MINISTRY OF ROAD TRANSPORT AND HIGHWAYS
MINISTRY OF RAILWAY
MINISTRY OF URBAN DEVELOPMENT
STATE GOVERNMENT (Delhi, Karnataka State, Tamil Nadu State, Maharashtra State, Gujarat State)

THE REPUBLIC OF INDIA

Data Collection Survey on Road/Railway Bridge Sector

FINAL REPORT

January 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.

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List of Abbreviations

AADT	Annual Average Daily Traffic
AH	Asian Highway
AUDA	Ahmedabad Urban Development Authority
B/C	Benefit / Cost
BIS	Bureau of Indian Standard
BOT	Built-Operate-Transfer
BRT	Bus Rapid Transit
BTO	Built-Transfer-Operate
CBIC	Chennai-Bengaluru Industrial Corridor
CFRP	Carbon Fiber Reinforce Plate
CPS	Country Partnership Strategy
CPI	Consumer Price Index
CR	Central Railway
CRRI	Central Road Research Institute
CRZ	Coastal Regulation Zone
DFR	Draft Final Report
DMIC	Deli-Mumbai Industrial Corridor
DPR	Detailed Project Report
EAC	Environmental Appraisal Committee
EC	Environment Clearance
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ENPV	Economic Net Present Value
EPC	Engineering, Procurement and Construction
ETC	Electronic Toll Collection
FR	Final Report
GCC	Greater Chennai Corporation
GSDP	Gross State Domestic Product
IAHE	Indian Academy of Highway Engineers
ICR	Inception Report
INR	Indian Rupee
ITR	Interim Report
IRC	Indian Road Congress
JETRO	Japan External Trade Organization

JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
KRDC	Karnataka Road Development Corporation
LC	Local Consultant
MOR	Ministry of Railway
MORTH	Ministry of Road Transport and Highways
MOUD	Ministry of Urban Development
NH	National Highway
NHAI	National Highways Authority of India
NWR	North Western Railway
ODA	Official Development Assistance
O/M	Operation / Management
PC	Prestressed Concrete
PCU	Passenger Car Unit
PFI	Private Finance Initiative
PHF	Peak Hour Factor
PPP	Public Private Partnership
PRIDeC	Peninsular Region Industrial Development Corridor
PWD	Public Works Development
QBS	Quality Based Selection
QCBS	Quality and Cost Based Selection
RC	Reinforced Concrete
ROB	Road Over Bridge
SEAC	South East Asia Command
SPC	Specific Purpose Company
STEP	Special Terms for Economic Partnership
THM	Tamil Nadu State Highways & Minor Ports Department
TNRDC	Tamil Nadu Road Development Company
TTC	Travel Time Cost
VOC	Vehicle Operation Cost
WR	Western Railway

1. INTRODUCTION

1.1 Background

In the Republic of India (hereinafter called India) roads and railways are important transportation mode supporting most of the domestic distribution. Road traffic volume has increased by 9.1% per year after 1950 in tandem with the population and economic growth. The Ministry of Road Transport and Highways (MORTH) is planning to expand the road network and to improve the national highway network. However, the existing road network is still unable to cope increasing road traffic volume. In metropolitan areas, such as Delhi, Mumbai, Kolkata, Bangalore and Chennai, traffic congestion has reached a chronic stage. While flyovers need to be constructed to these metropolitan areas, long-term traffic restrictions during construction are problematic. In addition, some serious damages of the existing bridges were identified and existing bridges have serious issues in inspection, rehabilitation, repair and reinforcement requirements. However, due to the fact that rehabilitation, repair and reinforcement of the existing bridges need advanced technology and rich experience, the planning and implementation for rehabilitation, repair and reinforcement of the existing bridges is not progressing.

Under these circumstances, the Indian Government is requesting the introduction of flyover and/or viaduct construction in congested areas using rapid construction methods and implementation of bridge rehabilitation, repair and reinforcement methods of the existing bridges using advanced Japanese technologies.

The length of the railway network in India under the Ministry of Railway (MOR) is about 64,000km with extensions and dualization work currently ongoing. Furthermore, the existing bridges along the railway lines and Road Over Bridges (ROBs) have the same issues as the road sector.

From the above background, the application of rapid construction for the flyover bridges and viaducts are requested to be considered in congested areas and latest bridge rehabilitation and reinforcement methods for the existing bridges also need to be considered.

1.2 Objectives of Survey

The objectives of the survey are shown in Table 1.2.1. And the locations of the survey areas are shown in Figure 1.2.1.

Table 1.2.1 Objectives of the Survey

Project Name	Data Collection Survey on Road/Railway Bridge Sector
Objective of the survey	➢ Grasp the current situation of Road/Railway bridges and viaducts in India. ➢ Selection of target bridges/viaducts in consideration of the application of the Japanese advanced technology such as rapid construction methods in urban areas and latest bridge rehabilitation and reinforcement methods.
Survey area	The main target areas are as follows: ➢ For Bridges: States which belong to the Delhi-Mumbai Industrial Corridor and Chennai-Bangalore Industrial Corridor (Uttar Pradesh, Haryana, Rajasthan Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh) ➢ For Flyover Bridges/Viaducts: Metropolitan areas such as Delhi, Mumbai, Bangalore, Ahmadabad and Kolkata
Counterparts	➢ Ministry of Road Transport and Highways (MORTH) ➢ Ministry of Railway (MOR) ➢ Ministry of Urban Development (MOUD) ➢ State Government

Source: JICA Study Team

Figure 1.2.1 Location Map of Target Area

1.3 Schedule of Survey

1.3.1 Flowchart of Survey

The survey flowchart is shown in Figure 1.3.1.

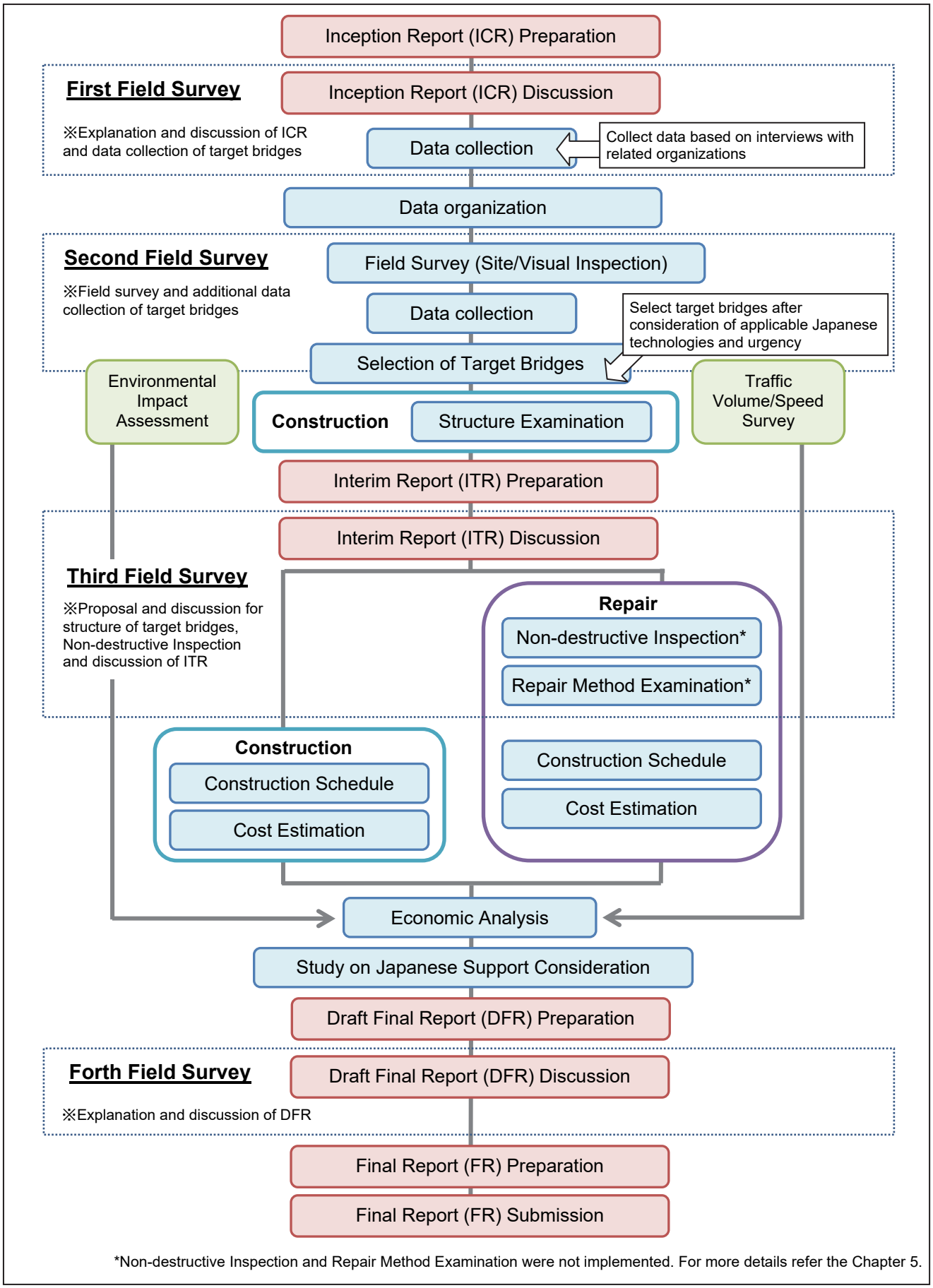


Figure 1.3.1 Survey Flowchart

1.3.2 Overall Schedule

The Survey work schedule is shown in Table 1.3.1. The Survey commenced at the Beginning of March, 2016 and the final report will be submitted at the Beginning of January, 2017.

Table 1.3.1 Survey Work Schedule

Contents of survey	2016										2017
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Preparation of Inception Report (ICR)											
First Field Survey Explanation and discussion of ICR and data collection of target bridges											
Organize collected data											
Second Field survey Field survey and additional data collection of target bridges											
Selection of target bridges (construction/repair)											
Traffic Volume/Speed Survey											
Environmental Impact Assessment											
Structure examination of target bridges (construction)											
Preparation of Interim Report (ITR)											
Third Field Survey Proposal and discussion for structure of target bridges, Non-destructive Inspection and discussion of ITR											
Construction schedule and cost estimation of target bridge (construction and repair)											
Economic analysis of target bridges											
Study on Japanese Support											
Preparation Draft Final Report (DFR)											
Forth Field Survey Explanation and discussion of DFR											
Preparation and Submission of Final Report (FR)											

1.3.3 Schedule for First Field Survey

In order to explain and discuss of inception report and collect data for target bridges, the first field survey is carried out on 30th March to 15th April, 2016. The schedule for the first field survey is shown in Table 1.3.2.

Table 1.3.2 Schedule for the First Field Survey

Date		Schedule
30-March-2016	Wed	Arrive in India
31-March-2016	Thu	Meeting with JICA
1-April-2016	Fri	Meeting with MORTH and MOR
2-April-2016	Sat	Data Organizing
3-April-2016	Sun	Data Organizing
4-April-2016	Mon	Meeting with MORTH
5-April-2016	Tue	Meeting with MORTH and MOUD
6-April-2016	Wed	Meeting with North Western Railway
7-Aprile-2016	Thu	Move to Mumbai Meeting with Maharashtra State Public Works Department, Western Railway and Central Railway
8-April-2016	Fri	Data Organizing
9-April-2016	Sat	Move to Delhi
10-April-2016	Sun	Data Organizing
11-April-2016	Mon	Data Organizing
12-April-2016	Tue	Move to Ahmadabad Meeting with Gujarat State Public Works Department and Ahmadabad Urban Development Authority Move to Bangalore
13-April-2016	Wed	Meeting with Karnataka Road Development Corporation Move to Delhi
14-April-2016	Thu	Meeting with Delhi Public Works Department Meeting with JICA
15-April-2016	Fri	Return to Japan

1.3.4 Schedule for Second Field Survey

In order to collect additional data of target bridges and carry out field survey, the second field survey is carried out on 22nd May to 24th June 2016.The schedule for the second field survey is shown in Table 1.3.3.

Table 1.3.3 Schedule for the Second field survey

Date		Schedule	
		Team 1	Team 2
22-May-2016	Sun	Arrive in India	
23-May-2016	Mon	Meeting with JICA	
24-May-2016	Tue	Meeting with MOR	
25-May-2016	Wed	Move to Chennai	
26-May-2016	Thu	Meeting with Tamil Nadu Road Development Company	
27-May-2016	Fri	Field Survey in Chennai	
28-May-2016	Sat	Move to Delhi	
29-May-2016	Sun	Data Organizing	
30-May-2016	Mon	Move to Bangalore Field Survey in Bangalore	
31-May-2016	Tue	Meeting with Local Consultant in Bangalore Field Survey in Bangalore	
1-June-2016	Wed	Move to Delhi	
2-June-2016	Thu	Meeting with Delhi Public Works Department Field Survey in Delhi	
3-June-2016	Fri	Field Survey in Delhi	
4-June-2016	Sat	Data Organizing	
5-June-2016	Sun	Move to Mumbai	
6-June-2016	Mon	Meeting with Western Railway	
7-June-2016	Tue	Field Survey in Mumbai	
8-June-2016	Wed	Field Survey in Mumbai	
9-June-2016	Thu	Field Survey in Mumbai	
10-June-2016	Fri	Move to Delhi	Field Survey in Mumbai
11-June-2016	Sat	Data Organizing	Data Organizing
12-June-2016	Sun	Data Organizing	Move to Vadodara
13-June-2016	Mon	Data Organizing	Field Survey in Vadodara
14-June-2016	Tue	Data Organizing	Field Survey in Vadodara
15-June-2016	Wed	Move to Kolkata	Field Survey in Vadodara
16-June-2016	Thu	Meeting with MORTH (Kolkata office)	Move to Delhi
17-June-2016	Fri	Field Survey in Kolkata	Data Organizing
18-June-2016	Sat	Move to Chennai	Data Organizing
19-June-2016	Sun	Data Organizing	Data Organizing
20-June-2016	Mon	Meeting with Greater Chennai Corporation	Data Organizing
21-June-2016	Tue	Meeting with Tamil Nadu State Highways & Minor Ports Department	Data Organizing
22-June-2016	Wed	Field Survey in Chennai Move to Delhi	Data Organizing
23-June-2016	Thu	Data Organizing	
24-June-2016	Fri	Meeting with JICA Return to Japan	

1.3.5 Schedule for Third Field Survey

For the proposal and discussion of the outline of bridges structures in accordance with result of second field survey, the third field survey is carried out on 15th August to 2nd September, 2016. In addition, Non-destructive investigation is planned to be carried out to damaged bridges. The schedule for the Third field survey is shown in Table 1.3.4.

Table 1.3.4 Schedule for the Third Field Survey

Date		Schedule
15-August-2016	Mon	Arrive in India
16-August-2016	Tue	Meeting with JICA Meeting with Delhi Public Works Department
17-August-2016	Wed	Meeting with MOR
18-August-2016	Thu	Data Organizing
19-August-2016	Fri	Meeting with MORTH
20-August-2016	Sat	Data Organizing
21-August-2016	Sun	Data Organizing
22-August-2016	Mon	Meeting with JICA
23-August-2016	Tue	Data Organizing
24-August-2016	Wed	Move to Bangalore Meeting with Local Consultant in Bangalore
25-August-2016	Thu	Move to Delhi
26-August-2016	Fri	Data Organizing
27-August-2016	Sat	Move to Patna Field Survey in New Mahatma Gandhi Bridge Move to Delhi
28-August-2016	Sun	Data Organizing
29-August-2016	Mon	Data Organizing
30-August-2016	Tue	Meeting with MORTH (Indian Academy of Highway Engineering)
31-August-2016	Wed	Data Organizing
1-September-2016	Thu	Data Organizing
2-September-2016	Fri	Meeting with JICA Return to Japan

1.3.6 Schedule for Forth Field Survey

For the explanations and discussion of draft final report, the forth field survey is carried out on 12th October to 21st October, 2016. The schedule for the forth field survey is shown in Table 1.3.5.

Table 1.3.5 Schedule for the Forth Field Survey

Date		Schedule
12-October-2016	Wed	Arrive in Delhi
13-October -2016	Thu	Meeting with JICA
14-October -2016	Fri	Meeting with Delhi Public Works Department
15-October -2016	Sat	Data Organizing
16-October -2016	Sun	Move to Chennai
17-October -2016	Mon	Meeting with Tamil Nadu State Highways & Minor Ports Department
18-October -2016	Tue	Move to Bangalore
19-October -2016	Wed	Meeting with Local Consultant in Bangalore Move to Delhi
20-October -2016	Thu	Meeting with JICA
21-October -2016	Fri	Return to Japan

2. INTERVIEWS WITH RELEVANT ORGANIZATIONS

2.1 Interviews with Relevant Organizations

The organizations relating to construction and maintenance of bridge sector in India and counterparts related the Survey are as follows.

- Ministry of Road Transport and Highways：MORTH
- Ministry of Railway：MOR
- Ministry of Urban Development：MOUD
- State Governments

The meeting list of field survey for the first, second, third and fourth are shown in Table 2.1.1, Table 2.1.2, Table 2.1.3 and Table 2.1.4, respectively.

Table 2.1.1 Meeting List of the First Field Survey

Date	Organization	City	Name (Title)	Contents
1-April	MOR	Delhi	Mr. M. K. Srivastava (Executive Director) Mr. S. K. Srivastva (Director Civil Engineer)	- Explanation of the Survey outline - Data collection of candidate railway bridge
1-April	MORTH	Delhi	Mr. B. K. Shinha (Chief Engineer)	- Explanation of the Survey outline - Data collection of candidate bridge and viaduct plan
4-April	MORTH	Delhi	Mr. V. Kaul (Chief Engineer of Bridge)	
5-April	MOUD	Delhi	Mr. M. K. Sinha (Executive Director Civil Engineer) Mr. R. K. Singh (Director)	- Explanation of the Survey outline - Request for support for data collection of candidate viaduct in urban area
5-April	MORTH	Noida	Mr. S. K Nirmal (Chief Engineer)	- Explanation of the Survey outline - Data collection of candidate bridge and viaduct plan
6-April	North Western Railway	Jaipur	Mr. Kalra (Chief Engineer)	- Explanation of the Survey outline - Data collection of candidate railway bridge in managed areas
7-April	Maharashtra States Public Works Department	Mumbai	Mr. S. B. Tamsekar (Secretary)	- Explanation of the Survey outline - Data collection of candidate bridge in Mumbai
7-April	Central Railway	Mumbai	Mr. R. C. Thakur (Chief Bridge Engineer)	- Explanation of the Survey outline - Data collection of candidate railway bridge in managed areas
7-April	Western Railway	Mumbai	Mr. J. P. Verma (Chief Bridge Engineer) Mr. A. K. Dy (Deputy Bridge Engineer)	- Explanation of the Survey outline - Data collection of candidate railway bridge in managed areas
12-April	Gujarat State Public Works Department	Ahmadabad	Mr. S. B. Vasana (Chief Engineer)	- Explanation of the Survey outline - Data collection of candidate bridge in Ahmadabad

Date	Organization	City	Name (Title)	Contents
12-April	Ahmadabad Urban Development Authority	Ahmadabad	Mr. S. K. Patel (Superintending Engineer)	- Explanation of the Survey outline - Data collection of candidate bridge in urban area in Ahmadabad
13-April	Karnataka Road Development Corporation	Bangalore	K. S. Krishna Reddy (Managing Director)	- Explanation of the Survey outline - Data collection of candidate bridge in Bangalore
14-April	Delhi Public Works Department	Delhi	Mr. S. K. Srivastava (Engineer-in-Chief) Mr. M. Amitabh (Chief Project Manager)	- Explanation of survey outline - Data collection of candidate bridge and viaduct plan in Delhi

Table 2.1.2 Meeting List of the Second Field Survey

Date	Organization	City	Name (Title)	Contents
24-May	MOR	Delhi	Mr. S. C. Jain (Executive Directo /Chief Engineer)	- Confirmation of investigation work regarding bridges managed by Western Railway
26-May	Tamil Nadu Road Development Company	Chennai	Mr. Y. R. Balaji (Chief General Manager)	- Explanation of the Survey outline - Data collection of viaduct construction plan in Chennai
31-May	Local Consultant	Bangalore	Mr. Rathnakara Reddy (Managing Director)	- Explanation of project outline for the viaduct construction proposed by Local Consultant - Discussion on applicable Japanese technologies
2-June 3-June	Delhi Public Works Department	Delhi	Mr. Deepak Gupta (Chief Engineer)	- Explanation of project outline for the proposed corridors in Delhi - Data collection of project plan details - Field Survey of proposed area
6-June	Western Railway	Mumbai	Mr. K. C. Swami (Chief Bridge Engineer) Mr. Meena (Divisional Engineer)	- Data collection of damaged bridges - Confirmation of execution of investigation work regarding to damaged bridges
16-June	MORTH	Kolkata	Mr. Vivek Jaiswal (Superintending Engineer)	- Data collection of damaged bridge and intersection improvement project by construction of flyover in Kolkata
20-June	Greater Chennai Corporation	Chennai	Mr. Cnandramohan (Commissioner) Mr. K. S. Kandasamy (Deputy Commissioner)	- Explanation of survey outline - Data collection of viaduct project plan in Chennai
21-June	Tamil Nadu State Highways & Minor Ports Department	Chennai	Dr. Rajeev Ranjan (Additional Chief Secretary)	- Explanation of the Survey outline - Data collection of viaduct project plan in Chennai

Table 2.1.3 Meeting List of the Third Field Survey

Date	Organization	City	Name (Title)	Contents
16-August	Delhi Public Works Department	Delhi	Mr. Sarvagya Srivastava (Engineer-in-Chie /Principal Secretary) Mr. P. K. Parmar (Chief Engineer)	- Presentation for two prioritized proposed viaduct construction for East-West and North-South corridors
17-August	MOR	Delhi	Mr. A. K. Singhal (Executive Director)	- Requested to provide a permission letter for site inspection (Non-destructive inspection) in Mumbai
19-August	MORTH	Delhi	Mr. A. D. James (Deputy Secretary) Mr. B. K. Sinha (Chief Engineer),	- Discussion about Bridge link at Koshi River and New Mahatma Gandhi Bridge.
24-August	Local Consultant	Bangalore	Mr. Rajasekhara Reddy L. P. (Associate Director)	- Explanation on proposed structure of viaduct in Bangalore
30-August	MORTH (IAHE)	Noida	Mr. V. L. Patankar (Director) Mr. S. K. Nirmal (Chief Engineer)	- Discussion and collection of data about New Mahatma Gandhi Bridge - Discussion about applicable Japanese technologies

Table 2.1.4 Meeting List of the Forth Field Survey

Date	Organization	City	Name (Title)	Contents
14-October	Delhi Public Works Department	Delhi	Mr. Sarvagya Srivastava (Engineer-in-Chief/Principal Secretary) Mr. P. K. Parmar (Chief Project Manager)	- Explanation on proposed structure of viaduct in Delhi - Discussion about future support by Japanese Government
17-October	Tamil Nadu State Highways & Minor Ports Department	Chennai	Mr. R.Baskaran (Chief Engineer Metro, Highway Department) Mr. A. Premnaty (Superintendent Engineer)	- Explanation on proposed structure of viaduct in Chennai - Discussion about future support by Japanese Government
19-October	Local consultant	Bangalore	Mr. B.G.P. Reddy (Associate Director)	- Explanation on proposed structure of viaduct in Bangalore - Discussion about future support by Japanese Government

The outline of organizations and detailed of meeting results are described below.

2.1.1 Ministry of Road Transport and Highways (MORTH)

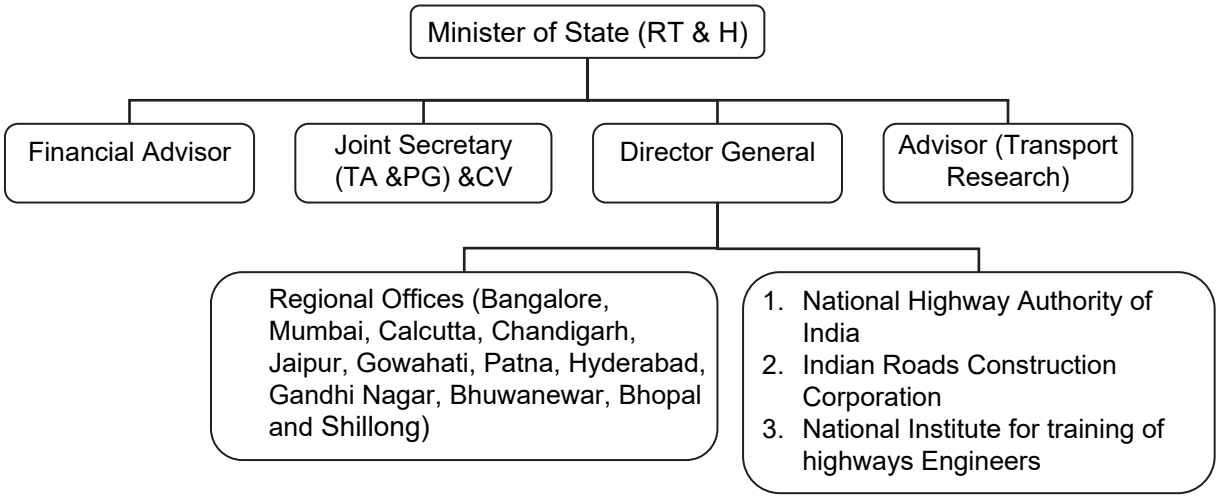
(1) Outline of Organization

The Ministry of Road Transport and Highways (MORTH) is responsible for the development of road transport and maintenance of National Highways. The main responsibility is as follows.

- Planning, development and maintenance of National Highways in the country

- Extends technical and financial support to State Governments for the development of state roads and the inter-state roads connectivity of economic importance
- Evolves standard specifications for roads and bridges in the country
- Serves as a repository of technical knowledge on roads and bridges

MORTH entrusts the actual work such as construction and maintenance of National Highway to the National Highway Authority of India (NHAI), which was established under the National Highways Act in 1988. In addition, MORTH is in charge of administration of Indian Academy of Highway Engineers (IAHE), which is a training institute of highway engineers.
The organization chart of MORTH is shown in Figure 2.1.1.



Source: MORTH

Figure 2.1.1 Organization Chart of MORTH

(2) Outline of Meeting with MORTH

The outline of the meeting with MORTH is shown as follows. The main purpose of this meeting is to introduce Japanese advanced technologies for construction and repair/reinforcement of bridge and collect the information of bridges which are able to apply those technologies. Totally five meetings were held during the Survey.

- **First Field Survey**

1) Meeting with MORTH on 1st April

Date	1st April, 2016
Place	Ministry of Road Transport & Highways (MORTH), Delhi
Attendees	Mr. B. K. Shinha (Chief Engineer) Mr. Toshiaki Shinozaki, Mr. Anurag Sinha (JICA India office) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of the Survey. (JICA) - Explanation of ICR of the Survey. (JICA Study Team) - Maharashtra State and Gujarat State are expected as target places. (MORTH) - Confirm with Chief Engineer about the latest list of damaged bridges. (MORTH)

2) Meeting with MORTH on 4th April

Date	4th April, 2016
Place	Ministry of Road Transport and Highways (MORTH), Delhi
Attendees	Mr. Verinder Kaul (Chief Engineer of Bridges (Goa, Maharashtra, Gujarat, Karnataka)) Mr. Toshiaki Shinozaki, Mr. Anurag Sinha (JICA India office) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of the Survey. (JICA) - Explanation of ICR of the Survey. (JICA Study Team) - The previous target bridges of last survey (Data Collection Survey on Bridge Sector) done in 2014 by JICA were small in scale and it was difficult to apply Japanese ODA Loan. (MORTH) - The contract of National Highway No. 17 has been concluded. (MORTH) - Bolim Bridge (Goa State) is now under repair and expected as a target bridge. (MORTH) - The new bridge has been constructed at Goa State by the State Government. (MORTH)

3) Meeting with MORTH on 5th April

Date	5th April, 2016
Place	Ministry of Road Transport and Highways (MORTH), Noida
Attendees	Mr. Sanjay K. Nirmal (Chief Engineer) Mr. Toshiaki Shinozaki (JICA India office) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of the Survey. (JICA) - Explanation of ICR of the Survey. (JICA Study Team) - The bridge managed by MORTH in whole of India will be surveyed by the local consulting company and it started in June. It will take 3 - 4 months to collect preliminary data and make a priority list (It will take about 3 years to finalize all of the data). Therefore the list of damaged bridges won't be shared until completion of this survey. (MORTH) - Request to share the priority list when it's completed. (JICA Study Team)

➢ Second Field Survey

1) Meeting with MORTH on 16th June

Date	16th June, 2016
Place	Ministry of Road Transport and Highways (MORTH) Kolkata office, Kolkata
Attendees	Mr. Vevek Jaiswal (Superintending Engineer) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - Request the survey of damaged bridges along a National Highway No.34 near international airport. (MORTH) - There is a plan to construct the flyover along National Highway No. 34 to solve traffic congestion. The Feasibility Study is carried out by local consultant. In addition, there is a plan to construct flyover at the intersection of National Highway No. 34 and No.35. The surveys of these plans are expected. (MORTH) - In case of these plans will be target of the survey after implementation of the visual inspection, request cooperation from MORTH. (JICA Study Team)

➢ **Third Field Survey**

1) Meeting with MORTH on 19th August

Date	19th August, 2016
Place	Ministry of Road Transport and Highways (MORTH), Delhi
Attendees	Mr. B.K. Sinha (Chief Engineer) Tomoyuki Konishi, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- Discussion on the construction plan of Koshi River Bridge in Bihar State. (JICA Study Team) - The Koshi River Bridge is missing link for surrounding road network and is requested to complete construction soon. Therefore, the local consultant has started to prepare the Detailed Project Report of this project. (MORTH) - The construction of new Mahatma Gandhi Bridge is considered. The implementation of the survey is requested to JICA. (MORTH) - JICA Study Team agrees carrying out the survey for new Mahatma Gandhi Bridge on Ganges River. (JICA Study Team)

2) Meeting with MORTH on 30th August

Date	30th August, 2016
Place	Ministry of Road Transport and Highways (MORTH), Noida
Attendees	Mr. V. L. Patankar (Director) Mr. Sanjay K. Nirmal (Chief Engineer) Mr. Anurag Shinha (JICA India office) Tomoyuki Konishi, Koichiro Oharu, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- The Feasibility Study of the new Mahatma Gandhi Bridge has been started under MORTH budget. Local Consultant Company is preparing the Draft Final Report. The current progress is as follows. (MORTH) ・The topography survey has started. ・It is temporarily decided that the new alignment will be at 35m upstream side of existing Mahatma Gandhi Bridge. Based on topography survey result, alignment will be reviewed. ・The structure of bridge is under consideration. The carriageway will be 4 lanes and span length of bridge will be 240m. - Explanation on proposed structure of the new Mahatma Gandhi Bridge, and discussion about future support by Japanese Government. (JICA Study Team)

2.1.2 Ministry of Railways (MOR)

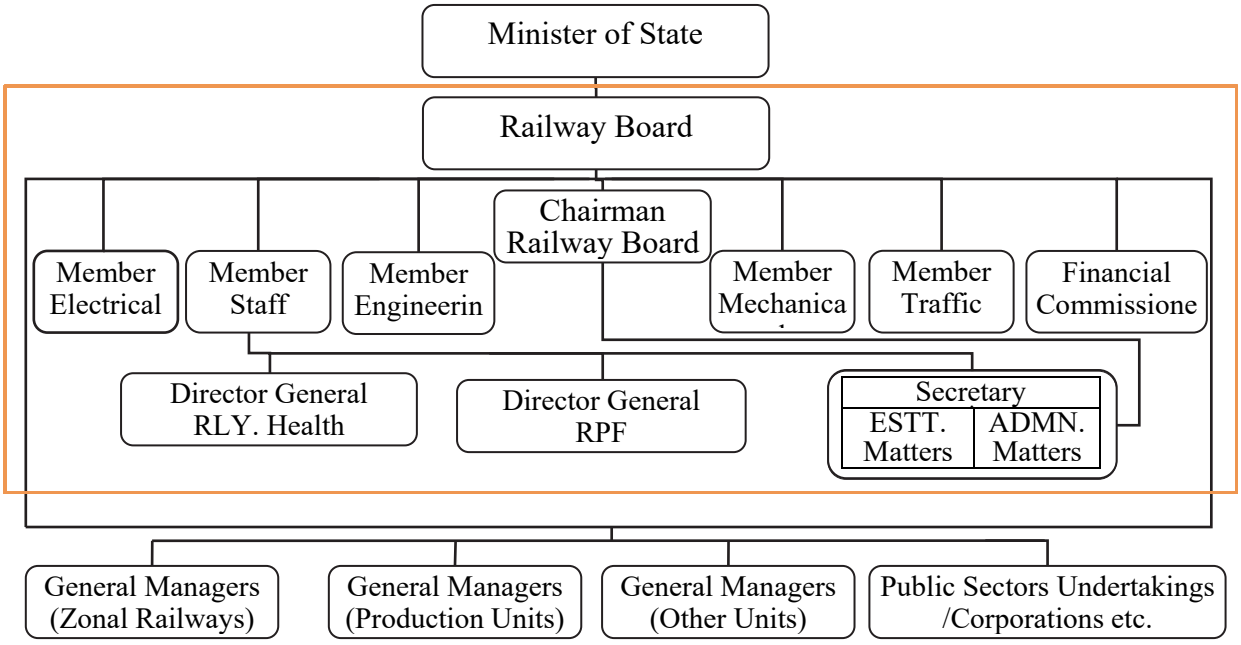
(1) Outline of Organization

The Ministry of Railways is responsible for the country's rail transport. Operation of railway is carried out by Indian Railways which is managed by MOR. Indian Railways operates and maintains about 60,000 km of railway and about 19,000 trains each day, comprising about 12,000 passenger trains and about 7,000 freight trains.

The Ministry of Railways has the following nine undertakings:

1. Rail India Technical & Economic Services Limited (RITES)
2. Indian Railway Construction International Limited (IRCON)
3. Indian Railway Finance Corporation Limited (IRFC)

4. Container Corporation of India Limited (CONCOR)
5. Konkan Railway Corporation Limited (KRCL)
6. Indian Railway Catering & Tourism Corporation Ltd (IRCTC)
7. Railtel Corporation of India Ltd. (Rail Tel)
8. Mumbai Rail Vikas Nigam Ltd. (MRVNL)
9. Rail Vikas Nigam Ltd. (RVNL)



Source: MOR

Figure 2.1.2 Organization Chart of MOR

Indian Railway manages 17 zones as follows.

Table 2.1.5 List of Zones and its divisions

No.	Name of Railway Zone	Zone Headquarters	Railway Divisions (Name of Cities)
1	Northern Railway	Delhi	Delhi, Ambala, Firozpur, Lucknow NR, Moradabad
2	North Eastern Railway	Gorakhpur	Izzatnagar, Lucknow NER, Varanasi
3	Northeast Frontier Railway	Guwahati	Alipurduar, Katihar, Rangiya, Lumding, Tinsukia
4	Eastern Railway	Kolkata	Howrah, Sealdah, Asansol, Malda
5	South Eastern Railway	Kolkata	Adra, Chakradharpur, Kharagpur, Ranchi
6	South Central Railway	Secunderabad	Secunderabad, Hyderabad, Vijayawada, Guntakal, Guntur, Nanded
7	Southern Railway	Chennai	Chennai, Tiruchirappalli, Madurai, Palakkad, Salem, Thiruvananthapuram
8	Central Railway	Mumbai	Mumbai, Bhusawal, Pune, Solapur, Nagpur
9	Western Railway	Mumbai	Mumbai WR, Ratlam, Ahmedabad, Rajkot, Bhavnagar,Vadodara
10	South Western Railway	Hubballi	Hubballi, Bengineeraluru, Mysuru
11	North Western Railway	Jaipur	Jaipur, Ajmer, Bikaner, Jodhpur

No.	Name of Railway Zone	Zone Headquarters	Railway Divisions (Name of Cities)
12	West Central Railway	Jabalpur	Jabalpur, Bhopal, Kota
13	North Central Railway	Allahabad	Allahabad, Agra, Jhansi
14	South East Central Railway	Bilaspur	Bilaspur, Raipur, Nagpur SEC
15	East Coast Railway	Bhubaneswar	Khurda Road, Sambalpur, Waltair
16	East Central Railway	Hajipur	Danapur, Dhanbad, Mughalsarai, Samastipur, Sonpur
17	Konkan Railway	CBD Belapur, Navi Mumbai	Karwar, Ratnagiri

Source: MOR

(2) Outline of Meeting with MOR

The outline of the meeting is listed as follows. The main purpose of this meeting is to introduce Japanese advanced technologies for repair and reinforcement of Railway Bridge/Road over Bridges and select the target bridges which are able to apply those technologies. The meetings were held totally 6 times during the Survey.

- **First Field Survey**

1) Meeting with MOR on 1st April

Date	1st April, 2016
Place	Ministry of Railways (MOR), Delhi
Attendees	Mr. Manoj Kumar Srivastava (Executive Director Perspective Planning) Mr. Sanjay Kumar Srivastava (Executive Director Civil Engineering) Mr. S. C. Jain (Executive Director) Mr. Toshiaki Shinozaki, Mr. Sanjeev Meholkar (JICA India Office) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of the Survey. (JICA) - Explanation of ICR of the Survey. (JICA Study Team) - The bridge management section is divided into 2 sections (Railway Bridge Section, Road Over Bridge Section). (MOR) - It is necessary to repair the bridge between Delhi and Kolkata, since it is old and damaged. (MOR) - Due to increment of axle load to 25t, capacity of the railway bridge is being surveyed. The survey result will be finalized in one month. (MOR) - Reconstruction of the Railway Bridge shall be carried out by construction method can minimize influence to railway service. (MOR) - There is a bridge in Kashmir which is expected to resolve the problems such as exposure of foundation. (MOR) - The railway route between Delhi and Mumbai (1,400km) is managed by 3 divisions (Northern Railway, Western Railway and North Western Railway). (MOR) - Information of in-charged persons about the bridges in Kashmir and the bridges between Delhi and Mumbai is given as follows; ・Kashmir：Mr. M.K. Gupta, ・Delhi to Mumbai：Mr. Kalra (Western Railway) and Mr. Swamy (North Western railway) - MOR has to intension to apply Japanese advanced technology to ROB and ROU if this technology can reduce influence to surrounding environmental during construction and is low cost. (MOR)

2) Meeting with North Western Railway on 6th April

Date	6th April, 2016
Place	North Western Railway (NWR), Jaipur
Attendees	Mr. Kalra (Chief Engineer) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - The railway between Delhi and Mumbai is divided in following sections. (NWR) ・Rewari - Jaipur (about 200km) ・Jaipur - Ajmer ・Ajmer - Marwar JV – Palanpur JP (about 350km) - The repair works of bridges in the above sections have completed in these 20 years. The repair works on substructure and replacing of superstructure have been implemented. (NWR) - There are several arch bridges with masonry structure which was built almost 100 years ago in Ajmer – Palanpur JP Section. For these bridges, evaluation method for soundness is unclear, therefore repair work has not been carried out yet. (NWR) - It is requested to change the limitation of axle load to 25t. However, even though 23t of the train is running now, malfunction is not occurred. Therefore, it is considered that change of axle load to 25t has no problem. (NWR) - Regarding to Road over Bridge (ROB), the construction failure happened at one bridge. However, there is no damage confirmed for other bridges. (NWR)

3) Meeting with Central Railway on 7th April

Date	7th April, 2016
Place	Central Railway (CR), Mumbai
Attendees	Mr. Ramesh C. Thakur (Chief Bridge Engineer) Tomoyuki Konishi, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey (JICA Study Team) - All of the area of Maharashtra State is under management by the Central Railway. (CR) - It is difficult to share the information without an official instruction from MOR (CR) - The damaged bridges have been repaired and there is no bridges needed further repair. (CR)

4) Meeting with Western Railway on 7th April

Date	7th April, 2016
Place	Western Railway (WR), Mumbai
Attendees	Mr. J. P. Verma (Chief Bridge Engineer) Mr. A. K. Dy (Deputy Bridge Engineer) Tatsuo Mukoyama, Koichiro Oharu (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - There are cracks in the railway bridges, and repairs are planned. The assessment is required on the permanent repair at 2 bridges in the Ratlam section. (WR) - There are bridges need to be repaired in the Mumbai section and Vadodara section. Especially, there are 6 bridges in the Mumbai section which was constructed more than 100 years. (WR) - The list of bridges which need to repair, reconstruct or carry out the investigation is submitted to JICA Study Team. (WR) - WR and JICA Study Team agreed to carry out filed survey based on above mentioned list. (JICA Study Team)

➢ Second Field Survey

1) Meeting with MOR on 24th May

Date	24h May, 2016
Place	Ministry of Railway (MOR), Delhi
Attendees	Mr. S. C. Jain (Executive Director/Chief Engineer) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg (JICA Study Team)
Points of Discussion	- The information given from Western Railway was explained. (JICA Study Team) - Approval for execution of field survey (visual inspection) was requested. (JICA Study Team) - Commencement of field survey (visual inspection) was agreed. (MOR)

2) Meeting with Western Railway on 6th June

Date	6h June, 2016
Place	Western Railway (WR), Mumbai
Attendees	Mr. K. C. Swami (Chief Bridge Engineer) Mr. Meena (Divisional Engineer) Tomoyuki Konishi, Koichiro Oharu, Koji Kawamata, Toshinao Yamaguchi, Eiji Noguchi, Keiko Kitahara, Gopal Das Garg, Rishi, Pal Nathi, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- Data collection of damaged bridges. (JICA Study Team) - Confirmation of damaged bridge list and acquire the permission of Field Survey (Visual Investigation) for damaged bridges. (JICA Study Team)

➢ Third Field Survey

1) Meeting with MOR on 17th August

Date	17h August, 2016
Place	Ministry of Railway (MOR), Delhi
Attendees	Mr. A K Singhal (Executive Director (B&S)) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg, Punit Lal Mahto, Rishi Pal Nathi (JICA Study Team)
Points of Discussion	- Report about visual inspection based on the damaged bridge list which was given from WR. For the next step, implementation of Non-destructive inspection is proposed. (JICA Study Team) - The permission letter is required to implement the Non-destructive inspection and deliver equipment from Japan. In order to issue the permission letter, it is necessary to receive the official request letter from JICA. (MOR) - JICA Study Team agreed to submit the official request letter from JICA to MOR, so as to support a Non-destructive inspection to be carried out for selected bridges. (JICA Study Team)

2) Meeting with MOR on 26th August

Date	17h August, 2016
Place	Ministry of Railway (MOR), Delhi
Attendees	Mr. A K Singhal, Executive Director (B&S) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- After the meeting on 17th August, JICA Study Team submitted the official request letter from JICA, and continues to request MOR to issue the permission letter to WR. However the letter was unavailable from MOR, so JICA Study Team has requested it again. (JICA Study Team) - To grant the permission letter, the international commitment is necessary. (MOR)

※More detailed about the process of permission letter regarding to Non-destructive inspection is written in Chapter 5.

2.1.3 Ministry of Urban Development (MOUD)

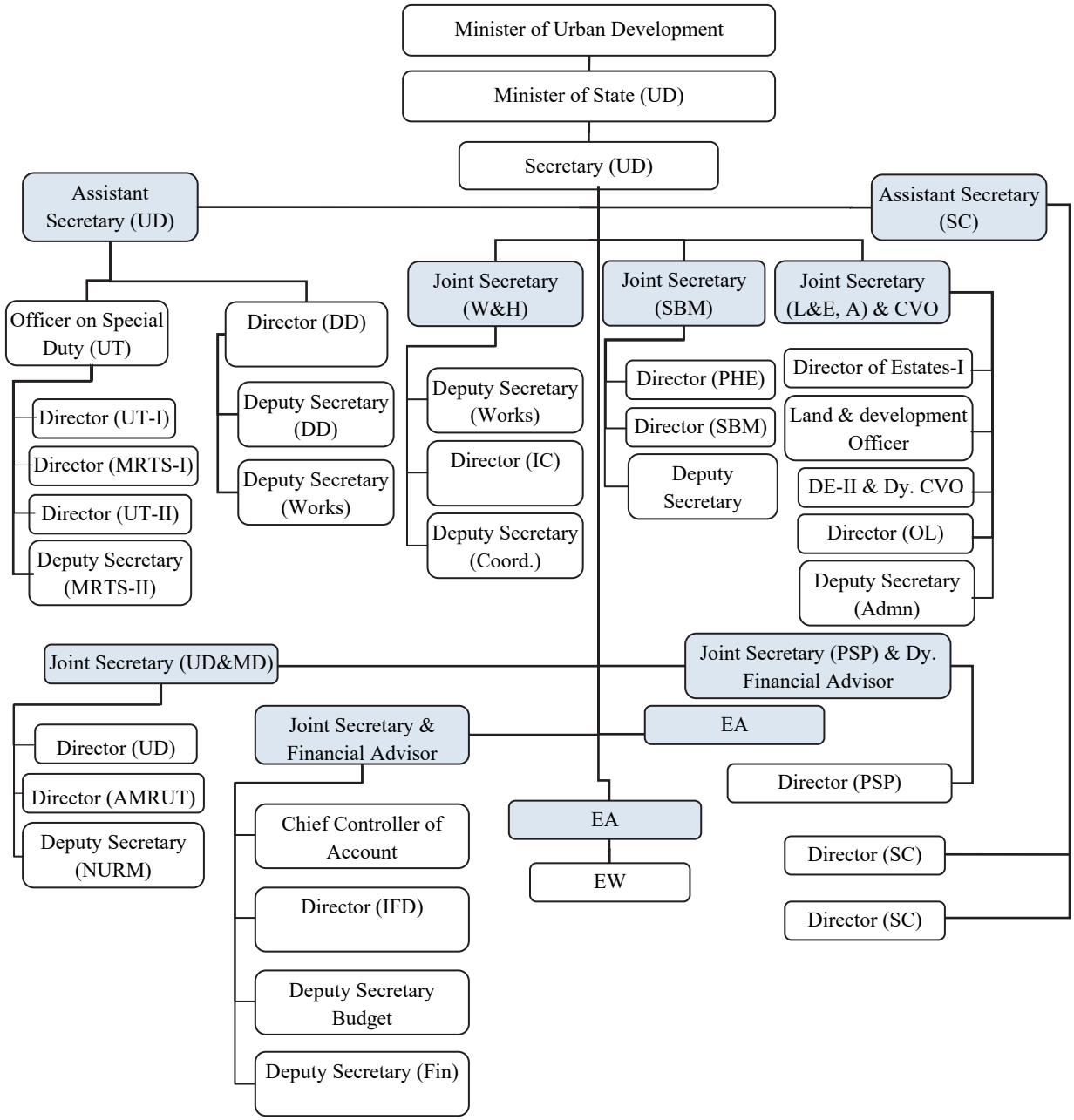
(1) Outline of Organization

The Ministry of Urban Development (MOUD) is responsible for the National level to formulate policies, decide the sponsor and support programs, and coordinate the activities of various Central Ministries, State Governments and other nodal Authorities. It also monitors the programs concerning all the issues of urban development in the country.

Main businesses allocated for the Ministry of Urban Development are as follows;

1. All Government Civil Works and Buildings including those of Union territories excluding Roads and works executed by or buildings belonging to the Ministry of Railways, Department of Posts, Department of Telecommunications, Department of Atomic Energy and the Department of Space.
2. Planning and coordination of urban transport systems with technical planning of rail based systems an also being subject to work allocated from the Ministry of Railways, Railway Board.
3. Planning and coordination for water supply, sewage, drainage and sanitation related to urban areas, linkages from allocated water resources, International cooperation and technical assistance.

The organization chart of MOUD is shown in Figure 2.1.3.



Source: MOUD

Figure 2.1.3 Organization Chart of MOUD

(2) Outline of Meeting with MOUD

The outline of the meeting is shown as follows. The main purpose of this meeting is to request the support to implement the Survey in each target states.

➢ **First Field Survey**

1) Meeting with MOUD on 5th April

Date	5th April, 2016
Place	Ministry of Urban Development (MOUD), Delhi
Attendees	Mr. Mukund Kumar Sinha (Executive Director Civil Engineering (B&S)) Mr. RK Singh (Director (UT)) Mr. Toshiaki Shinozaki (JICA India office) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of the Survey (JICA) - Explanation of ICR of the Survey. (JICA Study Team) - Request for support for data collection of candidate viaduct in urban areas. (JICA Study Team) - The list of flyovers in urban areas and the contact details of Public Works Department officers in each state government will be given in an email. (MOUD)

2.1.4 State Government

India has three Governments levels: the Central, the States and the Union Territories. The State Governments are the level of government below the central government. There are 29 State Governments in India, each of which is headed by the Governor and the Chief Minister.

(1) Roles and responsibilities of State Government

States Government have jurisdiction over education, agriculture, public health, sanitation and infrastructures development borne by many other departments. Major roles are as follows,

- Education: Providing a public education system, maintaining school buildings and colleges, employment of teachers.
- Agriculture: Provide support for farmers, funds for best farming practices, disease prevention and aid during disasters such as floods or droughts.
- Finances: Handles the financial powers of the state, such as all expenditure, taxation and loans by the State Government. It has controlled over taxes on entertainment, wealth, and sales tax.
- Transport: Runs the rails, trams, bus and ferry services and other public transportation in the cities and towns of the states.
- Water supply: Water supply to cities and towns for drinking, including irrigation for farmers

(2) State Owned and Public Private Companies

In India, state Owned and Public Private Companies are established in order to implement the public policy. Such Public Private Companies are playing a major role in planning, designing, construction and maintenance of Infrastructure Projects under monitoring by State Government. Some of the companies play a role as a technical advisor of the State Government for all development activities.

(3) Outline of Meeting with State Government

The target cities of the Survey are Delhi, Mumbai (Maharashtra State), Bangalore (Karnataka state), Ahmedabad (Gujarat State), Kolkata (West Bengal State) and Chennai (Tamil Nadu State). The purpose of meeting with each state (city) is to collect the information regarding road development plan and transportation plan. The aim is to explore the possibility of Japanese advanced technologies application on flyover in urban area. The outline of the meeting is shown as follows.

- **First Field Survey**

✧ **Maharashtra State**

1) Meeting with Maharashtra State Public Works Department on 7th April

Date	7th April, 2016
Place	Maharashtra State Public Works Department (PWD), Mumbai
Attendees	Mr. S. B. Tamsekar (Secretary) Tatsuo Mukoyama, Koichiro Oharu (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - The construction of flyovers and viaducts has started since 1990 and it's being operated in 55 places at the present. However, due to difficulty of land acquisition, there is no plan to construct new flyovers or viaducts now. (PWD) - In order to solve the congestion in the urban areas, it is planned to construct the Metrorail or Monorail. (PWD) - It is planned to construct the Coastal Road. However the plan is still in a primary stage. In addition, difficulty in land acquisition is expected; therefore it is considered the construction will be difficult. (PWD) - There are 2 roads which are the "Western Express Highway" leading to Ahmedabad and "Eastern Express Highway" leading to Delhi. (PWD)

✧ **Gujarat State**

1) Meeting with Ahmedabad Urban Development Authority on 12th April

Date	12th April, 2016
Place	Headquarter of Ahmadabad Urban Development Authority (AUDA), Ahmedabad
Attendees	Mr. S. B. Tamsekar (Secretary) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - There is a plan to improve 19 congested intersections inside the Ahmedabad city. First of all, improvement work will be carried out to 2 - 3 intersections which have high priority. (AUDA) - The Feasibility Study is being conducted to consider the priority order and improvement method. The information of target intersections is not able to be disclosed before finalizing the Feasibility Study. (AUDA) - There is a possibility to apply the Japanese technologies, only if the construction is implemented by low-cost. (AUDA)

2) Meeting with Gujarat State Public Works Department on 12th April

Date	12th April, 2016
Place	Gujarat State Public Works Department (PWD), Ahmedabad
Attendees	Mr. S. B. Vasana (Chief Engineer (R&B)/Additional Secretary) Mr. S. K. Patel (Superintending Engineer) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - There are no bridges which need to be repaired or replaced in Ahmedabad city or suburb area. (PWD) - There are new construction plans for 2 bridges. One is the Dwarka Bridge (length of bridge is 2km) which is an oversea bridge to connect to a small Island, and the other one is Narwada River Bridge (length of bridge is 1.2km) in the eastern area. Both of these are under Pre-Feasibility Study. (PWD) - There is the plan to construct flyover to improve level crossings to grade separation in 90 locations which are maintained by Western Railway. (PWD)

✧ Karnataka State

1) Meeting with Karnataka Road Development Corporation on 13th April

Date	13th April, 2016
Place	Karnataka Road Development Corporation (KRDC), Bangalore
Attendees	Mr. K. S. Krishna Reddy (Managing Director) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - 9 roads run to suburb areas radially from Bangalore city. Viaduct is applied to NH-7, AH-45 and AH-47. It is planned to construct 6 new viaducts which are connected to the above 9 roads. (KRDC) - The Pre-Feasibility Study is conducted before a Feasibility Study to calculate the construction cost, structure type and priority order. (KRDC) - JICA study team made an agreement to cooperate with the local consultants which are conducting the Pre-Feasibility Study in some parts to propose a plan using Japanese advanced technology. (JICA Study Team)

✧ Delhi

1) Meeting with Delhi Public Works Department on 14th April

Date	14th April, 2016
Place	Delhi Public Works Department (PWD), Delhi
Attendees	Mr. S. K. Srivastava (Engineer-in-Chief/Principal Secretary) Mr. M. Amitabh (Chief Project Manager (Housing)) Tomoyuki Konishi, Tatsuo Mukoyama, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - There is a plan to construct a new flyover on the East-West Corridor (pass through Delhi East to West) and South-North Corridor (pass through Delhi South to North and leading to the airport). (PWD) - JICA study team made agreement to propose a plan using Japanese advanced technologies on some part of this plan. (JICA Study Team)

➢ Second Field Survey

✧ Karnataka State

1) Meeting with Local Consultant on 31st May

Date	31th May, 2016
Place	Local Consultant (LC), Bangalore
Attendees	Mr.Rathnakara Reddy (Managing Director) Tomoyuki Konishi, Koichiro Oharu, Eiji Noguchi, Keiko Kitahara, Gopal Das Garg, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- Explanation of project outline of viaduct construction proposed by Local Consultants. (LC) - Traffic survey will be conducted in May. (LC) - It is agreed to carry out field survey for East-West Corridor and North-South Corridor and propose applicable Japanese advanced technologies based on field survey result. (JICA Study Team and LC)

✧ Delhi

1) Meeting with Delhi Public Works Department on 2nd June and 3rd June

Date	2nd June and 3rd June
Place	Delhi Public Works Department (PWD), Delhi
Attendees	Mr. Deepak Gupta (Chief Engineer) Tomoyuki Konishi, Koichiro Oharu, Eiji Noguchi, Keiko Kitahara, Gopal Das Garg, Punit Lal Mahto (JICA Study Team)
Points of Discussion	- Explanation of project outline of proposed corridors in Delhi (PWD) - Data collection of Delhi viaduct project plan. Explanation of applicable Japanese advanced technologies. (JICA Study Team and PWD) - Execution Field Survey of proposed area in Delhi. (JICA Study Team and PWD)

✧ Tamil Nadu State

1) Meeting with Tamil Nadu Road Development Company on 26th May

Date	14th April, 2016
Place	Tamil Nadu Road Development Company (TNDC), Chennai
Attendees	Mr. Y. R. Balaji (Chief General Manager) Tomoyuki Konishi, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - There is a project to construct viaduct along the IT corridor. DPR is under preparation and it will be submitted to State Government in August. Basically it is planned to construct with state budget. (TNRDC) - The advantage of proposed Japanese advanced technologies is understood by TNRDC. However DPR has already been under preparation, so if it is proposed before submission of DPR to State Government, it can be considered to be applied. (TNRDC)

2) Meeting with Greater Chennai Corporation on 20th June

Date	20th June, 2016
Place	Greater Chennai Corporation (GCC), Chennai
Attendees	Mr. Cnandramohan (Commissioner) Mr. K. S. Kandasamy (Deputy Commissioner) Tomoyuki Konishi, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)

Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - The project of flyover is under consideration for the southern area. (GCC) - For this project, there is a possibility to apply the Japanese advanced technologies, only if the advantage is confirmed. However due to no detail comparison between conventional technology and Japanese advanced technology, the advantage of Japanese advanced technology cannot be confirmed for now. Therefore, It is low possibility to apply in a jurisdiction of GCC. (GCC)

3) Meeting with Tamil Nadu State Highways & Minor Ports Department on 20th June

Date	20th June, 2016
Place	Tamil Nadu State Highways & Minor Ports Department (THM), Chennai
Attendees	Mr. Rajeev Ranjan (Additional Chief Secretary of Highways & Minor Ports Department) Tomoyuki Konishi, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of ICR of the Survey. (JICA Study Team) - The construction of viaduct is considered in southern area where traffic congestion is occurred frequently. Especially, the viaduct along East-Coast Road and National Highway No.45 is planned and request to study the construction method and suitable structure. (THM)

➢ Third Field Survey

✧ Karnataka State

1) Meeting with Local Consultant on 24th August

Date	24th August, 2016
Place	Local Consultant (LC), Bangalore
Attendees	Mr. Rajasekhara Reddy L. P. (Associate Director (Transportation)) Tomoyuki Konishi, Koichiro Oharu, Keiko Kitahara, Gopal Das Garg (JICA Study Team)
Points of Discussion	- The progress of the Feasibility Study for construction of viaduct is explained as follows and detail discussion is held with JICA Study Team. (JICA Study Team and LC) · The alignments of corridors are almost fixed. (Local Consultant) · The locations of on-off ramps have been fixed. (Local Consultant) · Topographic survey will start by the end of this week (27-Aug). Based on this result, the details of road structures will be adjusted. (Local Consultant) · The traffic demand forecast hasn't been finalized. (Local Consultant) · It is supposed to be done by September but now it was postponed till November. (It might be postponed again.) (Local Consultant) · It is planned to use the BOT scheme for construction of the corridors. (Local Consultant) · Introduce ETC system to charge the fee at the corridors. (Local Consultant) · The cars which use the corridors in Bangalore need to install the ETC machine. (Local Consultant) · The policy of the system is promoted now. (Local Consultant) · There is no government financial support to install the ETC machine. (Local Consultant) · There will be 3.5 years grace period before charging a penalty for the cars which pass the corridors without an ETC system. (Local Consultant) - JICA Study Team will show study results for several items (Rough cost estimation, Construction schedule and Economic Analysis result) for next visit in October. (JICA Study Team)

➢ Forth Field Survey

✧ Delhi

1) Meeting with Delhi Public Works Department on 14th October

Date	14th October, 2016
Place	Delhi Public Works Department (PWD), Delhi
Attendees	Mr. Sarvagya Kr. Srivastava (Engineer-in-Chief/Pr. Secretary) Mr. P. K. Parmar (Chief Project Manager) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of proposed viaduct structure. (JICA Study Team) - Detailed Project Report will be prepared after finalizing the alignments for East-West and North-South Corridors. (PWD) - Application of Japanese ODA Loan is under consideration. Preparation of the Detailed Project Report and the process of ODA Loan scheme will be started concurrently. (PWD)

✧ Tamil Nadu State

1) Meeting with Tamil Nadu State Highways and Minor Ports Department on 17th October

Date	17th October
Place	Tamil Nadu State Highways & Minor Ports Department (THM), Chennai
Attendees	Mr. R. Baskaran (Chief Engineer Metro, Highway & Minor Port Department) Mr. A. Premnaty (Superintendent Engineer) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of proposed viaduct structure along east coast road. (JICA Study Team) - The number of lanes has not been decided yet. It is considered to apply the PC well. However, if the number of lanes is two, the PC superstructure and RC substructure will be applied. (THM) - The proposed cost estimation result is expensive compared to cost applied PC superstructure and RC substructure. However this cost shows highest case. So it is possible to reduce the cost by combining existing technologies with new technologies. (JICA Study Team) - The top priority is to finalize the number of lanes. After that, application of new technologies to viaduct will be considered. (JICA Study Team)

✧ Karnataka State

1) Meeting with Local Consultant on 19th October

Date	19th October, 2016
Place	Local Consultant (LC), Bangalore
Attendees	Mr. B.G.P. Reddy (Associate Director) Tomoyuki Konishi, Koichiro Oharu, Gopal Das Garg (JICA Study Team)
Points of Discussion	- Explanation of proposed viaduct structure in Bangalore. (JICA Study Team) - Interest in new technologies such as PC Well and Rotary Penetration Steel Pile. (LC) - Feasibility Study will be completed in this year and the application of the new technology of this study will be considered in the future. (LC)

2.2 Trend of other Donors in the Road/Railway Bridge Sector

2.2.1 World Bank

(1) Assistance Policy of Aid in India

World Bank (WB) assistance in India started in 1948. WB assistance programs are guided by a Country Partnership Strategy (CPS), which sets out how the World Bank Group proposes to build a growing partnership with the Government of India. A key feature of 2013-2017 CPS is the significant shift in support toward low-income and special category states such as Arunachal Pradesh, Himachal Pradesh, Manipur, Meghalaya, Mizoram, Sikkim, Tripura and Uttarakhand, where many of India's poor and disadvantaged live. This proposal is for a lending program of US$3 billion to US$5 billion each year over the period of 2013 to 2017. Sixty percent of the financing is going to State Government-backed projects. Half of this, or 30% of total lending, is going to low-income or special category states, up from 18% of lending under the previous strategy.

WB support in the transport sector is focused on the reform and development of railways, highways and rural roads, intermodal transport, inland waterways, and on improving road safety. WB projects aim to improve transportation connectivity by upgrading and maintaining 7,000km of state highways and significantly increasing rail transport capacity on the eastern freight corridor.

(2) Outline of Projects in India

Main transport sector projects approved by WB in recent years are as follows,

Table 2.2.1 List of the projects in India (World Bank)

No.	Project Name	Project Cost
1	Eastern Dedicated Freight Corridor II (Kanpur – Mughal Sarai section)	US$ 1650.00 million
2	Eastern Dedicated Freight Corridor III (Ludhiana – Khurja section)	US$ 1107.00 million
3	Efficient & Sustainable City Bus Services	US$ 113.00 million
4	India Second Kerala State Transport Project	US$ 445.00 million
5	Mizoram State Roads II Regional Transport Connectivity Project	US$ 107.00 million
6	National Highways Interconnectivity Improvement Project	US$ 1146.05 million
7	Second Gujarat State Highway Project (GSHP II)	US$ 323.00 million
8	Second Tamil Nadu Road Sector Project	US$ 778.20 million
9	Bihar Rural Roads Project	US$ 335.00 million
10	Assam Inland Water Transport Project	US$ 150.00 million
11	Madhya Pradesh Rural Connectivity project	US$ 500.00 million

Source: JICA Study Team

2.2.2 Asia Development Bank

(1) Assistance Policy

Asia Development Bank (ADB) commenced operations in India in 1986 and has approved a total US$37.3 billion, including grant and sovereign and non-sovereign loans and technical assistance including co-financing. With the aim to improve regional connectivity and accessibility particularly around lagging states such as Bihar, Madhya Pradesh, Rajasthan, Uttar Pradesh etc., ADB is promoting safe and environmental friendly transport programs, to develop the various modes of transport in an integrated and sustainable manner, ADB already lent the cumulative amount of US$12 Billion to develop the transport sector of India.

The goal of ADB transport sector support under the country partnership strategy 2013-2017 is to increase the movement of people and goods in a more efficient, safe and sustainable manner. To achieve this, main outputs expected from ADB interventions are as follows,

1. 4,700km of state road improvements with pedestrian lanes, crossing points and other safety features, including 150km of sub regional connectivity.
2. 12,300km of rural roads improved to include pedestrian lanes, crossing points and other safety features
3. 840km of railways double-tracked; 640km railway track electrified
4. 3km of metro developed; 3 land customs stations developed with women friendly facilities

(2) Outline of Project in India

Main transport sector projects approved and proposed by the ADB in recent years are as follows,

Table 2.2.2 List of projects in India (Asia Development Bank)

No.	Project Name	Capital
1	Second Jharkhand State Road Project	US$ 200.00 million
2	Accelerating Infrastructure Investment Facility in India - Tranche 2	US$ 300.00 million
3	Uttar Pradesh Major District Roads Improvement Project	US$ 300.00 million
4	Bihar New Mahatma Gandhi Bridge Project	US$ 500.00 million
5	Karnataka State Highways Improvement III Project	US$ 350.00 million
6	Madhya Pradesh District Roads II Sector Project	US$ 350.00 million
7	Railway Sector Investment Program - Tranche 3	US$ 150.00 million
8	Rajasthan State Highway Investment Program	US$ 500.00 million
9	Rajasthan State Highway Investment Program - Tranche 1	US$ 220.00 million
10	Second Rural Connectivity Investment Program	US$ 500.00 million

Source: JICA Study Team

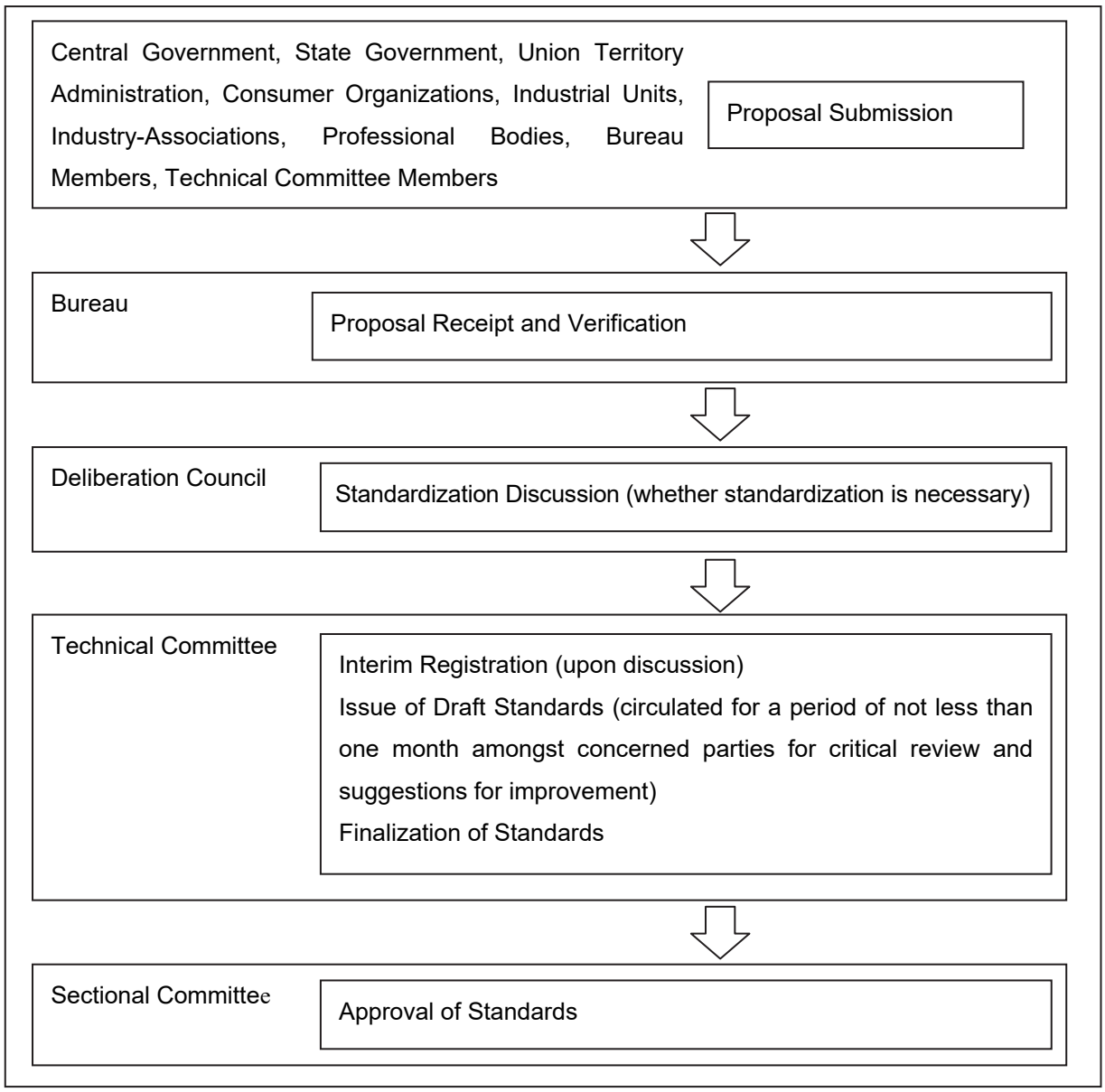
2.3 Issues with the Introduction of Japanese Advanced Technology for Bridge Construction and Repair/Rehabilitation

During the survey, the following issues appear in order to apply to the Japanese advanced technologies in India.

2.3.1 Standards in India

In India, it is required to be certified by the Indian Standard, developed by the Bureau of Indian Standards (BIS), in order to introduce Japanese advanced technology use new material, such as high-strength and module Fiber Carbon Reinforced Plate.

The certification by the BIS usually takes approximately 6 to 10 years, but this can be shortened when it is judged and agreed that an introduction of new technique/material has a big advantage. The general process of acquiring certification is shown in the Figure 2.3.1.



Source: JICA Study Team

Figure 2.3.1 Process of BIS Certification

It generally takes a great deal of time from the submission of a proposal until the commencement of deliberation by the Technical Committee. If the BIS and each ministry come to a mutual agreement, the processing time can be shortened.

In order to apply the Japanese technology to JICA ODA loan project without acquisition of BIS Certification, it is possible if it obtains the certificate from a competent authority. For example, if the permission from MORTH is required, it requires following the steps of procedure to Central Road Research Institute (CRRI) or Indian Road Congress (IRC) as same the steps of procedure as BIS, then, it is possible to acquire certificate it in a few years.

2.3.2 Responsibility of the Contractor by Design Build Scheme

In India, construction work by Design Build Scheme (EPC Scheme) is in common. Even in Japan, implementation by Design Build Scheme becomes popular, however, there is not much projects implemented by Design Build Scheme in Japan. There are many large scale projects in India. And, the Contractor considers risks by implementation by Design Build Scheme, especially by differences of geological condition between design stage and construction stage. Therefore, it is consider to support penetration of Indian market by Japanese contractor by establishment contract conditions can avoid risk by the Contractor.

2.3.3 Interest regarding Entry into the Indian Bridge Market

Some of the Japanese construction companies have an interest in entry into the Indian bridge market especially in case of using STEP (Special Terms for Economic Partnership) projects on bilateral cooperation projects.

Some Japanese manufacturing/steel mill companies were showing an interest in entry into the Indian market. However, they have to find construction companies to set up joint-ventures.

Some of the Japanese construction company have an interest in entry into the Indian bridge market. However it is difficult to enter into the market due to the price competition and high risk and high responsibility of general construction method in India. To enter, it is necessary to use the scheme such as STEP or Bilateral Tied Loan which are not disadvantage to Japanese companies.

In addition, the technology of bridge construction by the Major construction companies in India reaches a constant level. The entry of Japanese Company by not only the competition of QCBS but also QBS is a disadvantage. Therefore, due to formulation by Bilateral Tied Loan, it is necessary to consider with limited to Japanese companies.
Japanese steel companies and steel bridge production companies also have an interest in entry into the Indian bridge market. However, in order to entry into the market, cooperation with a god local company to form a joint venture is necessary.

2.4 Local Construction Companies in India

2.4.1 Interviews with Local Construction Companies in India

Some major Indian Construction Companies were interviewed in relation with the following matters;

I. Types of technology for general Bridge repair work
II. Construction method for general construction of flyover/viaduct
III. Construction method for rapid construction of flyover/viaduct

Based on the interviews with Indian Construction Companies, they follow "Guidelines on Techniques for Engineering and Rehabilitation of Bridges" IRC SP40-1993 for the basic technology for the repair work. Especially for the steel bridges, "Guidelines for Repair and Rehabilitation of Steel Bridges" IRC SP74-2007 is used. These guidelines cover common procedures for assessment of distress in bridges, selection of techniques and materials and also approach to remedial measures and formulation of suitable repair plans.

In India, in the case of general superstructure type of a flyover, cast-in-place PC Box girder, PC I-girder and composite structure by both steel and concrete are applied. Regarding to erection method precast much segment method launched by launching girder and tandem lifting method in areas where there is less traffic are applied. For the substructures, bored cast-in situ concrete piles, pile caps, piers and pier caps are being used.

For the rapid construction, PC Box girder used precast segmental and post tensioned PC I-Girder and composite structure by both steel and concrete are applied. Precast segments/girders are fabricated in a casting yard, transported by trailers and erected by mobile cranes or launching girders. In the case of River Bridges, precast segments erected by derrick crane using the balanced cantilever method or full span erection (e.g. U-girder) using cranes are applied. For the substructures, concrete pile, pile cap and pier column prefabricated at casting yard are used.

2.4.2 Interviews with Local Construction Companies in India

(1) Technology of Bridge Repair

In accordance with IRC SP40-1993, the method of repair due to poor construction such as cracks on the concrete surface and material separation is described. In addition, as technology for improving strength, it is specified about the introduction of attaching steel plate and additional prestress force by external cables using PC cable.

These technologies are commonly used in Japan and there are several examples which use these technologies for bridge repair.

In addition, in recent years, bridge repair technology using Carbon Fiber Reinforced Plastic (CFRP) is also applied. This method has been frequently used in Japan also in these days. The technical level of

India is considered as almost same level as Japanese technical level. However, it is noted that application of high-strength and high-module CFPR has not been applied yet in India.

(2) Technology of Rapid Construction

The bridge construction using pre-cast concrete segment is a technology commonly used in whole over of the world, and the technical level in India is considered as high. However, the steel superstructure and the steel pier which can save the construction period at site drastically are almost not applied in urban area (except for some areas). The technologies for rapid construction of bridge using steel members are in the process of development.

3. TARGET BRIDGE/VIADUCT SELECTIONS

3.1 Introduction

Based on interviews at first field survey with relevant organizations, second field survey was carried out.

Site visit to construction site of new viaduct and visual checking against damaged bridge are mainly carried out at second field survey. After this, selection of bridges which require new construction, reconstruction, repair and rehabilitation is made based on study result what kind of advanced technology can be adopted to these bridges in Japan. And, Non-destructive inspection will be carried out against bridges required to repair and rehabilitation work in order to understand level of damages more detail at third field survey. Based on this result, applicable repair and rehabilitation method will be proposed.

The results of the second field survey are shown below.

Based on survey and study result, candidate projects which can demonstrate advantage of Japanese Advanced Technology are summarized in chapter 3.8.
Moreover, proposal of bridge structure and its cost estimation for candidate projects are shown in Chapter 8 to Chapter 11.

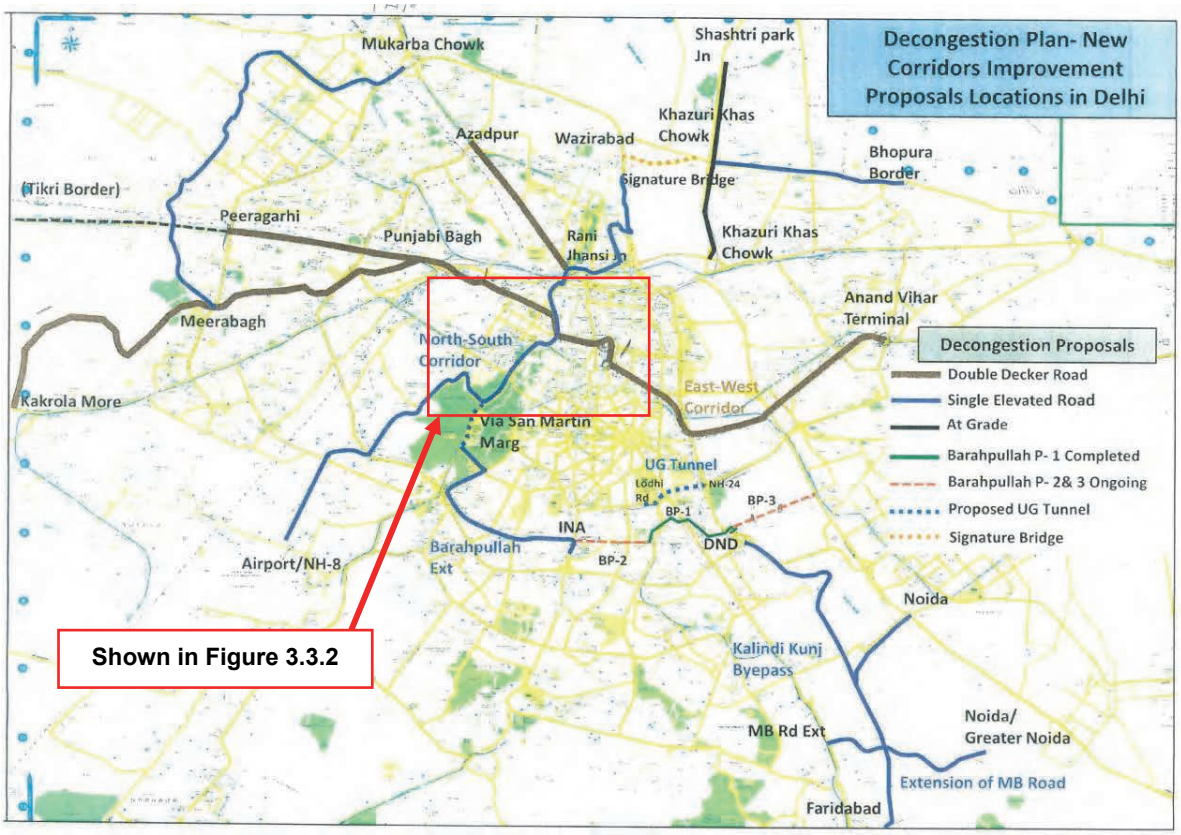
3.2 Viaduct Construction Project in Delhi

3.2.1 General

(1) Description of Project

In order to solve the congested situation inside Delhi city, a decongestion plan that includes construction of viaducts was studied. There are 11 corridors proposed by Delhi Public Works Department (PWD), and the total length of the project is approximately 150km. Most of the project is a viaduct construction project with 4-6 lanes. The overall plan for the Delhi Viaduct Construction Project is shown in Figure 3.2.1, and a list of proposed corridors is shown in Table 3.2.1.

Alignment study for East-West Corridor and North-South Corridor which bear the highest corridors priority which is in current their plan, is carried out under the pre-feasibility study by the Local Consultants. According to Delhi PWD, the alignment study shall conclude within year 2016, and preparation of DPR will be carried out accordingly.



Source: Presentation Document by Delhi PWD

Figure 3.2.1 Overall Plan for Viaduct Construction Project in Delhi

Table 3.2.1 List of Proposed Elevated Corridor

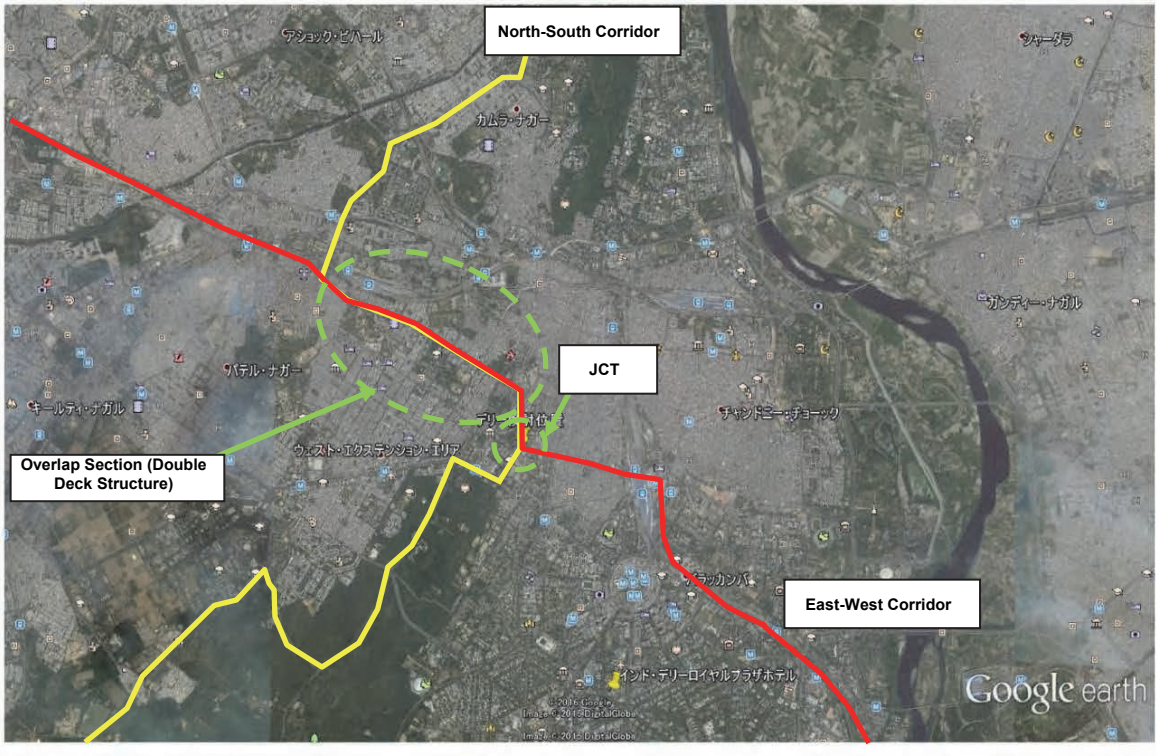
No	Name of Proposed Corridor	Length	No. of Lanes	Type
1	Elevated Road along Najafgarh Nallah	16.4km	-	Elevated
2	Elevated Road along supplementary drain (Nangloi Drain)	16.0km	-	Elevated
3	East-West Corridor	29.0km	6	Elevated
	East-West Corridor Extension	13.0km	6	Elevated
4	North-South Corridor	24.0km	6	Elevated
5	Barahpullah Extension	10.0km	-	Elevated
6	U-G Tunnel	3.0km	-	Tunnel
7	Mehrauli Bdarpur Road Extension	7.0km	-	Elevated
8	Khazuri Khas to Bhopura Border	3.2km	-	Elevated
9	Kalindi Kunj By pass	13.2km	-	Elevated
10	Azadpur to Rani Jhansi Road	6.0km	-	Elevated
11	Marginal Bundh Road	7.5km	-	At Grade

Source: Presentation Document by Delhi PWD

3.2.2 Target Inspection

(1) Target of Inspection

Based on discussions with Delhi Public Works Department (PWD), the North-South Corridor and East-West Corridor listed in Table 3.2.1 will be studied in this study, since these corridors are two of the most important corridors in their plan. Detailed routes of both the North-South Corridor and East–West Corridor are shown in Figure 3.2.2.

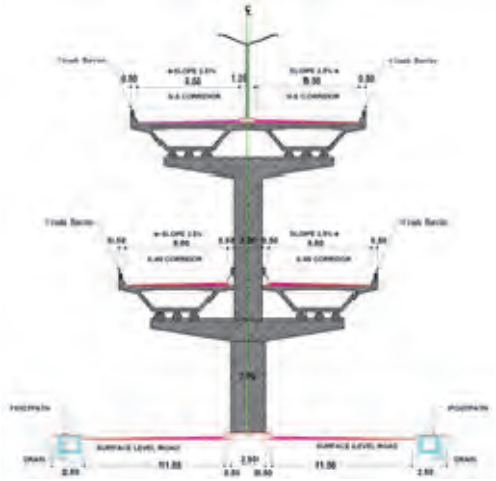


Source: JICA Study Team

Figure 3.2.2 Plan View of North-South Corridor and East-West Corridor

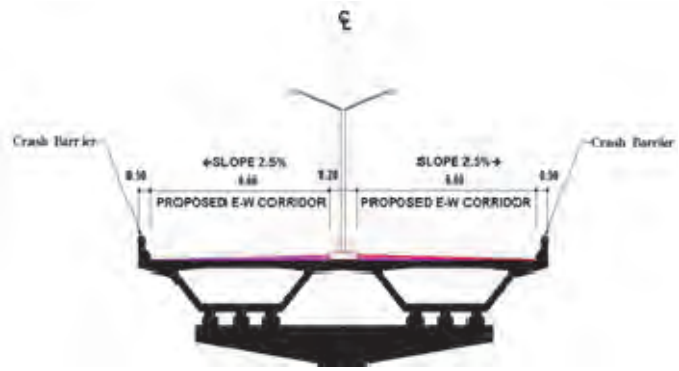
As shown in Figure 3.2.2, the North-South Corridor and East-West Corridor form a junction at the point where the "JCT" mark is shown. After this point, both corridors run along the same route. Therefore, Delhi PWD is considering constructing a double deck structure as shown in Figure 3.2.3. This kind of structure is very common in Tokyo Metropolitan Expressway. Because experience of planning and designing in Tokyo Metropolitan Expressway will be helpful to study this kind of structure, this overlap section will be studied in this study.

In order to optimize the efficiency of the proposed corridors, Junction structure is one of the most important for this project. In addition, due to restrictions of land, the dual alignment must be studied by engineers with enough experience such as design experience of Tokyo Metropolitan Expressway. Therefore, the dual alignment will also be studied in this study.



Source: Presentation Document by Delhi PWD

Figure 3.2.3 Double Deck Structure



Source: Presentation Document by Delhi PWD

Figure 3.2.4 Typical Cross Section for 6 Lanes Road

(2) Site Appreciation

Site investigation work was carried out on the 3rd and 4th of June, 2016. It was confirmed that both the North-South Corridor and East-West Corridor will pass through very congested areas and most of the section will be along an existing road. In addition, according to current planning, both the North-South Corridor and East-West Corridor will be 6 lanes and there are some sections in which the width of the existing road is narrower than the planned cross section as shown in Figure 3.2.4. Therefore, land acquisition will be necessary in order to construct the viaduct in accordance with their current planning. Land use status at the vicinity of the Junction is shown in Figure 3.2.5.

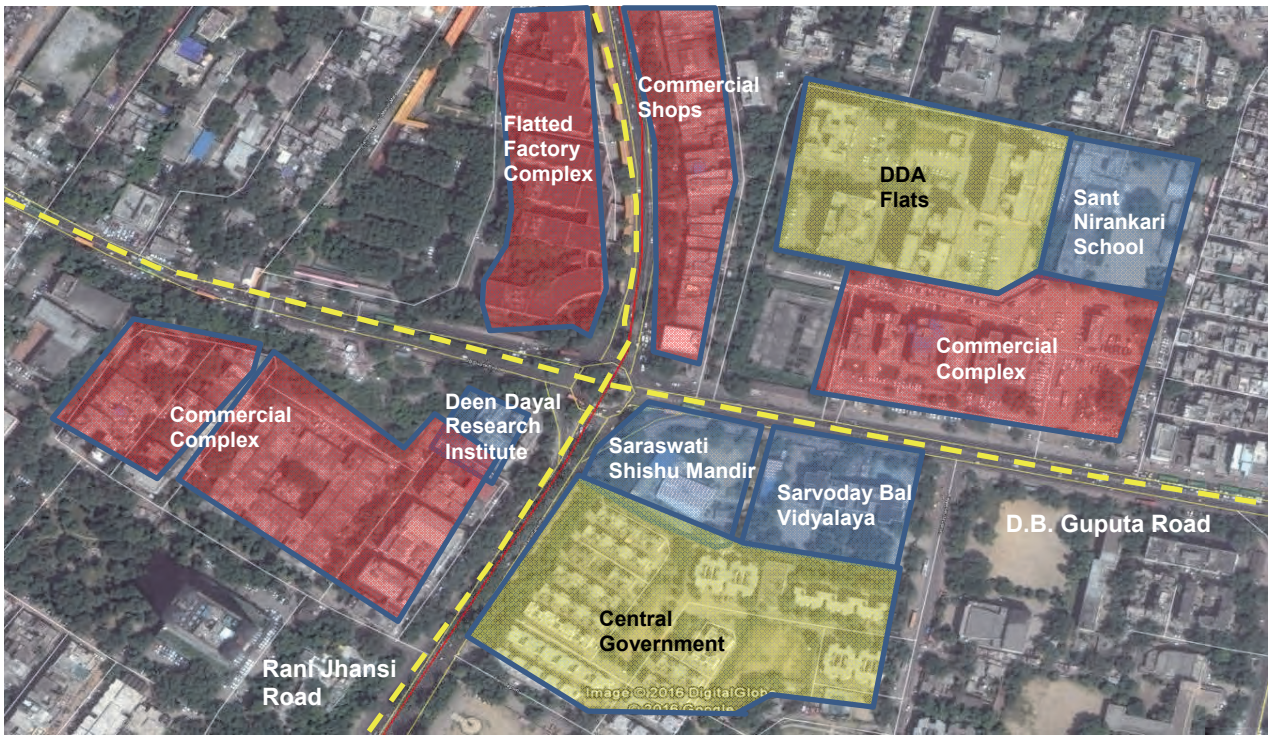
Photo 3.2.1 Current status of Rani Jhansi Road

At the JCT point, there is an existing intersection crossing by D. B. Gupta Road and Rani Jhansi Road. However, the existing road area is not large enough and the surrounding area is occupied by many buildings.


Photo 3.2.2 Existing Condition of Intersection between D. B. Gupta and Rani Jhansi

According to Delhi PWD, since a new Land Acquisition Act was issued in 2013, land acquisition work became very difficult. However, there is an area that belongs to the government. In order to smoothly implement this project, the dual structure is better located within the government area and existing road area.

Current land use situation around the JCT point is shown in Figure 3.2.5.



Note: Red Color: Private Land (Difficult for Land Acquisition)
Blue Color: School Land (Possible for Land Acquisition, but, take long time for procedure)
Yellow Color: Government Land (Possible for Land Acquisition)

Source: JICA Study Team

Figure 3.2.5 Current Land Use Status around JCT Point

3.2.3 Judgement of Validity of Execution for Outline Study

Based on result of site visit, it is confirmed that overlapped section for both North-South Corridor and East-West Corridor locates at very congested area in Delhi. In addition, due to overlapped section for both North-South Corridor and East-West Corridor, it is required to apply very complicated double-deck structure. Double-deck structure is commonly applied at Japan's urban expressway as shown in Photo 3.2.3. The photo revealed that Viaduct is constructed within narrow spaces with minimum land acquisition.

Source: HP of Obayashi Corporation

Photo 3.2.3 Example of Double-deck structure in urban

Moreover, due to the reason that there is a lot of existing traffic, construction using steel structure is opted due to the fact that it can be constructed within very shortly period. This construction method is very common to minimize effect to the existing traffic during construction.

Recently, many construction methods developed by Japanese Contractors enable quick construction at narrow spaces within congested area in cities and whilst minimize the social impact (details are shown in Chapter 6). It is considered that this project can really benefit by applying of Japanese Advanced Technology which enable quick construction at narrow space, since this project also requires the same construction methodology at very congested area inside the city.

Due to the fact that Junction structure for both East-West Corridor and North-South Corridor shall become very complicated structure as shown in Photo 3.2.4, it is very common to apply steel structure into it, since it can minimize various effects to the existing traffic during construction.

Photo 3.2.4 Nishi-shinjuku Junction (Tokyo-metropolitan

Although, there are many steel structures applied in India for ROBs and River bridges by Railway, steel structure is not applied to flyover and viaduct inside city except at some limited area (Steel structure is applied to viaduct in Kolkata since this is constructed by Japanese ODA). On the other hand, Japanese Contractors and Consultants have vast experiences on the construction of complicated junction that minimize the effect to the existing traffic during the construction of expressway inside city area. Hence, the design and construction of complicated junction can be relied on Japanese Advanced Technology and its long years of know-how.

Therefore, it is proposed that the outlined design for this project is to be carried out with structure type which Japanese Advanced Technology can be applied on.

3.3 Viaduct Construction Project in Bangalore

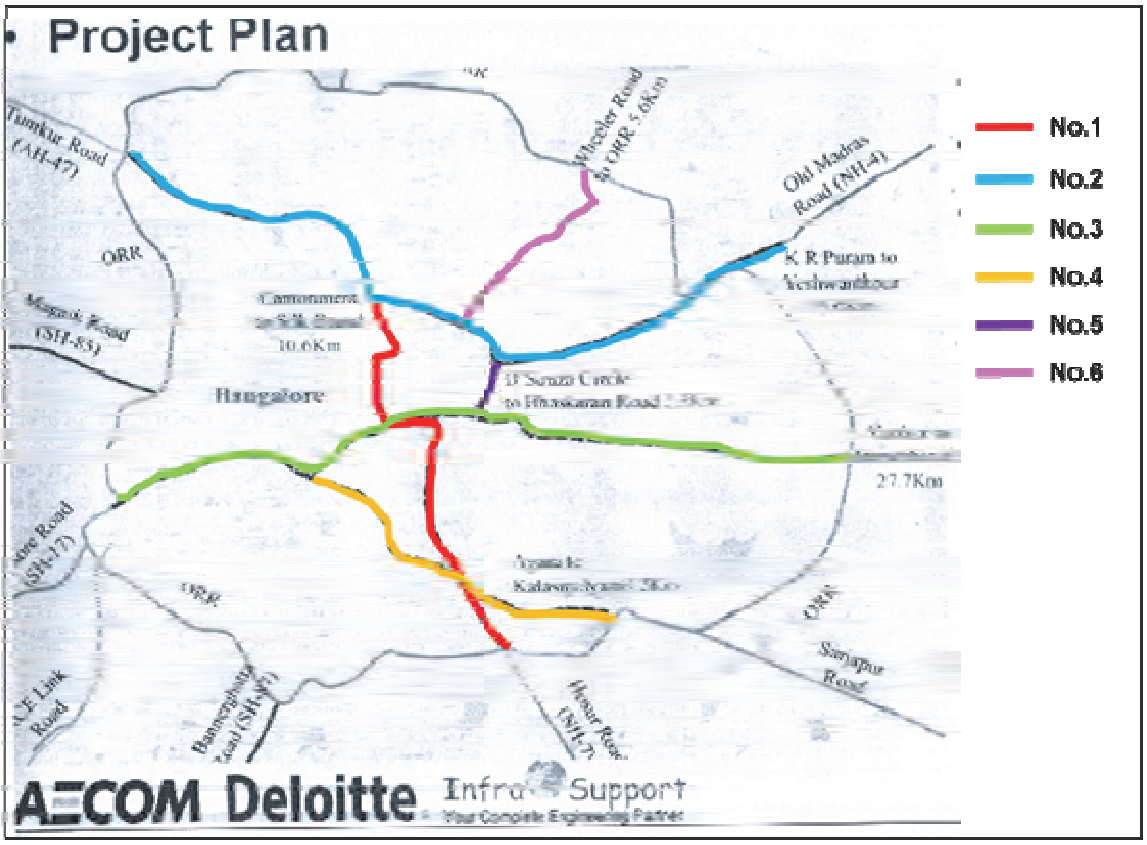
3.3.1 Outline of the Project

(1) Description of Project

The Project is aimed to alleviate congestion and provide unhindered travel along the Proposed Corridor.

The Feasibility Study and Preliminary Engineering Design are carried out by Local Consultant employed by Karnataka Road Development Corporation (KRDC), and scheduled to complete by November 2016. After the completion of this study, detailed design study will be carried out section by section.

The project plan and salient details of the elevated corridors are as follows.



Source: Presentation Document by Local Consultant (Edit by JICA Study Team)

Figure 3.3.1 Overall Plan for Bangalore Viaduct

Table 3.3.1 Salient Details of Proposed Elevated Corridors

No	Name of Proposed Corridor	Length	No. of Lanes	Type
1	North-South Corridor connecting central Silk Board to Cantonment (i.e., NH7 towards Hosur to NH towards Bellary)	10.60km	6	Elevated
2	East-West Corridor-1 connecting K.R.Puram to Gorguntepalya (i.e., NH4 towards old Madras Road and NH4 Bangalore – Pune Road)	19.70km	6	Elevated
3	East-West Corridor-2 connecting SH-17 to SH35 from Jnanagharathi on SH17 to Varthur Kodi on SH35.	27.70km	6	Elevated
4	Connecting Corridor-1; Connecting North-South Corridor & East-West Corridor-2 from Agra to Kalasipalya.	9.20km	4	Elevated
5	Connecting Corridor-2; Connecting East-West Corridor-1 & East-West Corridor-2 from Richmond Road to Ulsoor.	2.30km	4	Elevated
6	Connecting Corridor-3; Connecting Corridor from Kalyan Nagar Junection at Outer Rind Road to St. Johns Church Road and Wheelers Road Junction.	5.70km	4	Elevated

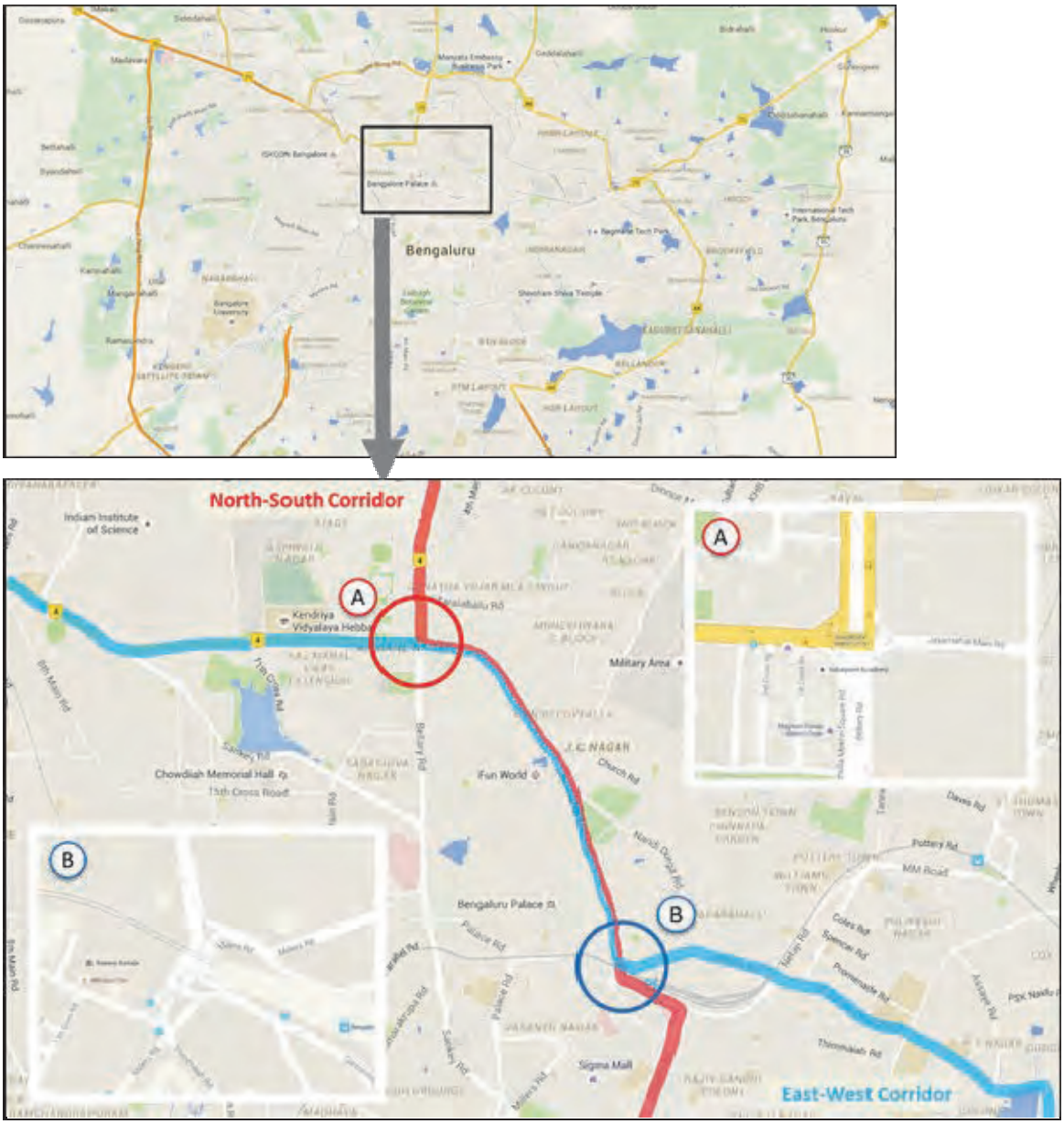
Source: Presentation Document by Local Consultant

3.3.2 Target of Inspection

(1) Target of Inspection

The North-South Corridor and East-West Corridor are the most important corridors of the project. Due to passing both corridors at very congested area, it is considered that Japanese Advanced Technology which can construct rapidly and at narrow space will have advantage. As same as viaduct construction project in Delhi, there is a section where both North-South Corridor and East-West Corridor are overlapped, this section will be studied in this study. Moreover, the junction which has not been inspected by the Indian side adequately will be studied also.

According to discussion result with KRDC at first field survey, it is confirmed KRDC has interest to apply construction method can minimize negative social impact such as rapid construction method and construction method at narrow space inside city area. And, it is requested that proposal from JICA Study Team shall be made through the Local Consultants who is carrying out the Feasibility Study, currently.



Source: JICA Study Team

Figure 3.3.2 Map of the North-South Corridor and East-West Corridor

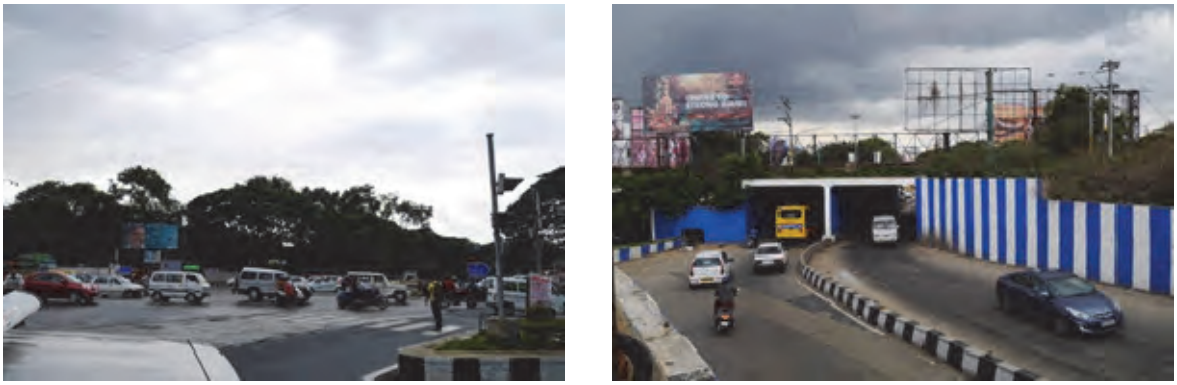


Photo 3.3.1 Pictures of JCT point (Left: Junction A and Right: Junction B)

(2) Site Appreciation

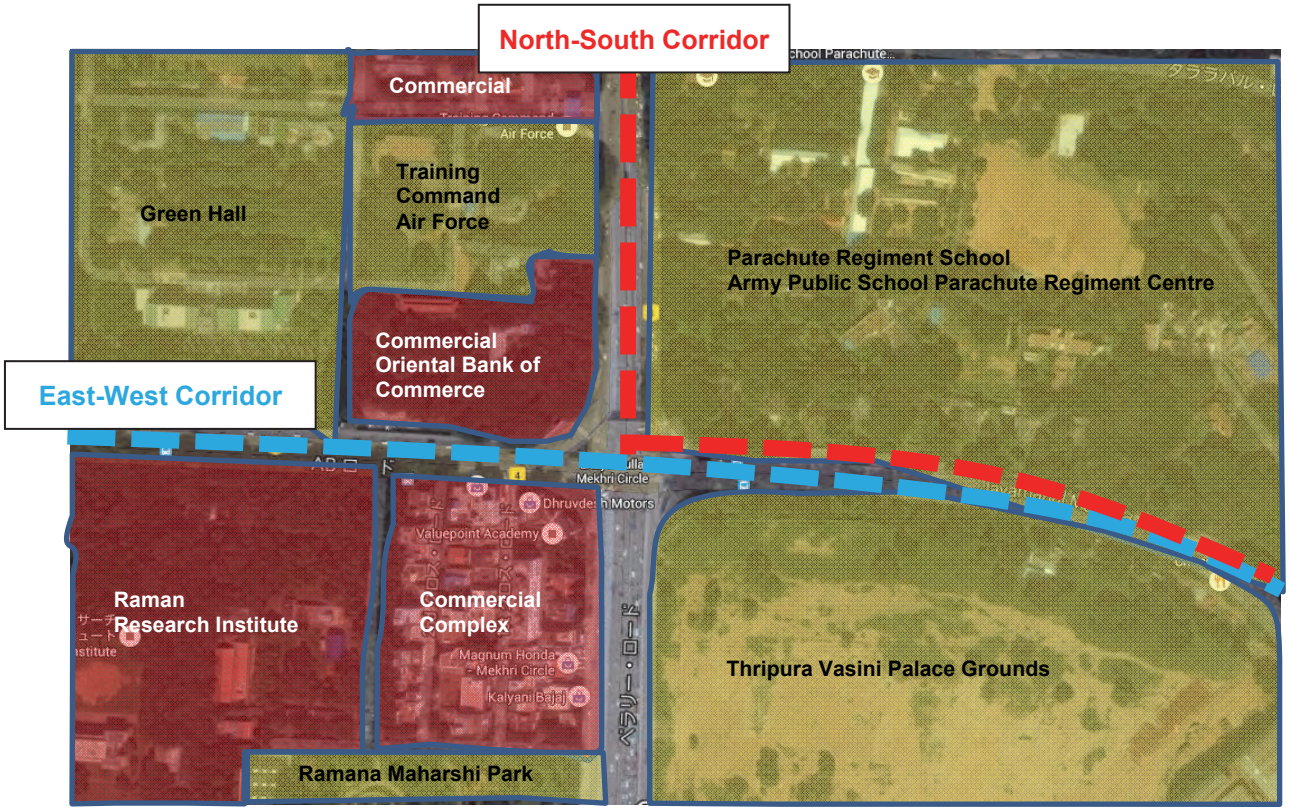
1) Overlapped section for both East-West Corridor and North-South Corridor

Site investigation work was carried out on the 31st of May and 1st of June, 2016. It was confirmed that both the North-South Corridor and East-West Corridor will pass through very congested areas and most of the section will be along an existing road. In addition, according to Local Consultant, both the North-South Corridor and East-West Corridor will be 6 lanes and there are some sections in which the width of the existing road is narrower than the planned cross section. Therefore, land acquisition will be necessary in order to construct the viaduct in accordance with their current planning.

Photo 3.3.2 Congested Situation inside Bangalore City

2) Junction A

The current land use situation around Junction A is shown in Figure 3.3.3. There are public land and private land around Junction A area, therefore, it is required to construct the Junction at very narrow area.



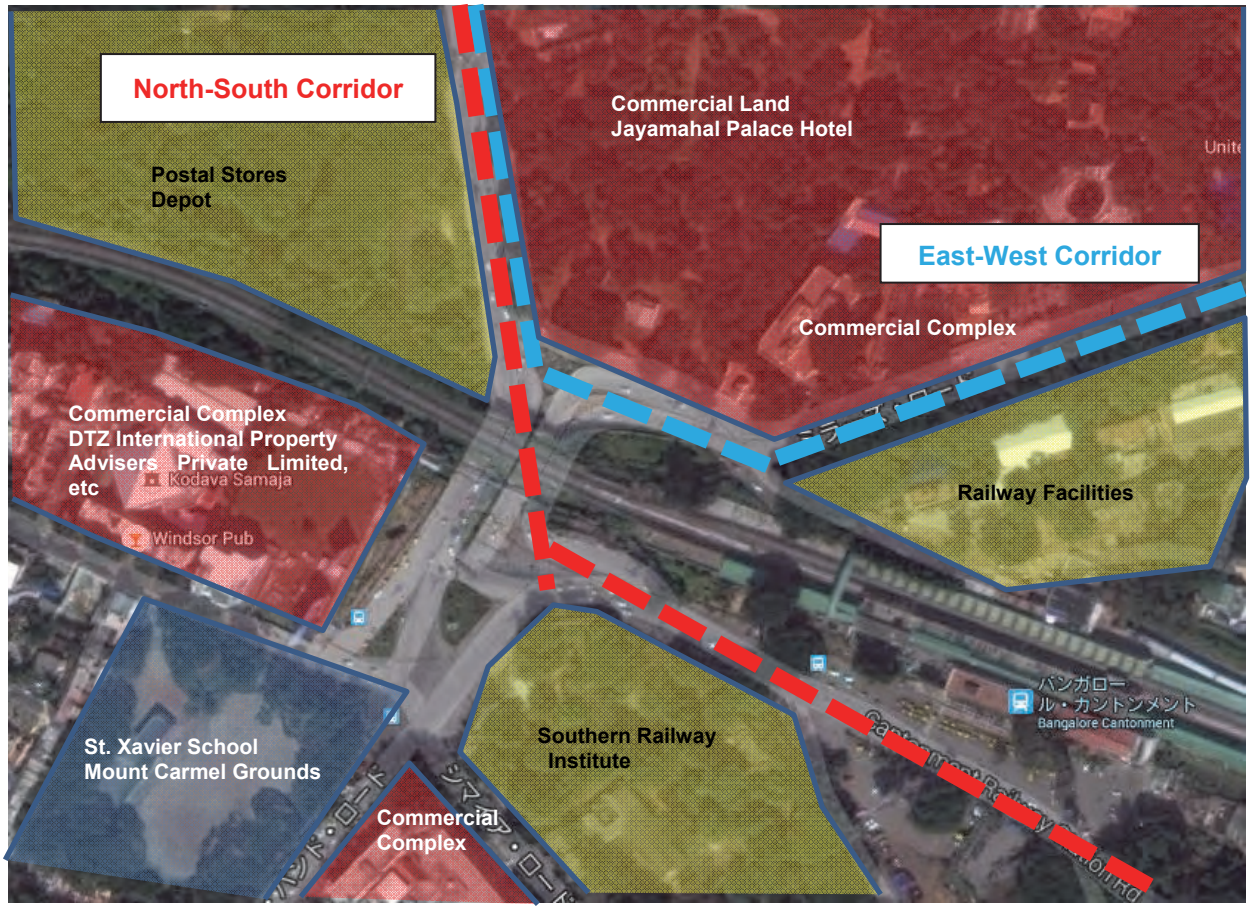
Note: Red Color: Private Land (Difficult for Land Acquisition)
Blue Color: School Land (Possible for Land Acquisition, but take long time for the procedure)
Yellow Color: Government Land (Possible for Land Acquisition)

Source: JICA Study Team

Figure 3.3.3 Current Land Use Status around Junction A

3) Junction B

The current land use situation around Junction B is shown in Figure 3.3.4 as same as Junction A. As same as Junction A area, there are public land and private land, it is required to construct the Junction at very narrow space. In addition, there is a railway line adjacent to Junction B area, it is required to construct very complicated structure for this Junction.



Note: Red Color: Private Land (Difficult for Land Acquisition)
Blue Color: School Land (Possible for Land Acquisition, but take long time for the procedure)
Yellow Color: Government Land (Possible for Land Acquisition)

Source: JICA Study Team

Figure 3.3.4 Current Land Use Status around Junction B

3.3.3 Judgement of Validity of Execution for Outlined Study

Based on result of site visit, it is confirmed that overlapped section for both North-South Corridor and East-West Corridor locates at very congested area in Bangalore. In addition, due to overlapped section for both North-South Corridor and East-West Corridor, it is required to apply very complicated double-deck structure. And, due to limitation of land use, Junction structure by both East-West Corridor and North-South Corridor will become very complexed structure.

As described in Chapter 3.2.3, due to construction in very congested area, it is recommended to apply Japanese Advanced Technology which can reduce negative social impact during construction work in

consideration of rapid construction and construction at narrow space. Moreover, it is necessary to apply steel superstructure and steel pier column at junction structure formulated by North-South Corridor and East-West Corridor.

Therefore, outlined design will be carry out for this project and structure type which Japanese Advanced Technology is applied is proposed.

3.4 Viaduct Construction Project in Chennai

3.4.1 Introduction

Tamil Nadu State Government, Greater Chennai Corporation and Tamil Nadu Road Development Company are involved for development of traffic improvement in Chennai. Therefore, interview to these 3 agencies are carried out in order to collect information about road development plan in Chennai at second field survey. Based on interview result, following 4 projects are selected.

- Viaduct Construction Project along IT Corridor
- Viaduct Construction Project along National Highway (NH) No.45
- Viaduct Construction Project along East Coast Road
- Improvement Project for Railway Crossing in Chennai

3.4.2 Viaduct Construction Project along IT Corridor

(1) Summary of Project

Upon meeting with the Chief General Manager, Tamil Nadu Road Development Company (TNRDC) on 26th May 2016, one viaduct construction plan was introduced. This viaduct will be constructed along the "IT Corridor" which starts from the intersection between Old Mahabalipuram Road and the East Coast Road to Mamallapuram village as shown in Figure 3.4.1. Currently, this road has 6 lanes for the Throughway + 4 lanes for the Frontage Roads from the intersection of the East Coast Road to Sipcot Bus Station and 4 lanes of Throughway from Sipcot Bus Station to Mamallapuram village. According to TNRDC, the viaduct will be implemented only in the section from the intersection with the East Coast Road to Sipcot Bus Station.

Regarding traffic volume, TNRDC has studied this already and the result is summarized in Table 3.4.1.

Source: JICA Study Team

Figure 3.4.1 Location Map of IT Corridor

Table 3.4.1 Result of Traffic Volume Forecast (Peak Hour)

(Unit: PCU/Hour)

Year	At Seevarm Toll Plaza	At Egaton Toll Plaza
Current	10,132	4,676
2025	20,884	9,300
2035	42,126	18,224

Source: Hearing from PPT Document

According to TNRDC, Detailed Project Report (DPR) is under preparation by the local consultants, submission of DPR to the state government is expected to be in August 2016.

Photo 3.4.1 Existing Condition of Current IT Corridor

(2) Judgement of Validity of Execution for Outlined Study

As mentioned in previous chapter, DPR for viaduct construction project along IT Corridor is underpreparing by TNRDC, most of the Project contents have been fixed already. Moreover, there is enough space along IT Corridor for construction work of viaduct, it is easy for construction of viaduct by conventional method which is applied in common in India. Therefore, it is difficult to propose Japanese Advanced Technology, and this project will not be selected for execution of outlined design.

3.4.3 Viaduct Construction Project along National Highway No. 45 and East Coast Road

(1) Summary of Project

Upon meeting with the Additional Chief Secretary, Highways & Minor Ports Department of Tamil Nadu Government on the 21st June 2016, 2 viaduct construction plans were introduced. According to him, there is a demand to construct viaducts along NH45 and East Coast Road as shown in Figure 3.4.1. However, there is no study commenced for viaduct construction plans for either NH45 or the East Coast Road.

(2) Judgement of Validity of Execution for Outlined Study

According to site visit result, there is enough space along NH45, it is easy to construct viaduct by PC Box Girder type which is commonly applied in Indi, and possible to construct by conventional type of foundation. Therefore, it is difficult to apply Japanese Advanced Technology and this project will not be selected for execution of outlined design.

Regarding to East Coast Road, there is some point where the width of existing road is very narrow (about 15m width), closure of existing traffic will be required if cast-in-placed concrete pile type which is very common in India is applied, sine the size of pile cap becomes large. Moreover, it is required to carry out land acquisition work if 4 lanes viaduct is constructed along existing road whose width is about 15m, this cause negative social impact. Therefore, it is possible to construct viaduct within existing road width if Japanese Advanced Technology which can be constructed in narrow area. Therefore, this project will be selected for execution of outlined design.

Photo 3.4.2 Current Status for East-Coast Road

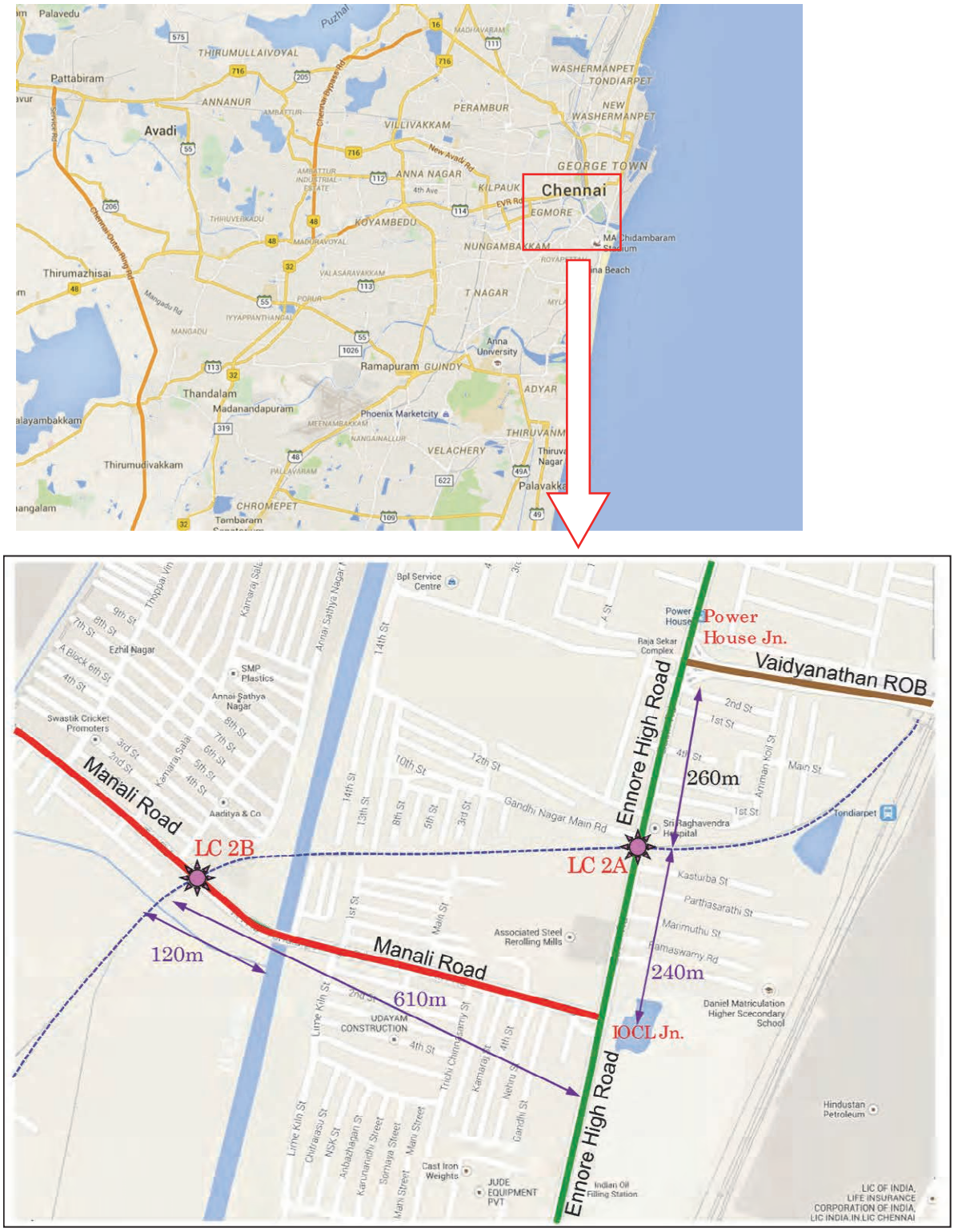
3.4.4 Improvement Project for Railway Crossing

(1) Summary of Project

Up on meeting with the Commissioner of Greater Chennai Corporation (GCC) on the 20th June 2016, 1 level crossing improvement project was introduced. The objective of this project is removal of level crossing LC 2A along Ennore High Road and LC 2B along Manali Road by construction of a T-shaped flyover as shown in Figure 3.4.2. Current condition of the Level Crossing is shown in Photo 3.4.3.

DPR has been prepared by GCC, and the tendering procedure will be commenced soon.

Photo 3.4.3 Current Status of Level Crossing (Left: No. 2A, Right: No. 2B)



Source: DPR received from GCC

Figure 3.4.2 Location Map for Level Crossing Improvement Plan

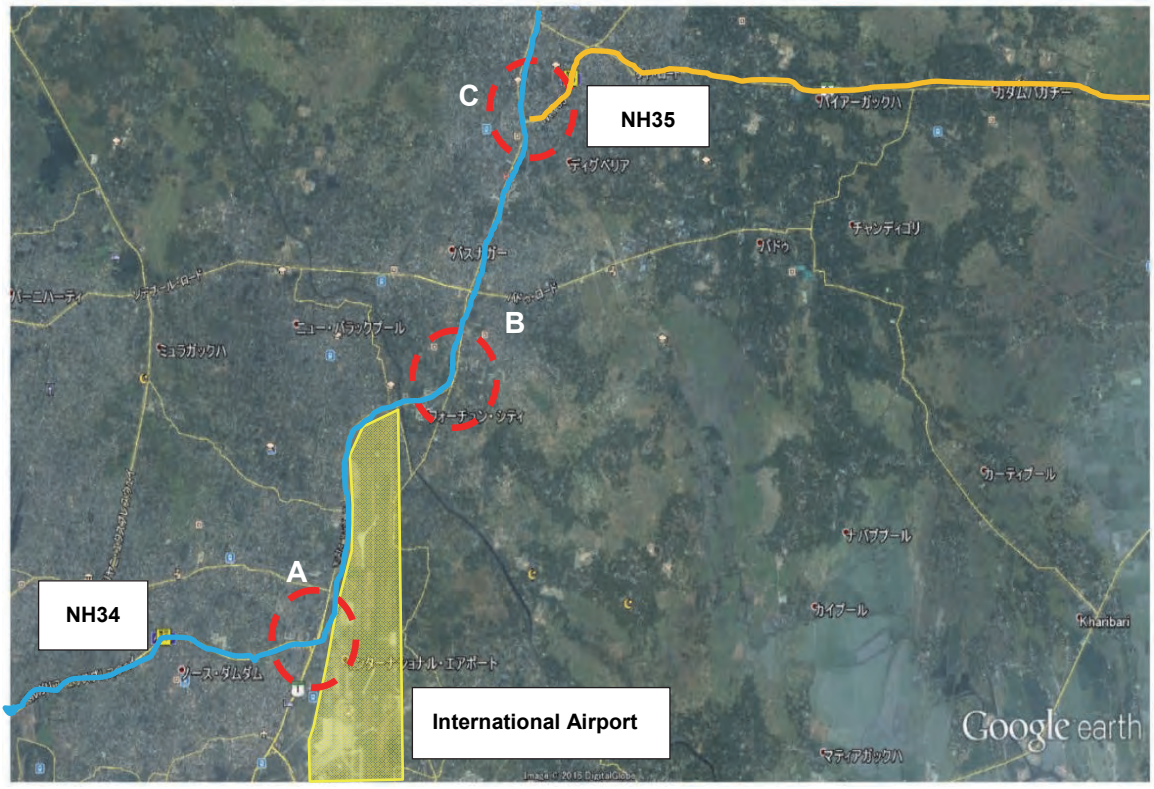
(2) Judgement of Validity of Execution for Outlined Study

As explained, DPR of this project has been completed already, and tendering procedure is expected to commence soon. Therefore, this project will not be selected for execution of outlined design.

3.5 Bridge Repair and Intersection Improvement Project in Kolkata

3.5.1 General

Upon meeting with Superintending Engineer, Ministry of Road Transport and Highways on the 17th June 2016, one damaged bridge and two intersection improvement plans were introduced, all bridges are located along NH34 as shown in Figure 3.5.1.



Source: JICA Study Team

Figure 3.5.1 Location Map for Candidate Bridges

3.5.2 Site Inspection

(1) Bridge Repair Project (Point "A" in Figure 3.5.1)

NH34 runs from the centre of Kolkata city bound for the International Airport, to this intersection in front of the airport. Two flyovers were constructed at this intersection in order to avoid traffic congestion. However, falling concrete piece was confirmed. These flyovers are 4 lanes and the superstructure type is PC Box Girder as shown in Photo 3.5.1.

Photo 3.5.1 General View of Damaged Flyovers

According to the inspection result, the quality of the concrete and construction was in very poor condition. As shown in Photo 3.5.2, treatment of the gap between the formworks was not well executed. Currently, this gap is covered by mortar and it is supposed there honeycomb occurred. However, it is impossible to visually determine how large or extensive the defects are which could cause more falling concrete piece.

Photo 3.5.2 Mortal Filling

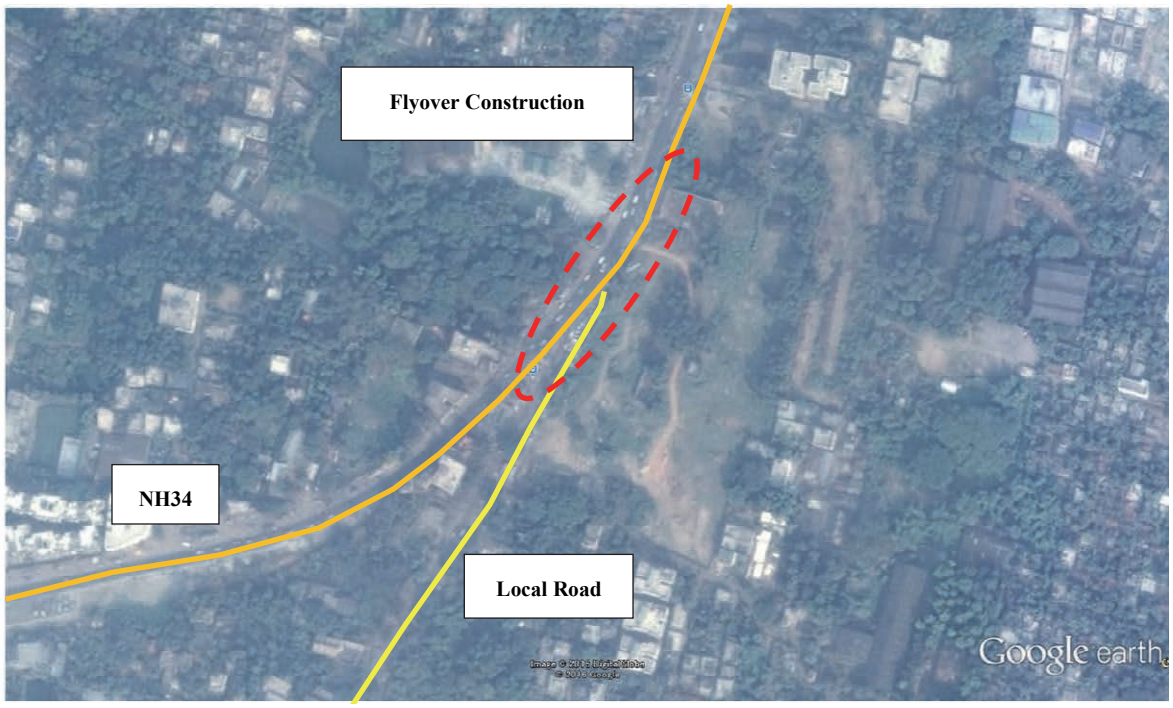
Photo 3.5.3 Horizontal and Inclined Cracks at Web

During the site inspection it was found that there were many vertical and inclined cracks at the webs as shown in Photo 3.5.3, and these cracks are considered as the biggest issue of these flyovers. In general, the reasons for these kinds of cracks are lack of capacity of the PC Box Girder against bending moment and shear force. Currently, the loading of these bridges is restricted by the managing authority (NHAI).

In consideration of the above mentioned phenomena, reinforcement work or replacement work will be necessary. However, due to very low traffic volume using these flyovers and traffic restrictions by the managed authority, the urgency of implementing these countermeasures action is not high.

(2) Intersection Improvement Project Plan No.1 (Point "B" in Figure 3.5.1)

There is a plan to construct a flyover along NH34 in order to solve the traffic congestion, according to MORTH Kolkata Office as shown in Figure 3.5.2.



Source: JICA Study Team

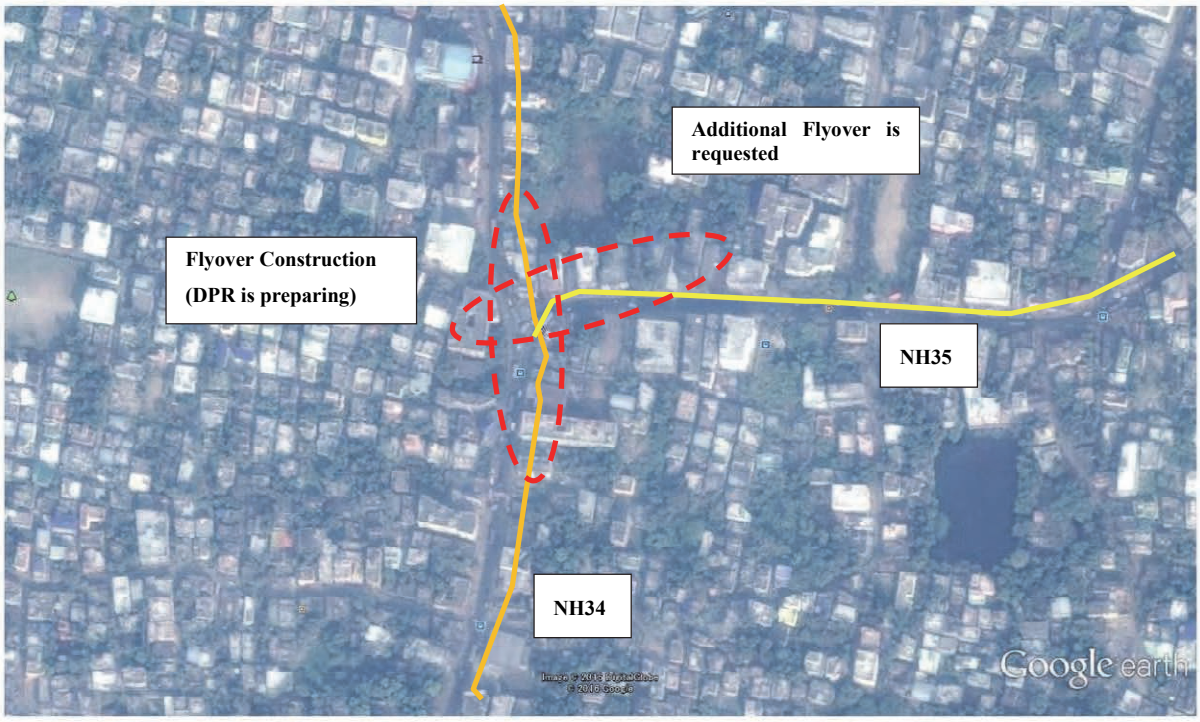
Figure 3.5.2 Location Map for Flyover No. 1

According to the site inspection result, huge numbers of heavy vehicles were confirmed along NH34. However, the capacity of the local road is not large. Therefore, it is considered not to construct a flyover, but to install proper traffic signal systems at this intersection. The general view is shown in Photo 3.5.4.

Photo 3.5.4 General View of Intersection between NH34 and Local Road

(3) Intersection Improvement Project No.2 (Point "C" in Figure 3.5.1)

There is a plan to construct a flyover at the intersection between NH34 and NH35. According to MORTH Kolkata Office, they are preparing a Feasibility Study for construction of a flyover along NH34. The DPR will be finalized soon. However, in order to increase traffic capacity at this intersection, an additional flyover connecting between NH34 and NH35 is required as shown in Figure 3.5.3.



Source: JICA Study Team

Figure 3.5.3 Location Map for Flyover No. 2

The site inspection confirmed the necessity of construction of a new flyover along NH34 for which a DPR is being prepared by MORTH Kolkata office. However, in consideration of the traffic management point of view and additional area for land acquisition, it is not necessary to construct an additional flyover to connect between NH34 and NH35. The current intersection status is shown in Photo 3.5.5.

Photo 3.5.5 General View of Intersection between NH34 and NH35

3.5.3 Judgement of Validity of Execution for Outlined Study

Based on result of Site Visit, execution of outlined study for 3 projects in Kolkata City is as follows;

- Bridge Repair Project (Point “A”)

  Due to low traffic volume use for these flyovers and traffic restrictions by the managed authority, the urgency of implementing these countermeasures action is not confirmed. Therefore, this bridge will not be selected for execution of outline design.

- Intersection Improvement Project No. 1 (Point “B”)

  Since necessity of project implementation cannot be confirmed, this bridge will not be selected for execution of outline design.

- Intersection Improvement Project No. 2 (Point “C”)

  Since necessity of project implementation cannot be confirmed, this bridge will not be selected for execution of outline design.

3.6 Construction of New Mahatma Gandhi Bridge in Patna

3.6.1 Introduction

Request for investigation of Koshi Bridge at Bihar State is received through JICA India Office at third field survey. Although meeting was held with MORTH about Koshi Bridge, MORTH explained DPR had been preparing by Local Consultants since Koshi Bridge locates missing rink and has high urgency. Therefore, expected implementation schedule by MORTH cannot meet with implementation schedule by Japanese ODA.

At the same time, execution of investigation for New Mahatma Gandhi Bridge was requested by MORTH. Therefore, meeting with MORTH (IAHE) who manages New Mahatma Gandhi Bridge was held after execution of site visit to New Mahatma Gandhi Bridge by JICA Study Team. However, IAHE explained study work has been commenced by Korean Consultants.

The study contents by JICA Study Team are shown below.

3.6.2 Necessity of construction for New Mahatma Gandhi Bridge

Although Bihar is one of India's poorest states, it has seen dramatic economic growth in recent years. As the area's economic activity has picked up, the rather underdeveloped highway network in the state has been improved, while the number of registered motor vehicles has increased threefold over the past five years. At the same time, North-South roads have also been enhanced in Bihar, as the state is situated on the trade routes connecting Nepal and Bhutan to India and trade between these regions is expected to expand in the future. Moreover, the capital of the state of Bihar, Patna City, in which the Mahatma Gandhi Bridge is located, is not only the center of the state's economic activity but also the main hub of North-South transportation.

(1) Current Status of Mahatma Gandhi Bridge

Mahatma Gandhi Bridge locates east side of Patna, crosses over Gange River and connects between east bank and west bank of Gange River. Mahatma Gandhi Bridge has 4 lanes of carriageway; however, due to large number of traffic, there is a lot of traffic congestion as shown in Photo 3.6.1.

Moreover, due to defect of existing Mahatma Gandhi Bridge at center hinge point, superstructure of existing Mahatma Gandhi Bridge is removing and plans to be reconstructed. Currently, only 1 span of superstructure (upper stream side) was removed by India Government as shown in Photo 3.6.2.

Photo 3.6.1 Traffic Congestion at existing Mahatma Gandhi Bridge

Photo 3.6.2 Removal of existing Superstructure from existing Mahatma Gandhi Bridge

(2) Bridge Construction status near Mahatma Gandhi Bridge

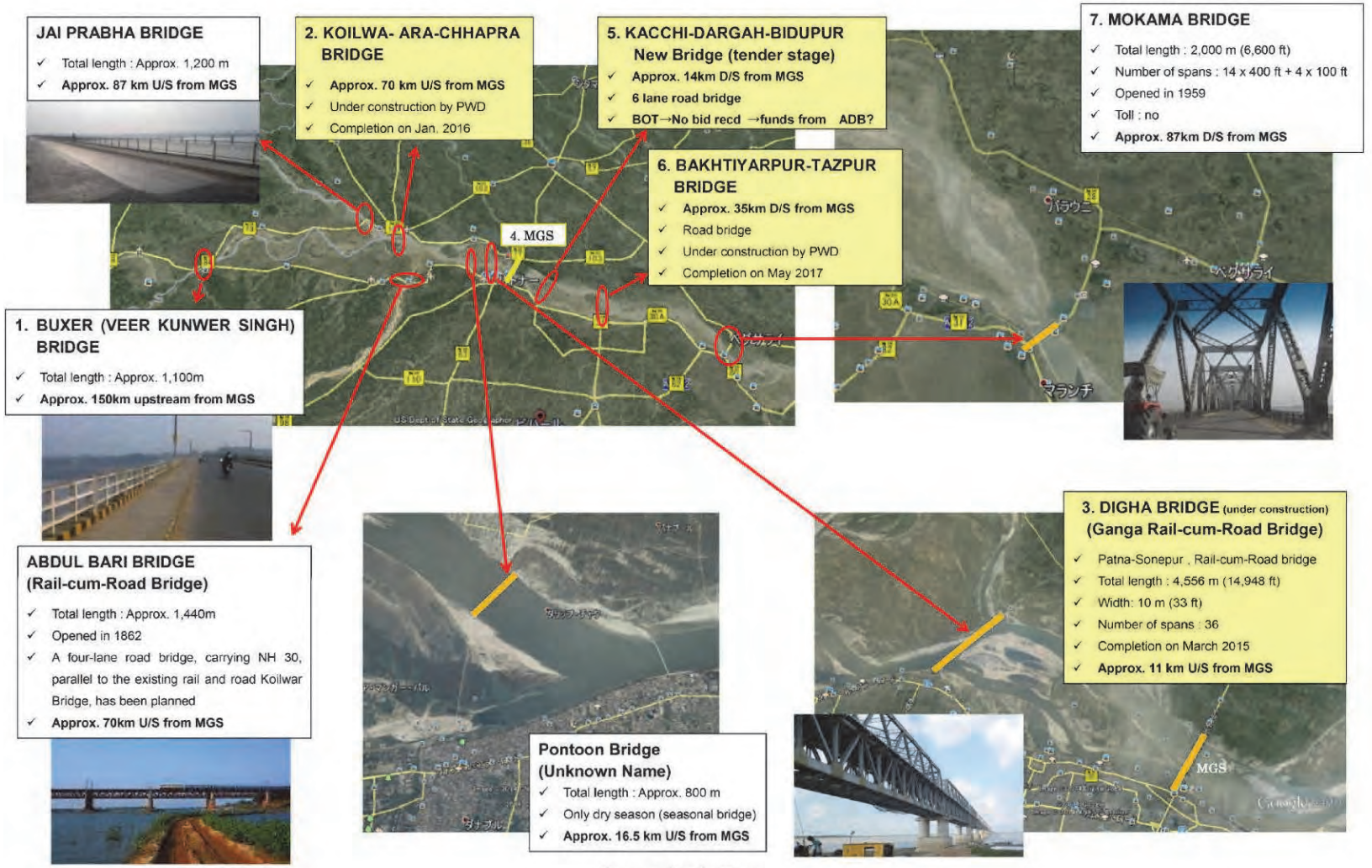
1) Existing Bridge

Currently, there are 2 existing bridges crossing Gange River except Mahatma Gandhi Bridge, namely, Rajendra Bridge and Vikramshila Bridge.

2) Bridge under Construction and in the preparation or planning stage

Following bridges are under construction and in the preparation or planning stage in order to complete for construction during 2015-2017.

- Munger Ganga Bridge
- Koilwa-Ara-Chhapra Bridge
- Degha Rail-Road Bridge
- Bakhtiyarpur-Bidupur Bridge



Source: METI Report on "Study on Mahatma Gandhi Setu Rehabilitation Project in the Republic of India"

Figure 3.6.1 Bridges around Mahatma Gandhi Bridge

(3) Traffic Forecast

1) Pre-conditions of Traffic Demand Forecast Study

According to study result by METI study on "Study on Mahatma Gandhi Setu Rehabilitation Project in the Republic of India", traffic demand forecast was carried out in consideration with completion of 4 new bridges along Ganges River. Scheduled completion year and traffic assignment percentage for each 4 bridges is shown in Table 3.6.1, and locations of 4 new bridges are shown in Figure 3.6.2.

Table 3.6.1 Scheduled Completion Year and Traffic Assignment for 4 New Bridges

	Scheduled Completion Year	Traffic assignment		
		2016	2017	2018
Mahatma Gandhi Bridge	-	50.8%	35.5%	28.7%
Koilwa-Ara-Chhapra Bridge	2016		17.1%	14.4%
Digha Bridge (Railway cum)	2015	49.2%	33.6%	27.3%
Kacchi-Dargah Bidupur Bridge	2017			18.6%
Bakhtiyarpur-Bidupur Bridge	2016		13.8%	11.0%

Source: METI Report on "Study on Mahatma Gandhi Setu Rehabilitation Project in the Republic of India"

Source: METI Report on "Study on Mahatma Gandhi Setu Rehabilitation Project in the Republic of India"

Figure 3.6.2 Location Map for Mahatma Gandhi Bridge and new 4 bridges

2) Result of Traffic Demand Forecast Study

In consideration with above mentioned pre-condition, traffic demand used for "Mahatma Gandhi Bridge" was forecasted, and result of this is shown in Table 3.6.2.

Table 3.6.2 Traffic Demand Forecast Result used at Mahatma Gandhi Bridge

	Car/Taxi/Jeep etc.	Bus	LCV	Truck	Total	2-W	3-W	Tractor	Others	Grand Total Veh. / day	Grand Total PCU / day
2013	11,890	2,161	3,268	11,982	29,301	11,576	6,306	850	508	48,541	80,107
2014	13,079	2,377	3,627	13,300	32,383	12,734	6,937	850	508	53,412	88,177
2015	14,387	2,615	4,026	14,763	35,791	14,007	7,631	850	508	58,787	97,104
2016	8,090	1,472	2,260	8,287	20,109	15,408	8,394	850	508	45,269	64,167
2017	6,233	1,224	1,726	6,327	15,510	16,949	9,233	850	508	43,050	55,702
2018	5,499	1,106	1,557	5,707	13,869	18,644	10,156	850	508	44,027	54,022
2022	7,905	1,589	2,321	8,508	20,323	26,800	14,599	850	508	63,080	77,072
2027	11,615	2,335	3,572	13,091	30,613	39,379	21,450	850	508	92,800	113,627
2032	15,544	3,125	5,010	18,363	42,042	52,699	28,705	850	508	124,804	153,937
2037	20,803	4,183	7,028	25,757	57,771	70,524	38,413	850	508	168,066	209,176
2042	27,839	5,597	9,857	36,126	79,419	94,376	51,406	850	508	226,559	284,906
2047	37,255	7,490	13,824	50,669	109,238	126,296	68,793	850	508	305,685	388,799
2052	49,855	10,023	19,388	71,066	150,332	169,012	92,061	850	508	412,763	531,402

Source: METI Report on "Study on Mahatma Gandhi Setu Rehabilitation Project in the Republic of India"

(4) Necessity of New Mahatma Gandhi Bridge

As shown in Table 3.6.2, traffic demand used at Mahatma Gandhi Bridge will become 77,072 [PCU/Day] at 2022 and 113,627 [PCU/Day] at 2027.

In accordance with Highway Capacity Manual (AASHTO), relationship between traffic volume and necessary number of lanes can be estimated as follows;

2 Lanes < 20,000
20,000 < 4 Lanes < 80,000
80,000 < 6 Lanes unit [PCU/Day]

Therefore, necessary number of lanes at Mahatma Gandhi Bridge can be estimated as follows; and it can be concluded construction of New Mahatma Gandhi Bridge is necessary.

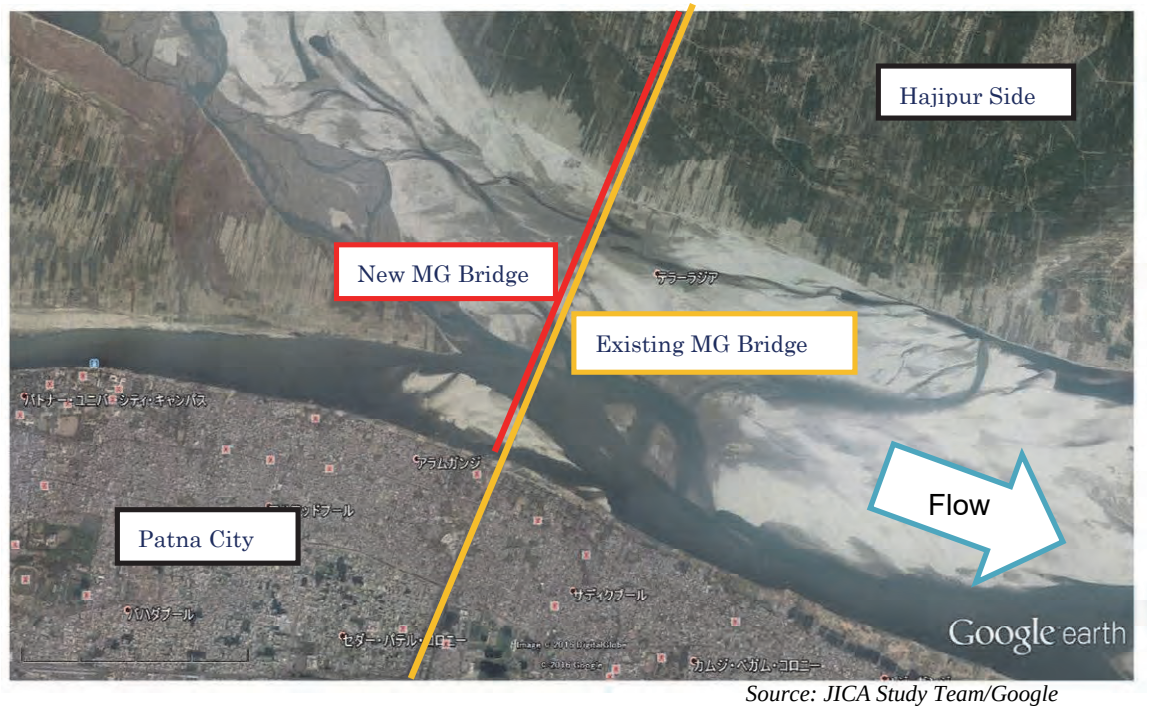
Year 2022 => 4 Lanes Required => Enough for current lane number
Year 2027 => 8 Lanes Required => NOT enough for current lane number

Based on traffic volume analysis result at 2022 and 2027, it is expected traffic volume at 2023 exceeds from traffic capacity of existing lane number. Therefore, it is required to complete construction of New Mahatma Gandhi Bridge as quick as possible after year 2022 in order to secure smooth traffic at Mahatma Gandhi Bridge.

3.6.3 Site Inspection

(1) Location of New Mahatma Gandhi Bridge

According to inspection result at site, New Mahatma Gandhi Bridge needs to be constructed upper stream side of existing Mahatma Gandhi Bridge since there are a lot of houses along downstream side of existing Mahatma Gandhi Bridge.



Source: JICA Study Team/Google

Figure 3.6.3 Location of New Mahatma Gandhi Bridge

In consideration of scouring effect to the existing Mahatma Gandhi Bridge, New Mahatma Gandhi Bridge will be constructed 50-100m far from existing Mahatma Gandhi Bridge as shown in Figure 3.6.3.

(2) Land Use Status on Patna City Side

According to site inspection result, it was confirmed there is some space along existing Mahatma Gandhi Bridge as shown in Figure 3.6.4.

Source: JICA Study Team/Google

Figure 3.6.4 Land Use Status at Patna City Side

(3) Land Use Status on Hajipur Side

According to site inspection result, it was confirmed most of land is used as agricultural land, however, there are some housed located beside existing road as shown in Figure 3.6.5.

Source: JICA Study Team

Figure 3.6.5 Land Use Status at Hajipur Side

3.6.4 Judgement of Validity of Execution for Outlined Study

As mentioned before, although site visit was conducted based on request from MORTH and Japanese Advanced technologies such as Steel Pipe Sheet Pile Foundation and Hybrid Extradosed Bridges which was applicable to this project were proposed to MORTH, it is confirmed DPR is under preparation by Korean Consultants at the meeting held at 30th August 2016. Therefore this bridge will not be selected for execution of outline design.

3.7 Damaged Bridges Managed by Western Railway of MOR

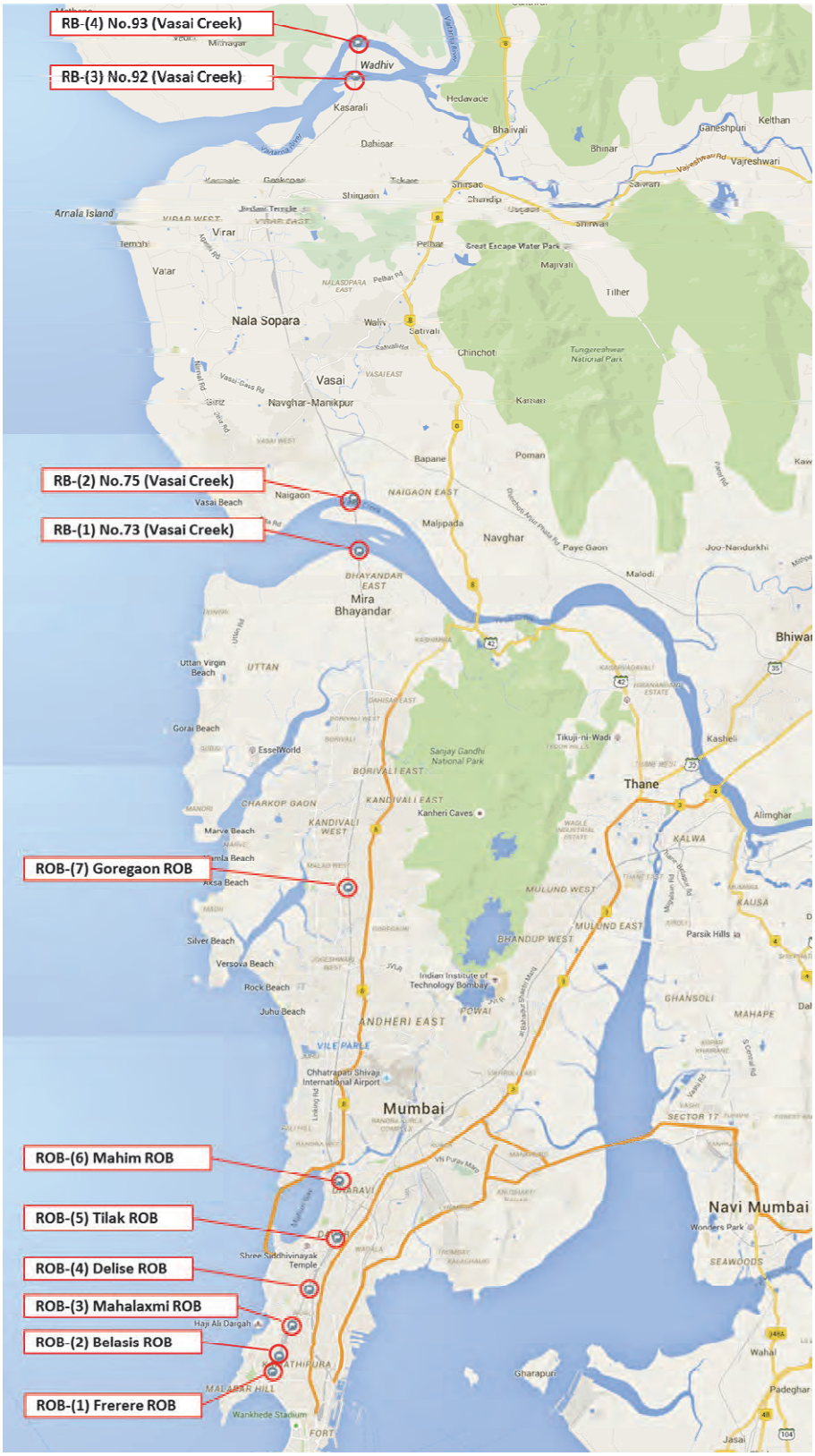
3.7.1 General

Upon meeting with the Chief Bridge Engineer of the Western Railway on 6th June 2016, we were given a list of Road over Bridges (ROB) and Railway Bridges requiring rehabilitation. The number and locations for these bridges are shown in Table 3.7.1, Figure 3.7.1 and Figure 3.7.2.

Table 3.7.1 Number and Locations for Damaged Bridges

Type of Bridge	Location	Number (18 Bridges)	Bridge Name
ROB	Mumbai	7	(1) Ferere ROB (No. 1) (2) Belasis ROB (No. 2) (3) Mahalaxmi ROB (No. 3) (4) Delise ROB (No. 4) (5) Tilak ROB (No. 5) (6) Mahim ROB (No. 6) (7) Goregaon ROB (No. 7)
	Vadodara	2	(8) LC No. 5/A (No. 8) (9) LC No. 2/X (No. 9)
Railway Bridge	Mumbai	4	(1)No.73 (Vasai Creek) (2)No.75(Vasai Creek) (3)No.92 (Vasai Creek) (4)No.93 (Vasai Creek)
	Ratlam	5	(5) No. 114 (6) No. 129 (7) No. 132 (8) No. R5 (9) No. R8

Source: List by Western Railway



Source: JICA Study Team

Figure 3.7.1 Location Map for Damaged Bridges (Mumbai)

Source: JICA Study Team

Figure 3.7.2 Location Map for Damaged Bridges (Vadodara, Ratlam)

3.7.2 Damaged ROBs in Mumbai

(1) Visual Inspection

Inspection results for ROBs are summarized in Table 3.7.2.

Table 3.7.2 Summary for Inspection Results of ROBs

No.	Bridge Name	Length [m]	Construction Year	Superstructure Type	Inspection Result
1	Ferere ROB	25.36	1921	2 Main Steel I-Girder with cross girders	Well maintained by re-painting work
2	Balasis ROB	31.50	1893	Steel I-Girder	Well maintained by re-painting work, but, lack of flange section
3	Mahalaxmi ROB	77.00	1920	Steel I-Girder	Under re-painting work, rust condition is not so severe
4	Delise ROB	63.20	1921	2 Main Steel I-Girder with cross girders	Severe rust condition is observed.
5	Tilak ROB	226.20	1925	2 Main Steel I-Girder with cross girders	Well maintained by re-painting work
6	Mahim ROB	80.00	1993	PC I-Shaped Girder	External PC cable was broken, but concrete condition for Superstructure is good. But concrete condition for Sub-structure is in worse condition.
7	Goregaon ROB	79.00	1993	PC I-Shaped Girder	External PC cable was broken, but concrete condition is good

Source: JICA Study Team

(2) Details of Investigation Result

Visual inspection result for 7 ROBs in Mumbai are shown in below;

1) Ferere ROB (No.1)

(a) General Information of Bridge

General information of Ferere ROB is shown below;

- Location: near Grant Road Station
- Bridge Length: 25.36m
- Bridge Width: 19.50m
- Span Number: 1 Span
- Superstructure Type: 2 Main Steel I-Girder with cross girders
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1921

Photo 3.7.1 General View of Ferere ROB

Photo 3.7.2 Main Girder and Cross Beam

(b) Inspection Result

a) Structural Consideration

Although this bridge has passed 95 years after completion, it has been maintained in sound condition.

Photo 3.7.3 Main Girder and Cross Beam

According to Western Railway, re-painting work was carried out 4-5 months ago with Zinc Paint. Therefore, the steel surface is well maintained. However, due to instructions by the Ministry of Railway (MOR) in 2011, clearance under ROB must be increased from 5.0m to 6.25m because the electric supply system will be revised from DC to AC, which requires more space above the train. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR.

b) Environmental Considerations

i) Pollution
A residential area is observed and might be affected by Noise and Air pollution during and After Construction.

ii) Social Environment
A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.
No sacred facility is observed.

iii) Natural Environment
No protected areas exist near the ROB.

Photo 3.7.4 View of Southwest from ROB

Photo 3.7.5 View of Northwest from ROB

2) Balasis ROB (No.2)

(a) General Information of Bridge

General information of Balasis ROB is shown below;

- Location: near Mumbai Central Station
- Bridge Length: 31.50m
- Bridge Width: 19.50m
- Span Number: 5 Spans
- Superstructure Type: Steel I-Girder (15 girders)
- Substructure Type: Stone Masonry Abutment and Steel Pier Column
- Construction Year: 1893

Photo 3.7.6 General View of Balasis ROB

Photo 3.7.7 Girder and Pier Column

(b) Inspection Result

a) Structural Consideration

This is one of the oldest steel bridges managed by Western Railway. Although re-painting work was executed as maintenance work, there is some portion in which rust or damages were observed. Especially, lack of a bottom flange can be observed as shown in Photo 3.7.8.

Photo 3.7.8 Lack of Section at Bottom Fringe

Photo 3.7.9 View of Northwest from ROB

There is a utility pipe hanging beside the main girder. In addition, there is a steel water pipe placed on the sidewalk. The same as Ferere ROB, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR

b) Environmental Considerations

i) Pollution
A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment
A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.
No sacred facility is observed.

iii) Natural Environment
No protected areas exist near the ROB.

Photo 3.7.10 View of Southwest from ROB

3) Mahalaxmi ROB (No.3)

(a) General Information of Bridge

General information of Mahalaxmi ROB is shown as below;

- Location: near Mahalaxmi Station

- Bridge Length: 77.00m
- Bridge Width: 25.00m
- Span Number: 5 Spans
- Superstructure Type: Steel I-Girder (15 girders)
- Substructure Type: Stone Masonry Abutment and Steel Pier Column
- Construction Year: 1920


Photo 3.7.11 Current Condition of Mahalaxmi ROB
(Left: General View, Right: Re-painting work)

(b) Inspection Result

a) Structural Consideration

Although this bridge has also passed 95 years after completion, it has been maintained in relatively sound condition.

Re-painting work is undergoing by Western Railway as shown in Photo 3.7.11. Based on our observation result at the section where re-painting work has not been completed, some rust was confirmed, however, this rust is not considered as a serious problem.

The same as the above bridges, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR.

Photo 3.7.12 View of Southeast from ROB

Photo 3.7.13 View of Northeast from ROB

b) Environmental Considerations

i) Pollution

A residential area is observed and might be

affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment

A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.

No sacred facility is observed.

iii) Natural Environment

No protected areas exist near the ROB.

4) Delise ROB (No.4)

(a) General Information

General information of Delise ROB is shown below;

- Location: near Lower Parel Station
- Bridge Length: 63.20m
- Bridge Width: 24.80m
- Span Number: 3 Spans
- Superstructure Type: 2 Main Steel I-Girder with cross girders (Skew angle: 26^0 30')
- Substructure Type: Stone Masonry Abutment and Steel Pier Column
- Construction Year: 1971


Photo 3.7.14 General View of Delise ROB

(b) Inspection Result

a) Structural Consideration

According to Western Railway, this bridge is the most damaged bridge in the damaged bridge list. There is severe rust observed at many members and lack of section at the bottom flange was confirmed also as shown in Photo 3.7.15. In addition, peeling, falling and free lime of surface concrete at bottom of deck slab also is confirmed.

The same as the above bridges, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR. In addition, due to not enough space between tracks, Western Railway wants to reconstruct this bridge as single span bridge

Photo 3.7.15 Rusts and Lack of Section at Bottom Flange

Photo 3.7.16 Peeling and Free Lime of concrete from Bottom of Deck Slab

Photo 3.7.17 View of Southeast from ROB

Photo 3.7.18 Temple on Southeast side from ROB

b) Environmental Considerations

i) Pollution

A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment

A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.

A temple is located on the southeast side.

iii) Natural Environment

No protected areas exist near the ROB.

5) Tilak ROB (No.5)

(a) General Information

General information of Tilak ROB is shown below;

- Location: near Dadar Station
- Bridge Length: 226.20 m (55m section is managed by Western Railway, remaining section is managed by Central Railway)
- Bridge Width: 20.00m
- Span Number: 3 Spans for Western Railway Section
- Superstructure Type: 2 Main Steel I-Girder with cross girders
- Substructure Type: Stone Masonry Abutment and Steel Pier Column
- Construction Year: 1925

Photo 3.7.19 General View of Tilak ROB

(b) Inspection Result

a) Structural Consideration

Although this bridge has also passed 90 years after completion, it has been maintained in relatively sound condition.

Trains by both Western Railway and Central Railway stop at Dadar station. Since trains by both Western Railway and Central Railway pass under Tilak ROB, a section of Tilak Bridge is managed by Western Railway and the remaining section is managed by Central Railway.

Photo 3.7.20 Main Girder and Cross Beam

Based on observation at the site, this bridge is well maintained by Western Railway by applying of re-painting work.

The same as the above bridges, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR.

b) Environmental Considerations

i) Pollution
A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment
A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.
No sacred facility is observed.

iii) Natural Environment
No protected areas exist near the ROB.

Photo 3.7.21 View of Southwest from ROB

Photo 3.7.22 View of Northwest from ROB

6) Mahim ROB (No.6)

(a) General Information

General information of Mahim ROB is shown below;

- Location: near Mahim Junction Station
- Bridge Length: 80.00 m
- Bridge Width: 28.30m
- Span Number: 3 Spans
- Superstructure Type: PC I-Shaped Girder
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 1993

Photo 3.7.23 General View of Mahim Bridge

Photo 3.7.24 Main Girder and Abutment

(b) Inspection Result

a) Structure Consideration

Due to failure of prestressing work during construction, external PC cables were installed at some girders as shown in Photo 3.7.25. However, during observation, the external PC cable was exposed because of a damaged sheath. There were no other defects observed during the site inspection except for the above mentioned external PC cable problem.

Photo 3.7.25 External Prestressed Cable

The same as the above bridges, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR.

Photo 3.7.26 External Prestressed Cable

Photo 3.7.27 RC Pier Colum

b) Environmental Considerations

i) Pollution
A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge. (Referring Photo 3.7.28).

ii) Social Environment
A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.

Photo 3.7.28 View of Southeast side from ROB

iii) Natural Environment
Cutting mangrove is expected on the northeast to make room for the bridge.

7) Goregaon ROB (No.7)

(a) General Information

General information of Goregaon ROB is shown below;

- Location: between Goregaon Station and Malad Station
- Bridge Length: 79.00 m
- Bridge Width: 27.50m
- Span Number: 2 Spans
- Superstructure Type: PC I-Shaped Girder
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 1993

Photo 3.7.29 Mangrove on Northeast from ROB

Photo 3.7.30 General View of Goregaon ROB

Photo 3.7.31 General View of Goregaon ROB

(b) Inspection Result

a) Structural Consideration

The same as Mahim ROB, due to construction errors, external PC cable was installed at only 2 girders out of 12 girders. However, due to damage of the Sheath, PC cable was cut for both girders, one in 1999 and one in 2012 as shown in Photo 3.7.32. However, during our observation, the external PC cables were exposed because of damaged sheaths. There is no other defect observed during site inspection except the aforementioned external PC cable problem.

Photo 3.7.32 Cut external PC Cable

The same as the above bridges, there is a request to increase clearance from 5.0m to 6.25m. Therefore, Western Railway wants to reconstruct this bridge in order to meet the requirements from MOR.

b) Environmental Considerations

i) Pollution
A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment
A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge. Squatters live on the site.

iii) Natural Environment
No protected areas exist near the ROB.

Photo 3.7.33 View of Northeast from ROB

Photo 3.7.34 Squatters under the ROB in Western Railway site

(3) Judgement of Validity of Execution for Outlined Study for ROBs in Mumbai

Based on result of site visit, it is confirmed most of bridges have passed 100 years and some of bridges have severe damage. Due to revision of clearance under ROBs, road profile shall be raised up also. In order to avoid negative social impact to surrounding area, it is required to apply thin superstructure and secure necessary clearance below.

Due to construction inside very congested area in Mumbai, and have necessity to apply very thin superstructure, it is possible to propose Japanese Advanced Technology. Therefore, these bridges will be selected for execution of outlined design.

3.7.3 Damaged ROBs in Vadodara

(1) Visual Inspection

Inspection results for ROBs which are requested to inspect by Western Railway in Vadodara are summarized in Table 3.7.3.

Table 3.7.3 Summary for Inspection Results of ROBs

No.	Bridge Name	Length [m]	Construction Year	Superstructure Type	Inspection Result
1	LC No. 5/A	85.00	2012	PC Box Girder	Many cracks are observed at bottom of deck slab
2	LC No. 2/A	35.08	2008	PC Box Girder	Many cracks are observed at bottom of deck slab

Source: JICA Study Team

(2) Details of Investigation Result (Visual Checking)

Visual checking result for 2 ROBs in Vadodara are shown in below;

1) LC No.5/A (No.8)

(a) General Information

General information of LC No.5/A ROB is shown below;

- Location: between Bharuch Station and Samni Station
- Bridge Length: 45.00 + 40.00m *2 Lane m
- Bridge Width: 27.50m
- Span Number: 2 Spans
- Superstructure Type: PSC Box Type
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 2011-2012

Photo 3.7.35 General View of LC No.5/A

Photo 3.7.36 General View of LC No.5/A

(b) Inspection Result

a) Structural Consideration

According to Western Railway, the Pre stressed box girder has longitudinal cracks in the bottom of the deck slab. During the survey, transverse cracks have also been noticed in the web of the box and diaphragm. There are many cracks noticed on the mid-section of the bottom surface of the deck slab. These cracks are parallel to the main reinforcement bar of the bottom. These cracks generally occur soon after construction and can accelerate corrosion of the reinforcing steel, possibly causing damage to the bridge aesthetics. As a result of these adverse effects of transverse cracking, the service life span of the bridge will be shortened.

Photo 3.7.37 Cracks of Deck Slab

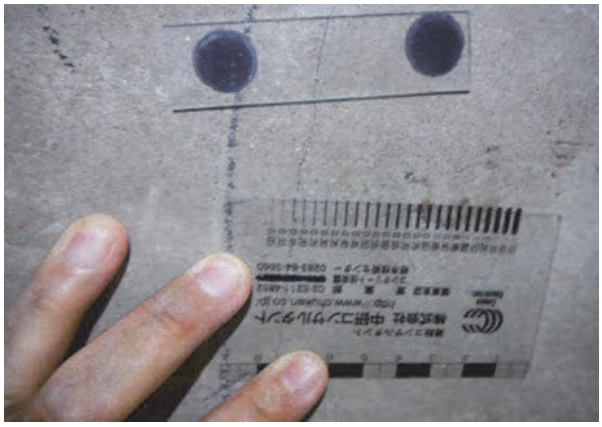


Photo 3.7.38 Cracks of Deck Slab

b) Environmental Considerations

i) Pollution

A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment

A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.

iii) Natural Environment

No protected areas exist near the ROB.

Photo 3.7.39 View of Northeast from ROB

Photo 3.7.40 View of Southeast from ROB

2) LC No.2/X South (No.9) and LC No.2/X North

(a) General Information

General information of LC No.2/X South ROB and LC No.2/X North ROB is shown below;

- Location: between Miyagaon Station and Karjan Station
- Bridge Length: 35.08m *2 Lanes
- Bridge Width: 6.35m
- Span Number: 1 Span
- Superstructure Type: PSC Box Type
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 2008

Photo 3.7.41 General View of LC No.2/A North

Photo 3.7.42 General View of LC No.2/A North

(b) Inspection Result

a) Structural Consideration

There has been an increase in the number of cracks in the deck slab. Restressed box girders have longitudinal cracks in the mid-section of the bottom of the deck slabs. During the survey transverse cracks were noticed in the web of box and diaphragm. These cracks develop at early ages after construction. These cracks are spaced 180mm to 250mm apart along the length of the bridge and can accelerate corrosion of the reinforcing steel, and possibly cause damage to the bridge aesthetics. As a result of these adverse effects of transverse cracking, the service life span of the bridge will be shortened.

Photo 3.7.43 General View of LC No.2/A North

Photo 3.7.44 General View of LC No.2/A North

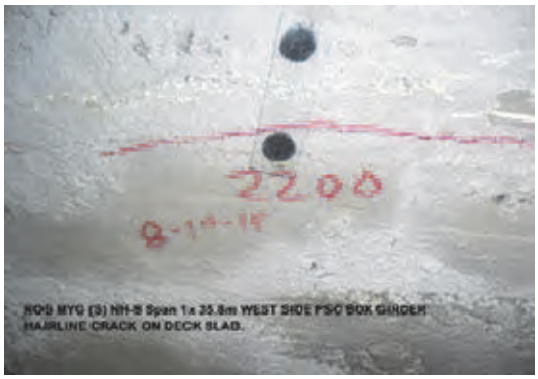


Photo 3.7.45 Cracks of Deck Slab South

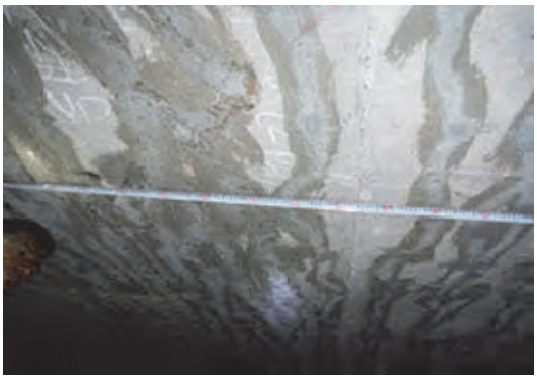


Photo 3.7.46 Cracks of Deck Slab North

b) Environmental Considerations

i) Pollution

A residential area is observed and might be affected by Noise and Air pollution in case of reconstruction of the bridge.

ii) Social Environment

A residential area and commercial area is observed and might be affected in case of reconstruction of the bridge.

iii) Natural Environment

No protected areas exist near the ROB.

Photo 3.7.47 View of Southwest from North ROB

Photo 3.7.48 View of Northwest from North ROB

(3) Judgement of Validity of Execution for Outlined Study for ROBs in Vadodara

Based on Site Visit result, it is confirmed that there are many cracks at bottom of deck slab for both 2 bridges. These cracks were generated soon after opening to traffic. In order to investigate result of damage, execution of Non-destructive inspection is proposed at third field survey.

Based on result of Non-destructive inspection, it can be possible to propose and study Japanese Advanced Technology of repair and rehabilitation method used by CFRP.

3.7.4 Damaged Railway Bridges in Mumbai

(1) Visual Inspection

Inspection results for Railway Bridges which are requested to inspect by Western Railway in Mumbai are summarized in Table 3.7.4.

Table 3.7.4 Summary for Inspection Result on Railway Bridges

No.	Bridge Name	Length [m]	Construction Year	Superstructure Type	Inspection Result
1	No. 73	1,450	1993	PC Box Girder	There are many cracks along Web. But, due to narrow width of cracks, it is considered as no problem.
2	No. 75	550	1993	PC Box Girder	There are many cracks along Web. But, due to narrow width of cracks, it is considered as no problem.
3	No. 92	380	1963	Steel I-Girder	Due to scoring some pile foundations were exposed. And, pile concrete was damaged, but, repair work was already done.
4	No. 93	410	1963	Steel I-Girder	Due to scoring some pile foundations were exposed. And, pile concrete was damaged, but, repair work was already done.

(2) Details of Inspection Result

Visual checking result for 4 Railway Bridges in Mumbai are shown in below;

1) Bridges No.73 and 75 (Vasai Creek)

(a) General Information of Bridge

General information of No. 73 and No. 75 is shown as below;

- Location: between Bhyandar Station and Naigaon Station
- Bridge Length: 1,450 m (No. 73) and 550m (No. 75)
- Span Number: 29 Spans (No. 73) and 11 Spans (No. 75)
- Superstructure Type: PC Box Girder
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 1993

Photo 3.7.49 General View of No. 73 Bridge

Photo 3.7.50 Between each Girder

(b) Inspection Result

a) Structural Consideration

There are many hair cracks that were generated after completion of construction. These cracks generated mainly horizontally and there are some cracks generated with an inclination as shown in Photo 3.2.51.

According to Western Railway, they conducted bridge inspection work once a year after completion, however, there were no cracks observed at the bridge surface. Then, some cracks were observed during their yearly inspection work in 2003. Since they observed the cracks especially in 4 girders, they conducted inspection work once per 3 months. And these cracks were monitored by them as shown in Photo 3.2.52. According to the monitoring result, the lengths of these cracks increased. Currently, they applied sand blasting to these cracks and coated them with Epoxy

material. In addition, they restricted train speed from 100km/h to 80km/h since 2006. However, due to no increment of crack length or number, train speed was returned to 100km/h at 2015.


Photo 3.7.51 Cracks inside PC Box Girder

These cracks were inspected by UK Study Team in 2009 and an METI Study Team from Japan in 2012. However, these inspection results are not available yet.

Photo 3.7.52 Monitor Sheet for Cracks

Photo 3.7.53 View of Southeast from Railway Bridges

Normally, cracks in a PC Girder are generated vertically or inclined due to lack of resistance capacity against bending moment and shear force. And, if the concrete becomes weakened by things such as Alkali-aggregate reaction, there is a possibility to have horizontal cracks along the sheaths for the PC Cables. However, according to our inspection result, horizontal cracks are generated at most of the web areas where PC Cables are not installed. Therefore, it is not considered these cracks were generated by structural defects. In addition, the widths of the cracks are not wide. Thus, it is recommended to apply an adequate crack repair method and keep monitoring.

b) Environmental Considerations

i) Pollution

A residential area is observed and might be affected by Noise and Air pollution during and After Construction.

Construction activities on the river might affect the water quality of the river.

ii) Social Environment

A residential area is observed but impact on it would be limited.

No sacred facility is observed.

iii) Natural Environment

Cutting mangrove is expected on the both banks.

Photo 3.7.54 View of Southwest from Railway Bridges

Photo 3.7.55 View of Eastside from Railway Bridges

2) Bridge No. 92 and 93 (Vaitarna River)

(a) General Information of Bridge

General information of No. 92 and No. 93 is shown below;

- Location: between Vaitama Station and Saphale Station
- Bridge Length: 380m (No. 92) and 410m (No. 93)
- Span Number: 20 Spans (No.92) and 22 Spans (No. 93)
- Superstructure Type: Steel I-Girder
- Substructure Type: RC Abutment and RC Pier Column
- Construction Year: 1963

Photo 3.7.56 General View of No. 92 Bridge

Photo 3.7.57 Girder and Pier Column

(b) Inspection Result

a) Structural Consideration

According to the result of the inspection by Western Railway in 2012, there were some pile foundations that had damaged liner plates and the main re-bar of some piles was exposed. In addition, there is scouring. Regarding the pile foundations, Western Railway carried out repair work in 2015 as shown in Photo 3.7.58.

Photo 3.7.58 Repair of Damaged Pile

Regarding the Superstructure, Western Railway carried out replacement work for all girders in 1998. Due to progressing inclination of and cracks in the A2 Abutment, reconstruction work of A2 Abutment and replacement work of the Superstructure for the last span was carried out in 2016.

b) Environmental Consideration

i) Pollution

There is no residential areas nearby the bridge. Construction activities on the river might affect the water quality of the river.

ii) Social Environment

No dwellings will be affected.

No sacred facility is observed.

iii) Natural Environment

Cutting mangroves is expected on the both banks.

Photo 3.7.59 View of Westside from Railway Bridge

Photo 3.7.60 View of Eastside from Railway Bridges

(3) Judgement of Validity of Execution for Outlined Study for Railway Bridges in Mumbai

Based on result of site visit, execution of outline study for 4 railway bridges is as follows;

- No. 73 and 75

  Although it is confirmed many cracks at web of girder, width of cracks are narrow and it is not considered as serious situation. Therefore, these bridges will not be selected for execution of outlined design.

- No. 92 and 93

  There are some piles exposed by scouring. And, concrete pile was damaged. However, repair work has been conducted already; therefore, these bridges will not be selected for execution of outlined design.

3.7.5 Damaged Railway Bridges in Ratram

(1) Visual Inspection

Inspection results for Railway Bridges which are requested to inspect by Western Railway in Ratram are summarized in Table 3.7.5.

Table 3.7.5 Summary for Inspection Result on Railway Bridges

No.	Bridge Name	Length [m]	Construction Year	Superstructure Type	Inspection Result
1	No. 114	80	1960	PC I-Shaped Girder	Inclined cracks were observed at web. But, these cracks were repaired using epoxy and CFRP.
2	No. 129	60	1960	PC I-Shaped Girder	Due to observation of cracks, repair work by CFRP is now in progress.
3	No. 132	20	1960	PC I-Shaped Girder	Inclined cracks were observed at web. But, these cracks were repaired using epoxy and CFRP.
4	No. R5	20	1960	PC I-Shaped Girder	Inclined cracks were observed at web. But, these cracks were repaired using epoxy and CFRP.
5	No. R8	20	1960	PC I-Shaped Girder	Inclined cracks were observed at web. But, these cracks were repaired using epoxy and CFRP.

(2) Details of Inspection Result

Visual checking result for 5 Railway Bridges in Ratram are shown in below;

1) Bridge No.114

(a) General Information

General information of No. 114 is shown below;

- Location: between Dahod Station and Dhamarda Station
- Bridge Length: 80m
- Bridge Width: 4.30m
- Span Number: 4 Spans
- Superstructure Type: PSC I-Girder
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1958-60

Photo 3.7.61 General View of No. 114 Bridge

Photo 3.7.62 PSC I-Girder of No. 114 Bridge

(b) Inspection Result

a) Structural Consideration

Superstructure is of two PC-I girders with RCC deck slab. There are cracks in the web and bottom flange of the girders. These are structural cracks originating from the bottom of the girders. Repairing by CFRP Epoxy Coating Laminate applied to strengthen the superstructure and to increase the life of the structure, Carbon fibre strip stressed and anchored at both ends of Girders. (Three-Layers of Carbon Fibres at Bottom of I-Girder and on both sides of flange of girder)

Photo 3.7.63 CFRP Epoxy Coating

b) Environmental Considerations

i) Pollution
No residential area nearby the bridge. Construction activities on the river might affect the water quality of the river.

ii) Social Environment
No dwellings will be affected.
No sacred facility is observed.

iii) Natural Environment
No protected areas exist near the ROB. But there is a need to check the impact on the waterside of the birds.

Photo 3.7.64 View of South side from Railway Bridges

Photo 3.7.65 View of North side from Railway Bridges

2) Bridge No.132

(a) General Information

General information of No. 132 is shown below;

- Location: between Bordi Station and Anas Station
- Bridge Length: 20m
- Bridge Width: 4.30m
- Span Number: 1 Span
- Superstructure Type: PSC I-Girder
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1958-60

Photo 3.7.66 General View of No. 132 Bridge

Photo 3.7.67 PSC I-Girder of No. 132 Bridge

(b) Inspection Result

a) Structural Consideration

Superstructure is of two PC-I girders with RCC deck slab Carbon Fibre Reinforcement Polymer (CFRP) strips applied to existing girders. The CFRP strips were bonded on the bottom and side surfaces of the flange of girders to prevent-propagation of the existing cracks.

Photo 3.7.68 CFRP Epoxy Coating

b) Environmental Considerations

i) Pollution

There is no residential areas nearby the bridge. In the dry season, there is less water in the river. But in the rainy season construction activities on the river might affect the water quality of the river.

ii) Social Environment

No dwellings will be affected.

No sacred facility is observed.

iii) Natural Environment

No protected areas exist near the bridge.

Photo 3.7.69 View of South Side from Railway Bridges

Photo 3.7.70 View of North Side from Railway Bridges

3) Bridge No.129

(a) General Information

General information of No. 129 is shown below;

- Location: between BORDI Station and ANAS Station
- Bridge Length: 60.00m
- Bridge Width: 4.30m
- Span Number: 3 Spans
- Superstructure Type: PSC I-Girder
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1958-60

Photo 3.7.71 General View of No. 129 Bridge

Photo 3.7.72 PSC I-Girder of No. 129 Bridge

(b) Inspection Result

a) Structural Consideration

Superstructure is of two PC-I girders with RCC deck slab. According to Western Railway after cracks were observed in the PC-I girders in 2014, repairing work has been in progress at bridge No.129. Carbon Fibre Reinforcement Plates (CFRP) has been applied the damaged PC-I Girders. The CFRP were anchored on the bottom and side surfaces of the flanges of the girders. Epoxy Coating Laminate has been applied to strengthen the superstructure and to increase the life of the superstructure and prevent propagation of the existing cracks. However the deck slab of the Superstructures is damaged and reinforcement bars are exposed and not repaired.

Photo 3.7.73 Repair Work

b) Environmental Considerations

i) Pollution

No residential areas are nearby the bridge. In the dry season, there is less water in the river. But in the rainy season construction activities on the river might affect the water quality of the river.

ii) Social Environment

No dwellings will be affected.

No sacred facility is observed.

iii) Natural Environment

No protected areas exist near the bridge.

Photo 3.7.74 View of South side from Railway Bridges

Photo 3.7.75 View of North side from Railway Bridges

4) Bridge No. R5

(a) General Information

General information of No. R5 is shown below;

- Location: between Limkheda Station and Mangal Mahudi Station
- Bridge Length: 20m
- Bridge Width: 4.30m
- Span Number: 1 Span
- Superstructure Type: PSC I-Girder
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1958-60

Photo 3.7.76 General View of No. R5 Bridge

Photo 3.7.77 PSC I-Girder of No. R5 Bridge

(b) Inspection Result

a) Structural Consideration

Superstructure is of two PC-I girders with RCC deck slab. There are cracks in the web and bottom flange of the girders. These are structural cracks originating from the bottom of the girders and have been repaired using Epoxy Coating Laminate applied to strengthen the superstructure and to increase the life of the structure The Deck slab has been damaged and the bottom layer of the Deck slab reinforcement is exposed.


Photo 3.7.78 Exposed Reinforcement

b) Environmental Considerations

i) Pollution
No residential area is nearby the bridge.
In the dry season, there is less water in the river. But in the rainy season construction activities on the river might affect the water quality of the river.

ii) Social Environment
No dwellings will be affected.
A temple is located on the southwest side but will not be directly affected.

iii) Natural Environment
No protected areas exist near the bridge.



Photo 3.7.79 View of South side from Railway Bridges

5) Bridge No. R8

(a) General Information

General information of No. R8 is shown below;

- Location: between Limkheda Station and Mangal Mahudi Station
- Bridge Length: 20m
- Bridge Width: 4.30m
- Span Number: 1 Span
- Superstructure Type: PSC I-Girder
- Substructure Type: Stone Masonry Abutment
- Construction Year: 1958-60

Photo 3.7.80 General View of No. R8 Bridge

Photo 3.7.81 PSC I-Girder of No. R8 Bridge

(b) Inspection Result

a) Structural Consideration

The same as Bridge No.R5, Superstructure is of two PC-I girders with RCC deck slab. There are cracks in the web and bottom flange of the girders. These are structural cracks originating from the bottom of the girders and has been repaired using Epoxy Coating Laminate applied to strengthen the superstructure and to increase the life of the structure, The Deck slab has been damaged and the bottom layer of reinforcement of the deck is exposed.

Photo 3.7.82 Exposed Reinforcement

Photo 3.7.83 Cracking after Repair

b) Environmental Considerations

i) Pollution

No residential area is nearby the bridge.

In the dry season, there is less water in the river. But in the rainy season construction activities on the river might affect the water quality of the river.

ii) Social Environment

No dwellings will be affected.

No sacred facility is observed.

iii) Natural Environment

No protected areas exist near the bridge.

Photo 3.7.84 View of West side from Railway Bridges

Photo 3.7.85 View of East side from Railway Bridges

(3) Judgement of Validity of Execution for Outlined Study for Railway Bridges in Mumbai

Although inclined cracks are confirmed at web of girder, repair work by CFRP and Epoxy has already been applied. Therefore, this bridge will not be selected for execution of outline design.

3.8 Summary of Collected Data and Study for Next Step

Based on second field survey result, the target bridges are selected. A summary of collected data and the result of the site investigation are shown in Table 3.8.1.

Table 3.8.1 Summary of Collected Data

No.	Project Name	Counterpart	Comment	Next Stage
1	**Viaduct Construction Project in Delhi**	**Delhi Public Works Department**	**There are many new viaduct construction lines in congested areas. Due to construction at city center, it is necessary to propose Japanese Advanced Technology in order to minimize social impact. It is required to apply steel structure at Junction Structure. Outline study will be carried out at Junction Structure and viaduct to be connected Junction.**	**YES**
2	**Viaduct Construction Project in Bangalore**	**Karnataka Road Development Corporation**	**There are many new viaduct construction lines in congested areas. Due to construction at city center, it is necessary to propose Japanese Advanced Technology in order to minimize social impact. It is required to apply steel structure at Junction Structure. Outline study will be carried out at Junction Structure and viaduct to be connected Junction.**	**YES**
3	Viaduct Construction Project along IT Corridor in Chennai	Tamil Nadu Development Company	DPR is under preparation by TNDC. Advantage of Japanese Technology cannot be confirmed during site investigation.	
4	Viaduct Construction Project along National Highway No. 45 in Chennai	Tamil Nadu Highways and Minor Ports Department	Due to adequate width of existing road, advantage of Japanese Technology cannot be confirmed during site investigation.	
5	**Viaduct Construction Project along East Coast Road in Chennai**	**Tamil Nadu Highways and Minor Ports Department**	**Since width of existing road is not adequate to construct by conventional method, it is possible to apply Japanese Advanced Technology such as narrow space construction method. Therefore, outline study will be carried out.**	**YES**
6	Improvement Project for Railway Crossing in Chennai	Greater Chennai Corporation	DPR has been completed, and tendering of the Contractor will be commenced soon.	
7	Bridge Repair Project in Kolkata	MORTH Kolkata Office	Because of low traffic volume and limitation of large size vehicle, urgency cannot be confirmed.	
8	Intersection Improvement Project Plan at NH34 in Kolkata	MORTH Kolkata Office	Necessity cannot be confirmed during site investigation.	
9	Intersection Improvement Project Plan at NH34 and NH35 in Kolkata	MORTH Kolkata Office	Necessity cannot be confirmed during site investigation.	
10	New Mahatma Gandhi Bridge Construction Project in Patna	MORTH	DPR is under preparation by MORTH.	
11	**Reconstruction Project of ROBs in Mumbai** **- Ferere ROB** **- Balasis ROB** **- Mahalaxmi ROB** **- Delise ROB** **- Tilak ROB** **- Mahim ROB** **- Goregaon ROB**	**Western Railway**	**Most of ROBs have passed 100 years and some of ROBs has severe damage. Since reconstruction work above working railway, it is possible to apply Japanese Advanced Technology. Outline study will be carried out.**	**Yes**

No.	Project Name	Counterpart	Comment	Next Stage
12	**Rehabilitation Project of ROBs in Vadodara - LC No. 5/A ROB - LC No. 2/X ROB**	**Western Railway**	**Many cracks are observed at bottom of deck slab. Detailed investigation will be carried out by Non-destructive inspection. Based on this, there is possibility to apply Japanese Advanced Technology for repair work.**	**YES**
13	Rehabilitation Project of Railway Bridge in Mumbai - No. 73 and No. 75	Western Railway	There are many cracks along the Webs. But, due to narrow width of cracks, it is not considered to be a problem.	
	- No. 92 and No. 93	Ditto	Due to scouring some pile foundations were exposed and pile concrete was damaged, but repair work was done already.	
14	Rehabilitation Project of Railway Bridge in Ratlam - No. 114, No. 129, No. 132, No. R5 and No. R8	Western Railway	Inclined cracks were observed at the web. But, these cracks were repaired using epoxy and CPRP.	

4. ENVIRONMENTAL AND SOCIAL IMPACTS

4.1 Introduction

This chapter focus on the laws and legislations concerning to the environmental and social consideration in India along with the key items to be evaluated during the Environmental Impact Assessment (EIA).
The social and natural characteristic, the laws and legislations regarding to environmental and social consideration, outline of the environmental assessment and the mitigation measures of each project sites are shown in the chapter 8-11.

4.2 Related Environmental Legislation

4.2.1 EIA Law (Environmental Impact Assessment Notification (2006, 2009 and 2012))

In India, the EIA is stipulated in The Environmental (Protection) Act, 1986 and related processes are described in the Environmental Impact Assessment Notification (2006, 2009 and 2012). According to the EIA Notification (2006), projects listed in the SCHEDULE require prior Environmental Clearance (EC). All projects and activities are broadly categorized into two categories - Category A and Category B, based on the types and size of the projects.

The category contents of category A and B on roads are shown in Table 4.2.1 below. In the EIA, there are no contents on the railway business, therefore it will be examined with reference to other related categories such as road projects.

Table 4.2.1 List of Prior Environmental Clearance

Project Activity		Category		Conditions if any
		Category A (Jurisdiction by National Government)	Category B (Jurisdiction by State Government)	
7f	Highway	i) New National Highways; and ii) Expansion of National Highways greater than 30km involving additional right of way greater than 20m involving land acquisition and passing through more than one State.	i) New State Highways; and ii) Expansion of National/State Highways greater than 30km involving additional right of way greater than 20m involving land acquisition.	General Condition shall apply

Source :Notification, Ministry of Environment and Forests

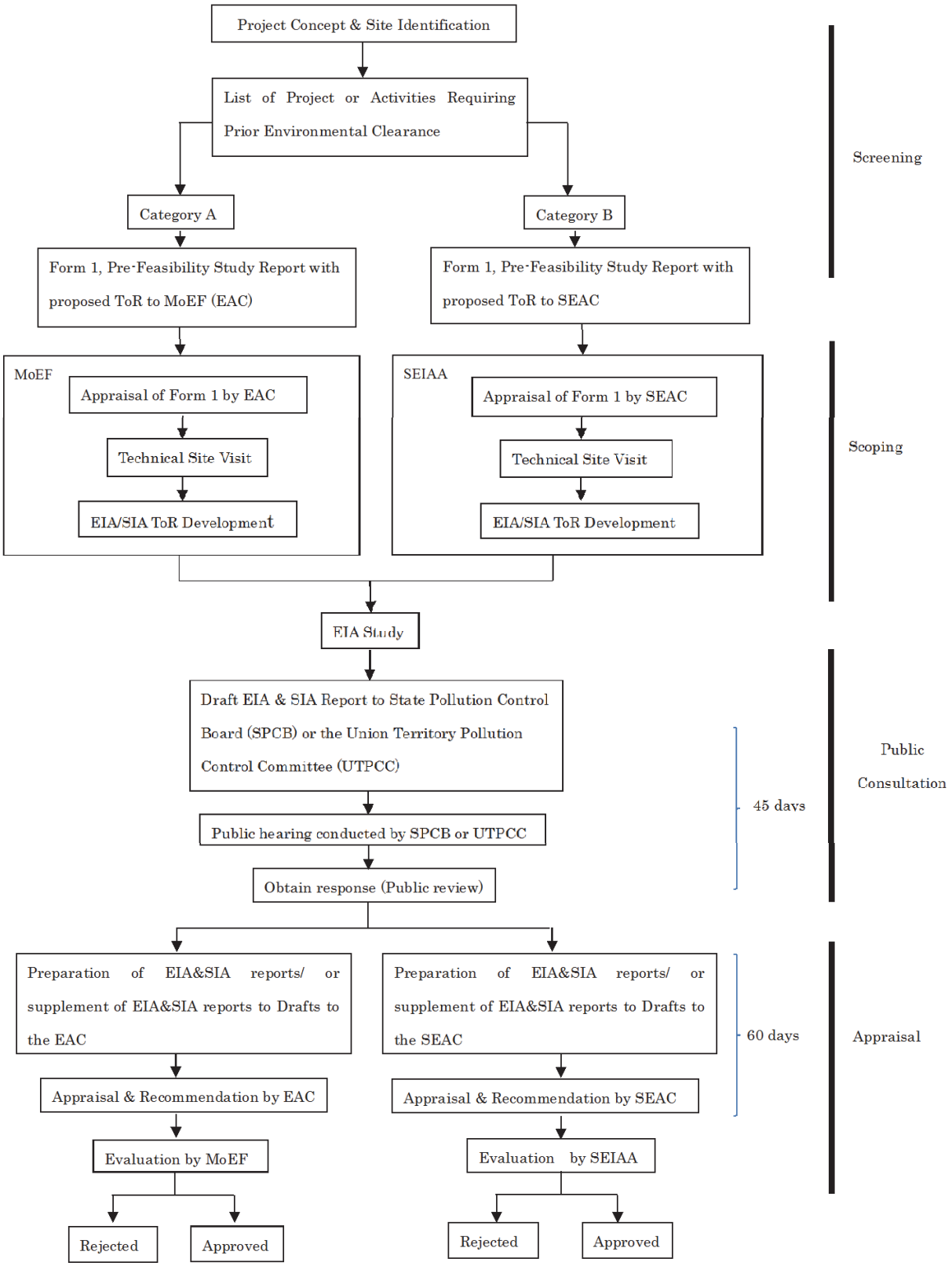
The projects included as Category A will require prior environmental clearance from the Central Government in the Ministry of Environment and Forests on the recommendations of an Expert Appraisal Committee (EAC). Projects included as Category 'B' in the Schedule will require prior environmental clearance from the State/Union territory Environment Impact Assessment Authority (SEIAA). The SEIAA shall base its decision on the recommendations of a State or Union territory level Expert Appraisal Committee (SEAC).

General process of obtaining the EC is shown in Figure 4.2.1.

In the viaduct construction, neither the environmental evaluation category A nor B is applicable. Therefore acquisition of Environmental Clearance (EC) is considered unnecessary.

For the projects requiring only reconstruction of superstructure etc., it is unnecessary to acquire permission such as Environmental Clearance. However, if the new alignment of bridge reconstruction is inside the Coastal Regulation Zone (CRZ), it is necessary to acquire Environmental Clearance from Ministry of Forestry and Environment.

The normal acquisition process of Environmental Clearance is shown in Figure 4.2.1.



Source: JICA Study Team (based on Environmental Impact Assessment Notification (2006, 2009 and 2012))

Figure 4.2.1 Flowchart of EIA

4.2.2 Coastal Regulation Zone (Coastal Regulation Zone Notification (2011))

Coastal Regulation Zone Notification (2011) restricts setting up and expansion of industries, operations and processes in the Coastal Regulation Zone (CRZ) in order to ensure the livelihood security of the community and living in the coastal zone as well as to conserve the coastal environment. CRZ is strictly classified and activities subjected to the CRZ are categorised into the permissible activities and prohibited activities. For those permissible activities, acquisition of the clearance is required and the process of seeking clearance is described in the notification. In relation to the project, mangrove forests and wetlands were confirmed in coastal areas and estuaries of the Reconstruction Project of ROBs in Mumbai (Maharashtra State). Depending on the location and activity of the project, the provincial government determines the need to acquire licenses for CRZ.

4.2.3 Land Acquisition (Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (2013))

Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (2013) received the approval of the President of India on September 2013 and it came into force from the 1st of January 2014.This new law stipulates not only appropriate compensation for landowners, but also rights for the person who earns his livelihood on the affected land. The fundamental principle of the new law is shown below;

- Clarification of purpose for land acquisition
- Amendment of compensation policy (fair evaluation methodology for compensation and disclosure, compensation for land owner and persons who has basis of livelihood on affected land)
- Obligation of social impact assessment
- Restriction of unintended use after land acquisition
- Monitoring of land acquisition process by state government and central government

With regard to the project, when the replacement of the new bridge with approach road is necessary, land acquisition as well as resettlement based on this act might be demanded. In that case, Social Impact Assessment needs to be conducted.

4.2.4 Tree Cutting Permission by Local Government

All permission shall be obtained after identification of final affected area and number of trees based on detailed design and investigation of affected trees. The Legal framework and process are shown in Table 4.2.2.

Table 4.2.2 Tree Cutting Permission Process

Item \ State Government		Delhi	Karnataka	Tamil Nadu	Maharashtra
1	Name of Permission	Permission of felling trees along the project corridor.	Permission of felling trees along the project corridor.	Permission of felling trees of affected area.	Permission for Logging of Project Affected Trees
2	Applicable law and regulation	Delhi Preservation of Tree Act, 1994	Karnataka Preservation of Tree Act, 1976 and Karnataka Preservation of Tree Rules, 1977	Tamil Nadu Preservation of Private Forest Act,1949	Maharashtra Felling of Trees (Regulations Acts, 1964) Amended in 2006
3	Approval Authority	Conservator of Forests, Delhi	Deputy Conservator of Forests/Tree Officer, Bengaluru Urban Division	District Forest Officer	MCGM (Municipal Corporation for Greater Mumbai)
4	Due date to be approved	60 days	30 days	60 days	67 days before cutting trees
5	Process for obtaining permission	(1) Identification of forest land to be diverted (2) Site survey of affected species, location and numbers (3) Submission of Application form. (4) Joint Inspection (5) NOC for tree felling	Filing of application form along with the site plan or survey sketch specifying clearly the site or survey numbers, the number of trees, the kind and girth of the tree sought to be cut and the reason for chopping the tree.	(1) Identification of forest land to be diverted (2) Site survey of affected species, location and numbers (3) Submission of Application form. (4) Joint Inspection (5) NOC for tree felling	(1) Marking affected area after detailed design (2) Fix the of affected area based on detailed design (3) Site survey affected species, location and numbers (4) Submission of application form and result of survey (5) Inspection and review (6) Issue of permission
6	Process period	3-6 months	3-6 months	3-6 months	(4)-(6): 3-6 months (depends on case)

Source: JICA Study Team

4.2.5 Other Relevant Laws

Other related Environmental Policies and Regulations in India are shown in Table 4.2.3.

Table 4.2.3 Related Environmental Legislation

No.	Name	Year
1	Environmental Protection Act	1986
2	Environment Impact Assessment Notification	2006, 2009, 2012
3	Forest Conservation Act	1927, 1980
4	National Forest Policy	1952, 1988
5	Coastal Regulation Zone Notification	2011
6	Wildlife Protection Act	1972
7	Land Acquisition Act	1894, 1989
8	Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act	2013
9	Air Prevention and Control of Pollution Act	1981
10	Hazardous Waste Management and Handling Rules	1989, 2003
11	Municipal Solid Waste Management and Handling Rules	2000
12	Noise Pollution Regulation and Control Rule	2000
13	Water Prevention and Control of Pollution Ac	1974

Source: JICA Study Team

4.3 Key Items to be Evaluated

Several key items are selected as indicators for final candidate bridges based on the natural and social environment features at the each bridge through preliminary environmental survey. Although most candidate bridges are located out of residential area, some dwellings and commercial shops are distributed along the approach road.

Selected key items, reasons and proposed criteria are shown in Table 4.3.1.

Table 4.3.1 Selected Key Items and Justification regarding Environmental Evaluation

Area	Key item	Justification	Detailed Item	Proposed Rating Criteria		
				A	B	C
I. Pollution	1. Noise and air pollution	Reconstruction of bridge with the new approach road may give negative impact to residential area	Distance from the nearest residential area	D≦50m	50<D<100m	100m≦D
	2. Turbid water	Foundation repair works may generate turbid water in the river	Necessity of foundation repair works	No. of repaired foundation 3 or more	No. of repaired foundation 1 or 2	No. of repaired foundation 0
II. Social	1. Involuntary Resettlement	Construction activities may give impact to dwellings and sacred places. Reconstructed bridge on new alignment may cause resettlement and land acquisition.	Number of affected dwellings	50≦No.	10<No.<50	No. ≦10
	2. Culture (sacred place)		Number of affected religious facilities	1&more (not moveable)	1&more (moveable)	No.=0
III. Natural	1. Biota	Mangrove area may be cut by setting up of construction yard and reconstructed bridge on new alignment.	Affected Mangrove area	10,000m^2≦A	100 <A< 10,000m^2	A≦100m^2

Source: JICA Study Team

4.4 Screening Result on JICA Guidelines

The bridges to be reconstructed may acquire land for new approach road, thus land acquisition and resettlement may be necessary. However it is expected that the number of re-settlers will not exceed 200 households. Hence reconstruction bridges are categorized as "Category B" and other bridges that will only get repair works done are classified as "Category C" basically in accordance with JICA Guidelines for Environmental and Social Considerations (2010).

Table 4.4.1 Definition of Category on JICA Guideline

Category	Definition
Category A	Proposed projects are classified as Category A if they are likely to have significant adverse impacts on the environment and society. Projects with complicated or unprecedented impacts that are difficult to assess, or projects with a wide range of impacts or irreversible impacts, are also classified as Category A. These impacts may affect an area broader than the sites or facilities subject to physical construction. Category A, in principle, includes projects in sensitive sectors, projects that have characteristics that are liable to cause adverse environmental impacts, and projects located in or near sensitive areas.
Category B	Proposed projects are classified as Category B if their potential adverse impacts on the environment and society are less adverse than those of Category A projects. Generally, they are site-specific; few if any are irreversible; and in most cases, normal mitigation measures can be designed more readily.
Category C	Proposed projects are classified as Category C if they are likely to have minimal or little adverse impact on the environment and society.

Source: JICA Guidelines for Environmental and Social Considerations (2010)

The screening results on JICA Guidelines of each project are shown in Chapter 8-11.

5. SURVEY ON DAMAGED BRIDGES

5.1 Introduction

Base on the visual investigation results at second field survey as mentioned in Chapter 3, Non-destructive inspection is planned to be carried out to bridges managed by Western Railway as shown below in order to understand damaged condition of bridge more clearly.

Table 5.1.1 Target Bridges for Non-destructive Survey from Western Railway

Type of Bridge	Location	Bridge Name
ROB (Concrete)	Vadodara	LC No. 5/A (No.8)
		LC No.2/X (No.9)

Source: JICA Study Team

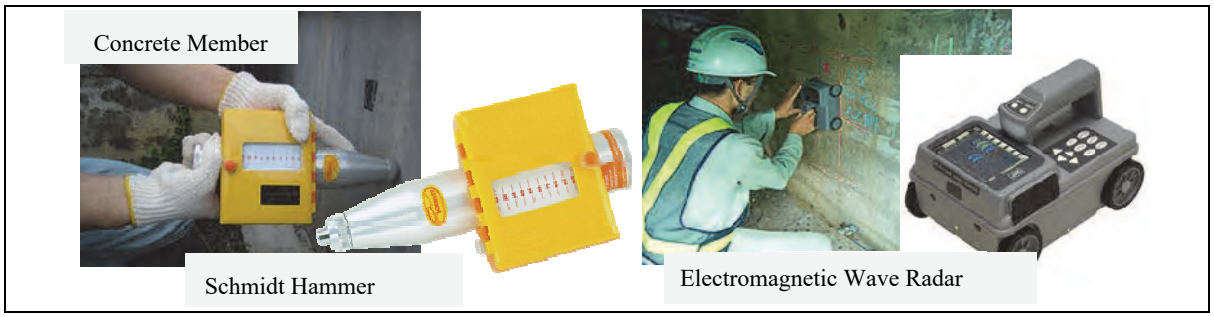
These bridges are PC Box Girder and have a lot of cracks at bottom of upper deck slab. It is considered that cause of this kind of damage is either lack of concrete strength or incorrect allocation of re-bar. Therefore, it is required to carry out proper rehabilitation and reinforcement work based on detailed investigation result and proper understanding of damage conditions of bridges. All of target bridges are opened to the public traffic; therefore, it is required not to close existing traffic during investigation work. In order to carry out investigation work by keeping existing traffic, execution of Non-destructive inspection is proposed.

5.2 Non-destructive Inspection

5.2.1 Inspection Items

For the concrete members, estimate the compressive strength of the concrete by "Schmidt Hammer Inspection" and examination of the state of arrangement and diameter of reinforcing bar inside the concrete by "Wave Radar System".

Based on the results, structural resistance and durability performance are estimated, and it is possible to judge necessity of repair work and carry out basic design for repair and reinforcement work.



Source: JICA Study Team

Figure 5.2.1 Non-destructive Inspection

5.2.2 Outline of Inspection Work

Outline of "Schmit Hammer Inspection" and "Wave Radar System" which are planned to be carried out by this survey are shown as follows;

(1) Schmit Hammer Inspection

In order to measure concrete strength of existing structure, compressive test is executed against core sampling specimen. However, "Schmit Hammer Inspection" is widely applied because "Schmit Hammer Inspection" can measure concrete strength without giving any damage to the existing structure and can carry out easily. "Schmit Hammer Inspection" was developed at 1948 in Switzerland, has old history and well known inspection method in the world. In Japan, Manual of this inspection method was established by Material Testing Research Association of Japan at 1958.

This inspection method is used for estimation of surface concrete strength. There is a relationship between rebound height (rebound degree) of test hammer when test hammer hit concrete surface by certain energy and concrete strength therefore, this method was started to use for estimation of concrete strength. Measurement range is 10~70 [N/mm2], and fudge factor I about ±15%.

Concrete strength measurement is carried out by measurement of rebound degrees at 9 points which have distance of 25~90mm. Average value of these 9 points measurement results is applied. Following formula is used for estimation of concrete strength from average value of rebound degree measured at site.

$F\ [N/mm^2] = (-18.0 + 1.27 \times R0) \times \alpha$

Where F: Concrete strength
R0: Rebound Degree
A: Factor of material age

(2) Wave Radar System

Technology of wave radar system was existed about at 1939; however, application of this technology to concrete structure had not been made until Wave Radar System Equipment was developed by Japanese Company. Since that Wave Radar System Equipment was developed by American Company and Switzerland Company. Currently, "Wave Radar System" became popular inspection method in developed country.

This inspection method can search re-bar, void, honeycomb and crack inside concrete and cover thickness of re-bar, also. Mainly, this inspection is used for confirmation of re-bar location and measurement of cover thickness. Measured object is re-bar, D10-D51 and fudge factor is about ±10mm.

Measured area is more than 60cm x 60cm, and measurement is made at 2-3 points at both of soundness part and damaged part.

5.2.3 Current Status of Non-destructive Inspection in India

As mentioned in Chapter 2, basic technique about repair work is specified in IRC SP40-1993 in India. "Schmit Hammer Inspection" and "Wave Radar System" are specified in this specification, therefore, these technique are considered as well known technique in India. "Schmit Hammer Inspection" is used at site frequently; however, "Wave Radar System" has not been applied actual site inspection work, yet.

5.3 Execution of Non-destructive Inspection in the Survey

Issuance of direction/acceptance letter from MOR was required from Western Railway for Non-destructive inspection before commencement of third field survey.

Therefore, JICA India Office and JICA Study Team had meeting with MOR, and requested MOR to issue direction/acceptance letter.

Although MOR understands purpose of this study and contents of Non-destructive inspection, direction/acceptance letter had not been issued during third field survey. As a result of this, Non-destructive inspection could not been carried out during third field survey, even preparation work of Non-destructive inspection was completed.

Actual strength of structure will be estimated based on Non-destructive inspection result. Based on this result, it is possible to decide scale of repair and rehabilitation work (number of the layer or area of CFRP installation, for example). Because of none execution of Non-destructive inspection at site, it became difficult to carry out outline study for repair and rehabilitation work. As a result of discussion between JICA India Office and JICA Study Team, it was decided to omit “Rehabilitation Project of ROBs in Vadodara” from scope of this survey finally.

5.4 Recommendation to "Rehabilitation Project of ROBs in Vadodara"

As described in the previous chapter, due to non-execution of the Non-destructive inspection in the Survey, study for necessity of repair or rehabilitation work and its magnitude for "Rehabilitation Project of ROBs in Vadodara" cannot be carried out by the Survey. However, as described in Chapter 3, situation of candidate bridges are severe, therefore, following actions are recommended to be carried out.

- Measurement of actual concrete strength for candidate bridges by Non-destructive inspection or concrete strength test by core sampling
- Review of shear capacity and flexural capacity based on actual concrete strength
- Monitoring of width and length for cracks
- Restriction of axial weight

It is necessary to carry out repair / rehabilitation work by installing CFRP or reconstruction work in case shear capacity and flexural capacity is lacked based on the measurement result of the actual concrete strength. If it is judged shear capacity and flexural capacity is sufficient, repair of cracks shall be carried out and it is also recommended to carry out crack monitoring.

6. JAPANESE ADVANCED TECHNOLOGY CAN BE APPLIED

6.1 Introduction

Based on selection result described in Chapter 3, the outline design was made against selected 4 projects in Chapter 8-11. In this chapter, it is mentioned about Japanese advanced technologies can be applied to these projects. Contents of these projects are summarized in Table 6.1.1

Table 6.1.1 Summary of Projects for Further Study

No.	Project Name	Counterpart	Comment
1	Viaduct Construction Project in Delhi	Delhi Public Works Department	There is plan to construct viaduct for 11 corridors in Delhi. Outline study is made for about 1.55km overlapped section by North-South Corridor and East-West Corridor, including Junction.
2	Viaduct Construction Project in Bangalore	Karnataka Road Development Corporation	There is plan to construct viaduct for 6 corridors in Bangalore. Outline study is made for about 1.55km overlapped section by North-South Corridor and East-West Corridor, including Junction.
3	Viaduct Construction Project along East Coast Road in Chennai	Tamil Nadu Highways and Minor Ports Department	In order to solve traffic congestion, viaduct construction is planned along East Coast Road in Chennai. Since there is a 7.77km section the width of the existing road is not wide enough to construct viaduct by conventional methods, study on application of Japanese Advanced Technology such as narrow space construction method is carried out.
4	Reconstruction Project for ROBs in Mumbai 1. Ferere ROB 2. Balasis ROB 3. Mahalaxmi ROB 4. Delise ROB 5. Tilak ROB 6. Mahim ROB 7. Goregaon ROB	Western Railway	Most of the targeted 7 bridges were constructed nearly 100 years ago, and some structures were severely damaged. Due to reconstruction of the bridges above the existing railway, some Japanese Advanced Technology may be applied.

6.2. Advanced Technology can be applied in these Projects

6.2.1 Policy on selection of Japanese Advanced Technology

In order to select applicable Japanese Advanced Technology against 4 projects shown in Table 6.1.1, selection work is carried out in accordance with flow chart shown as Figure 6.2.1.

Figure 6.2.1 Flow Chart for Selection of Japanese Advanced Technology

6.2.2 Features of the Selected Projects

After reviewing the contents of all Projects as described in Chapter 3, the following features can be pointed out.

(1) Construction of Bridge/Viaduct in Very Congested Area

In order to minimize the negative social impact, it is required to apply advanced technology which can reduce construction period, space and release of harmful substances such as noise, air pollution, vibration, polluted sludge from the excavation and so on.

(2) Reconstruction of ROBs by Low Depth of Girder

Due to the requirement to increase the clearance from 5.5m to 6.0m at ROBs of Western Railway, because of revision of electricity supply system to rail car, the height of the new Superstructure has to be as low as possible in order to prevent negative impact against area along approach road.

6.2.3 Advanced Technologies can be Applied to Projects

In consideration of the features of the Projects and the latest advanced technology in Japan, a list of advanced technology is summarized as shown in Table 6.2.1. A detailed explanation for each advanced technology is shown in later chapters.

Table 6.2.1 List of Advanced Technology

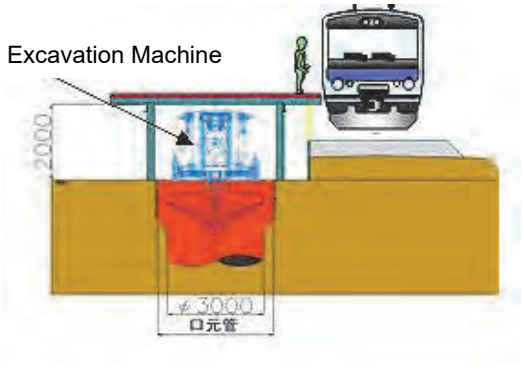
Applicable Features of Selected Project	Name of Technology	Feature
(1)	Cast-in-place Concrete Pile under low clearance	Construction Equipment can construct cast-in-place concrete pile under low clearance and narrow space
(1)	Rotary Penetration Steel Pile	New type of steel pile which can be constructed in a narrow space and utilize a smaller size of pile cap due to large load carrying capacity compared with Cast-in-place Concrete Pile. In addition, due to no generation of excavated soil, low vibration and low noise, this pile type is very eco-friendly type.
(1)	PC Well	New type of foundation which can be constructed in a narrow space and utilize a smaller size of foundation because no pile cap is required
(1)	Steel Pipe Socket Connection Method	New connection method between steel pier column and pile cap/pile by omitting anchor frame which can achieve shorter construction time and possible to apply PC Well foundation.
(2)	Bi-Prestressing PC System	New Superstructure type which can utilize a thinner Girder Height than the conventional type
(2)	Pre-flexed PC Beam	New Superstructure type which can make thinner the Girder Height than conventional type
(2)	Composite Floor Slab	New Superstructure type which can utilize a thinner the Girder Height than the conventional type
(1)	Composite Slab	New deck slab type which has high durability and safe for construction, especially, underneath of deck slab

(1) Cast-in-place Concrete Pile under low clearance

1) Outline of Construction Method

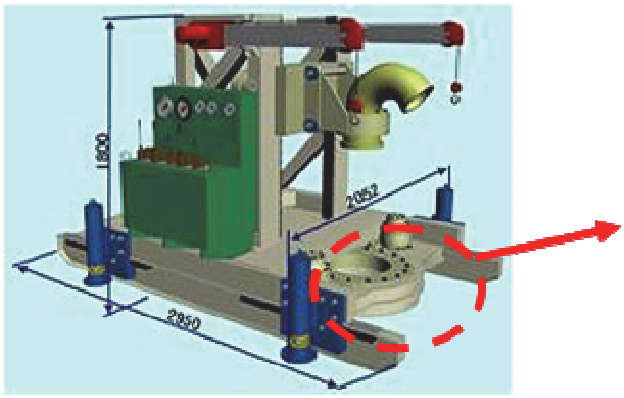
This technique employs a turntable type driving system for the excavation rod. It is possible to construct within a height of less than 2m by combining a special type of Kelly rod.

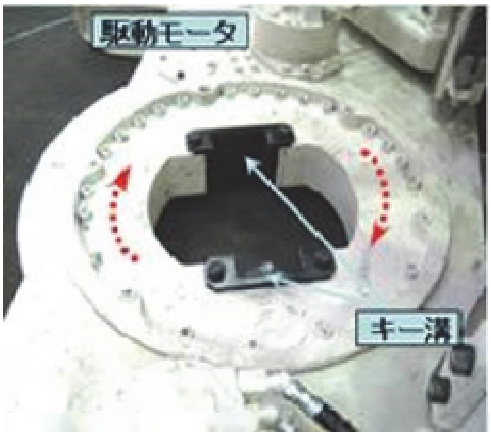
Construction of Cast-in-situ pile under low clearance (under existing bridge) becomes possible by using this special type of equipment.



Source: HP of East Japan Railway Company

Figure 6.2.2 Sketch for Applying this Technology





Source: - HP of East Japan Railway Company

Source: HP of Tekken Corporation

Figure 6.2.3 Drilling Machine for this Technology

2) Possibility to Apply in India

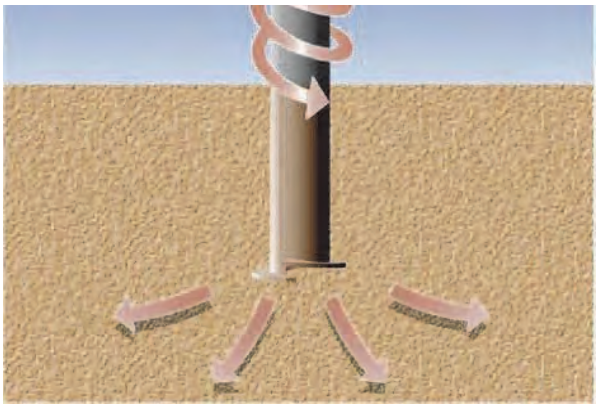
This technique is applied expansion work of station platform and construction work of ROB in Japan. These kinds of works are required to be carried out not only in Japan, but also in other countries. Therefore, it is considered this technique has competitiveness in international market. Because construction work is done by special equipment, it is possible to introduce this technique in India easily if special equipment is imported and receive instruction from Development Company for this technique.

(2) Rotary Penetration Steel Pile

1) Outline of Construction Method

This is a Steel Pipe Foundation in which a helical steel plate (Wing) is welded to the tip of the steel pipe. The pile is then rotated so that it screws into the ground.

It obtains a large bearing force because of the base enlarging effect of the Wing. And, due to the penetration method, there is no excavated soil at the site. Therefore, it will be possible to employ eco-friendly construction with no emissions, low-vibration and reduce the number of piles.



Source: Pamphlet of NS Ecopile

Figure 6.2.4 Image of Rotary Penetration

Source: Pamphlet of NS Ecopile

Figure 6.2.5 Photograph of Rotary Penetration Steel Pile (Left: Installation Machine, Right: Tip of Rotary Penetration Steel Pile)

2) Possibility to Apply in India

This technique generates no emission, low vibration and low noise, therefore, is considered as eco-friendly construction method. In addition, it is possible to construct at narrow space. This technique can show effectiveness especially, at very congested area. This technique has been applied not only Japan but

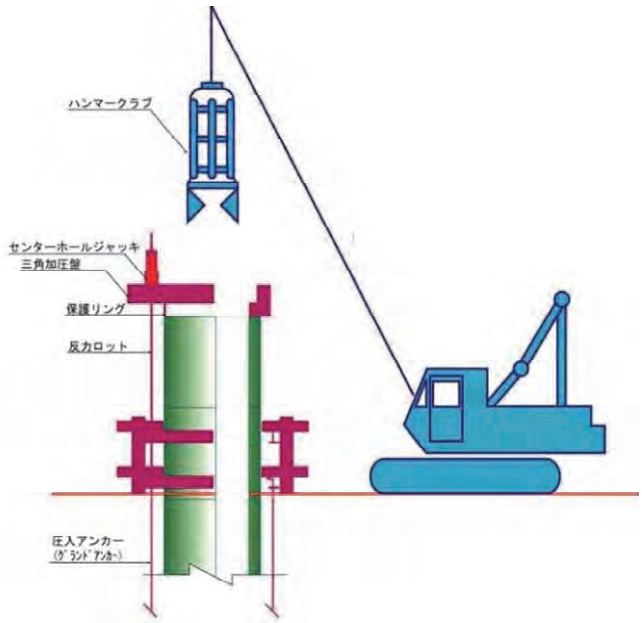
also other countries such as Vietnam and Uganda for flyover construction project inside city area by Japanese ODA. Therefore, it is considered this technique has competitiveness in international market.
Pile material used for this technique has "Wing" which is made by high-tensile steel at pile tip. Fabrication of "Wing" has know-how by Development Company, therefore, it is difficult to fabricate "Wing" by other company. However, fabrication of pile itself and connection work between pile and wing does not require special technique. It is possible to fabricate pile material and construct pile foundation by Indian Contractor, therefore, it is possible to introduce this technique in India easily if they receive instruction from Development Company for this technique.

(3) PC Well

1) Outline of Construction Method

The PC Well foundation is comprised of precast concrete cylinders (Circular or Oval shape). Each precast concrete cylinder is connected to the adjacent cylinder by a Post-tension method after they are placed at the site. After placing precast concrete block and connecting them to each other, excavation work is carried out and they are compressed into the ground.

This technique is very effective, especially inside city, since, it is possible to construct large diameter pile (up to D=8m), construct small size foundation by Steel Pipe Socket Connection Method described later.



Source: HP of Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism

Source: HP of Nippon Hume Corporation Ltd.

Figure 6.2.6 Sketch and Photograph of PC Well

2) Possibility to Apply in India

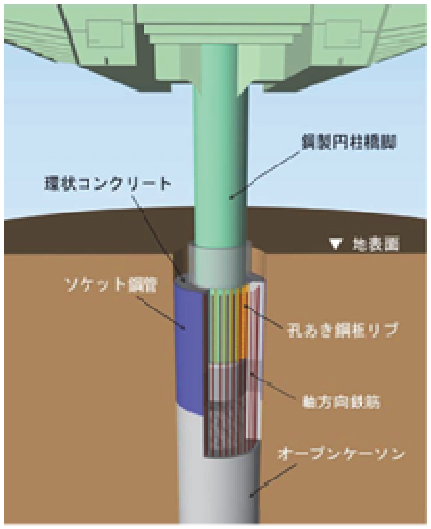
This technique can construct at narrow space, therefore, can show effectiveness especially, at congested city area. This kind of construction work will be required not only Japan but also other countries. Therefore, it is considered this technique has competitiveness in international market.

This technique comprises of pile body part which is made by pre-cast concrete and post-tension part which can connect segments each other. Each structure is not special one, therefore, it is possible to introduce this technique in India easily if they receive instruction from Development Company for this technique.

(4) Steel Pipe Socket Connection Method

1) Outline of Construction Method

The Steel Pipe Socket Connection Method is a jointing technique of inserting a Steel Column into a Steel Pipe Socket which is constructed at the top of the foundation, and filling it with concrete. It is possible to reduce the construction period because it omits the Pile Cap and Anchor Frame used in the conventional method.



Source: Investigation Report by MLIT named "solidification construction by quick construction method for Kosaka intersection"

Figure 6.2.7 Sketch and Photograph of Steel Pipe Socket Connection Method

2) Possibility to Apply in India

Since conventional Anchor Frame connection method between steel column and concrete foundation is very complicated work, it is required long working time at site. This technique can reduce working time at site, therefore, this technique has effectiveness to apply especially flyover and viaduct construction project inside city. This kind of construction work will be required not only Japan but also other countries. Therefore, it is considered this technique has competitiveness in international market.

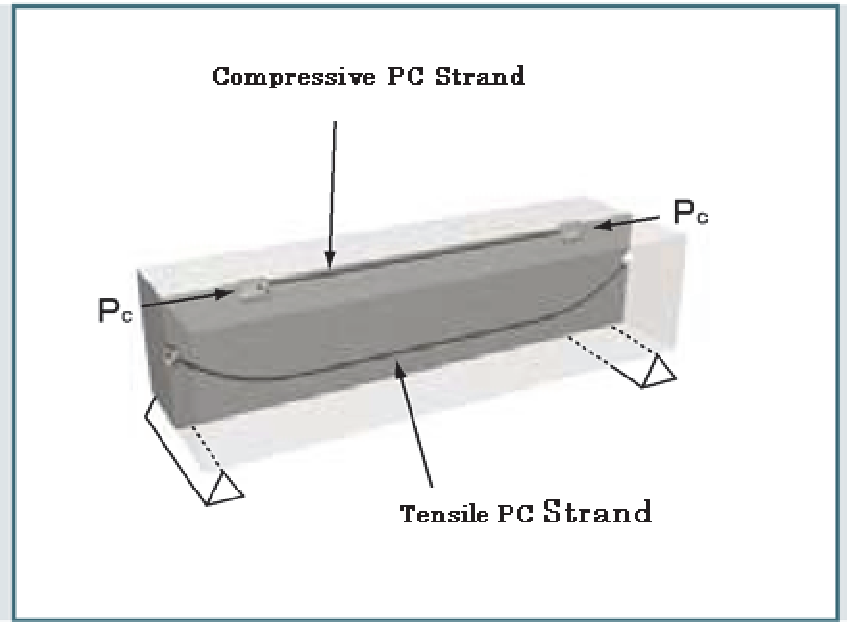
This technique requires knowhow especially at connection part between steel column and filling concrete inside socket structure. However, it is possible to construct by Indian Contractor technically; therefore, it is possible to introduce this technique in India easily if they receive technical support and instruction from a Company that developed this technique.

(5) Bi-Prestressing PC System

1) Outline of Construction Method

This construction method is to combine a conventional prestressed method (give compressive force to concrete by tensioning the PC Strand) with a Post-compression method (give tension force to concrete by pushing PC strand). It is thereby possible to reduce girder height and extend span length.

Ratio of Span Length and Girder Height will be approximately 1/32 for this superstructure type and smaller than conventional PC Girder type which has approximately 1/18 ratio of Span Length and Girder depth.



Source: Pamphlet of Bi-Prestressing System Institution

Figure 6.2.8 Model of Bi-Prestressing System

2) Possibility to Apply in India

This technique has advantage to apply the project which requires to reduce girder depth in order to avoid negative impact against surrounding environment (reduce approach road length and connect existing intersection) especially at very congested area inside city. There are many projects needs to reduce increment of additional vertical alignment as same as reconstruction project of ROB in Western Railway, therefore, it is considered this technique has competitiveness in international market.

This technique does not use any special material, therefore, it is possible to fabricate and erect by Indian Contractor. However, due to no experience of usage of compressive PC Strand, technical support and instruction from a Company developed this Girder is required in order to use this technique by Indian Contractor.

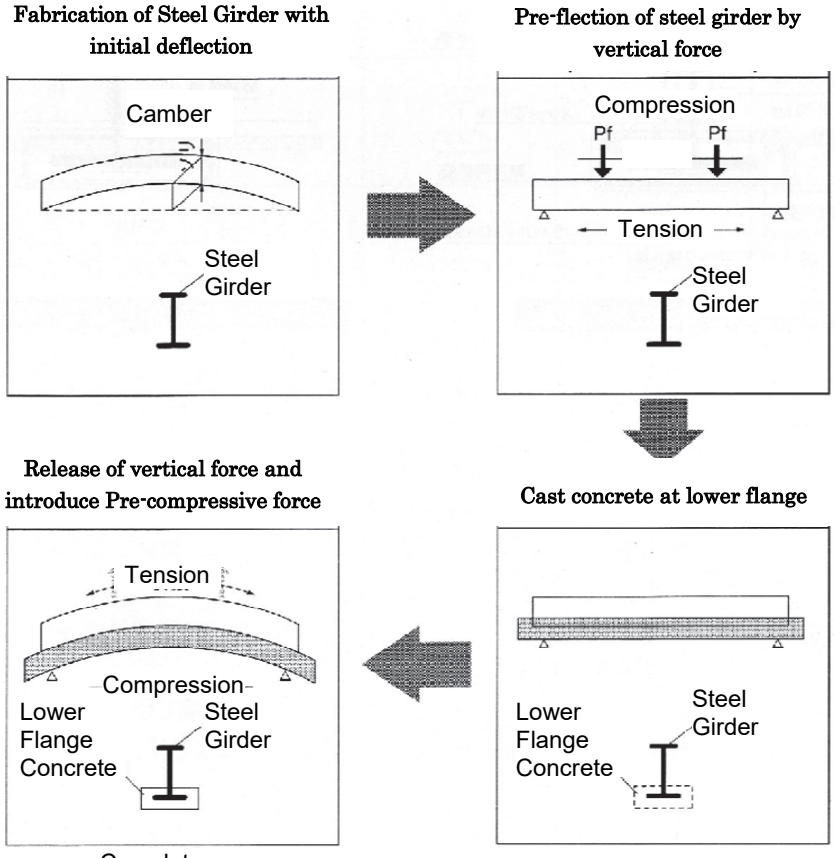
(6) Pre-flexed PC Beam

1) Outline of Construction Method

This is a composite girder of steel and concrete.

The Steel girder is pre-flexed in advance by applying a vertical force and introducing pre-stress by releasing it after casting the concrete for the lower flange. It is possible to use this method of construction under very low girder depth compared to other methods.

Ratio of Span Length and Girder Height will be approximately 1/35 for this superstructure type and smaller than conventional PC Girder type which has approximately 1/18 ration of Span Length and Girder Depth.



Source: Pamphlet of PREBEAM Promotion Association

Figure 6.2.9 Fabrication Sequence of Pre-flexed PC Beam

2) Possibility to Apply in India

Feature of this technique is same as "Bi-Prestressing PC System" mentioned in previous chapter, therefore, it is considered this technique has competitiveness in international market.

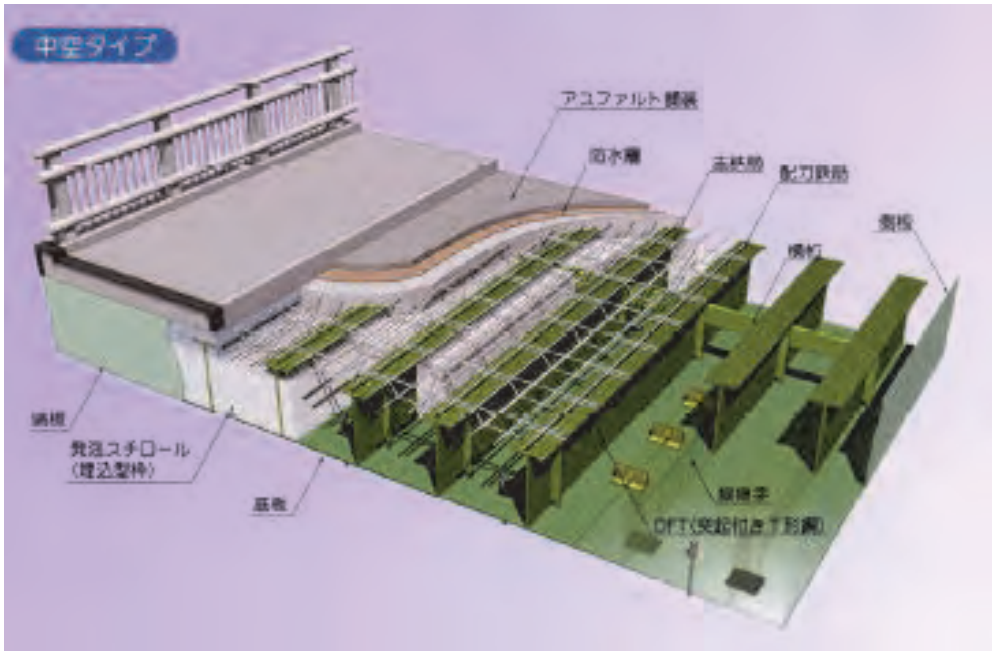
Due to no special material used by this technique, it is possible to fabricate and erect by Indian Contractor. However, instruction from Development Company is required to knowhow for connection part between concrete and steel at lower flange.

(7) Composite Deck Slab Girder

1) Outline of Construction Method

The main girder is a simple structure that is comprised of T-shape steel, a bottom plate and concrete filling as the main cross section. In order to reduce the Girder Depth, the T-shaped steel is provided with projections which act as shear keys.

Ratio of Span Length and Girder Depth will be approximately 1/30-1/42 (extremely thin structure) for this superstructure type and smaller than conventional PC Girder type which has approximately 1/18 ration of Span Length and Girder Depth.



Source: Pamphlet of Composite Floor Slab

Figure 6.2.10 Sketch of Composite Deck Slab Girder

2) Possibility to Apply in India

Feature of this technique is same as “Bi-Prestressing PC System” mentioned in previous chapter, therefore, it is considered this technique has competitiveness in international market.

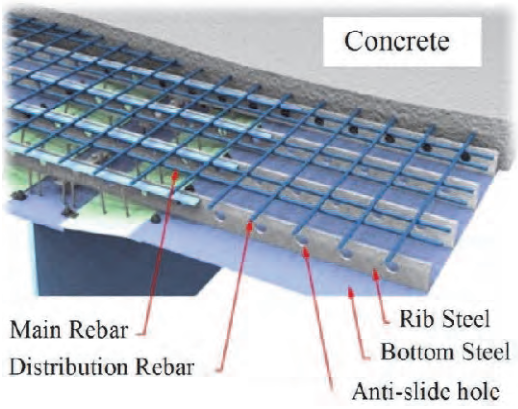
Due to no special material used by this technique, it is possible to fabricate and erect by Indian Contractor. However, instruction from a Company this girder with the construction experience of is required to get knowhow for connection part between filling concrete and steel.

(8) Composite Deck Slab

1) Outline of Construction Method

This is new type of deck slab structure composite of steel structure and concrete structure. Bottom of the composite deck slab is covered by steel plate reinforced by T/I shaped steel, then, concrete will be poured after installation of bottom steel.

This deck slab has more durability compared with conventional RC deck slab, and can achieve quick construction. Due to installation of steel plate at first, there is no risk about leakage of wet concrete during construction, and cause no restriction of traffic usage underneath of deck slab during construction work. Sketch of Composite Deck Slab is shown in Figure 6.2.11.



Source: HP of New Technology Information System

Figure 6.2.11 Composite Deck Slab

2) Possibility to Apply in India

Due to application of this technique, it is not required to restrict existing traffic under deck slab during construction work. Therefore, it can show effectiveness at congested area. In addition, this technique has more durability compared with conventional RC Slab and can show effectiveness of application of this technique at underdevelopment countries which normally have problem about overloaded truck, therefore, it is considered this technique has competitiveness in international market.

Due to no special material used by this technique, it is possible to fabricate and erect by Indian Contractor. However, instruction from a Company with the construction experience is required to get knowhow for connection part between filling concrete and steel.

7 TRAFFIC DEMAND FORECAST AND ECONOMIC ANALYSIS

7.1 Introduction

Economic Analysis is conducted on 4 projects among 5 selected projects in Chapter 3 apart from "Rehabilitation of ROB in Vadodara Section", such as Viaduct Construction Project in Delhi, Viaduct Construction Project in Bangalore, Viaduct Construction Project along East Coast Road in Chennai, Reconstruction Project of ROBs in Mumbai. "Rehabilitation Project of ROBs in Vadodara" was excluded due to lack of permission to conduct the Non-destructive inspection.

In this chapter, the basic data is organized in such a way that it is applicable for the economic analysis for each project. The results of the economic analysis and traffic demand forecasts are shown in chapter 8-11.

7.2 Traffic Count Survey

7.2.1 General

The data obtained from the traffic count survey will be utilized to carry out traffic demand forecast and to evaluate benefits from bridge improvements. The results of the traffic count survey for each project are shown in Chapter 8-11.

7.2.2 Classified Traffic Volume Counts

Traffic counts were recorded continuously for 24 hours on each location. For carrying out the counts, the vehicles have been grouped under the following categories as in Table 7.2.1

Table 7.2.1 Vehicle Classification Systems

<table>
<tr><th colspan="2">Motorized Traffic</th><th>Non-motorized Traffic</th></tr>
<tr><td colspan="2">2 wheelers, Auto rickshaw (3-wheeler),Passenger Car, Jeep, Taxi & Van, Goods Car, Traveler, School Van</td><td rowspan="4">Bicycle, Cycle Rickshaw, Animal Drawn/Hand Cart</td></tr>
<tr><td>Bus</td><td>Mini Bus, Standard Bus (Government/Private)</td></tr>
<tr><td>Trucks</td><td>Light Commercial Vehicle (LCV), 2&3 – Axle Rigid Chassis Truck (HCV), Multi Axle Truck (MAV)</td></tr>
<tr><td>Other Vehicles</td><td>Agriculture Tractor, Tractor & Trailer etc.</td></tr>
</table>

For the purpose of counts, a day was divided into two shifts of 12 hours each and different groups of enumerators with a supervisor have been assigned for each shift. The count data was recorded at 15 minutes intervals for each vehicle group for each direction of travel separately. Hourly totals have been made in the end of the shift.

7.3 Traffic Demand Forecast

7.3.1 Introduction

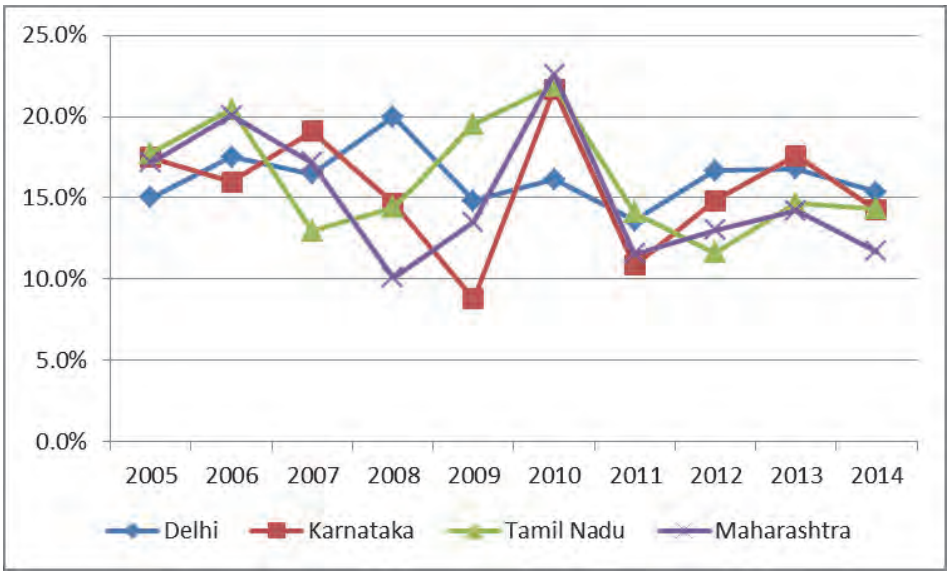
To calculate the traffic demand forecast, the JICA Study Team utilized national statistical data of India, such as Gross Domestic Product (GDP) of India, Gross State Domestic Product (GSDP) of study area (Delhi, Karnataka, Tamil Nadu, and Maharashtra), and number of vehicle registrations of study area (Delhi, Bangalore, Chennai, and Mumbai), and annual growth rate of the total length of National Highway.

- Statistical Data
  - All India Report of 6th Economic Census (Ministry of Statistics & Programme Implementation, March 2016)
  - GSDP of study area (Delhi, Karnataka, Tamil Nadu, and Maharashtra) (Ministry of Statistics & Programme Implementation, March 2016)
  - Statistical Year Book, India 2016(Ministry of Statistics & Programme Implementation, December 2015)
  - Future Estimation of Population (National Commission on Population, May 2006)

7.3.2 Estimation of Growth Rate of Traffic Volume

The following graphs show the statistical data of items relevant to traffic growth rate, such as nominal Annual Growth Rate of NOMINAL Gross State Domestic Product (GSDP), Annual Growth Rate of REAL Gross State Domestic Product (GSDP), Annual Growth Rate of Number of Vehicle Registrations, Annual Growth Rate of Total Length of National Highway.

(1) NOMINAL GSDP of Study Area (Delhi, Karnataka, Tamil Nadu, and Maharashtra)



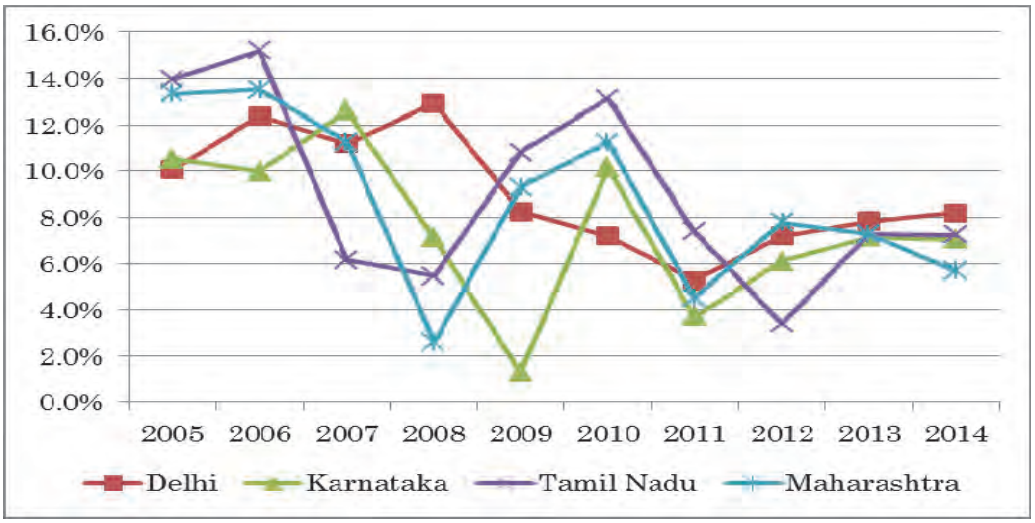
State\UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Delhi	15.0%	17.5%	16.5%	20.0%	14.8%	16.1%	13.6%	16.7%	16.8%	15.3%	16.2%
Karnataka	17.5%	16.0%	19.1%	14.7%	8.8%	21.7%	10.8%	14.8%	17.6%	14.2%	15.5%
Tamil Nadu	17.7%	20.4%	13.0%	14.4%	19.5%	21.9%	14.1%	11.6%	14.7%	14.3%	16.2%
Maharashtra	17.2%	20.1%	17.2%	10.1%	13.5%	22.6%	11.5%	13.0%	14.2%	11.7%	15.1%

Source: Website of Ministry of Statistics and Programme Implementation

Figure 7.3.1 Annual Growth Rate of Nominal GSDP in study area (Delhi, Karnataka, Tamil Nadu, and Maharashtra)

The JICA Study Team selected 4 states to which the study areas belong. The average annual growth rate in the most recent 10 years (2005-2014) is very high at more than 15%

(2) REAL GSDP of Study Area (Delhi, Karnataka, Tamil Nadu, and Maharashtra)



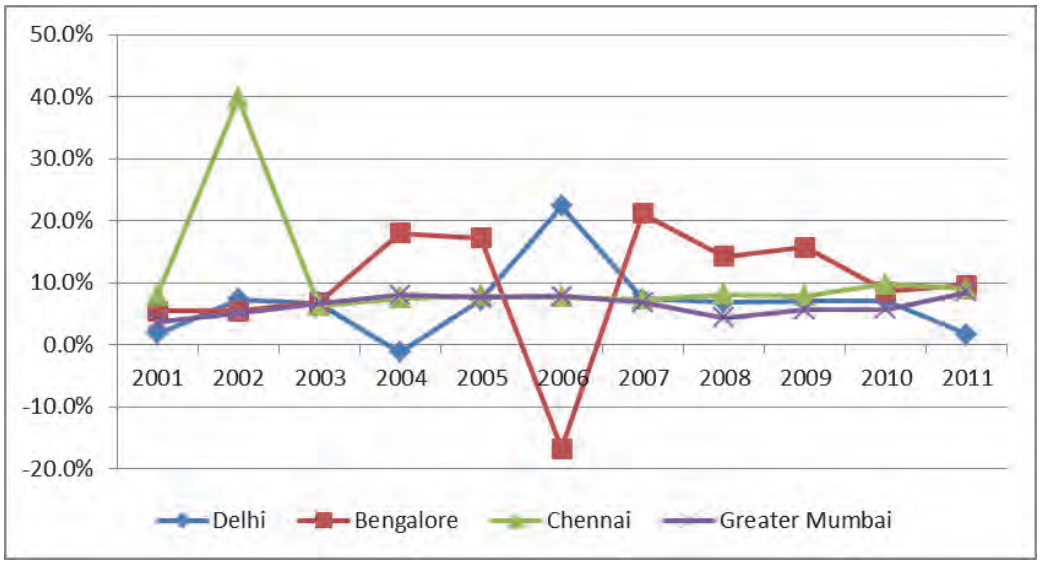
State\UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Delhi	10.0%	12.4%	11.2%	12.9%	8.2%	7.2%	5.3%	7.2%	7.8%	8.2%	9.0%
Karnataka	10.5%	10.0%	12.6%	7.1%	1.3%	10.2%	3.7%	6.1%	7.2%	7.0%	7.6%
Tamil Nadu	14.0%	15.2%	6.1%	5.5%	10.8%	13.1%	7.4%	3.4%	7.3%	7.2%	9.0%
Maharashtra	13.3%	13.5%	11.3%	2.6%	9.3%	11.3%	4.5%	7.8%	7.3%	5.7%	8.7%

Source: Website of Ministry of Statistics and Programme Implementation

Figure 7.3.2 Annual Growth Rate of Real GSDP in Study Area (Delhi, Karnataka, Tamil Nadu, and Maharashtra)

The JICA Study Team selected 4 states to which the study areas belong. The average annual growth rate in recent 10 years (2005-2014) is very high at between 7.6% to 9.0%.

(3) Annual Growth Rate of Number of Vehicle Registrations by City



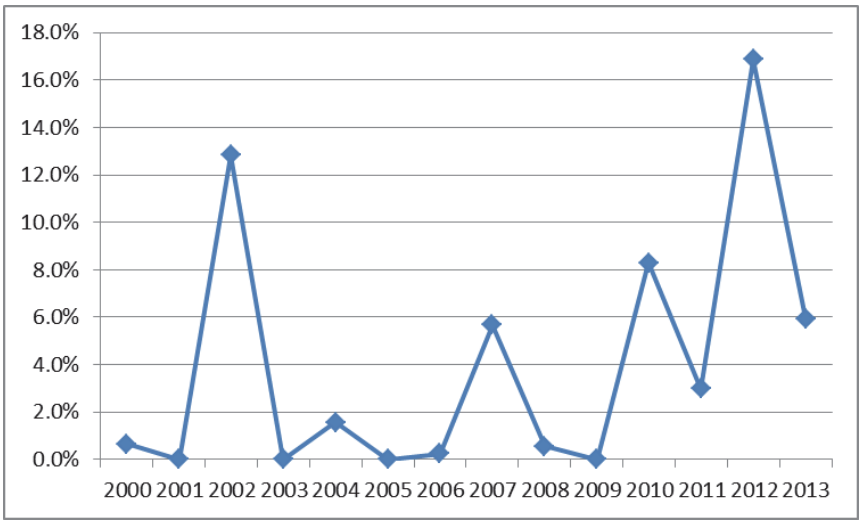
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Delhi	1.8%	7.4%	6.7%	-1.2%	7.2%	22.4%	7.4%	6.8%	7.1%	7.1%	1.7%	6.8%
Bangalore	5.5%	5.4%	6.8%	18.0%	17.2%	-16.7%	21.2%	14.2%	15.7%	8.6%	9.6%	9.6%
Chennai	7.9%	39.7%	6.3%	7.5%	7.9%	7.7%	7.3%	8.1%	7.9%	9.7%	9.0%	10.8%
Greater Mumbai	3.8%	5.1%	6.7%	8.0%	7.6%	7.8%	6.8%	4.3%	5.6%	5.8%	8.5%	6.4%

Source: Statistical Year Book, India 2016

Figure 7.3.3 Annual Growth Rate of Number of Vehicle Registrations by Cities

The survey team selected 4 Cities to which the study areas belong. The average annual growth rate in the most recent 10 years (2005-2014) is very high at between 6.8% to 10.8%

(4) Annual Growth Rate of the Length of National Highway



2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
0.6%	0.0%	12.8%	0.0%	1.6%	0.0%	0.2%	5.7%	0.5%	0.0%	8.3%	3.0%	16.9%	5.9%

Source: Statistical Year Book, India 2016

Figure 7.3.4 Annual Growth Rate of the Length of National Highway

Here the annual growth rate of the length of national highway is studied. The average annual growth rate in recent 14 years (2000-2013) is high at 4.0%

(5) Growth Rate of the Traffic Forecast Demand

The JICA Study Team selected the average value of Annual Growth Rate of Real GSDP in the Survey area and Annual Growth Rate of Number of Vehicle Registrations by City, which yielded 8.5% as the growth rate of the traffic forecast demand, which is a moderate rate among above mentioned annual growth rates.

7.4 Economic Analysis

7.4.1 Introduction

Social economic benefit is calculated by adding two cost of saving, one is vehicle operating cost (VOC) of running vehicles in project road section, and the other is travel time cost (TTC) of the passengers who are on the running vehicle in project road section.

3 economic indicators are applied to judge the economic feasibility of the 4 projects, such as Economic Internal Rate of Return (EIRR), Economic Net Present Value (ENPV), and Benefit by Cost (B/C).

7.4.2 General Condition

The following table shows the conditions of the economic analysis.

Table 7.4.1 General Conditions of Economic Analysis

Item	Conditions
(1) Analysis Period	30 years (2020-2049)
(2) Traffic Demand Forecast	Refer to Chapter 8-11
(3) Evaluation Indicators	EIRR (Economic Internal Rate of Return), ENPV (Economic Net Present Value), B/C (Benefit/Cost)
(4) Social Discount Rate	12% (refer to other infrastructure implementation studies)
(5) Cost	Refer to Chapter 8-11
(6) Annual Operation Cost	0.5% of Initial Cost for implementation
(7) Repair/rehabilitation Cost	4.0% of Initial Cost for implementation every 10 years
(8) Exchange Rates	1 USD ＝ 66.97 INR 1 USD ＝101.80 JPY 1 INR ＝ 1.52 JPY
(9) Base Year	2016
(10) Method	Calculating VOC (vehicle operation cost) and TTC (travel time cost) of both “With Case” and “Without Case” the savings of both factors will the benefits of the project.

Source: JICA Study Team

7.4.3 Project Benefit Calculation

(1) Vehicle Operation Cost (VOC)

Unit vehicle operation cost is set according to the final report of the “Data collection survey on the Bridge sector (April 2014) in the Republic of India”. Since there are scarce difference in prices of vehicles and vehicle parts among states, this unit VOC is applied to all 4 projects in this survey.

Table 7.4.2 Vehicle Operation Cost (2014)

(Unit: Indian Rupee/vehicle･km)

Year	Car	Bus	Truck
2014	3.52	9.49	12.75

Source: Final Report of the “Data Collection Survey on the Bridge Sector (Apr. 2014) in the Republic of India”

The above value is converted to the value of 2016 utilizing the CPI (Consumer Index Price) of India which is published by the Indian Government.

Table 7.4.3 CPI (Consumer Index Price)

Year	2012	2013	2014	2015	2016*
2012＝10	100.0	110.0	117.4	123.1	127.4
2014＝100	－	－	100.0	104.9	108.5

Source: Government Data (OGD) Platform India

Table 7.4.4 Vehicle Operation Cost (2016)

(Unit: Indian Rupee/vehicle･km)

Year	Car	Bus	Truck
2016	3.82	10.30	13.83

Source: JICA Study Team

Benefit calculation formula of VOC is referred from "Manual of Cost Benefit Analysis, Nov. 2008, Ministry of Land, Infrastructure Transport and Tourism" as shown below.

Social Benefit by reducing Vehicle Operating Cost: $BR = BR_o - BR_w$
Total Vehicle Operating Cost $BR_i = \Sigma\Sigma\ (Q_{ij} \times L_{ijl} \times \beta_j)\ \times 365$
where,
BR: Social Benefit by reducing Vehicle Operating Cost
BR_i: Total Vehicle Operating Cost of Case i
Q_{ijl}: Traffic volume at section l of vehicle type j in Case i (vehicle/day)
L_l: Length of Section l (100km)
β_j: Unit vehicle operation cost of vehicle type j (INR/vehicle/1000km))
i: Case, Without project: o, With project: w
j: Vehicle type
l: Section

(2) Travel Time Cost

Unit travel time cost is set according to the final report of the "Data collection survey on the Bridge sector (April 2014) in the Republic of India". The amount of income among the users of the projected bridge differ considerably by state, correction factor are estimated from GSDP per capita of project sites. Applied unit travel time cost (TTC) is shown in Table 7.4.7.

Table 7.4.5 Travel Time Cost (2014)

(Unit: Indian Rupee/vehicle･km)

Year	Car	Bus	Truck
2014	75.00	47.40	52.14

Source: Final Report of the "Data Collection Survey on the Bridge Sector (Apr. 2014) in the Republic of India"

The above value is converted to the value of 2016 utilizing the CPI (Consumer Index Price) of India which is published by the Indian Government.

Table 7.4.6 Travel Time Cost (2016)

(Unit: Indian Rupee/vehicle･km)

Year	Car	Bus	Truck
2016	81.38	51.43	56.57

Source: JICA Study Team

To convert the above mentioned Travel Time Cost, GDP per capita of all India and GSDP per capita by states of 2015 was used to calculate the correction factor. Travel Time Cost by vehicle and by study area is set using the correction factor.

Table 7.4.7 Travel Time Cost by Vehicle and by Study Area (2016)

(Unit: Indian Rupee/vehicle･km)

Location	GDP or GSDP per Capita	Correction Factor	Car	Bus	Truck
All-India	86,879	1.00	81.38	51.43	56.57
Delhi	252,011	2.90	236.05	149.18	164.10
Karnataka	130,897	1.51	122.60	77.49	85.23
Tamil Nadu	135,806	1.56	127.20	80.39	88.43
Maharashtra	134,081	1.54	125.59	79.37	87.31

Source: JICA Study Team using data of the Website of Ministry of Statistics and Programme Implementation

Benefit calculation formula of TTC is referred from the "Manual of Cost Benefit Analysis, Nov. 2008, Ministry of Land, Infrastructure Transport and Tourism" as is shown below.

Social Benefit by reducing Travel Time Cost: $BT = BT_o - BT_w$

Total Travel Time Cost: $BT_i = \Sigma\Sigma (Q_{ij} \times T_{ijl} \times \alpha_j) \times 365$

where,

BT: Social Benefit by reducing Travel Time Cost

BT_i: Total Travel Time Cost of Case i

Q_{ijl}: Traffic volume at section l of vehicle type j in Case i (vehicle/day)

T_{ijl}: Travel time of vehicle type j at section l in Case i (hour)

α_j: Unit travel time cost of vehicle type j (INR/hour/vehicle)

i: Case, Without project: o, With project: w

j: Vehicle type

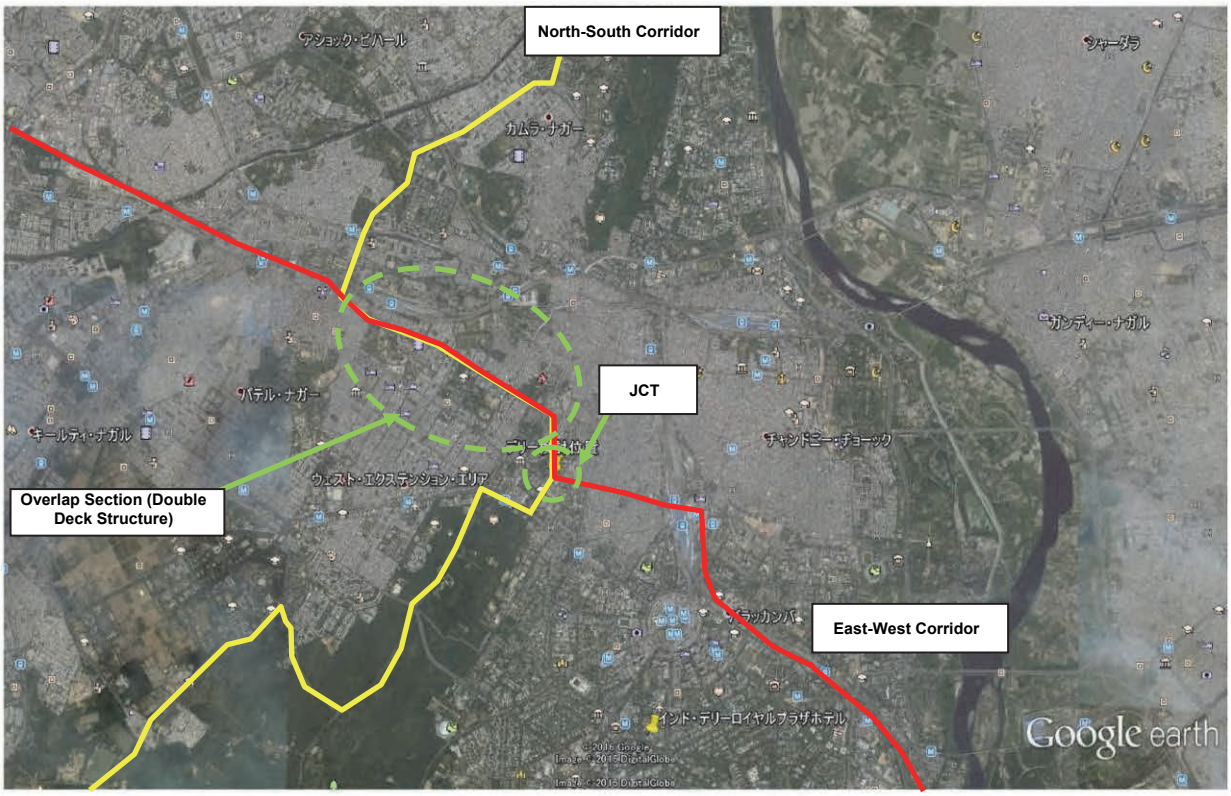
l: Section

8 STUDY ON VIADUCT CONSTRUCTION PROJECT IN DELHI

8.1 Introduction

In this chapter, it is mentioned about proposed structures, the result of economic analysis and environmental assessment of the viaduct construction project in Delhi based on "Chapter 4 Environmental and Social Impact", "Chapter 6 Japanese Advanced Technology can be Apply" and "Chapter 7 Traffic Forecast Demand and Economic Analysis".

The target area of this project is as follows.



Source: JICA Study Team

Figure 8.1.1 Target Area (Overlap Section and Junction A)

8.2 Natural and Social Features

8.2.1 Social Aspect

Population in Delhi city which is the project site of the viaduct construction project in Delhi is shown in Table 8.2.1

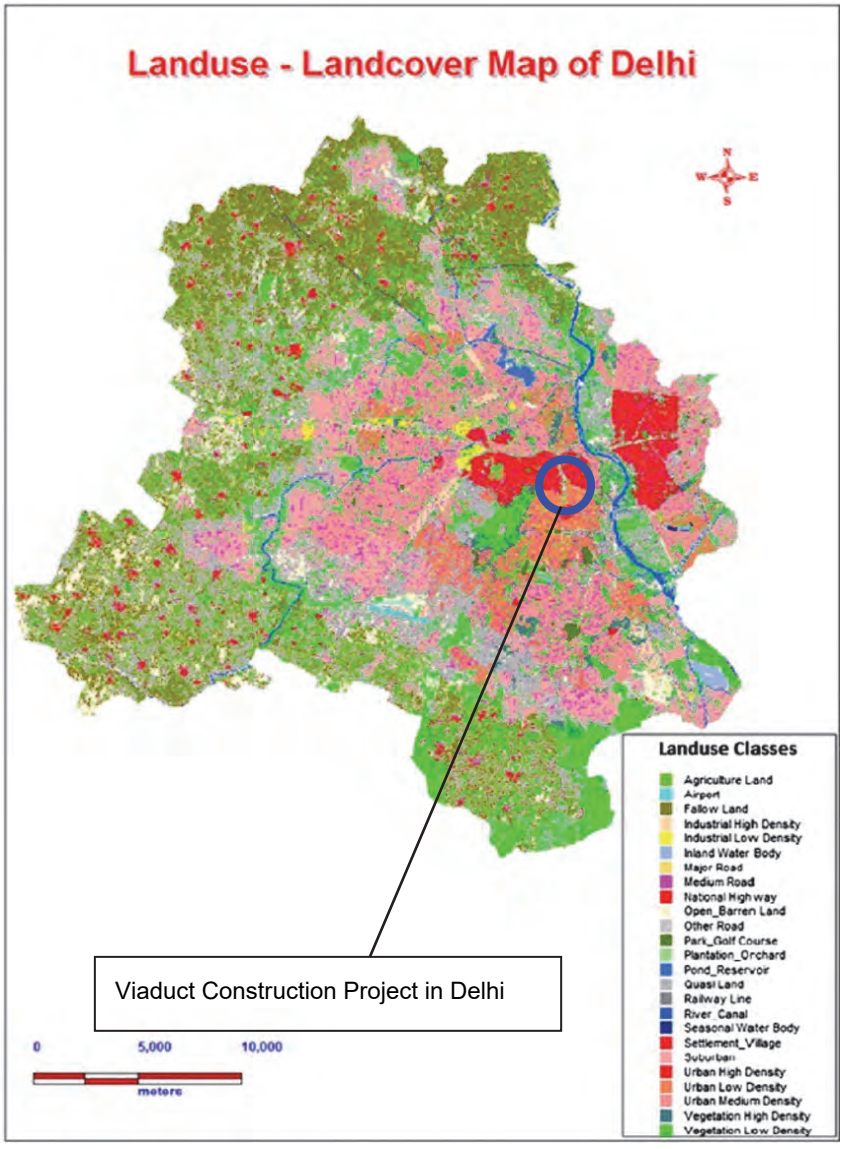
Table 8.2.1 Population of Delhi

State	Population (2011)
Delhi	16,787,941

Source: 2011 Census Data, Government of India, Ministry of Home Affairs

8.2.2 Natural Aspect

The land use map of the project sites are shown in Figure 8.2.1.The situation of land use of the project site is mainly urban and commercial areas. And, there are a lot of houses and buildings in the project site.



Source: Government of Delhi

Figure 8.2.1 Land Use Map and the Location of the Project Site in Delhi (Viaduct Construction Project in Delhi)

8.3 Proposed Structure

8.3.1 Introduction

The study on structures was carried out at one Junction connecting between the East-West Corridor and the North-South Corridor and a normal section overlapped for both the East-West Corridor and North-South Corridor as shown in Figure 8.1.1. The study on structures is carried out in consideration of Japanese Advanced Technology which is explained in Chapter 6.

8.3.2 Study Overlapped section for both the East-West and North-South Corridors

(1) Study on Pier Column Type

According to the current study result by Local Consultants, both the East-West Corridor and North-South Corridor are 6 lanes. Thus, the total number of lanes in the studied section must be 12 lanes. However, due to difficulty of land acquisition and the limitation of the existing road width, a double decked structure is required to accommodate the necessary number of lanes.

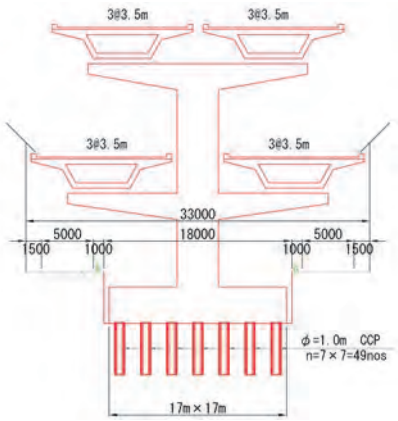
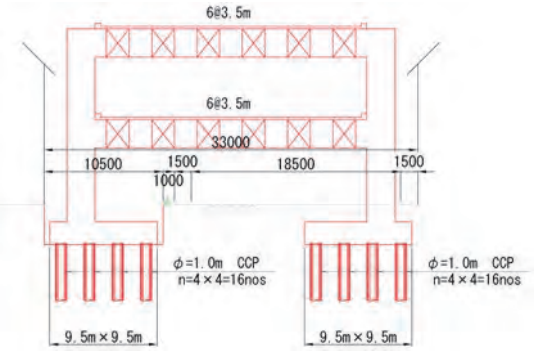
Assumptions of study are shown below;

- Lane Number: 6 lanes (Upper Deck) and 6 lanes (Lower Deck)
- Application of pile foundation because of 10m depth of bearing layer from ground surface

Comparison of pier column type is made between concrete structure type which is commonly applied in India and steel structure type which is applied usually for viaduct structure inside city in Japan.

Comparison study is made against single pier column structure for concrete structure type and portal pier column structure for steel structure. Originally, due to large scale structure, portal structure type is recommended. However, if portal structure type is applied to concrete structure, it is required to stop existing traffic during the foundation work of beam because of installation of temporary supporting for earth retaining. In case single pier column structure is applied to concrete structure, it is possible to construct half construction and give less negative impact against existing traffic, therefore, single pier column structure is applied to concrete pier column in this study.

Table 8.3.1 Comparison of Pier Column Type

	Concrete Type	Steel Type
General View		
Comment Structure	✓ Due to wide width of carriageway by PC Superstructure, cantilever part of pier column requires prestressed forces. And, due to heavy weight structure, cross section of column and foundation becomes much larger than Steel Type. ✓ Construction period will be 5-6 months.	✓ There are a lot of steel pier column applied in urban area in Japan, despite of high cost. ✓ Easy to apply steel pier column for complicated structure. ✓ Construction period will be 3 months.
Comment Existing Traffic	✓ During construction of pile cap, only 10m width can be used for existing traffic. ✓ During construction of cantilever pier head, half of existing load will be closed because of scaffolding installation.	✓ During construction of pile cap, 18.5m width can be used for existing traffic. ✓ Because of steel structure, only 1-2 nights will be closed during erection of steel pier column.
Construction Cost	Superior	Inferior
Social Effect	Inferior (Due to large width of foundation and longer construction period by cast in-situ)	Superior (Due to narrow width of foundation and shorter construction period by prefabrication)
Estimate		Recommended

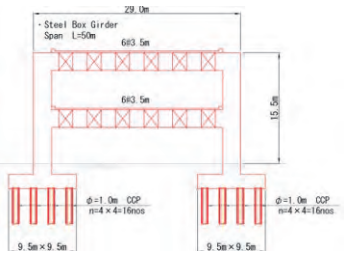
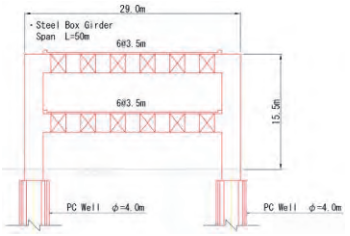
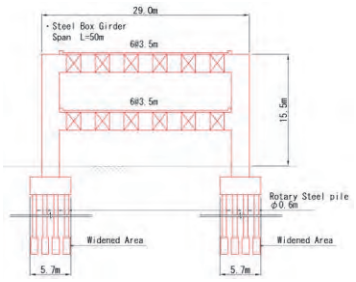
Although construction cost becomes higher than concrete type, it is possible to shorten construction period and to reduce negative impact to surrounding environment, therefore, steel type pier column is recommended to apply.

(2) Study on Foundation Type

The study area is located near the center of Delhi city; therefore, there is a lot of traffic, currently. In order to avoid/minimize negative impacts to the surrounding area, advanced technologies that can minimize the space required for construction or reduce negative impacts to the surrounding area are being studied. In this chapter, comparisons between conventional foundation type (Cast-in-place concrete pile), PC Well and Rotary Penetration Steel Pile is carried out. A comparison table is shown in Table 8.3.2.

Although construction cost becomes higher than cast-in-place concrete pile, it is possible to shorten construction period and to reduce negative impact to surrounding environment, therefore, both PC Well and Rotary Penetration Steel Pile is recommended to apply.

Table 8.3.2 Comparison of Foundation Type

	Type-1 Cast-in-place Concrete Pile	**Type-2** PC Well	**Type-3** Rotary Penetration Steel Pile
General View			
Comment	✓ Common foundation type has many past records and is most economical ✓ Widest width of pile cap, will cause negative impact to existing traffic during construction	✓ Width of foundation is narrow and will not cause negative impact to existing traffic during construction. ✓ Shortest construction period due to unified structure with pier column	✓ Narrower width of pile cap than Type-1 will cause less impact to existing traffic during construction. ✓ Due to no excavation required, less impact to residences during construction.
Construction Period	Long	Very Short	Short
Construction Cost	Superior	Inferior	Moderate
Social Effect	Inferior	Moderate	Superior
Estimate		Recommended	Recommended

(3) Study on Superstructure Type

As mentioned in previous chapter, steel structure is recommended for pier column structure in consideration of social impact during construction; even initial cost has no advantage compared with concrete structure. As same as pier column, it is recommended to apply steel superstructure in order to minimize social impact during construction and reduce dead load and size of steel pier column.

In addition, Composite Deck Slab is also recommended to apply since this type has more durability and suite to Indian traffic condition which passes many overloaded trucks. And, there is no restriction during construction of composite deck slab.

8.3.3 Study on Junction Structure

Land use status is carefully considered during the study of Junction Structures.

(1) Policy of Study

This Junction is to connect between North-South Corridor and East-West Corridor. Both North-South Corridor and East-West Corridor formulate double deck structure and connect intersection point from north side. After intersection point, North-South Corridor runs toward south direction, on the other side, East-West Corridor runs toward east direction.

According to information from Delhi PWD, alignment of North-South Corridor is still under studying. However, they accepted to study Junction structure in accordance with alignment shown in Figure 3.2.1.

2 alternatives are studied as follows;

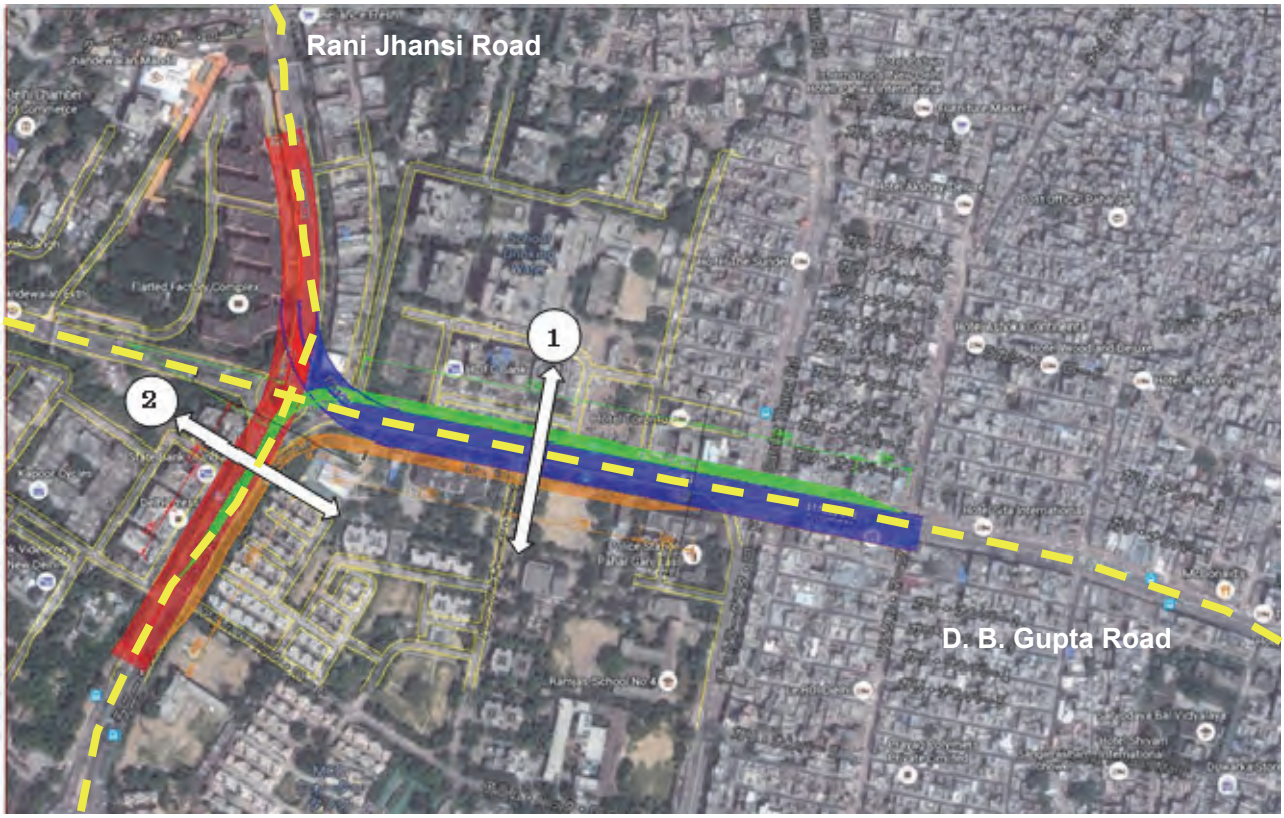
Alternative 1: No consideration of surrounding to land status, and a compact size of Junction

Alternative 2: Consideration of surrounding land status

Design speed: 50km/h and minimum curve radius with 50m are applied for study of Junction alignment.

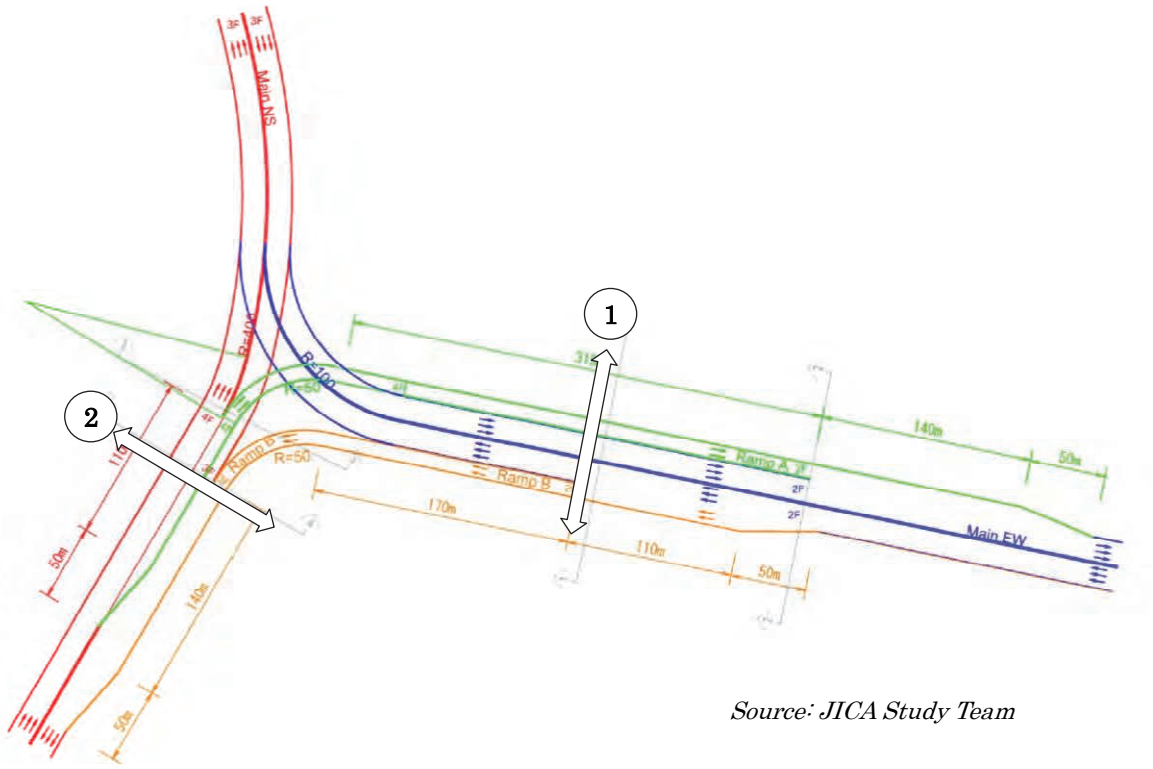
(2) Study result of Alternative 1

Plan view of Alternative 1 is shown in Figure 8.3.1.



Source: JICA Study Team/Google

Figure 8.3.1 Plan of Alternative 1



Source: JICA Study Team

Figure 8.3.2 Alignment of Alternative 1

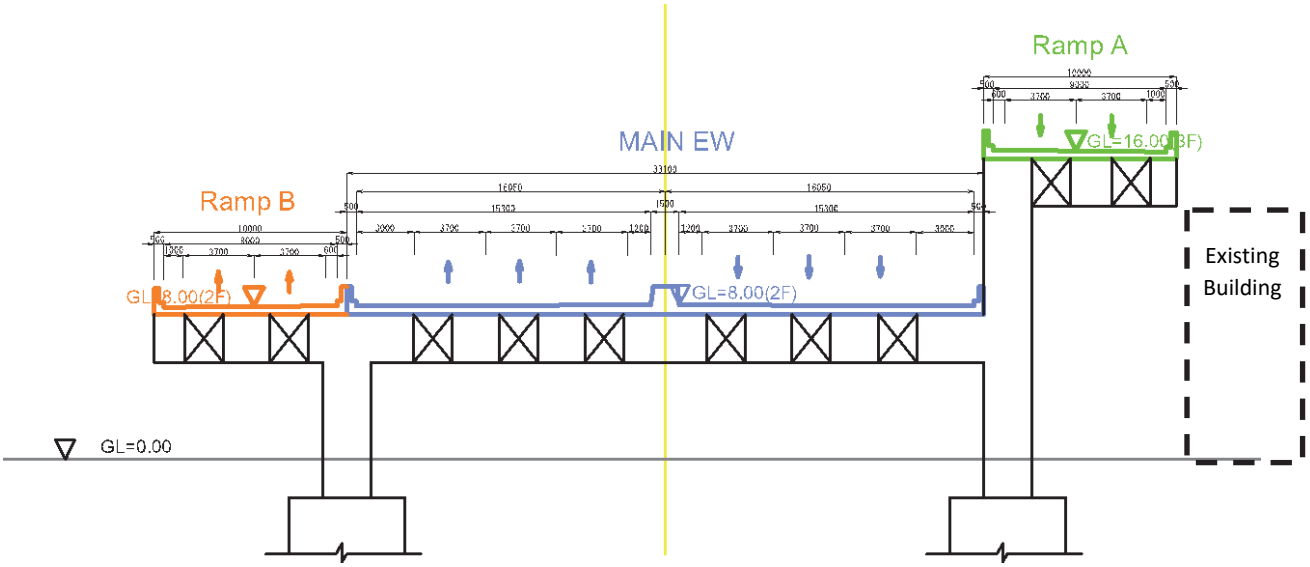
Alignment of Alternative 1 is shown in Figure 8.3.2. In order to understand the junction structure easily, a model was made for this alternative. Photograph of this model is shown in Figure 8.3.3

Source: JICA Study Team

Figure 8.3.3 Photograph of Model of Alternative 1

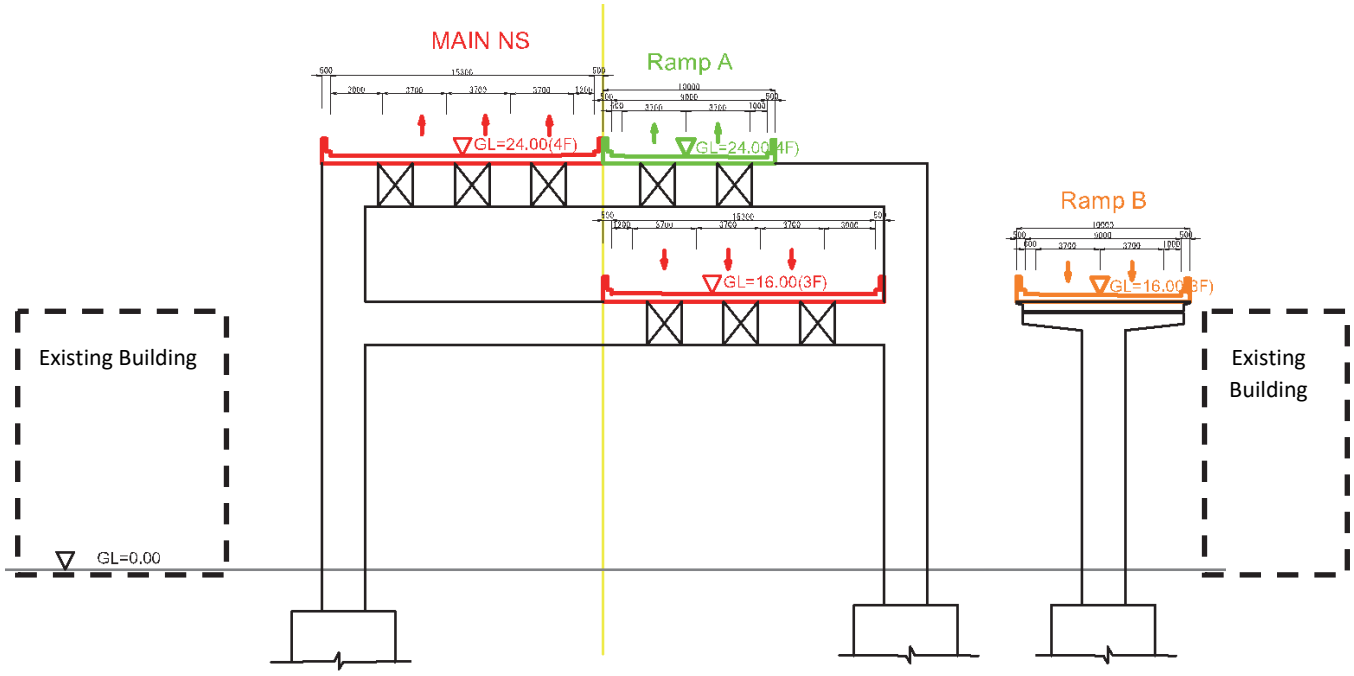
In Alternative 1, full accessibility can be achieved for all 6 directions.

Due to the very complicated alignment of the Junction, the bridge structure, especially the pier column structure, becomes very complicated also. Cross section of 1 and 2 of Figure 8.3.1 are shown in Figure 8.3.4 and Figure 8.3.5, respectively. Width of both cross sections become wider than existing width, therefore, additional land acquisition will be necessary unless necessary number of lanes is reviewed.



Source: JICA Study Team

Figure 8.3.4 Cross Section 1



Source: JICA Study Team

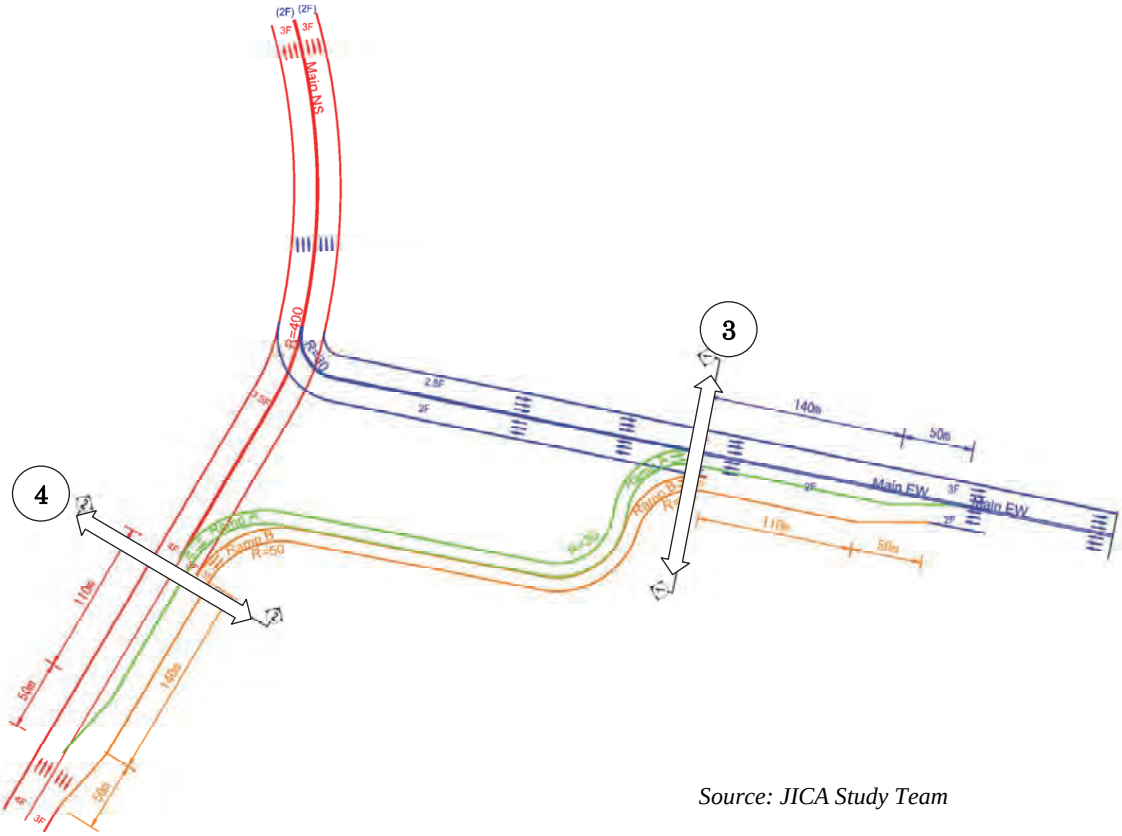
Figure 8.3.5 Cross Section 2

(3) Study of Alternative 2

A plan of Alternative 2 is shown in Figure 8.3.6. As explained before, this alternative is studied giving consideration to the land status as shown in Figure 3.2.5.

Source: JICA Study Team/Google

Figure 8.3.6 Plan of Alternative 2



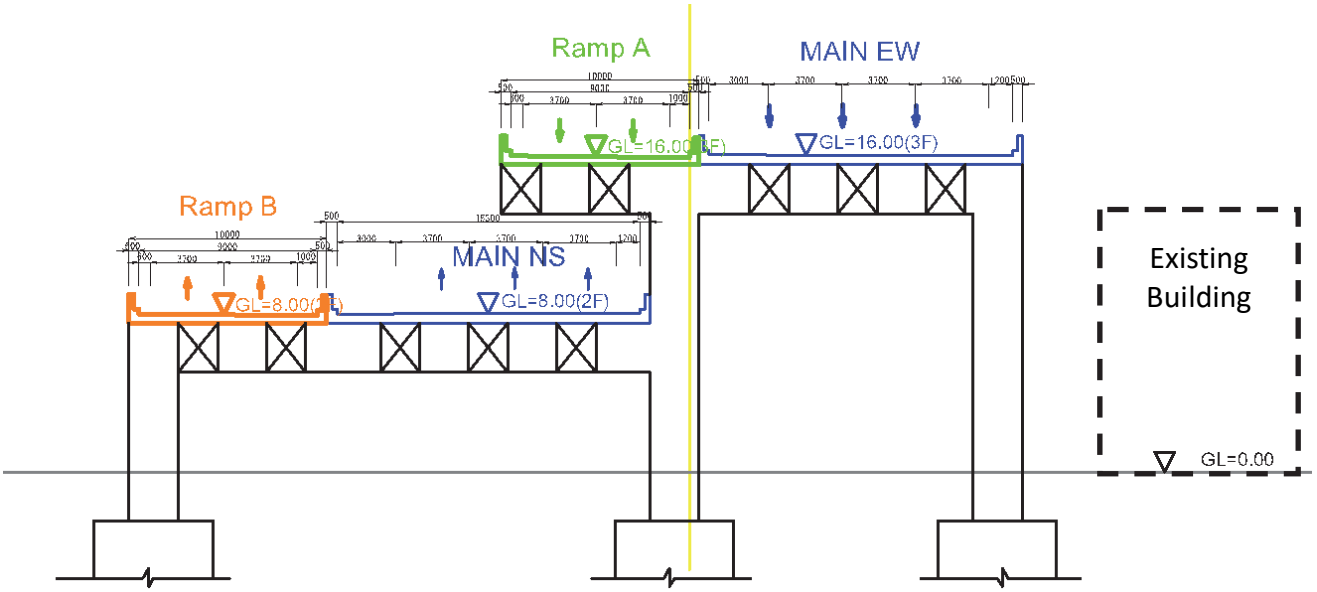
Source: JICA Study Team

Figure 8.3.7 Alignment of Alternative 2

An alignment view of Alternative 2 is shown in Figure 8.3.7. In this alternative, a very small radius curve (R=30m, equivalent of Design Speed 20km/h) is applied at the intersection for the East-West Corridor in order to avoid occupation of private land as shown in Figure 3.2.5 as land use status. Moreover, the locations of 2 ramps to connect between the North-South Corridor and East-West Corridor were decided in order to avoid school land which is very difficult to acquire for construction projects.

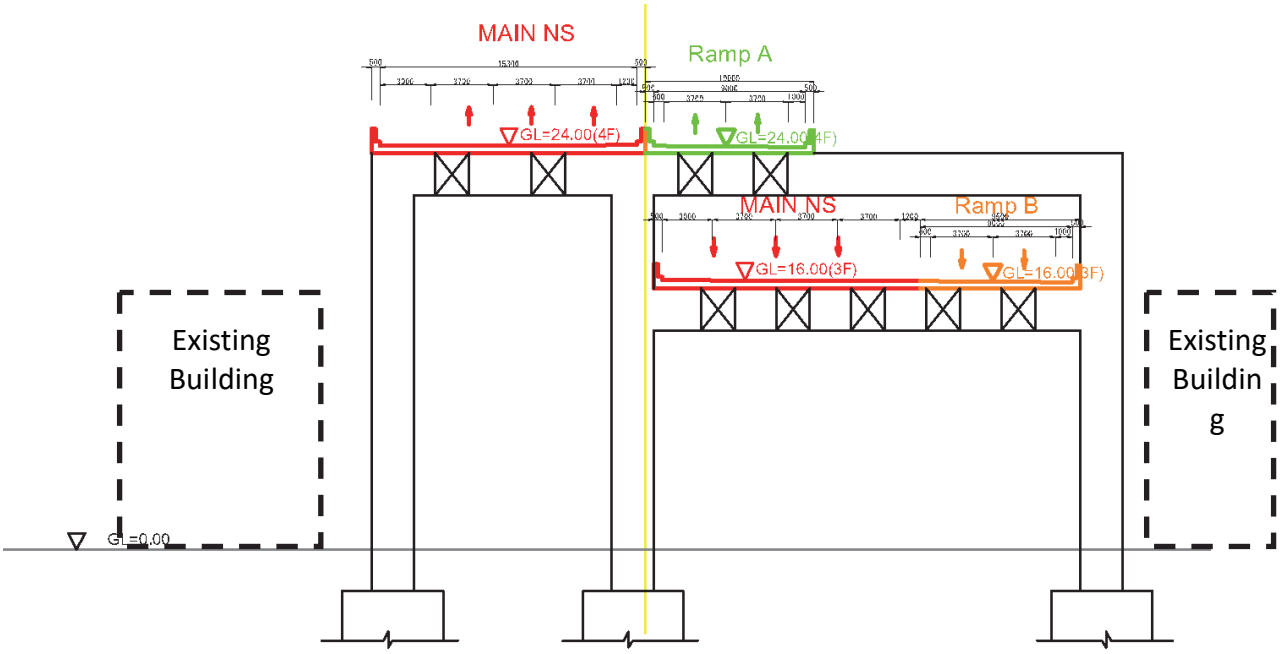
In Alternative 2, full accessibility can be achieved for all 6 directions.

Due to the very complicated alignment of the Junction, the bridge structure, especially the pier column structure, becomes very complicated also. Cross section of 3 and 4 are shown in Figure 8.3.8 and Figure 8.3.9, respectively. Width of both cross sections become wider than existing width, therefore, additional land acquisition will be necessary unless necessary number of lane is reviewed.



Source: JICA Study Team

Figure 8.3.8 Cross Section 3



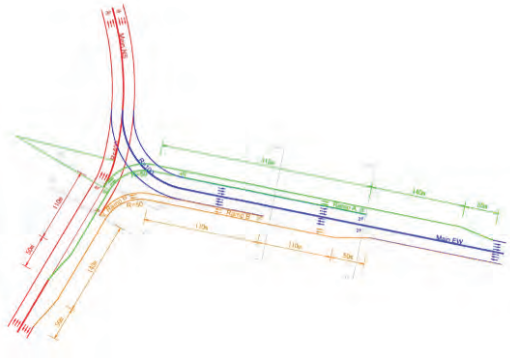
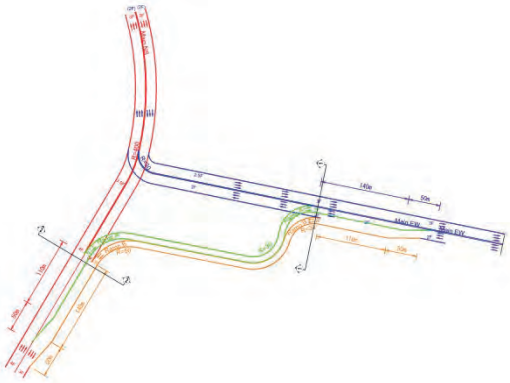
Source: JICA Study Team

Figure 8.3.9 Cross Section 4

(4) Comparison of Alternative Junction Structures

Comparison table for alternative Junction Structures is shown in Table 8.3.3.

Table 8.3.3 Comparison of Junction Structures

	Alternative 1	Alternative 2
Plan View		
Feature	✓ No restriction on land use, to be compact size junction	✓ Consideration of actual land use situation, to be larger size junction
Access	✓ Possible to access all 6 directions	✓ Possible to access for all 6 directions
Advantage	✓ Due to most compact size junction, length of ramp becomes shortest.	✓ No land acquisition in Private Land area
Disadvantage	✓ Additional land acquisition will be necessary in Private Land area.	✓ In order to avoid land acquisition in Private Land area, a very small radius curve is applied. (R=30m) ✓ Problem with the usage of land where surrounded by Ramp and E-W line.

Both alternatives have advantage and disadvantage. Ramp structure becomes very complicated. It is considered to become more reality in planning by applying steel pier column and new foundation type (PC Well or Rotary Penetration Steel Pile) which can minimize negative impact surrounding environment.

Currently, 6 lanes carriageway is required, however, width of viaduct is wider than existing road width. Therefore, it is required to review necessary number of lanes based on traffic volume analysis result in consideration of total road network in Delhi at next stage.

8.3.4 Advanced Technologies can be Applied to Projects

Japanese Advanced Technologies which can be applicable for Viaduct Construction Project in Delhi are summarized in Table 8.3.4. According to apply these technologies, the construction of viaduct in narrow area in the city becomes more realistic and it is possible to be environment - friendly construction in more short term compared with construction by existing technology.

For details of the technologies are shown in chapter 6.

Table 8.3.4 List of Advanced Technology

Name of Technology	Feature
Cast-in-place Concrete Pile under low clearance	Construction Equipment can construct cast-in-place concrete pile under low clearance and narrow space
Rotary Penetration Steel Pile	New type of steel pile which can be constructed in a narrow space and utilize a smaller size of pile cap due to large load carrying capacity compared with Cast-in-place Concrete Pile. In addition, due to no generation of excavated soil, low vibration and low noise, this pile type is very eco-friendly type.
PC Well	New type of foundation which can be constructed in a narrow space and utilize a smaller size of foundation because no pile cap is required
Steel Pipe Socket Connection Method	New connection method between steel pier column and pile cap/pile by omitting anchor frame which can achieve shorter construction time and possible to apply PC Well foundation.
Composite Slab	New deck slab type which has high durability and safe for construction, especially, underneath of deck slab

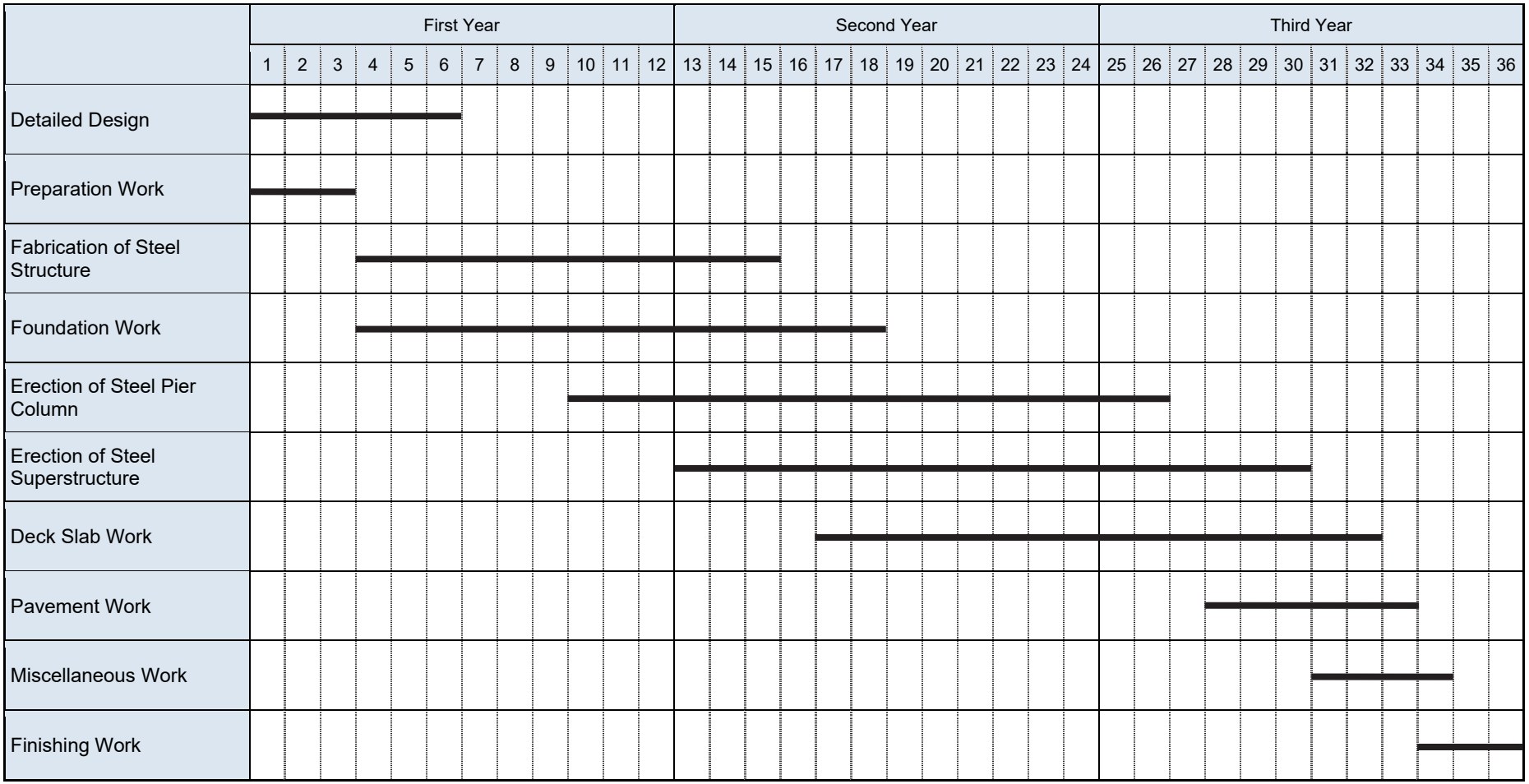
8.3.5 Overall Construction Schedule

Overall construction schedule for viaduct construction is shown in Table 8.3.5. It is possible to complete construction work by applying of Steel Pier Column, PC Well or Rotary Penetration Steel Pile and Steel Superstructure.

On the other hand, expected construction schedule is about 5 years in case conventional structure type is applied. However, it is impossible to estimate precise construction schedule since construction schedule is affected by number of construction teams and construction package.

In addition, it is recommended to establish construction planning to distinguish sections applied either Japanese advanced technology or conventional method, since application of Japanese advanced technology causes significant increment of construction cost.

Table 8.3.5 Overall Construction Schedule for Viaduct Construction Project in Delhi



8.3.6 Cost Estimation

(1) Exchange Rate

Exchange rate used for calculation of cost estimation is average value for 2 weeks from the end of August 2016 to the beginning of September 2016. Applied exchange rate is shown as below;

- 1 USD = 101.80 [Yen]
- 1 INR = 1.52 [Yen]

(2) Estimated Project Cost

Estimated project costs in case of Japanese support are shown in Table 8.3.6 . The estimated total project cost (including construction costs, design costs and supervision costs) is approximately51.5 billion Yen (33.9 billion INR).

Table 8.3.6 Estimated project Cost

Project Location	Contents	Unit	Quantity	Unit [100 Yen]	Project Cost [Million Yen]				Project Cost [Million INR]			
					Construction	Design	Supervision	Total	Construction	Design	Supervision	Total
Delhi	- Length of Viaduct1.55km - Steel Box Girder （6Lanes×2） - Steel Pier Column (Double Deck)	m^2	68,200	337.0	22,985	920	2,069	25,974	15,122	605	1,361	17,088
	Junction (Alternative 2)	m^2	58,216	388.6	22,622	904	2,035	25,561	14,883	595	1,339	16,817
	Total				45,607	1,824	4,104	51,535	30,005	1,200	2,700	33,905

8.4 Traffic Demand Forecast

8.4.1 The existing Traffic Volume of the Study Area

The result of traffic survey executed by Delhi PWD was applied for the analysis of the Viaduct Construction Project in Delhi. Therefore, traffic survey was not carried out for this project by the Survey.

8.4.2 Existing Traffic Volume at Study Area

The existing traffic volume of the study area is shown in Table 8.4.1.

Table 8.4.1 The existing Traffic Volume (Viaduct Construction Project in Delhi, 2016)

Location	Rani Jhansi Road-DB Gupta Road		New Roahtak Road-Rani Jhansi Road		New Rohtak Road-Swami Naryan Marg	
unit	Vehicle	PCU	Vehicle	PCU	Vehicle	PCU
Passenger car	33,086	33,086	25,592	25,592	60,245	60,245
Bus	4,737	14,211	383	1,149	2,935	8,805
Truck	337	1,517	168	756	714	3,213
Total	38,160	26,143	26,143	27,497	63,894	72,263

Source: JICA Study Team

8.4.3 Traffic Demand Forecast of the Study Area

Annual Average Daily Traffic (AADT) of the study area is estimated in consideration with the existing traffic volume at the study area shown in Table 8.4.1 and estimated growth rate for future traffic volume described in Chapter 7.3.2. Estimated result of AADT is shown in Table 8.4.2.

The rate of vehicles which will use viaducts which are planned in the Survey is fixed as 60% following the document of Delhi PWD.

Table 8.4.2 Traffic Demand Forecast (Viaduct Construction Plan in Delhi, 2017)

(Unit: PCU)

	Car	Bus	Truck	Total
2020	33,451	6,797	1,543	41,791
2021	36,428	7,402	1,680	45,510
2022	39,670	8,061	1,830	49,561
2023	43,201	8,778	1,993	53,972
2024	47,046	9,560	2,170	58,775
2025	51,233	10,410	2,363	64,006
2026	55,792	11,337	2,574	69,703
2027	60,758	12,346	2,803	75,906
2028	66,165	13,445	3,052	82,662
2029	72,054	14,641	3,324	90,019
2030	78,467	15,944	3,619	98,031
2031	85,450	17,363	3,942	106,755
2032	93,055	18,909	4,292	116,257
2033	101,337	20,592	4,674	126,603
2034	110,356	22,424	5,090	137,871
2035	120,178	24,420	5,543	150,142
2036	130,874	26,593	6,037	163,504
2037	142,522	28,960	6,574	178,056
2038	155,206	31,538	7,159	193,903
2039	169,020	34,345	7,796	211,160
2040	184,062	37,401	8,490	229,954

Source: JICA Study Team

8.5 Economic Analysis

8.5.1 Introduction

In this section, social economic benefit is calculated for Viaduct Construction Project in Delhi used for traffic demand forecast result as explained in Chapter 8.4. Social economic benefit is defined as the savings of social cost by implementing each project mentioned above, which is the difference of social cost between With Case (with implementing the project) and Without Case (without implementing the project).

8.5.2 Cases to be Studied

Steel double deck viaduct is planned for the section in which the North-South corridor and East-West corridor overlap. The "With Case" is the one in which the steel double deck is implemented, the "Without Case" is the one in which a PC superstructure and RC substructure is implemented instead.

Table 8.5.1 "With Case" and "Without Case" (Viaduct Construction Project in Delhi)

With Case	Without Case
Construct elevated viaduct from the intersection of New Rohtak Road and Ajmal Khan Road to the intersection of Rani Jhansi Road and Desh Bandhu Gupta Road. The Elevated viaduct is a double deck steel bridge constructed by Japanese advanced construction technology and methods that minimize congestion of the existing traffic. Both the starting and ending points will be connected to the N-S corridor and E-W corridor by a junction. The implementation will start from 2020 when the viaduct will be opened	PC superstructure and RC substructure is constructed in the same location as the "With Case". The existing traffic will be congested due to wide construction field and forced to make detours. Construction Period will be longer than "With Case".

Source: JICA Study Team

8.5.3 Implementation Schedule for Economic Analysis

Elevated viaduct will be implemented along the existing road both in Viaduct Construction Project in Delhi. If the steel double deck is not implemented, a concrete viaduct is implemented instead.

Table 8.5.2 Implementation Schedule for Economic Analysis (Viaduct Construction Project in Delhi)

	With Case	Without Case	Remarks
2019	D/D	D/D	
2020	Construction	Construction	With Case: with Japanese advanced construction method Without Case: with conventional construction method
2021	Construction	Construction	
2022	New viaduct open	Construction	
2023	↓	Construction	
2024	↓	New viaduct open	
2025	↓	↓	
↓	↓	↓	
2048	End of analysis period	End of analysis period	

Source: JICA Study Team

8.5.4 Project Cost

The following table shows project cost for the economic analysis in the study area. (Refer to 8.3.5 for the details)

Table 8.5.3 Project Cost by Study Area

(Unit: Million Indian Rupees)

	With Case				Without Case			
Location	Construction	D/D	C/S	Total	Construction	D/D	C/S	Total
Delhi	30,005	1,200	2,700	33,905	23,081	923	2,077	26,081

Source: JICA Study Team

8.5.5 Cost Benefit Analysis

The result of cost benefit analysis under the condition shown in Chapter 7.3.4 is shown in following table.

Table 8.5.4 Cost Benefit Analysis Result

Evaluation Indicator	Delhi
Economic Internal Rate of Return (EIRR, %)	20.7%
Economic Net Present Value (ENPV, Million Indian Rupee)	1,745
Benefit/Cost (B/C)	1.21

- Economic Internal Rate of Return (EIRR) = (Discount rate value which makes ENPV = 0)
- Economic Net Present Value (ENPV)
  = (Net present benefit of project benefit) – (Net present cost of project benefit)
- Benefit/Cost (B/C) = (Net present benefit of project benefit)/(Net present cost of project benefit)
  where,
  benefit of project = benefit reducing VOC + benefit reducing TTC
  cost of project = Implementing Cost + Operation & Maintenance Cost

Source: JICA Study Team

As shown is Table 8.5.4, the numerical of EIRR of the target four projects are over 12%, the validity of these projects are confirmed. For the projects of Delhi use the conventional flyover construction method as Without Case. The construction cost will be increased with using proposal structures; however the social convenient will be improved such as shortening of construction period and ensuring the traffic of existing roads. Therefore, it will be possible to improve the numerical of EIRR.

8.6 Environmental Evaluations

8.6.1 Screening Result based on JICA Guideline

The target for screening is surrounding areas of North-South Corridor and East-West corridor which is shown in Figure 3.2.2 of Chapter 3.

Screening result based on JICA Guideline is shown in following table.

I. Pollution, the evaluation was A in Rating of Noise/Vibration and Air pollution (Dust) During and After Const. II. Social, it was the evaluation A in Rating of Involuntary Resettlement. III. Natural, little impact is assumed. In the JICA Category, it was the evaluation A in Rating of the Result of Screening based on JICA Guideline for Environmental and Social Considerations (2010).

Table 8.6.1 Preliminary Environmental Evaluation and Screening based on JICA Guideline (as of October 5th, 2016) – Viaduct Construction Project in Delhi

Type of Bridge	Location	St. No	Br. No	Affected Item: Name	Affected Item: Repair /Reconstruction	Ⅰ.Pollution: Noise/ Vibration and Air pollution (Dust) During and After Const. Rating	Ⅰ.Pollution: Noise/ Vibration and Air pollution (Dust) During and After Const. Description	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Rating	Ⅰ.Pollution: Water Quality (Turbid Water) During Const. Description	Ⅱ.Social Environment: Involuntary Resettlement Rating	Ⅱ.Social Environment: Involuntary Resettlement Description	Ⅱ.Social Environment: Culture (Sacred place and Facility) Rating	Ⅱ.Social Environment: Culture (Sacred place and Facility) Description	Ⅲ.Natural Environment: Mangrove Trees Rating	Ⅲ.Natural Environment: Mangrove Trees Description	JICA Category: Result of **Screening** based on JICA Guideline for Environmental and Social Considerations (2010)		Expected clearances to be acquired: EC	Expected clearances to be acquired: Clearance for CRZ
Viaduct	Delhi	1	1	-	New Construction	A	Residential area is observed and might be affected.	C	No river by the bridge.	A	Residential area and commercial area is observed and might be affected.	C	Mosque is located in the south west side but not directly affected.	C	No mangrove observed.	**A**	Many resettlements are expected and land acquisition might be required.	✓	-

Impact Rating: (A): Serious impact is expected. (B): Some impact is expected. (C): Few impacts are expected. (D): Impact is unknown (serious impacts are not expected, but detailed survey is required on preparatory survey stage)

Screening definition: (A) serious (B) A degree of impact, but not serious (C) Few impacts are expected (refer to Table 3.5.3 Definition of Category on JICA Guideline)

Source: JICA Study Team

8.6.2 Recommended Environmental Mitigation Measures

Recommended major mitigation measures are shown below;

Table 8.6.2 Environmental Management Plan (Expected Mitigation Measures)

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Pollution	1	Air pollution	- Dust Water sprinkling near residential area	Appropriate land use management on roadside roads
	2	Water pollution	- Turbid water Sheet pile method is adopted to minimize turbid water during foundation repair works	-
	3	Waste	- Construction waste (waste concrete) Construction waste such as waste concrete is disposed at designated disposal site	-
	4	Soil contamination	-	-
	5	Noise and vibration	- Construction noise near residential area Installing noise barrier and selecting low-noise equipment. Avoiding works of heavy equipment during night time. Informing the construction schedule to surrounding communities to obtain their consensus.	Setting of noise barriers depending on need Appropriate land use management on roadside roads
	6	Sediment quality	-	-
Natural environment	9	Protected Area	CRZ permission shall be requested from environmental authorization agency (Ministry of Environment and Forest), if the reconstruction bridge with new approach road is in CRZ	-
	11	Hydrology	Designing of bridges with sufficient capacity	-
	12	Topography and geology	-	-
Social environment	13	Involuntary resettlement	Appropriate compensation shall be implemented in accordance with JICA Guidelines	-
	14	The poor		-
	15	Indigenous and ethnic people		-
	16	Local economy such as employment and livelihood		-
	17	Land use and utilization of local resources		
	18	Water usage	Installation of alternative water distribution system when unexpected situation such as reduction of water level of wells, if any	
	19	Existing social infrastructures and services	Appropriate compensation and displacement shall be implemented in accordance with JICA Guidelines	-
	22	Local conflict of interests	Local workforce is prioritized for construction of the bridge.	-
	23	Cultural heritage	If the project effect on the community temple, sacred places and monument, appropriate consultation and agreement shall be concluded with local stakeholders	-
	27	Infectious diseases such as HIV/AIDS	In order to prevent spread of infectious diseases such as HIV/AIDS, awareness of the laborers is promoted.	-

Category	No.	Item JICA Guidelines	Recommended Mitigation Measures	
			Pre and During Construction phase	Operation phase
Others	29	Accidents	- Installing gate structure at the entrance of the construction site to set up restricted area - Deploying flagman at the gate and crossing points of the construction vehicles - Installing fence around the construction site to keep out local people such as children - Restricting mobilization speed in the construction site - Safety training for the workers - Safety patrol at the construction site by supervisors - Monthly safety meeting	Traffic safety control and management should be done on the bridges without sidewalk (Excluding motor vehicle exclusive road)
	30	Cross boundary impacts and climate change	-	-

(-): Not required mitigation measures since negative impacts are negligible

Source: JICA Study Team