samtse District, the construction of a road connecting Samtse District and Phuentsholing is not yet finished. As a result, products are imported and exported through seven gates in Samtse District, and all imported products are consumed within the district. The reason that the trading volume within Samtse District is almost the same as the trading volume at the Gelephu and Samdrupjongkhar Gates is that the largest cement company (Penden Cement Authority) in the country is located at Gomtu in the district.



Source: Department of Revenue and Custom, Ministry of Finance

<Figure 4-15> Composition ratio of trading volume at each customs clearance gate (2013)

As stated above, land transportation is mostly used for transport to and from India via Phuentsholing, which reveals that the main channel of distribution in Bhutan is PNH-2. In addition, because there is no road that extends from Phuentsholing in the east/west directions, products from Phuentsholing are distributed to Thimphu via PNH-2, as well as to eastern areas in Bhutan via PNH-1.

4-5. Benefit to the Poor

Poverty status of each Dongkhag of Bhutan is summarized in “BHUTAN Multidimensional Poverty Index 2012” issued by the government of Bhutan. Multidimensional poverty index (MPI) that quantifies the degree of seriousness of the poverty in terms of health, education, and standard of living take both of the extent of poverty and the number of people in poverty into account. In the case of Bhutan, 12.7% of the population is in the multidimensional poverty as shown in Table4-2. The Poor are distributed throughout the country, however there is a difference in distribution in each Dzongkhag. Comparing the poverty distribution value and the population data of census 2005, there are 13 Dzongkhg, mainly in rural areas, in which the poverty distribution is increasing more rapidly than the resident population. Table4-3 shows the relationship between those 13 Dzongkhag and the PNH passing through those Dzongkhag. According to this data, one or more PNH, including the Southern East-West Corridor, pass through all of those Dongkhag in which the large number of poor are living. Therefore it can be said that the maintenance and the improvement of each PNH will be a project that highly benefit to the poor.

<Table 4-2> Poverty status of each Dzongkhag

Dzongkhag	BHUTAN Multidimensional Poverty Index 2012				Census 2005	
	MPI	Headcount (%)	Intensity of deprivation (%)	Distribution of Poor (%)	Population (persons)	Distribution of population (%)
Bumthang	0.006	1.6	37.8	0.3	16,116	2.5
Chukha	0.075	17.6	42.7	13.1	74,682	11.8
Dagana	0.071	17.6	40.1	4.6	22,375	3.5
Gasa	0.149	37.6	39.6	1.6	3,116	0.5
Haa	0.040	10.2	39.0	1.2	12,745	2.0
Lhuentse	0.043	10.4	41.2	2.0	15,395	2.4
Mongar	0.083	20.9	39.8	10.8	37,069	5.8
Paro	0.018	4.7	37.9	2.0	35,260	5.6
Pemagatshel	0.044	11.6	38.2	3.5	22,287	3.5
Punakha	0.056	13.0	42.9	3.9	23,462	3.7
Samdrup Jongkhar	0.061	16.4	37.0	6.8	33,889	5.3
Samtse	0.074	18.7	39.3	14.0	59,003	9.3
Sarpang	0.022	5.9	38.0	2.8	37,191	5.9
Thimphu	0.007	1.6	41.6	1.9	94,102	14.8
Trashigang	0.056	14.0	40.1	8.3	48,783	7.7
Trashiyangtse	0.062	16.5	37.5	3.6	17,740	2.8
Trongsa	0.075	18.2	41.3	3.3	13,344	2.1
Tsirang	0.061	15.2	40.2	3.9	18,667	2.9
Wangdue Phodrang	0.079	18.5	42.7	8.5	31,120	4.9
Zhemgang	0.056	15.0	36.9	3.9	18,636	2.9
Bhutan	**0.051**	**12.7**	**40.1**	**100**	**634,982**	**100**

Source：BHUTAN Multidimensional Poverty Index 2012、Census 2005

<Table4-3> Relationship between 13 Dzongkhag and the PNH

Name of route	Dzongkhag in which many poor are living that the PNH passes through
PNH-1	Wangdue Phodrang, Trongsa, Monggar, Trashigang
PNH-2	Chhukha
PNH-3	Trashigang, Samdrupjongkhar
PNH-4	Trongsa, Zhemgang
PNH-5	Wangdue Phodrang, Dagana, Tsirang
Southern East-West Corridor	Chhukha, Dagana, Samdrupjongkhar, Samtse

Source: JICA Study Team

4-6.Relationship with National Projects

The most important factor for economic development of Bhutan is construction of the hydropower plants. The 11th Five-Year Plan refers to ten hydropower plant construction projects (three currently under way and seven under contemplation). Details of each of these projects are summarized in Table4-4 and the project locations are shown in Figure4-16.

Locations indicated with red in the figure are the three projects currently under construction. When viewed in terms of the relationship between the project sites and the national highways, the construction sites are found to be located in the vicinity of the national highways. This is partly due to a fact that the national highways are constructed along the principal rivers in Bhutan. In this sense, the national highway may be said to play an important role for transportation of dam construction materials.

Next, the transportation route of equipment and material for hydropower plant construction is discussed. The major transportation route for each hydropower plant is as shown in Table 4-4. Also, the importance of the PNH will be considered by categorizing them into PNH which have high importance during implementation of the 11th Five-Year Plan (2013-2018) and PNH that will have high importance during implementation of the 12th Five-Year Plan (2019-2024) according to the construction schedule for each project.

Note that the construction schedule shown in the table is said to be greatly dependent on whether or not assistance is available from India and when such assistance is implemented.

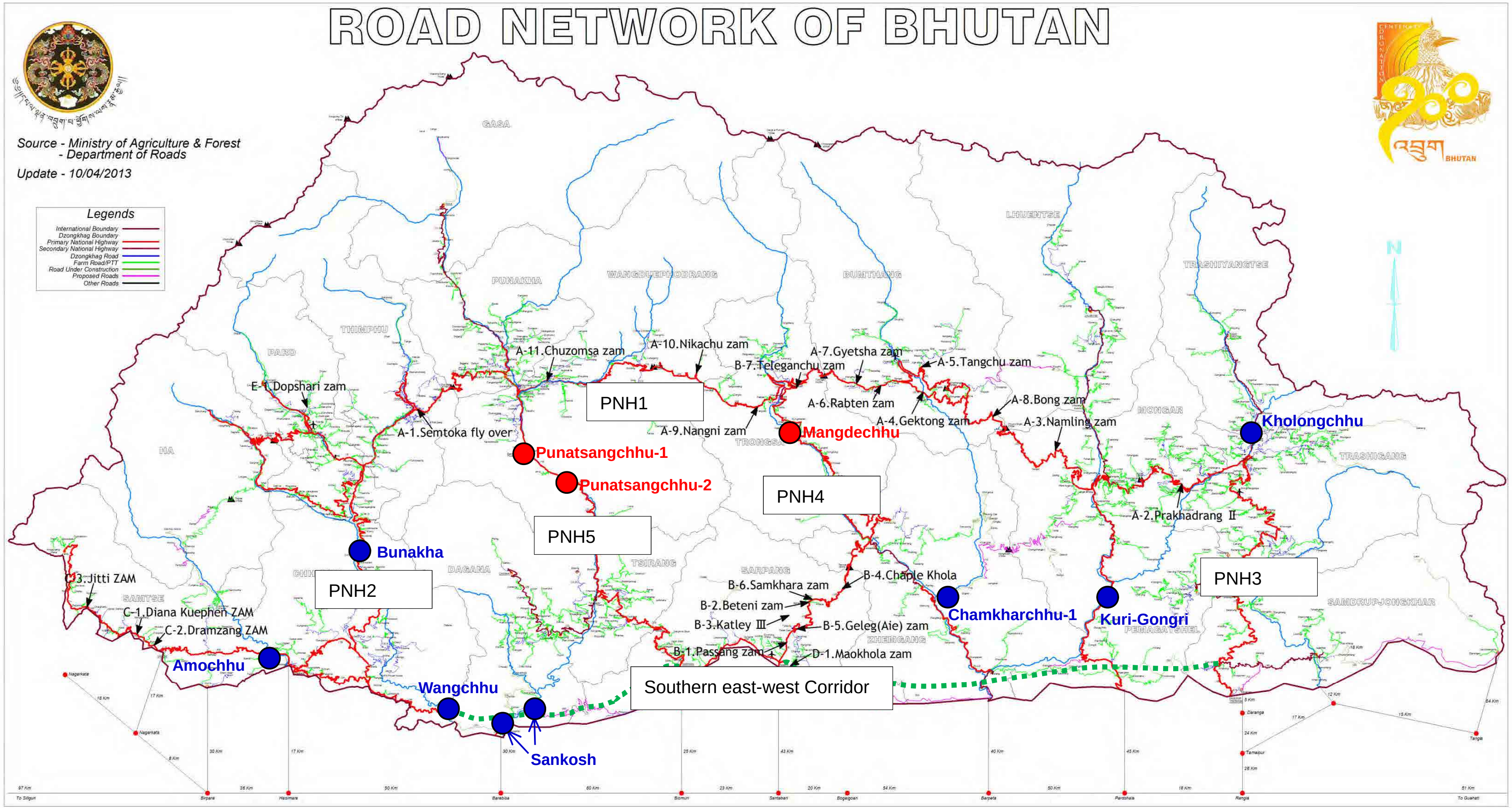
- PNH that have high importance during implementation of the 11th Five-Year plan (2013-2018)
  PNH-1, PNH-2, PNH-4
- PNH that will have high importance during implementation of the 12th Five-Year Plan (2019-2024)
  PNH-4, Southern East-West Corridor

<Table 4-4> Hydropower plant construction projects currently under way and under contemplation

No.	Project Name	Capacity (MW)	Implementing Agency	Construction Schedule	Major route for transportation	Remarks
1	Punatsangchhu-I	1,200	GoI	2008-2017	PNH-1,2,5	Under construction
2	Punatsangchhu-II	1,020	GoI	2010-2017	PNH-1,2,5	Under construction
3	Mangdechhu	720	GoI	2010-2017	PNH-1,2,4	Under construction
4	Amochhu	540	GoI	-	Southern East-West Corridor	DPR cleared by CEA, GoI
5	Sankosh	2,560	GoI	2015-2023	South East-West Corridor	DPR yet to be cleared by CEA, GoI
6	Kuri-Gongri	2,640	GoI	-	PNH1,4	DPR to be prepared in 11th FYP
7	Kholongchhu	600	RGoB	2014-2021	PNH1,2	DPR cleared & ready for implementation
8	Bunakha	180	RGoB	2015-2020	PNH2	DPR cleared by CEA, GoI
9	Wangchhu	570	RGoB	2015-2023	South East-West Corridor	DPR cleared by CEA, GoI
10	Chamkharchhu-1	770	RGoB	2015-2024	PNH4	DPR yet to be cleared by CEA, GoI
	Total	10,800				

Note: DPR＝Detailed Project Report、CEA＝Central Electricity Authority of India

Source: Hydropower Development Division, Department of Hydropower & Power System, Ministry of Economic Affairs



Source: JICA Study Team based on the interview with the Hydropower Development Division, Department of Hydropower & Power System, Ministry of Economic Affairs

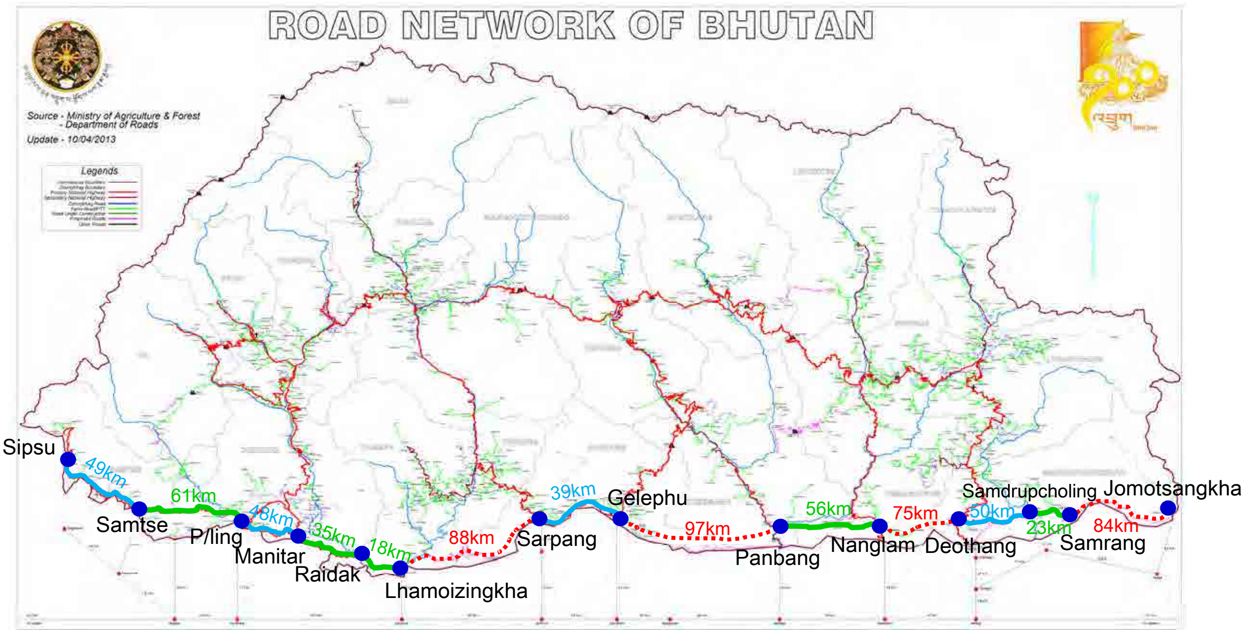
<Figure4-16> Location map of Hydropower project sites

4-19

4-7.Current State of the Southern East-West Corridor

The Southern East-West Corridor is extremely important as an alternative to the existing northern East-West Corridor (PNH-1), and the Government of Bhutan has ranked this Corridor as the top priority project and is constructing, at an accelerated speed, the sections not yet connected to this route. The “Bhutan 2020” sets up the specific target value that the Southern East-West Corridor is to be completed by 2017. This Corridor runs almost parallel to the border with India on the south side of Bhutan and includes total length of 723km (as of May, 2014). When compared with the northern East-West Corridor, the southern Corridor is flat in land form, so that the Corridor, if completed, is expected to secure the safety of the travelers and to shorten the drive time. Imported cargoes are unloaded generally at Kolkata (Calcutta) Port, India, and after customs clearance in Phuentholing, the city on the border, transported over land to the capital, Thimphu. As for the routes for transport to cities which are eastern side of Thimphu, there are two ways, transportation by PNH-1 from Phuentholing toward north through PNH-2, or transportation by PNH-3, PNH-4 and PNH-5 through India after checking custom at Phuentholing. In this context, the Southern East-West Corridor is important not only as an alternative to the northern East-West Corridor, but also as a means to secure a safe and convenient cargo shipment route in the east to west direction.

Figure4-17 shows the location of the Southern East-West Corridor.



Source: JICA Study Team based on an interview with DoR

<Figure4-17> Location of the Southern East-West Corridor

As shown in Table4-5, construction is suspended on four sections (1) Lhamoizingkha – Sarpang section, (2) Gelephu – Panbang section, (3) Nanglam – Deothang section, and (4) Samrang – Jomotsangkha section）. For these sections, ADB conducted F/S under additional funding of RNP2 Project and submitted the final report in April, 2012 (TA No.7803-BHU). The study results proved the project feasible for sections (1) through (3), but not feasible for section (4) similarly to the study result by TA of RNP2. On the basis of these results, DoR ranked road development of section (3) as top priority. According to the F/S results, the construction cost for the sections concerned amounts to Nu 1,441 million (= US$28.8 million). The total project cost including the resettlement cost, consulting fees, contingency, price escalation, etc. amounts to Nu 2,185 million (= US$43.7 million). The F/S team proposes implementation in four separate packages.

On the basis of the above results, the detailed design was implemented for section (3) and the report was submitted in March, 2014. The bid for construction work is scheduled for around November, this year. The bidding will be International Competitive Bidding (ICB).

For section (4), DoR will begin with development of the simple road under financial assistance from the Government of Bhutan. The F/S has already been completed and the construction is scheduled to start in July, 2014.

<Table4-5> Development state of the Southern East-West Highway (as of May, 2014)

No	Section	Length (Km)	Development state
1	Sipsu – Samtse	49	Existing road
2	Samtse- Phuentsholing	61	Under construction (The 10th 5 Year Plan, Bhutan country funds)
3	Phuentsholing – Manitar	48	Existing road
4	Manitar – Raidak	35	Under construction (The 10th 5 Year Plan, ADB(RNP2))
5	Raidak – Lhamoizingkha	18	Under construction (The 10th 5 Year Plan, ADB(RNP2))
6	Lhamoizingkha – Sarpang	88	Under contemplation (The 11th 5 Year Plan, Budget=1,366.710 Million Nu)
7	Sarpang – Gelephu	39	Existing road
8	Gelephu – Panbang	97	Under contemplation (The 11th 5 Year Plan, Budget=1,793.360 Million Nu)
9	Panbang – Nanglam	56	Under construction (The 10th 5 Year Plan, ADB(RNP2))
10	Nanglam – Deothang	75	Under contemplation (The 11th 5 Year Plan, Budget=799.069 Million Nu)
11	Deothang – Samdrupcholing	50	Existing road
12	Samdrupcholing – Samrang	23	Under construction (The 10th 5 Year Plan, ADB(RNP2))
13	Samrang – Jomotsangkha	84	Under contemplation (The 11th 5 Year plan, Budget =1,221.340 Million Nu)
	Total	723	

Source: DoR

The Gelephu - Pangbang section will pass through the Royal Manas National Park, but this will present no problem because the 4th King has authorized the construction. Concerning this matter, the secretary of MoWHS sent an official letter (DoR/DIR/2012-13/4615, dated on April 9, 2013) to the secretary of GNHC (see Appendix-2). The road within this section will be constructed using Environment Friendly Road Construction (EFRC) technology, and designed to minimize the impact of deforestation and take into account the possibility of wildlife needing to cross the road according to the Wildlife Conservation Ordinance.

4-8.Summary of the Importance of National Highways

Table4-6 shows the summary of the priority among PNHs established on the basis of the viewpoint and method of analysis in Chapter 4-1. Individual assessment viewpoints were assigned with the score placing the project into one of three stages (A, B, C) and the priority A was assumed to be the case when the total of five assessment viewpoint scores was 24 or more (= average score is 4 or more). Since all of the Primary National Highways remain the principal trunk roads, even though there are differences in the current traffic volume and the project benefit to the poverty group, all of them, except for PNH-3, are ranked at priority A.

<Table4-6> Results of analysis of the priority among National Highways

Name	Length (KM)	Importance (by JICA Study Team)	Analytic View						
			Role/characteristics of route	Traffic Volume (Average Daily Traffic)	Priority in the five year plan (Government policy)	Logistics	Direct benefits for the poor	Relevant to huge national project (contribution to the nation's development)	Rating (A=5,B=3, C=1)
PNH1	545	A	A The only highwaythat crosses east-west direction in Bhutan	A Approx.1,700 veh/day (Dochula, 2014)	A Proposal in 11th FYP	A The only highwaythat crosses east-west direction and most important route for domestic logistics in Bhutan	A The poor in Wangduephodrang, Trongsa, Mongar and Trashigang	A Mangdechhu HPP, Punatsangchhu-I&II HPP, Some future hydropower projects	30
PNH2	168	A	A Directly connecting the capital Thimphu with the border city Phuentsholing, designated to Asian Highway (AH-48).	A Approx.1,000 veh/day (Rinchending, 2014)	B Damchu–Chhukha bypass by DANTAK	A More than 80% of goods imported from India are entering from Phuentsholing and distributed via PNH2.	A The poor in Chhukha	A Bunakha and some future hydropower projects	28
PNH3	180	B	A Connects Tashigang with border city Samdrup Jongkhar, and connects with NH1 at Tashigang.	B Approx.600 veh/day (Trashigang, 2014)	B Widening project	B Only 6% of goods imported from India are entering from Samdrupjongkhar, therefore, it can be said that logistics via PNH3 are still minor.	A The poor in Trashigang and Samdrupjongkhar	B Kholongchhu HPP, but main transportation route will be PNH1	21
PNH4	244	A	A Heavily used for construction of Mangdechhu HPP	C Approx.430 veh/day (Geleg Zam, 2014)	A In 10th FYP	B Only 4% of goods imported from India are entering from Gelephu, therefore, it can be said that logistics via PNH4 are still minor.	A The poor in Zhemgang and Trongsa	A Mangdechhu HPP	24
PNH5	112	A	A Heavily used for construction of Punatsangchhu-I&II HPP	C Approx.450 veh/day (Sarpang, 2014)	A In 10th FYP	B Only 4% of goods imported from India are entering from Gelephu, therefore, it can be said that logistics via PNH5 are still minor.	A The poor in Dagana, Tsirang and Wangduephodrang	A Punatsangchhu-I&II HPP, Dagachhu HPP	24
Southern East-West Corridor	723	A	A Very important as the alternative route of PNH1	- -	A In 11th FYP	- -	A The poor in several Dzongkhags near Indian border	A Some future hydropower projects	-

Source: JICA Study Team

Table4-7 shows the summary of the necessity of improvement by means of Japan's aid. As a result of three-stage qualitative assessment of three viewpoints shown in the table, it was determined that **PNH-1**, **PNH-4**, and **the Southern East – West Corridor** are vital as targets of Japan's future aid.

＜Table4-7> Necessity of improvement by Japan's aid

Name	Priority for JICA's Study	Analytic View: Insufficiency of geometric/surface condition	Analytic View: Urgency for countermeasures against natural disaster	Analytic View: Necessity of donor assistance	Analytic View: Remarks
PNH1	1	Middle Widening/maintenance by DoR	High Land slide, flood, snowfall	High No donor assistance	High needs from DoR
PNH2	2	Middle Widening/maintenance by DANTAK	Middle Land slide, flood	Low Controlled by DANTAK	
PNH3	2	High	High Land slide, flood	Low Controlled by DANTAK	
PNH4	1	High Heavily damaged by vehicles of Mangdechhu HPP	High Land slide, flood	Middle GOI (for hydropower project, at northern part only)	High needs from DoR for JICA's cooperation to bridge replacement
PNH5	2	High Heavily damaged by vehicles of Punatsangchhu-I&II HPP	High Land slide, flood	Low GOI (for hydropower project)	
Southern East-West Corridor	1	High For existing road section only	High Land slide, flood	Middle Assistance by ADB, GOI, WB	High needs from DoR (especially for Mau Khola bridge construction)

Source: JICA Study Team

Chapter 5 Analysis of Traffic Bottlenecks on PNH

5-1.Viewpoint and Method of Analysis

Analysis of traffic bottlenecks on PNH was done on the basis of the results of a site survey and interview with the relevant authorities. Issues observed in the current states of PNH, which are considered to be related to traffic bottlenecks, are summarized below. Note that analysis of traffic bottlenecks was done only on three national highways, PNH-1, PNH-4, and the Southern East – West Corridor that were determined to be vital as targets of Japan’s future aid as described in Chapter 4.

(1) Narrow Carriageway Width

【National Highways concerned】PNH-1, PNH-4, and the Southern East –West Corridor (existing sections only)

There are many sections of both roads and bridges in which only the carriageway width enough for one lane can be secured. Presently, the traffic volume is small in rural areas in particular, so that there are no problems such as traffic congestion, etc. However, with increasing traffic volume and the number of heavy vehicles in the future, traffic congestion and the traffic accidents during passing may possibly increase in the future.

Source: JICA Study Team

<Figure5-1> Narrow width bridge of the Southern East-West Corridor (Diana Kuenphen zam Bridge)

(2) Deficient Geometric Design due to Precipitous Terrain and Rocky Areas

【National Highways concerned】PNH-1, PNH-4

In the site survey along PNH-1 and PNH-4, overhang terrain was observed in many slopes with exposed rocks. In such locations, the road alignment has horizontal curves with small radius to avoid the projecting rocky areas. Further, the sight distance and the vertical clearance are not secured to a satisfactory degree. The situations as above described are bottlenecks to safe and comfortable traveling because of the increase in trip time and traffic accidents (mainly head-on collisions) due to poor visibility.

Source: JICA Study Team
<Figure5-2> Overhanging rock slope (PNH-1)

(3) Damages/Deterioration of Bridges

【National Highways concerned】PNH-1, PNH-4, and the Southern East –West Corridor (existing sections only)

There are old and damaged/broken bridges, and the increase in heavy vehicles in the future in line with the increase in the traffic volume may cause damage to or failure of the bridges. In this study, the site survey was conducted to determine the soundness of the bridges, and the results are detailed in Chapter 5-2.

Source: JICA Study Team
<Figure5-3> Deteriorated bridge on PNH-1 (Nagni zam Bridge) and PNH-4 (Chaplekhola zam Bridge)

(4) Bridges with Insufficient Loading Capacity

【National Highways concerned】PNH-1, PNH-4, and the Southern East –West Corridor (existing sections only)

Currently, bridges on the same national highway differ in the allowable load. Insufficient loading capacity will become a traffic bottleneck for heavy vehicles as their numbers increase in line with construction of hydropower plants in the future.

In the case of PNH-1, insufficiency of the loading capacity (40 R = about 58.5 MT) of existing bridges will become a bottleneck for smooth transport of the transformers used in the construction project of the Mangdechhu Hydroelectric Project, which is extremely important for the development of Bhutan. The transformer carrier's weight is a total of 115 MT including 80 MT of the transformer proper and 35MT for the trailer for its transportation.

Source: JICA Study Team

<Figure5-4> Chuzomsa zam Bridge on PNH-1 (Loading capacity=40R)

(5) Road Blockage by Slope Failure

【National Highways concerned】PNH-1, PNH-4, and the Southern East –West Corridor (existing sections only)

For all national highways in Bhutan, there exists a problem of road blockage caused by slope failure. The site survey along PNH-1 and PNH-4 confirmed loose rocks and small-scale failures in many talus slopes and the as-cut unstable slopes without any countermeasures in the cut slopes for road widening. Particularly in the rural areas, however, the traffic volume is so small that rock falling or slope failure does not interfere with the traffic enough to result in traffic accidents.

Namely, the current countermeasures are applied only to the long-term road blockages caused by large-scale failure. Once the road is blocked due to large-scale slope failure, personnel and logistics may possibly be disrupted for a long period of time.

Source: JICA Study Team

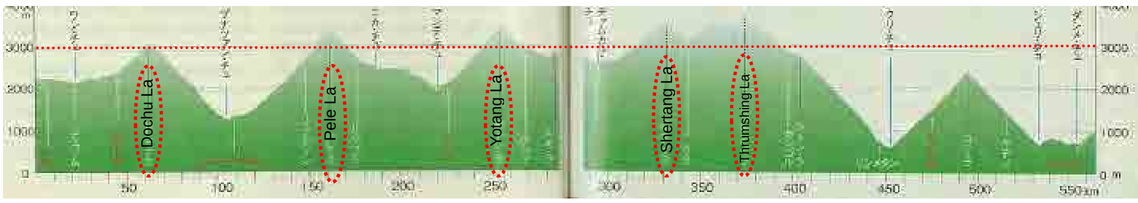
<Figure5-5> States of slope failure points along PNH-4

(6) Road Blockage by Snow Damage

【National Highways concerned】PNH-1

PNH-1 has five passes with an altitude of 3,000 m or more above sea level (see Figure5-6). They are Dochu La (3,150m above sea level), Pele La (3,360m above sea level), Yotang La (3,400m above sea level), Shertang La (3,596m above sea level), and Thrumshing La (3,740m above sea level). Being located at high altitude, they have snowfall in the winter. Any snow cover on roads with steep slopes will make climbing of vehicles difficult, and vehicles have to wait in a long row till snow is removed by the regional office of DoR. These passes can be bottlenecks in the winter. The snow cover state in Thrumshing La and snow removal by DoR are shown in Figure5-7. According to a report from the DoR Lingmethang Regional Office, details of snow removal in Thrumshing La are as follows:

- Performance : 2,000,000Nu/year for 2012 and 1,500,000Nu/year for 2013
- Details: Snow removal with a payloader
  (average scope of work = Length 15 km x width 6m x thickness 15 cm)
  Spreading of snow melting agent (calcium chloride)
- Construction machinery of the DoR Limithang Regional Office: Payloader, chipper



Source: Globe-Trotter Travel Guide Book ('12～'13)

<Figure5-6> Altitude graph of PNH-1

Source: DoR

<Figure5-7> Snow cover state of the Thrumshing La and snow removal by DoR

(7) Damage to the Pavement at High Altitude Pass

【National Highways concerned】PNH-1

Of five passes on PNH-1 as previously described, the section of about 5 km on the northern slope of Thrumshing La Pass is left neglected with the pavement surface course removed and the base course exposed because of low temperature and snow cover in winter and insufficient daylight hours for repair. For this section, repaving was attempted under assistance from ADB in 2004, but failed. Subsequently, DoR repeated re-pavement independently, with all attempts up to now resulting in failure. Poor road condition may be said to be a factor causing a traffic bottleneck because of increase in trip time or vehicle damage.

Source: JICA Study Team

<Figure5-8> Road surface condition on northern slope of Thrumshing La Pass

(8) Road Blockage by Heavy Rain

【National Highways concerned】PNH-4, and the Southern East –West Corridor (existing sections only)

For existing roads in the southern area, the embankment height was determined without taking into account the high water level of the river in many locations. In such locations, high water allows river water to overflow over the road surface, resulting in road flooding and disrupting vehicle traffic. According to the onsite report, heavy rainfall in rainy season causes overflow at the points indicated with arrows in Figure5-9, disrupting the road traffic, within the city of Gelephu along PNH-4.

Source: JICA Study Team

<Figure5-9> PNH-4 in Gelephu

(9) Lack of Alternative Route to PNH-1 (East – West Highway)

【National Highways concerned】Southern East–West Corridor

The construction work is delayed at present for the unconnected sections of the Southern East-West Corridor, which is an important alternative to PNH-1. This presents a bottleneck for securing safe and convenient material transportation route within Bhutan.

Source: JICA Study Team (photo taken from inside Gelephu City toward the planned center line)

<Figure5-10> States of the unconnected section of the Southern East-West Corridor (the approach to Maukhola Bridge)

5-2. Evaluation of Soundness of Existing Bridges

5-2-1.Summary of Bridges concerned

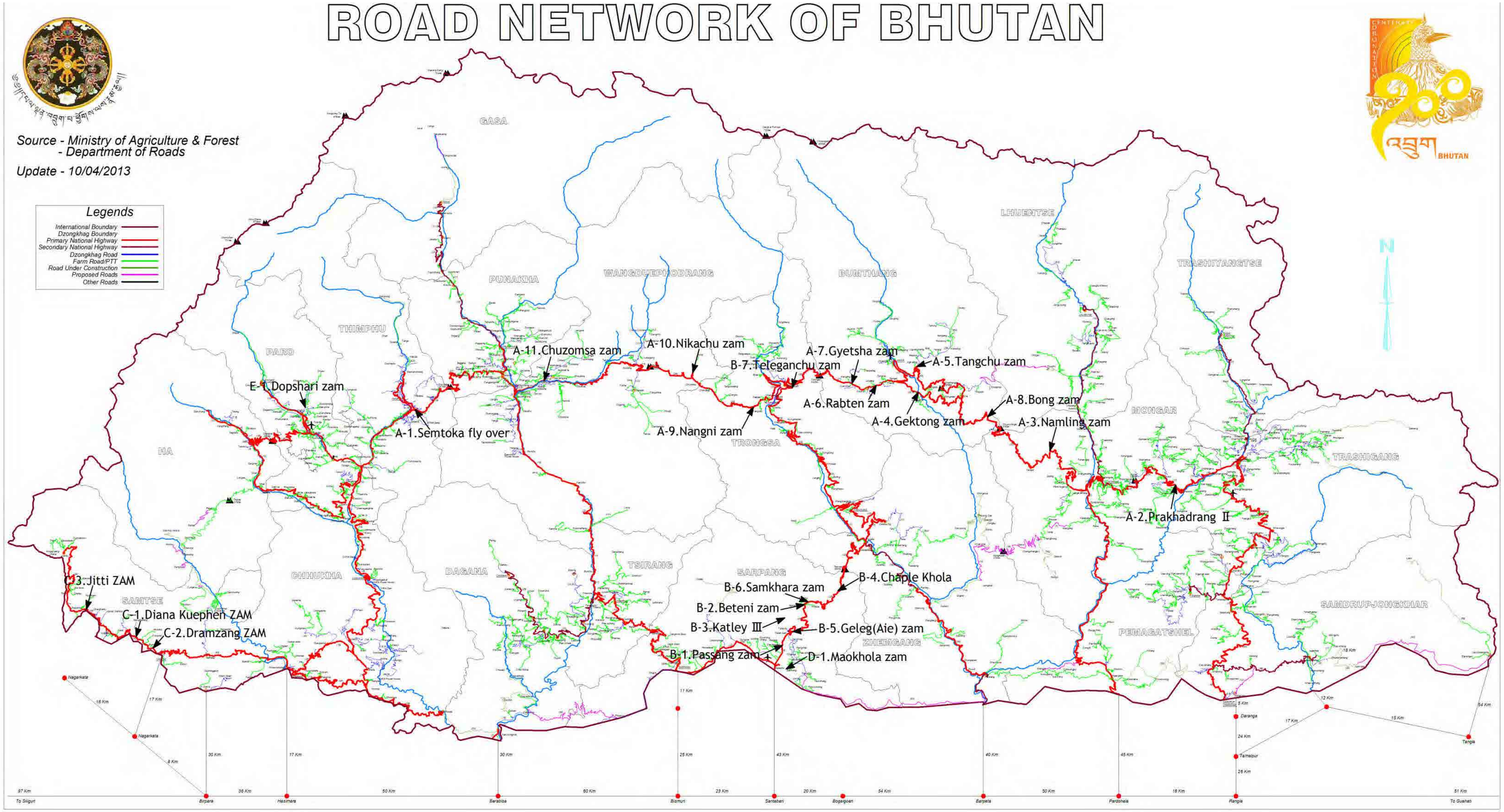
(1) Basic Data regarding the Bridges

A site survey was conducted to confirm the current states of national highways and the states of existing infrastructure. Twenty three bridges are concerned as listed in Table5-1. Their locations are shown on the next page in Figure 5-11.

<Table 5-1> Bridges covered by the survey

	No	Name of bridges	type	m	ft	width	year
A)Semtokha-Trashigang PNH	A-1	Semtokha flyover	RCT-Beam	15		4.75	1964
	A-2	Prakhadrang Ⅱ	BB		80	3.27	2004
	A-3	Namling zam	BB		90	3.27	2003
	A-4	Gektong zam	BB		110	4.27	2012
	A-5	Tangchu zam	RCCT-Beam	33.5		4.5	1987
	A-6	Rabten zam	RCCT-Beam	25		4.5	1982
	A-7	Gyetsha zam	RCCT-Beam	23.6		4.5	1981
	A-8	Bong zam	RCCT-Beam	23.6		4.5	1981
	A-9	Nangni zam	RCCT-Beam	24.7		4.5	1982
	A-10	Nikachu zam	RCCT-Beam	28		4.5	1982
	A-11	Chuzomsa zam	RCCT-Beam	28		4.5	1988
B)Gelephu-Trongsa PNH	B-1	Passang zam	Steel Hemilton	40		7.5	1970
	B-2	Beteni zam	RC-T Beam	25		4.2	1987
	B-3	Katley Ⅲ	RCCT-Beam	25		4.5	1981
	B-4	Chaplekhola	RCCT-Beam	20		4.5	1969
	B-5	Geleg(Aie) zam	Steel-Truss	120		4.3	2001
	B-6	Samkhara zam	Steel-Truss	61		4.3	2001
	B-7	Telegangchu zam	RCCT-Beam	25		4.5	1981
C)Samtse-Sipsu PNH	C-1	Diana Kuephen zam	RSB&BB		1020	3.27	2003
	C-2	Dramzang zam	BB		380	3.27	1990
	C-3	Jitti zam	BB		250	3.27	2001
D)Gelephu-Panbang PNH	D-1	Maokhola zam	New Bridge Proposal				
E)Paro Thromde	E-1	Dopshari zam	RCT-Beam	28.8		4.5	?

Source: JICA Study Team



Source: JICA Study Team

<Figure5-11> Location Map of Candidate Bridges

(2) Existing Survey Data

For some of the bridges concerned, the soundness survey was done by DoR in 2006. The soundness survey data includes the name of the bridge, name of the route, summary of bridge data, and the soundness assessment for each bridge member. An example is shown in the figure below.

[Basic Data]

Bridge Name:	Semtokha Flyover Zam (TH-15)

①	Geographic Data	(1)	Road Name	Semtokha – Trashigang Highway
		(2)	Dzongkhag	Thimphu
		(3)	Division/Agency	FD, DoR, Thimphu
		(4)	Location (km)	0 (from Semtokha)
②	Bridge Data	(5)	Type of Bridge	RCC Slab
		(6)	Bridge Length [m]	9.75
		(7)	Bridge Span [m]	9.0
		(8)	Effective Width [m]	4.1
		(9)	Total Width [m]	4.9
		(10)	Height of bridge from the Road level [m]	5.8
		(11)	Height of abutment(L/B) [m]	5.7
		(12)	Height of abutment(R/B) [m]	5.7
		(13)	Height of pier [m]	N.P.
		(14)	Type of Deck	RCC
		(15)	Type of Pavement	Asphalt
		(16)	Type of wheel guard	RCC
		(17)	Type of Abutment	RRM
		(18)	Loading Capacity [t]	40
		(19)	Year of Construction	N/A
		(20)	Final Record of repair	N/A
		(21)	Traffic Volume [veh/day]	N/A

Date of Record:	20th,Jul,2006
Name:	Hiroshi Tsujino
	Karma Tenzin

[Inspection Data]

Bridge Name: Semtokha Flyover Zam (TH-15)

Total Condition: C

A B C D E [A(very good),B(good),[illegible],E(very bad)]

Bridge Parts		Rating						Remarks
①Foundations								
	Footings	V.G	G	F	P	N.P.	**N/A**	
	Piles	V.G	G	F	P	**N.P.**	N/A	
②Substructure								
	Abutment(L/B)	V.G	**G**	F	P	N.P.	N/A	
	Abutment(R/B)	V.G	**G**	F	P	N.P.	N/A	
	Pier	V.G	G	F	P	**N.P.**	N/A	
	Wing Wall(L/B/US)	V.G	**G**	F	P	N.P.	N/A	
	Wing Wall(L/B/DS)	V.G	G	F	P	**N.P.**	N/A	
	Wing Wall(R/B/US)	V.G	G	F	P	**N.P.**	N/A	
	Wing Wall(R/B/DS)	V.G	**G**	F	P	N.P.	N/A	
	Embankment	V.G	**G**	F	P	N.P.	N/A	
③Superstructure								
	Pavement	V.G	**G**	F	P	N.P.	N/A	
	Slab	V.G	**G**	F	P	N.P.	N/A	
	Panels(Bailey)	V.G	G	F	P	**N.P.**	N/A	
	Main Girder	V.G	**G**	F	P	N.P.	N/A	
	Cross Girder	V.G	G	**F**	P	N.P.	N/A	
	Stringer	V.G	G	F	P	**N.P.**	N/A	
	Sway Bracing	V.G	G	F	P	**N.P.**	N/A	
	Lateral Bracing	V.G	G	F	P	**N.P.**	N/A	
	Tower	V.G	G	F	P	**N.P.**	N/A	
	Cable	V.G	G	F	P	**N.P.**	N/A	
	Wheel Guard	V.G	**G**	F	P	N.P.	N/A	
	Drain	V.G	**G**	F	P	N.P.	N/A	
④Others								
	Others	V.G	G	**F**	P	N.P.	N/A	

Date of Record	20th,Jul,2006
Name:	Hiroshi Tsujino
	Karma Tenzin

Source: DoR

<Figure 5-12> Existing soundness survey data (1)

[Comments/Findings]

①	Defects on main girder is due to hiting by the over loading height of the public carrier
②	Recommended to provide H-shape steel to protect the main girder
③	Reinforcement bar revealing
④	White washing has been carried out
⑤	For details kindly refer the photograghs.
⑥	-
⑦	-
⑧	-
⑨	-
⑩	-

Date of Record:	20th,Jul,2006
Name:	Hiroshi Tsujino
	Karma Tenzin

Signature:

1 ____________________ 2 ____________________

[Bridge Condition Photos] Bridge Name: Semtokha Flyover Zam (TH-15) Date: 20th,Jul,2006

Source: DoR

<Figure 5-13> Existing soundness survey data (2)

(3) Verification of the Existing Survey Data

Verification was made on the report of bridge soundness survey conducted in 2006 by DoR. Details are summarized in the table below.

<Table 5-2> Bridges covered by the survey

Road	No	Name of bridge	Report by DoR	Memo
			Condition	
A)PNH1	A-1	Semtokha flyover	Rebar exposure on girder	
	A-2	Prakhadrang II	-	Change of Bridge name, 「Youdiri Zam」⇒「Prakhadrang II」
	A-3	Namling zam	-	
	A-4	Gektong zam	-	No report document due to completion on 2012
	A-5	Tangchu zam	Scouring measurement of pier, necessity of repair for accessory	Change of bridge name, 「Mambar Tsho Zam」⇒「Tangchu zam」
	A-6	Rabten zam	Scouring measurement of pier, necessity of repair for accessory	Change of Bridge name, 「Mambar Tsho Zam」⇒「Tangchu zam」
	A-7	Gyetsha zam	-	Change of Bridge name, 「Gayzamchu Zam」⇒「Gyetsha zam」
	A-8	Bong zam	Necessity of repair for accessory	
	A-9	Nangni zam	Scouring measurement of pier, necessity of repair for accessory	Change of Bridge name, 「Naagina zam」⇒「Nangni zam」
	A-10	Nikachu zam	Necessity of repair for accessory	Different photos by Mr. Tujino report
	A-11	Chuzomsa zam	Necessity of repair for accessory	
B)PNH4	B-1	Passang zam	Necessity of steel member (painting)	
	B-2	Beteni zam	Necessity of Deck slab/pavement, crack on abutment	
	B-3	Katley III	Necessity of pavement repair	Change of Bridge name, 「Katley Zam(I)」⇒「Katley III」
	B-4	Chaplekhola	Necessity of pavement/accessory repair	Change of Bridge name, 「Chaplechu Zam」⇒「Chaplekhola」
	B-5	Geleg(Aie) zam	Necessity of steel member (painting), and parapet	Change of Bridge name, 「Geleg zam」⇒「Geleg(Aie) zam」
	B-6	Samkhara zam	Necessity of steel member (painting)	Change of Bridge name, 「Samkhar zam」⇒「Samkhara zam」
	B-7	Telegangchu zam	Necessity of deck slab/pavement, crack on abutment	
C)South East-West Corridor	C-1	Diana Kuephen zam	Crack on Anchorage, incline of main tower	
	C-2	Dramzang zam	free lime dfrom the both abutments, crack on pier	Change of bridge name, 「Chamurchi Zam」⇒「Dramzang zam」
	C-3	Jitti zam	Scouring at pier, deformation of road surface	
E)Paro Thromde	E-1	Dopshari zam	Necessity of repair for deck slab/accessory, scouring measurement of pier	

Source: JICA Study Team

5-2-2. Result of the Soundness Determined for Each Bridge

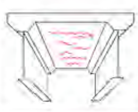
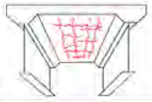
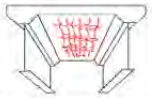
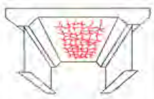
(1) Basic Survey Policy

On the basis of the report by DoR on the soundness survey on the bridges, a soundness survey was conducted in the Study according to the damage evaluation criteria (a～e) of the Ministry of Land, Infrastructure, Transport and Tourism, Japan. The details of the evaluation criteria are shown below. The survey consists mainly of visual inspection at a distance, and visual inspection in close proximity if it is possible to come closer.

1) Damage State to be Determined and Recorded ※ Bridge main body

Structure	Member	Material	Damage	Possibility of confirmation		Damage evaluation criterion (a ~ e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan))
				Visual inspection (from a distance)	Visual inspection (closer)	
Super-structure	Deck Slab	Concrete	Spalling/ Rebar exposure	○	○	a:Not found, b:-, c:Peeling, d:Rebar exposure(small), e:Rebar exposure(big)
			Water leakage/ Free lime	○	○	a:Not found, b:-, c:Water leakage, d:Free lime, e:Free lime+Rust fluid
			Crack	○	○	Appendix
			peeling off	△	○	a:Not found b:- c:- d:- e:Found
			Loose part	△	○	a:Not found b:- c:- d:- e:Found
	Main Girder	Steel	Corrosion	○	○	Appendix
			Crack	×	○	a:Not found b:- c:Crack of paintingcoating d:- e:Absolute crack
			Loosen / dropping of bolts	△	○	a:Not found, b:-, c:less than 5% of total, d:-, e:more than 5% of total
			Fracture	△	○	a:Not found b:- c:- d:- e:Found
			Deterioration of anti-corrosion function	△	○	a:Not found b:- c:Partial loose part d:Spalling e:Spalling and spot rusting
		Concrete	Crack	○	○	Appendix
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid
			Loose part	△	○	a:Not found b:- c:- d:- e:Found
Substructure	Body	Concrete	Crack	○	○	Appendix
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leak d:Free lime e:Free lime+Rust fluid
		Concrete block/ masonry	Deformation	○	○	a:Not found b:- c:- d:- e:Found

【Crack on slab】

	Crack phenomenon	
a	【Crack spacing & crack characteristic】 Crack has occured only on one direction and more than 1.0m as minimum crack spacing. 【Crack width】 Less than 0.05mm of maximum crack width (such as hair-crack)	
b	【Crack spacing & crack characteristic】 Crack has mainly occured on one direction and crack spacing of between 1.0m~0.5m, but not square-block type. 【crack width】 Mainly less than 0.1mm, but partly over 0.1mm.	
c	【Crack spacing & crack characteristic】 Crack has occured on about 0.5m before square-block type. 【Crack width】 Mainly less than 0.2mm, but partly over 0.2mm.	
d	【Crack spacing & Crack characteristic】 Crack has occured on 0.5m~0.2m and also square-block type. 【Crack width】 Over 0.2mm and partly peeling off concrete	
e	【Crack spacing & Crack characteristic】 Crack has occured on less than 0.2m and mainly square-block type. 【Crack width】 More than 0.2mm and continuously peeling off concrete	

【Corrosion on steel】

	Corrosion phenomenon
a	Nothing
b	Corrosion has ocuurred on steel surface, but impossible to see reduction of its thickness. Furtheremore very minor area of corrosion damage.
c	Corrosion has occurred on steel surface, but impossible to see reduction of its thickness. And crack has occurred entirely on focusing parts or some spred area.
d	Corrosion has occurred on steel surface, also possible to see slightly reduction of its thickness. And crack has occurred entirely on focusing parts or many spred area.
e	Corrosion has apparently expanded on steel surface, also possible to see definitely reduction of its thickness. And crack has occurred entirely with many spred area.

【Crack on concrete structure】

	Crack phenomenon
a	Nothing
b	Small crack width (less than 0.2mm in case of RC structure), large crack spacing (over o.5m in case of minimum crack spacing)
c	Small crack width (less than 0.2mm in case of RC structure), small crack spacing (over o.5m in case of minimum crack spacing)
	Or modest crack width (more than 0.2mm less than 0.3mm in case of RC structure), large crack spacing (more than 0.5m in case of minimum crack spacing)
d	Modest crack width (more than 0.2mm less than 0.3mm in case of RC structure), small crack spacing (more than 0.5m in case of minimum crack spacing)
	Or large crack with (more than 0.3mm in case of RC struture), large crack spacing (more than 0.5m in case of minimum crack spacing)
e	Large crack width (more than 0.3mm in case of RC structure), small crack spacing (less than 0.5m in case of minimum crack spacing)

2) Damage State to be Determined and Recorded * Bridge accessories

Structure	Member	Kinds of damage	Contents	Damage evaluation criterion (a ~ e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan)
Bearing shoe	Shoe	Functional deficit	Severe corrosion, damage/hardening/missing of parts	a:Not found b:- c:- d:- e:Functional deficit due to damage
		Extraordinary noises	Extraordinary noises in case of passing of vehicle	a:Not found b:- c:- d:- e:Found
	Mortar	Clogging with soil	Clogging with soil and water	a:Not found b:- c:- d:- e:Found
		Deformation· Deficit	Crack of mortar, partial deficit	a:Not found b:- c:Partially found d:- e:Severely deficit
Ancillary facilities	Railing, Guardrail	Deformation· Deficit	Broken due to collision of vehicle Dangerous location for passangers	a:Not found b:- c:Partially found d:- e:Severely deficit
Deck surface	Pavement	Abnormity on pavement	Hole, big pothole, crack	a:Not found b:- c:- d:- e:Crack width is more than 5mm, etc
		Unevenness on road surface	Dangerous parts for passangers	a:Not found b:- c:less than 2cm d:- e:more than 2cm
	Expansion joint	Unevenness on road surface	Big gaps	a:Not found b:- c:less than 2cm d:- e:more than 2cm
		Abnormity at expansion gap	Broken	a:Not found b:- c:Small disconnect d:- e:Disjunction or contact
Drainage facilities		Clogging with soil	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found
		Water leak, Bearing water	Drainage facilities are broken and girder is directly afftected by drained water, etc.	a:Not found b:- c:- d:- e:Water leakage· Bearing water
Whole bridge		Extraordinary deflection	Extraordinary deflection is found	a:Not found b:- c:- d:- e:Found
		Settlement, movement, tilting	Settlement, movement, incline at foundation and bearing, etc.	a:Not found b:- c:- d:- e:Found
		Scouring	Scouring at pier, foundation	a:Not found b:- c:Scouring d:- e:Severe scouring
		Others	Illegal occupation, graffiti, damage by birds, damage by fire, etc.	Only record

Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

<Figure5-14> Evaluation criteria

(2) Survey Result

<Table5-3> Summary table of damage evaluation criterion (PNH1: A-1～A-11bridge)

●Judgment/record of condition of damage

Structure	Member	Material	Damage	Possibility of confirmation by visual inspection: Visual inspection (from a distance)	Possibility of confirmation by visual inspection: Visual inspection (closer)	Damage evaluation criterion (a～e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan))	A-1 Semtokha flyover	A-2 Prakhadrang II	A-3 Namling zam	A-4 Gektong zam	A-5 Tangchu zam	A-6 Rabten zam	A-7 Gyetsha zam	A-8 Bong zam	A-9 Nangni zam	A-10 Nikachu zam	A-11 Chuzomsa zam
Super-structure	Deck Slab	Concrete	Spalling/ Rebar exposure	○	○	a:Not found, b:-, c:Peeling, d:Rebar exposure(small), e:Rebar exposure(big)	a				a	a	a	a	a	a	a
			Water leakage/ Free lime	○	○	a:Not found, b:-, c:Water leakage, d:Free lime, e:Free lime+Rust fluid	a				a	a	a	a	a	a	a
			Crack	○	○	Appendix	a				a	a	a	a	a	a	a
			peeling off	△	○	a:Not found b:- c:- d:- e:Found	a				a	a	a	a	a	a	a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found	a				a	a	a	a	a	a	a
	Main Girder	Steel	Corrosion	○	○	Appendix		a	a	a							
			Crack	×	○	a:Not found b:- c:Crack of paintingcoating d:- e:Absolute crack		Unconfirmed	Unconfirmed	Unconfirmed							
			Loosen / dropping of bolts	△	○	a:Not found, b:-, c:less than 5% of total, d:-, e:more than 5% of total		a	a	a							
			Fracture	△	○	a:Not found b:- c:- d:- e:Found		a	a	a							
			Deterioration of anti-corrosion function	△	○	a:Not found b:- c:Partial loose part d:Spalling e:Spalling and spot rusting		a	a	a							
		Concrete	Crack	○	○	Appendix	a				a	a	a	a	a	a	a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)	a				a	a	d	d	a	a	a
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid	a				a	a	a	a	a	a	a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found	a				a	a	a	a	a	a	a
Substructure	Body	Concrete	Crack	○	○	Appendix	a	a	a	a	a	a	a	a	a	d	a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)	a	a	a	a	d	a	a	a	a	a	d
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leak d:Free lime e:Free lime+Rust fluid	a	a	a	a	a	a	a	a	a	a	a
		Concrete block masonry	Deformation	○	○	a:Not found b:- c:- d:- e:Found						a	a	a	a	a	

●Judgment/record of existence or non-existence of damage

Structure	Member	Kinds of damage	Contents	Damage evaluation criterion (a～e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan))	A-1 Semtokha flyover	A-2 Prakhadrang II	A-3 Namling zam	A-4 Gektong zam	A-5 Tangchu zam	A-6 Rabten zam	A-7 Gyetsha zam	A-8 Bong zam	A-9 Nangni zam	A-10 Nikachu zam	A-11 Chuzomsa zam
Bearing shoe	Shoe	Functional deficit	Severe corrosion, damage/hardening/missing of parts	a:Not found b:- c:- d:- e:Functional deficit due to damage		a	a	a	a	a	a	a	e	a	Unconfirmed
		Extraordinary noises	Extraordinary noises in case of passing of vehicle	a:Not found b:- c:- d:- e:Found		a	a	a	a	a	a	a	a	a	a
	Mortar	Clogging with soil	Clogging with soil and water	a:Not found b:- c:- d:- e:Found		a	a	a	e	a	Unconfirmed	Unconfirmed	e	a	Unconfirmed
		Deformation・Deficit	Crack of mortar, partial deficit	a:Not found b:- c:Partially found d:- e:Severely deficit		a	a	a	a	a	Unconfirmed	Unconfirmed	Unconfirmed	a	Unconfirmed
Ancillary facilities	Railing, Guardrail	Deformation・Deficit	Broken due to collision of vehicle	a:Not found b:- c:Partially found d:- e:Severely deficit	e				c	a	c	c	e	e	a
			Dangerous location for passangers		e				a	a	a	a	e	e	a
Deck surface	Pavement	Abnormity on pavement	Hole, big pothole, crack	a:Not found b:- c:- d:- e:Crack width is more than 5mm, etc	a	a	a	a	a	a	a	a	a	a	a
		Unevenness on road surface	Dangerous parts for passangers	a:Not found b:- c:less than 2cm d:- e:more than 2cm	a	a	e	a	c	a	a	a	a	c	c
	Expansion joint	Unevenness on road surface	Big gaps	a:Not found b:- c:less than 2cm d:- e:more than 2cm	a				c	a	a	a	a	c	c
		Abnormity at expansion gap	Broken	a:Not found b:- c:Small disconnect d:- e:Disjunction or contact	a				a	a	a	a	a	a	a
Drainage facilities		Clogging with soil	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found					a	e	a	c	a	e	a
		Water leak, Bearing water	Drainage facilities are broken and girder is directly afftected by drained water, etc.	a:Not found b:- c:- d:- e:Water leakage・Bearing water					a	a	a	a	e	e	e
Whole bridge		Extraordinary deflection	Extraordinary deflection is found	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a	a	a	a	a
		Settlement, movement, tilting	Settlement, movement, incline at foundation and bearing, etc.	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a	a	a	a	a
		Scouring	Scouring at pier, foundation	a:Not found b:- c:Scouring d:- e:Severe scouring	a	a	a	a	a	c	a	a	e	a	a
		Others	Illegal occupation, graffiti, damage by birds, damage by fire, etc.	Only record	Under construction	-	-	-	a	a	a	a	-	Different height of bearing shoe	-

Source: JICA Study Team

<Table5-4> Summary table of damage evaluation criterion (PNH4: B-1～B-7 Bridge）

◎Judgment/record of condition of damage

Structure	Member	Material	Damage	Possibility of confirmation by visual inspection: Visual inspection (from a distance)	Possibility of confirmation by visual inspection: Visual inspection (closer)	Damage evaluation criterion (a～e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan))	B-1 Passang zam	B-2 Beteni zam	B-3 Katley III	B-4 Chaplekhola	B-5 Geleg(Aie) zam	B-6 Samkhara zam	B-7 Telegangchu zam
Super-structure	Deck Slab	Concrete	Spalling/ Rebar exposure	○	○	a:Not found, b:-, c:Peeling, d:Rebar exposure(small), e:Rebar exposure(big)	c	a	a	a	a	a	e
			Water leakage/ Free lime	○	○	a:Not found, b:-, c:Water leakage, d:Free lime, e:Free lime+Rust fluid	c	a	a	a	a	d	a
			Crack	○	○	Appendix	b	a	a	a	a	d	a
			peeling off	△	○	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a
	Main Girder	Steel	Corrosion	○	○	Appendix	c				b	b	
			Crack	×	○	a:Not found b:- c:Crack of paintingcoating d:- e:Absolute crack	Unconfirmed				Unconfirmed	Unconfirmed	
			Loosen / dropping of bolts	△	○	a:Not found, b:-, c:less than 5% of total, d:-, e:more than 5% of total	a				a	a	
			Fracture	△	○	a:Not found b:- c:- d:- e:Found	a				a	a	
			Deterioration of anti-corrosion function	△	○	a:Not found b:- c:Partial loose part d:Spalling e:Spalling and spot rusting	e				e	e	
		Concrete	Crack	○	○	Appendix		a	a	c			a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)		a	a	d			d
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid		a	a	a			a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found		a	a	a			a
Substructure	Body	Concrete	Crack	○	○	Appendix	No filling material	d (Cold joint)	a	a	e	a	a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)	a	a	a	a	a	a	a
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leak d:Free lime e:Free lime+Rust fluid	a	a	a	a	e	a	a
		Concrete block masonry	Deformation	○	○	a:Not found b:- c:- d:- e:Found	e	a	e (Necessity for detailed survey)	a			a

◎Judgment/record of existence or non-existence of damage

Structure	Member	Kinds of damage	Contents	Damage evaluation criterion (a～e) (Reference : Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan))	B-1 Passang zam	B-2 Beteni zam	B-3 Katley III	B-4 Chaplekhola	B-5 Geleg(Aie) zam	B-6 Samkhara zam	B-7 Telegangchu zam
Bearing shoe	Shoe	Functional deficit	Severe corrosion, damage/hardening/missing of parts	a:Not found b:- c:- d:- e:Functional deficit due to damage	e	e	Unconfirmed	e	a	a	e
		Extraordinary noises	Extraordinary noises in case of passing of vehicle	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a
	Mortar	Clogging with soil	Clogging with soil and water	a:Not found b:- c:- d:- e:Found	e	e	Unconfirmed	a	a	e	a
		Deformation・Deficit	Crack of mortar, partial deficit	a:Not found b:- c:Partially found d:- e:Severely deficit	Unconfirmed	Unconfirmed	Unconfirmed	a	e	a	a
Ancillary facilities	Railing, Guardrail	Deformation・Deficit	Broken due to collision of vehicle	a:Not found b:- c:Partially found d:- e:Severely deficit	a	a	c	e	a	a	c
			Dangerous location for passangers		a	a	c	e	a	a	c
Deck surface	Pavement	Abnormity on pavement	Hole, big pothole, crack	a:Not found b:- c:- d:- e:Crack width is more than 5mm, etc	e	e	a	a	a	a	No asphalt material
		Unevenness on road surface	Dangerous parts for passangers	a:Not found b:- c:less than 2cm d:- e:more than 2cm	a	a	a	c	a	e	c
	Expansion joint	Unevenness on road surface	Big gaps	a:Not found b:- c:less than 2cm d:- e:more than 2cm	Overlay	c	c	a	a	a	c
		Abnormity at expansion gap	Broken	a:Not found b:- c:Small disconnect d:- e:Disjunction or contact	Overlay	e Contact	a	a	a	a	c
Drainage facilities		Clogging with soil	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found	a	a	e	e	a	a	Nothing
		Water leak, Bearing water	Drainage facilities are broken and girder is directly afftected by drained water, etc.	a:Not found b:- c:- d:- e:Water leakage・Bearing water	e	a	e	a	a	a	Nothing
Whole bridge		Extraordinary deflection	Extraordinary deflection is found	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a
		Settlement, movement, tilting	Settlement, movement, incline at foundation and bearing, etc.	a:Not found b:- c:- d:- e:Found	a	a	a	a	a	a	a
		Scouring	Scouring at pier, foundation	a:Not found b:- c:Scouring d:- e:Severe scouring	a	a	a	a	a	a	a
		Others	Illegal occupation, graffiti, damage by birds, damage by fire, etc.	Only record	Bird nest			Moss			Moss

Source: JICA Study Team

<Table5-5> Summary table of damage evaluation criterion (South East-West Corridor: C-1～C-3 Bridge) & Paro Thromde (E-1 Bridge)

◎Judgement/record of condition of damage

Structure	Member	Material	Damage	Possibility of confirmation by visual inspection: Visual inspection (from a distance)	Possibility of confirmation by visual inspection: Visual inspection (closer)	Damage evaluation criterion (a～e) （Reference：Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan））	C-1 Diana Kuephen zam	C-2 Dramzang zam	C-3 Jitti zam	E-1 Dopshari zam
Super-structure	Deck Slab	Concrete	Spalling/ Rebar exposure	○	○	a:Not found, b:-, c:Peeling, d:Rebar exposure(small), e:Rebar exposure(big)				a
			Water leakage/ Free lime	○	○	a:Not found, b:-, c:Water leakage, d:Free lime, e:Free lime+Rust fluid				a
			Crack	○	○	Appendix				a
			peeling off	△	○	a:Not found b:- c:- d:- e:Found				a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found				a
	Main Girder	Steel	Corrosion	○	○	Appendix	a	a	a	
			Crack	×	○	a:Not found b:- c:Crack of paintingcoating d:- e:Absolute crack	a	a	a	
			Loosen / dropping of bolts	△	○	a:Not found, b:-, c:less than 5% of total, d:-, e:more than 5% of total	a	a	a	
			Fracture	△	○	a:Not found b:- c:- d:- e:Found	a	a	a	
			Deterioration of anti-corrosion function	△	○	a:Not found b:- c:Partial loose part d:Spalling e:Spalling and spot rusting	a	a	a	
		Concrete	Crack	○	○	Appendix				a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)				a
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leakage d:Free lime e:Free lime+Rust fluid				a
			Loose part	△	○	a:Not found b:- c:- d:- e:Found				a
Substructure	Body	Concrete	Crack	○	○	Appendix	c	d	c	a
			Spalling/ Rebar exposure	○	○	a:Not found b:- c:Peeling d:Rebar exposure(small) e:Rebar exposure(big)	a	a	c	a
			Water leakage/ Free lime	○	○	a:Not found b:- c:Water leak d:Free lime e:Free lime+Rust fluid	a	d	c	a
		Concrete block masonry	Deformation	○	○	a:Not found b:- c:- d:- e:Found				

◎Judgement/record of existence or non-existence of damage

Structure	Member	Kinds of damage	Contents	Damage evaluation criterion (a～e) （Reference：Ministry of Land, Infrastructure, Transport and Tourism, MLIT in Japan））	C-1 Diana Kuephen zam	C-2 Dramzang zam	C-3 Jitti zam	E-1 Dopshari zam
Bearing shoe	Shoe	Functional deficit	Severe corrosion, damage/hardening/missing of parts	a:Not found b:- c:- d:- e:Functional deficit due to damage	a	a	a	
		Extraordinary noises	Extraordinary noises in case of passing of vehicle	a:Not found b:- c:- d:- e:Found	a	a	a	
	Mortar	Clogging with soil	Clogging with soil and water	a:Not found b:- c:- d:- e:Found	a	c	c	e
		Deformation・Deficit	Crack of mortar, partial deficit	a:Not found b:- c:Partially found d:- e:Severely deficit	a	a	a	a
Ancillary facilities	Railing, Guardrail	Deformation・Deficit	Broken due to collision of vehicle	a:Not found b:- c:Partially found d:- e:Severely deficit	a	a	c	c
			Dangerous location for passangers		a	a	a	a
Deck surface	Pavement	Abnormity on pavement	Hole, big pothole, crack	a:Not found b:- c:- d:- e:Crack width is more than 5mm, etc			c	e
		Unevenness on road surface	Dangerous parts for passangers	a:Not found b:- c:less than 2cm d:- e:more than 2cm			a	a
	Expansion joint	Unevenness on road surface	Big gaps	a:Not found b:- c:less than 2cm d:- e:more than 2cm			a	e
		Abnormity at expansion gap	Broken	a:Not found b:- c:Small disconnect d:- e:Disjunction or contact			a	a
Drainage facilities		Clogging with soil	Clogging with soil and overlay	a:Not found b:- c:- d:- e:Found				a
		Water leak, Bearing water	Drainage facilities are broken and girder is directly afftected by drained water, etc.	a:Not found b:- c:- d:- e:Water leakage・Bearing water				a
Whole bridge		Extraordinary deflection	Extraordinary deflection is found	a:Not found b:- c:- d:- e:Found	a	a	c	a
		Settlement, movement, tilting	Settlement, movement, incline at foundation and bearing, etc.	a:Not found b:- c:- d:- e:Found	e	a	a	a
		Scouring	Scouring at pier, foundation	a:Not found b:- c:Scouring d:- e:Severe scouring	a	a	c	c
		Others	Illegal occupation, graffiti, damage by birds, damage by fire, etc.	Only record				Damage to pier (debris flow)

Source: JICA Study Team

(3) Overall Evaluation

On the basis of the survey results, overall evaluation is as follows for each bridge.

1) Overall Evaluation

A: Sound bridge, B: Bridge requiring measures, such as repair, C: Bridge requiring detailed survey for investigation of cause

2) Evaluation Criteria

The bridge is ranked "B" if there is any damage affecting its safety and stability as a bridge structure. Specifically, the bridges with "damage ranked at "d" or "e" regarding the superstructure and/or substructure" and/or with "damage ranked at "e" for the entire bridge" are categorized as "B". The bridges for which the cause of damage is difficult to determine in this visual inspection and for which the judgment as above described applies are categorized as "C".

<Table5-6> Summary table of damage evaluation

Road	No	Name of bridges	Result of evaluation of soundness	States of damage
A)Semtokha-Trashigang PNH	A-1	Semtokha flyover	A	
	A-2	Prakhadrang II	A	
	A-3	Namling zam	A	
	A-4	Gektong zam	A	
	A-5	Tangchu zam	B	Substructure: Rebar exprosure
	A-6	Rabten zam	A	
	A-7	Gyetsha zam	B	Superstructure: rebar exprosure
	A-8	Bong zam	B	Superstructure: rebar exprosure
	A-9	Nangni zam	B	Scouring
	A-10	Nikachu zam	B	Substructure: Crack
	A-11	Chuzomsa zam	B	Superstructure: rebar exprosure
B)Gelephu-Trongsa PNH	B-1	Passang zam	B	Superstructure: peeling off, corrosion Subtructure: deformation of maisonry
	B-2	Beteni zam	B	Substructure: Crack
	B-3	Katley III	B	Deformation of substructure: neccesity of detailed survey
	B-4	Chaplekhola	B	Superstructure: rebar exprosure
	B-5	Geleg(Aie) zam	B	Superstructure: peeling off, corrosion Substructure: free lime, rust fluid
	B-6	Samkhara zam	B	Superstructure: peeling off, corrosion
	B-7	Telegangchu zam	B	Superstructure: rebar exprosure
C)Samtse-Sipsu PNH	C-1	Diana Kuephen zam	C	Bridge: inclination
	C-2	Dramzang zam	B	Substructure: Crack
	C-3	Jitti zam	A	
E)Paro Thromde	E-1	Dopshari zam	A	

Source: JICA Study Team

Scouring at the foundation of Nangni zam Bridge has not progressed since the study in 2006. However, a re-survey is required considering the sudden swelling of the river recently. In addition, damage seems to be increasing as new cracks and exposure of reinforcing bar have been appeared on Nikachu zam Bridge and Chuzomusa zam Bridge since 2006. Condition of each bridge as assessed by the Study Team is shown in Appendix-3.

3) Proposal of Detailed Survey on Diana Kuephen zam Bridge

Diana Kuephen zam Bridge is a 1020-feet long Bailey bridge (suspension type) opened for service in 2003. The 2007 survey identified “inclination of the main tower” and “cracks in the anchorage”, but it is still in service. The visual inspection of this survey could not determine whether or not “inclination of the main tower” or “cracks in the anchorage” are critical. Since this bridge is on the Southern East-West Corridor and its damage state is likely related to the structural system, different from other bridges, the detailed survey as described below is proposed.

1) Observations of the Survey on Inclination of the Main Tower

- The pin bearing at the lower end of the main tower foundation functions as follows to adjust inclination of the tower. Namely, the tower is intentionally inclined toward the side span when there is no vehicle running on the bridge and is inclined toward the center span under the weight of vehicles if any are running on the center span.
- Panel points of the main tower are not rigid connections, but pin connections. Although the vertical load is predominant in the main tower, inclination caused by the unbalanced lateral load acting on the pin connections may lead to collapse because it is difficult to maintain its stability.
- The tower top is structured to allow sliding of the cable (wire). If this portion is so corroded as to make wire sliding impossible, a horizontal force occurs at the top and the resultant horizontal force may cause collapse of the tower similarly to the case above described. Specifically, such horizontal force may cause turning of the pin connections of the tower (no bending moment occurs because the connections are pin connections, but rotation may occur).

Source: JICA Study Team

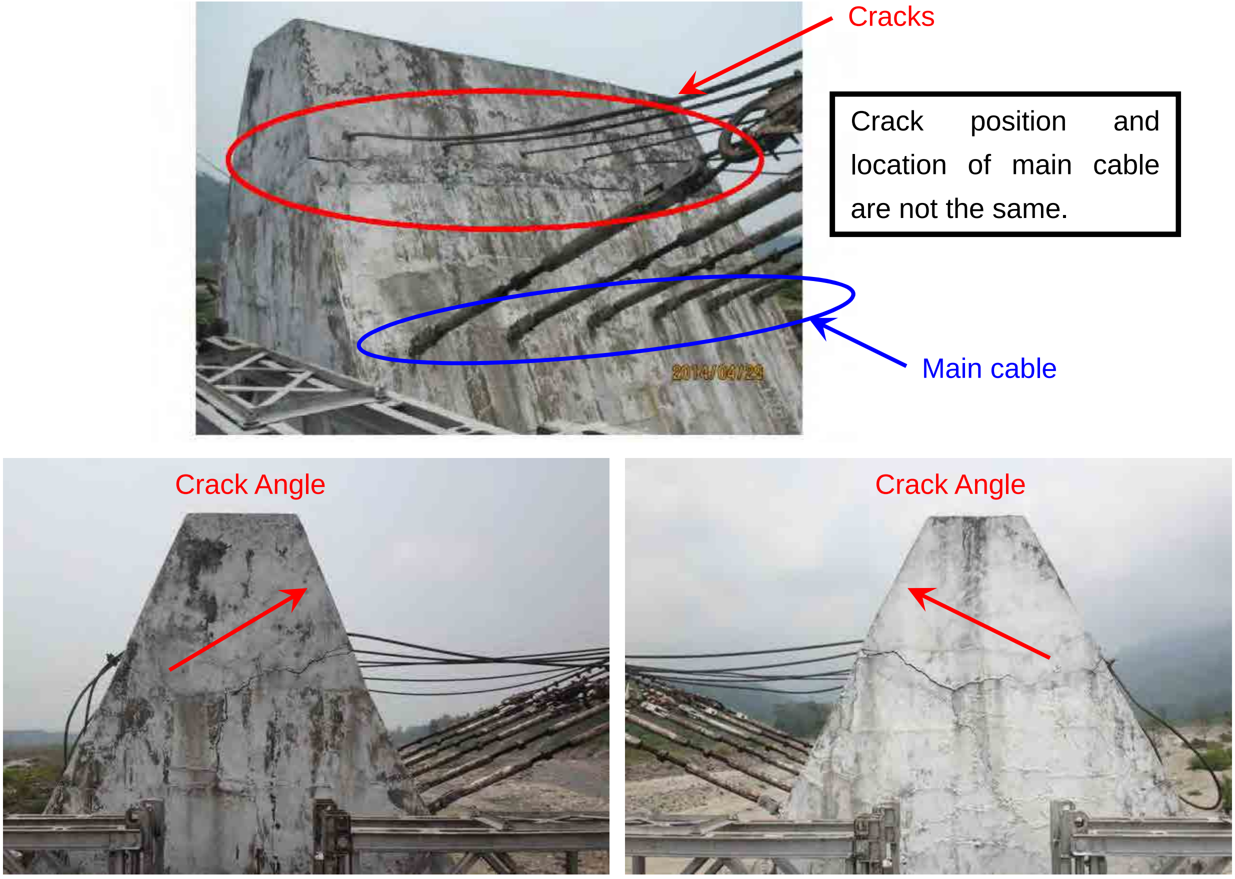
<Figure5-15> States of inclination of the main tower

＜Considerations related to inspection and survey＞

- It is considered essential to check the lubrication (grease is recommended) so as to prevent corrosion of the wire on the tower top.
- It may be necessary to fix (weld) the pin connections of the main tower to the vertical members (flat steel, angle, or H shape steel) to enable transmission of rotation.

2) Observations of the Survey on Cracks in the Anchorage

- The structure of wire anchoring of anchorage is not known. If the flat steel is provided to the wire rear portion, bearing pressure from flat steel is considered to have cause crack in the 45 degrees direction.



Source: JICA Study Team

<Figure5-16> Cracks in the anchorage

＜Considerations related to inspection and survey＞

- It is necessary to confirm the anchorage structure by referring to design drawings, etc.
- It is necessary to summarize the damage state, such as the direction of crack, etc.

3) Proposal of the Survey

【Primary survey : Intended to estimate the cause of damage】

a) Survey while referring to the design calculation

To estimate the cause of damage in the site, the design calculation is to be collected and checked:

・ Checking the design calculation model

Inclination of the main tower was observed. As the lower end is of a pin structure, inclination to a certain degree may occur.

・ Checking the design members

The member dimensions and arrangement as well as the materials used are checked by means of the core strength test of concrete, etc.

・ Anchorage design calculation

Stress calculation results, etc. are to be checked.

Source: JICA Study Team

<Figure5-17> Connection status of main tower and the bridge pier and beam

b) Survey to determine the damage state

・ Visual inspection and preparation of a damage map (location, direction, size of crack, and checking for buckling, etc.)

・ Survey of anchorage for cracks

For large cracks, the survey in terms of following points is conducted. (Structural factors; durability against temperature fluctuation; initial defect, construction joint during construction work)

【Secondary survey: Survey to identify the structural damage and the damage level related to durability】

a) Survey on the state related to the structure

State when active load is applied

Checking for abnormal displacement and/or distortion--Dynamic loading test

Checking the stress that has occurred --------------Static loading test

(Vehicles whose load is known)

b) Survey on the state related to the deterioration mechanism

Concrete members---Chipping survey (covering, steel member corrosion state), chloride ion test, carbonation depth measurement, alkali-aggregate reaction test

Steel members--------Checking for pitting corrosion and degree of corrosion

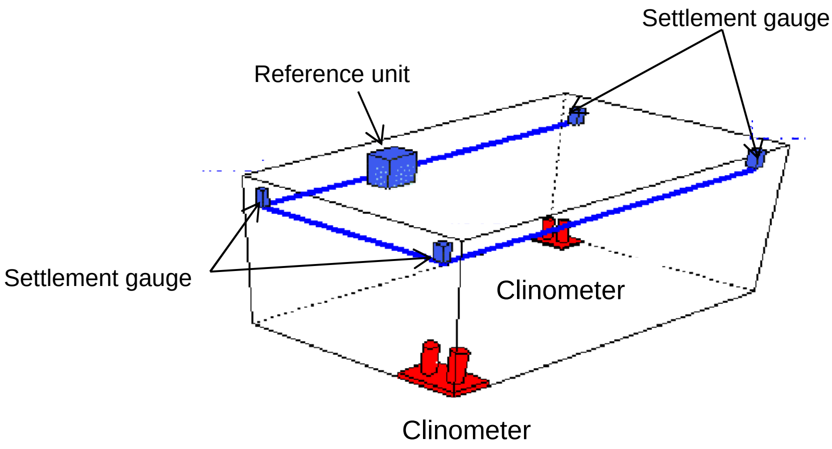
【Observation】

After completion of the survey, it is recommended to perform observations to identify the progress of damage.

Main tower: inclination of the anchorage: Inclinometer (Example; the figure in the right)

Cable tension: Strain gauge, EM sensor

Fixed point observation of sagging : Sagging of the main cable to be measured by means of camera



Source: Website

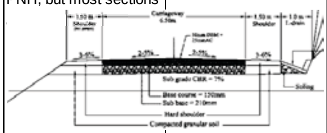
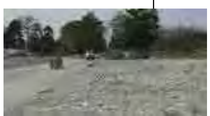
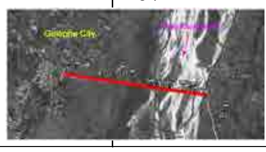
<Figure5-18> Measurement Procedure for subsidence and inclination of structure (Example)

5-3.Summary of Traffic Bottlenecks on National Highways

After the summary of details in the above description, eight traffic bottlenecks in the survey could be identified as follows. Table5-7 summarizes the details of each factor hindering transportation.

① Narrow carriageway width (including bridge width)
② Deficient geometric design due to precipitous terrain and rocky area
③ Bridges with insufficient loading capacity
④ Damage to the pavement at high altitude pass
⑤ Road blockage by slope failure
⑥ Road blockage by snow damage
⑦ Road blockage by heavy rain
⑧ Lack of alternative route to PNH-1 (East – West Highway)

<Table5-7> Details of factors hindering transportation as confirmed in this study

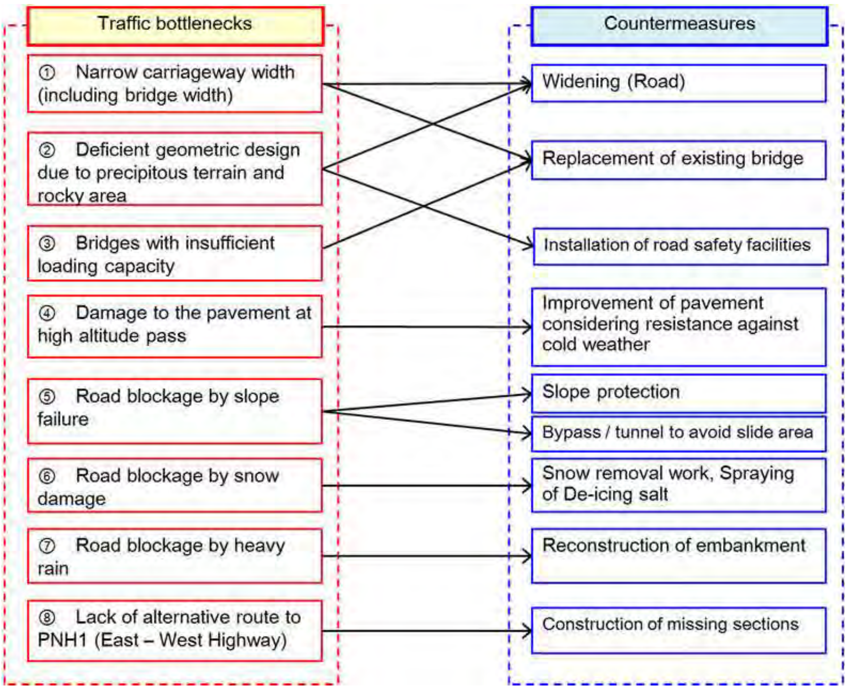
No.	Bottleneck to be found	Name of PNH	States	Problems	Measures	Remarks
①	Narrow carriageway width (including bridge width)	PNH-1	6.5m of carriageway width is required for PNH, but most sections 	-Traffic jam	-Widening	Widening is being carried out by DoR. 
②	Deficient geometric design due to precipitous terrain and rocky area	PNH1,PNH-4	Small radius is used in order to avoid obstacle of rock. Sight distance and vertical clearance cannot be ensured.	-Traffic accident (head-on collision, rockfall) -Uncomfortable travelling -Loss of travelling time	- Widening (Half tunneling) - Tunnel - Installation of road safety facilities (curved mirror, etc) 	 
③	Bridges with insufficient loading capacity	PNH-1 PNH-4 Southern East-West Corridor (existing section only)	"IRC load class 70R" is required for bridge on PNH, but most existing bridges are less than that (18MT, 40MT).	Collapse/damage of bridge in case of heavy vehicle passing	Replacement/ strengthening of existing bridge	Following three bridges on PNH-1 will be replaced by JICA; Nangni zam Nikachu zam Chuzomsa zam
④	Damage to the pavement at high altitude pass	PNH1	At the north side of Thrumshingla, pavement is severely damaged due to low temperature and snowfall in the winter.	- Uncomfortable travelling - Loss of travelling time - Damage to the vehicle	Improvement of pavement considering resistance against cold weather 	ADB carried out a project on improvement of pavement at the north side of Thrumshingla in 2004, but it resulted in failure.
⑤	Road blockage by slope failure	PNH-1 PNH-4 Southern East-West Corridor (existing section only)	During the rainy season, slope failure is happened at several locations along PNH and road is blocked.	- Accident (rockfall, slope failure) - Traffic jam / loss of travelling time	- Slope protection (ground anchor, rock bolt, flame, etc.) - Bypass / tunnel to avoid slide area	Study for slope management will be carried out in another JICA study which is going to start in July 2014.
⑥	Road blockage by snow damage	PNH1	In 2013 at Thrumshingla, snow removal work was carried out by regional office 10-15 times from November to March and Nu.1.5 million has been spent.	- Road is blocked and traffic jam happens during snow removal work. - Traffic accident due to snow covering 	- Clearing with pay loader - Spraying of De-icing salt - Re-align of vertical alignment (to make gradient gentle)	Equipment and material that regional office uses for snow removal work are lacking in numbers and the technology level is low also. 
⑦	Road blockage by heavy rain (submerged road)	PNH-4 Southern East-West Corridor (existing section only)	In the southern part of Bhutan, some sections of PNH are submerged during rainy season because of insufficient height of embankment.	- Traffic jam / loss of travelling time due to roadblock - Damage to the vehicle due to rolling stone	Reconstruction of embankment considering high water level in the rainy season 	
⑧	Lack of alternative route to PNH1 (East – West Highway)	Southern East-West Corridor (existing section only)	There is no alternative route of PNH-1 at present due to incompletion of SEWC.	Cutoff of logistics in case of disruption of PNH-1	Construction of missing sections (road and bridge) of SEWC 	Assistance for construction of Mau Khola Bridge is highly expected to JICA from DoR.

Source: JICA Study Team

Chapter 6 Review of the Priority Order for Expected Infrastructure Development, Selection of Priority Projects, and Various Reviews

6-1. Summary of Expected Infrastructure Development

Figure6-1 shows the relationship between eight traffic bottlenecks as extracted in Chapter 5 and the countermeasures necessary to overcome such factors. The countermeasures shown in the figure can be candidates of infrastructure development to be implemented by Japan's future aid.



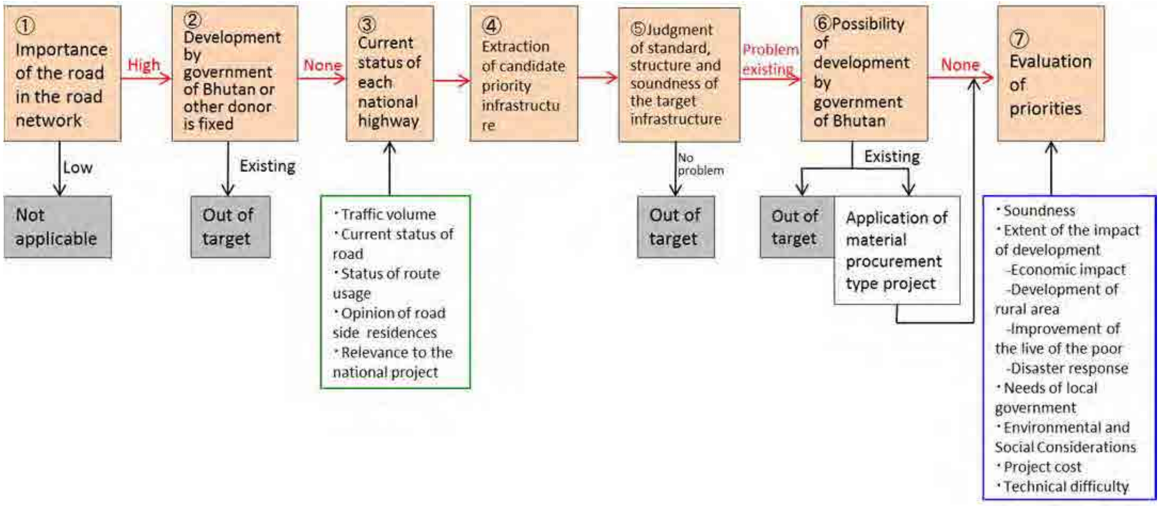
Source: JICA Study Team

<Figure6-1> Relationship between traffic bottlenecks and expected infrastructure development projects

6-2.Viewpoint and Method of Review

The order of priority of infrastructure development is determined according to the flow shown in Figure6-2. Such determination is made not only on the basis of the traffic volume (large/small), but also by taking into account the correction of regional disparity between urban and rural areas, which has been the subject of development in Bhutan, and improvement of the life quality of the poor. In this event, review is performed by referring to the information, such as the population, industry, education, etc., of each Geog summarized in the "Dzongkhag Rural Access Planning (DRAP)" established for each Dzongkhag. It is also essential to consider the relationship with the large-scale national projects vital for economic development of the country. Specifically, factors important for construction of the Punatsangchhu and the Mangdechhu Hydroelectric Project currently under way in Wangdue Phodrang Dzongkhag, Trongsa

Dzongkhag, and other Dzongkhags include the possibility of transporting the materials and equipment for facility construction. It is also essential to consider the infrastructure development from the viewpoint of enhancing the project effects through synergetic effects by linking with the projects implemented under Japan's aid.



Source: JICA Study Team

<Figure6-2>Priority order selection flow

For the bridge reconstruction project, the bridges to be reconstructed are functionally insufficient in terms of the width (4.0 - 4.5m), loading capacity, and height restriction. It is not all of them that face substantial structural problems. In this context, reconstruction of bridges, if it should be done, must normally be implemented in the priority order beginning with the bridge ensuring higher economic effect.

6-3.Selection of Priority Projects

6-3-1. Selection of Priority Projects

For the 11 infrastructure development projects listed in Table 6-1, the priority was assessed on the basis of five assessment viewpoints shown in Table6-1. Individual assessment viewpoints were assigned with the score of one of three stages (A, B, C) and the priority A was assumed to be the case when the total of five assessment viewpoint scores was 20 or more (average score is 4 or more). Four priority projects shown below were selected in this study:

① Reconstruction of existing bridges
② Tunnel based on road widening in rocky area
③ Improvement of pavement in high-altitude areas (pavement in cold areas)
④ Construction of the road/bridge in the missing section of the Southern East-West Corridor

Note that the road widening project is ranked priority A. However the project is excluded from the priority projects because it is no problem for DoR to carry it out using their own technology. And also the measures on slope and bypass/tunnel construction are ranked priority A. However these projects are excluded from the priority projects because their formation would better be done by DoR through implementation of a JICA Technical Cooperation Project, "Project for Master Plan Study on Road Slope Management in Bhutan," which is scheduled to be started in July, 2014.

<Table6-1> Selection of the priority projects

No.	Kind of Bottleneck	Countermeasure	Priority	Evaluation of priorities					
				Importance in road network	Priority within DoR	Contribution to the local people	Urgency (Soundness)	Technical difficulties	Rating (A=5,B=3,C=1)
①	Narrow carriageway width (including bridge width)	Widening (Road)	B	A	A	A	B	B	21
		Replacement of existing bridge	A	A	A	A	A	A	25
②	Deficient geometric design due to precipitous terrain and rocky area	Widening (Road)	A	A	A	A	B	A	23
		Installation of road safety facilities	B	B	C	B	B	A	15
③	Bridges with insufficient loading capacity	Replacement of existing bridge	A	A	A	A	A	A	25
④	Damage to the pavement at high altitude pass	Improvement of pavement considering resistance against cold weather	A	A	A	B	B	A	21
⑤	Road blockage by slope failure	Slope protection	A	A	A	A	A	A	25
		Bypass / tunnel to avoid slide area	A	A	A	A	B	A	23
⑥	Road blockage by snow damage	Snow removal work, Spraying of De-icing salt	B	A	B	B	B	B	17
⑦	Road blockage by heavy rain	Reconstruction of embankment	C	B	C	B	B	B	13
⑧	Lack of alternative route to PNH1 (East – West Highway)	Construction of missing sections	A	A	A	A	A	A	25

Source: JICA Study Team

6-3-2. Review of the Reconstruction Priority of Existing Bridges

In this section, the reconstruction priority was reviewed on the 22 bridges concerned by focusing on “Reconstruction of existing bridge” in priority projects shown in Chapter6-3-1 above. The eight factors listed below were taken into account for assessment of the priority of reconstruction:

① Width
② Loading capacity
③ Traffic volume
④ Degree of damage
⑤ Construction timing and lifetime
⑥ Risk of natural disaster
⑦ Contribution to the hydropower plant construction projects
⑧ Priority by DoR

Individual assessment viewpoints were assigned with the score (5, 3, or 1points) of one of three categories (A, B, C). The bridge for which the total of assessment points of each item is 30 or more is chosen as a bridge reconstruction priority project. Assessment results are shown in Table6-2 to Table6-4.

<Table6-2> Results of review on the reconstruction priority among existing bridges

Bridges on PNH-1

SN	Bridge Name	Length	Type	Evaluation viewpoint (Necessity of improvement) ① Width	② Loading capacity	③ Traffic volume	④ Degree of damage	⑤ Construction timing and lifetime	⑥ Risk against natural disaster	⑦ Contribution to hydropower project	⑧ DoR's Priority for replacement	Rating (A=5,B=3,C=1)	Priority by JICA Study Team
A	Semtokha - Trashigang PNH (PNH-1)												
1	Semtokha flyover	15m	RC T-Beam	A	A	A	C	A	C	A	A	32	A
				4.75m	30MT			1964	-	-	This bridge is in core city area and important link to central and eastern Bhutan		
2	Prakhadrang II	80ft	BB	A	A	C	B	A	A	B	A	32	A
				3.27m	18MT			2004, but temporary bridge only	Flood	Kholongchhu HPP	This bridge is on northern east - west highway. It was constructed using old Bailey bridge parts and its width and load carrying capacity is limited.		
3	Namling zam	90ft	BB	A	A	C	B	A	A	B	A	32	A
				3.27m	18MT			2003, but temporary bridge only	Flood	Rothpashong HPP	This bridge is on northern east - west highway. Its width and load carrying capacity is limited.		
4	Gektong zam	110ft	BB	A	A	B	B	B	C	B	A	28	B
				4.27m	40MT			2012, but temporary bridge only	-		This bridge is on northern east - west bypass highway. Its width and load carrying capacity is limited.		
5	Tangchu zam	33.5m	RCC T-Beam	A	A	B	B	A	C	C	B	26	B
				4.50m	40MT			1987	-	-	Bridgeis quite old and has width and load carrying capacity restrictions		
6	Rabten zam	25m	RCC T-Beam	A	A	C	C	A	B	C	B	24	C
				4.50m	40MT			1982			Bridgeis quite old and has width and load carrying capacity restrictions		
7	Gyetsha zam	23.6m	RCC T-Beam	A	A	C	B	A	B	C	B	26	B
				4.50m	40MT			1981			Bridgeis quite old and has width and load carrying capacity restrictions		
8	Bong zam	23.6m	RCC T-Beam	A	A	C	B	A	B	C	B	26	B
				4.50m	40MT			1981			Bridgeis quite old and has width and load carrying capacity restrictions		
9	Nangni zam	24.7m	RCC T-Beam	A	A	B	B	A	B	A	A	34	A
				4.50m	40MT			1982		Mangdechu HPP, Nikachu and Chamkharchu HPPs	This is proposed to be replaced for transportation of heavy electro-mechanical equipments for Mangdechu Hydropower projects, upcoming Nikachu and Chamkharchu Hydropower projects.		
10	Nikachu zam	28m	RCC T-Beam	A	A	B	B	A	B	A	A	34	A
				4.50m	40MT			1982		Mangdechu HPP, Nikachu and Chamkharchu HPPs	This is proposed to be replaced for transportation of heavy electro-mechanical equipments for Mangdechu Hydropower projects, upcoming Nikachu and Chamkharchu Hydropower projects.		
11	Chuzomsa zam	28m	RCC T-Beam	A	A	B	B	A	B	A	A	34	A
				4.50m	40MT			1988		Mangdechu HPP, Nikachu and Chamkharchu HPPs	This is proposed to be replaced for transportation of heavy electro-mechanical equipments for Mangdechu Hydropower projects, upcoming Nikachu and Chamkharchu Hydropower projects.		

Source: JICA Study Team

<Table6-3> Results of review on the reconstruction priority among existing bridges

Bridges on PNH-4

SN	Bridge Name	Length	Type	Evaluation viewpoint (Necessity of improvement) ① Width	② Loading capacity	③ Traffic volume	④ Degree of damage	⑤ Construction timing and lifetime	⑥ Risk against natural disaster	⑦ Contribution to hydropower project		⑧ DoR's Priority for replacement		Rating (A=5,B=3,C=1)	Priority by JICA Study Team
B	Gelephu - Trongsa PNH (PNH-4)														
1	Passang zam	40m	Steel Hemilton	C	A	C	B	A	A	A	Mangdechu HPP and upcoming Nikachu and Chamkharchu HPPs	A	These bridges are on north-south highway. They are proposed to be replaced for transportation of heavy electro-mechanical equipments for Mangdechu Hydropower projects, upcoming Nikachu and Chamkharchu Hydropower projects.	30	A
				7.5m	24MT		-	1970	Flood						
2	Beteni zam	25m	RC T-Beam	A	A	C	B	A	C	A		A		30	A
				4.2m	40MT		-	1987	-						
3	Katley III	25m	RCC T-Beam	A	A	C	B	A	B	A		A		32	A
				4.5m	40MT		-	1981	Land slide						
4	Chaplekhola	20m	RCC T-Beam	A	A	C	B	A	C	A		A		30	A
				4.5m	40MT		-	1969	-						
5	Geleg (Aie) zam	120m	Steel Truss	A	A	C	B	B	C	A		A		28	B
				4.3m	40MT		-	2001	-						
6	Samkhara zam	61m	Steel Truss	A	A	C	B	B	B	A		A		30	A
				4.3m	40MT		-	2001	Debris						
7	Telegangchu zam	25m	RCC T-Beam	A	A	C	B	A	C	A		A		30	A
				4.5m	40MT		-	1981	-						

Source: JICA Study Team

<Table6-4> Results of review on the reconstruction priority among existing bridges
Bridges on the Southern East-West Corridor and in Paro Thromde

SN	Bridge Name	Length	Type	Evaluation viewpoint (Necessity of improvement)								Rating (A=5,B=3,C=1)	Priority by JICA Study Team
				① Width	② Loading capacity	③ Traffic volume	④ Degree of damage	⑤ Construction timing and lifetime	⑥ Risk against natural disaster	⑦ Contribution to hydropower project	⑧ DoR's Priority for replacement		
C	Samtse-Sipsu PNH (SEWC)												
				A	A	C	A	A	A	C	A		
1	Diana Kuephen zam	1020ft	BSB & BB	3.27m	12MT			2003, but temporary bridge only	Flood		This bridge is one of the most critical bridges on southern east-west highway. The existing bridge constructed in 2003 had initial load carrying capacity of 18 MT. However, due to old age and development of cracks on sub-structure, its capacity is now reduced. Vehicles carrying higher loads than its capacity are one of the factors for degradation of existing structures. The Department has plans to replace it as early as possible. The Life span of Bailey Suspension bridge is only for around 10 to 15 years. With the upcoming industries in Samtse, heavy traffic are expected and this bridge would be widely used. They would also require higher load carrying capacity bridges on this highway. As such, the replacement of this bridge as early as possible is seen as top most priority.	32	A
				A	A	C	B	A	A	C	B		
2	Dramzang zam	380ft	BB	3.27m	18MT			1990	Flood		This bridge is one of the oldest bridge on southern east-west highway. Due to land slides on the upstream side, lots of debris gets deposited near the bridge. The river also changes it course frequently washing away road embankments and posing risk to abutments. With the upcoming industries in Samtse, heavy traffic are expected and it would require bridge with higher load carrying capacity. As such, the replacement of this bridge as early as possible is seen as top most priority.	28	B
				A	A	C	C	A	A	C	B		
3	Jitti zam	250ft	BB	3.27m	18MT			2001, but temporary bridge only	Flood		This bridge is also crucial on the southern east-west highway. During monsoon it brings lot of debris. With the upcoming industries in Samtse, heavy traffic are expected and it would require bridge with higher load carrying capacity. As such, it is proposed for replacement.	26	B
E	Paro Thromde												
				A	A	C	C	A	B	C	B		
1	Dopshari zam	28.8m	RC T-Beam	4.5m	30MT			N.A, but old			This bridge is quite old with some of the concrete surfaces spalling off and reinforcements exposed. It has width and load carrying capacity restrictions	24	C

Source: JICA Study Team

As a result of the priority assessment as described above, the eight bridges shown in Table6-5 were determined as priority projects.

<Table6-5>Priority Bridge Project

Priority	Score	Bridge name		Route	Remarks
A more than 30 points	34	Nangni zam	A-9	PNH-1	These bridges will be reconstructed in another JICA project, therefore, these are excluded from priority project in this study.
	34	Nikachu zam	A-10	PNH-1	
	34	Chuzomsa zam	A-11	PNH-1	
	32	Semtokha flyover	A-1	PNH-1	Replacement is planned by DoR, therefore, this bridge is excluded from JICA's future project.
	32	Prakhadrang II	A-2	PNH-1	This bridge will be reconstructed by GOI.
	32	Namling zam	A-3	PNH-1	Selected as a priority project in the study
	32	Katley III	B-3	PNH-4	
	32	Diana Kuephen zam	C-1	SEWC	
	30	Passang zam	B-1	PNH-4	
	30	Beteni zam	B-2	PNH-4	
	30	Chaplekhola	B-4	PNH-4	
	30	Samkhara zam	B-6	PNH-4	
	30	Telegangchu zam	B-7	PNH-4	
B 25-29 points	28	Gektong zam	A-4	PNH-1	
	28	Geleg (Aie) zam	B-5	PNH-4	
	28	Dramzang zam	C-2	SEWC	
	26	Tangchu zam	A-5	PNH-1	
	26	Gyetsha zam	A-7	PNH-1	
	26	Bong zam	A-8	PNH-1	
	26	Jitti zam	C-3	SEWC	
C less than 25 points	24	Rabten zam	A-6	PNH-1	
	24	Dopshari zam	E-1	Paro Thromde	

Source: JICA Study Team

6-3-3. Selection of Target Location of Road Widening on Rocky Slopes

With regard to road widening on bedrock slopes, many spots which can be selected as target project are spread along the whole of each national highway. Among them Namling Cliff and Thomang Cliff on PNH-1 have particularly long lengths and the priority and urgency of DoR regarding them is high.

Thomang Cliff is located between Wangdue and Trongsa on PNH-1 and this section has the second largest traffic volume on PNH-1 after the section between Thimphu and Wangdue, therefore this section has high importance as a part of the road network. In addition, this is the section that construction vehicles for the Mangdechhu Hydroelectric Project travel, therefore the road widening of this section is important to promote the construction as well. Also, Thomang Cliff and Namling Cliff are massive rocks with few cracks and have a structure that contains many opposite dips. Therefore, a project that can implement countermeasures to avoid the risk of peeling-off of the rocks, which could occur after construction will increase the probability that Japan will cooperate in the future. For these reasons, Thomang Cliff and Namling Cliff are selected as priority projects.

6-3-4. Selection of Target Location on the Improvement of Pavement in the Snowy Cold Region

With regard to the improvement of pavement in the snowy cold region, only mountain passes on PNH-1 can be targeted. There are 5 mountain pass lyocations which are more than 3,000m in altitude and it was confirmed that only the 5km section on the north slope of Thrumshingla Pass has heavy damage to the pavement as observed in the site inspection of this study. Also, according to DoR, other mountain passes can be improved using the Bhutanese technology level, therefore only Thrumshingla Pass is selected as a priority project in this study.

6-4.Various Reviews on Priority Projects

6-4-1. Verification of Impacts on Surrounding Environment and Society

Concerning the priority projects, JICA Study Team visited the project sites and checked for the impacts they may have on the environment and society. JICA Study Team decided to check the results of the onsite survey based on the Environmental Check List attached to JICA Guidelines for Environmental and Social Considerations (2010). Since all of the priority projects concern bridges and road improvement, our verification was made against items in the Bridge and Road section in the Environmental Check List.

The results of this abbreviated scoping for each priority project are shown in Appendix-4. The study on Maukhola Bridge is described in Chapter 7.

(1) Necessity of Permission and Authorization for Development

As mentioned aforesaid, all of the priority projects require environmental clearance before starting construction work. Since not all of the priority projects have been subject to an environmental assessment, JICA Study Team will need, for some of the projects, to consult the DoR and conduct surveys on environmental and social considerations around the infrastructure before applying for environmental clearance. In particular, it should be noted that, for the projects located in or around the national parks and biological corridors to be discussed later, JICA Study Team will very probably need to consult MoAF that controls the national parks and follow EIA procedure before conducting environmental surveys.

(2) Measures against Pollution

JICA Study Team checked the bridge projects for their impact on air quality, water quality, noise, and vibration, which were picked up from the items regarding Bridges on the checklist; and also for the tunnel and pavement improvement projects for their impact on air quality, water quality, noise and vibration, and waste materials picked up from the items regarding Roads on the checklist. The results of the verification are as shown below.

<Table6-6> Verification of measures against pollution

No	Impact Items										Tunnel		Pavement improvement	Remarks
			A-3	B-1	B-2	B-3	B-4	B-6	B-7	C-1				
			Namling zam	Passang zam	Beteni zam	Katley III	Chaplekhola	Samkhara zam	Telegangchu zam	Diana Kuephen zam	Thomang Cliff	Namling Cliff	Thrumshingla Pass	
1	Air Quality	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
2	Water Quality	Pre/During Construction Phase	2	2	2	2	2	2	2	2	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
3	Noise and Vibration	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
4	Waste	Pre/During Construction Phase	-	-	-	-	-	-	-	-	2	2	2	Bridge is not applicable
		Opreration Phase	-	-	-	-	-	-	-	-	4	4	4	

1 : Serious impact is expected
2 : Some impact is expected
3 : Extent of impact is unknown (Detailed survey is required)
4 : Few Impacts are expeced

Source: JICA Study Team

1) Air Quality

For the Bridge/Tunnel/Pavement Improvement projects, there is a concern regarding the impact of dust from vehicles and machinery working on the site. Since this is limited to the construction period, however, JICA Study Team assumes that they won't have a serious impact on the surrounding environment.

2) Water Quality

For the Bridge projects, there is a concern about water contamination since all of the bridges cross rivers. Since the rivers are low during the dry season and the construction is limited to this period, JICA Study Team assumed that they won't have a serious impact on the surrounding environment. For the Tunnel and Pavement Improvement projects, there will be no impact on water quality, because there are no rivers near them.

3) Noise and Vibration

For the Bridge/Tunnel/Pavement Improvement projects, noise and vibration are to be expected from construction machinery at work. Since this is limited to the construction period, however, JICA Study Team assumes that they won't have a serious impact on the surrounding environment.

4) Waste Materials

For the Tunnel/Pavement Improvement projects, it is necessary to dispose, according to Bhutanese regulations, earth and rocks from excavation of road slopes and pavement materials and aggregates from replaced pavements.

(3) Natural Environment

JICA Study Team checked each project for its impact on protected areas, ecosystems, hydrology, terrain and geology, as listed in the items in the Bridges and Roads checklist. The results of verification are as shown below. During road widening and maintenance of bridge approach roads when tree cutting is involved in the modification of a slope, obtaining Forest Clearance is required. This Forest Clearance is also necessary when environmental clearance is acquired in the government development project. Also, the "National Forest Policy" suggests planting trees equivalent to the trees that have been cut down.

<Table6-7> Verification of impact on the natural environment

No	Impact Items		A-3	B-1	B-2	B-3	B-4	B-6	B-7	C-1	Tunnel		Pavement improvement	Remarks
			Namling zam	Passang zam	Beteni zam	Katley III	Chaplekhola	Samkhara zam	Telegangchu zam	Diana Kuephen zam	Thomang Cliff	Namling Cliff	Thrumshingla Pass	
1	Proteced Area	Pre/During Construction Phase	2	4	4	2	2	4	4	4	4	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
2	Ecosystem	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
3	Hydrology	Pre/During Construction Phase	4	4	4	4	4	4	4	4	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
4	Topogaphy and Geology	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	2	4	2	2	2	2	2	4	4	4	2	

1 : Serious impact is expected

2 : Some impact is expected

3 : Extent of impact is unknown (Detailed survey is required)

4 : Few Impacts are expeced

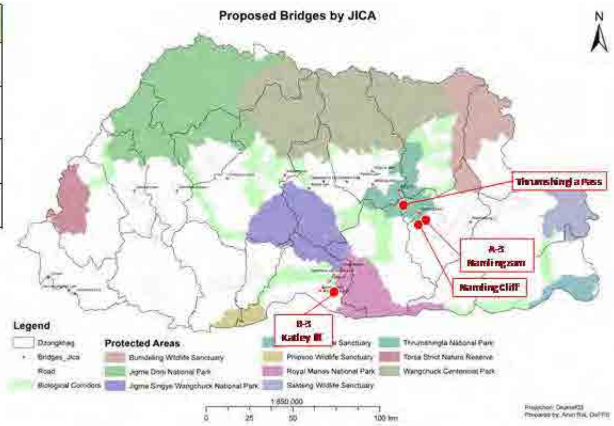
Source: JICA Study Team

1) Protected Areas

For the locations of bridges and their relationships with national parks, wildlife sanctuaries, and biological corridors, JICA Study Team offered data on bridge locations (GPS data) that JICA Study Team had collected during the onsite survey, to the Department of Forest and Park Services (DFPS), MoAF, who is in charge of these facilities, for their verification and confirmation. The DFPS confirmed that Namling zam and Katlely III are located within national parks or biological corridors, as shown below. From the locality map of national parks, wildlife sanctuaries, and biological corridors offered by the DFPS, JICA Study Team judged that Namling Cliff, where the construction of a tunnel is being considered, and Thrumshingla Pass, where pavement improvement work is planned, are located in national parks, too.

JICA Study Team assumes that these projects located in national parks and on biological corridors won't have serious impacts if the project is for replacing an existing bridge, since the scope of work is limited to the bridge and its periphery. For tunnels and pavement improvement projects, further surveys will be necessary before implementing them, because their impact may vary depending on how long the work continues or how large the tunnel is. Note that for all projects it is necessary to check with MoAF and follow the environmental assessment and other procedures prescribed for development projects in national parks and check for their environmental impacts again.

Items	No.	Name of project	National Parks, Wildlife Sanctuaries and Biological Corridors which project site is located
Bridge	A-3	Namling zam	Thrumshingla National Park
	B-3	Katley III	Biological Corridor (Connecting Jigme Singye Wangchuck National Park - Royal Manas National Park - Phipsoo Wildlife Sanctuary)
Tunnel		Namling Cliff	Thrumshingla National Park
Pavement improvement		Thrumshingla Pass	Thrumshingla National Park



Source: Department of Forest and Park Services, MoAF
<Figure 6-3> Relationship between the locations of priority projects and national parks, wildlife sanctuaries, and biological corridors

2) Ecosystems

JICA Study Team assumes that the priority projects won't have serious impacts on ecosystems, because they all consist in replacing existing bridges, improving pavements or building tunnels along the road, with the scope of work limited to the bridge, road, and their periphery, and won't have negative impacts on flora, fauna or animal corridors.

3) Hydrology

JICA Study Team assume that the Bridge projects won't have negative impact on the hydrology, because they mainly consist in replacing existing bridges and don't include any work that might adversely influence the flow of the river, such as river improvement work. As to Tunnel projects, a possible concern is changes in surface water flows, despite the absence of rivers around the site, due to the excavation of the tunnel and resulting changes in terrain, but JICA Study Team thinks to be able to avoid serious impacts by carefully designing the tunnel drainage. In addition, impacts on groundwater level by excavation are expected. Since there are no residences or villages observed near the project sites, no impact on living, such as dried wells is expected, however, a hydrological survey beforehand and monitoring of water level and water quality during construction are required considering the water use in the future. As for Pavement Improvement projects, JICA Study Team assumes that the work will not have significant impacts on the flow of water as long as the scope of work is limited to improvement.

4) Geography and Geology

For Bridge projects, substructure work may effect some change in geography. For tunnels, excavation work, etc. may cause change in geography. For Pavement projects, they won't have any impact on geography or geology if the work is limited to improvement. In many of the priority projects, the road often runs at the foot of a steep slope and is prone to rock falls and landslides, so care should be taken to protect against such accidents before, during, and after the completion of the work, in particular in the rainy season.

(4) Social Environment

JICA Study Team checked each project for its impact on resettlement, the lives and living of the project affected people, and cultural heritages, as well as its impact on landscape, ethnic minorities, indigenous people and working conditions, picked up from the items on the Bridges and Roads checklist. The results of the verification are as shown below.

<Table6-8> Verification of impact on social environment

No	Impact Items		A-3	B-1	B-2	B-3	B-4	B-6	B-7	C-1	Tunnel		Pavement improvement	Remarks
			Namling zam	Passang zam	Beteni zam	Katley III	Chaplekhola	Samkhara zam	Telegangchu zam	Diana Kuephen zam	Thomang Cliff	Namling Cliff	Thrumshingla Pass	
1	Resettlement	Pre/During Construction Phase	4	4	4	4	4	4	4	4	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
2	Living and Livelihood	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
3	Heritage	Pre/During Construction Phase	4	4	4	4	4	4	4	4	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
4	Heritage	Pre/During Construction Phase	4	4	4	4	4	4	4	4	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
5	Ethnic Minorities and	Pre/During Construction Phase	4	4	4	4	4	4	4	4	4	4	4	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
6	Labor environment	Pre/During Construction Phase	2	2	2	2	2	2	2	2	2	2	2	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	

1 : Serious impact is expected
2 : Some impact is expected
3 : Extent of impact is unknown (Detailed survey is required)
4 : Few Impacts are expeced

Source: JICA Study Team

1) Resettlement

Regarding resettlement, the site surveys showed that there were no villages or residences observed near any priority project site. Hence, resettlement caused by projects is not expected.

2) Lives and Living

All of the priority projects are located along national highways. If traffic is restricted during the work, that may influence the circulation of people and goods because there will be no other route to take. However, considering that most of the Bridge projects are very likely to be replacement of existing bridges, the work won't have serious impacts on the lives and living of inhabitants if JICA Study Team will be careful to ensure traffic can flow during the work using the existing bridge and, even if the execution plan makes it unavoidable to restrict traffic, to finish the restriction as early as possible. As to the Tunnel projects, there probably will be traffic control for large-scale work such as excavation, because it will be difficult to ensure smooth traffic flow even using the one-way alternating traffic method. So, the execution plan will have to be arranged so that the duration of control is as short as possible. As to the Pavement Improvement projects, the impact may be less, because there is a good chance that JICA Study Team can ensure traffic to some extent by using the one-way alternating traffic method, etc.

3) Cultural Heritage

There is no archeological, historic, cultural, item of religious heritage or monument of importance around any of the priority project sites.

4) Landscape

There is no remarkable landscape to take special care of around any of the priority project sites.

5) Ethnic Minorities and Indigenous People

There are no ethnic minorities or indigenous people to take special care of that are living around any of the priority project sites.

6) Working Conditions

In each priority project, care should be taken regarding workers' working environment during the work. Since bridge and tunnel construction sites, in particular, often include work on a slope or at height, consideration should be given to requiring the contractor to take safety measures to ensure workers' safety at work. Further, considering that many sites include slopes with exposed or weathered rocks, care should be taken to take necessary safety measures against rock falls.

(5) Others

JICA Study Team checked each project for its impact during the work and monitoring, which was listed in the items in the Bridge and Road checklist. The results of the verification are as shown below.

<Table6-9> Verification of impacts during the work and monitoring system

No	Impact Items		A-3	B-1	B-2	B-3	B-4	B-6	B-7	C-1	Tunnel		Pavement improvement	Remarks
			Namling zam	Passang zam	Beteni zam	Katley III	Chaplekhola	Samkhara zam	Telegangchu zam	Diana Kuephen zam	Thomang Cliff	Namling Cliff	Thrumshingla Pass	
1	Impacts during Construction	Pre/During Construction Phase	3	3	3	3	3	3	3	3	3	3	3	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	
2	Monitoring	Pre/During Construction Phase	3	3	3	3	3	3	3	3	3	3	3	
		Opreration Phase	4	4	4	4	4	4	4	4	4	4	4	

1 : Serious impact is expected
2 : Some impact is expected
3 : Extent of impact is unknown (Detailed survey is required)
4 : Few Impacts are expeced

Source: JICA Study Team

1) Impact of the Project during the Construction

The type and method of work selected for each priority project varies with the natural environment, terrain, and geology in or on which the project is located. As to measures to protect against probable environmental pollution from the construction, JICA Study Team should discuss and reconsider, with the designers and the host national agency, measures that are adapted to the selected type and method of construction to prevent or mitigate the impacts before implementing the project.

Further, consideration should be given anew to the social impacts not only of measures to protect against pollution but also of traffic control during the construction (the necessity/duration of traffic control).

2) Monitoring

For each priority project, JICA Study Team needs to develop a plan for monitoring environmental pollution likely to be caused by the work (method, frequency, and system) adapted to the execution plan, type and method of work of the project. This requires a further detailed survey every time each project is surveyed. Moreover, when conducting the survey, consideration should be given to requiring the contractor to monitor how the work is done and report the results thereof.

6-4-2. Review of the Necessity of Disaster Prevention Measures

If the priority project covers a bridge, road, slope, or tunnel, it is essential to take into account the possible debris avalanche due to rainfall, damage and scouring of piers by flood, damage to the bridge by falling rocks from both banks at the bridge position, and damage by landslide.

Since the bridge access slope contains cut rocky outcrops, disaster could be expected to occur due to falling rocks or debris avalanche. It could also be expected to suffer disaster due to debris avalanche on the upstream side of the bridge position. Bhutan is also a quake-prone country, and the project may be affected by earthquake.

The necessity of disaster preventive measures for the bridges to be surveyed is summarized in the table below.

<Table 6-10>State of access to the bridge as viewed from disaster

No.	Name of bridge	Type
A	PNH1	
3	Namling zam	Rocky outcrop on the linear wall on both banks. Concrete spraying necessary.
B	PNH4	
1	Passang zam	Dry valley. Land appropriation for military site necessary? No disaster
2	Beteni zam	Low possibility of disaster
3	Katley III	Low possibility of disaster
4	Chaplekhola	Rocky outcrop (L: 30 m, H: 20 m) on the right bank. Concrete spraying necessary.
6	Samkhara zam	There are many rolling stones and the risk of debris flow is high. In addition, scour is observed.
7	Telegangchu zam	Low possibility of disaster
C	Southern East-West Corridor	
1	DianaKuenphen zam	Possibility of flood

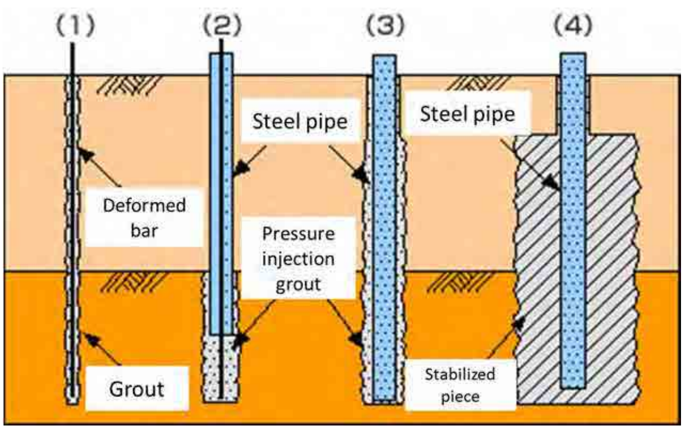
Source: JICA Study Team

6-4-3. Review of the Possibility of Introducing Japanese Technology

(1) Reconstruction of Existing Bridges

1) Micro Pile Method

"Micro piles" are bored and cast-in-place piles, with the pile diameter being 300 mm or less. This is the small-diameter pile method, in which the ground is bored, into which steel reinforcement (re-bars, steel pipes, etc.) are inserted and grout is injected to secure them to the ground. The micro pile method is a technology born in the 1950s to repair historical structures, such as temples and churches made from bricks and stones, and to reinforce the foundation. This technology has developed mainly in Europe and the USA and is referred to variously as micro pile, route pile, pin pile, and mini-pile, in various parts of the world. This method can be implemented even in the applications with only narrow access by means of a highly-mobile compact construction machine. This method can be applied to a wide application fields including structural foundations, reinforcement of cut slopes, etc.



Source: NETIS

<Figure6-4> Micro pile method

[Features]

a. With a highly-mobile compact machine or plant, this method proves extremely effective in a narrow place where the construction environment is severe.

b. By selecting the drilling method that is appropriate for the ground conditions, piling under various geological conditions is possible.

c. Environmental consciousness to minimize vibration and noise in the course of construction is important,

Source: NETIS

<Figure6-5>Execution

[Applicable to Bhutan]

This method that allows construction within a narrow yard may be advantageous in Bhutan where the yard for construction of structural foundations, piling for reinforcement of cut slope, etc. is difficult to secure. In Japan, this method is employed when the construction yard is restricted, such as under bridges, on steep slopes, etc.

2) Reinforcing Construction of Existing RC Piers by Spraying Special Polymer Cement Mortar

A RC lining method which is a general reinforcing construction method for existing RC piers requires a thickness of more than 250mm for the lining and it is sometimes difficult to adopt because of some issues such as limitation in structural dimensions,, for example construction gauge, impediment of river flow, and increased load on the pier foundation.

This method to improve the seismic performance is integrated with the existing pier by contact placement of reinforcing steel in the existing bridge pier and spraying it with a special polymer cement mortar until the prescribed coverage is obtained and in this way it is possible to reduce the thickness of the lining to about 1/5 that of alternate methods.

In other RC lining methods, the reinforcement of the bridge piers usually increases the weight due to the increase in cross-section, however in this method the load on the pier foundation can actually be reduced.

【Features】

a. The thickness of the lining can be decreased to about 1/5 of that required by other methods in the past by setting the reinforcing steel on the surface of the existing pier and spraying with a special polymer cement mortar lining material which is great in strength characteristics (compression, bending, adhesion, etc.) and durability rather than using concrete.

Source: NETIS

<Figure6-6>Execution

b. The following effects can be expected by adopting by spraying the mortar lining;

・Since the area over which this can be implemented at the same time is large, the work goes very rapidly.

・Because the speed of execution is fast, the work period is shortened and this is good in terms of economy.

・This method is excellent for repletion of the cement mortar on the back side of the reinforcement bar.

・The high spray pressure has a compacting effect and adherence to the base material is excellent.

【Expected effect】

a. For piers designed based on old specifications, it is possible to increase strength by this construction method.

b. If the body width and construction width has no limitation, RC lining is economically great.

3) Rejuvenation of Bearings

Rejuvenation of existing steel bearings is achieved by treating them with an anticorrosive rust preventative lubricant.

Source: NETIS

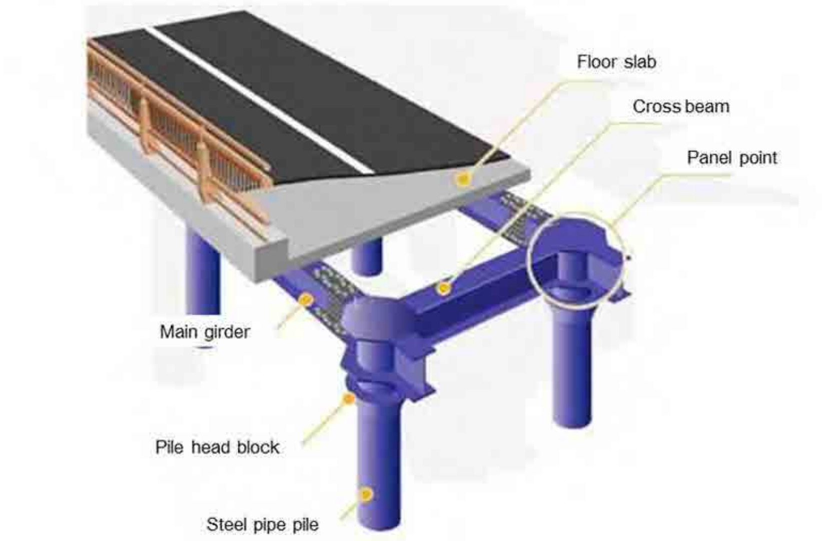
<Figure6-7> Rejuvenation of bearings

Long-term anticorrosion can be applied to bearing that are exposed to corrosion and thus malfunctioning can be prevented.

(2) Widening of Road

1) Structural Steel Road Method

The structural steel road method is a piled road construction technique which can be used to newly construct or widen narrow roads along a river or steep slope. It is composed of steel pipe piles, panel point girders (cross beam + panel point), main girders and slabs and connects the piles, cross beams and main girders at the panel point and it is a steric rigid frame bridge both in road direction and at right angles to the road direction.



Source: NETIS

<Figure6-8> Structural steel road method

【Features】

a. This method requires the prefabrication of short structural sections that are easy to transport and erect. Weight of each section is approximately 2ton.

b. The jointing method can absorb errors in pile work up to 100mm

c. The impact of existing traffic can be minimized by implementing a launching erection method

Source: NETIS

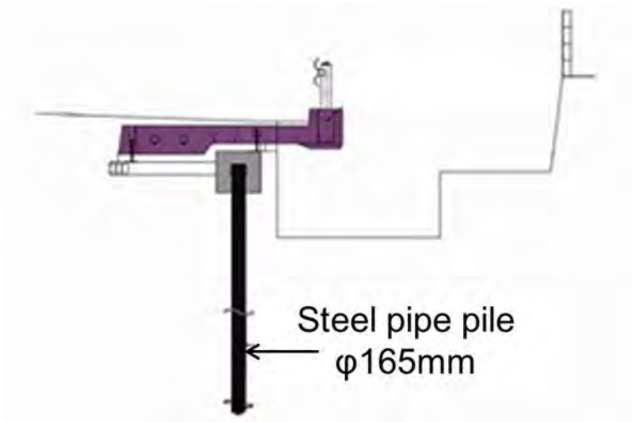
<Figure6-9>Example of the method

【Expected effect】

a. Widening and new construction of roads such as roads of narrow width on steep slopes or alongside of rivers and roads which need to avoid the impact of current existing traffic, which was difficult using existing methods, can now be possible.
b. The work period is greatly shortened since the girders are manufactured in a factory along with the substructure and therefore, the amount of work onsite is small.
c. Earth work such as cutting can be minimized and this method is effective in the places where the transport of sediment and/or construction materials is difficult.
d. It can be follow the alignment of the existing road.

2) Overhanging Roadway Construction Method

This is a road widening method which installs direct foundations or pile foundations on existing roads on both the mountain side and valley side, and then constructs a new road surface by setting precast a PC floor slab that extends a part of the floor slab over the valley side. Usually excavation of slopes on the mountainside or embankments on the valley side are necessary for widening of current roads. However that requires a large cost and long work period on the steep mountain road. Also there is a widening method of placing a jetty on the valley side, however this is in danger of damaging the landscape. The overhanging roadway construction method can resolve the aforementioned issues and create a passing-place and double-lane for narrow roads on steep slope and it protects the landscape.



Source: NETIS

<Figure6-10>Overhanging roadway construction method

【Features】

a. This method maximizes the principle of leverage to ensure stability by constructing a precast retaining wall on the mountain side of floor slab and pouring cast-in place concrete behind the wall to make the slab stable.
b. It is applicable to every geological condition and road alignment. Few impacts on the natural environment are expected since it does not violate sleep on the both side of mountainside and valley side.

Source: NETIS

<Figure6-11>Example of the method

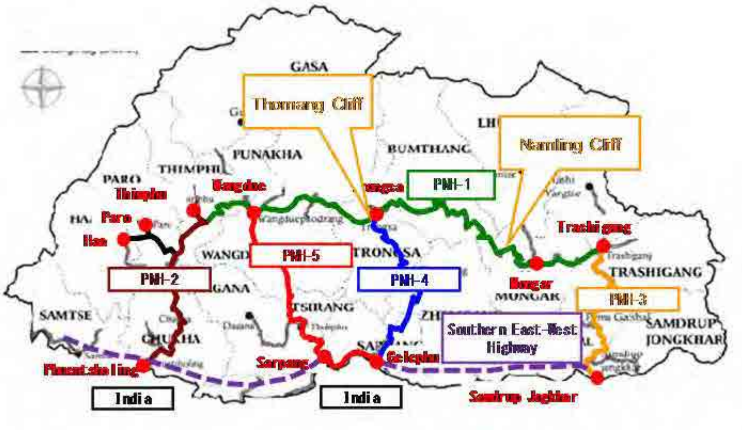
【Expected effect】

a. Widening and new construction of roads such as roads of narrow width on steep slopes or alongside of rivers and roads which need to avoid the impact of current existing traffic, which were difficult using existing methods, can now be possible.
b. Earth work such as cutting can be minimized and it is effective in places where transport of sediment and construction materials is difficult.
c. It can follow the shape of the existing road.

(3) Road Widening Plan at Namling Cliff and Thomang Cliff

There is a narrow road on the steep escarpment, which is a bottleneck on the national highway. The road was constructed with the width of about 5 m, through excavation along the land form. In particular, massive rocks are prominent. Namling Cliff and Thomang Cliff are disputed points.

Thomang Cliff is located about 3 km in a straight line to the east of Trongsa and Namling Cliff about 15 km to the northwest of Mongar.



Source: JICA Study Team

<Figure6-12>Location of each Cliff

When widening the road from the existing 5m to 8m, it is necessary to cut the mountain slope by providing gradient. If massive rock blocks exist, cutting along the existing slope gradient is difficult. The existing road shows remarkable overhang of precipitous rock, which suggests the difficulty facing the construction work in the past.

Several methods based on application of Japanese technology may be proposed. The methods such as the mountain tunnel, rock fall protection net, rock bolts and mortar spraying, or rock sheds may be introduced. The approach for review may also include the review of measures concerning road slope and management while making the best of the slope treatment record.

1) Description of Various Construction Methods

Description of various construction methods regarding advanced Japanese technology is shown below.

Category	Characteristics
Mountain tunnel  Source: Sumitomo Mitsui Construction Co., Ltd. website	In mountainous areas, it reduces the severity of the curves, gradients, and switchbacks regardless of the terrain of the ground and transport is facilitated. Also it reduces the risk of rock fall. The NATM method is the mainstream and the site excavated is fixed with concrete by spraying quickly and rock bolts are drilled deeply into the rock to use the holding power of the ground itself. This is an essential facility in the areas where steep terrain is continuous. The cross-sectional area is limited by earth pressure and water pressure acting on the tunnel, and this sets the vehicle limit in some cases. Air is likely to become foul in long tunnels.
Rock fall protection net  Source: Hinomaru website	The net covers the entire surface of the slope that rock fall may occur on using lightweight materials such as wire mesh or wire rope. Quick construction is possible because it is lightweight. ① Covering type rock fall protection net : It binds the rocks that have lost their binding force to the ground by the tension of the wire mesh and friction of the ground wire mesh. It doesn't allow falling rock to bound but lets them slide along the slope. ② Pocket type rock fall protection net : This is composed of hanging ropes, props, wire mesh, wire rope etc. and provides an entrance for falling rock on the upper part and absorbs the energy of the falling rock by collision of the falling rocks with the wire net. It is adopted when there is small scale rock fall, exfoliation from base rock, rock fall that tends to occur frequently and rock fall from high places is expected.
Rock bolts  Rolling Bridge, Bhutan	This is the method inserts steel bolts deeper than the sliding surface of the land mass and fixes the material with grout and it generates tension passively on the steel through the deformation of the ground in order to suppress the deformation of the ground and mass of rocks and it is used as a countermeasure for shallow landslides such as flaking, rock fall and small to middle sized landslides. If slide depth and volume is less than medium scale, this method will be relatively inexpensive, but if the scale is large it increases the steel length and the number of bolts required and the economical merit diminishes.

Spraying method  Source: Amanokigyo inc. website	This prevents weathering of rock, collapse and erosion due to penetration of rainwater by spraying mortar and concrete on the slope. For the cliff surface degraded by weathering, etc., it is one of the methods with a high adoption record since the blocking effect on water penetration, the changes of temperature and outside air is very high and workability is excellent. It is also adopted for the cut slopes and tunnel lining. This is conducted by transportation of mortar and concrete to the prescribed position through a high pressure hose or pipe by compressed air and the cast concrete and compaction is done by spraying powered by the compressed air not using concrete forms.
Rock shed  Source: NIHON Samicon Co., LTD. website	This structure is shaped similar to the tunnel for protection. The one for roads is called a “rock shed”. On the upper surface of the rock shed, a buffer is laid out in order to mitigate the shock caused by the rock fall. The upper part has a structure which can absorb or deflect the energy of the rock fall to the side and is planned to ensure the traffic safety. This is adopted when there is a steep slope on which rock fall tends to occur frequently, the scale of rock fall is large, or there is a risk that falling rocks will fly over the rock fall protection net. The fallen rock deposited on the shed needs to be removed.
Half Tunnel  South Africa Source: Tripadvisor website	In order to ensure the stabilization of bed rock on the roof, rock bolts and spraying is implemented to create a stable bedrock condition. This is a tunnel which is open on one side. Some type of structure must support the open side. Design is expected to be difficult since this requires the examination of the arch effect unlike the shape of a round tunnel. Location of rock bolts needs to be determined depending on the exfoliation of the rock bed, cracks and the size of the rock bed. It is used in the cases where road alignment matching the topography is preferable.

Source: JICA Study Team

<Figure6-13>Description of various countermeasures

2) Survey State

Surveys were done at Thomang Cliff and Namling Cliff. Then, the locations where the countermeasures utilizing the technologies of Bhutan were considered difficult were extracted as shown in Figure6-16 to Figure6-20. The survey section is 955 m long for Thomang Cliff and 1320 m for Namling Cliff.

The section for construction work is selected from the section length as described above. By focusing on the blocky rocks with the cliff height of about 20 m or more, the section can be narrowed down to 700 for Thomang Cliff and 550 m for Namling Cliff.

The geological condition consists mainly of granite and amphibolite, with the rock classified in the range of B to CII classes. Here the rock is classified approximately CI class for the design. The strike and dip is predominantly N20W~25E and 60S ~ 25N for Thomang Cliff and N30E~40E and 45N～15N for Namling Cliff. Construction along the road may uncover stratum with opposite dip in many locations. However, dip slope and break-away may cause falling rocks in certain locations.

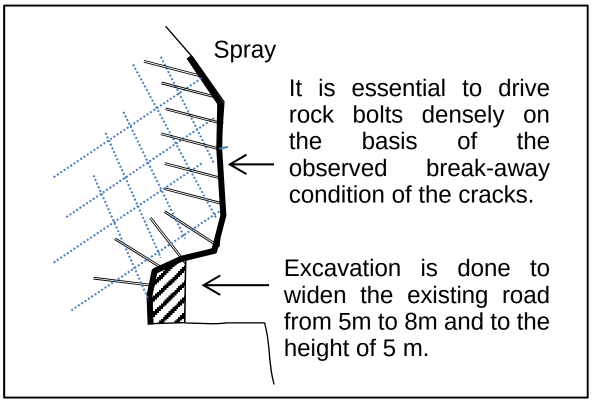
Source: JICA Study Team

<Figure6-14>Site condition

Cracks tend to be wedge-wise fall-off or block-like separation of more or less 2m, as shown above. It is essential to select a construction method that can handle these rocks.

3) Selection of the Work Method

Geological features at Thomang Cliff and Namling Cliff include blocky rock and mostly stratum with opposite dip, which presents issues such as the evaluation and countermeasures concerning break-off and cracks in the surface layer. In the case of widening on a rocky slope, the mountain side is to be dug out by about 3 m and the overhang is to be supported by rock bolts. Although it is blocky rock, it has cracks, which makes it difficult to determine whether or not rock bolts can be employed.

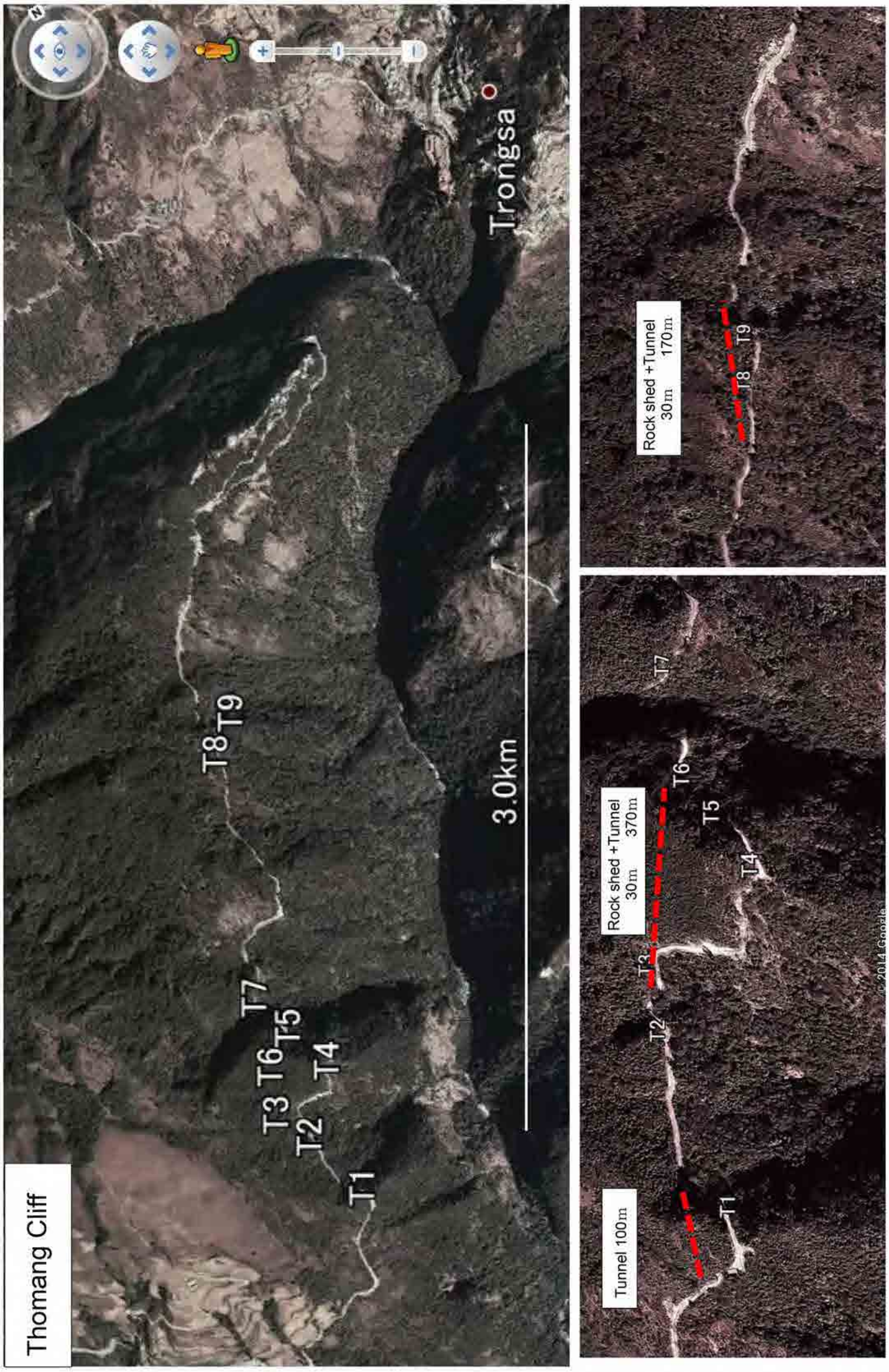


Source: JICA Study Team

<Figure 6-15> Conceptual view of widening on a rocky slope

Since it is necessary to smoothen the road alignments, a combination of tunneling (NATM blasting method), rock sheds, and rock fall protection nets is selected.

Tunneling is chosen for the mountain ridge and blocky rocks of 20 m or more for the benefit of road alignment. Rock sheds are to be applied to the slope before and after the tunnel to function as rock fall protection. For the rock fall protection net, the spray work is to be employed along with rock bolts and applied to the slope or precipitous wall of 20 m or less. Figures6-16 to 6-20 show the survey state and the section selected for construction.



Source: JICA Study Team

<Figure6-16> Location of survey for Thomang Cliff

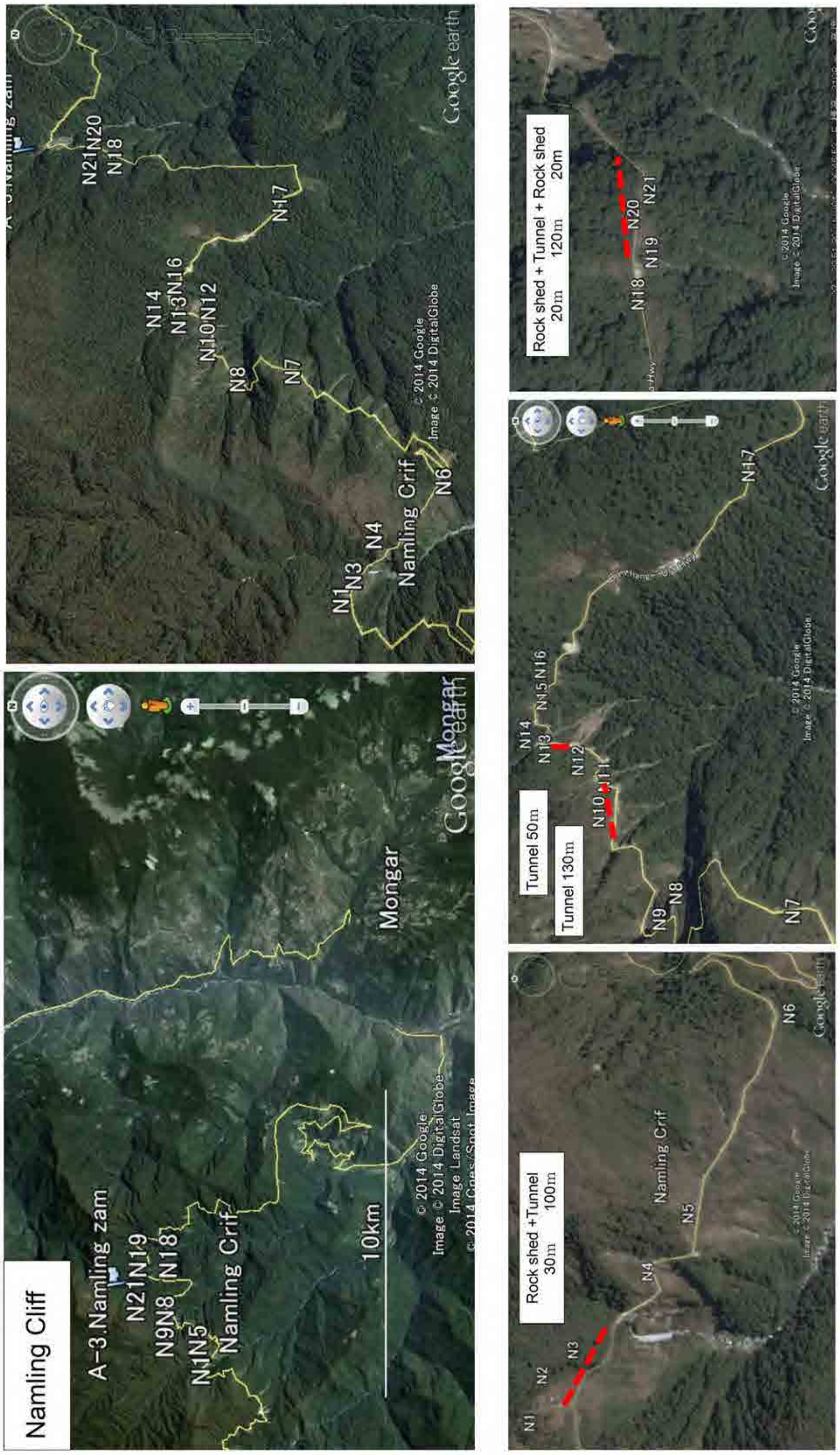
Thomang Cliff (1/1)

Location	T1	T2	T3	T4	T5
Latitude/Longitude	N27°28' 6.7"	N27°28' 16"	N27°28' 19.5"	N27°28' 23.4"	N27°28' 26.1"
	E90°28' 47.5"	E90°28' 45"	E90°28' 45.3"	E90°28' 53"	E90°28' 52"
Length(m)	190	20	30	150	50
Height(m)	30	30	20	30	30
Photo					
Construction method	Tunnel 100m Rock fall protection net（Portal）20 m×2	—	Rock shed 30m Tunnel 70m	Tunnel 150m	Tunnel 50m

Location	T6	T7	T8	T9	Total
Latitude/Longitude	N27°28' 27.6"	N27°28' 35.3"	N27°29' 5.8"	N27°29' 8.5"	
	E90°28' 50.3"	E90°28' 48.5"	E90°29' 2.1"	E90°29' 3"	
Legth(m)	150	145	130	90	955
Height(m)	30	80	30	30	
Photo					
Construction method	Tunnel100m Rock fall protection net（Portal）20 m	—	Rock shed 30m Tunnel 120m	Tunnel 50m	

Source: JICA Study Team

<Figure 6-17> Results of survey for Thomang Cliff



Source: JICA Study Team

<Figure 6-18> Location of survey for Namling Cliff

Namling Cliff (1/2)

Location	N1	N2	N3	N4	N5	—
Latitude/Longitude	N27°19' 48.3"	N27°19' 47.3"	N27°19' 45.8"	N27°19' 39.2"	N27°19' 36.4"	—
	E91°4' 48.4"	E91°4' 51.4"	E91°4' 53.1"	E91°4' 59.4"	E91°5' 3.3"	—
Length (m)	80	30	40	40	150	—
Height (m)	50	30	30	30	30	—
Photo						—
Construction method	Rock fall protection net 80m	Rock shed 30m	Tunnel 100m Rock fall protection net (Portal) 20m	—	—	—

Location	N6	N7	N8	N9	N10	N11
Latitude/Longitude	N27°19' 28.2"	N27°20' 0.5"	N27°20' 12.2"	N27°20' 12.4"	N27°20' 19.2"	N27°20' 20"
	E91°5' 15.4"	E91°5' 39"	E91°5' 36.3"	E91°5' 36.6"	E91°5' 44.8"	E91°5' 46.7"
Length (m)	40	120	70	40	50	80
Height (m)	40	40	30	40	80	30
Photo						
Construction method	—	—	—	—	Tunnel 50m Rock fall protection net (Portal) 20m	Tunnel 80m Rock fall protection net (Portal) 20m

Source: JICA Study Team

<Figure 6-19> Survey results for Namling Cliff (1)

Namling Cliff (2/2)

Location	N12	N13	N14	N15	N16	N17
Latitude/Longitude	N27°20' 22.1"	N27°20' 25.9"	N27°20' 28.7"	N27°20' 27.8"	N27°20' 27.5"	N27°20' 5.3"
	E91°5' 49.9"	E91°5' 51.1"	E91°5' 52.5"	E91°5' 58.6"	E91°6' 0.7"	E91°6' 20.3"
Length(m)	30	50	60	30	20	40
Height(m)	20	40	25	25	15	20
Photo						
Construction method	—	Tunnel 50m Rock fall protection net（Portal）20m×2	—	—	—	—

Location	N18	N19	N20	N21	Total
Latitude/Longitude	N27°20' 43.3"	N27°20' 44.2"	N27°20' 45.7"	N27°20' 46.8"	
	E91°6' 30.9"	E91°6' 31.6"	E91°6' 32.6"	E91°6' 33.1"	
Length(m)	140	50	80	80	1320
Height(m)	20	15	30	30	
Photo					
Construction method	—	—	Rock shed 20m Tunnel 60m	Tunnel 60m Rock shed 20m	

Source: JICA Study Team

<Figure 6-20> Survey results for Namling Cliff (2)

(4) Improvement of Pavement in High-Altitude Areas (Pavement in Cold Areas)

Anti-freezing asphalt technology is a Japanese technology for pavement in cold areas. The anti-freezing asphalt technology ensures the safety of travelling vehicles by preventing roads from freezing and effectively removing snow in the snowy cold season. In Japan, this technology has rapidly become widely popular since the enactment of the "Studded Tires Regulation Act."

The anti-freezing technology is intended to suppress or prevent freezing of roads at a road surface temperature of as low as -5 degrees Celsius and consequently to prevent snow ice from accumulating on the asphalt. Further, with this technology, snow ice hardly accumulates on road surfaces and is easily removed if there is any, which leads to effective snow removal.

Its effects include shortening of road freezing time period, reduced amount of anti-freezing agents to be sprinkled on roads, saving in time and effort to sprinkle the agents, and improved efficiency of snow removal from the road surface.

The anti-freezing asphalt technology is applicable especially in sharp corners, hills, intersections, mouths of tunnels, mountain areas, bridge decks, and other places where safety assurance is required. It does not require special running cost after the completion of construction, compared to road heating and snow melting systems.

The anti-freezing asphalt technology is divided into two categories: chemical type and physical type, as described below. Also, the past record of construction in Japan and Applicable Products List of anti-freezing pavement is shown in Table 6-10.

1) Chemical Type Anti-Freezing Asphalt

Chemical type anti-freezing asphalt is accomplished by adding or mixing material that contains an anti-freezing agent such as sodium chloride and calcium chloride into the asphalt concrete mixture. Eluting the active ingredient of the anti-freezing agent mixed in the asphalt causes the freezing point to drop.

Anti-freezing agents include impalpable powder minerals and water absorptive polymer as absorption type agent and crushed special cement solidification with chloride added as mixture type agent.

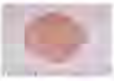
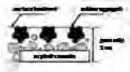
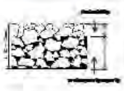
2) Physical Type Anti-Freezing Asphalt

Physical type anti-freezing asphalt is accomplished by imposing the loads of travelling vehicles on elastic materials within the asphalt to promote ablation and crushing of snow ice. Typical elastic materials to be used include rubber, waste tire rubber, and polyurethane resin.

Elastic materials are mixed into the asphalt concrete mixture or spread over/pressed in the asphalt. This technology further includes the elastic material/chloride added type and elastic material/agent filled type.

Especially the elastic material mixture type has good anti-freezing effect because of less adherence strength of ice plates and can keep its effect longer than the chemical type anti-freezing asphalt.

<Table6-11>Past record of construction in Japan and Applicable Products List of anti-freezing pavement

Counter measur	Type of Material	Name of Countermeasure	Characteristic		Achievements in Japan (million m2)
Chemical type	Additional material mixture type	Non-freeze		Special cement solidification materials added chloride is crushed and replaced with the crush stones which size are from 2.5 mm to 13 mm and them. After paving, chloride materials in special cement solidification is slowly eluted and exhibited excellent freezing inhibit effect over a long life.	4.07
		Vergimil V260		"Vergimil" is replaced aggregate under 10 mm and stone powder of asphalt mixture with chemical materials. Active ingredient slowly eluted from asphalt surface is exhibited excellent freezing inhibit effect over a long life. V-260 keeps high heat-resisting property and is possible to be adapted to the mixed materials used the modified asphalt.	
		Mallion		"Mallion" is adsorbed with active ingredient of chloride to the voids of a porous igneous rock fine powder. It is replaced with the stone powder. Active ingredient slowly eluted and distributed in the mixture materials is exhibited excellent freezing inhibit effect over a long life.	
	Additional material mixture/ Adsorption type	Dia Twin Winter		"Dia Twin Winter" is the semi-flexible freezing inhibit pavement permeated the freezing inhibit cement-milk to the void of a porous asphalt mixture materials. This material is mixed with chloride and water retaining material in permeable cement. Then this material is possible to expect the sustainability for eluting chloride when snowing and for absorbing chloride during spraying chloride on road surface management in the winter time.	
	Active adsorption type	Freeze Attack Pave		"Freeze Attack Pave" is composed of the cement milk of semi-flexible pavement and the mixture materials added the absorbency polymer. Polymer absorbed the salts (potassium acetate, etc.) is to continue exhibiting excellent freezing inhibit effect during 6 years.	
Physical type	Elastic material mixture type	Rubit		"Rubit" is composed of the dense-grade asphalt mixture and the rubber particles of useless tires. As rubber particles exists on and in the pavement surface, ice of asphalt surface is smoothly crushed and removed by vehicle loading.	1.95
		RA Pave		"RA Pave" is composed of the special modified asphalt filler rubber particles (5 mm with thickness) on binder course of special asphalt. In order to include a lot of rubber particles, freezing inhibit of crushing and removing of surface ice is effectiveness.	
	Elastic material mixture/ spraying type	Aok Silent		"Aok silent" is composed of the rubber particles into open-graded asphalt mixture which is high percentage of voids. Asphalt surface is sprayed rubber particles and then bonded. This type is effectiveness for function of drainage, noise reduction and freezing inhibit.	
	Elastic press filling type	Rubber Rolled		"Rubber Rolled" is composed of special rubber aggregate into the rolled asphalt pavement. During traveling vehicles, special rubber aggregate deforms and crushes ice on the asphalt pavement surface.	
	Void filling type	Ameni Urethane		"Ameni Urethane" is filled up the freezing inhibit materials composed of urethane resin into surface voids of drainable pavement. This materials inhibit freezing of pavement surface using physical effects.	
	Grooving filling type	Grooving Urethane		"Grooving Urethane" is composed of the urethane resin filled up into strip grooved on asphalt pavement, semi-flexible pavement and cement concrete pavement. Urethane strip composed of small intervals lets ice on pavement surface break away and splash by vehicles.	
Physical/Chemical type	Elastic/ Additional material mixture type	Twin Melt Pave		"Twin Melt Pave" is the combined freezing inhibit pavement of physical and chemical type which is composed of the elastic rubber chip mixed crusher-run stone with mastic rubber mixture (SMA) and the freezing inhibit materials mixed chloride system. This countermeasure is able to exhibit freezing inhibit effect, because there is little influence of traffic volume and outdoor temperature compared to only freezing inhibit pavement of physical and chemical type.	0.125
	Void filling type	The Pec P		"The Pec P" is composed of the rubber chip to the surface void of porous asphalt pavement and the filling of the freezing inhabit materials made from mainly an antifreezing admixture. The freezing inhabit effect is secured traveling safety of vehicles at snowfall. To remain voids on the asphalt surface without filling the freezing inhabit materials is to be continued the original function as a porous asphalt pavement.	
	Grooving filling type	The Pec G		"The Pec G" is composed of the the rubber chip to the road-surface groove-strip forming and the filling of the freezing inhabit materials made from mainly an antifreezing admixture. The freezing inhabit effect is secured traveling safety of vehicles at snowfall. To remain groove-strip forming on the asphalt surface without filling the freezing inhibit materials is also possible to secure travelling safety of vehicles during rainfall.	
Tuberosity type	Tuberosity of road surface type	Drainable multifunction		"Drainable multifunction" is a pavement to expect improvement of slip resistance for promoting abrasion of ice stuck on asphalt road surface by roughening pavement surface and by touching of traveling vehicle tires. This type is more little surface water compared to other type in order to percolate rain into the pavement. Then asphalt surface freezing is inhibited.	0.097
				Total Areas of Achievements	6.242

Sourse: Study Class for Freezind Inhibit Pavement (Japan)

Source: Study Class for Freezing Inhibit Pavement (Japan)

6-5. Calculation of the Approximate Construction Cost for Priority Projects

6-5-1.Bridge List for Calculation of the Construction Cost

(1) List of Bridges for Construction Cost Estimates

The approximate construction cost is calculated for the bridges with high priority for reconstruction, as follows. Note that Katley III bridge on PNH-4 and Namling zam Bridge on PNH-1 may be classified as A in terms of JICA's Environmental Category because they are located within the national park though their reconstruction priority is high. Therefore these bridges are excluded from the target for cost estimates.

<Table 6-12> Data regarding bridges concerned and the bridges proposed for reconstruction

SN	Bridge Name	Existing							Proposed			
		Br Type	Span		Width (mtr)	Load Cap (MT)	Year of Compln	Br Type	Approx. Span (mtr)	Carriage width (mtr)	IRC Load Class
			feet	mtr							
B	**Gelephu - Trongsa PNH4**										
1	Passang zam	Steel Hemilton		40.0	7.50	24	1970	PSC Bridge	50	7	70R
2	Beteni zam	RC T-Beam		25.0	4.20	40	1987	PSC Bridge	30	7	70R
4	Chaplekhola	RCC T-Beam		20.0	4.50	40	1969	RC T-Beam	25	7	70R
6	Samkhara zam	Steel Truss		61.0	4.30	40	2001	Steel Truss	65	7	70R
7	Telegangchu zam	RCC T-Beam		25.0	4.50	40	1981	RC T-Beam	28	7	70R
C	**Samtse-Sipsu PNH**										
1	Diana Kuephen zam	BSB & BB	1020		3.27	12	2003	PSC or Steel multi-span	300	7	70R

Source: JICA Study Team

1) Length And Width of Bridges to be Reconstructed

- Bridge length : The length shown in the table above is the one presented by DoR in the proposed alteration plan. Verification of the length is made by referring to the results of the bridge survey and alteration is proposed as required. Note that the details are provided in the comments for each bridge in the subsequent pages.
- Width : The effective width is to be 7 m (*7m=carriageway width (=3.25m+3.25m) + shoulder on both sides (each 0.25m) in accordance with the Guidelines on use of Standard Work Items Common Road Works. The total width is to be 8.2 m by taking into account the curb width (0.6 m on one side) of the Japanese standard.

Standard Specification for permanent bridges on various roads					
SL No.	Road Classification	Carriage width (m)	Loading capacity	Footpath	Remarks
1	Asian Highway (AH-48)	7.50	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
2	Primary National Highway (PNH)	7.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Optional	
3	Secondary National Highway (SNH)	5.50	IRC Class A (double lane)	Optional	
4	Dzongkhag Road	3.50	IRC class A (Single lane)	Optional	
5	Farm road	3.50	IRC class A (Single lane)		
6	Thromde road	Varies from 7.50 to 15.00	Single lane IRC 70R (Wheeled) OR Double lane IRC class A (whichever is critical)	Both side 1.50m wide	

Source: Guidelines on use of Standard Work Items for Common Road Works

<Figure 6-21> Effective width

(2) Considerations for Calculation of the Approximate Construction Cost of Bridges

On the basis of the site surveys of the bridges, the comments on the construction method, bridge type, etc. are given below.

<table>
<tr><td colspan="2">B-1.Passang zam Bridge</td></tr>
<tr><td>
</td><td>· The existing bridge is 40 m long. The new bridge position must be changed to the upstream or downstream side according to the road alignments. Since the bridge may possibly reduce the river width, it is essential to analyze the river conditions and to set up the proper bridge length. If the bridge length of 50 m in the reconstruction proposal is valid, a prestressed concrete bridge should be preferred (the post tensioning box-girder preferred).
· Since the river is dried up except for the wet season, erection of the superstructure with the fixed support (the representative method with the cast-in-place box girder) may be possible depending on the results of the study.</td></tr>
<tr><td colspan="2">B-2.Beteni zam Bridge</td></tr>
<tr><td>
</td><td>· The existing bridge is 25 m long. A new bridge may have to be repositioned to the downstream side, with the length increased slightly. If the length of 30 m shown in the table is selected, a prestressed concrete bridge should be preferred (the post tensioning T-girder considered preferred).
· Erection with erection girders is planned because the large cranes are considered difficult to carry to the site.</td></tr>
</table>

<table>
<tr><td colspan="2">B-4.Chaplekhola Bridge</td></tr>
<tr><td>
</td><td>

・ The existing bridge is 20 m long. A new bridge may have to be repositioned to the downstream side, with the length increased slightly. The length of 25m in the table is selected.
・ If the length of 25 m shown in the table is selected, a PC bridge should be preferred rather than RC bridge considering the design load of 70R. (In Japan, PCT girder is preferable if the bride is 25m long.)
⇒Construction cost is calculated for a PC bridge.
・ Erection with an erection girder is planned because the valley is deep and construction of timbering is considered to be difficult and the large cranes are considered to be difficult to carry to the site.</td></tr>
<tr><td colspan="2">B-6.Samkhara zam Bridge</td></tr>
<tr><td></td><td>

• The existing bridge is 61m long. A new bridge may have to be repositioned to the downstream side, with the length increased slightly. (The substructure of an older bridge is on the upstream side). It is proposed to be steel truss bridge of the length of 65m in this bridge plan, reexamination of bridge type considering the erection method is necessary in the detail plan stage.
⇒Construction cost is calculated for a steel truss bridge (65m)
• Rock is exposed and a spread foundation substructure is considered to be possible.</td></tr>
<tr><td colspan="2">B-7.Telegangchu zam Bridge</td></tr>
<tr><td>
</td><td>

・ The existing bridge is 25 m long. A new bridge may have to be repositioned to the downstream side, with the length increased slightly. A bridge length of 28 m in the table is selected.
・ Considering the design load (70R), the reinforced concrete bridge of 25 m in length, if selected, may be economically unacceptable when compared with a prestressed concrete bridge. (In Japan, the prestressed concrete T girder is predominant when the bridge length is 25 m.) ⇒ **The construction cost was calculated for the prestressed concrete bridge.**
・ Erection with erection girders is planned because the valley is so deep and the river level is so high that support would be difficult to construct and large cranes are considered difficult to carry to the site.</td></tr>
</table>

C-1.Diana Kuephen zam Bridge

- The existing bridge is 310.9m long. Proposed reconstruction is a 300 m long new prestressed concrete bridge or a steel continuous girder bridge. For the new bridge a bridge type comparison including the number of spans is necessary while taking into account the river conditions.
- There is no detour. Since the water flow in the river is small in the dry season, an embankment road is constructed to secure the vehicle traffic.
- Unless ongoing reconstruction of the arch bridge and Dramzang zam and widening of the road are completed, carry-in of large cranes is considered difficult.　A method other than erection by crane, such as erection with erection girders, should be preferred.

⇒ The construction cost was calculated for the prestressed concrete bridge.

*** Concerning the steel bridge, attention was paid to the fact that steel materials could not be manufactured within Bhutan.**

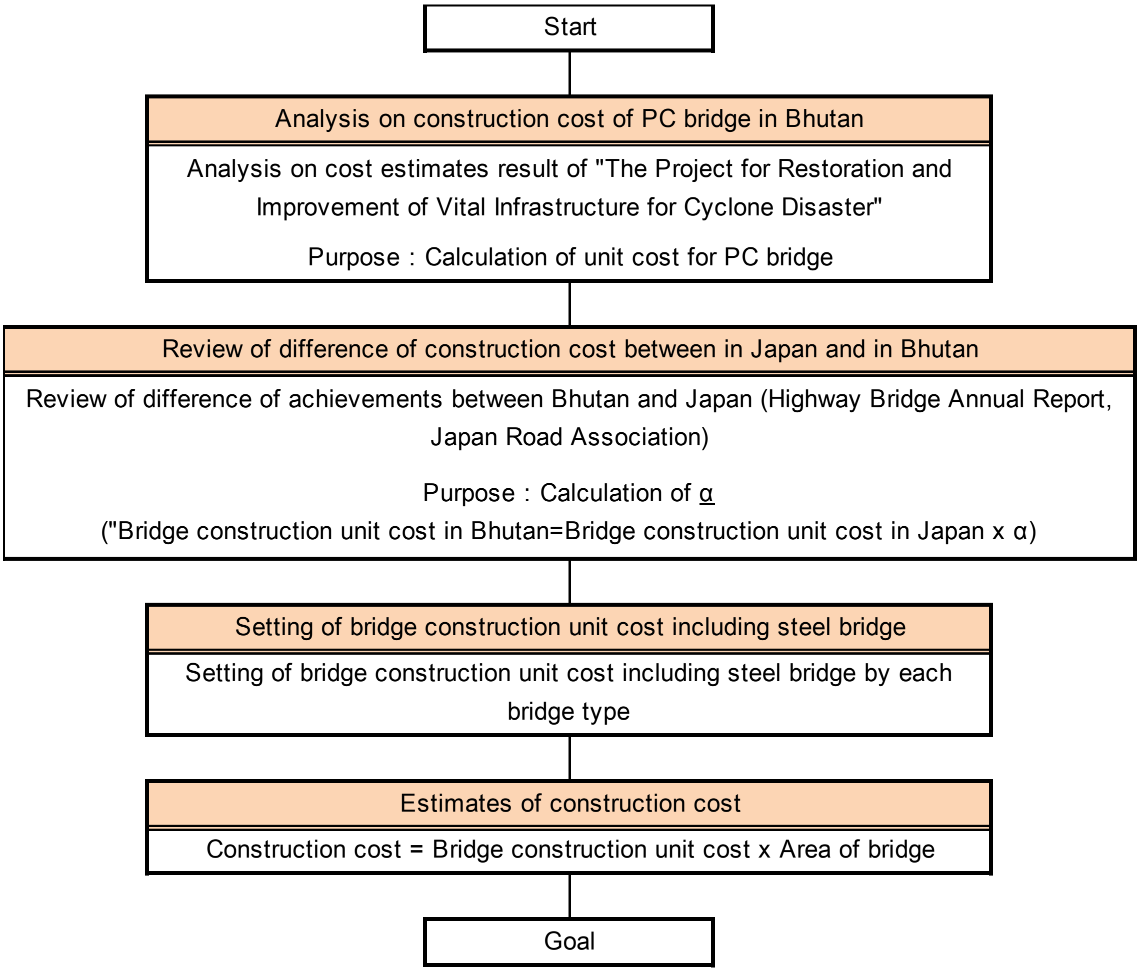
Source: JICA Study Team

<Figure 6-22> Comments on each bridge

(3) Construction Cost Estimates

1) Policy of Calculation

The construction cost is expressed in hundred million Yen and calculated using the unit cost per bridge area established on the basis of the bridge type, bridge length, and width from the construction results in Bhutan and those in Japan. The work flow is shown below.



Source: JICA Study Team

<Figure 6-23> Work flow for calculation of the construction cost

2) Unit Cost for Calculation of the Construction Cost of Bridges

The resultant unit cost (the unit cost per m^2) established according to the flow shown above is shown in the table below. The cost was determined according to the procedure shown below. Note that the data related to analysis of the construction results is attached as reference.

Unit cost (thousand yen / m^2) = (a×x + b) × coefficient × change rate

- (a × x + b) : Trendline determined from the Bridge Annual Report (x=span length)
- Coefficient (1.02) : Coefficient indicating the difference in construction results between Bhutan and Japan
- Change rate : Change rate between the rate (1Nu = 1.99 Yen) used in the construction results of Bhutan and the rate (1Nu = 1.81 Yen) of this project (1.99/1.81 = 1.099)

<Table 6-13> List of unit costs for calculation of the construction cost

SN	Bridge Name	Proposed					
		Br Type (Proposal)	Approx. Span (mtr)	Unit cost (thousand yen/m2)			
					approximate line	coefficient	change rate
B	Gelephu - Trongsa PNH						
1	Passang zam	PSC Bridge(PCBOX)	50	**503**	= (1.9470 x+ 350.70)×	1.020 ×	1.099
2	Beteni zam	PSC Bridge(PCT)	30	**491**	= (2.8713 x+ 351.54)×	1.020 ×	1.099
4	Chaplekhola	RCC T-Beam	25	**475**	= (2.8713 x+ 351.54)×	1.020 ×	1.099
6	Samkhara zam	Steel Truss	65	**593**	= (2.2933 x+ 379.16)×	1.020 ×	1.099
7	Telegangchu zam	RC T-Beam(PCT)	28	**485**	= (2.8713 x+ 351.54)×	1.020 ×	1.099
C	Samtse-Sipsu SEWC						
1	Diana Kuephen zam	PSC or Steel multi-span(PCT)	300 span= 43	**533**	= (2.8713 x+ 351.54)×	1.020 ×	1.099

Source: JICA Study Team

3) Calculation of the Construction Cost

① Construction Cost of Individual Bridges

The construction cost is calculated as follows:

Construction cost＝Bridge area (bridge length x width) x unit cost (per m2) + equipment procured in Japan

Note that for the equipment procured in Japan (b. Equipment in the table), the sum of 200 million yen was determined by adding the overhead (about two-fold of the direct cost) to 110 million yen (direct cost) that is the total of common and erection equipment as derived from the "Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan."

<Table 6-14> Construction cost of individual bridges

SN	Bridge Name	Proposed								
		Br Type (Proposal)	Approx. Span (mtr)	Total width (mtr)	Area of Bridge (m^2)	Unit cost (thousand yen/m2)	a.Bridge cost (thousand)	b.equip ment cost (thousand)	Total (a+b) (thousand)	Total (100 million yen)
B	**Gelephu - Trongsa PNH4**									
1	Passang zam	PSC Bridge(PCBOX)	50	8.2	410	503	206,000	200,000	406,000	**4.1**
2	Beteni zam	PSC Bridge(PCT)	30	8.2	246	491	121,000	200,000	321,000	**3.3**
4	Chaplekhola	RCC T-Beam	25	8.2	205	475	97,000	200,000	297,000	**3.0**
6	Samkhara zam	Steel Truss	65	8.2	533	593	316,000	200,000	516,000	**5.2**
7	Telegangchu zam	RC T-Beam(PCT)	28	8.2	229.6	485	111,000	200,000	311,000	**3.2**
C	**Samtse-Sipsu PNH**									
1	Diana Kuephen zam	PSC or Steel multi-span(PCT)	300 span= 43	8.2	2460	533	1,311,000	200,000	1,511,000	**15.2**

Source: JICA Study Team

② Construction Cost Summarized by Neighboring Bridges

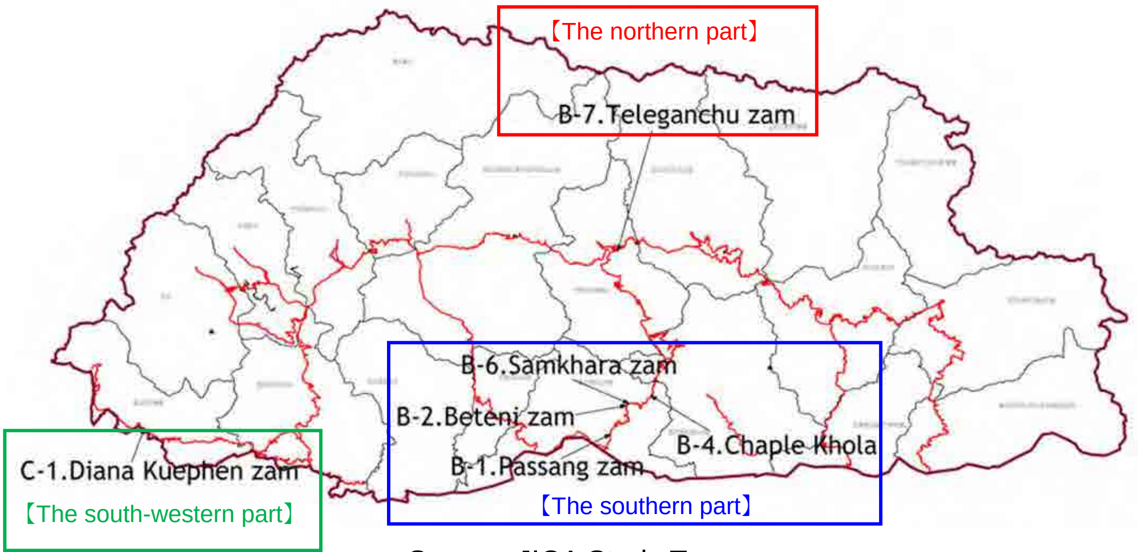
For the equipment procured in Japan (b. Equipment in Table6-14), some neighboring bridges may be combined in the estimation of the construction cost. Actually, in the "Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan," 125 million yen was appropriated as the direct cost for planning and construction of five bridges.

The construction cost is summarized by assuming that a blanket order is placed for the neighboring bridges. The location and construction cost of the bridges concerned are shown in Figure6-24 and Table6-15.

<Table6-15> Construction cost summarized by route bridges

SN	Bridge Name	Proposed				
		Br Type (Proposal)	a.Bridge cost (thousand)	b.equip ment cost (thousand)	Total (a+b) (thousand)	Total (100 million yen)
The northern part(PNH4)						
B-7	Telegangchu zam	RC T-Beam(PCT)	111,000	200,000	311,000	**3.2**
The southern part (PNH4)						
B-1	Passang zam	PSC Bridge(PCBOX)	206,000	200,000	1,140,000	**11.4**
B-2	Beteni zam	PSC Bridge(PCT)	121,000			
B-4	Chaplekhola	RCC T-Beam	97,000			
B-6	Samkhara zam	Steel Truss	316,000	200,000		
The south-western part (SEWC)						
C-1	Diana Kuephen zam	PSC or Steel multi-span(PCT)	1,311,000	200,000	1,511,000	**15.2**

Source: JICA Study Team



Source: JICA Study Team

<Figure 6-24> Location map of bridges concerned

(4) Summary of Calculation of the Construction Cost

1) Construction Cost

- Direct construction cost is calculated to be about 1.46 billion yen when a blanket order is placed for five bridges.
- Direct construction cost is calculated to be about 1.52 billion yen for Diana Kuephen zam Bridge

2) Bridge Data

Regarding Diana Kuephen zam Bridge located in Samtse district, it is necessary to analyze the river conditions, and the bridge length and type must be reviewed on the basis of river conditions thus analyzed.

3) Handling of the Transportation Cost

As a result of analysis of the transportation cost on the basis of this unit cost, it was determined that the difference in the transport distance exerts only a minor effect on the accuracy of the calculation of this construction cost. The future detailed survey must involve the study on "one bridge in Samtse Dzongkhag", "bridge in the vicinity of Gelephu," and "bridge using large amount of materials (mainly, steels) that are not produced in Bhutan." In this case, the study must take into account direct carry-in of materials from India. Carry-in of materials (prestressed concrete cables, steel plates, etc.) that cannot be produced in Bhutan is currently possible via the following two routes based in Phuentsholing, a town on the border with India.

The transport distances of the two routes are as follows:

[Route 1 (red line)]

「P/ling～Thimphu～Gelephu」

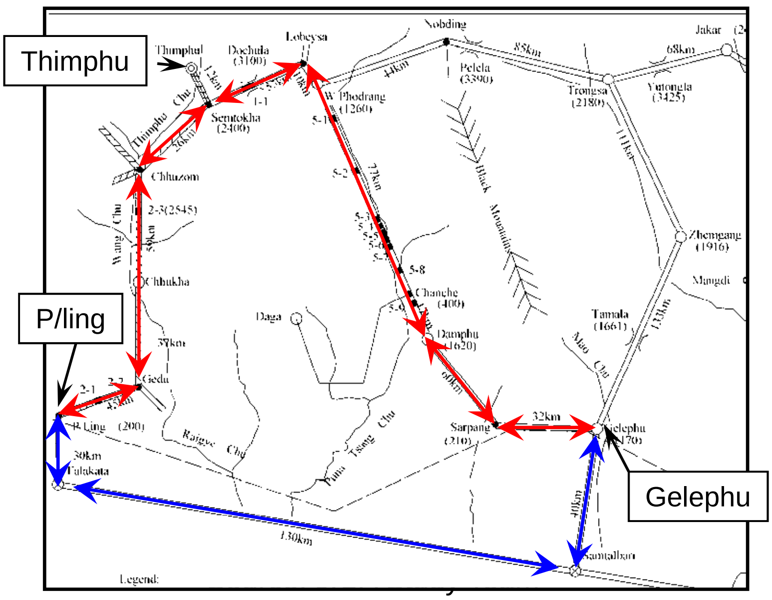
⇒

45+37+59+26+55+10+77+17+60+32=418km

[Route 2 (blue line)]

「P/ling~(via India)~Gelephu」

⇒ 30+130+40=200km



Source: JICA Study Team

<Figure 6-25> Transportation routes

4) Equipment procured in Japan

Among the construction cost, the "equipment procured in Japan" includes the common equipment, such as cranes, etc., and special equipment used for erection. The total construction cost may be reduced when construction of several bridges is combined and equipment/materials are redeployed.

* The construction cost of (4) above was calculated by assuming redeployment of equipment/materials.

[Reference material]

(1) Unit Cost of the Actual Construction of Prestressed Concrete Bridges in Bhutan

1) Project referred to

The ratio of various expenses in the direct cost, the transportation cost, equipment carry-in cost, and other costs are summarized on the basis of actual estimation of costs since 2011, the Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan (five bridges in Table6-16).

<Table6-16> Bridges in “the Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan”

Bridge	Length (m)	Width (m)	Bridge type	Constructio method for temporary works
Dolkhola Bridge	70.0	7.000	PC post tensioning T-girder Bridge	Erection of erection girder
Jigmiling Bridge	70.0	7.000	PC post tensioning T-girder Bridge	Erection of erection girder
Mandechhu Bridge	103.7	3.277	Balley Suspension Bridge	Only substructure
Kela Bridge	48.0	3.277	Balley Bridge	Only substructure
Jangbi Bridge	48.0	3.277	Balley Bridge	Only substructure

※Total width=0.6(Wheel guard)+7.0(Width)+0.6(Wheel guard)

Source: Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

2) Breakdown of the Construction Cost

The breakdown of the construction cost is shown in Table6-17. Considerations are also listed.

<Table6-17> Breakdown of the construction cost in the Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

Types			Japanese Yen (1Nu=1.99Yen)	Ratio to total construction cost(%)		Note
Direct construction cost	A.Structure body	I. Dolkhola Bridge	71,100,000		7.7	Include approach road and bank protection
		II. Jigmiling Bridge	72,200,000		7.8	Include approach road and bank protection
		III. Mandechhu Bridge	43,300,000		4.7	Only substructure.Include approach road and bank protection
		IV. Kela Bridge	2,300,000		0.2	Only substructure.Include approach road and bank protection
		V. Jangbi Bridge	2,200,000		0.2	Only substructure.Include approach road and bank protection
		∑A(I～V)=	191,100,000	20.6		
	B.Others	i. Dispatch of skilled worker	34,000,000		3.7	Technician for manufacturing PC girder⇒17million/1bridge
		ii. Equipent procured from Japan	125,000,000		13.5	Common equipment such as cranes⇒About 30 million Equipment for PC erection⇒About 80 million
		iii. Temporary work cost	30,000,000		3.2	Building of construction yard
		iv.Transportation	99,000,000		10.7	To be analysed separately
		∑B(i～iv)=	288,000,000	31.1		
Overhead charge	C.Indirect cost	a.Common temporary work cost	201,000,000		21.7	
		b. Site expenses	173,000,000		18.7	
	D.Head office expenses		74,000,000		8.0	
		∑(C～D)=	448,000,000	48.3		
Total construction cost		∑(A～D)=	927,100,000	100.0	100.0	

Source: Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

- In the direct cost, the ratio of expenses of “Others” is higher than those of “Main body.”
- In the direct cost (other expenses), the “machinery procured in Japan” and “Transportation” account for approximately 90%.
- In the machinery procured in Japan, the ratio of “prestressed concrete erection materials” is high.
- Various expenses account for 48% of the total construction cost, which is approximately equal to the direct cost. * In the case of Japan, the approximate construction cost is mostly equal to the direct cost plus various expenses (direct cost x 0.5).

3) Breakdown of the Transportation Cost

For the transportation cost, the breakdown of construction cost in terms of the bridge distance and transportation amount is as shown in Table6-18.

<Table 6-18> Breakdown of the transportation cost of “the Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan”

Types			Japanese yen (1Nu=1.99yen)	Transportation volume (m3)	Transportation volume (t)	Ratio to total transportation cost(%)
Transportation cost for aggregate (Quarry near the site ~ Site)	Concrete･asphalt aggretate,crushed stone etc.	Dolkhola Bridge	15,400,000	3,500	-	15.6
		Jigmiling Bridge	15,100,000	3,600	-	15.3
		Mandechhu Bridge	41,300,000	4,000	-	41.7
		Kela Bridge	1,000,000	100	-	1.0
		Jangbi Bridge	1,100,000	100	-	1.1
		∑=	73,900,000	-	-	74.6
Transportation cost for material for major work (P/ling ~ Thimphu ~ Site)	Reinforcing steel･cement etc.	Dolkhola Bridge-402km	2,700,000	-	470	2.7
		Jigmiling Bridge-406km	2,800,000	-	460	2.8
		Mandechhu Bridge-454km	6,900,000	-	1,040	7.0
		Kela Bridge-401km	400,000	-	26	0.4
		Jangbi Bridge-418km	300,000	-	27	0.3
		∑=	13,100,000	-	-	13.2
Transportation cost for PC material (India ~ P/ling)	PC cable, sheath etc.	Dolkhola Bridge	3,800,000	-	-	3.8
		Jigmiling Bridge	3,800,000	-	-	3.8
		∑=	7,600,000	-	-	7.7
Transportation cost fo PC material (P/ling~Thimphu ~ Site)	PC cable, sheath etc.	Dolkhola Bridge	2,200,000	-	-	2.2
		Jigmiling Bridge	2,200,000	-	-	2.2
		∑=	4,400,000	-	-	4.4
Total transportation cost			**99,000,000**	-	-	100.0

Source: Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

- In the transportation cost, the aggregate transportation charge (domestic procurement) accounts for about 70%.
- The main-body material transportation cost is approximately proportional to the transportation distance.

  (Example) Dolkhola : 2686 thousand yen/402km/470t=0.014 thousand yen/(km・t)

  Mangdechhu: 6858 thousand yen/454km/1040t=0.015 thousand yen/(km・t)

  * The results calculated above are approximately equal, with the cost varying more or less equally when the kilometer is used as the variable.
- In the prestressed concrete material transportation cost, the ratio of “India-Phuentsholing” is approximately equal to that of “Phuentsholing - Thimphu - site.”

4) Breakdown of the Construction Cost of Dolkhola Bridge and Jigmiling Bridge

Dolkhola Bridge and Jigmiling Bridge, which are prestressed concrete bridges, are extracted to help summarize the construction cost. Considerations are also listed.

- The machinery procured in Japan includes common equipment such as the cranes (used in construction of all bridges: two 25t cranes, three trucks, one tire roller; duration of service, 1.7 years) and the special equipment (one set of equipment for erection of erection girders) to erect the prestressed concrete girders. When the above machinery is added to the construction cost of each bridge, its ratio relative to the total construction cost per bridge increases. On the other hand, the reduction of total cost is considered possible if construction of several bridges is combined and the equipment/materials are appropriated,
- The difference in the transportation distance of individual bridges has an effect on the “Transport (main equipment/materials)” and “Transport (prestressed concrete materials).” However, such difference is 3% or less of the total construction cost, so that its effect is considered minor when considering the accuracy of the calculation of the main construction cost.

<Table6-19> Breakdown of the construction cost of Dolkhola Bridge and Jigmiling Bridge

Types of work		Dolkhola Bridge		Jigmiling Bridge	
		Breakdown of construction cost	÷Total construction cost (%)	Breakdown of construction cost	÷Total construction cost (%)
Direct construction cost	Body: Supersructure/Substructure	71,100,000	15.1	72,200,000	15.3
	Dispatch of skilled worker	17,000,000	3.6	17,000,000	3.6
	Equipment procured from Japan	110,000,000	23.4	110,000,000	23.2
	Temporary work cost(blocks by sandbags,building of construction yard)	12,500,000	2.7	13,500,000	2.9
	Transportation(aggregate)	15,400,000	3.3	15,100,000	3.2
	Transportation(Material for major work)	2,700,000	0.6	2,800,000	0.6
	Transportation(PCmaterial：India~P/ling)	3,800,000	0.8	3,800,000	0.8
	Transportation(PCmatrial：P/ling~Site)	2,200,000	0.5	2,200,000	0.5
	Direct consruction cost total=	234,700,000	-	236,600,000	-
Total construction cost(Direct construction cost×2.0)=		469,400,000	100.0	473,200,000	100.0
Cost per square meter：total construction cost/(70*(7+1.2))=		817,770		824,390	
Adopted value (thousand yen/m^2)=		818		825	

Source: Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

(2) Setting of the Unit Cost for Calculation of the Construction Cost

1) Handling of the "Equipment Procured in Japan" and the Unit Cost for Employment of the 35 M Span Prestressed Concrete Girders

The reference value shown below for the main construction cost is the remainder after deducting the "equipment procured in Japan." For the "equipment procured in Japan," the combination of various bridge constructions is proposed and the final construction cost is calculated by adding the expenses as required.

The unit cost per m^2 established for the 35 m span prestressed concrete T girder bridge to be constructed in Bhutan is estimated to be 439 thousand yen/m^2 (* (435 + 442) /2).

<Table6-20> Breakdown of the construction cost of Dolkhola Bridge and Jigmiling Bridge (excluding the machinery procured in Japan)

Types of work		Dolkhola Bridge		Jigmiling Bridge	
		Breakdown of construction cost	÷Total construction cost (%)	Breakdown of construction cost	÷Total construction cost (%)
Direct construction cost	Body: Supersructure/Substructure	71,100,000	28.5	72,200,000	28.5
	Dispatch of skilled worker	17,000,000	6.8	17,000,000	6.7
	Equipment procured from Japan	0	0.0	0	0.0
	Temporary work cost(blocks by sandbags,building of construction yard)	12,500,000	5.0	13,500,000	5.3
	Transportation(aggregate)	15,400,000	6.2	15,100,000	6.0
	Transportation(Material for major work)	2,700,000	1.1	2,800,000	1.1
	Transportation(PCmaterial : India ~ P/ling)	3,800,000	1.5	3,800,000	1.5
	Transportation(PCmatrial : P/ling ~ Site)	2,200,000	0.9	2,200,000	0.9
	Direct consruction cost total=	124,700,000	-	126,600,000	-
Total construction cost(Direct construction cost×2.0)=		249,400,000	100.0	253,200,000	100.0
Cost per square meter : total construction cost/(70*(7+1.2))=		434,495		441,115	
Adopted value (thousand yen/m^2)=		435		442	

Source: Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

2) Comparison with the Japanese Standard Unit Costs for Prestressed Concrete Bridges

The figure below shows the relationship between the span and total construction cost of prestressed concrete bridges constructed in Japan as described in the "Highway Bridge Annual Report, April 2012, by the Japan Road Association."

Dolkhola Bridge and Jigmiling Bridge correspond to post tensioning T-girder bridges. The post tensioning T-girder bridge is extracted from the data shown in the table below and the trend line is determined, which results in "y=2.8713x+351.54." "x" in the figure means the span. Substituting the 35m, which are the spans of Dolkhola Bridge and Jigmiling Bridge result in the unit cost of 432 thousand yen/m^2.

As described above, the construction unit cost per m^2 in Bhutan is 439 thousand yen/m^2 and the difference ratio is 439÷432=1.02. Subsequently, this coefficient will be used for calculation of the construction cost of individual bridges.

Note that the trend line of prestressed concrete box girders for reconstruction is represented by y=1.947x+350.7.

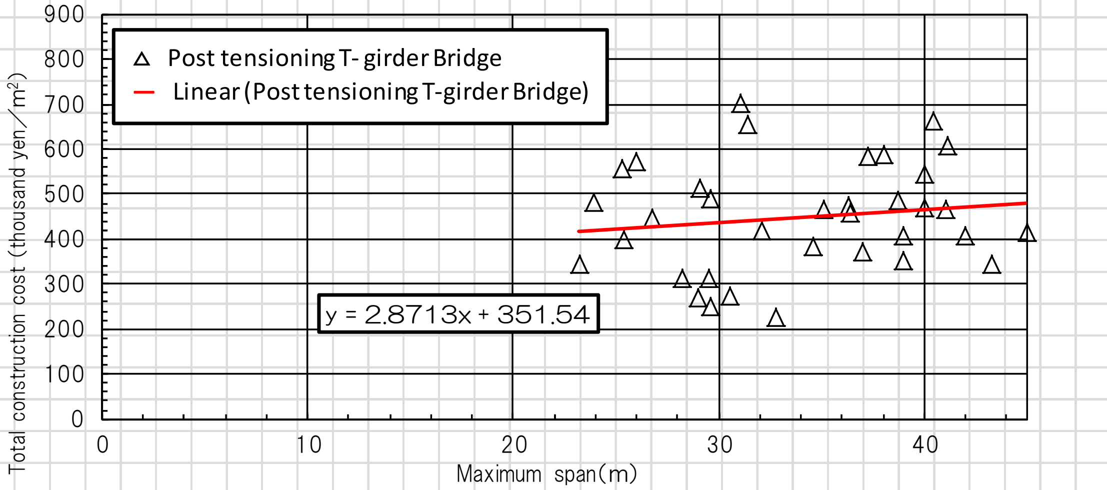


Figure-21 Concrete bridge–Total construction cost per㎡ by superstructure type (Incuding overhead cost)…I-girder・ T-girder

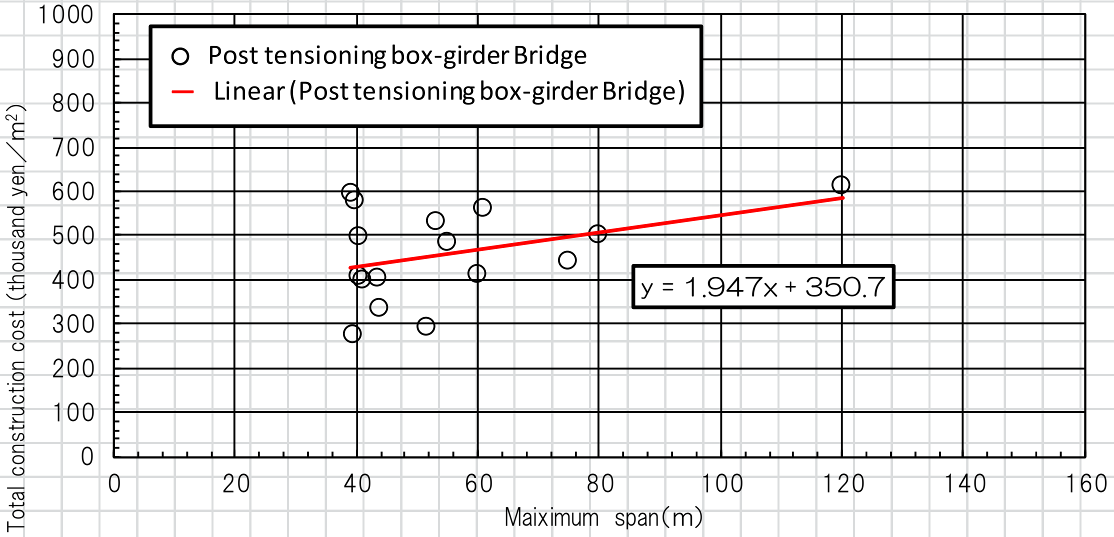


Figure-23 Concrete bridge–Total construction cost per㎡ by superstructure type (Incuding overhead cost)
… cost tensioning box-girder continuous

Source: Highway Bridge Annual Report, April 2012, by the Japan Road Association

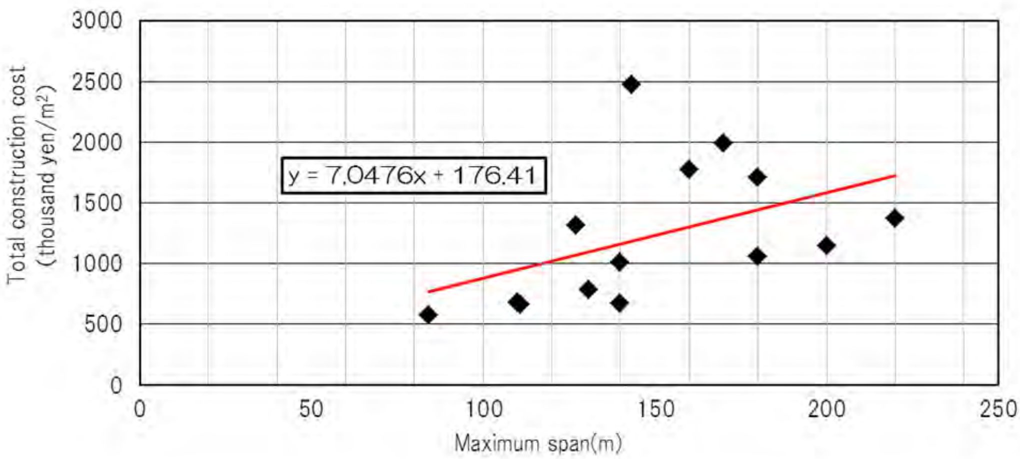
<Figure6-26> Excerpt from the construction results of concrete bridges in the “Highway Bridge Annual Report for 2010”

3) Establishing the Unit Cost of the Extradosed Prestressed Concrete Bridges

The unit cost of construction for extradosed prestressed concrete bridges is established from the construction results.

Note that the main unit cost and the steel bridge construction unit cost shown on the next page were used during study of the bridge type for the Maukhola Bridge.

	Constrution period	Bridge length (m)	Span arrangement	Maximum span (m)	Effective width (m)	Concrete volume (m3)	Volume of steel for PC (t)	Contruction method for erection of main girder	Construction cost for superstructure (million yen)	Construction cost for substucture and foundation work (million yen)	Total construction cost (million yen)	Total construction cost per m2 (thousand/m2)
Yanagawa dam	2002.12-2007.1	264.00	2 spans	130.70	14～16	6,136	205	Cantilever	2,336	553	2,889	782
Okuibiko ohashi	2004.3-2011.3	232.60	2 spans	143.30	8～11	5,224	280	Cantilever	1,670	2,927	4,597	2,470
Asagiri ohashi	2004.9-2006.10	166.00	2 spans	84.20	17～19	3,400	130	Fixed	1,186	440	1,626	576
Shirasunagawa bashi	2007.2-2013.3	210.75	2 spans	110.75	16～19	3,755	183	Cantilever	1,949	290	2,239	664
Sannohebokyo ohashi	2000.10-2005.5	400.00	3 spans	200.00	9.30	14,401	333	Cantilever	2,858	1,422	4,280	1,151
Minamichiku bashi	1997.3-2006.8	248.00	3 spans	110.00	19.8～23.8	5,820	331	Cantilever	2,355	1,000	3,355	683
Tsukuhara bashi	1994.12-1997.11	323.00	3 spans	180.00	9.25	13,470	363	Cantilever	3,067	2,052	5,119	1,713
Okuyama bashi (West bound)	1993.2-1998.3	285.00	3 spans	140.00	8.9～15.4	3,625	233	Cantilever	1,485	1,082	2,567	1,012
Kanisawa ohashi	1994.10-1998.3	380.00	3 spans	180.00	16.50	7,089	543		5,274	1,386	6,660	1,062
Yumekake ohashi	2002.1-2010.3	288.95	3 spans	127.00	10.51～13.81	5,690	308	Cantilever	2,621	1,382	4,003	1,318
Tokunoyama hattoku bashi	2001.3-2006.9	503.00	3 spans	220.00	7.00	7,108	340	Cantilever	2,882	1,940	4,822	1,369
Oumi oodorri bashi (upbound)	2000.2-2007.3	495.00	4 spans	170.00	16.50	32,895	1,177	Cantilever	11,786	4,470	16,256	1,990
Oumi oodorri bashi(downbound)	2000.2-2007.3	555.00	5 spans	160.00	16.50	32,895	1,177	Cantilever	11,786	4,470	16,256	1,775
Shikari ohashi	1995.3-2001.12	610.00	5 spans	140.00	22.00	16,138	1,088	Cantilever	7,000	2,050	9,050	674



Source: JICA Study Team

<Figure 6-27> Construction results as well as the maximum span and unit cost per m^2 of the extradosed bridge

4) Establishing the Construction Unit Cost of Steel Bridges

Similarly, the unit cost is established by using the figure illustrating the relationship between the span (maximum span) and the total construction cost of steel bridges constructed in Japan as described in the "Highway Bridge Annual Report, April 2012, by the Japan Road Association."

Since actual construction of truss and arch bridges has been scarce recently in Japan, the unit cost is established according to the procedure described below.

- The inclination of the trend line is determined from the data regarding steel plate and box girders, which have abundant construction records. (The span, steel weight and construction cost are in linear relationships in the steel bridges.)
- With the above inclination as the immobilization condition, the trend line is determined for each bridge type.

As a result of calculation according to the procedure as described above, the trend line becomes as follows.

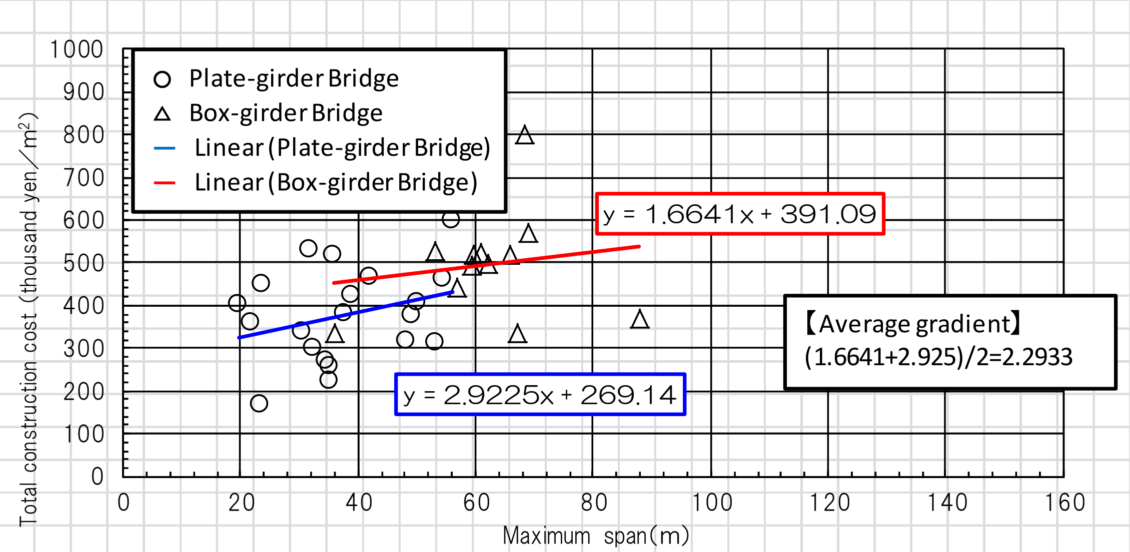


Figure-5 Steel bridge–Total construction cost per㎡ by superstructure type (Incuding overhead cost)

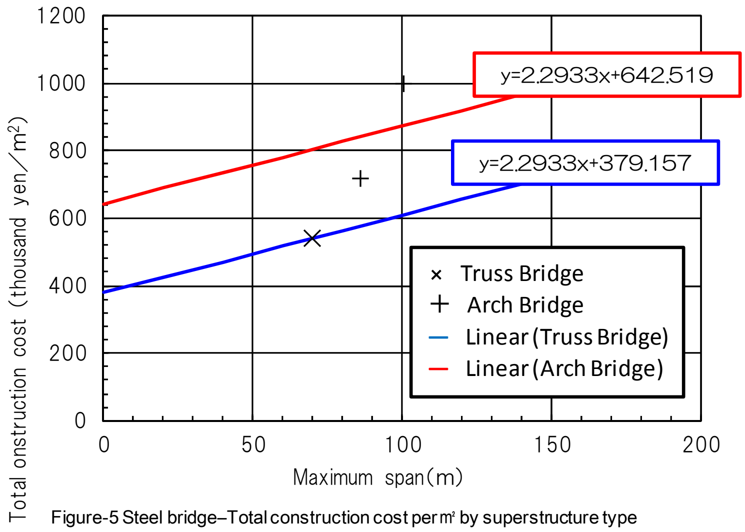


Figure-5 Steel bridge–Total construction cost per m² by superstructure type (Incuding overhead cost)

(Supplement)
According to the "2nd phase Bridge Reconstruction Plan", written by Keiko Watanabe of JICA, the total bridge deck surface of three steel Langer bridges (arch bridges) (with lengths of 86m, 70m, and 95.2m and widths of 6.0m, 5.5m, and 5.5m) is calculated as 1424.6m^2 and the main body construction cost as 1,296 million yen. The unit cost for bridge construction is 910,000 yen/m2. It may be judged that this is not much difference when compared with the above figure.

Source: Highway Bridge Annual Report, April 2012, by the Japan Road Association

<Figure 6-28> Excerpt from the steel bridge construction results in the "Highway Bridge Annual Report" of 2009 and 2010

6-5-2. Approximate Construction Cost for the Pavement Improvement Project (L = 5 Km) on the Northern Slope of Trumshing La Pass

(1) Pavement Structure

For the pavement structure, reference is made to the road pavement work implemented up to now in Bhutan.

The pavement structure consists basically of the sub-base, base course, binder course, and wearing course from the bottom upward. The thickness of each course differs depending on the temperature at the road surface, traffic volume, and the percentage of large vehicles. The pavement structures shown below are based on the examples in the past:

- Wearing course: Asphalt concrete, thickness 25 mm
- Binder course: Asphalt concrete (DBM), thickness 50 mm
- Base course: Thickness 150 mm
- Sub-base: Thickness 210 mm

(2) Pavement Unit Cost

The pavement unit cost includes the construction cost price (direct construction cost + common temporary facilities cost + site management cost) + general administration cost. This unit cost is as follows according to the past record of Bhutan:

Construction cost (including the roadway, shoulders)	:	300 yen/m2
Material cost (including the transport costs)	:	5,500 yen/m2
Direct cost Total	:	5,800 yen/m2

On the basis of the above results, the total of common temporary facility cost, site management cost, and general administration cost, all of which can be handled in terms of the expense ratio, tends to be approximately 1.5 to 2.0 times the direct work cost.

When the thickness of the above pavement structure is considered on the basis of the above results, the pavement unit cost of asphalt work falls within the range shown below:

Pavement unit cost: 5,800 yen/m2 x 1.5〜2.0 = 8,700 yen/m2 - 11,600 yen/m2

The pavement structure is therefore based on the cold region specifications, and the altitude is high and a severe transportation state is expected. Accordingly, the expense ratio is set to the maximum 2.0 times, so that the pavement unit cost is 11,600 yen/m2.

(3) Approximate Construction Cost

The roadway standard width described in the guideline of Bhutan is assumed to be:

6.5 m x 5,000 m x 11,600 = 377 million yen

In consequence, the approximate construction cost for the 5 km section amounts to 377 million yen.

6-5-3.Approximate Construction Cost of the Road Widening Project

Table 6-21 shows the approximate construction cost of the road widening project. The material unit price includes both the direct cost and the indirect cost that is assumed to be 92% of direct cost. These costs were established by referring to the actual record of the Project for Reconstruction of Bridges (Phase III) implemented since 2008.

(1) Considerations for Cost Estimates

The survey is to be performed for the total distance of 700 m + 550 m = 1250 m for both sites of Thomang Cliff and Namling Cliff, which amounts to 2.37 billion yen. The approximate unit cost per meter was determined to be a little more than 1.5 million yen.

The above estimation does not take into account deterioration of the efficiency due to the blockage of existing roads, or the problem of handling of excavated soil. Excavation with a drill jumbo is proposed at this time, and the cost will change depending on the method of procurement and import of the drill jumbo.

The survey was done through observation from the road, so that it is possible that unstable rocks on the upper slope were overlooked. In such an event, change of the method could be necessary.

(2) Considerations for Detailed Survey

Further detailed survey, if necessary, requires assessment of the upper slope. But preparation of the slope treatment file requires climbing skill with due care on the safety by preventing falling rocks, downfall, slip drop, etc.

As no detailed map is currently available, a large-scale survey map becomes necessary. For the macroscopic rock assessment, geophysical exploration by seismic exploration may also become necessary.

<Table 6-21> Approximate construction cost

No.	Construction method	Length (m)				Cost for material and labor(thousand yen)				Remarks
						Tunnel	Rock fall protection net	Rock shed	Pavement	
		Tunnel	Rock fall protection net	Rock shed	Pavement	1,594	1,065	2,512	92	
T1	Tunnel	100	40		100	159,400	42,600	0	9,200	
T2	-					0	0	0	0	
T3	Tunnel/ Rock shed	70		30	100	111,580	0	75,360	9,200	
T4	Tunnel	150			150	239,100	0	0	13,800	
T5	Tunnel	50			50	79,700	0	0	4,600	
T6	Tunnel	100	20		100	159,400	21,300	0	9,200	
T7	-					0	0	0	0	
T8	Rock shed/ Tunnel	120		30	150	191,280	0	75,360	13,800	
T9	Tunnel	50	20		50	79,700	21,300	0	4,600	
Subtotal		640	80	60	700	1,020,160	85,200	150,720	64,400	
Thomang Cliff Total					700				1,320,480	
		-							1,886	Per 1m
N 1	Rock fall protection net		80		80	0	85,200	0	7,360	
N 2	Rock shed			30	30	0	0	75,360	2,760	
N 3	Tunnel	100	20		100	159,400	21,300	0	9,200	
N 4	-					0	0	0	0	
N 5	-					0	0	0	0	
N 6	-					0	0	0	0	
N 7	-					0	0	0	0	
N 8	-					0	0	0	0	
N 9	-					0	0	0	0	
N 1 0	Tunnel	50	20		50	79,700	21,300	0	4,600	
N 1 1	Tunnel	80	20		80	127,520	21,300	0	7,360	
N 1 2	-					0	0	0	0	
N 1 3	Tunnel	50	40		50	79,700	42,600	0	4,600	
N 1 4	-					0	0	0	0	
N 1 5	-					0	0	0	0	
N 1 6	-					0	0	0	0	
N 1 7	-					0	0	0	0	
N 1 8	-					0	0	0	0	
N 1 9						0	0	0	0	
N 2 0	Rock shed / Tunnel	60		20	80	95,640	0	50,240	7,360	
N 2 1	Tunnel/ Rock shed	60		20	80	95,640	0	50,240	7,360	
Subtotal		400	180	70	550	637,600	191,700	175,840	50,600	
Namling Cliff Total					550				1,055,740	
		-							1,920	Per 1m
Thomang Cliff + Namling Cliff Total		-				1,657,760	276,900	326,560	115,000	
									2,376,220	
									1,901	Per 1m

※ Pavement width is calculated as 8m per 1m of road length.

Source: JICA Study Team

Chapter 7 Results of the Study on Maukhola Bridge

7-1. Summary of the Results of the Site Survey

7-1-1. Bridge

(1) Objective of the survey

To check the location planned for Maukhola Bridge construction and to conduct a brief survey (to prepare the cross section) on the river section at the planned bridge location

(2) Survey Procedure

Date : April 18, 2014

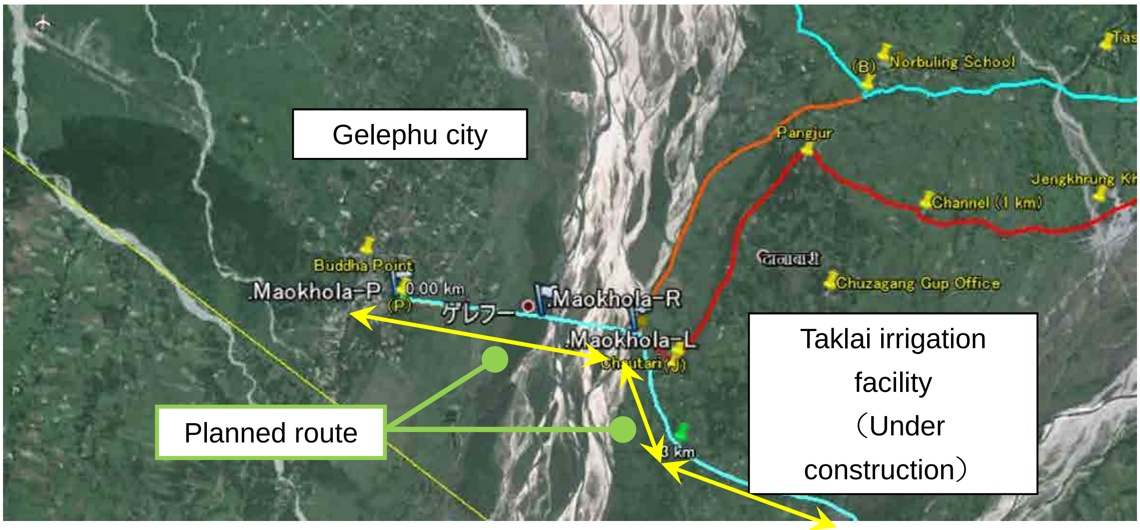
Members :

【DoR】Karma Dorji (Chief Engineer of the Sarpang Regional Office, DoR), Ngawang Thinley (DoR H.Q.)【JICA Study Team】Keigo Konno (Team leader), Yoshiteru Shutta (River engineer), Shinichi Nii (Bridge engineer)

Survey equipment : GPS, laser measurement, measuring tape

(3) Survey Route

The bridge location map provided by DoR is shown below.



Source: DoR

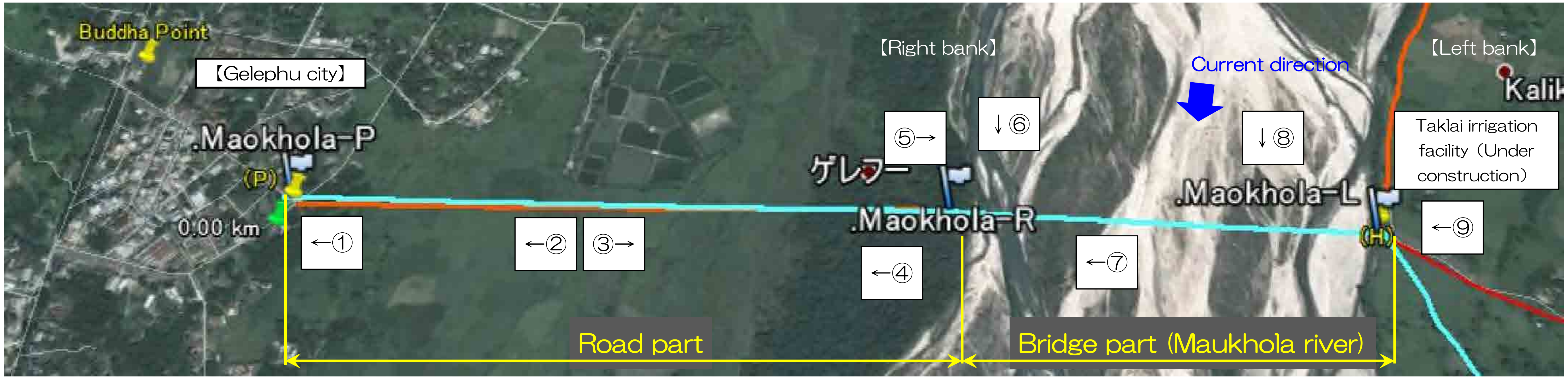
<Figure 7-1> Road planning map (provided by DoR)

Source: JICA Study Team

<Figure 7-2> Survey location map

(4) Survey Result

1) Road Part (Gelephu city ~ bridge)



No.	Photo	Contents
①		The origin of the road in Gelephu city is shown. It is planned to build an extension of the road in the center of the photo towards the river side (front side of photo).
② ③ ④	  	② : Farmland spreads. ③ : Facility in the left is a fish farm. The road is planned to avoid this facility. ④ : Forest spreads.

Source: JICA Study Team

<Figure 7-3> Survey result (Road part)

2) Bridge Part (Maukhola River)

No.	Photo	Contents
⑤		Views of Maukhola river, the opposite shore and Sandbank from the abutment position of the right bank. (Elevation difference between the log way on the right bank is small)
⑥		Log way on right bank side
⑦		Sandbank almost in the middle between both banks.
⑧		Log way on left bank side
⑨		Views on Maukhola river, sandbank and opposite shore from the abutment position of the left bank. (There is an elevation difference between the log way in the left bank.)

Source: JICA Study Team
<Figure 7-4> Survey result (Bridge part)

7-1-2.Rivers

(1) Objective of the Survey

To understand the current situation of the river around the location planned for Maukhola Bridge construction and confirm the situation of tributary inflow.

(2) Survey in Dry Season

1) Survey Procedure

Date : April 18-19, 2014

Members :

【DOR】Karma Dorji (Chief Engineer of the Sarpang Regional Office, DoR), Ngawang Thinley (DoR H.Q.)【JICA Study Team】Keigo Konno (Team leader), Yoshiteru Shutta (River engineer), Shinichi Nii (Bridge engineer)

Survey equipment : GPS, laser measurement, measuring tape

2) Survey Area

Survey area is from around upstream of Geleg (Aie) zam Bridge to the location planned for Maukhola Bridge construction.

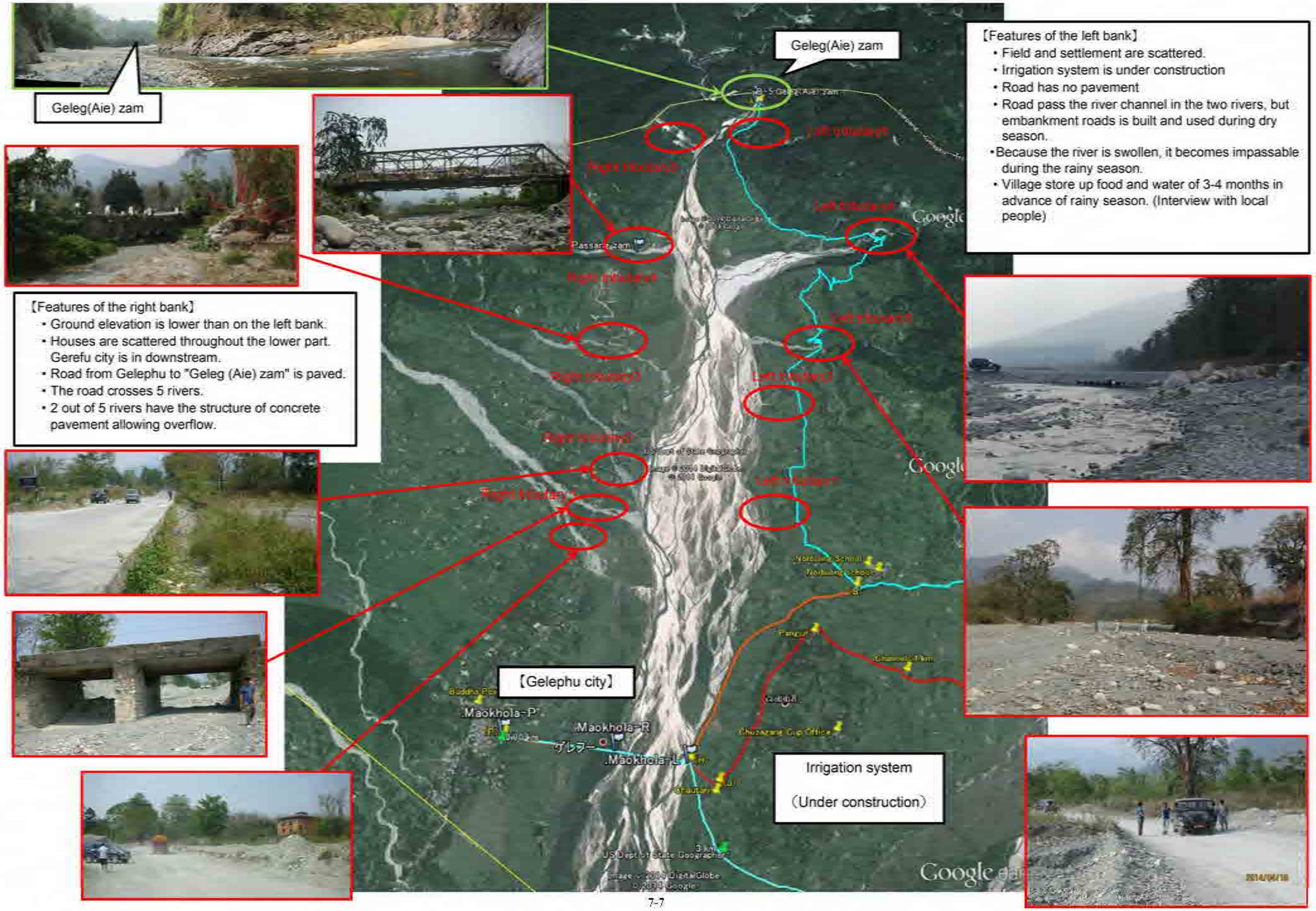
3) Survey Result

a) Main Stream of Maukhola River

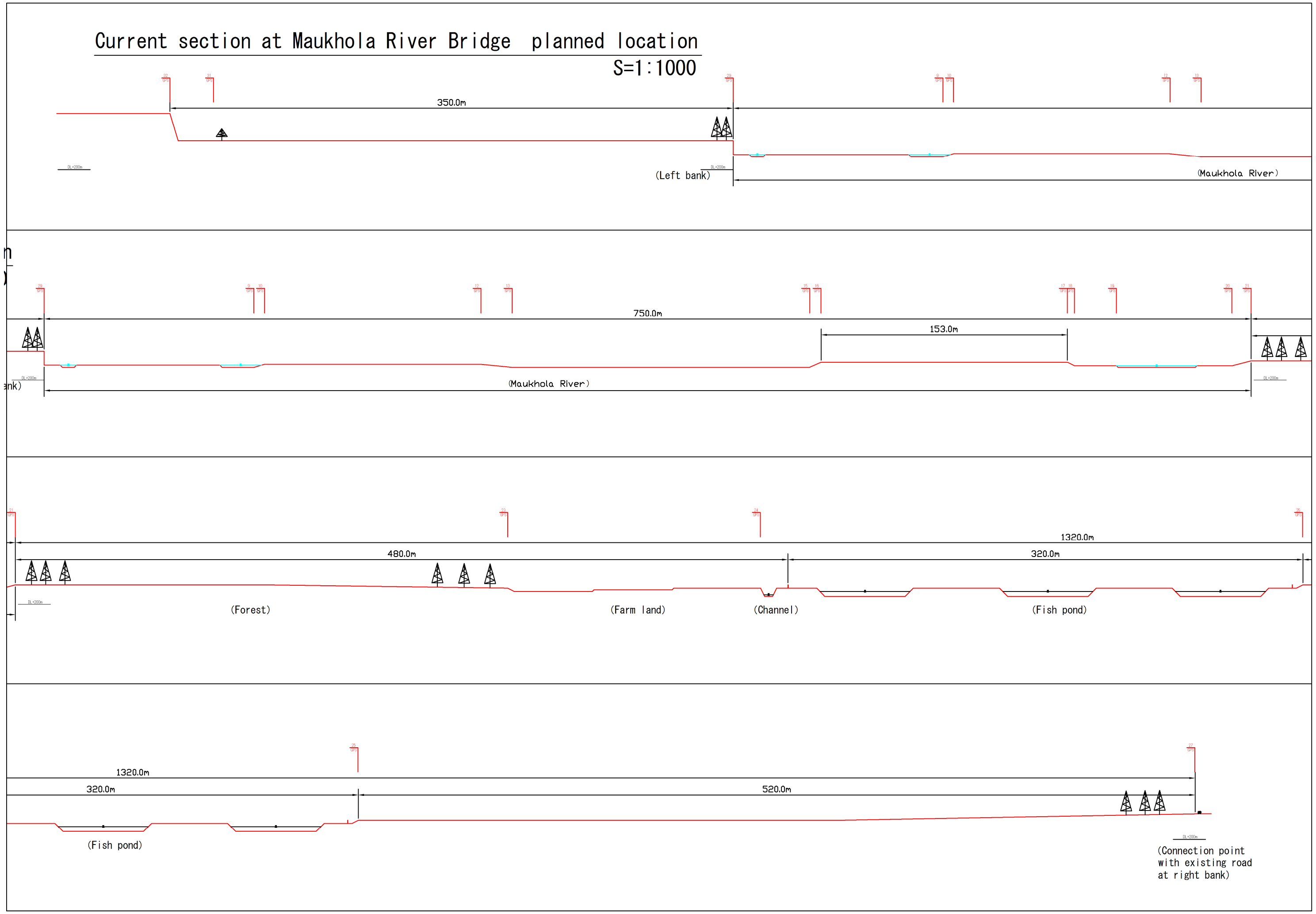
- Downstream of Geleg (Aie) zam Bridge is mainly excavated river channel (Embankment is not continuous but partial).
- Width of the river is about 120m around Geleg (Aie) zam Bridge and about 750m around the planned bridge construction site.
- The river has a gravel riverbed in all sections from Geleg (Aie) zam Bridge to downstream of the bridge construction site.
- The source of gravel is thought to be mainly from the main stream (because the bed of the main stream contains mica flakes and the gravel of the main stream is distributed more broadly than the gravel of the tributaries in the downstream area.).
- Sediment is from the tributaries.
- Sandbank in the river channel is partly forested.
- Water route in each cross-section is about 20m in width and 1m~50cm in depth.
- The material of the river bed is about 50cm in diameter in the largest, however they are mainly 5~10cm in diameter.
- There is a water intake facility for drinking water on the right bank near the city of Gelephu.

b) Tributaries

- Right tributary 1 and right tributary 2 have concrete structures that allow overflow (It is a structure of stream flowing down the road at the same level as the river bed during flood. Traffic is closed during flood).
- Right tributary 4, right tributary 5 and left tributary 5 are steep streams and there is slope failure therefore large diameter gravel is washed into the river.
- There are no crossing facilities in the left tributary 3 or the left tributary 4. A raised section is built in the river channel for crossing during the dry season.
- All tributaries are excavated river channels (It is partly embankment, but it is considered to be temporary storage of excavated soil from the river bed.).
- Water flow was observed in the left tributary 1 and the left tributary 4, but there is no water except for this.
- None of the material in the river beds in any of the tributaries contain mica flakes. Some of rock sizes in steep tributaries are about 1m, while other tributaries have mainly 5 ~10cm diameter.

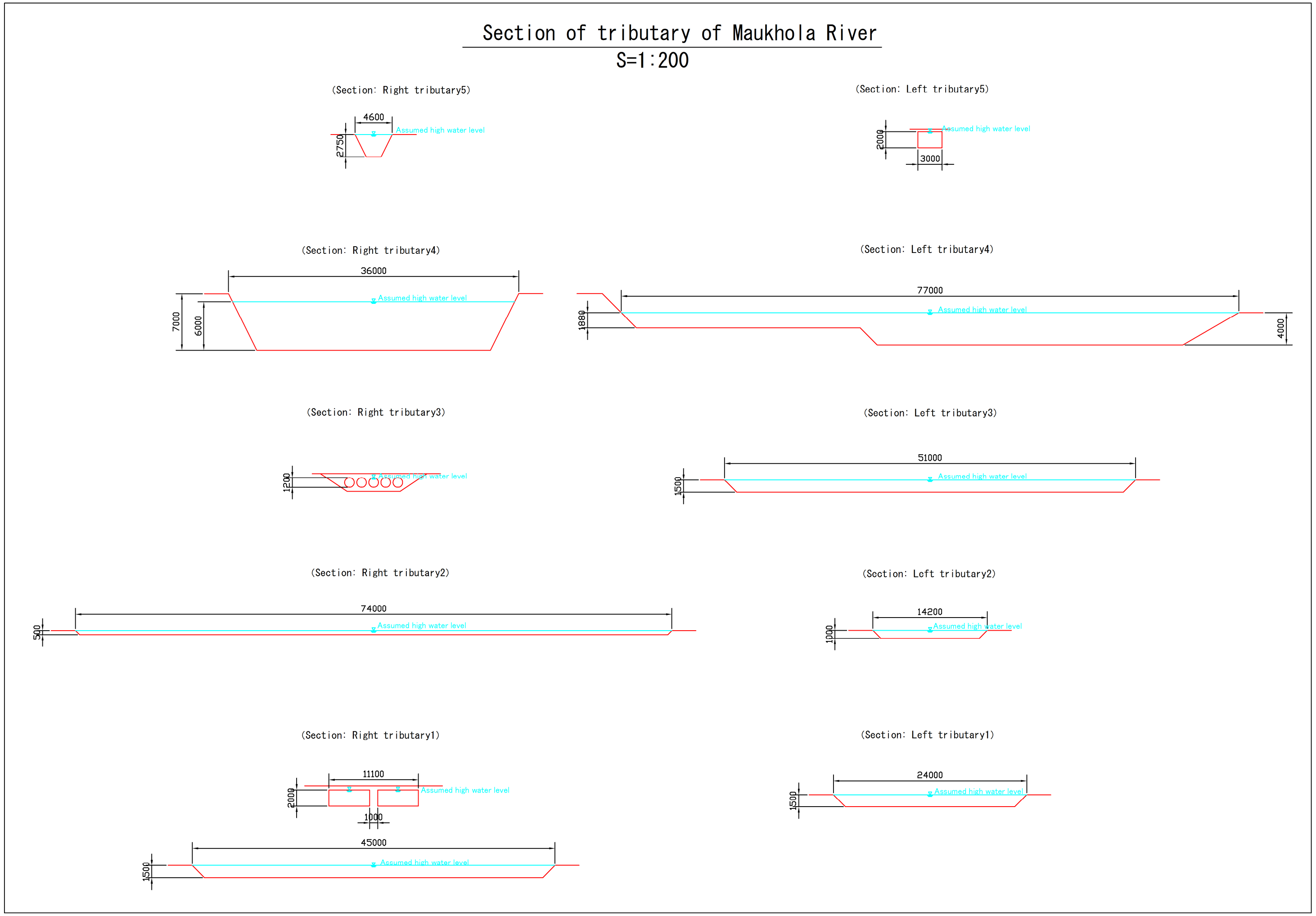


Source: JICA Study Team
<Figure 7-5> Present Condition of Maukhola River



Source: JICA Study Team

<Figure 7-6> Current section at Maukhola River Bridge planned location



Source: JICA Study Team

<Figure 7-7> Section of tributary of Maukhola River

【Photos of Project Site 1/7】

Photo	Remarks
	Maukhola River ・View upstream from Geleg (Aie) zam ・ Flow of the Maukhola river moves from the mountain area to an alluvial fan area.
	Maukhola River ・View downstream from Geleg (Aie) zam ・ Flow of the Maukhola river moves from the mountain area to an alluvial fan area.
	Maukhola River ・ Gauging station upstream of Geleg of (Aie) zam.
	Maukhola River ・Water route on the right bank side

Source: JICA Study Team

<Figure 7-8> Photos of project site (1/7)

【Photos of Project Site 2/7】

Photo	Remarks
	Maukhola River ・View upstream ・Water route on the right bank. ・ Near Maukhola bridge construction site
	Maukhola River ・View downstream ・Sandbank in the center of the water route ・Progress of greening
	Right tributary1 (Downstream side of the bifurcate) ・ Concrete pavement allowing overflow (River bed and road surface is at the same height. Traffic is closed during flood)
	Right tributary1 (Downstream side of the bifurcate) ・No water in the river channel.

Source: JICA Study Team

<Figure 7-9> Photos of project site (2/7)

【Photos of Project Site 3/7】

Photo	Remarks
	Right tributary1 (Downstream side of the bifurcate) ・View downstream ・No water in the river channel. ・Embankment on the left and right bank is the soil excavated from the river bed
	Right tributary1 (Downstream side of the bifurcate) ・View upstream ・No water in the river channel. ・Embankments on the left and right are made of the soil excavated from the river bed
	Right tributary 2 ・View upstream ・No water in the river channel.
	Right tributary 2 ・View downstream ・No water in the river channel. ・Concrete pavement allowing overflow

Source: JICA Study Team

<Figure 7-10> Photos of project site (3/7)

【Photos of Project Site 4/7】

Photo	Remarks
	Right tributary 3 ・View downstream ・No water in the river channel.
	Right tributary 3 ・View downstream ・No water in the river channel. ・Structure of road intersection is 5 statios hume pipe.
	Right tributary 4 ・View upstream ・No water in the river channel. ・The largest rock is about φ = 1.0m. ・ Excavation of river bed is conducted before the rainy season. (interview with DoR)
	Right tributary 4 ・View downstream ・No water in the river channel. ・The largest rock is about φ = 1.0m・Excavation of river bed is conducted before the rainy season.(interview with DoR)

Source: JICA Study Team

<Figure 7-11> Photos of project site (4/7)

【Photos of Project Site 5/7】

Photo	Remarks
	Right tributary 5 ・View upstream ・Soil from slope failure is washed into the river channel.
	Right tributary 5 ・View downstream ・Soil from slope failure is washed into the river channel.
	Left tributary 1 ・View upstream ・Water and vegetation exist.
	Left tributary 1 ・View downstream ・Water and vegetation exist.

Source: JICA Study Team

<Figure 7-12> Photos of project site (5/7)

【Photos of Project Site 6/7】

Photo	Remarks
	Left tributary 2 ・View upstream ・No water in the river channel.
	Left tributary 2 ・View downstream ・No water in the river channel.
	Left tributary 3 ・View upstream ・No water in the river channel.
	Left tributary 3 ・View downstream ・No water.

Source: JICA Study Team

<Figure 7-13> Photos of project site (6/7)

【Photos of Project Site 7/7】

Photo	Remarks
	Left tributary 4 ・View upstream ・Water exists. Flow volume is small.
	Left tributary 4 ・View downstream ・Water exists. Flow volume is small. ・It is temporary structure of hume pipe and embankment in the crossing point of river channel.
	Left tributary 5 ・View upstream ・No water in the river channel. ・The largest rock is about φ = 1.0m
	Left tributary 5 ・View upstream from the main stream ・No water in the river channel.

Source: JICA Study Team

<Figure 7-14> Photos of project site (7/7)

(3) Survey in the Rainy Season

1) Survey Outline

Date: 14th July 2014～15th July 2014

Survey members:

【DoR】Ngawang Thinley（DoR H.Q.)

【JICA Study Team】Keigo Konno (Team leader), Yoshiteru Shutta (River engineer), Yasuhisa Suganuma (Road and traffic engineer)

2) Survey Target

Survey area is between Geleg (Aie) bridge and location of Maukhola Bridge.

3) Result of the Survey

- A small island (woodland and grass field) in the channel of Maukhola river remains the same as in the dry season.
- The river channel does not seem to ever become more swollen than the current river channel.
- The increase of water volume was small at the time of the survey. (Total amount of rainfall of June 2014 was at the average level.)
- The flow velocity of the center of flow was about 4m/s at the time of the survey. (simple measurement at site)

【Photo of Site During Rainy Season：Distant View of Maukhola River】

Rainy season（2014.7.15）

・The river channel does not seem to ever become more swollen than the current river channel. ・The small island with grass field remains in all seasons. ・The number of water routes has increased above those in the dry season and the volume of water has increased compared to the dry season. However, the volume is small.

Source: JICA Study Team

<Figure 7-15>View of Maukhola river

【Photos of Site During Rainy Season Geleg（Aie）Bridge】

Dry season（2014.4.18）	Rainy season（2014.7.15）
	

・The change in the material of the river bed is small and flood is not expected at the moment.

・Water flow has increased.

<Figure 7-16>Photo at Geleg（Aie）Bridge (taken by JICA Study Team)

【Photos of Site During Rainy Season Near the Junction of Right Tributary 1】

Dry season（2014.4.18）	Rainy season（2014.7.15）
	

・The increase of water volume is observed. However the quantity of vegetation has not decreased and flooding is not expected at the moment.

<Figure 7-17>Photo near the junction of the right tributary 1 (taken by JICA Study Team)

【Photos of Site during Rainy Season near the Location of an Abutment on the Right Bank】

Dry season（2014.4.18）	Rainy season（2014.7.15）
	

・The increase of water volume is observed but no evidence of the flooding can be seen.

・A small island with woodland remains visible therefore no flooding is expected at the moment.

・The flow velocity of the center of the channel was about 4m/s at the time of the survey. (simple measurement at site)

<Figure 7-18>Near the location of an abutment on the right bank（Taken by JICA Study Team）

4) Trend of Rainfall in Recent Years

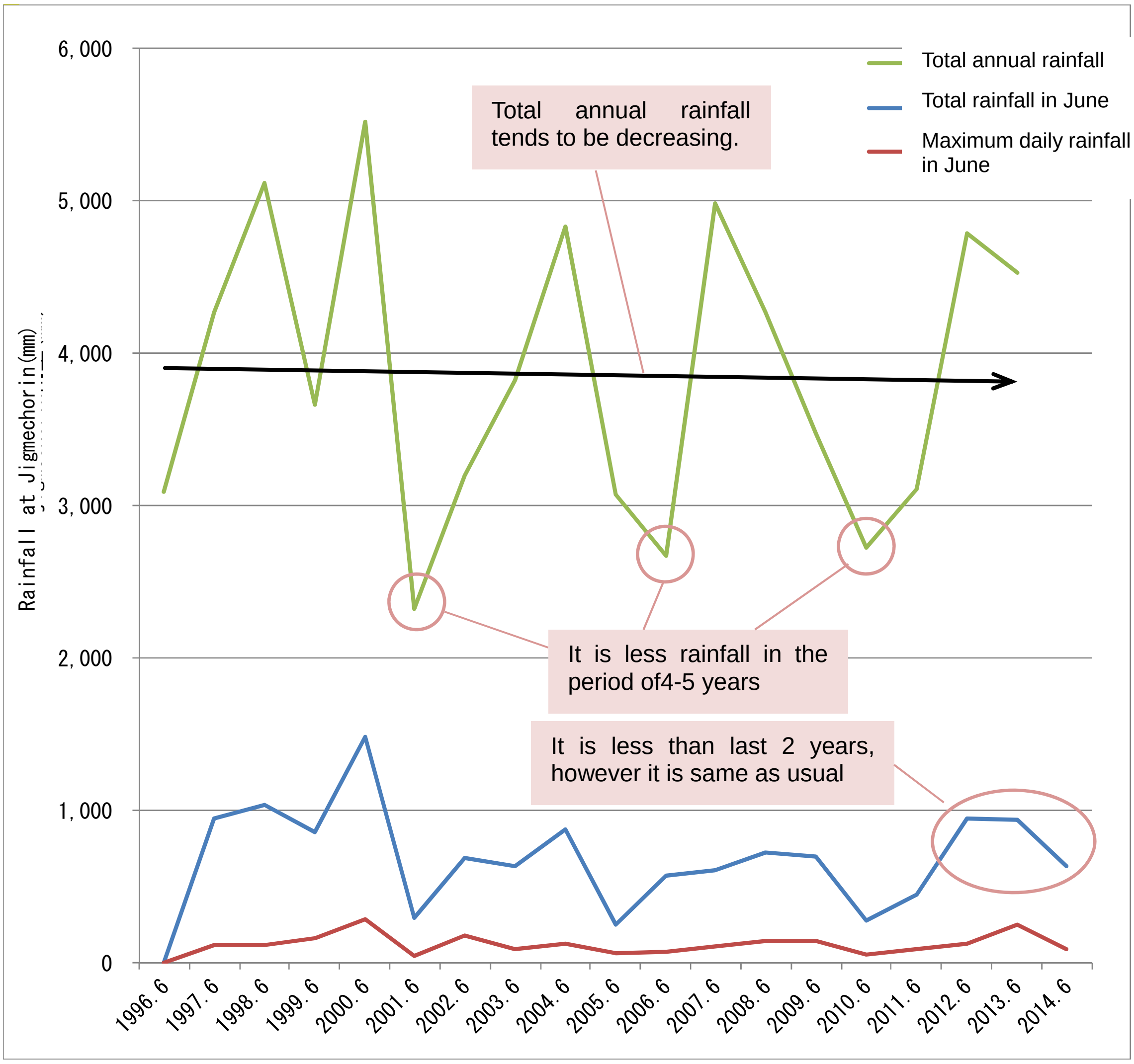
According to an interview of people at the site (near the Maukhola river) the information that the rainfall in 2014 is less than usual was obtained. Therefore, the trend in recent years was identified from rainfall data at Jigmechoring station

As a result of the identification of the trend from the available rainfall data until June 2014, the following information was confirmed.

- The rainfall in June 2014 is less than the last 2 years, however it is the same as usual.
- Total annual rainfall of about 20 years has decreased gradually.
- Every four or five years there is a year with less rainfall than normal and that this year is a year of less rainfall.

<Table7-1>Jigmechoring station Transition in rainfall in June (Unit:mm)

Jigmechoring	Rainfall in June		Total annual rainfall
	Total	Maximum	
1996.6	0.0	0.0	3088.3
1997.6	943.6	120.0	4271.7
1998.6	1033.8	119.0	5117.1
1999.6	857.8	163.8	3665.6
2000.6	1480.1	288.4	5522.3
2001.6	293.6	45.2	2320.8
2002.6	689.2	182.2	3199.0
2003.6	637.4	89.0	3820.6
2004.6	878.2	126.6	4828.3
2005.6	247.6	61.4	3069.8
2006.6	572.2	72.8	2669.4
2007.6	610.0	103.6	4987.4
2008.6	720.2	140.0	4267.7
2009.6	701.8	147.6	3474.1
2010.6	278.9	57.6	2727.6
2011.6	447.0	93.6	3108.4
2012.6	950.7	122.4	4788.4
2013.6	942.1	251.4	4530.7
2014.6	636.0	88.4	–

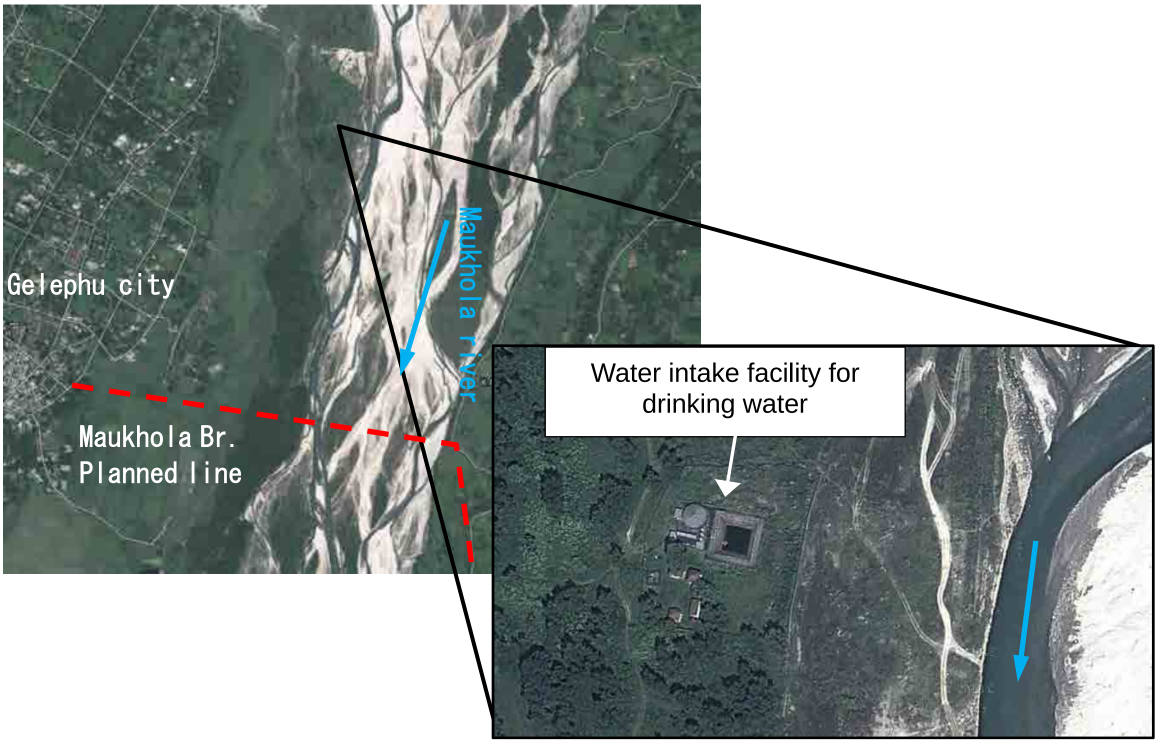


<Figure7-19>Jigmechoring station rainfall in June (Source: JICA Study Team)

(4) Water Intake Facility for Drinking Water

A Water intake facility for drinking water has been built on the right bank of Maukhola river and it has become a source of water for Gelephu City. The method of water intake is natural intake of ground water from Maukhola river that was designed so as to ensure a water storage pond of about 4m depth. The facility has been operated since 2010 and the volume of water intake is about 600 m3/day.

The items to be considered for the facility are the impact to the groundwater (Decline of groundwater level and decrease in water volume) when the embankment is installed or river channel of Maukhola river is relocated. Accordingly, the construction of an embankment in the front of the facility (right bank side) is difficult.



Source: JICA Study Team

<Figure7-20>The location of water intake facility for drinking water

Source: JEONGSAN ENGINEERING&TECH（Korea）Website

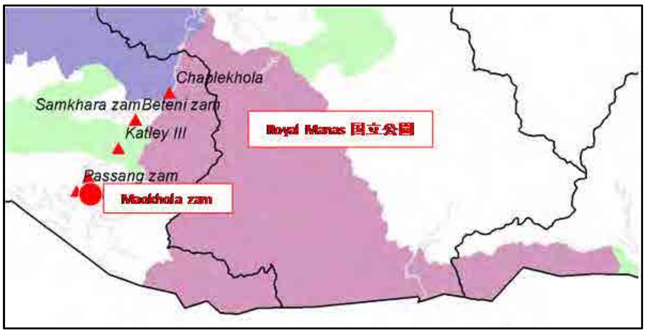
<Figure7-21>Water intake facility for drinking water

7-1-3. Surrounding Environment

The site survey around Maukhola Bridge focusing on its natural and social environment is conducted.

(1) Natural Environment

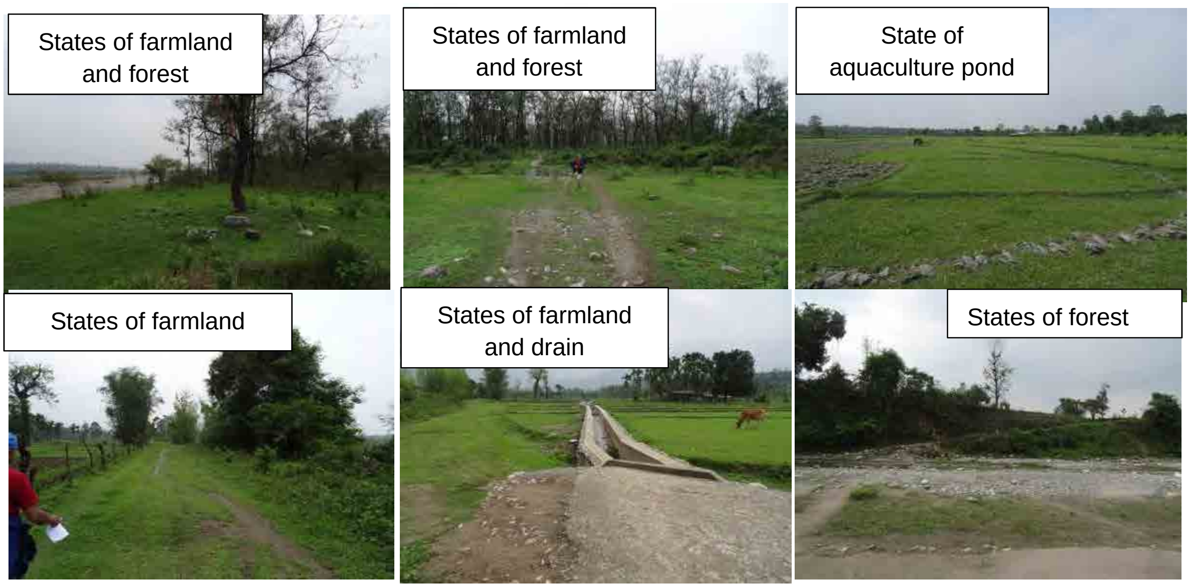
There are Royal Manas National Park and ecosystem corridors near Maukhola Bridge. However, the locality map provided by the DFPS, MoAF, confirms that the bridge is not located in any national park or ecosystem corridor. Further, as shown in “Chapter 7-1-1. Bridge”, it is confirmed that the banks of the Maukhola River, where the bridge crosses it, are used as agricultural fields, farms, or thickets, and don’t form any forests providing habitat for rare animals or plants. There is no slope around the bridge, which minimizes the risk of accidents such as rock fall and slope failure. The Maukhola River may flood when it rises during the rainy season, but, according to MoWHS, a bank protection work is being planned for the right bank. It can be assumed that, if the plan is implemented, the risk of flood will be reduced.



<Figure 7-22> Positions of national parks and Maukhola Bridge (Source: Department of Forest and Park Services, MoAF)

(2) Social Environment

As stated earlier, where the bridge crosses the Maukhola River, the banks are used as agricultural fields, farms, or thickets. When building an approach road, land acquisition will be needed. Since cutting down trees may require the permission of the MoAF, detailed discussion with the National Land Commission and the MoAF will be needed before mowing crops or cutting down thickets.



Source: JICA Study Team

<Figure7-23>Bridge construction site Maukhola River, left bank

The Maukhola River runs low during the dry season and allows people to ford it at some points. Mostly, however, it is over some temporary bridges placed over the river that people come and go between the banks. During the rainy season, these temporary bridges are washed away by flood, so people use boats to cross the river, but the river, when running high and rapid, is dangerous.

On the right bank of the river lies the city of Gelephu, while, on the left bank, spread agricultural fields. On the left bank, irrigation facilities have been under improvement by JICA in recent years and the expansion of villages is expected. In the future, traffic is expected to grow as more and more people transport agricultural products to cities and receive urban services (medicine, education, etc.). To get to the other side of the river by road, one must take a long detour northward along PNH-4, which takes much time and is inconvenient. Allowing inhabitants to circulate safely in any season will boost the circulation of people and goods within the region.

Source: JICA Study Team

<Figure7-24>Temporary timber bridge over the Maukhola

7-2. River Planning

In order to study the river cross section required at the Maukhola Bridge construction site, the run-off of the Maukhola River is reviewed and the cross section of the river channel is established at the bridge position.

Since the Department of Engineering Services (DoE) in MoWHS is studying the river control plan now, possibility of the reduction of river width is examined in a range of existing materials based on DoE's plan.

(1) Plan of DoE

The Flood Engineering Management division, DoE is planning a project for the development of bank protection on Maukhola and its tributaries and construction of erosion-control dams on the tributaries in the project "Integrated Maukhola Basin Flood Management".

It is considered that the current river terrace is to be used as commercial land by building an embankment of about 400m width on the right bank of the Maukhola River.

The construction of mud-control dams is being considered for the Thewar River (Left tributary2)

Flood management handled by the department is considered as an important policy of the country (with high priority) by the Royal Government of Bhutan, the annual budget of this department is approximately 120 million Nu, and about 50 million Nu is planned to be devoted to the Maukhola River related project.

Bank protection is under construction on the right tributary1of the Shetikharey River in Sarpang. The current situation as of July 2014 is as below.

Source: JICA Study Team

<Figure 7-25> Embankment protection works on Shetikharey river (Right tributary1)

(2) Reviewing the Run-Off of the Maukhola River

The Maukhola River has a catchment area of about 820 km^2 at the bridge position and a river channel length of 53 km, and more than 90% of the catchment area is mountainous. Gelephu City (population, about 10,000) on the border with India is within this basin. Its central area is densely-built with houses, accommodation facilities, and small commercial facilities.

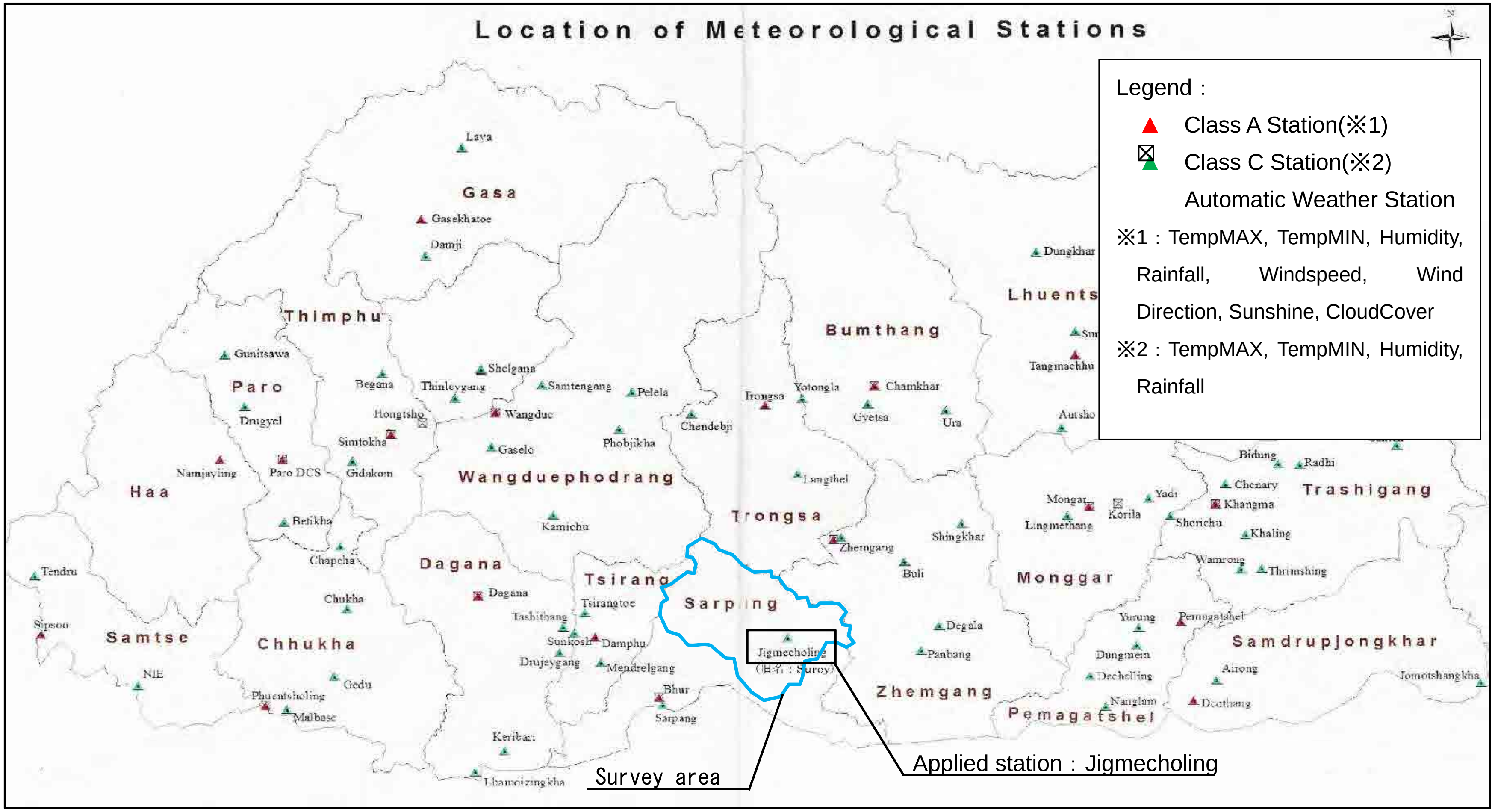
1) Confirmation of Existing Materials

Collected materials for the review are as follows

a) Rainfall
- Obtained from the Department of Hydro-Met Service, Meteorology Division
- Daily rainfall data
- 1996.1～2013.12, No missing data

b) Water level
- Obtained from the Department of Hydro-Met Service, Hydrology Division
- Low-water observation data up stream of Geleg zam bridge
- Low-water stage (daily data) of 1994-2013 only
- No observation data at the time of flood

c) Record of flood
- As an observation record up stream of Geleg bridge, a water-level gauge has been installed with the riverbed set as 0m and a value of 6.5m was recorded during the flood on 19th July 2007 (based on an interview with local people).



Source: Legend, catchment area and information from the adopted stations are added to the materials obtained from Meteorology Division, Department of Hydro-Met Service

<Figure7-26> Locations of metrological stations in Bhutan

2) Determination of Run-off Formula

In the Study, the rational run-off formula was used for the method that calculates run-off of Maukhola River for the following reasons

- The objective is to calculate peak flow at the bridge location.
- The impact due to the lack of storage shall be large if there is no facility/place that provides a storage effect such as a dam in the basin and the basin area increases. However, it is the basin shape that reduces the storage effect because the shape of the basin is not one river channel but river channels from several tributaries that gather to the central area in the basin, which runs from east to west.
- It is practically difficult to use a method that considers the basin storage effect (storage function method etc.) since there are no flood records (water level, rainfall, cross-section).

Rational run-off formula

The rational run-off formula is a simplified method of estimating the peak flow during flood and is widely applied to cases when only the peak flow is required on a river where there is no need of taking into account the storage phenomena. Various formulas to estimate the peak flow generally determine the peak flow as a function of the basin area. The Creager curve of specific run-off method is one of such various methods. Since originally the maximum flow is not the function of drainage area alone, the run-off calculation method is demanded, which takes into account, for example, the rainfall intensity, vegetation in the basin, the slope, etc. By taking the flood frequency additionally into factor, the above method will prove further useful for planning the river, etc. The proposed simplified method based on consideration of these factors is a rational run-off formula. According to this formula, the basin is shaped as a rectangle symmetrical to the river channel and rainwater is assumed to flow down the basin slope at a given rate into the river channel. The time for the rainwater falling at the remotest point of the basin to reach its outlet is called the time of flood concentration. The rainfall intensity during this time period is multiplied by the run-off coefficient appropriate to the land use, establishing the run-off.

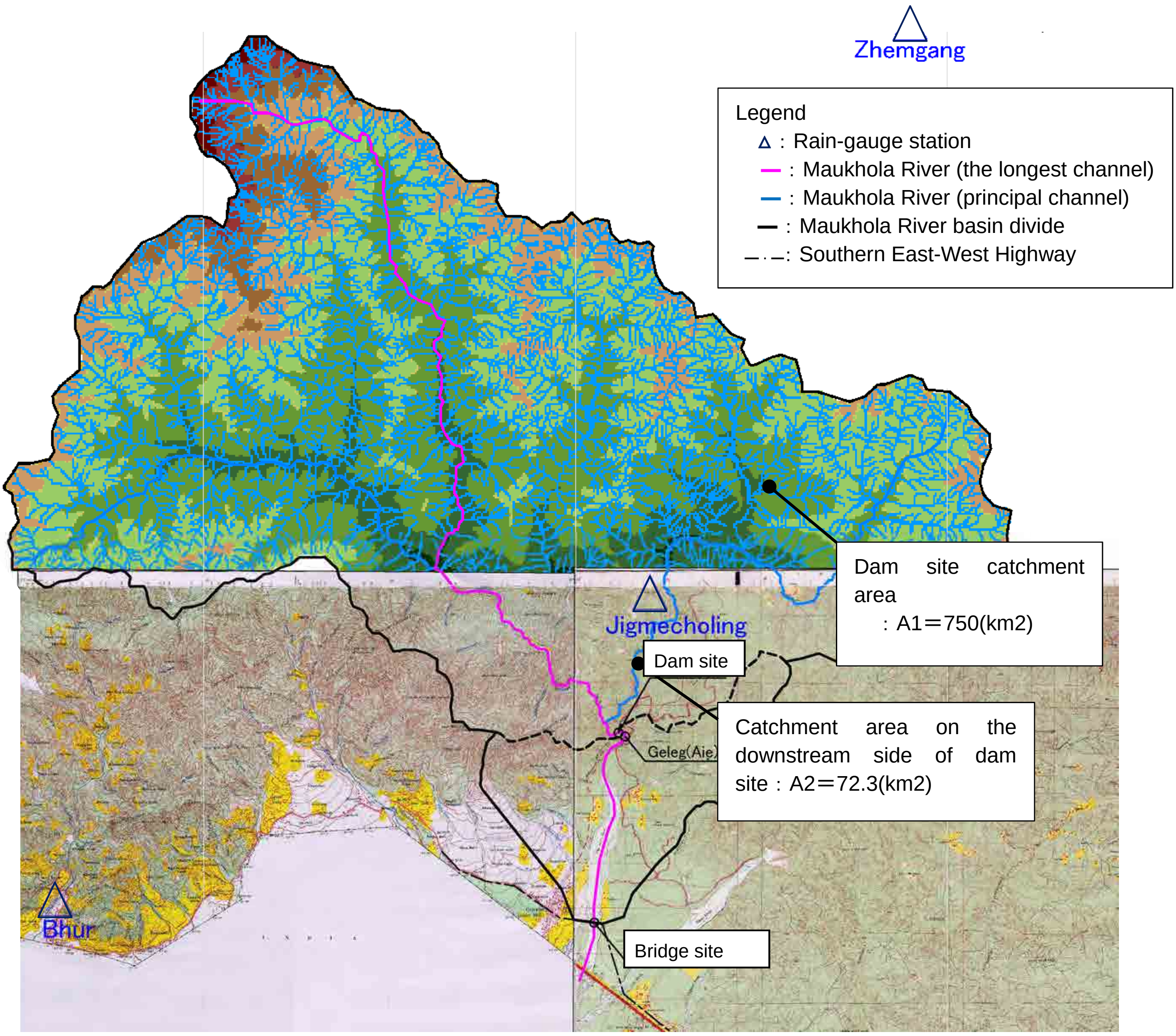
The peak flow is determined as follows according to the rational run-off formula.

Source: Technical Criteria for River Works and Sabo Works, Survey (Edition; June, 2012, Water and Disaster Management Bureau, the Ministry of Land, Infrastructure, Transport and Tourism)

<Figure7-27> Explanation of rational run-off formula

3) Catchment Area: A

- Dam site: 750km2 (”PSF of AIECHHU Hydropower Project（Dec 2011）”
  (Hereinafter described as “Dam Review Report”)
- Downstream of the dam site 72.30 (km2)（Measured by Auto CAD）
- Total of catchment areas A=750.00+72.30=822.3(km2)



Source: JICA Study Team

Note) For the basin of the Maukhola River, the basin map from the “Dam Study Report” was referred to. The basin area on the downstream side of the dam site was measured this time.

<Figure7-28> Catchment area at the bridge construction position

4) Run-off Coefficient: f

- Run-off coefficient refers to the Japanese technical standard for river and erosion control.
- With regard to the application to Bhutan, it is considered the same as the rivers of Japan since 90% of the basin is a mountainous area and the vegetation on the mountains is a mixture of conifer trees and broad leaf trees.
- Average catchment area Run-off coefficient : f=0.7

<Table7-2>List of run-off coefficients

Area of basin	Area by landuse (km2)						Coefficient of discharge
	Density built-up area	General urban area	Paddy field	Field and Plain	Mountains	Pond	
(km2)	f=0.9	f=0.8	f=0.7	f=0.6	f=0.7	f=1.0	
822.30	0.00	1.60	0.00	21.30	794.70	4.70	0.70

Source: Japanese technical standard for river and erosion control

Determination of the flood run-off model constants

When the constants of the flood run-off model for conversion of the rainfall that produces the flow are to be determined, due care must be taken on the following points:

1. Difference in the flood scale between the actual record and the plan
2. Change of basin conditions due to development

Explanation

Constants of the flood run-off model are normally determined from the actual small scale flood records, but due care must be taken during determination to avoid irrational results.

In addition, determination of constants must also take into account any changes in the basin conditions due to development occurring during the period from the time of the previous actual flood up to the time of planning. In particular, the run-off percentage must be reviewed carefully because it is greatly dependent on the basin conditions and those conditions exert substantial influence on the flood run-off and flood peak flow.

The inlet time (the time for rainwater to flow from the remotest point of the basin to the river channel) necessary for calculation of the run-off coefficient and time of flood concentration when the rational run-off formula is used may be established on the basis of the following values. For the equation to determine the time of flood concentration, refer to the Technical Criteria. For River Works and Sabo Works (draft), Survey Edition.

<Run-off coefficient>	
Densely built-up area	0.9
General urban area	0.8
Field and plain	0.6
Paddy field	0.7
Mountains	0.7

<Inlet time>	$2km^2$	30 min
Mountainous basin	$2km^2$	20 min
Basin on the steep slope in particular	$2km^2$	30 min
Area provided with sewerage service		

Source: Japanese technical standard for river and erosion control (Edition; June, 2005, P 35. River Bureau, the Ministry of Land, Infrastructure, Transport and Tourism)

<Figure7-29> Determination of the flood run-off model constants

5) Rainfall Intensity within the Time of Flood Concentration: R

- Since the bridge is designed for a lifetime of 100 years, the river planning scale is to be 100 years.
- For rainfall observation data, the daily rainfall data of the period from 1996 to 2013 is used. There is no missing observation data.
- Jigmecholing shall be used since it has the most impact on the rainfall in the basin and Damphu, Bhur and Zhemgang are farther from the basin.
- A probability distribution of a Generalized extreme value distribution was adopted after checking the degree of fitness of several models regarding the probability distribution model calculating rainfall intensity (processing flow and calculation result are below)
- Rainfall of 24 hours at 100 year return period: r 24＝652.9 (mm) (Calculated by Gev)
- Rainfall intensity : R＝652.9／24＝27.21 （mm/ h)

[Reference]

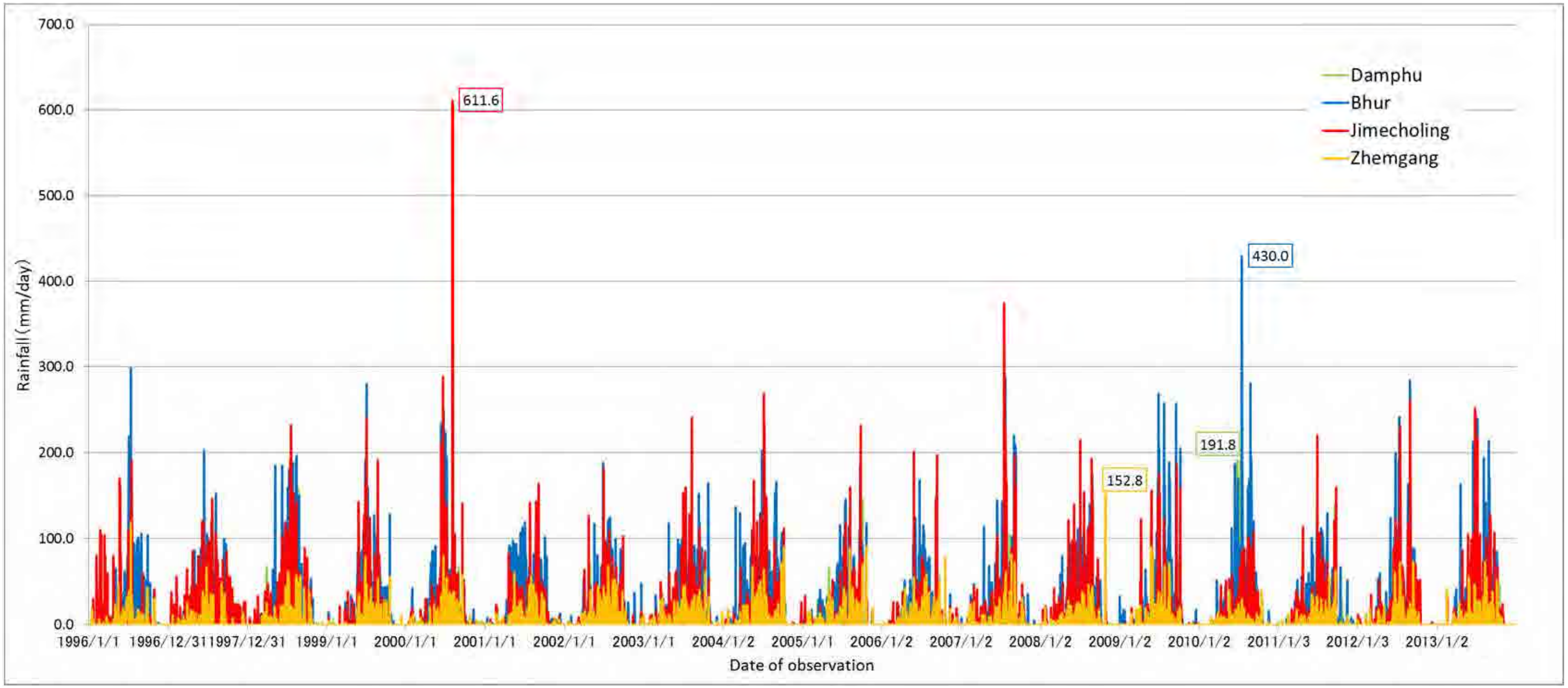
Note that the rainfall intensity within the time of flood concentration as calculated back from data (basin area, planned flow) established in the "Dam Review Report" is as follows.

$$Q = 1 / 3.6 \times f \times R \times A$$

In this time, Q＝2430(m3/s), f＝0.7 (Assumed） A＝750(km2)

Namely,

$$R = 3.6 \times 2430 / (0.7 \times 750) = 16.66 (mm/h)$$



Source: JICA Study Team

<Figure7-30>Comparison of daily rainfall at stations near target basin

<Table7-3>Situation of surrounding stations at the time of maximum rainfall observed

	Daily rainfall(Date/mm,Damp at the maximum)			
	Damp	Bhur	Jime	Zhem
25/6/2010	0.0	1.2	2.8	0.0
26/6/2010	3.0	122.8	2.6	0.1
27/6/2010	**191.8**	95.0	18.6	9.5
28/6/2010	104.0	4.2	13.4	6.0
29/6/2010	0.8	**170.0**	10.4	4.1
30/6/2010	24.8	10.8	20.8	18.3
1/7/2010	0.0	52.0	19.8	0.4
2/7/2010	0.0	56.4	**42.8**	**24.1**
3/7/2010	4.6	9.0	25.6	23.1
4/7/2010	1.4	42.8	5.8	2.0

(Rainfall of surrounding stations at the time of the maximum rainfall observed at Damphu)

	Daily rainfall(Date/mm,Bhur at the maximum)			
	Damp	Bhur	Jime	Zhem
14/7/2010	16.8	0.0	5.4	0.0
15/7/2010	1.0	6.8	5.6	6.0
16/7/2010	17.0	30.0	**85.4**	6.0
17/7/2010	16.4	189.0	8.8	0.6
18/7/2010	22.0	**430.0**	16.3	**30.0**
19/7/2010	67.4	44.8	28.5	18.0
20/7/2010	29.8	24.0	23.8	14.3
21/7/2010	**108.4**	178.0	34.2	14.0
22/7/2010	1.8	25.6	10.3	9.9
23/7/2010	1.2	0.0	2.6	0.1

(Rainfall of surrounding stations at the time of the maximum rainfall observed at Bhur)

	Daily fainfall(Date/mm,Jigmecholin at the maximum)			
	Damp	Bhur	Jime	Zhem
28/7/2000	1.4	0.0	4.6	0.0
29/7/2000	2.0	16.6	21.4	0.0
30/7/200	11.6	18.2	11.8	0.0
31/7/2000	29.3	2.4	7.2	11.2
1/8/2000	68.2	100.4	19.6	9.6
2/8/2000	**129.8**	184.0	**611.6**	35.2
3/8/2000	24.6	**341.8**	437.6	31.2
4/8/2000	0.0	32.6	606.6	**36.8**
5/8/2000	0.0	0.0	7.6	0.0
6/8/2000	1.2	0.0	1.6	0.0

(Rainfall of surrounding stations at the time of the maximum rainfall observed at Jigmechorin)

	Daily rainfall(Date/mm, Zhemgang at the maximum)			
	Damp	Bhur	Jime	Zhem
22/10/2008	0.0	0.0	0.0	0.0
23/10/2008	0.0	0.0	0.0	0.0
24/10/2008	0.0	0.0	0.0	0.0
25/10/2008	0.0	0.0	0.0	0.0
26/10/2008	8.4	6.0	0.0	13.4
27/10/2008	**73.0**	**35.8**	13.6	**152.8**
28/10/2008	0.0	0.0	**38.8**	0.0
29/10/2008	0.0	0.0	0.0	0.0
30/10/2008	0.0	0.0	0.0	0.0
31/10/2008	0.0	0.0	0.0	0.0

(Rainfall of surrounding stations at the time of the maximum rainfall observed at Zhemgang)
Source: JICA Study Team based on data from each observation station

<Table7-4> Selection process of the probability distribution

Water system	–
River	Mau Khola river
Station	Jimecholing
Number of data	18
α	0.4

Bootstrap number of samples	2000
LN4PM upper limit g	-9999
LN4PM lower imit b	0
K(Annually) = (Xp – X)/S	2.82
K(Non-annually) = (Xp – X)/S	2.82

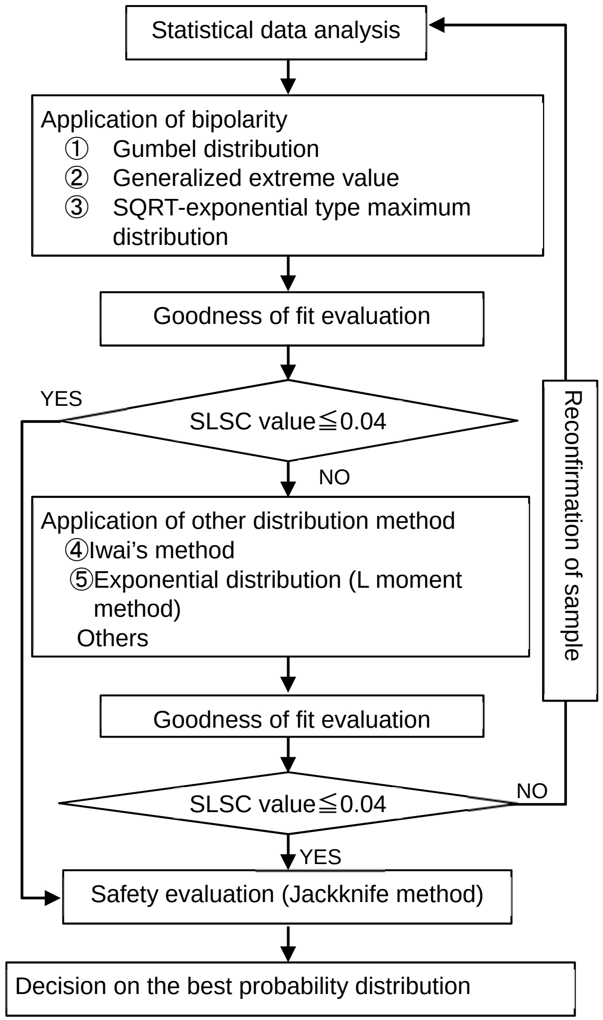
	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM	Lexp	Gp	GpExp
X-COR(99%)	0.935	0.907	0.931	0.957	–	–	0.928	–	0.923	–	–	–	–	0.935	–	0.935
P-COR(99%)	0.911	0.971	0.977	0.977	–	–	0.973	–	0.975	–	–	–	–	0.911	–	0.931
SLSC(99%)	0.084	0.103	0.077	0.061	–	–	0.063	–	0.065	–	–	–	–	0.084	–	0.069
Log likelihood	-101	-104.5	-103.8	-105.1	–	–	-104.1	–	-104	–	–	–	–	-101	–	-105.9
pAIC	206	212.9	211.6	216.2	–	–	214.1	–	214.1	–	–	–	–	206	–	215.9
X-COR(50%)	0.927	0.911	0.93	0.953	–	–	0.926	–	0.922	–	–	–	–	0.927	–	0.927
P-COR(50%)	0.896	0.898	0.909	0.918	–	–	0.902	–	0.905	–	–	–	–	0.896	–	0.87
SLSC(50%)	0.132	0.209	0.151	0.095	–	–	0.14	–	0.149	–	–	–	–	0.132	–	0.095

Probability hydrological value	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM	Lexp	Gp	GpExp
	2	209.3	224.9	218.7	211.1	–	–	218.4	–	219.1	–	–	–	–	176.4	–	156.3
	3	250.1	263.8	255.1	244.7	–	–	257.2	–	256.6	–	–	–	–	230.4	–	227.3
	5	301.6	307.2	298.5	288.3	–	–	303.3	–	300.3	–	–	–	–	290.5	–	306.4
	10	371.3	361.7	357.5	354	–	–	364.7	–	357.7	–	–	–	–	366.1	–	405.8
	20	441.1	414	418.4	430.9	–	–	426.9	–	415.1	–	–	–	–	438.5	–	501.1
	30	481.9	444	455.5	482.4	–	–	464.2	–	449.3	–	–	–	–	480.2	–	555.9
	50	533.3	481.6	503.8	555.4	–	–	512.4	–	493	–	–	–	–	532.3	–	624.5
	80	580.7	516	550	631.9	–	–	558.1	–	534.2	–	–	–	–	580	–	687.2
	100	603.1	532.3	572.6	671.6	–	–	580.3	–	554.1	–	–	–	–	602.6	–	716.9
	150	643.9	561.9	614.5	750.2	–	–	621.4	–	590.8	–	–	–	–	643.6	–	770.8
	200	672.9	582.8	645.1	811.4	–	–	651.3	–	617.4	–	–	–	–	672.6	–	809
	400	742.7	633.3	721.4	979.7	–	–	725.7	–	683.3	–	–	–	–	742.5	–	901

JackKnife point estimate	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM	Lexp	Gp	GpExp
	2	209.3	224.9	218.7	208.1	–	–	91.4	–	219.2	–	–	–	–	176.4	–	133.2
	3	250.1	263.8	258.4	245.3	–	–	190.2	–	261.9	–	–	–	–	230.4	–	223.8
	5	301.6	307.2	305.8	295.2	–	–	300	–	310.3	–	–	–	–	290.5	–	324.6
	10	371.3	361.7	370.2	369.4	–	–	434	–	370.7	–	–	–	–	366.1	–	451.4
	20	441.1	414	437	450.7	–	–	553.9	–	427.3	–	–	–	–	438.5	–	572.9
	30	481.9	444	477.6	500.8	–	–	616.7	–	459.1	–	–	–	–	480.2	–	642.8
	50	533.3	481.6	530.6	565.6	–	–	685.9	–	498	–	–	–	–	532.3	–	730.3
	80	580.7	516	581.3	625.2	–	–	737.2	–	532.6	–	–	–	–	580	–	810.3
	100	603.1	532.3	606	**652.9**	–	–	756.4	–	548.6	–	–	–	–	602.6	–	848.2
	150	643.9	561.9	652.1	701.4	–	–	780.6	–	577.2	–	–	–	–	643.6	–	916.9
	200	672.9	582.8	685.7	733.4	–	–	788	–	597	–	–	–	–	672.6	–	965.6
	400	742.7	633.3	769.6	797	–	–	762.9	–	642.9	–	–	–	–	742.5	–	1082.9

JackKnife estimate error	Return period	Exp	Gumbel	SqrtEt	Gev	LP3Rs	LogP3	Iwai	IshiTaka	LN3Q	LN3PM	LN2LM	LN2PM	LN4PM	Lexp	Gp	GpExp
	2	17.1	21	17	12.5	–	–	100.3	–	14.7	–	–	–	–	14.9	–	27.4
	3	28.9	33.7	21.7	13.8	–	–	68.2	–	23.3	–	–	–	–	22.6	–	24.4
	5	47.4	49.5	31.3	28	–	–	68	–	40.2	–	–	–	–	43.3	–	37.2
	10	73.8	70.1	47.1	63.8	–	–	120.2	–	68.3	–	–	–	–	71.8	–	61.7
	20	100.6	90.1	65.1	117	–	–	183.9	–	100.9	–	–	–	–	99.6	–	87.3
	30	116.4	101.7	76.6	157.1	–	–	220.5	–	122.1	–	–	–	–	115.7	–	102.4
	50	136.3	116.3	91.9	218.6	–	–	263.8	–	151	–	–	–	–	135.9	–	121.5
	80	154.7	129.6	106.8	287.7	–	–	299.8	–	179.8	–	–	–	–	154.4	–	139
	100	163.4	135.9	114.2	325.3	–	–	315.5	–	194.2	–	–	–	–	163.2	–	147.4
	150	179.3	147.4	128.2	402.5	–	–	341.9	–	221.6	–	–	–	–	179.1	–	162.5
	200	190.5	155.5	138.4	465.1	–	–	359.6	–	242.1	–	–	–	–	190.4	–	173.3
	400	217.7	175.1	164.4	647.4	–	–	407.4	–	295	–	–	–	–	217.6	–	199.2

Source: JICA Study Team



Source: JICA Study Team

<Figure7-31>Selection of probability distribution

6) Calculating the Run-off : Q

$Q = 1/3.6 \times f \times R \times A$

$= 1/3.6 \times 0.7 \times 27.21 \times 822.3$

$= 4{,}350.6$ → **4,360 (m3/s) (Return period: 100 years)**

[Reference 1] Rainfall intensity as calculated back from the “Dam Review Report” is used.)

$Q = 1/3.6 \times f \times R \times A$

$= 1/3.6 \times 0.7 \times 16.66 \times 822.3$

$= 2{,}663.7$ → 2,670 (m3/s)

[Reference 2] 50-year rainfall intensity (R＝23.57mm/h) is used

$Q = 1/3.6 \times f \times R \times A$

$= 1/3.6 \times 0.7 \times 23.57 \times 822.3$

$= 3{,}768.6$ → 3,770 (m3/s) (Return period: 50 years)

(3) Setting of the River Channel Cross Section

1) Setting of the River Channel Data (Base Reference to be described later)

- Planned flow (100-year return period): Q＝4360 (m3/s)
- Riverbed slope: i＝1/165（0.61％）
- Roughness coefficient: n＝0.04
- Freeboard: 1.2m (of embankment structure)
- Crown width: 5.0ｍ (of embankment structure)

2) Freeboard

Freeboard is decided as follows based on the Japanese standard.

$\Delta h = 1.2m$

3) Crown Width

Crown width is decided as follows based on the Japanese standard.

B = 5.0m

4) Roughness Coefficient

Roughness coefficient is decided as follows based on the Japanese standard.

n = 0.04

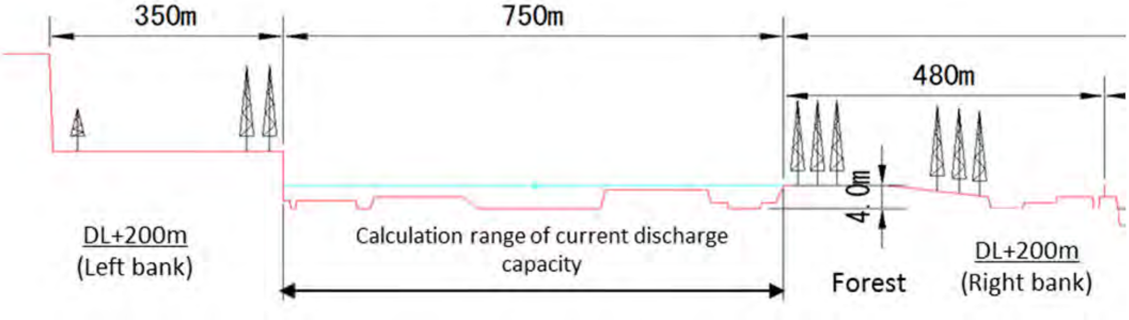
5) Confirmation of the Existing Flow Capacity

The existing flow capacity at the bridge position was confirmed.

The existing flow capacity is to cover the area from the slope shoulder of the forest area on the right bank to the precipitous terrain on the left bank.

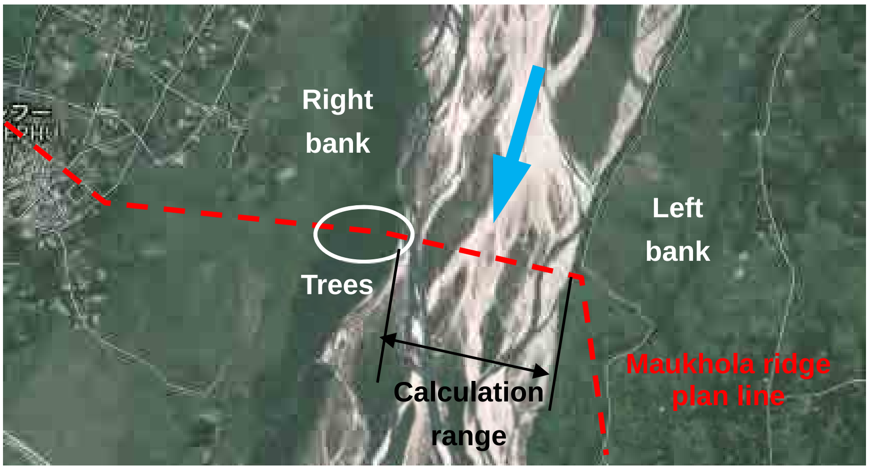
- $Q = i^{1/2} \times R^{2/3} \times A / n$
- A＝1984.144 (m2)
- S＝757.086 (m)
- R＝A／S＝2.621 (m)
- $Q = 0.0061^{1/2} \times 2.621^{2/3} \times 1984.144 / 0.04 = 7364.7 > 4360$(m3/s)

As a result, it was confirmed that the existing cross-sectional area at the bridge position allows the planned flow.



Source: JICA Study Team

<Figure7-32>Existing cross-sectional view at the position of Maukhola Bridge (width ratio 1 : 10）



Source: JICA Study Team

<Figure7-33>Aerial photo of the position of Maukhola Bridge

6) Setting of the Cross Section

When setting the planned cross section, it is considered not practical to set the uniform gauge section to reduce the river width. The reasons are described below.

- The sediment in the existing river channel is carried down from the main stream and distributed at the bridge position. It is considered that both the soil supply amount and the flow velocity (tractive force) are high.
- It is assumed that the soil supply amount is large. If the construction work is to be done with the gauge section, the river channel may have to be dredged regularly for the life of the bridge.
- The running costs including the maintenance cost, dredged spoil storage cost, etc. may need to be borne permanently.
- If the cross section cannot be secured immediately by dredging after a flood, the risk of inundation, dyke break, etc. increases.

From the above, the river width will be recommended to be kept in the current condition (750m).

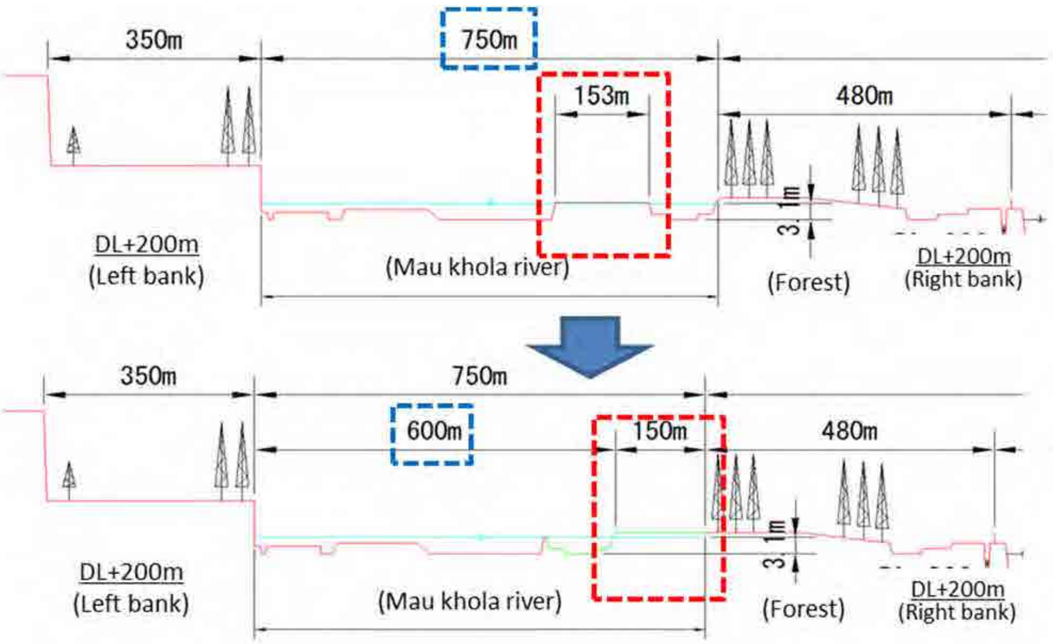
(4) Reference Study: Study in the Case to reduce River Width

On the basis of the existing cross-sectional shape, the cross section was established so that the disaster potential is equivalent to the current situation. In this event, due care was taken not to substantially change the flow regime (flow velocity, water depth) and the water level in the case of a flood.

1) River Width

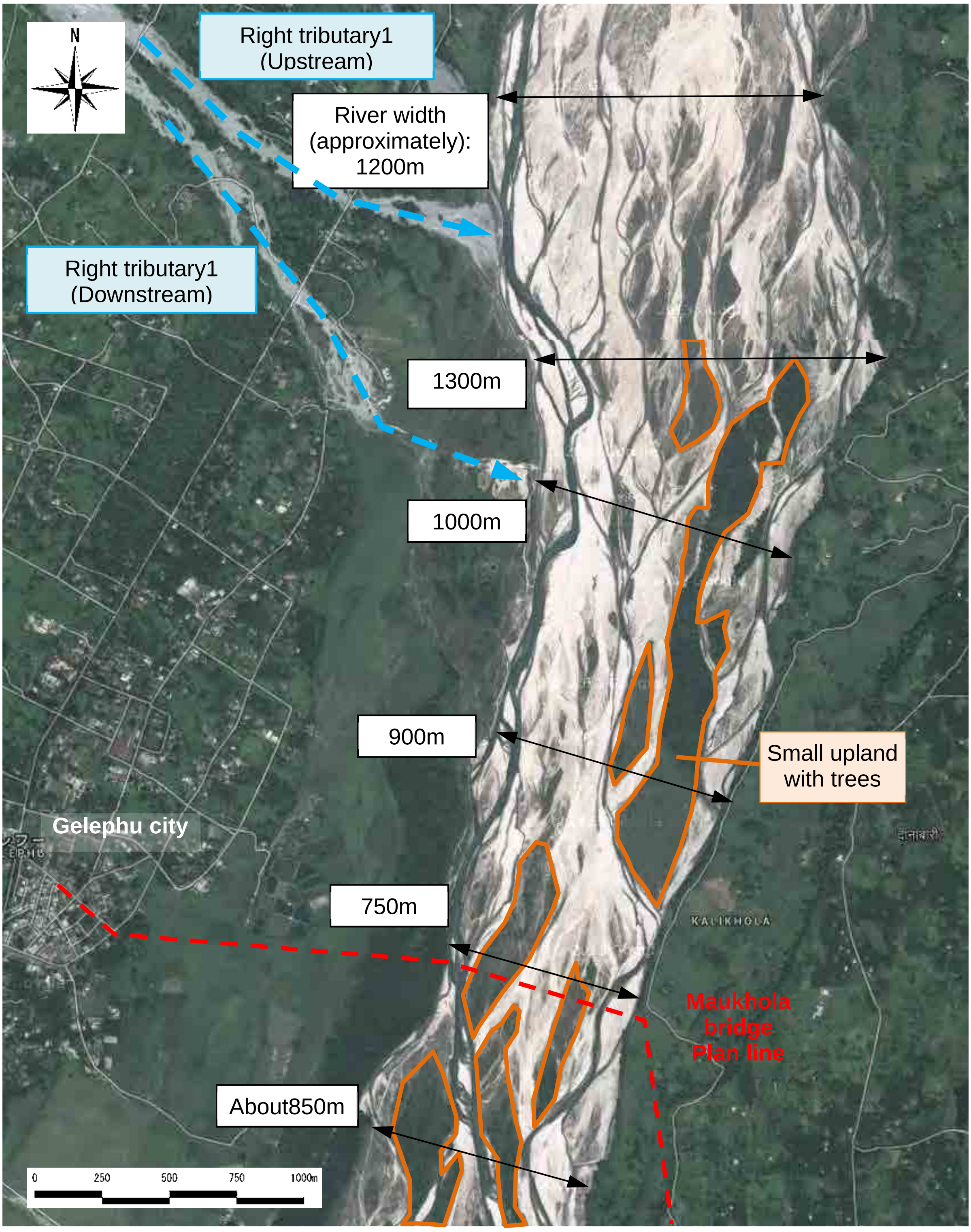
With the existing cross section at the bridge point, the water depth necessary to ensure the 100-year planned flow is 3.1 m. In this event, a minor island with grown trees exists inside of the river channel with a width of about 150 m as measured roughly perpendicular to the direction of flow. Such minor island with grown trees exists not only in the cross section of bridge, but also for the distance of about 2 km upstream. Therefore, the 150 m minor island at the position of Maukhola Bridge is reduced to obtain the river width of 600m (= 750-150).

Even when the width of the channel was reduced by the 150 m, the water depth does not change substantially and the flow velocity does not change much either relative to the 100-year planned flow (the flow velocity is proportional to the water depth).



Source: JICA Study Team

<Figure7-34>Required cross sectional width at the position of Maukhola Bridge (width ratio 1 : 10）



Source: JICA Study Team

Note) A minor island with grown trees exists for the length of about 2 km on the upstream side of the bridge position.

<Figure 7-35> Aerial photo of the area around the Maukhola Bridge position

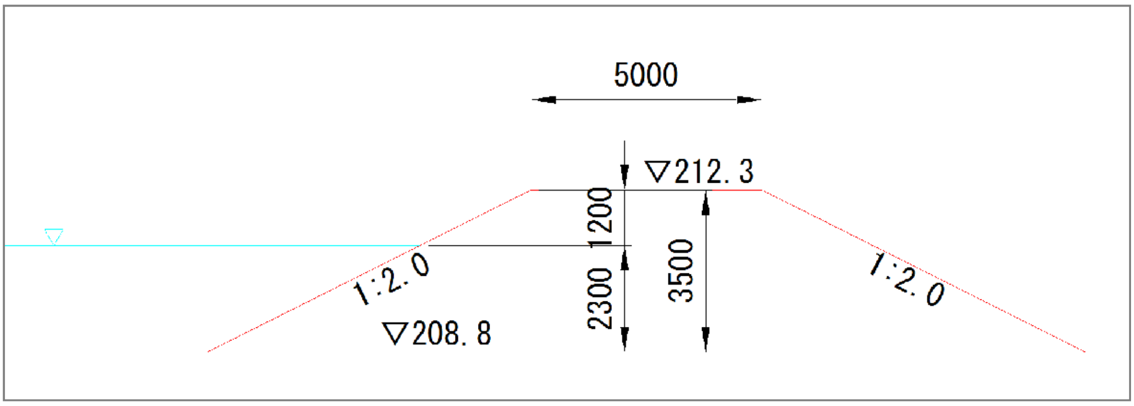
2) Establishing the Section of Dyke

The dyke section is to be established to develop facilities including bridges, dyke, and embankment.

The dyke section appropriated for the river flow scale is established after temporarily setting the river channel gauge section so that the river height does not exceed the guideline, that is, the normal depth when the 100-year flow is allowed to flow through the existing river channel.

As a result, the levee section becomes as follows:

- Planned flow: Q＝4360 （m3/s）
- Crown width of levee: B = 5.0(m) (from the Government Ordinance for Structural Standard for River Administration Facilities)
- Freeboard: Δh = 1.2(m) (from the Government Ordinance for Structural Standard for River Administration Facilities)
- Water depth: h =2.3 (m) (The water depth at the gauge section was established from the water established in the existing section and the average river bed height.)
- Slope grade: 1 ： 2.0



Source: JICA Study Team

<Figure7-36> Establishing the levee section (Position of Maukhola Bridge)

Since the river bed height shown in the figure above is the average river bed height, the river bed height for the facility planning must be approximately equal to the existing river bed height. 208.0 m must be used.

(5) Result of Review

In this study, based on the Maukhola river width reduction plan of Bhutan, the possibility of reduction of the river width is examined based on site survey and existing information. As a result, the reduction of Maukhola river width is confirmed to be not appropriate considering the situation of the earth and soil and the reality of maintenance etc.

Accordingly, the study of Maukhola is conducted based on the plan of the current river width.

(6) Items to be considered

1) Improvement of the run-off calculation accuracy (already discussed with DoE)

The run-off of Maukhola River is calculated according to the rational run-off formula. According to the Technical Criteria for River Works, this rational formula is to be applied to around 100 km^2 or less. Though this is 700 km^2 in the case of Maukhola River, the rational formula was applied because of limited available data. If further data is made available in the future, other analytical methods may be used to obtain the run-off with higher accuracy.

The run-off analytical approach to ensure enhanced accuracy may be the storage function method when considering the basin area scale of Maukhola River. The following data must be collected to enable an analysis:

- Flow observation data (multiple flood observation data, at 2 points)
- Surveyed cross sections of the river (about 25 km on the upstream side of the Maukhola Bridge, at 500 m intervals, including the bridge flow observation point)

2) Collection of Continuous Water-level Observation Data (already discussed with DoE)

A water level observatory gauging station is provided at present at the Geleg (Aie) zam Bridge. Only the data in the normal state is available and no continuous observation is made. To understand the run-off from the basin with accuracy, it is essential to collect the water level data during flood at the gauge points.

7-3. Bridge Plan

The bridge plan is established on the basis of the DoR plan policy and in accordance with the survey results and Japanese standards (Standards for River Administration Facilities).

7-3-1. Planning Policy

(1) Outline of the DoR Planning Policy

Construction of Maukhola Bridge is one of the vital infrastructures demanded by Bhutan and DoR as indicated in the past study report. The plan policies contained in the study are listed below.

【Summary: as extracted from the study report】

- ・Basically, the bridge position is 2 km upstream from the border with India.
- ・The bridge length is to be around 800 m as assumed from the river width at the bridge position.
- ・The effective bridge width is 7 m.
- ・For the design load, the use of "Class A" is recommended.
- ・For the bridge type, the suspension bridge and cable-stayed bridge are evidently more expensive than the continuous girder bridge and thus not employed. (Estimation shows that suspension and cable-stayed bridges are more expensive than the continuous girder bridge by 3.5 times.)
- ・For the purpose of selecting a bridge type using domestic materials in large numbers, the prestressed concrete bridge will be a candidate for selection. This type of bridge is selected because it is less expensive than the steel bridge.

【Summary: Transcription of original text】

a) The proposed location for the Maukhola Bridge is about 2km upstream of the Indo-Bhutan Border and the approximate span of the bridge at the proposed location is 800mtrs.

b) The team proposes a permanent multi-span pre-stressed concrete I-girder bridge supported by Reinforced Concrete abutments and piers.

c) A double lane carriageway width of 7.00m is proposed and the recommend live load is Class A (the total weight of one train of vehicles per lane is 55 tons) as per IRC-6.

(2) Considerations Concerning Planning Policy of DoR

Considerations of the planning based on DoR plan policy are listed below.

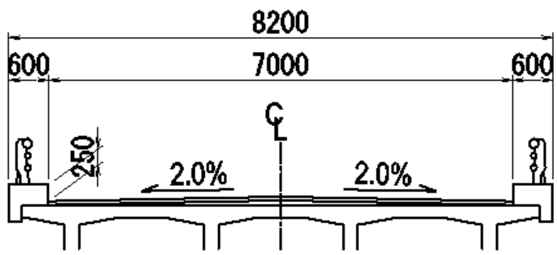
- The bridge position is based on the results of a review by DoR.
- The bridge length is proposed on the basis of the results of that review.
- The effective width is 7 m.
- For the bridge type, the above three plans are extracted to establish the review plan by calculating the approximate construction cost from the unit price per m2.

7-3-2. Basic Conditions

(1) Road Conditions

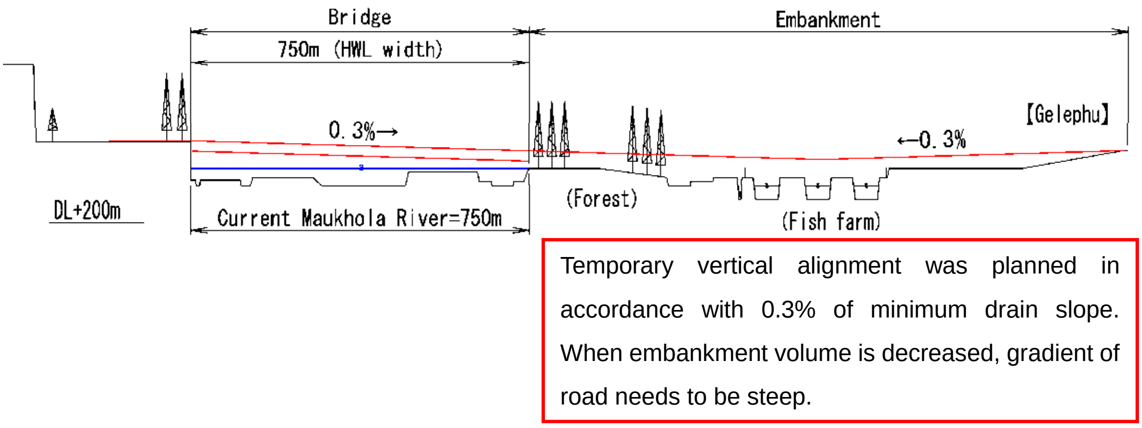
The width is to include the effective width of 7 m and the curb of 0.6 m (the Japanese standard). No detailed road plan exists in terms of horizontal and vertical alignments. The basic plan as follows was drafted by using the existing information and on the basis of discussions with DoR.

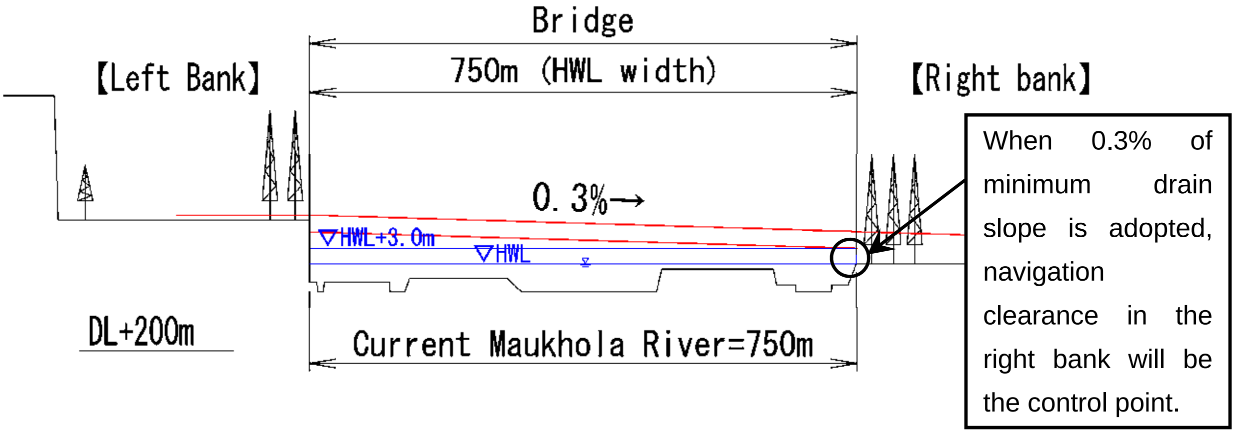
- Horizontal alignment
- On the basis of the design high water level, the clearance under the girder (3 m according to the DoR request and the Indian Standard), and the height of the beam, the existing height of the left bank is used as the control point for the road height.
- Gradient is 0.3% or more while paying attention to the minimum drainage gradient (Road Structure Ordinance).



Source: JICA Study Team

<Figure7-37>Width composition





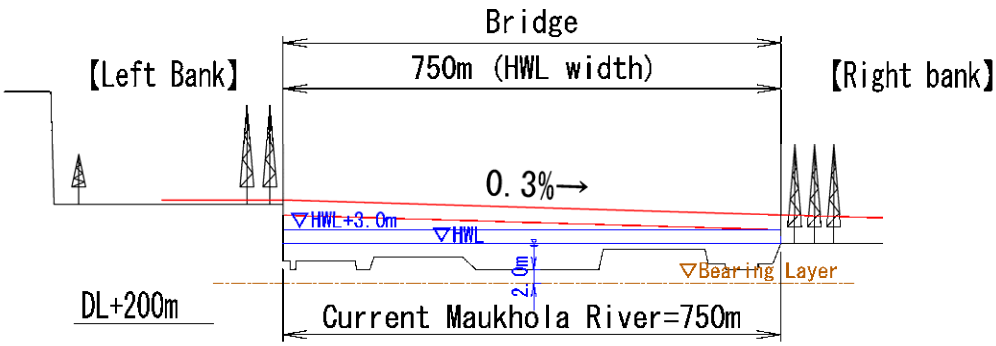
Source: JICA Study Team

<Figure7-38> Road plan (draft) (Above: Gelephu City～bridge, Below : Bridge)

(2) Ground Conditions

This survey does not cover the ground survey, so that the foundation type is based on the ground conditions encountered in other projects in the neighborhood that were reviewed as candidates for employment.

Bridges selected as reference are Dolkhpla Bridge and Jigmiling Bridge designed and constructed according to the “Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan.” Both bridges are located about 10 km to the west from Gelephu City. These are bridges crossing the river. The bearing layer is located below the riverbed and the foundation is the spread foundation. By assuming that the bearing layer is 2 m below the existing riverbed, the bridge is designed to allow the use of spread foundations.



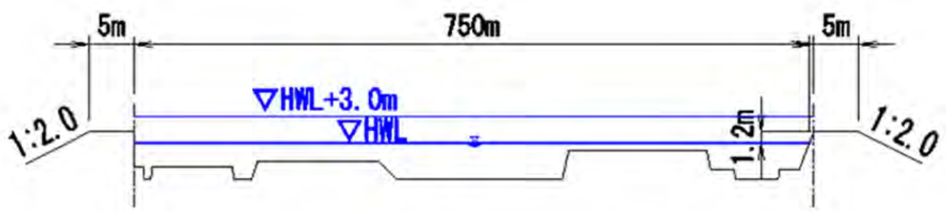
Source: JICA Study Team

<Figure7-39> Ground conditions (assumed)

(3) River Conditions

The review results are shown below. Note that 3 m is secured for the clearance under the girder in view of the DoR request and the Indian Standard.

- Design discharge volume: Q=4360 (m3/s) *100-year return period
- Riverbed slope: i＝1/165 (0.61%)
- Dyke crown width: B=5.0 (m) (Standards for River Administration Facilities)
- Dyke free-board: ⊿h=1.2 (m) (Standards for River Administration Facilities)
- Clearance under girder: ⊿h=3.0 (m) (DoR request and Indian Standard)
- Slope gradient: 1:2.0
- Reference section: Figure below



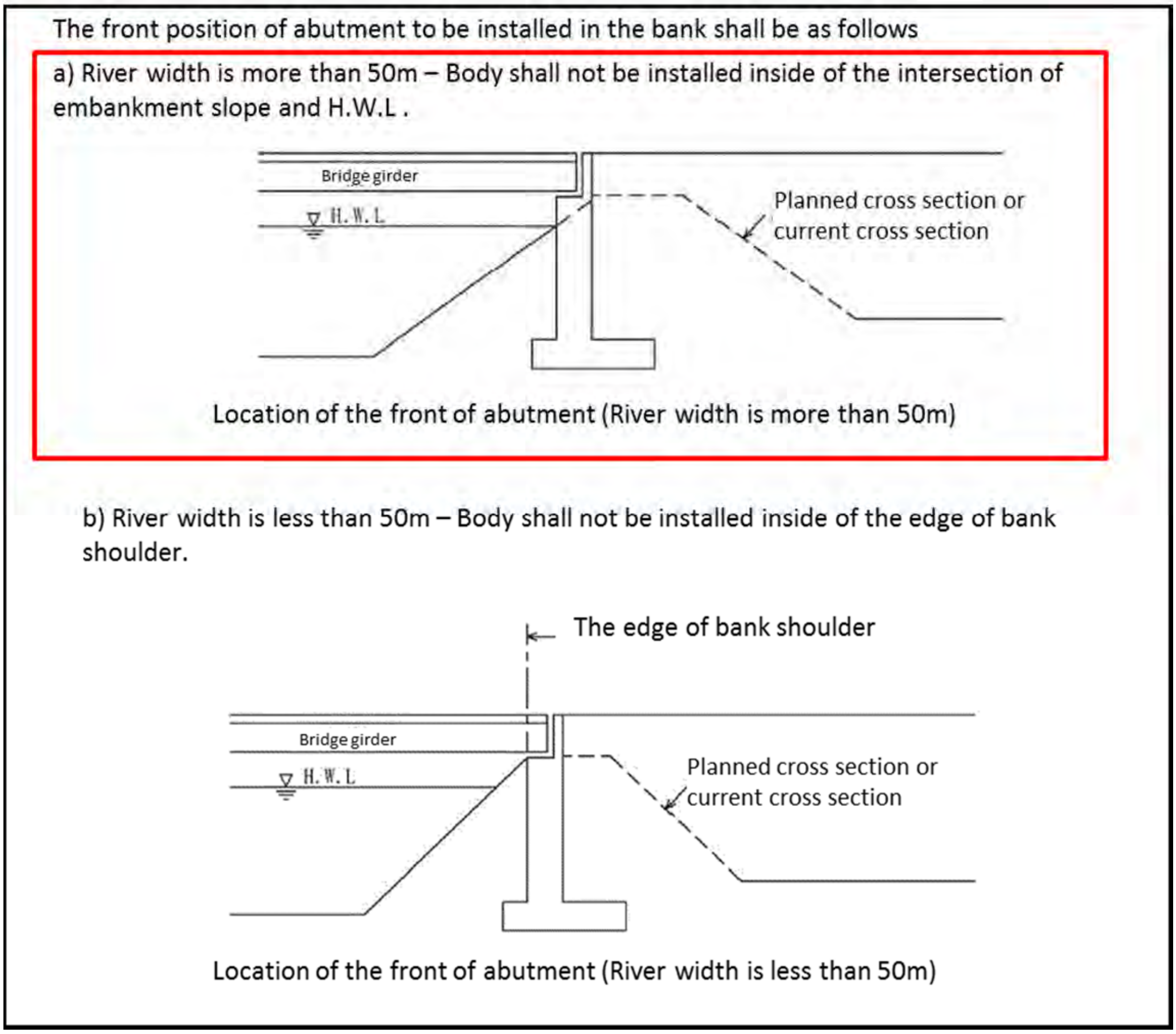
Source: JICA Study Team

<Figure7-40> Maukhola River Reference section

7-3-3. Basic Bridge Plan

(1) Setting of the Bridge Length

The abutment front position is set according to the Standards for River Administration Facilities (Japanese standard) and the bridge seat width is added between both abutment fronts. Note that the guideline for the total span length (the distance between supports of both abutments) is **752m or more** (750m+1.0m or more×2).



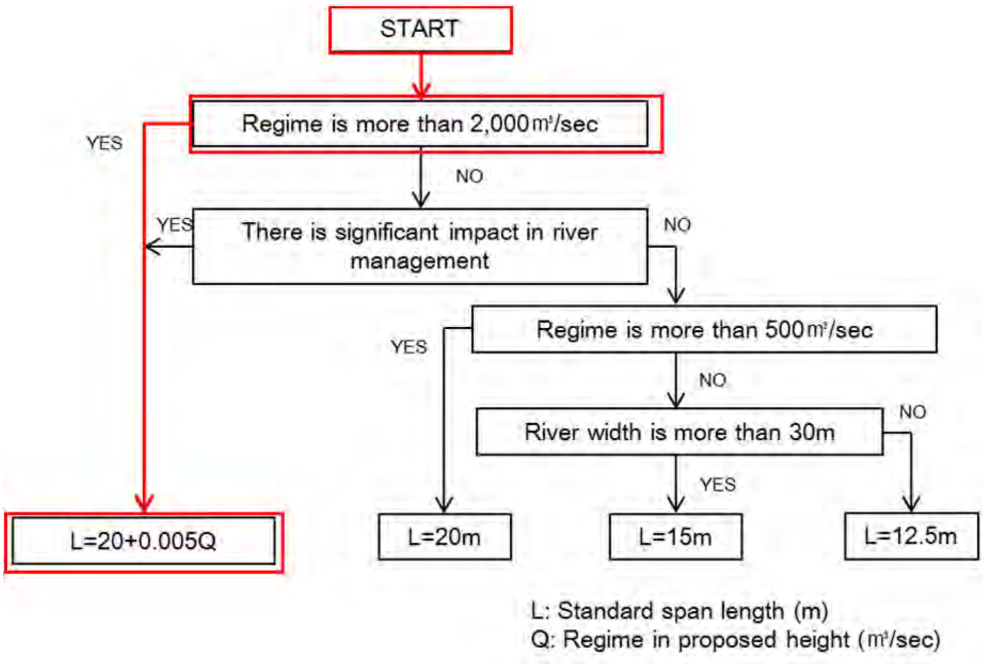
Source: Standards for River Administration Facilities

<Figure7-41> Concept of abutment position

(2) Reference Span Length

The reference span length (minimum span) of the bridge is determined according to the Standards for River Administration Facilities (Japanese Standard). The reference span length is **41.8m or more** from the design flow (4360m3/s).

Calculation formula：L=20+0.005×Q(m3/s：discharge)=20+0.005×4360=41.8m



Source: Standards for River Administration Facilities

<Figure7-42> Flowchart for determination of length of span

(3) Summary of the Number of Piers and Cross-sectional Blocking Ratio

The cross-sectional blocking ratio (= total pier width/river width at the design high water level x 100) is basically set to 5% or less according to the Standards for River Administration Facilities (Japanese standard). The relationship between the average span length, the number of piers, width of each pier, and cross-sectional blocking ratio is shown in the table below.

<Table7-5> Number of piers and the cross-sectional blocking ratio

The width of river in high water level = 750m

Average span length (m)	Number of spans	Total span length (m)	Number of piers	Width of piers (m)	Total width of piers (m)	Ratio of river blockade (%)	Result of adoption	Remarks
42	**18**	**756**	**17**	**2.0**	**34**	**4.53**	○	
43	17	731	16	2.0	32	4.27	×	Total span length<less than 752m
44	17	748	16	2.0	32	4.27	×	Total span length<less than 752m
45	**17**	**765**	**16**	**2.0**	**32**	**4.27**	○	
46	16	736	15	2.0	30	4.00	×	Total span length<less than 752m
47	**16**	**752**	**15**	**2.0**	**30**	**4.00**	○	
47	16	752	15	2.5	37.5	5.00	×	Ratio of river blockade>5%
50	15	750	14	2.5	35	4.67	×	Total span length<less than 752m
51	**15**	**765**	**14**	**2.5**	**35**	**4.67**	○	

*752m=river width + 2 x [Bering position (1m from parapet)]

Source: Standards for River Administration Facilities

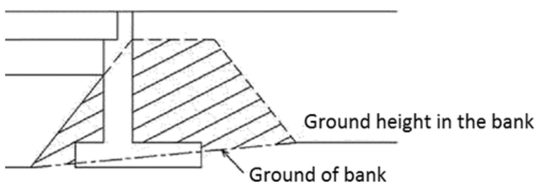
(4) Substructure Planning

The embedment location is determined for abutments and piers according to the Standards for River Administration Facilities (Japanese standard) and the basic structural configuration is established.

<table>
<tr><th>Japanese river standard</th><th>Dimension of structure</th></tr>
<tr><td>

【A1 abutment (right bank)】

The right bank is an embankment structure with the footing bottom surface being below the line connecting the interior ground height and riverbed (dyke ground of the figure below)



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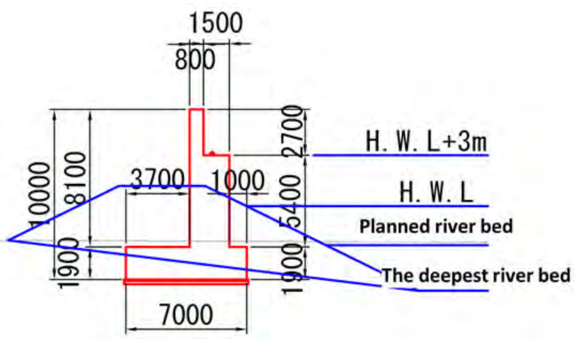

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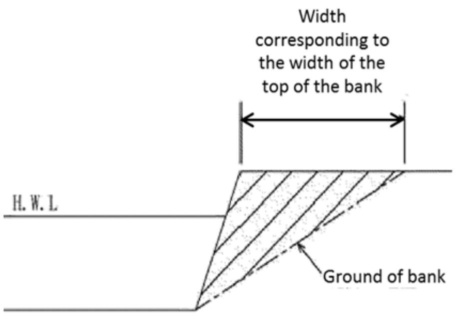
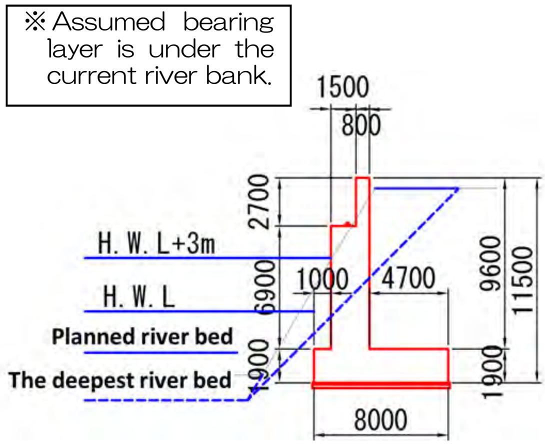
</table>

【A2 abutment (left bank)】

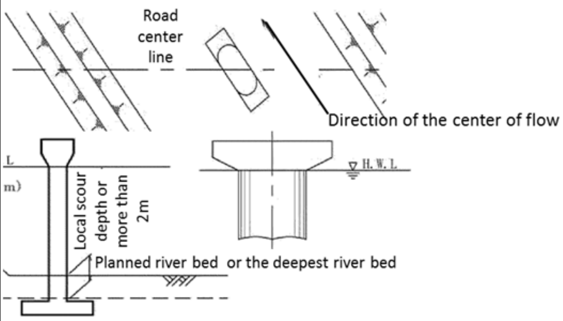
The left bank is the artificially-excavated river channel, with the footing bottom surface being below the line connecting the existing levee crown width and riverbed (dyke ground of the figure below).

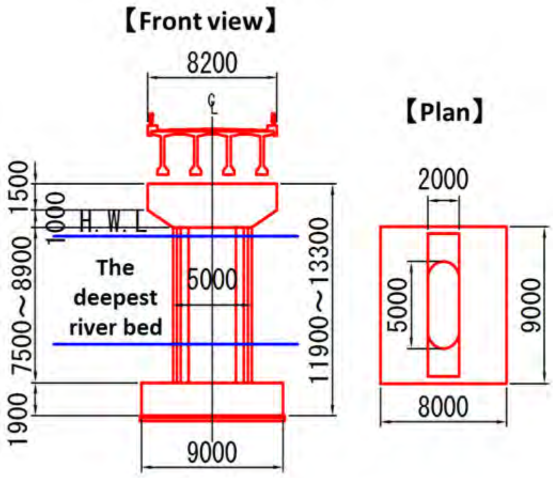




【Pier】

The piers are of an oval type and parallel to the center line of the stream. The root of the overhang is at HWL or above, with the footing top surface being 2 m or more from the designed riverbed or the deepest riverbed, whichever is deeper.





Source: Standards for River Administration Facilities

<Figure7-43> Substructure planning

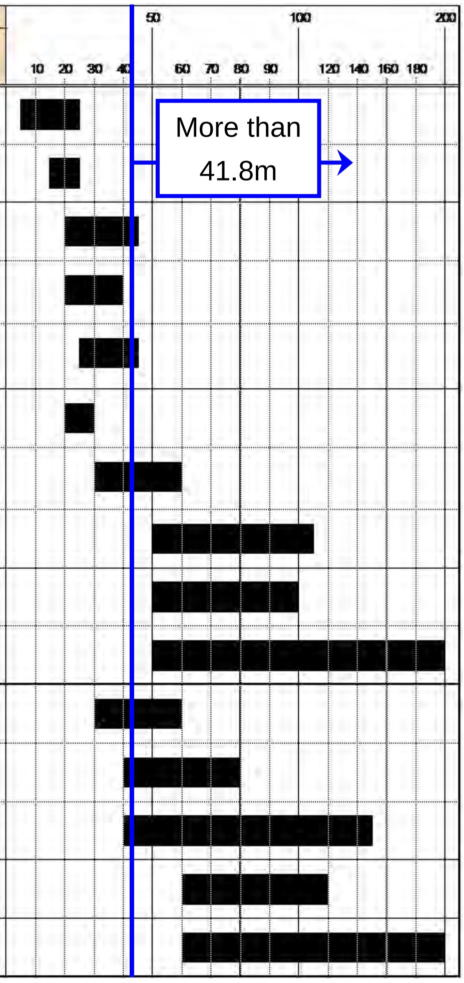
7-3-4. Selection of Bridge Type

(1) Extraction of Candidates for Selection

The bridge type is extracted from the reference span length.

<Table7-6> Table of type selection

Adopted standard span length by types						
Stuctural type				Figure	Method for erection	Adopted span length
PC Bridge	Precast continuous girder	Pre-tensioning	Slab-girder		Erection by crane	5~24
			T-girder Bridge		Erection by crane	18~24
		Post-tensioning	T-girder Bridge		Erection by crane Erection by erection girder	20~45
			Composite girder Bridge		Erection by crane Erection by erection girder	20~40
			PC component Bridge		Erection by crane Erection by erection girder	25~45
	Cast-in-place concrete continuous bridge		Hollow slab bridge		Fixed scaffolding Scaffolding	20~30
			Box-girder Bridge		Fixed scaffolding Incremental launching method	30~60
					Cantilever method	50~110
	Extradosed bridge			※Cross section is box-girder figure	Fixed scaffolding	50~100
					Cantilever method	100~200
Steel Bridge	Steel-girder Bridge		Continuous I-girder Bridge		Erection by crane	30~60
			Continuous Box-girder Bridge		Erection by crane Launching method	40~80
			Steel plate deck Box-girder Bridge		Erection by crane Launching method	40~150
	Continuous truss				Erection by using tower crane etc.	60~120
	Multiple arch Bridge				Erection by using tower crane etc.	60~200



Source: Design manual of Ministry of Land, Infrastructure, Transport and Tourism

Candidates for selection are as follows:

【PC bridge】

- Post-tension continuous girder bridge (T-girder bridge)*1
- Cast-in place continuous girder bridge (Box girder bridge)
- Extradosed bridge

【Steel bridge】

- Steel girder bridge (Continuous I girder bridge）*2
- Continuous truss
- Arch bridge

*1: For the proposed post-tension continuous girder bridge, the T girder bridge is studied because this type of bridge has been constructed in large numbers in Bhutan.

*2: Among steel bridges, the continuous I girder bridge, which is the most inexpensive, is studied.

(2) Selection of Three Alternatives for Review

By calculating the approximate construction cost from the unit cost per m2 determined from the construction record, the top three alternatives were selected. Detailed review is made by including the number of substructures, span division, and material transport expenses in the details to be reviewed.

【Calculation conditions】

- The span length for determination of the unit price per m2 is the average span length (43 m) on the basis of the minimum value shown in the table of the previous page or the cross-sectional blocking ratio
- The bridge area is 8.2m×756m.
- The unit price per m2 does not include the transport cost for the steel, or the effect of the cost of the materials and equipment used for erection. This unit price is solely for selection of the bridge type. The unit price is shown in the table below.

<Table7-7> Unit cost for rough estimated construction cost for extraction of bridge type

SN	Proposed					
	Br Type (Proposal)	Approx. Span (mtr)	Unit cost (thousand yen/m^2)			
				approximate line	coefficient	change rate
PC	PC T	43	**533**	= (2.8713 x+ 351.54)×	1.020	× 1.099
	PC Box	43	**487**	= (1.9470 x+ 350.70)×	1.020	× 1.099
	Extradosed	50	**593**	= (7.0476 x+ 176.41)×	1.020	× 1.099
Steel	Steel I girder	43	**443**	= (2.9225 x+ 269.14)×	1.020	× 1.099
	Steel Truss	60	**580**	= (2.2933 x+ 379.16)×	1.020	× 1.099
	Steel Arch	60	**875**	= (2.2933 x+ 642.52)×	1.020	× 1.099

Source: JICA Study Team

From the table below, the PCT girder bridge, PC box girder bridge, and Steel plate girder bridge are selected as alternatives for review.

<Table 7-8> Approximate construction cost for extraction of bridge type

SN	Proposed							
	Br Type (Proposal)	Approx. Span (mtr)	Total width (mtr)	Area of Bridge (m^2)	Unit cost (thousand yen/m^2)	Bridge cost (thousand yen)	Total (hundred million yen)	Rank
PC	PC T	756	8.2	6199.2	533	3,304,000	**33.1**	**3**
	PC Box	756	8.2	6199.2	487	3,019,000	**30.2**	**2**
	Extradosed	756	8.2	6199.2	593	3,676,000	**36.8**	**5**
Steel	Steel I girder	756	8.2	6199.2	443	2,746,000	**27.5**	**1**
	Steel Truss	756	8.2	6199.2	580	3,596,000	**36.0**	**4**
	Steel Arch	756	8.2	6199.2	875	5,424,000	**54.3**	**6**

Source: JICA Study Team

7-4. Summary of Environment and Social Considerations

The following is an investigation of the impact of the Maukhola Bridge construction work on the environment and society. As with the environmental and social impacts of the priority projects seen earlier, onsite verification and assessments were conducted and determined the impacts of the construction work on the environment and society based on the Environmental Checklist (Bridges) attached to JICA Guidelines for Environmental and Social Considerations, published in April 2010.

(1) Necessity of Permission or Authorization for Development

As stated earlier, all construction work requires application for and obtainment of environmental clearance. For Maukhola Bridge, no environmental survey has been made so far, so, when filing the application for environmental clearance, discussions with the DoR will be needed and new surveys on the impact of the work on the environment and society around the site shall be conducted. Since there are agricultural fields and thickets around the site, full discussions with MoA and the National Land Commission will be needed at the time of land acquisition or cutting down trees to check land acquisition procedures and whether any permission is necessary to cut down trees.

(2) Measures against Pollution

For bridges, the impacts of the projects on air quality, water quality, and noise and vibration, that were picked up by the checklist items for Bridge were addressed.

<Table7-9> Summary on countermeasures against pollution

No	Impact Items	Rating		Reasons of the ragting
		Pre/During Construction Phase	Opreration Phae	
1	Air Quality	2	4	Generatin of dust is expected due to consruction work. In the operation phase, the generation of traffic is expected. However, the expected imact is small since the traffic volume is limited.
2	Water Quality	2	4	The water pollution caused by sediment influx due to the work in substructure is expeted during construction phase. No major impact is expeced in operation phase.
3	Noise and Vibration	2	4	Noise and vibration generation is expected due to works of construction machines and equipment. In the operation phase, the generation of traffic is expected. However, the expected imact is small since the traffic volume is limited.

1：Serious impact is expected
2：Some impact is expected
3：Extent of impact is unknown (Detailed survey is required)
4：Few Impacts are expeced

Source: JICA Study Team

With regards to pollution, the construction work might generate dust, pollute river water, and cause noise and vibration from construction machinery. It is assumed, however, that none of the above will have serious impacts on the environment, because they are limited to the construction period and to the periphery of the bridge.

(3) Natural Environment

Impacts of the project on protected areas, ecosystems, hydrology, terrain, and geology are described below.

<Table7-10> Summary of impacts on the natural environment

No	Impact Items	Rating		Reasons of the ragting
		Pre/During Construction Phase	Opreration Phae	
1	Protected Areas	4	4	No Protected Area is obserbed near project site.
2	Ecosystem	4	4	No particular rare speicies is obserbed near project site. In addtion, there is no environment which animals and plants are mainly living such as forests near project site.
3	Hydology	2	4	Bank protection and river improvement work is required. Measures for swollen river during rainy season is necessary. There might be decrease in the risk of flood because the measurement of swollen river will be taken.
4	Topography and Geology	2	4	During construction phase, due to the construction work of substructure, small topografic modification might be expected.

1:Serious impact is expected
2:Some impact is expected
3:Extent of impact is unknown (Detailed survey is required)
4:Few Impacts are expeced

Source: JICA Study Team

The projects are not located in any of the protected areas. Since these are bridge projects, the scope of work is limited to the periphery of the bridge and approach road. Hence, it is assumed that the work will not have serious impacts on flora and fauna or animal corridors and that the impact of the project on ecosystems is limited and minor.

As to rivers, the projects might have some influence on the flow of the river, but it is assumed that they will not have serious adverse impact, because the MoWHS is currently planning a bank protection work, which will reduce the risk of flood. It should be noted, however, that the substructure work might cause minor changes in terrain around the site.

(4) Social Environment

Impact of the project on inhabitants' relocation, their lives and living, and cultural heritage as well as ethnic minorities and indigenous people, and the working environment for workers is addressed.

Without any houses found around the site, the project will not require resettlement. As stated earlier, however, it requires mowing crops and cutting down thickets, so land acquisition will be needed before starting the work. However, it is assumed that it will not require major land acquisition, because this is only for the approach road.

It is expected that there will be no adverse impact on the lives and living of the inhabitants, because this is a new bridge construction project. Allowing inhabitants to come and go across the river safely in any season will boost the movement and exchange of the population.

<Table7-11> Social environment

No	Impact Items	Rating		Reasons of the ragting
		Pre/During Construction Phase	Oprerotion Phae	
8	Resettlement	2	4	Resettlement is not expected since there is no residence in project site. However, design and construction of approach road might pass farmland. Therefore, land aquisition is expected to be caused although it is not a large scale.
9	Living and Livelihood	4	4	Few impact is expected since there is no activities such as traffic regulation. Currently, people needs to use a detour route or creat a temporary timber bridge in dry season. In rainy season , people occasionally needs to use boats to pass the river and it is very dangerous situation. Therefore positive impact is expected in operation phase.
10	Heritage	4	4	No heritage is obserbed near projet site.
11	Landscape	4	4	No impact is expected.
12	Ethinic Minorities and Indigenous Peoples	4	4	Ethnic minorities and Indigenous peoples are not obserbed in project site
13	Working Conditions	2	4	Construction work environment needs to be considered in accordance with relevant laws and regulations. Also, safety measuers need to be considered since work in high place is expected. No impact is exepected in operation phase.

1:Serious impact is expected
2:Some impact is expected
3:Extent of impact is unknown (Detailed survey is required)
4:Few Impacts are expeced

Source: JICA Study Team

7-5. Estimates of the Approximate Construction Cost

(1) Alternatives

On the basis of the previously described bridge plans, the approximate construction cost is calculated for alternatives as follows:

Alternative-1: Prestressed concrete 18-span continuous T-girder bridge (maximum span 42m)
Alternative-2: Prestressed concrete 18-span continuous box girder bridge (maximum span 42m)
Alternative-3: Steel 18-span continuous non-composite steel plate girder bridge (maximum span 42m)
Alternative-4: Prestressed concrete 15-span continuous box girder bridge (maximum span 50 m)
Alternative-5 : Steel 15-span continuous non-composite steel plate girder bridge (maximum span 50 m)

[Policy of selection]

- The bridge types are to be three proposed types (Prestressed concrete T girder, prestressed concrete box girder, and steel plate girder) for which the lowest approximate construction cost was the most preferred bridge plan.
- The number of spans is to be established on the basis of the span length of 42 m and 50.5 m (It will be the middle of 50m and 51m considering the river width).
- The proposed span length of 42 m is the minimum span length determined from the river conditions.
- The span length of 50.5 m is proposed for verification of the relationship between the increase in the cost of superstructure due to increase in the span length and the decrease in the cost of substructure due to reduction of the number of substructures. Note that the Prestressed concrete T girder in the proposed span length of 50.5 m is not the applicable span.

(2) Considerations for Estimates of the Construction Cost

Considerations are listed below.

[Considerations]

- The superstructure construction cost of a prestressed concrete bridge is calculated by establishing the unit cost per m^2 referring to the actual construction record of Bhutan as well as in Japan (source: Bridge Annual Report).
- The construction cost of the superstructure of a steel bridge is calculated referring to the information from steel manufacturers having factories in India.
- Quantity calculation is performed for each substructure to calculate the volume of concrete and the amount of reinforcement. Then, the unit cost is calculated from the actual construction record of Bhutan.
- The transportation cost is calculated according to the transportation route after determination of the amount of pc cables and aggregates to be transported based on the scale of the superstructure and substructure.
- Route of transport for steel for steel bridge shall be from factory in India to Gelephu to the bridge site.
- Regarding the proposed span lengths of 42m and 50.5m, the reaction of the superstructure increases in the latter proposal, so that the scale (member thickness) of the substructure is increased proportionally. The difference is reflected in the construction cost.
- The construction cost covers the access road of 50 m before and after the bridge, revetment in front of the abutment (around 30 m/abutment), building of the construction yard (embankment, dyke), material procurement cost, and skilled workers.

(3) Result of Review

1) Results of Review by Bridge Type

The list of review contents is attached on the next page. The review results for each bridge type are also shown below.

[Prestressed concrete T girder bridge] Evaluation: ◎

This type has ever been employed in Bhutan, but is recommended in the DoR's study report. This type allows heavy usage of Bhutan's materials and construction in the rainy season. This in turn contributes to reduction of the work days. Consequently, this type is proposed in this study.

[Prestressed concrete box girder bridge] Evaluation: △

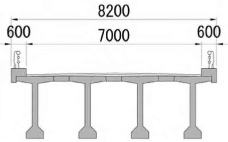
This type has never been employed in Bhutan. As the bridge is constructed by building the fixed support within the river, construction work in the rainy season is impossible. The construction cost increases due to increasing the number of work days. (In the case of box girder bridge with multiple spans, bridge construction with the support in the river carries a high risk in the course of actual construction work, such as the prestressed concrete tensioning sequence, temporary interruption of girder work, girder position, etc.)

[Steel plate girder bridge] Evaluation: ○

This type requires procurement of all steel materials from foreign countries. The discussions with the Japanese manufacturers having factories in India showed that the construction cost is the lowest. Since this type of bridge has never been constructed in Bhutan, this proposal was estimated to require further review. Note that the transportation route for steel materials is from factory in India to Gelephu to the bridge position and that the effects of change of the transportation route on the construction cost are small.

Proposal 1: Prestressed concrete 18-span continuous T girder bridge

Plan drawing



*Bridge length and span division are common.

Erection of erection girders

Features

Structure: Prestressed concrete T girder bridge with the maximum span length of 42

Bridge construction: Procurement of large cranes considered difficult. The method of erecting the erection girders, for which Bhutan has actual construction experience, is employed. Girders to be manufactured in the site.

Construction in the wet season possible, enabling reduction of the work period. (Reflected in the construction cost)

Equipment: Equipment for erection of erection girders to be procured from other countries

Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Prestressed concrete T girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure	302,500
Substructure	165,300
Road and enbankment (bridge section)	19,800
Skilled worker/equipment procurement	896,800
Temporary work	135,300
Transportation (domestic)	42,100
Transportation (via Thimphu)	87,800
Direct construction cost=	1,649,600
Rough estimated construction cost=	3,299,200
Ratio :	1.505

【Prestressed concrete T girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure	302,500
Substructure	165,300
Enbankment (bridge secion) only	5,500
Skilled worker/equipment procurement	896,800
Temporary work cost	135,300
Transportation (domestic)	42,100
Transportation (via India)	8,300
Direct construction cost=	1,555,800
Rough estimated construction cost=	3,111,600
Ratio :	1.419

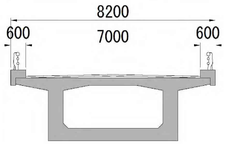
Evaluation

◎

Recommended because of actual construction experience of Bhutan and heavy usage of Bhutan's materials

Proposal 2: Prestressed concrete 18-span continuous box girder bridge

Plan drawing



Erection of fixed support

Features

Structure: Prestressed concrete box girder bridge with the maximum span length of 42

Bridge construction: With the support built within the river, the girders are manufactured by cast-in-place

As construction in the wet season is impossible, the work period becomes longer than the case of T girders. (Reflected in the construction cost)

Equipment: Equipment for tensioning of prestressed concrete is to be procured from other countries.

Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries.

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Prestressed concrete box girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure	275,200
Substructure	165,300
Road and enbankment (bridge section)	19,800
Skilled worker/equipment procurement	1,138,000
Temporary work	135,300
Transportation (domestic)	44,300
Transportation (via Thimphu)	95,900
Direct construction cost=	1,873,800
Rough estimated construction cost=	3,747,600
Ratio :	1.710

【Prestressed concrete box girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure	275,200
Substructure	165,300
Enbankment (bridge secion) only	5,500
Skilled worker/equipment procurement	1,138,000
Temporary work cost	135,300
Transportation (domestic)	44,300
Transportation (via India)	8,800
Direct construction cost=	1,772,400
Rough estimated construction cost=	3,544,800
Ratio :	1.617

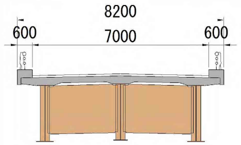
Evaluation

△

Disadvantageous in terms of the construction cost, workability (construction in wet season), and work period

Proposal 3: Steel 18-span continuous non-composite steel plate girder bridge

Plan drawing



Crane and bent erection

Features

Structure: Steel plate girder bridge with the maximum span of 42 m

Bridge construction: With the bent built within the river, bridge is constructed using the crane. Girders to be manufacture in other countries (India in this case * Jointly with the Japanese manufacturer)

Construction in the wet season impossible

Equipment: Cranes and trailers to be procured from other countries

Materials: Steel materials to be procured from other countries

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Steel plate girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	800,200
Substructure	165,300
Road and enbankment (bridge section)	19,800
Skilled worker	190,000
Temporary work	135,300
Transportation (domestic)	18,800
Transportation (via Thimphu)	7,700
Transortatinon of steel (from India)	43,200
Direct construction cost=	1,380,300
Rough estimated construction cost=	2,760,600
Ratio :	1.259

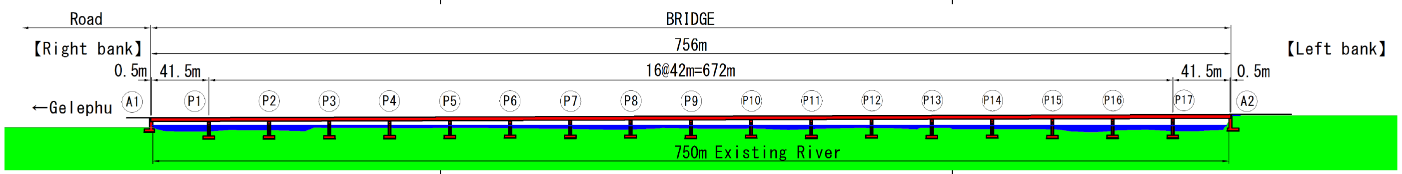
【Steel plate girder bridge (42m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	800,200
Substructure	165,300
Enbankment (bridge secion) only	5,500
Skilled worker	190,000
Temporary work cost	135,300
Transportation (domestic)	18,800
Transportation (via India)	3,200
Transortatinon of steel (from India)	43,200
Direct construction cost=	1,361,500
Rough estimated construction cost=	2,723,000
Ratio :	1.242

Evaluation

○

Though the construction cost is the smallest, further study is necessary concerning procurement of steels from other countries.



Source: JICA Study Team

<Figure7-44>Comparison table of bridge types (span 42m)

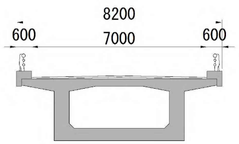
	Prestressed concrete T girder bridge * Not applicable span	Proposal 4: Prestressed concrete 15-span continuous box girder bridge	Proposal 5: Steel 15-span continuous non-composite steel plate girder bridge

Plan drawing

Prestressed concrete T girder bridge: * Not applicable span

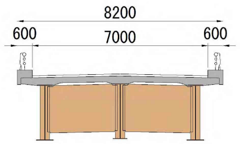
*Bridge length and span division are common

Proposal 4:

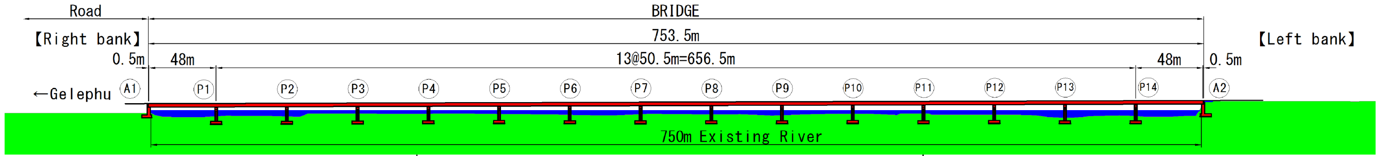


Erection of fixed support

Proposal 5:



Crane and bent erection



Features

Proposal 4:

- Structure: Prestressed concrete box girder bridge with the maximum span length of 5[…]
- Bridge construction: With the support built within the river, the girders are manufactured by cast-in-place
  As construction in the wet season is impossible, the work period becomes longer than the case of T girders. (Reflected in the construction cost)
- Equipment: Equipment for tensioning of prestressed concrete is procured from other countries.
- Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries.
- Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Proposal 5:

- Structure: Steel plate girder bridge with the maximum span length of 50.5m
- Bridge construction: With the bent built within the river, bridge is constructed using the crane.
  Girders to be manufacture in other countries (India in this case * Jointly with the Japanese manufacturer)
  Construction in the wet season impossible
- Equipment: Cranes and trailers to be procured from other countries
- Materials: Steel materials to be procured from other countries
- Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

Proposal 4:

【Steel plate girder bridge (50.5m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	846,400
Substructure	160,000
Road and enbankment (bridge section)	19,800
Skilled worker	166,300
Temporary work	125,400
Transportation (domestic)	18,300
Transportation (via Thimphu)	7,400
Transortatinon of steel (from India)	45,900
Direct construction cost=	1,389,500
Rough estimated construction cost=	2,779,000
Ratio :	1.268

【Steel plate girder bridge (50.5m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	846,400
Substructure	160,000
Enbankment (bridge secion) only	5,500
Skilled worker	166,300
Temporary work cost	125,400
Transportation (domestic)	18,300
Transportation (via India)	3,100
Transortatinon of steel (from India)	45,900
Direct construction cost=	1,370,900
Rough estimated construction cost=	2,741,800
Ratio :	1.251

Proposal 5:

【Steel plate girder bridge (50.5m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	846,400
Substructure	160,000
Road and enbankment (bridge section)	19,800
Skilled worker	166,300
Temporary work	125,400
Transportation (domestic)	18,300
Transportation (via Thimphu)	7,400
Transortatinon of steel (from India)	45,900
Direct construction cost=	1,389,500
Rough estimated construction cost=	2,779,000
Ratio :	1.268

【Steel plate girder bridge (50.5m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	846,400
Substructure	160,000
Enbankment (bridge secion) only	5,500
Skilled worker	166,300
Temporary work cost	125,400
Transportation (domestic)	18,300
Transportation (via India)	3,100
Transortatinon of steel (from India)	45,900
Direct construction cost=	1,370,900
Rough estimated construction cost=	2,741,800
Ratio :	1.251

Evaluation

Prestressed concrete T girder bridge: * Not applicable span

Proposal 4: △

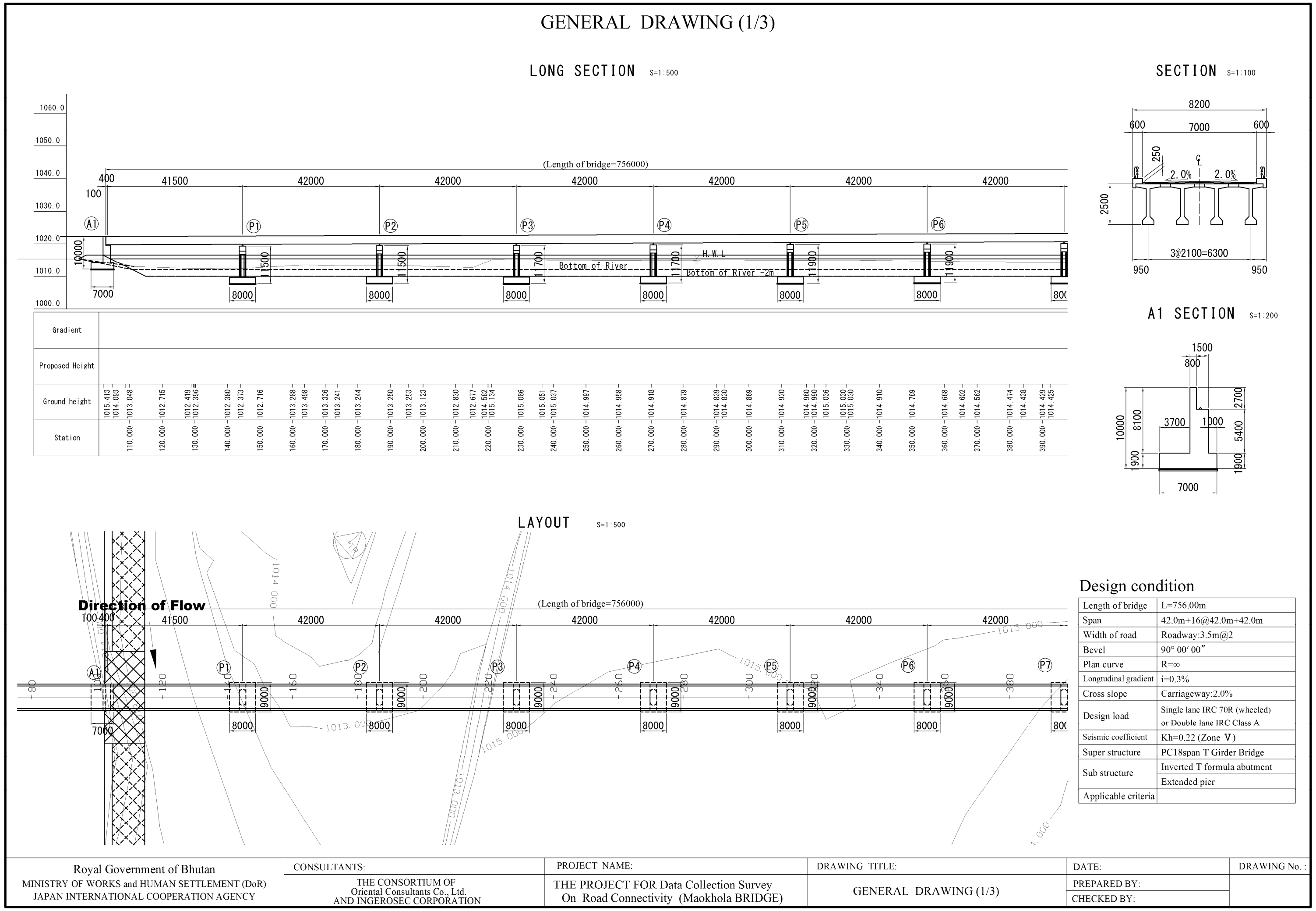
Disadvantageous in terms of the construction cost, workability (construction in wet season), and work period

Proposal 5: ○

Though the construction cost is small, further study is necessary concerning procurement of steels from other countries.

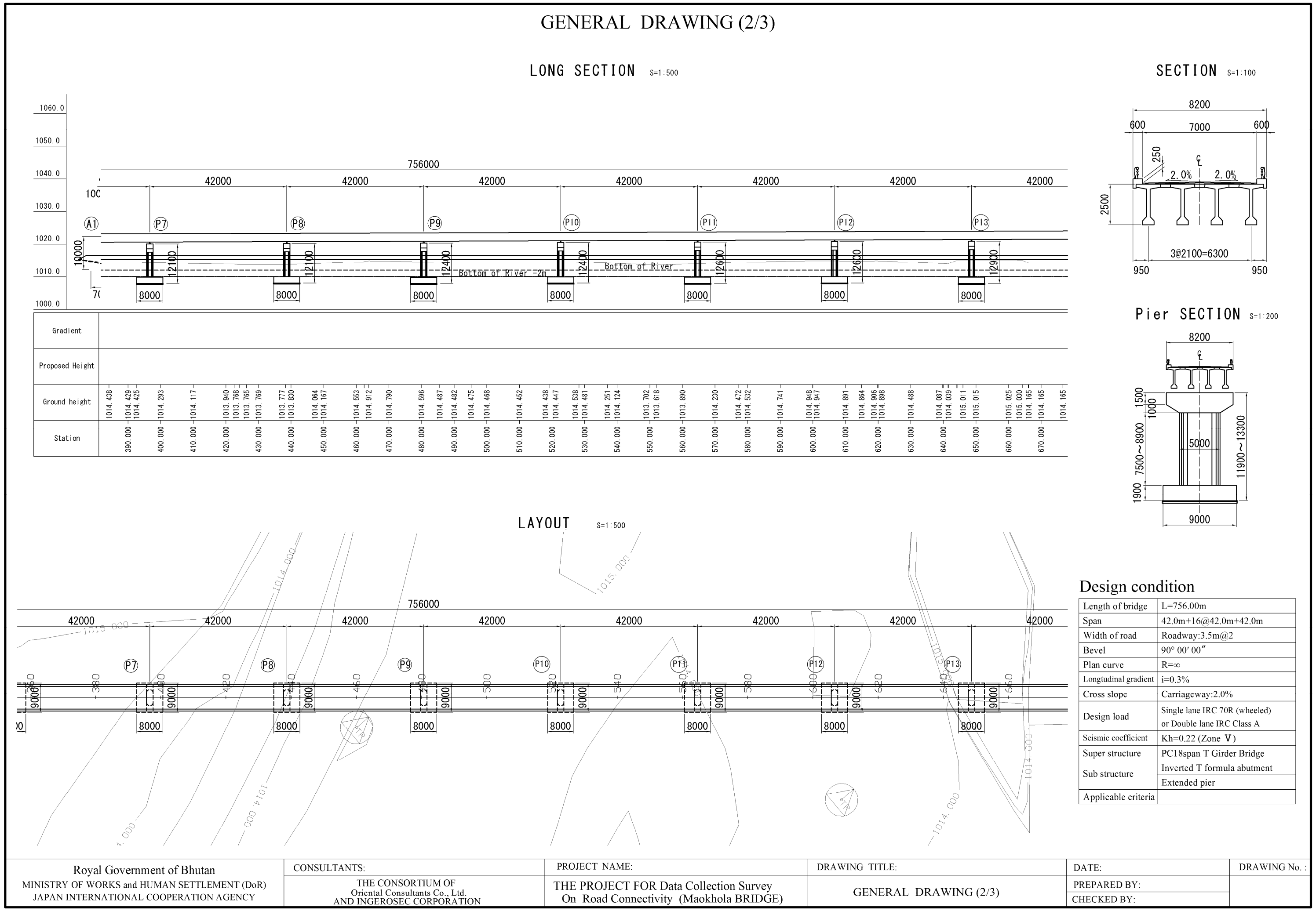
Source: JICA Study Team

<Figure7-45> Comparison table of bridge types (span 50.5m)



Source: JICA Study Team

<Figure7-46> General Drawing (1/3)

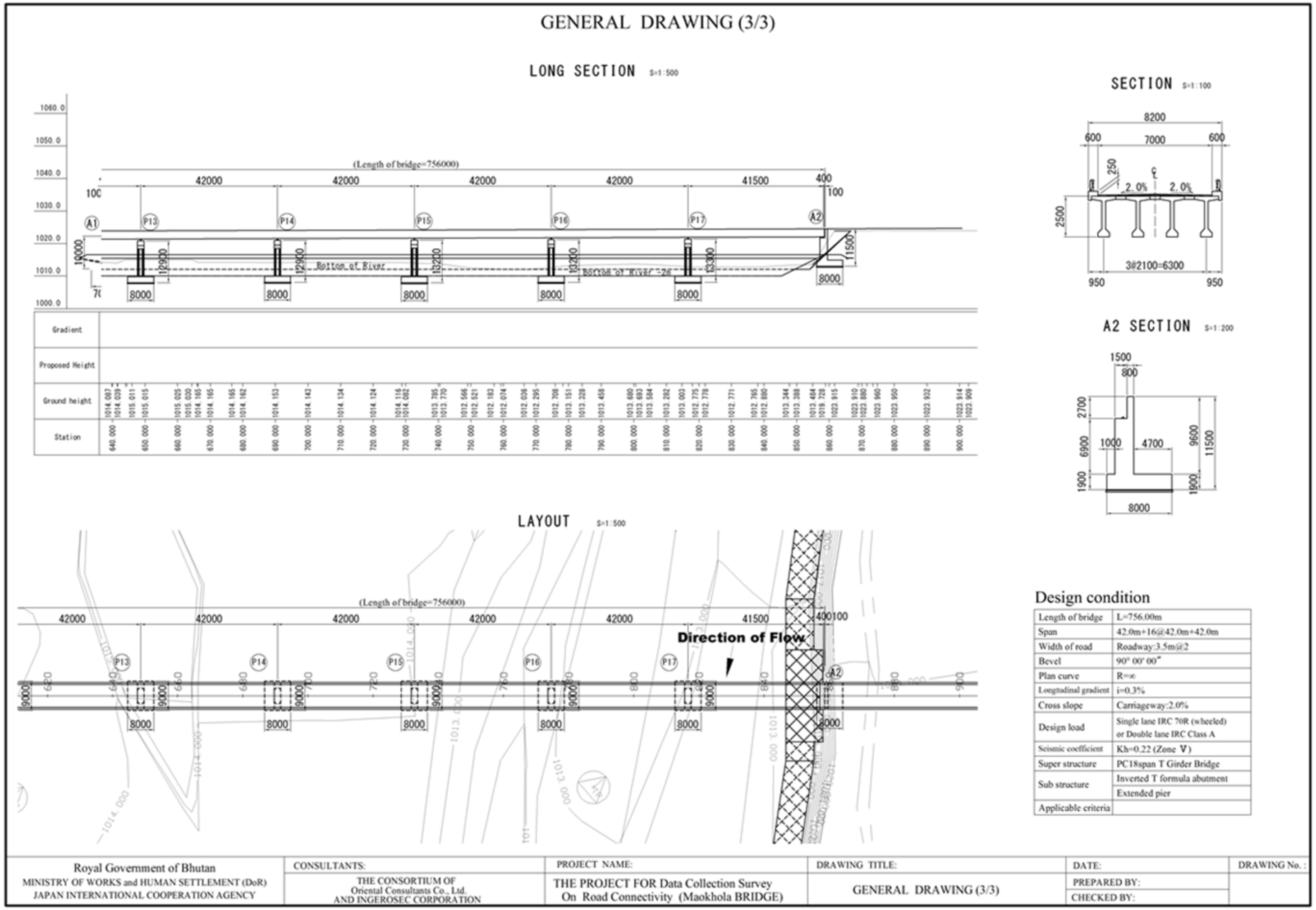


Design condition

Length of bridge	L=756.00m
Span	42.0m+16@42.0m+42.0m
Width of road	Roadway:3.5m@2
Bevel	90° 00′ 00″
Plan curve	R=∞
Longtudinal gradient	i=0.3%
Cross slope	Carriageway:2.0%
Design load	Single lane IRC 70R (wheeled) or Double lane IRC Class A
Seismic coefficient	Kh=0.22 (Zone Ⅴ)
Super structure	PC18span T Girder Bridge
Sub structure	Inverted T formula abutment Extended pier
Applicable criteria	

Source: JICA Study Team

<Figure7-47> General Drawing (2/3)



Source: JICA Study Team

<Figure7-48> General Drawing (3/3)

2) Turnover Comments

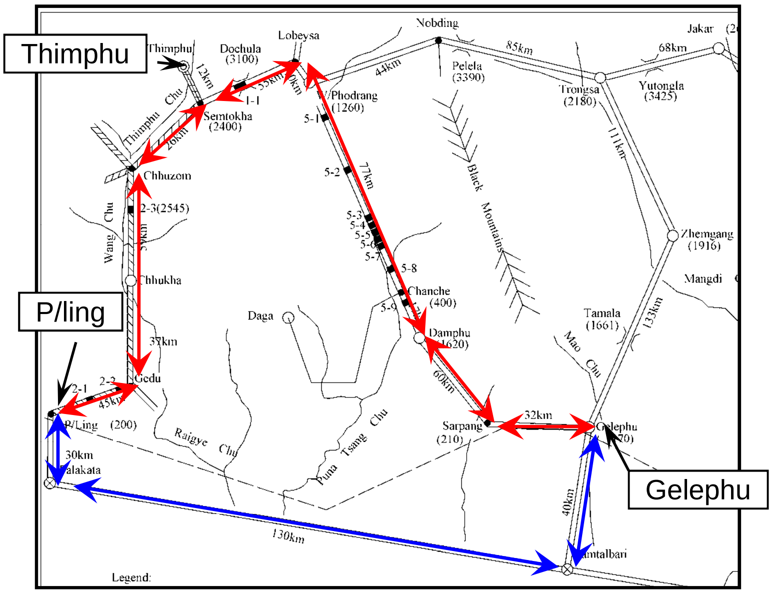
- The relationship between the span length and construction cost should be reconsidered at the time of detailed design.
- For the steel bridges, detailed study is necessary, including the procurement plan.
- For the materials to be transported, starting in other countries (via India) and Phuentsholing, the transportation via Thimphu (Route 1 in the figure below) is changed to the one via India (Route 2 in the figure below). In addition, the construction cost of the proposed prestressed-concrete T-girder bridge can be cut from 3.30 billion yen to 3.13 billion yen (5% down) when the access road to the bridge is to be constructed by Bhutan.
-

[Route 1 (red line)]

「P/ling～Thimphu～Gelephu」
⇒
45+37+59+26+55+10+
77+17+60+32=418km

[Route 2 (blue line)]

「 P/ling ～ (via India) ～ Gelephu」
⇒ 30+130+40=200km



Source: JICA Study Team
<Figure7-49>Transportation route

(4) Approximate Construction Costs for the Proposal of River Width Reduction

Approximate construction cost on the proposals below in the case that river width is reduced by the building of an embankment on the left bank near the bridge location as described in Chapter 7-2 is calculated.

Proposal 1: Prestressed concrete 14-span continuous T-girder bridge (max span 43 m)
Proposal 2: Prestressed concrete 14-span continuous box girder bridge (max span 43 m)
Proposal 3: Steel 14-span continuous non-composite steel plate girder bridge (max span 43 m)
Proposal 4: Prestressed concrete 12-span continuous box girder bridge (max span 50 m)
Proposal 5 : Steel 12-span continuous non-composite steel plate girder bridge (max span 50 m)

[Policy of selection]

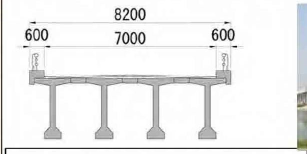
- There are to be three proposed bridge types (the prestressed concrete T girder, prestressed concrete box girder, and steel plate girder) for which the lowest approximate construction cost was most preferred for the bridge plan.
- The number of spans is to be established on the basis of the span length of 43 m and 50 m.
- The proposed span length of 43 m is the minimum span length determined from the river conditions.
- The span length of 50 m was proposed for verification of the relationship between the increase in the cost of superstructure due to increase in the span length and the decrease in the cost of substructure due to reduction of the manpower for substructure. Note that the prestressed concrete T girder in the proposed span length of 50 m is not an applicable span.

In the next chapter, a comparison table of approximate construction costs and bridge general drawings are shown. The approximate construction cost of the proposal for each bridge type is about 500-800 million yen cheaper if the channel is made more narrow than that of proposals on the current river width since the bridge length is shorter. However, this proposal is based on implementation of the plan for bank protection development by the Royal Government of Bhutan, therefore the feasibility is uncertain.

・River width 600m Comparison of bridge types (43 m span)

Plan drawing

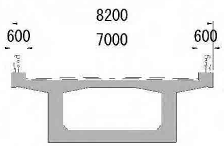
Proposal 1: Prestressed concrete 14-span continuous T girder bridge



*Bridge length and span division are common.

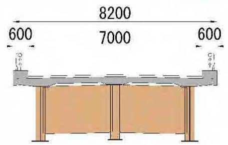
Erection of erection girders

Proposal 2: Prestressed concrete 14-span continuous box girder bridge

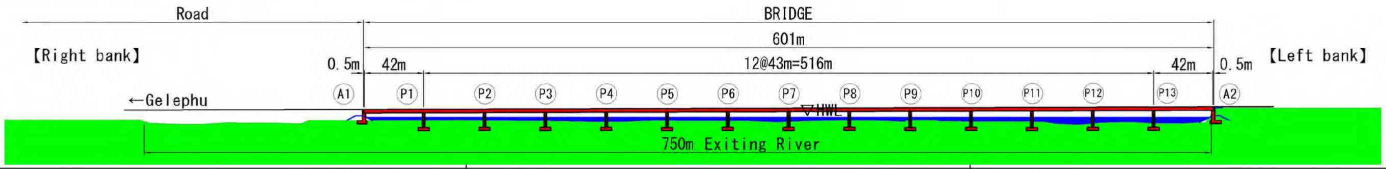


Erection of fixed support

Proposal 3: Steel 14-span continuous non-composite steel plate girder bridge



Crane and bent erection



Features

Proposal 1

Structure: Prestressed concrete T girder bridge with the maximum span length of 43

Bridge construction: Procurement of large cranes considered difficult. The method of erecting the erection girders, for which Bhutan has actual construction experience, is employed. Girders to be manufactured in the site.

Construction in the wet season possible, enabling reduction of the work period. (Reflected in the construction cost)

Equipment: Equipment for erection of erection girders to be procured from other countries

Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Proposal 2

Structure: Prestressed concrete box girder bridge with the maximum span length of 43

Bridge construction: With the support built within the river, the girders are manufactured by cast-in-place

As construction in the wet season is impossible, the work period becomes longer than the case of T girders. (Reflected in the construction cost)

Equipment: Equipment for tensioning of prestressed concrete is to be procured from other countries.

Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries.

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Proposal 3

Structure: Steel plate girder bridge with the maximum span of 43 m

Bridge construction: With the bent built within the river, bridge is constructed using the crane. Girders to be manufacture in other countries (India in this case * Jointly with the Japanese manufacturer)

Construction in the wet season impossible

Equipment: Cranes and trailers to be procured from other countries

Materials: Steel materials to be procured from other countries

Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Prestressed concrete 14-span continuous T girder bridge (43m)】

Types of work	Construction cost (thousand yen)
Superstructure	240,500
Substructure	130,500
Road and enbankment (bridge section)	19,800
Skilled worker/equipment procurement	704,800
Temporary work	107,100
Transportation (domestic)	33,300
Transportation (via Thimphu)	69,900
Direct construction cost=	1,305,900
Rough estimated construction cost=	2,611,800
Ratio:	1.191

【Prestressed concrete 14-span continuous T girder bridge (43m)】

Types of work	Construction cost (thousand yen)
Superstructure	240,500
Substructure	130,500
Enbankment (bridge secion) only	5,500
Skilled worker/equipment procurement	704,800
Temporary work cost	107,100
Transportation (domestic)	33,300
Transportation (via India)	6,500
Direct construction cost=	1,228,200
Rough estimated construction cost=	2,456,400
Ratio:	1.121

【Prestressed concrete 14-span continuous box girder bridge(43m)】

Types of work	Construction cost (thousand yen)
Superstructure	218,800
Substructure	130,500
Road and enbankment (bridge section)	19,800
Skilled worker/equipment procurement	892,400
Temporary work	107,100
Transportation (domestic)	35,200
Transportation (via Thimphu)	76,200
Direct construction cost=	1,480,000
Rough estimated construction cost=	2,960,000
Ratio:	1.350

【Prestressed concrete 14-span continuous box girder bridge(43m)】

Types of work	Construction cost (thousand yen)
Superstructure	218,800
Substructure	130,500
Enbankment (bridge secion) only	5,500
Skilled worker/equipment procurement	892,400
Temporary work cost	107,100
Transportation (domestic)	35,200
Transportation (via India)	6,900
Direct construction cost=	1,396,400
Rough estimated construction cost=	2,792,800
Ratio:	1.274

【Steel 14-span continuous non-composite steel plate girder bridge (43m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	636,100
Substructure	130,500
Road and enbankment (bridge section)	19,800
Skilled worker	156,400
Temporary work	107,100
Transportation (domestic)	14,800
Transportation (via Thimphu)	6,100
Transortatinon of steel (from India)	43,200
Direct construction cost=	1,114,000
Rough estimated construction cost=	2,228,000
Ratio:	1.016

【Steel 14-span continuous non-composite steel plate girder bridge (43m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	636,100
Substructure	130,500
Enbankment (bridge secion) only	5,500
Skilled worker	156,400
Temporary work cost	107,100
Transportation (domestic)	14,800
Transportation (via India)	2,500
Transortatinon of steel (from India)	43,200
Direct construction cost=	1,096,100
Rough estimated construction cost=	2,192,200
Ratio:	1.000

Evaluation

Proposal 1: ◎ Recommended because of actual construction experience of Bhutan and heavy usage of Bhutan's materials

Proposal 2: △ Disadvantageous in terms of the construction cost, workability (construction in wet season), and work period

Proposal 3: ○ Though the construction cost is the smallest, further study is necessary concerning procurement of steels from other countries.

Source: JICA Study Team

<Figure7-50> Comparison table of bridge types (span 43m)

·River width 600m Comparison of bridge types (50 m span)

Prestressed concrete T girder bridge * Not applicable span

Plan drawing: * Not applicable span

*Bridge length and span division are common

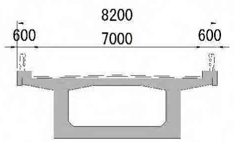
Features: —

Approximate construction cost: —

Evaluation: * Not applicable span

Proposal 5: Prestressed concrete 12-span continuous box girder bridge

Plan drawing



Erection of fixed support

Features

- Structure: Prestressed concrete box girder bridge with the maximum span length of 5
- Bridge construction: With the support built within the river, the girders are manufactured by cast-in-place. As construction in the wet season is impossible, the work period becomes longer than the case of T girders. (Reflected in the construction cost)
- Equipment: Equipment for tensioning of prestressed concrete is procured from other countries.
- Materials: Materials, such as prestressed concrete cable, etc. for prestressed concrete girder to be procured from other countries.
- Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Prestressed concrete 12-span continuous box girder bridge (50m)】

Types of work	Construction cost (thousand yen)
Superstructure	226,000
Substructure	129,400
Road and enbankment (bridge section)	19,800
Skilled worker/equipment procurement	769,600
Temporary work	100,500
Transportation (domestic)	35,700
Transportation (via Thimphu)	78,300
Direct construction cost=	1,359,300
Rough estimated construction cost=	2,718,600
Ratio:	1.240

【Prestressed concrete 12-span continuous box girder bridge (50m)】

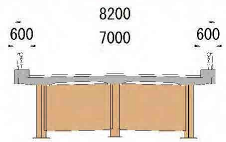
Types of work	Construction cost (thousand yen)
Superstructure	226,000
Substructure	129,400
Enbankment (bridge secion) only	5,500
Skilled worker/equipment procurement	769,600
Temporary work cost	100,500
Transportation (domestic)	35,700
Transportation (via India)	6,900
Direct construction cost=	1,273,600
Rough estimated construction cost=	2,547,200
Ratio:	1.162

Evaluation: △

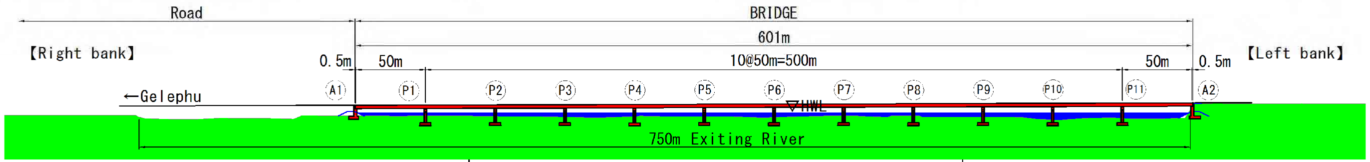
Disadvantageous in terms of the construction cost, workability (construction in wet season), and work period

Proposal 6: Steel 12-span continuous non-composite steel plate girder bridge

Plan drawing



Crane and bent erection



Features

- Structure: Steel plate girder bridge with the maximum span length of 50m
- Bridge construction: With the bent built within the river, bridge is constructed using the crane. Girders to be manufacture in other countries (India in this case * Jointly with the Japanese manufacturer). Construction in the wet season impossible
- Equipment: Cranes and trailers to be procured from other countries
- Materials: Steel materials to be procured from other countries
- Transportation: Materials other than aggregates to be transported from India or P/ling. (For the construction cost shown below, two routes (one via Thimphu and one via India) are assumed for calculation.)

Approximate construction cost

【Steel 12-span continuous non-composite steel plate girder bridge (50m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	667,800
Substructure	129,400
Road and enbankment (bridge section)	19,800
Skilled worker	140,800
Temporary work	100,500
Transportation (domestic)	14,700
Transportation (via Thimphu)	6,000
Transortatinon of steel (from India)	45,400
Direct construction cost=	1,124,400
Rough estimated construction cost=	2,248,800
Ratio:	1.026

【Steel 12-span continuous non-composite steel plate girder bridge (50m)】

Types of work	Construction cost (thousand yen)
Superstructure *including equipment	667,800
Substructure	129,400
Enbankment (bridge secion) only	5,500
Skilled worker	140,800
Temporary work cost	100,500
Transportation (domestic)	14,700
Transportation (via India)	2,500
Transortatinon of steel (from India)	45,400
Direct construction cost=	1,106,600
Rough estimated construction cost=	2,213,200
Ratio:	1.010

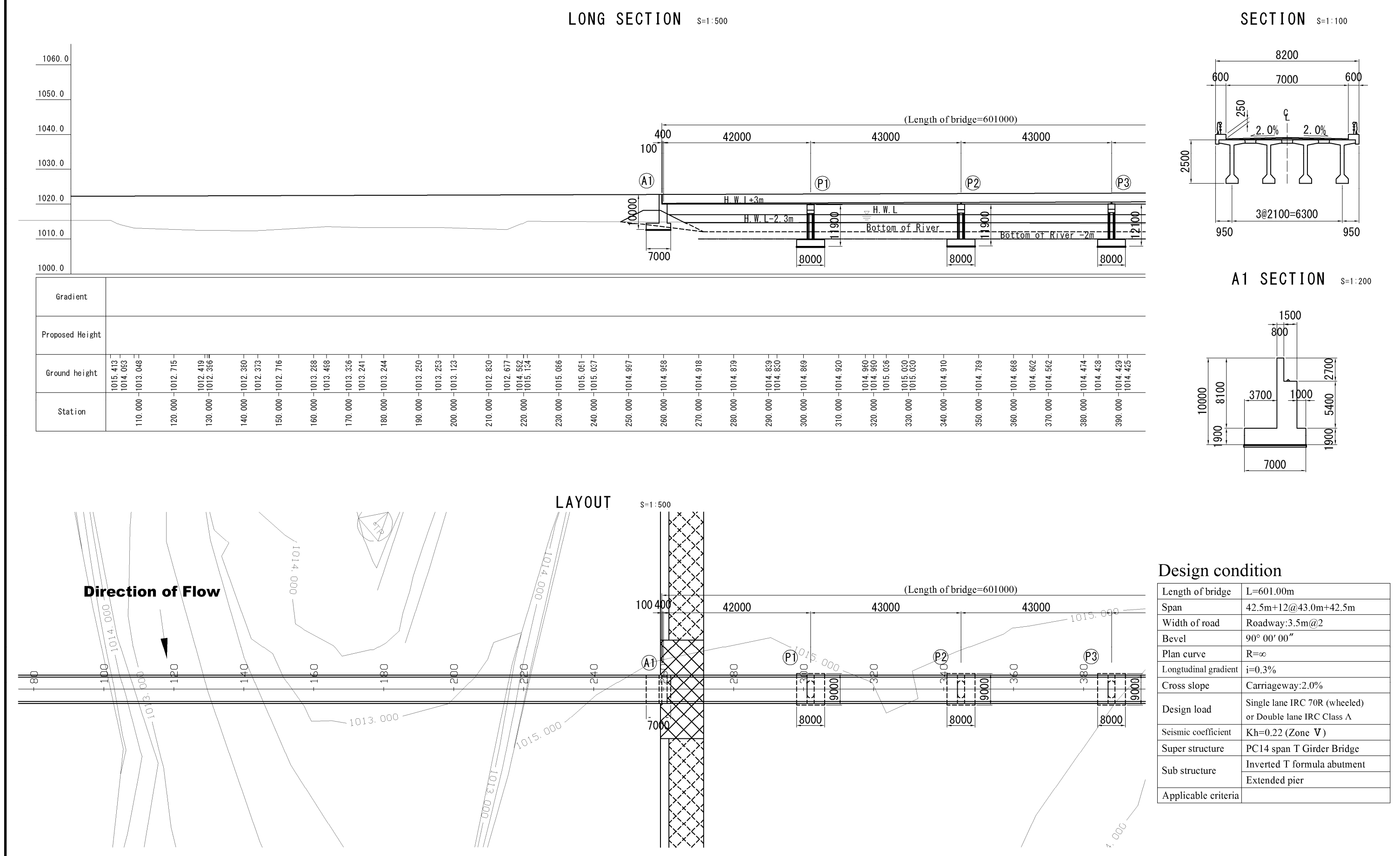
Evaluation: ○

Though the construction cost is small, further study is necessary concerning procurement of steels from other countries.

Source: JICA Study Team

<Figure7-51> Comparison table of bridge types (span 50m)

GENERAL DRAWING (1/3)



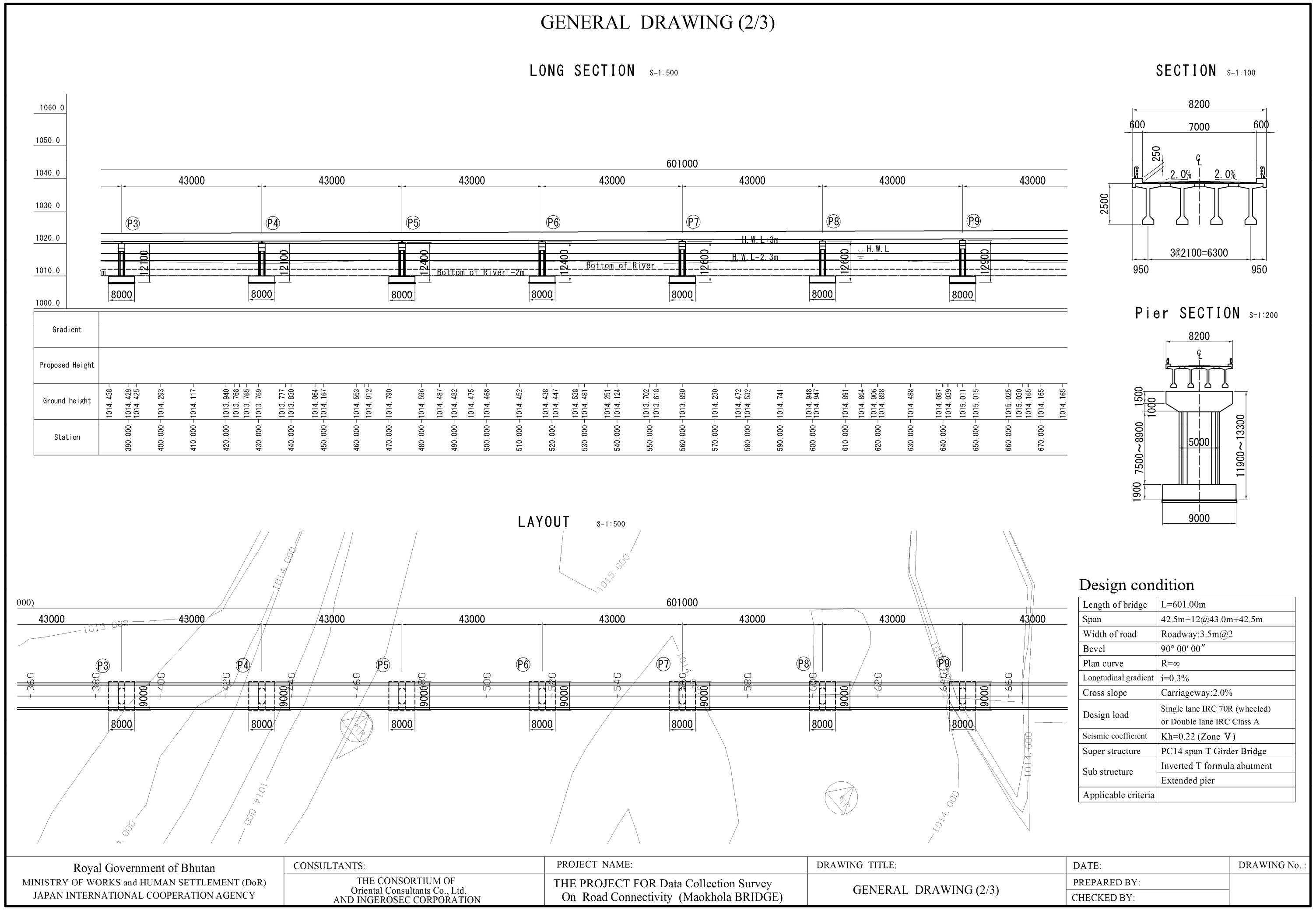
Design condition

Length of bridge	L=601.00m
Span	42.5m+12@43.0m+42.5m
Width of road	Roadway:3.5m@2
Bevel	90° 00′ 00″
Plan curve	R=∞
Longtudinal gradient	i=0.3%
Cross slope	Carriageway:2.0%
Design load	Single lane IRC 70R (wheeled) or Double lane IRC Class A
Seismic coefficient	Kh=0.22 (Zone V)
Super structure	PC14 span T Girder Bridge
Sub structure	Inverted T formula abutment
	Extended pier
Applicable criteria	

Royal Government of Bhutan MINISTRY OF WORKS and HUMAN SETTLEMENT (DoR) JAPAN INTERNATIONAL COOPERATION AGENCY	CONSULTANTS: THE CONSORTIUM OF Oriental Consultants Co., Ltd. AND INGEROSEC CORPORATION	PROJECT NAME: THE PROJECT FOR Data Collection Survey On Road Connectivity (Maokhola BRIDGE)	DRAWING TITLE: GENERAL DRAWING (1/3)	DATE: PREPARED BY: CHECKED BY:	DRAWING No. :

Source: JICA Study Team

<Figure7-52> General Drawing (1/3)

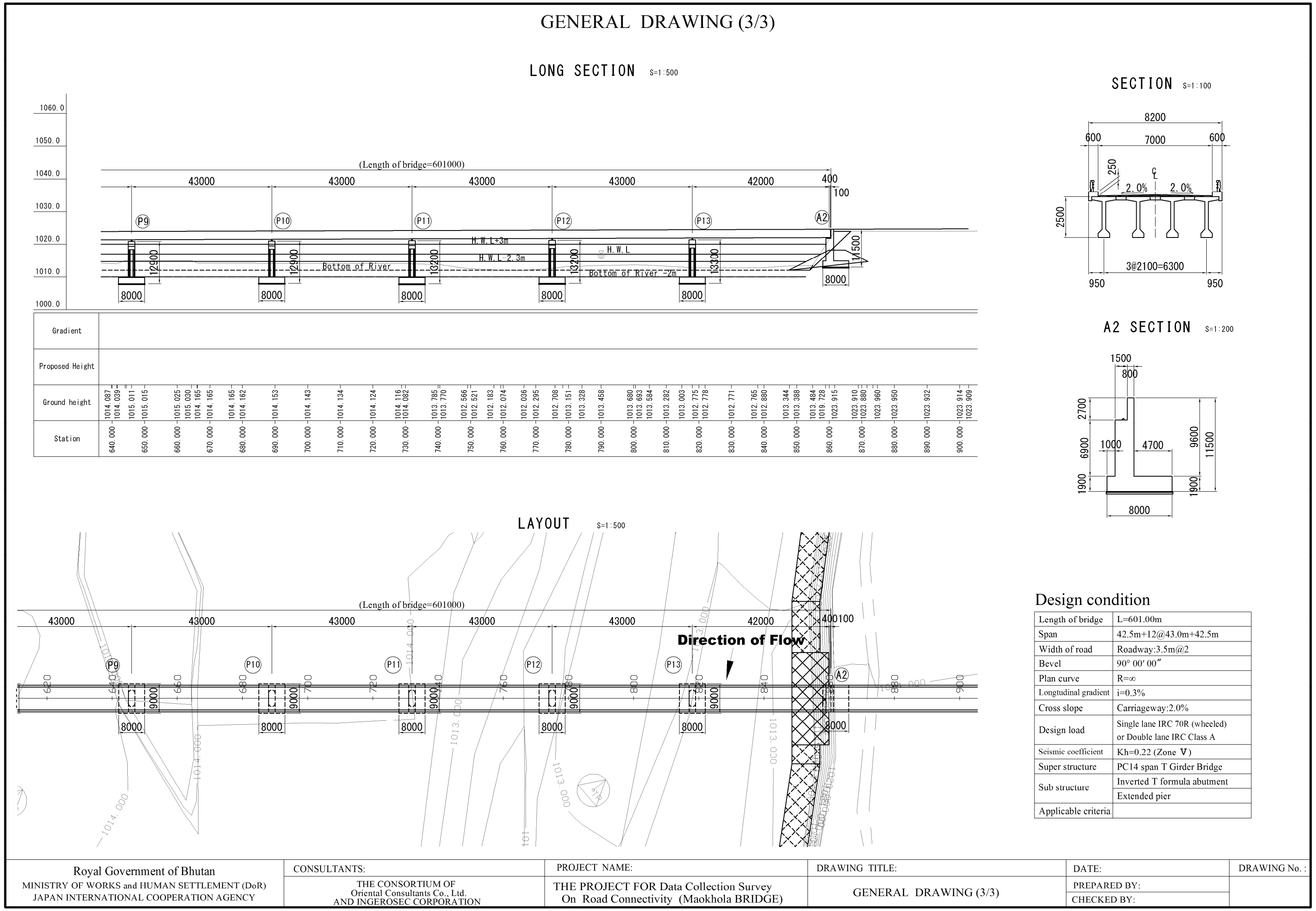


Design condition

Length of bridge	L=601.00m
Span	42.5m+12@43.0m+42.5m
Width of road	Roadway:3.5m@2
Bevel	90° 00′ 00″
Plan curve	R=∞
Longtudinal gradient	i=0.3%
Cross slope	Carriageway:2.0%
Design load	Single lane IRC 70R (wheeled) or Double lane IRC Class A
Seismic coefficient	Kh=0.22 (Zone Ⅴ)
Super structure	PC14 span T Girder Bridge
Sub structure	Inverted T formula abutment Extended pier
Applicable criteria	

Source: JICA Study Team

<Figure7-53> General Drawing (2/3)



Design condition

Length of bridge	L=601.00m
Span	42.5m+12@43.0m+42.5m
Width of road	Roadway:3.5m@2
Bevel	90° 00' 00"
Plan curve	R=∞
Longtudinal gradient	i=0.3%
Cross slope	Carriageway:2.0%
Design load	Single lane IRC 70R (wheeled) or Double lane IRC Class A
Seismic coefficient	Kh=0.22 (Zone Ⅴ)
Super structure	PC14 span T Girder Bridge
Sub structure	Inverted T formula abutment Extended pier
Applicable criteria	

Source: JICA Study Team

<Figure7-54> General Drawing (3/3)