INDIA
BANGALORE DEVELOPMENT AUTHORITY
DIRECTORATE OF URBAN LAND TRANSPORT,
GOVERNMENT OF KARNATAKA

JICA EXPERTS ON BENGALURU PERIPHERAL RING ROAD PROJECT IN INDIA

FINAL REPORT
(TECHNICAL REVIEW REPORT)

OCTOBER 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

JICA STUDY TEAM Consisted by
NIPPON KOEI CO., LTD.
EAST NIPPON EXPRESSWAY CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

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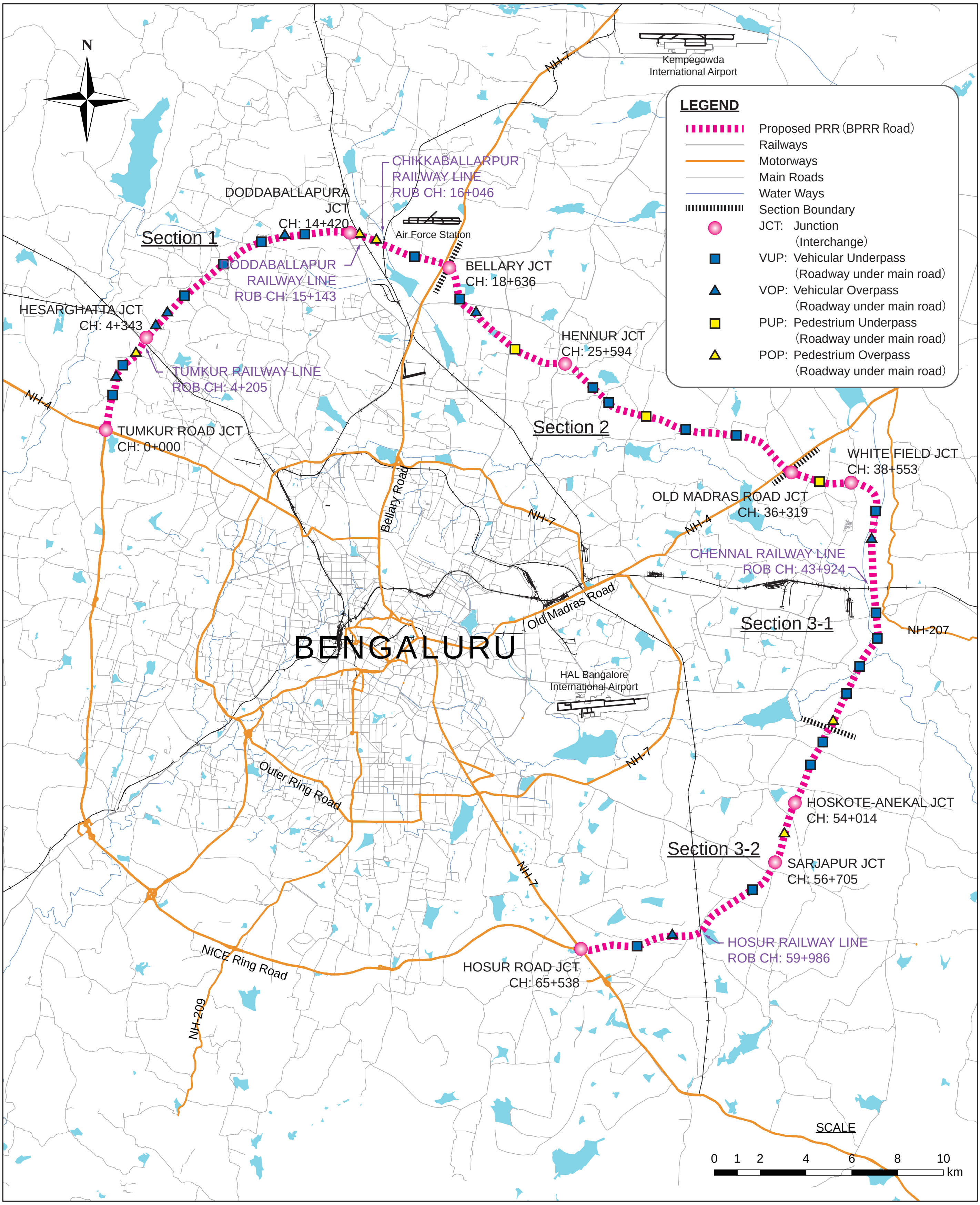

Source : JICA Experts

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Abbreviation:

AASHTO : American Association of State Highway and Transportation Officials

B/C : Benefit-Cost Ratio
BDA : Bangalore Development Authority
BOT : Built Operate and Transfer
BPRR : Bengaluru Peripheral Ring Road

CDP : Comprehensive Development Plan
CIP : Cast-In-Place
CTTP : Comprehensive Traffic and Transportation Plan for Bengaluru

D/D : Detailed Design
DBOT : Design, Build, Operation and Transfer
DP(s) : Discussion Paper(s)
DPR : Detailed Project Report
DR : Discount Rate
DULT : Directorate of Urban Land Transport

EIRR : Economic Internal Rate Return
ETC : Electronic Toll Collection

FEM : Finite Element Method
FX (Cost) : Foreign Exchange (Cost)

Gov : Government

H(h) : Height

IC :Interchange
IRC : Indian Road Congress
IRR : Internal Rate Return
ITS : Intelligent Transport Systems

JCT : Junction
JICA : Japan International Cooperation Agency

KM : kilometer(s)

L/A : Loan Agreement
LCV : Light Commercial Vehicle
LOS : Level of Service

MAV : Multi Axle Vehicle
MORTH : Ministry of Road Transport and Highways
MSE : Mechanical Stabilized Earth (Retaining Wall)

NDDP : Net District Domestic Product
NH : National Highway(s)
NPV : Net Present Value

O&M(O/M) : Operation and Maintenance
OBU : On Board Unit

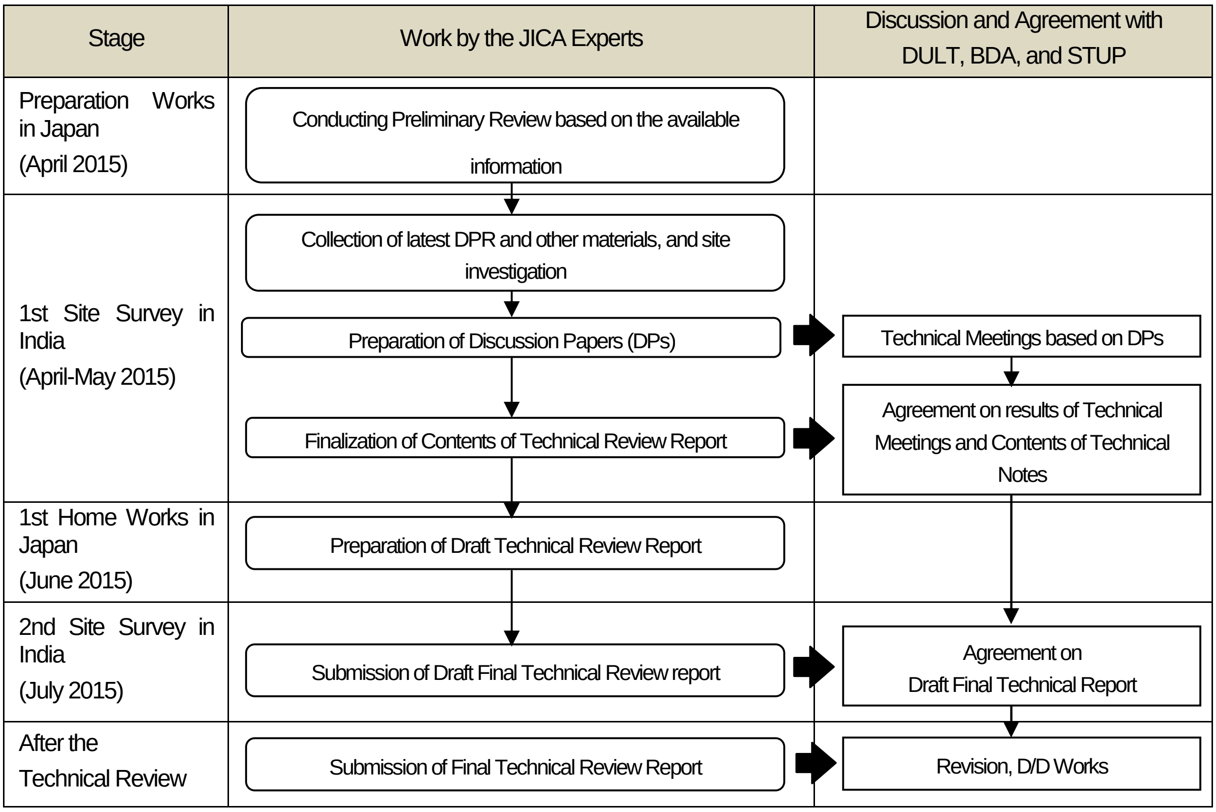
OD	: Origin and Destination
pa	: per annual
PC-I	: Prestressed Concrete I Girder (Bridge)
PCU	: Passenger Car (Equivalent) Unit
PHF	: Peak Hour Flow
POP	: Pedestrian Overpasses
Prv	: Private
PUP	: Pedestrian Underpasses
RC	: Reinforced Concrete (Bridge)
ROB	: Railway Over Bridges
ROW	: Right of Way
RUB	: Railway Under Bridges
SPC	: Special Purpose Company
SPV	: Special Purpose Vehicle
STUP	: STUP Consultants Pvt. Ltd.
T&G	: Touch & Go
TTC	: Travel Time Cost
VGF	: Viability Gap Fund
VOC	: Vehicle Operation Cost
VOP	: Vehicular Overpasses
VUP	: Vehicular Underpasses
WACC	: Weighted Average Cost of Capital

(1) INTRODUCTION

The Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched the JICA Experts as the Technical Review Team for the Bengaluru Peripheral Ring Road (BPRR) Project (hereinafter referred to as "the Project") in accordance with the minutes of meeting (MoM) on 16th January 2015 among JICA, the Directorate of Urban Land Transport (DULT), and the Bengaluru Development Authority (BDA).

The objectives of the technical review are to review the final DPR (Detailed Project Report) prepared by BDA, and to provide necessary technical advisory for the detailed engineering design which will be conducted by BDA.

Figure 1 shows the working flow of the technical review works.



Stage	Work by the JICA Experts	Discussion and Agreement with DULT, BDA, and STUP
Preparation Works in Japan (April 2015)	Conducting Preliminary Review based on the available information	
1st Site Survey in India (April-May 2015)	Collection of latest DPR and other materials, and site investigation Preparation of Discussion Papers (DPs) Finalization of Contents of Technical Review Report	Technical Meetings based on DPs Agreement on results of Technical Meetings and Contents of Technical Notes
1st Home Works in Japan (June 2015)	Preparation of Draft Technical Review Report	
2nd Site Survey in India (July 2015)	Submission of Draft Final Technical Review report	Agreement on Draft Final Technical Report
After the Technical Review	Submission of Final Technical Review Report	Revision, D/D Works

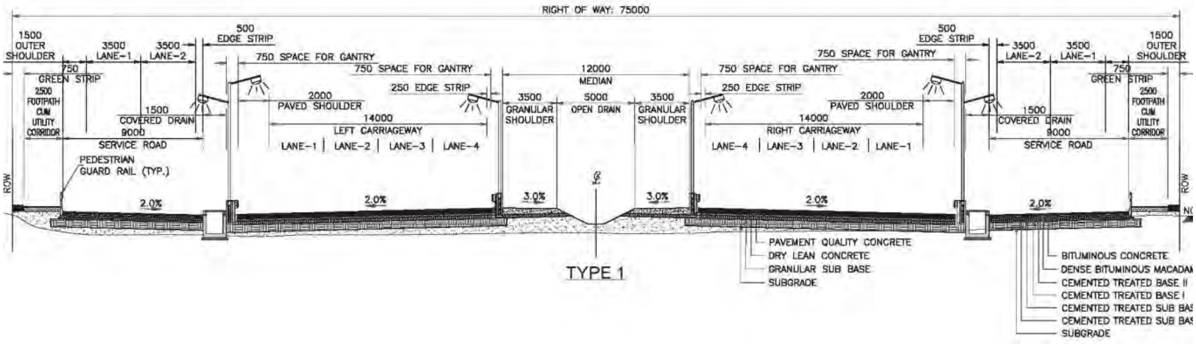
Source: JICA Experts

Figure 1 Work Flow of Technical Review

(2) ROAD DESIGN

The road design of DPR has been reviewed by JICA Experts. In DPR, the design speed of the Project was not defined clearly within the range between 80-100km/h. In this study, the road classification of BPRR was confirmed as "urban road" (not "expressway") with the design speed of 80 km/h.

Based on the definitive road classification and design speed, the geometric design elements of the drawings of DPR were reviewed referring to the IRC (Indian Road Congress) and the substandard elements have been pointed out and technical recommendations were provided in this report for the detailed design.



Source: JICA Experts

Figure 2 Definitive Typical Cross Section

The interchange/junction layout has also been reviewed by JICA Experts. In DPR, there are 3 sections which have more than 10km length between adjacent interchanges as shown in Figure 3. The corridor along the proposed BPRR will be developed and urbanized after the completion of the road and will require interchanges with proper interval for the convenience of the road user and enhancement of use of BPRR. JICA Experts proposed three (3) additional interchanges at above mentioned sections. The traffic volume on the additional interchanges has been estimated by the traffic demand forecast.

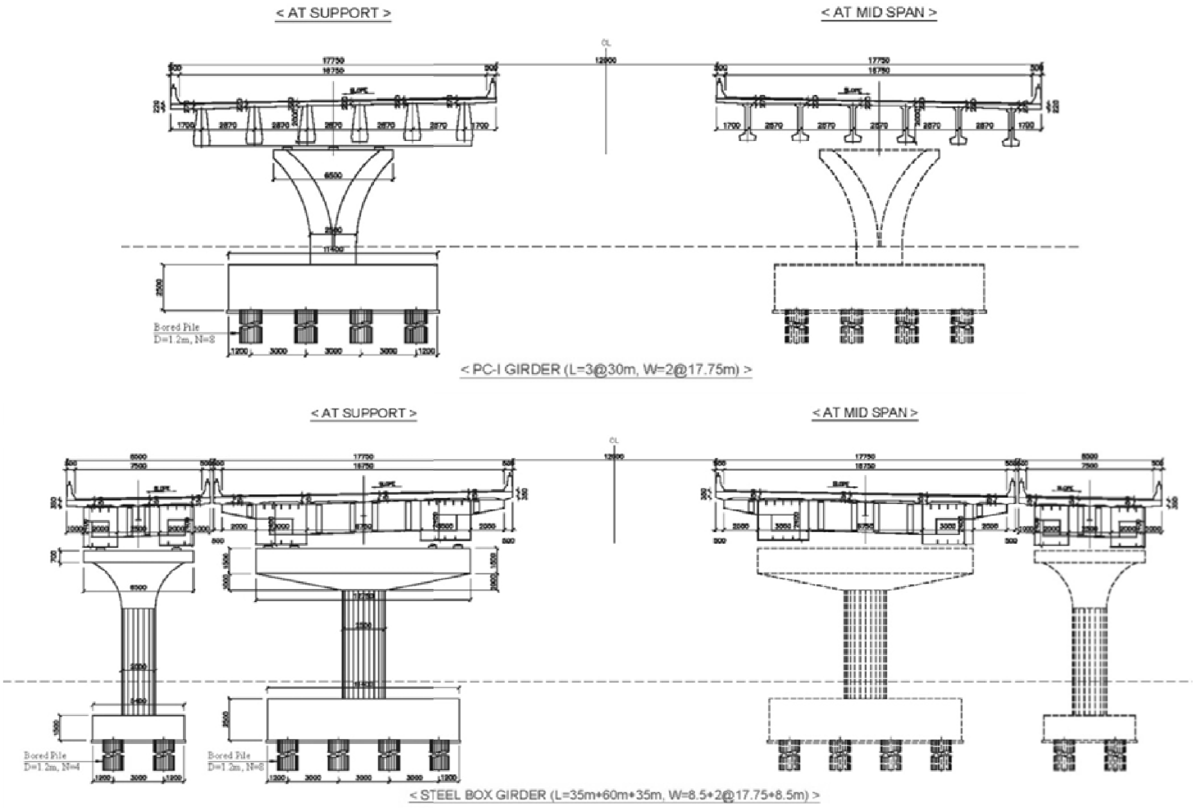
Source: JICA Experts

Figure 3 Long Interval of Interchanges

(3) STRUCTURAL DESIGN

The structural design of DPR has been reviewed by JICA Experts in parallel with the review of the road design.

In DPR, PC-Box Girder was proposed for all of the bridges. JICA Experts additionally proposed two (2) types of bridges, PC-I Girder and Steel Box Girder, based on the required span length, method of erection at the site, economically reasonable cost, etc.



Source: JICA Experts

Figure 4 Additional Types of Bridges

The section of the bridges at two (2) railway crossings was extended to avoid the high retaining wall (approximately 18m height) at the approach sections of the bridges on swampy land. Other structure design such as box culvert, etc. was also reviewed and the technical suggestions were provided.

(4) TRAFFIC DEMAND FORECAST

JICA Experts conducted the traffic demand forecast based on the demand forecast model of ITS M/P Study by JICA (Master Plan Study on the Introduction of Intelligent Transport Systems (ITS) in Bengaluru and Mysore).

The necessity of the number of lanes proposed by DPR (i.e. 8-lane for the mainline and 4-lane for the service road) was justified by the demand forecast by JICA Experts.

Table 1 Result of Traffic Demand Forecast on Main Lane of BPRR by Section

Year	Section 1 (0-18 km)	Section 2 (18-36 km)	Section 3-1 (36-50 km)	Section 3-2 (50-65 km)	Total Average (PCU/day)
2022	39,000	41,000	40,000	39,000	42,000
2030	84,000	78,000	69,000	64,000	74,000
2040	146,000	141,000	116,000	105,000	128,000

Source: JICA Experts

Table 2 Result of Traffic Demand Forecast on Service Road of BPRR by Section

Year	Section 1 (0-18 km)	Section 2 (18-36 km)	Section 3-1 (36-50 km)	Section 3-2 (50-65 km)	Total Average (PCU/day)
2022	11,000	23,000	14,000	15,000	15,000
2030	23,000	30,000	20,000	24,000	25,000
2040	29,000	36,000	28,000	37,000	33,000

Source: JICA Experts

Also the number of booths on the toll gates has been estimated for the reference of the detailed design.

(5) INTELLIGENT TRANSPORT SYSTEMS (ITS)

In DPR, the cost of ITS was tentatively estimated based on the available information from the draft report of ITS M/P Study. JICA Experts reviewed the scope and the cost of the ITS based on the final report of ITS M/P Study and the demarcation of the scope of the grant portion (project requested for Japanese grant scheme) and the loan portion (the Project).

Table 3 ITS Components by the Grant and Loan Projects

ITS Component			Grant	Loan
City ITS	Bengaluru Traffic Information System (B-TIC)	Centre System (including Probe Car System)	●	●
		Queue Length Measurement System		
		Automatic Traffic Counter-Cum Classifier (ATCC) System		
		Variable Message Sign (VMS) System		
		Internet System		
	Area Traffic Signal Control System (ATCS) (*1)		●	●
	Clearinghouse for Common Smartcard			●
ITS for PRR	Highway Traffic Management System (HTMS)			●
	Toll Management System (TMS)			●

Source: JICA Expert

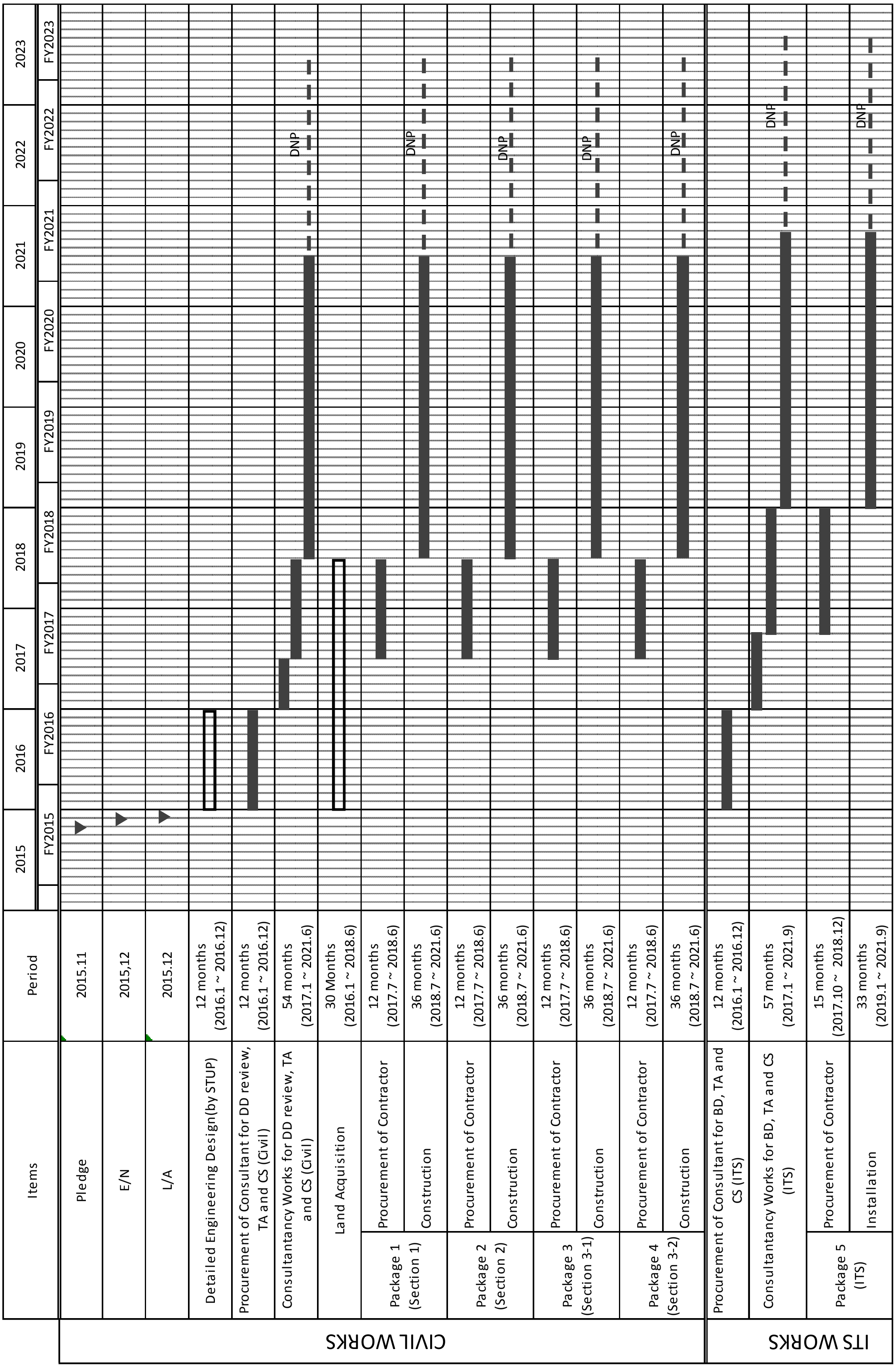
*Note (*1): Additional ATCS will be installed by Indian government after the loan project implementation.*

Also the implementation scheme such as task demarcation during installation and operation stage of each authority has been reviewed based on the series of discussions with concerned authorities such as Traffic Police.

(6) IMPLEMENTATION PLAN

JICA Experts prepared the implementation plan in this report assuming the loan funding will be given due consideration by JICA.

Figure 5 shows the proposed implementation plan.



	Items		Period
CIVIL WORKS	Pledge		2015.11
	E/N		2015,12
	L/A		2015.12
	Detailed Engineering Design(by STUP)		12 months (2016.1 ~ 2016.12)
	Procurement of Consultant for DD review, TA and CS (Civil)		12 months (2016.1 ~ 2016.12)
	Consultantancy Works for DD review, TA and CS (Civil)		54 months (2017.1 ~ 2021.6)
	Land Acquisition		30 Months (2016.1 ~ 2018.6)
	Package 1 (Section 1)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 2 (Section 2)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 3 (Section 3-1)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 4 (Section 3-2)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
ITS WORKS	Procurement of Consultant for BD, TA and CS (ITS)		12 months (2016.1 ~ 2016.12)
	Consultantancy Works for BD, TA and CS (ITS)		57 months (2017.1 ~ 2021.9)
	Package 5 (ITS)	Procurement of Contractor	15 months (2017.10 ~ 2018.12)
		Installation	33 months (2019.1 ~ 2021.9)

Source: JICA Experts

Figure 5 Implementation Plan

(7) COST ESTIMATE

The project packaging (Sections) in DPR are divided into three sections at the points of intersection with National Highways. The project scale of Section 3 is quite larger than other sections. Therefore, the JICA Experts proposed to divide Section 3 into two sections (namely Section 3-1 and Section 3-2).

Table 4 Project Packaging for Implementation

Section	Chainage	Length (km)
Section 1	KM 0.000 (Tumkur Road) - KM 18.367 (Bellary Road)	18.367
Section 2	KM 18.367 (Bellary Road) - KM 36.323 (Old Madras Road)	17.956
Section 3-1	KM 36.323 (Old Madras Road) - KM 50.000	13.677
Section 3-2	KM 50.000 - KM 65.538 (Hosur Road)	15.538

Source: JICA Experts

Table 5 Structure of Project Cost Estimate

Structure of Project Cost Estimate for JICA Appraisal			Structure of Project Cost Estimate R(3) in DPR	
Item		Total Amount	Item	Total Amount
		million INR		million INR
A. ELIGIBLE PORTION				
I)	Procurement / Construction	38,018	A. Road Works, B. Structure Works, C. Earth Retaining Structures, F. Other Items of Work	37,557
i)	Package-1 (Section-1 : KM00+000-KM18+367)	8,797	A, B, C, F) Strech-1 (KM00+000-KM18+367)	7,604
ii)	Package-2 (Section-2 : KM18+367-KM36+323)	6,386	A, B, C, F) Strech-2 (KM18+367-KM36+323)	6,120
iii)	Package-3 (Section-3-1 : KM36+323-KM50+000)	7,611	A, B, C, F) Strech-3 (KM36+323-KM65+538)	10,648
iv)	Package-4 (Section3-2 : KM50+000-KM65+538)	7,623		
v)	Package-5 (ITS : BPRR & Bengaluru City)	3,724	G) ITS	8,000
vi)	Dispute Boards (Package-2&3)	0	-	
vii)	Dispute Boards (Package-1&4&5)	0	-	
	Base Cost for JICA Financing (i+ii+iii+iv+v+vi+vii)	34,140	Sub Total （A+B+C+F+G）	32,372
	Price Escalation	2,069	F-12) Price Escalation (a) for Year 2014-15	2,074
			F-12) Price Escalation (b) for Year 2015-16	2,074
	Physical Contingency	1,810	F-11) Contingency	1,037
II)	Consulting Services	2,995	F-7) Supervision Consultancy	604
	Consulting Services for Civil Works	1,780	a. PRR - Civil Construction	207
	Consulting Services for ITS Works	922	b. PRR - ITS Implementation	73
			c. City - ITS Implementation	323
	Base Cost	2,703	Sub Total (a+b+c)	604
	Price Escalation	150	-	0
	Physical Contingency	143	-	0
Total (I+II)		41,014	Total	38,161
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	Procurement / Construction	0
	Base Cost for GoI Financing	0	-	0
	Price Escalation	0	-	0
	Physical Contingency	0	-	0
b	Consulting Services	161	Consulting Services	156
	Base Cost (Detailed Design by STUP)	152	F-8) Design Fee	156
			F-1) Preparatory works like Topography, Soil Investigation, Construction Material assessment & test. etc.	415
	Price Escalation	1	-	0
	Physical Contingency	8	-	0
c	Land Acquisition	81,000	Land Acquisisition Cost	57,500
	Base Cost	81,000	E) Land Acquistion Cost (excl Rehabilitation / resettlement cost)	53,800
			F-3) Rehabilitation and Resettlement Cost	3,700
	Price Escalation	0	-	0
	Physical Contingency	0	-	0
d	Administration Cost	104	F-9) Approvals	176
			A-10) Provision and Maintenance of Vehicles and Mobile	8
e	VAT	5,970	-	0
f	Import Tax	437	-	0
Total (a+b+c+d+e+f)		87,671	Total	57,839
TOTAL (A+B)		128,685	**TOTAL**	96,000
C. Interest during Construction		553	-	0
	Interest during Construction(Const.)	537	-	0
	Interest during Construction (Consul.)	16	-	0
D. Front End Fee		82	-	0
GRAND TOTAL (A+B+C+D)		129,320	GRAND TOTAL	96,000
E. JICA Finance Portion (A)		41,014		38,161

Source: JICA Experts

(8) ECONOMIC AND FINANCIAL EVALUATION

Although the economic and financial analysis was conducted in DPR, there are some issues listed below.

- The Project cost was only for the construction cost, excluding the land acquisition cost. This proposed Bengaluru Peripheral Ring Road (BPRR) project is a green field project, thus the land acquisition cost should be included in the Project cost.

- Only the vehicle operation cost (VOC) benefit was estimated. Travel time cost saving was not mentioned. For a high standard urban road project, the benefit of travel time cost (TTC) saving is quite big. Thus, TTC saving should be fully considered for this Project.

Since the Project cost and estimate of attracted traffic along BPRR were reviewed by the JICA Expert, economic and financial evaluation has been revised.

Table 6 presents the evaluation results of the economic analysis.

Table 6 Result of Economic Analysis

EIRR	15.0%
B/C	1.33
NPV (Rs in million @ i	21,214

Source: JICA Experts

The economic costs and benefits of the Project generated a positive NPV and an EIRR that are higher than the government-prescribed hurdle rate (12%). These values indicate that the Project is economically viable.

Table 7 shows the evaluation results of the financial analysis.

Table 7 Result of Financial Analysis

Case	Results		
	Project IRR	IRR for SPV	Equity IRR
Case 1: Pure BOT	1.42%	5.87%	4.50%
Case 2: BOT with GFS		8.47%	7.88%

Source: JICA Experts

Project IRR, which considers all costs including construction cost, consultancy cost, ROW acquisition cost, and O&M cost, is 1.42%. This implies that the private sector investment is not financially viable. The Project up to the completion of facilities is planned to be invested by the government.

IRR for SPV, which considers construction cost, consultancy cost and O&M cost to be invested by the private company, is 5.87% for Case 1 and 8.47% for Case 2. WACC is estimated to be 11.6%. Thus, the Project is not financially viable and will not be attractive to the private sector for both cases.

Equity IRR is estimated to be at 4.50% for Case 1 and 7.88% for Case 2. This is considered low to attract the interest of the private sector.

CHAPTER 1 INTRODUCTION

The Japan International Cooperation Agency (hereinafter referred to as “JICA”) dispatched the JICA Experts as the Technical Review Team for the Bengaluru Peripheral Ring Road (BPRR) Project (hereinafter referred to as “the Project”) in accordance with the minutes of meeting (MoM) on 16th January 2015 among JICA, the Directorate of Urban Land Transport (DULT), and the Bengaluru Development Authority (BDA).

1.1 Objectives and Scope of the Technical Review

1.1.1 Objectives of the Technical Review

The objectives of the technical review are to review the Final DPR (Detailed Project Report) prepared by BDA, and to provide necessary technical advisory for the detailed engineering design and other necessary advisory services.

Table 1.1.1 Project Features

Items	Contents
Project Name	Bengaluru Peripheral Ring Road (BPRR) Project
Project Site	Bengaluru City, Karnataka State, the Republic of India (See project location map in the beginning of this inception report)
Project Objective	Contributing regional economic development by mitigating traffic congestion inside the Bengaluru City area.
Main Features of Project Facilities	Road Classification: High-standard highway (Toll road) Road Length: 65 km Nos. of Lane: 8 lanes (Main line), 4 lanes (Service road) Junction (IC): 10 locations Main Structures/Facilities: Retaining wall, bridge, box culvert and ITS
Relevant Master Plan	Comprehensive Development Plan (CDP), Comprehensive Traffic and Transportation Plan (CTTP) for Bengaluru City

Source: The JICA Experts based on DPR

1.1.2 Scope of the Technical Review based on the Minutes of Meeting

The scope of the technical review follows the terms of reference (ToR) which were agreed and signed among JICA, DULT, and BDA in the MoM on 16th January 2015.

The scope of the technical review agreed in the MoM is itemized below. It is noted that the technical review in this stage covers item no. 1 only.

<u>**Scope of the Technical Review (Section II, Annex, MoM)**</u>

1. Reviewing the following items of the final DPR
   - 1-1 Design of interchanges between BPRR and radial roads
   - 1-2 Structural design of flyover and underpass

1-3 Traffic analysis and traffic demand forecast for toll plaza planning, layout and designs
1-4 Planning and design of toll plaza (with ETC, T&G and manual lane, etc.)

2. To provide necessary technical advisory for detailed engineering design within the land acquired by BDA, and other necessary advisory services in a speedy and effective manner.

2-1 To modify the design if necessary during the detailed engineering design stage.

In addition, the review of the cost estimate on the DPR was conducted based on the design review by the above.

1.1.3 Actual Work Items during Technical Review

Having the fully supportive cooperation from DULT, BDA and the STUP Consultant Pvt. Ltd (hereinafter referred to as "STUP"), the JICA Experts could review the items in Table 1.1.2 on the DPR during the series of the technical discussions. Some items are beyond the scope of works in MoM. The JICA Experts would like to express great thanks for the kind support from DULT, BDA, and STUP.

Table 1.1.2 Comparison of Review Items Between MoM and Actual Work

Review Items Under MoM	Actual Reviewed Items
Design of interchanges	Design of interchanges
	(Additional) Additional interchanges (3 nos)
-	***(Additional)*** Design of horizontal and vertical alignment of mainline
Structural design of flyover and underpass	Structure design of flyover and underpass
Traffic analysis and traffic demand forecast for toll plaza planning, layout and designs	Traffic analysis and traffic demand forecast for toll plaza planning, layout and designs
	(Additional) Traffic analysis of mainline and service road
Planning and design of toll plaza (with ETC, T&G and manual lane, etc.)	Planning and design of toll plaza (with ETC, T&G and manual lane, etc.)
-	***(Additional)*** Implementation schedule
-	***(Additional)*** Cost estimate

Source: JICA Experts

1.1.4 Counterparts

The counterpart authorities of Indian side to the technical review are listed below:

- Bengaluru Development Authority (BDA)
- Directorate of Urban Land Transport (DULT), Government of Karnataka

1.1.5 JICA Experts

The JICA Experts are shown in Table 1.1.3.

Table 1.1.3 JICA Experts for Technical Review Team

Position	Name
Team Leader/Transport Planner	Takaaki TANAKA
Road Design 1 (Geometric Design)	Noboru KONDO
Road Design 2 (Structure/Bridge)	Tetsuya MAEDA
Traffic Demand Forecast	Ryuichi OIKAWA
Economic and Financial Analyses	Ryuichi UENO
Road Design 3 (Assistant Engineer)	Shuuei YAMADA
Cost Estimate	Fumiyasu NAKADA
ITS	Hiroya TOTANI

Source: JICA Experts

1.1.6 Design Consultant of DPR

The design consultant of DPR, the STUP, has also involved for the technical review meetings based on the request from DULT and BDA. The STUP is going to carry out the detailed design services for the Project under BDA and the technical review results by the JICA Experts shall be shared with STUP for the detailed design works.

1.2 Methodology of Technical Review

1.2.1 Base Report for Technical Review

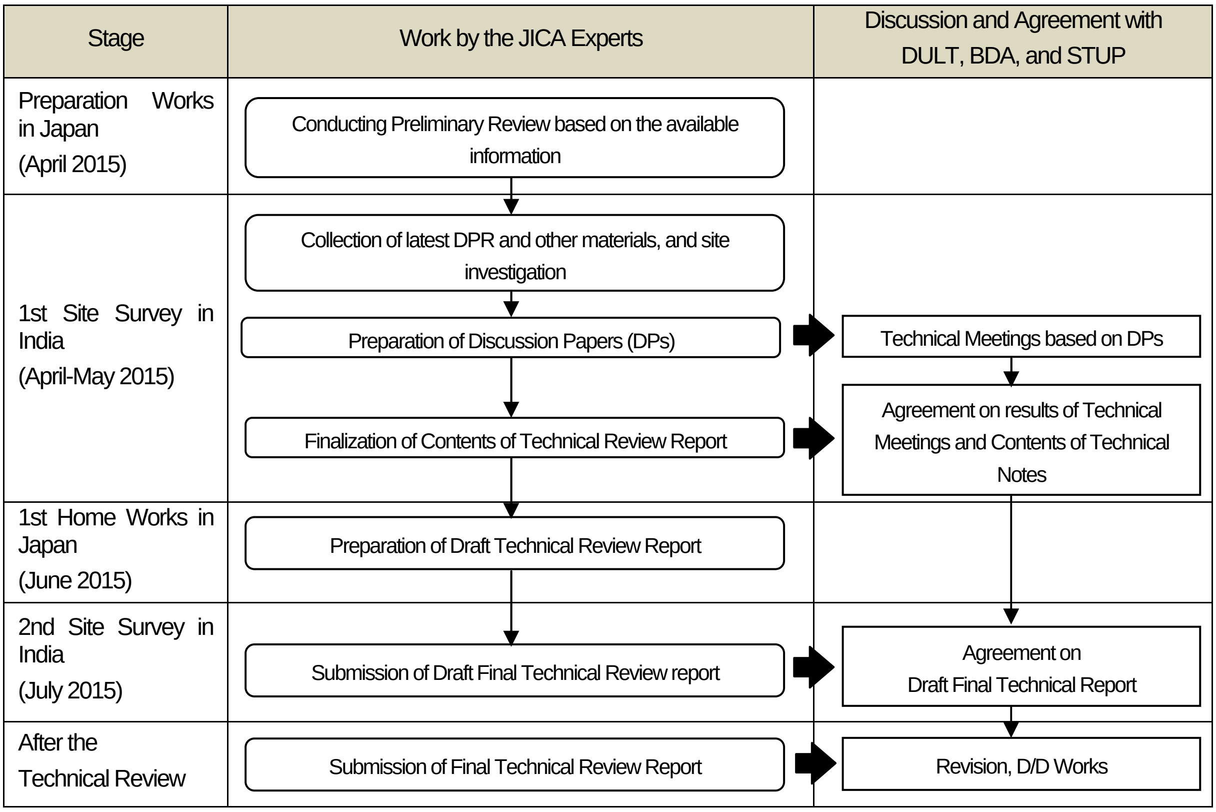
Prior to commence the technical review, the JICA Experts were provided the following latest version of the DPR from BDA and STUP as a base report and drawings for the review work.

- Final DPR, Version RN-05 Rev R(5), BDA
- Full set of DPR Drawings, BDA (provided by STUP on 7th May 2015 by PDF)
- Bill of Quantities and Cost Estimate, Rev No. R(3) dated on 22nd August 2014 (provided by STUP on 7th May 2015)

1.2.2 Work Flow of Technical Review

As proposed during the kick-off meeting on 28th April 2015, the JICA Experts prepared discussion materials as the Discussion Papers (DPs) and the technical discussions were held in the participation of DULT, BDA, and STUP to discuss regarding each review item proposed by the JICA Experts based on DPs. The conclusions of each technical discussion were recorded in the record of discussions. Each discussion paper and record of discussion were officially submitted to the commissioner of DULT and the engineer member of BDA for their confirmation.

The Figure 1.2.1 shows the working flow of the technical review works.



Source: JICA Experts

Figure 1.2.1 Work Flow of Technical Review

1.2.3 Technical Discussions

Technical Discussions were called by DULT and held as listed in Table 1.2.1.

Table 1.2.1 Schedule of Technical Discussions

No.	Date	Meetings	Matters discussed
1	28th April 2015	Kick-off Meeting	Work Procedure and Summary of Inception Report
2	6th May 2015	1st Technical Discussion >> Record of Discussion was issued on 6th May.	Discussion Paper R01 (Road) Discussion Paper S01 (Structure)
3	11th May 2015	2nd Technical Discussion >> Record of Discussion was issued on 16th May.	Discussion Paper R02 (Road) Discussion Paper R03 (Road)
4	12th May 2015	Explanation to Engineer Member, BDA >> Record of Discussion was issued on 13th May.	Discussion Paper R01 (Road) Discussion Paper S01 (Structure)
5	13th May 2015	3rd Technical Discussion >> Record of Discussion was issued on 19th May.	Discussion Paper S02 (Structure)
6	18th May 2015	4th Technical Discussion >> Record of Discussion was issued on 19th May.	Discussion Paper C01 (Cost) Discussion Paper E01 (Economic/Financial Analysis) Discussion Paper R04 (Road) Discussion Paper S03 (Structure) Discussion Paper T01 (Traffic Analysis)
7	19th May 2015	Explanation to Engineer Member, BDA >> Record of Discussion was issued on 20th May.	Discussion Paper R02 (Road) Discussion Paper R03 (Road) Discussion Paper C01 (Cost Estimate) Discussion Paper R04 (Road) Discussion Paper S03 (Structure)
8	21st May 2015	Wrap-up Meeting >> Minutes of Meeting was signed on 21st May.	Summary of Technical Discussions
9	26th May 2015	5th Technical Discussion >> Record of Discussion was issued on 26th May.	Discussion Paper C02 (Cost Estimate)
10	6th July 2015	6th Technical Discussion	Discussion Paper C03 (Cost Estimate)
11	9th July 2015	Submission of Draft Final Technical Report	Draft Final Technical Report
12	20th Aug. 2015	Comments on Draft Final Report by DULT/BDA	Draft Final Technical Report

Source : JICA Experts

Matters discussed during the series of the discussions will be technically considered for the detailed design which will be conducted by BDA.

CHAPTER 2 ROAD DESIGN

2.1 Road Design

2.1.1 Road Classification of Bengaluru Peripheral Ring Road (BPRR) and Applied Design Standard

(1) Comments and Suggestions on Detailed Project Report (DPR)

According to the detailed project report (DPR), BPRR is not classified/designed as an expressway under the Indian Design Guidelines (Guidelines for Expressways, 2010). Due to limited available land, BPRR was designed as an urban road, referring to the Indian Design Guidelines (IRC 86-1983). This decision was made by Bengaluru Development Authority (BDA), Directorate of Urban Land Transport (DULT). The JICA Experts respect this administrative decision.

(2) Conclusion

The JICA Experts confirmed that BPRR is designed as an urban road and not as an expressway.

2.1.2 Design Speed of BPRR (Main Line)

(1) Comments and Suggestions on DPR

In the DPR, the design speed of BPRR was determined as follows:

Main Line:	100 km/h (ruling), 80 km/h (minimum)
Service Road:	30 km/h
Junction/Junction Ramps	unknown

There were two types of design speed (100 km/h and 80 km/h) for the main line of BPRR originally proposed in the DPR.

The JICA Experts reviewed the horizontal alignment in the DPR based on IRC 86-1983 and IRC-Guidelines for Expressways. IRC 86-1983 specifies the design speed up to 80 km/h and the requirement for 100 km/h is not available. Therefore, IRC-Guidelines for Expressways was referred to check the100 km/h requirement.

The JICA Experts have pointed out that there are many sections which do not fulfill the geometric design requirement for 100 km/h design speed as presented in Table 2.1.1. During the course of discussion, STUP / BDA informed that the alignment corridor was finalized by BDA and STUP was directed to design the alignment within 75m Right of Way. Hence, the design speed of 100km/h cannot be used at most sections

Operational control (speed limit sign board, etc.) for frequency changes of the design speed along the same alignment is not practical and the JICA Experts suggested to adopt a uniform design speed of 80 km/h throughout the alignment of BPRR.

Many sections (49 curves as shown in Table 2.1.1) of the horizontal alignment shall be modified in case of a 100 km/h design speed. It will largely affect the land acquisition.

Table 2.1.1 Review on Geometric Elements of Horizontal Alignment of BPRR

	Elements on DPR										Check											
	Chainage				Circle		Spiral			Super elevation	Circle				Spiral						Superelevation	
											R		L(Lc+Ls)	L(Lc+Ls)	Omit Spiral		Ls1		A1			
	BS	BC	EC	ES	R	Lc	Ls1	Ls2	A1		IRC 86 V=80km/h	IRC-E (Desirable) V=100km/h	IRC-E V=80km/h	IRC-E V=100km/h	IRC-E V=80km/h	IRC-E V=100km/h	IRC 86 V=80km/h	IRC-E V=100km/h	JRSO V=80km/h	JRSO V=100km/h	IRC 86 V=80km/h	IRC 86 V=100km/h
1		0+151.792	0+175.115		2500	23.323	0.000	0.000	0.000	2.5%	OK	OK	error	error	Omit	Required		error		error	1.1%	1.8%
2		0+980.475	1+257.060		1800	276.585	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Required	Required	error	error	error	error	1.6%	2.5%
3	1+537.945	1+632.945	1+725.675	1+820.675	1200	92.730	95.000	95.000	337.639	3.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.4%	3.7%
4	2+203.792	2+328.792	2+751.691	2+876.691	800	422.899	125.000	125.000	316.228	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.6%	5.6%
5		2+917.515	3+244.575		2500	327.060	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
6	3+327.963	3+452.963	3+582.017	3+707.017	560	129.054	125.000	125.000	264.575	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	OK	5.1%	7.9%
7	4+124.109	4+224.109	4+375.411	4+475.411	1150	151.302	100.000	100.000	339.116	3.9%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.5%	3.9%
8		8+583.351	8+786.483		2500	203.132	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
9	9+356.422	9+431.422	9+432.120	9+507.120	1500	0.698	75.000	75.000	335.410	3.0%	OK	OK	OK	error	Required	Required	OK	OK	OK	OK	1.9%	3.0%
10	9+752.543	9+867.543	10+003.562	10+118.562	955	136.019	115.000	115.000	331.399	4.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.0%	4.7%
11		10+494.314	10+747.295		1800	252.981	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Required	Required	error	error	error	error	1.6%	2.5%
12	11+275.795	11+355.795	11+470.027	11+550.027	1425	114.232	80.000	80.000	337.639	3.1%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.0%	3.1%
13		13+286.723	13+576.540		2000	289.817	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.4%	2.2%
14	14+180.534	14+295.534	14+426.884	14+541.884	950	131.350	115.000	115.000	330.530	4.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.0%	4.7%
15	15+179.583	15+304.583	15+306.112	15+431.112	925	1.529	125.000	125.000	340.037	4.8%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.1%	4.8%
16		16+748.563	17+226.125		2500	477.562	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
17	18+356.553	18+481.553	19+321.089	19+446.089	835	839.536	125.000	125.000	323.071	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.4%	5.3%
18	19+985.184	20+110.184	20+682.792	20+807.792	890	572.608	125.000	125.000	333.542	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.2%	5.0%
19	21+062.118	21+157.118	21+314.510	21+409.510	750	157.392	95.000	95.000	266.927	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.8%	5.9%
20		21+446.283	21+724.530		1200	278.247	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Required	Required	error	error	error	error	2.4%	3.7%
21		23+215.583	23+778.370		2000	562.787	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.4%	2.2%
22	24+557.937	24+682.937	24+914.470	25+039.470	775	231.533	125.000	125.000	311.247	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.7%	5.7%
23	25+381.141	25+506.141	25+668.274	25+793.274	480	162.133	125.000	125.000	244.949	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	error	5.9%	9.3%
24	25+890.351	26+015.351	26+163.382	26+288.382	850	148.031	125.000	125.000	325.960	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.3%	5.2%
25		26+356.361	26+576.870		1400	220.509	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Required	Required	error	error	error	error	2.0%	3.2%
26		27+335.965	27+461.488		3000	125.523	0.000	0.000	0.000	2.5%	OK	OK	error	error	Omit	Omit				error	0.9%	1.5%
27		27+833.695	28+017.066		3000	183.371	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Omit				error	0.9%	1.5%
28	28+096.163	28+156.163	28+551.195	28+611.195	800	395.032	60.000	60.000	219.089	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	error	3.6%	5.6%
29		29+694.977	29+809.148		1327	114.171	0.000	0.000	0.000	3.3%	OK	OK	error	error	Required	Required	error	error	error	error	2.1%	3.3%
30	30+158.748	30+198.748	30+488.994	30+528.994	1200	290.246	40.000	40.000	219.089	3.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	error	2.4%	3.7%
31	31+024.673	31+059.673	31+370.136	31+405.136	1500	310.463	35.000	35.000	229.129	3.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	error	1.9%	3.0%
32		31+861.552	32+245.629		2000	384.077	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.4%	2.2%
33		32+479.798	32+598.286		2000	118.488	0.000	0.000	0.000	2.5%	OK	OK	error	error	Omit	Required		error		error	1.4%	2.2%
34		33+227.481	33+310.650		2000	83.169	0.000	0.000	0.000	2.5%	OK	OK	error	error	Omit	Required		error		error	1.4%	2.2%
35	33+831.494	33+956.494	33+966.986	34+091.986	650	10.492	125.000	125.000	285.044	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	OK	4.4%	6.8%
36	34+474.833	34+599.833	34+894.156	35+019.156	785	294.323	125.000	125.000	313.249	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.6%	5.7%
37		35+543.185	35+689.832		2000	146.647	0.000	0.000	0.000	2.5%	OK	OK	OK	error	Omit	Required		error		error	1.4%	2.2%
38	36+180.112	36+305.112	36+406.550	36+531.550	480	101.438	125.000	125.000	244.949	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	error	5.9%	9.3%
39		37+362.248	37+622.563		3000	260.315	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Omit				error	0.9%	1.5%
40		38+313.164	38+848.723		3000	535.559	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Omit				error	0.9%	1.5%
41	39+830.410	39+890.410	40+599.925	40+659.925	800	709.515	60.000	60.000	219.089	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	error	3.6%	5.6%
42		41+382.823	41+495.057		4000	112.234	0.000	0.000	0.000	2.5%	OK	OK	error	error	Omit	Omit				error	0.7%	1.1%
43		43+419.365	43+636.316		4000	216.951	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Omit				error	0.7%	1.1%
44	45+158.333	45+283.333	45+602.861	45+727.861	585	319.528	125.000	125.000	270.416	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	OK	4.9%	7.6%
45	46+237.168	46+337.168	46+481.304	46+581.304	1150	144.136	100.000	100.000	339.116	3.9%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.5%	3.9%
46		49+118.894	49+308.209		2000	189.315	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.4%	2.2%
47	49+373.000	49+498.000	49+587.725	49+712.725	735	89.725	125.000	125.000	303.109	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.9%	6.0%
48	49+788.397	49+913.397	49+988.690	50+113.690	725	75.293	125.000	125.000	301.040	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.9%	6.1%
49	50+289.857	50+414.857	50+432.549	50+557.549	850	17.692	125.000	125.000	325.960	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.3%	5.2%
50		51+048.058	51+538.066		2500	490.008	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
51		52+179.790	52+426.590		2500	246.800	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
52		53+429.783	53+893.096		2500	463.313	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Omit	Required		error		error	1.1%	1.8%
53	55+250.422	55+350.422	55+552.228	55+652.228	1175	201.806	100.000	100.000	342.783	3.8%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.4%	3.8%
54	56+544.446	56+669.446	56+870.052	56+995.052	670	200.606	125.000	125.000	289.396	5.0%	OK	error	OK	OK	Required	Required	OK	OK	OK	OK	4.2%	6.6%
55	59+109.762	59+234.762	59+433.807	59+558.807	775	199.045	125.000	125.000	311.247	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.7%	5.7%
56	59+851.465	59+976.465	60+630.551	60+755.551	800	654.086	125.000	125.000	316.228	5.0%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	3.6%	5.6%
57		61+544.571	62+274.977		1800	730.406	0.000	0.000	0.000	2.5%	OK	OK	OK	OK	Required	Required	error	error	error	error	1.6%	2.5%
58	62+595.889	62+690.889	63+231.700	63+326.700	1200	540.811	95.000	95.000	337.639	3.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.4%	3.7%
59	63+723.236	63+818.236	64+155.012	64+250.012	1200	336.776	95.000	95.000	337.639	3.7%	OK	OK	OK	OK	Required	Required	OK	OK	OK	OK	2.4%	3.7%
60		64+829.111	65+057.580		500	228.469	0.000	0.000	0.000	5.0%	OK	error	OK	OK	Required	Required	error	error	error	error	5.7%	8.9%

Source: JICA Experts

Requirements of both IRC manuals on Table 2.1.1 are summarized below.

Table 2.1.2 Requirements of IRCs

Design Elements	Design Speed	Requirements	Remarks
R: Minimum Radius	80 km/h	R> 265 m	IRC 86-1983
	100 km/h	R>700 m (desirable)	IRC Expressway
L: Length of Curve	80 km/h	L>140 m	IRC Expressway
	100 km/h	L>170 m	IRC Expressway
Omission of Transition Curve	80 km/h	R>2000 m	IRC Expressway
	100 km/h	R>3000 m	IRC Expressway
Ls: Length of Spiral (Transition)	80 km/h	Ls>$\frac{0.0215V^3}{CR}$ V: Design speed R: Radius of circular curve C=$\frac{80}{75+V}$	IRC 86-1983
	100 km/h		IRC Expressway
A: Parameter of Clothoid	80 km/h	A>180	JRSO
	100 km/h	A>250	JRSO

Source: JICA Experts

(2) Conclusion

The design speed of the main line of BPRR shall be 80 km/h. Design will be as per IRC 86-1983.

2.1.3 Horizontal Alignment of BPRR (Main Line)

2.1.3.1 Length of Curves

(1) Comments and Suggestions on DPR

In the DPR, there are some curves which do not fulfill the minimum length of curves specified in the design standard (IRC).

IRC 86-1983 does not specify the minimum length of curves. Therefore, IRC-Guidelines for Expressways was referenced. The minimum length of curves in the IRC-Guidelines is 140 m for an 80 km/h design speed which is incorporated to the time of maneuver required for drivers (6 seconds). It is noted that the length does not include the length of transposition curves too.

Table 2.1.3 presents the section to be modified to ensure the required minimum length of curves.

Table 2.1.3 Curves Required to be Modified

ID	Chainage	Radius	Length in DPR	Minimum Length Required
1	0+160	2500 m	23 m	140 m (6 seconds for maneuvering the handle by driver)
26	27+400	3000 m	125 m	
29	29+750	1327 m	114 m	
33	32+550	2000 m	118 m	
34	33+250	2000 m	83 m	
42	41+450	4000 m	112 m	

Source: JICA Experts

(2) Conclusion

The proposed modification of curve length was agreed. The JICA Experts made sample drawings as shown in Appendix 1-B and showed the modification details in Table 2.1.4. Requirements for the modifications shall be reflected in the detailed design.

Table 2.1.4 Modification regarding Length of Curves

	Chainage				Circle		Spiral			Modification Details
					R	L(Lc+Ls)	Omit Spiral	Ls1	A1	
	BS	BC	EC	ES	IRC 86 V=80 km/h	IRC-E V=80 km/h	IRC-E V=80 km/h	IRC 86 V=80 km/h	JRSO V=80 km/h	
1		0+151.792	0+175.115		OK	error	Omit			Radius=16000 m Length of Curve=140 m
26		27+335.965	27+461.488		OK	error	Omit			Radius=3500 m Length of Curve=140 m
29		29+694.977	29+809.148		OK	error	Required	error	error	Add spiral before and after the curve. Spiral length=70 m Radius=1000 m Length of Curve=86 m A=300
33		32+479.798	32+598.286		OK	error	Omit			Radius=3500 m Length of Curve=140 m
34		33+227.481	33+310.650		OK	error	Omit			Radius=3500 m Length of Curve=140 m
42		41+382.823	41+495.057		OK	error	Omit			Radius=3500 m Length of Curve=140 m

Source: JICA Experts

2.1.3.2 Transition Curves

(1) Comments and Suggestions on DPR

In the DPR, there are discrepancies in the method of adoption of transition curves. For instance, the curve at 1+700 with R=1200 adopts transition curves properly but the curve at 21+600 (ID 20) does not apply transition curve (tangent-curve type). The method of adoption of transition curves is not uniform. Therefore, such discrepancy in the design should be rectified.

IRC 86-1983 does not clearly specify the limitation of applying transition curves. IRC 86-1983 is prepared for arterial roads in urban areas. The main line of BPRR is classified as a high-speed semi-expressway and proper transition curves need to be applied for safety. On the other hand, IRC-Guidelines clearly specifies the limitation to applying transition curves, where a radius of less than R=2000 m shall require transition curves.

Table 2.1.5 Curves Required to Add Transition Curves

ID	Chainage	Radius	Minimum Length of Transition Curve
2	1+100	1800 m	70 m (3 seconds time for maneuvering the handle by driver)
11	10+600	1800 m	
20	21+600	1200 m	
25	26+450	1400 m	
29	29+750	1327 m	
57	61+900	1800 m	
60	64+900	500 m	

Source: JICA Experts

(2) Conclusion

The JICA Experts confirmed that the lack of transition curves needs to be modified if radius is below 2000 m. The JICA Experts prepared sample drawings as shown in Appendix 1-B and showed the modification details in Table2.1.6. Requirement for modification should be reflected in the detailed design.

Table 2.1.6 Modification regarding Transition Curves

	Chainage				Circle		Spiral			Modification Details
					R	L(Lc+Ls)	Omit Spiral	Ls1	A1	
	BS	BC	EC	ES	IRC 86	IRC-E	IRC-E	IRC 86	JRSO	
					V=80 km/h	V=80 km/h	V=80 km/h	V=80 km/h	V=80 km/h	
2		0+980.475	1+257.060		OK	OK	Required	error	error	Radius=2000 m Length of Curve=307.2 m
11		10+494.314	10+747.295		OK	OK	Required	error	error	Radius=2000 m Length of Curve=280 m
20		21+446.283	21+724.530		OK	OK	Required	error	error	Add spiral before and after the curve. Spiral length=95 m Radius=750 m Length of Curve=157.392 m A=343.57
25		26+356.361	26+576.870		OK	OK	Required	error	error	Add spiral before and after the curve. Spiral length=70 m Radius=720 m Length of Curve=80.51 m A=240.76
29		29+694.977	29+809.148		OK	error	Required	error	error	Add spiral before and after the curve. Spiral length=70 m Radius=1000 m Length of Curve=86 m A=300
57		61+544.571	62+274.977		OK	OK	Required	error	error	Radius=2000 m Length of Curve=810.5 m
60		64+829.111	65+057.580		OK	OK	Required	error	error	Add spiral before and after the curve. Spiral length=70 m Radius=500 m Length of Curve=80 m A=200

Source: JICA Experts

2.1.4 Superelevation

(1) Comments and Suggestions on DPR

The maximum superelevation in the curves is likely to be set at 5% in the DPR.

The JICA Experts calculated the required superelevation of each curve. The superelevation greater than 5% is only in four sections as listed below.

Table 2.1.7 Superelevation Exceeding 5% in the DPR

ID	Chainage	Radius	Calculated Superelevation
6	3+500	560 m	5.1%
23	25+600	480 m	5.9%
38	36+350	480 m	5.9%
60	65+000	500 m	5.7%

Source: JICA Experts

IRC 86-1983 accepts the range of superelevation between 4% (desirable) to 7% (maximum). IRC 86-1983 recommends 4% for urban roads considering easy turning movement (mainly at intersections). The main line of BPRR will be a full access controlled road (semi-expressway) and needs to apply appropriate superelevation calculated as technically required in order to secure driving safety under an 80 km/h design speed.

Accordingly, the JICA Experts proposed to eliminate the limitation of the superelevation.

(2) Conclusion

The limitation for adopting superelevation was omitted.

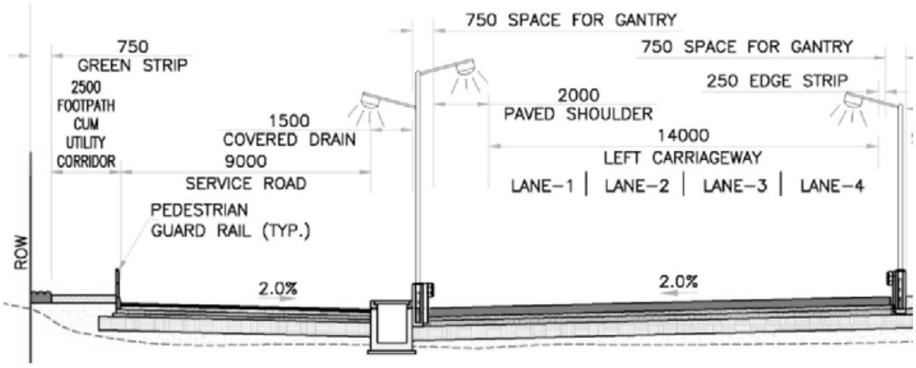
2.1.5 Cross Sections

2.1.5.1 General

(1) Comments and Suggestions on DPR

Based on the review by the JICA Experts in 2012/13, provision of the shoulders for the main line was agreed. Figure 2.1.1 shows the updated cross section in the drawings of typical cross sections in the Final DPR. Main modifications from draft DPR are listed below.

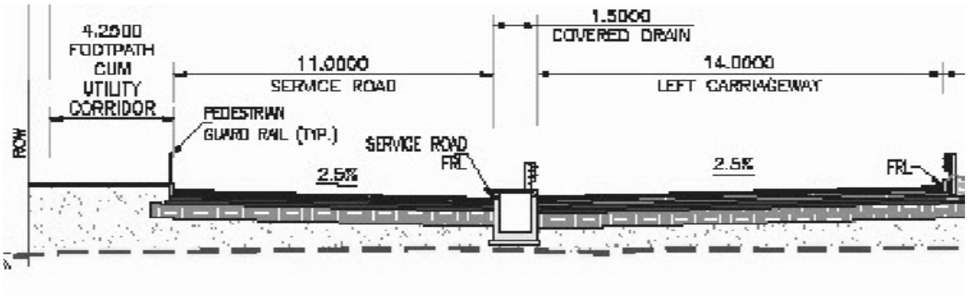
- Provision of outer shoulder (2.0 m)
- Provision of inner shoulder (0.25 m) as an edge strip
- Provision of 0.75 m width at inner/outer carriageway for gantry space
- Reduction of carriageway and footpath width of service road



Source: Final DPR, 2014

Figure 2.1.1 Cross Section in Final DPR

However, the old cross sections without shoulders were still found in the drawings of junctions in the DPR.



Source: Final DPR, 2014

Figure 2.1.2 Old Cross Section in Draft DPR

The JICA Experts suggested BDA and STUP to conduct the detailed design using only the agreed cross sections.

(2) Conclusion

Only updated cross sections shall be applied to the detailed design drawings.

2.1.5.2 Lane Width of Main Line

(1) Comments and Suggestions on DPR

The lane width of BPRR is 3.5 m based on IRC 86-1983. For reference, the lane width of an expressway is 3.75 m in plain and rolling terrains and 3.5 m only in mountainous terrains.

(2) Conclusion

It was confirmed that the 3.5 m lane width of BPRR was fixed based on IRC 86-1983 (urban road).

2.1.5.3 Shoulder and Edge Strip Width

(1) Comments and Suggestions on DPR

BPRR is designed as an urban road. The necessity of shoulders is not mentioned in IRC 86-1983. The necessity of shoulders was mutually agreed between DULT/BDA/STUP and JICA in 2012/2013 since the design speed of BPRR is 80 km/h with urban road geometric features. Therefore IRC-Guidelines was referred to finalize the dimension of the shoulders for BPRR.

Table 2.1.8 presents the required width of edge strips according to IRC-Guidelines.

Table 2.1.8 Width of Edge Strips in IRC-Guidelines

Terrain	Width of Edge Strip	
	Left (outer side)	Right (median side)
Plain	0.5 m	0.75 m
Rolling	0.5 m	0.75 m

Source: IRC-Guidelines for Expressways, 2010

According to IRC-Guidelines, "*edge strips should provide lateral support to the carriageway properly and will also accommodate the edge markings and edge strip shall be provided so as to enhance the delineation effect to drivers and to constitute a part of lateral clearance for the safety of vehicles*".

The width of edge strip in the final DPR is only 0.25 m and it does not fulfill the above requirement. Provision of 0.75 m width of edge strip (inner shoulder) was recommended by the JICA Experts. Table 2.1.9 presents the required width of shoulders (outer shoulder) according to IRC-Expressway.

Table 2.1.9 Width of Shoulders in IRC-Guidelines

Terrain	Paved Shoulder
Plain	3.0 m
Rolling	3.0 m

Source: Guidelines for Expressways, IRC, 2010

Provision of the above width is actually quite difficult for BPRR due to the available fixed land. However, the concept of the outer shoulder stipulated in IRC-Guidelines should be considered as much as technically practical.

IRC-Guidelines stated the following important functions regarding the provision of shoulders:

i) Space is provided for stopping of vehicle and make the through traffic lane free from obstruction because of mechanical difficulty, a flat tyre, or other emergencies;

ii) Space is provided for the occasional driver who is required to stop, to decide road ramps, service areas, or for other reasons;

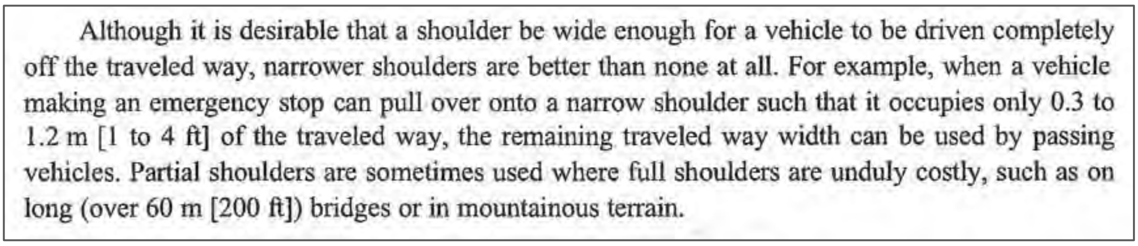
iii) Space is provided to avoid potential accidents or reduce their severity;

iv) The sense of openness created by shoulders of adequate width contributes much to driving ease and freedom from strain;

v) Sight distance is improved in cut sections, thereby improving safety; and

vi) Space is provided for road maintenance, operation and security.

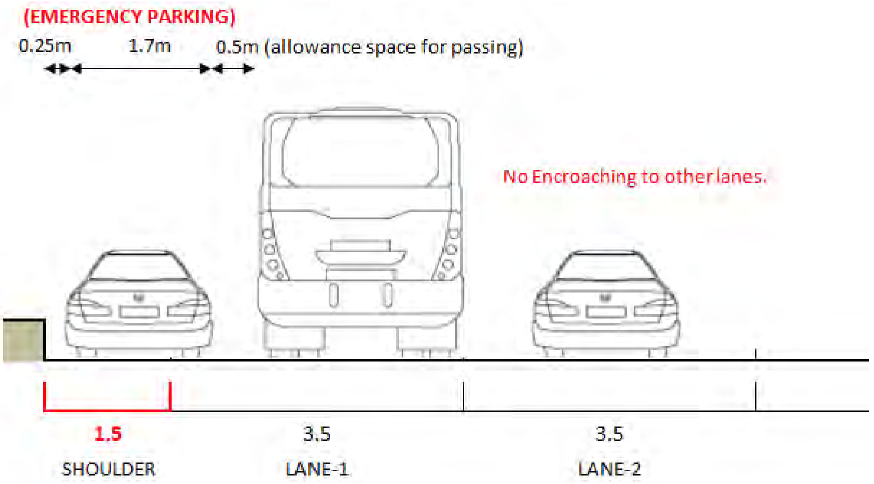
Accordingly, the JICA Experts have introduced “Partial Shoulder” concept which is well-known in other developed countries’ design guidelines (i.e., AASHTO) and proposed 1.5 m width of the outer shoulder for BPRR.



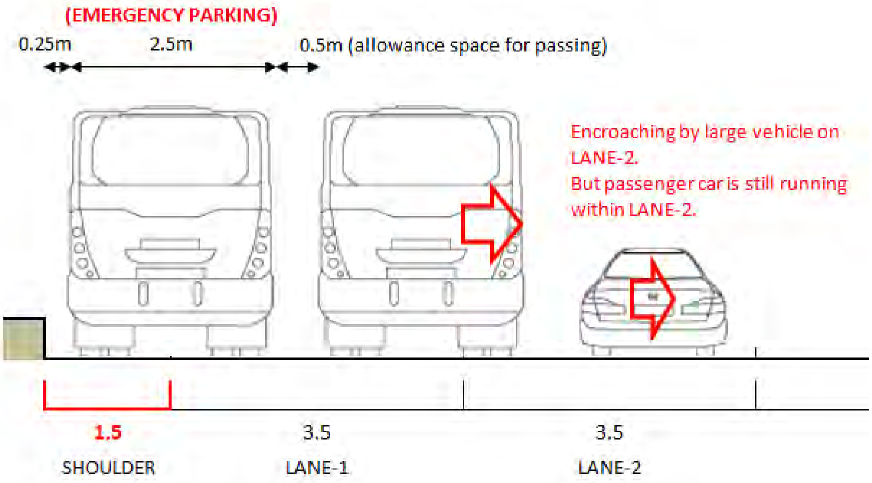
Although it is desirable that a shoulder be wide enough for a vehicle to be driven completely off the traveled way, narrower shoulders are better than none at all. For example, when a vehicle making an emergency stop can pull over onto a narrow shoulder such that it occupies only 0.3 to 1.2 m [1 to 4 ft] of the traveled way, the remaining traveled way width can be used by passing vehicles. Partial shoulders are sometimes used where full shoulders are unduly costly, such as on long (over 60 m [200 ft]) bridges or in mountainous terrain.

Source: A Policy on Geometric Design of Highways and Streets, AASHTO

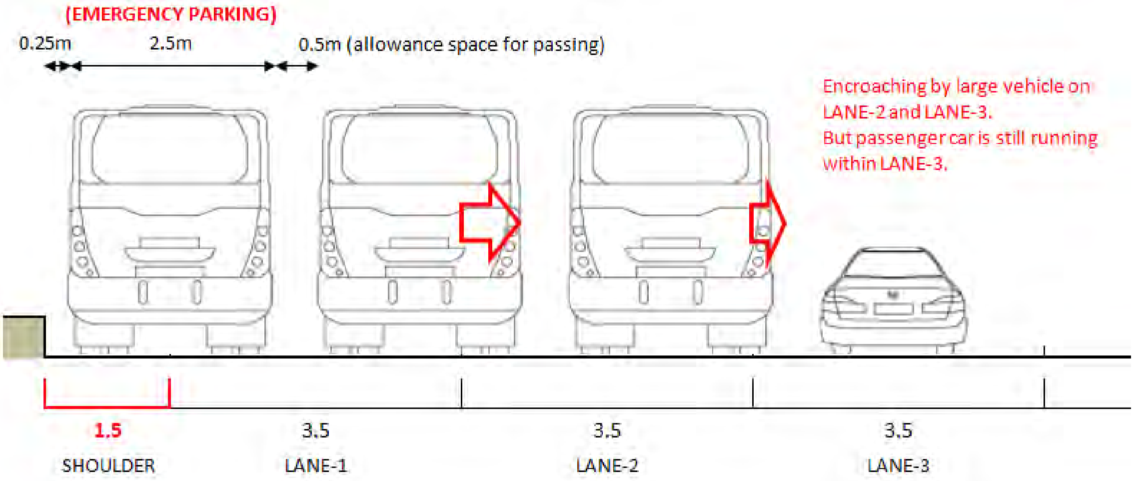
The concept of the proposal of the JICA Experts is shown in Figure 2.1.3. The JICA Experts proposed a 1.5 m width of the partial outer shoulder.



(CASE-1: Emergency Parking by Passenger Car on Outer Shoulder)



(CASE-2: Emergency Parking by Large Vehicle on Outer Shoulder)

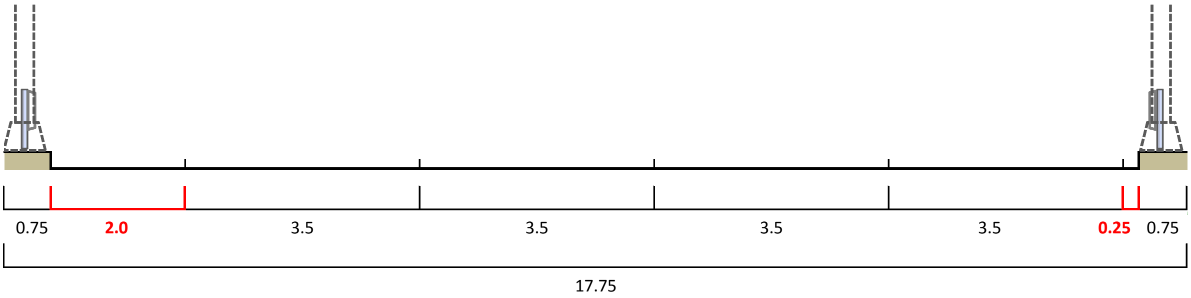


(CASE-2a: Emergency Parking by Large Vehicle on Outer Shoulder)

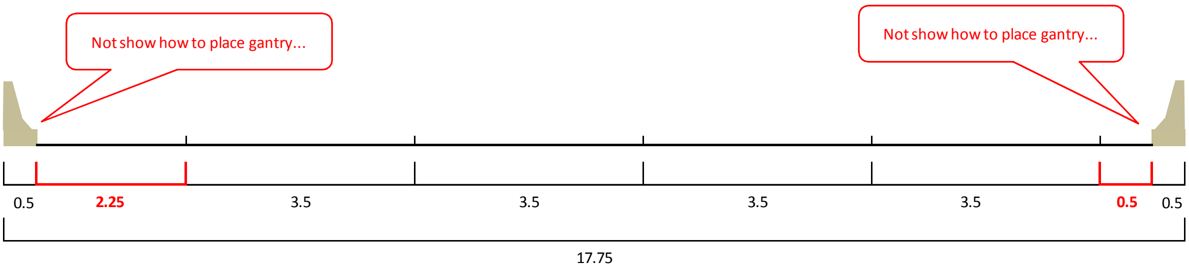
Source: JICA Experts

Figure 2.1.3 Proposed Concept of Partial Outer Shoulder for BPRR

Figure 2.1.4 showed the cross sections designed in the DPR.



(Cross Section of At-grade Section)

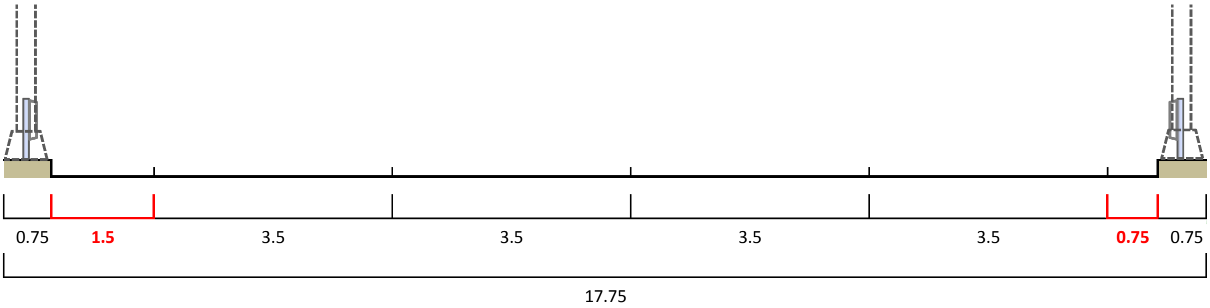


(Cross Section of Elevated Section)

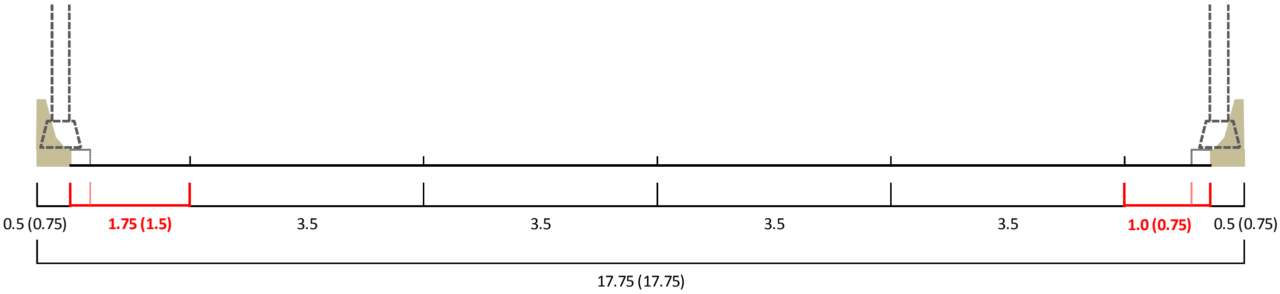
Source: Draft DPR

Figure 2.1.4 Cross Sections of Main Line of BPRR (Draft DPR)

The JICA Experts proposed the cross sections as shown in Figure 2.1.5.



(Cross Section of At-grade Section)



Note: Figure in parentheses shows the width with gantry pole for ITS.

(Cross Section of Elevated Section)

Source: JICA Experts

Figure 2.1.5 Cross Sections of Main Line of BPRR (Proposed)

(2) Conclusion

The width of outer shoulder (minimum=2.0 m) and edge strip (minimum=0.5 m) of BPRR was determined based on IRC SP 99-2013. Therefore, the basis of the determination is not revised and 0.25 m of the narrow edge strip is applied only at the section with gantry facility of ITS. However, it was suggested to provide lane marking to delineate the paved shoulder from main carriageway.

2.1.5.4 Cross Fall of Main Line

(1) Comments and Suggestions on DPR

The DPR modified the cross fall from 2.5% to 2.0% due to the change of the type of pavement. However, the JICA Experts found differences regarding the cross fall between DPR report (2.0%) and DPR drawings (2.5% in some drawings).

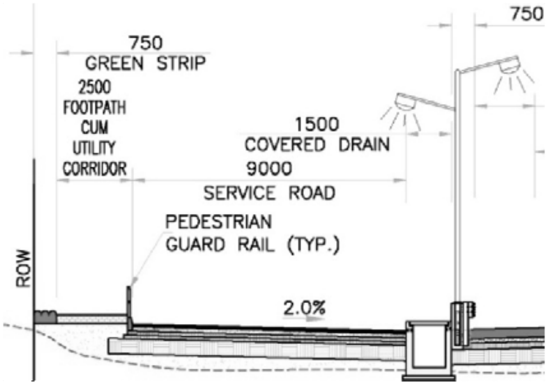
(2) Conclusion

It was agreed to apply 2.0% as the standard cross fall of BPRR with rigid pavement.

2.1.5.5 Cross Section of Service Road

(1) Comments and Suggestions on DPR

Figure 2.1.6 shows the cross section of the service road designed in the DPR. The number of lanes for the service road is not clearly mentioned in the DPR.



Source: Final DPR, 2014

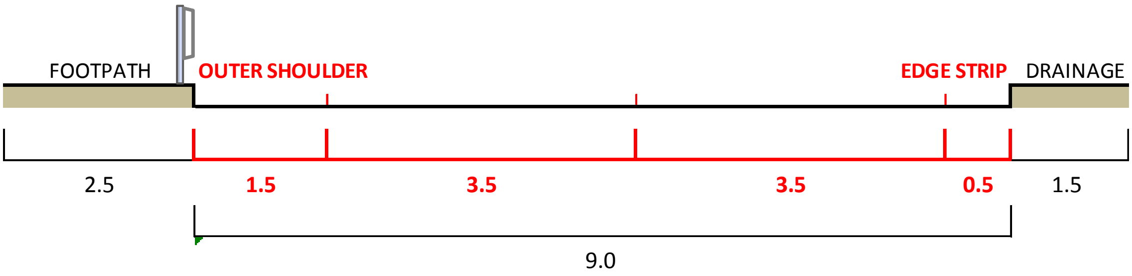
Figure 2.1.6 Cross Section of Service Road in the Final DPR

According to IRC 86-1983, 3-lane roads require 10.5 m of the carriageway width in total. Therefore, 9.0 m of the carriageway width for BPRR could accommodate only two lanes.

Figure 2.1.7 shows the cross section of the service road designed in the DPR. The JICA Experts proposed the lane configuration as shown in Figure 2.1.8.

Source: Draft DPR

Figure 2.1.7 Cross Sections of Service Road of BPRR (Draft DPR)



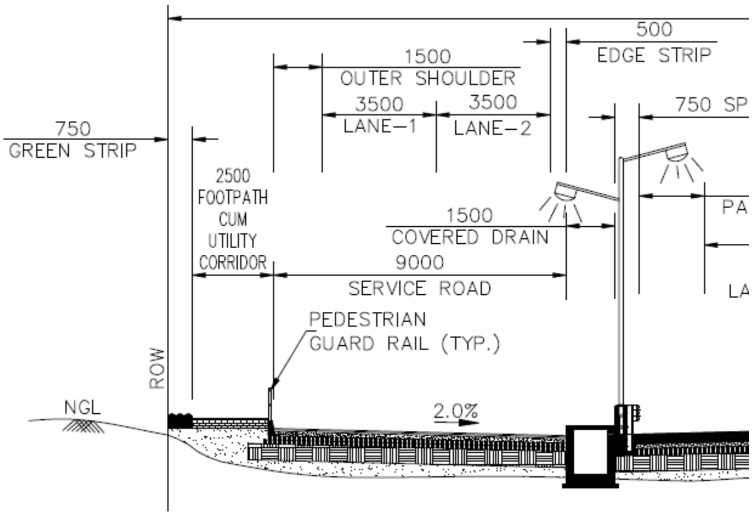
Source: JICA Experts

Figure 2.1.8 Cross Sections of Service Road of BPRR (Proposed)

(2) Conclusion

It was confirmed that the current width of carriageway (W=9.0 m) is derived based on the available width of 75 m ROW for development of formation with other cross section elements firmed up.

In principle, the number of lanes of the service road is two lanes, with wider shoulder as shown in Figure 2.1.9. The final lane configuration shall be further discussed and determined during the detailed design stage with proper lane markings.



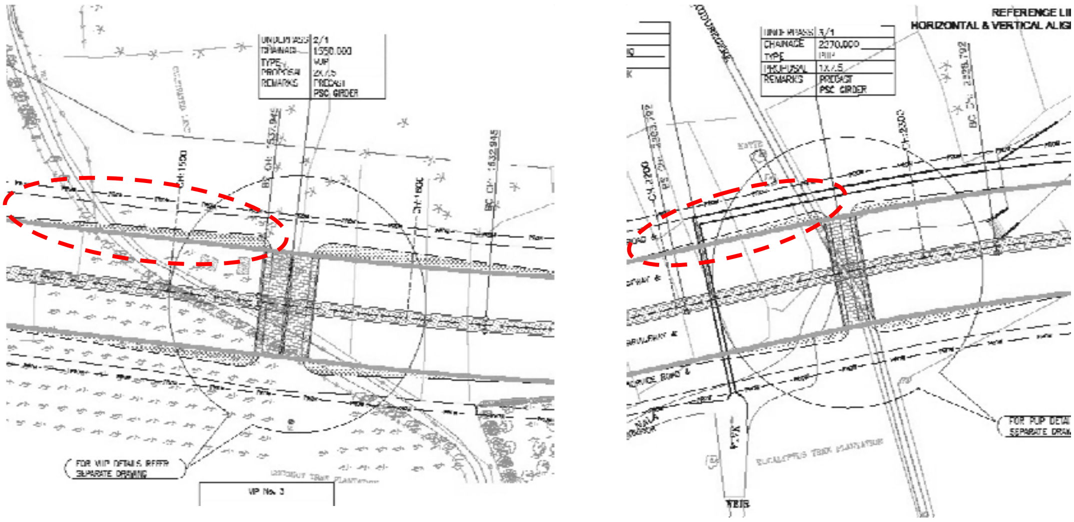
Source: JICA Experts

Figure 2.1.9 Cross Section of Service Road

2.1.6 Cross Sectional Bottleneck of the Service Road

(1) Comments and Suggestions on DPR

In the DPR drawings, width of carriageway of the service road is narrowed to 7.5m from 9m at the approach to Vehicular Underpasses (VUP) and Pedestrian Underpasses (PUP) for traffic turning. Figure 2.1.10 shows the narrowed carriageway of the service roads.



(Bottleneck for VUP) (Bottleneck for PUP)

Source: Final DPR

Figure 2.1.10 Bottleneck of Carriageway

The narrowed carriageway will induce traffic congestion and the width of the carriageway should maintain the original required width (9.0 m).

In addition, the proposed width of box culvert cannot accommodate the traffic flow properly. The width of VUP shall be much larger to secure minimum turning movement.

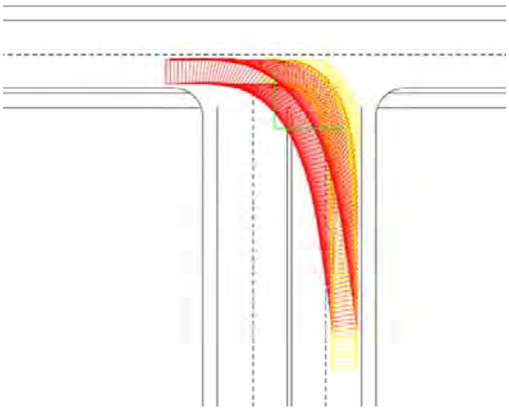
(2) Conclusion

The JICA Experts confirmed to STUP that compliance was already given to the JICA 3rd Mission comments that the end of underpass will be flared (6 m x 6 m at VUP and 3 m x 3 m at PUP) in the detailed design stage to have a proper sight distance and also to avoid narrowing of road section at approaches.

It was confirmed that the bottleneck of the service road would be eliminated and the turning movement of heavy vehicles would be considered at selected VUP and in the detailed design taking into account future development along BPRR. According to BDA, it was concluded that the VUP will be provided with 3 lane configuration in each traffic direction.

The JICA Experts confirmed that there were minor impacts on structure design as shown in Figure 2.1.11. Therefore, detail of VUP mentioned in Chapter 3.3 Box Culvert Structure has considered turning movement.

The appropriate structure plan considering the turning radius of large-sized vehicles should be incorporated in the detailed design.



Source: JICA Experts

Figure 2.1.11 Vehicle Motion Path at VUP

2.1.7 Vertical Alignment

2.1.7.1 Gradient

(1) Comments and Suggestions on DPR

In the DPR, the maximum gradient adopted in vertical design is restricted to 3.33%.According to IRC SP 23-1993, minimum gradient was determined at 0.3% if the longitudinal drains are lined. However, minimum gradient was not noted in the DPR.

The JICA Experts reviewed the vertical alignment of DPR based on IRC 86-1983 and IRC-SP 23-1993. IRC 86-1983 specifies the absolute minimum gradient as 0.3% if the longitudinal drainage is lined and 4.0% as a maximum gradient.

The JICA Experts pointed out that there were many sections not fulfilling the requirement for minimum gradient as presented in Table 2.1.10. Table 2.1.10 is a part of check list of main line.

The modifications of the vertical alignment should be required at 19 curves with respect to minimum gradient and 8 curves with respect to maximum gradient.

Accordingly, the JICA Experts suggested that the gradient should be 0.3% as a minimum and 4.0% as a maximum gradient.

Table 2.1.10 Review on Gradient of Vertical Alignment of BPRR (Main Line)

	Elements on DPR														Check			
	Tangent 1		VCR				Tangent 2		Gradient			Tangent		Gradient (max)		Gradient (min)	Gradient (min)
			Start		End									IRC 86	IRC-sp23	IRC 86 (desirable)	IRC 86 (absolute)
	Ch.	Elev	Ch.	Elev	Ch.	Elev	Ch.	Elev	i1	i2	i1-i2	L1	L2	(i1<4%)	(i1<3.3%)	(i1>0.5%)	(i1>0.3%)
1	0+100.000	859.528	0+470.000	850.045	0+570.000	849.885	1+400.000	868.504	-2.563%	2.243%	4.806%	370	830	OK	OK	OK	OK
2	0+570.000	849.885	1+400.000	868.504	1+700.000	868.876	2+165.000	859.597	2.243%	-1.995%	-4.239%	830	465	OK	OK	OK	OK
3	1+700.000	868.876	2+165.000	859.597	2+265.000	858.676	2+339.898	858.790	-1.995%	0.152%	2.148%	465	75	OK	OK	OK	OK
4	2+265.000	858.676	2+339.898	858.790	2+439.898	860.142	2+700.000	866.775	0.152%	2.550%	2.398%	75	260	OK	OK	error	error
5	2+439.898	860.142	2+700.000	866.775	3+000.000	871.282	3+079.087	871.642	2.550%	0.455%	-2.095%	260	79	OK	OK	OK	OK
6	3+000.000	871.282	3+079.087	871.642	3+179.087	872.301	3+510.000	875.161	0.455%	0.864%	0.409%	79	331	OK	OK	error	OK
7	3+179.087	872.301	3+510.000	875.161	3+610.000	875.495	4+245.000	874.253	0.864%	-0.196%	-1.060%	331	635	OK	OK	OK	OK
8	3+610.000	875.495	4+245.000	874.253	4+345.000	872.473	4+416.000	870.086	-0.196%	-3.362%	-3.166%	635	71	OK	OK	error	error
9	4+345.000	872.473	4+416.000	870.086	4+516.000	867.830	4+711.214	865.588	-3.362%	-1.148%	2.213%	71	195	OK	error	OK	OK
10	4+516.000	867.830	4+711.214	865.588	4+811.214	865.173	5+650.000	867.841	-1.148%	0.318%	1.467%	195	839	OK	OK	OK	OK
11	4+811.214	865.173	5+650.000	867.841	5+750.000	867.208	5+822.574	866.058	0.318%	-1.585%	-1.903%	839	73	OK	OK	error	OK
12	5+750.000	867.208	5+822.574	866.058	5+922.574	866.636	6+600.000	885.191	-1.585%	2.739%	4.324%	73	677	OK	OK	OK	OK
13	5+922.574	866.636	6+600.000	885.191	6+900.000	886.816	7+099.992	883.503	2.739%	-1.657%	-4.396%	677	200	OK	OK	OK	OK
14	6+900.000	886.816	7+099.992	883.503	7+199.992	882.319	7+413.975	880.795	-1.657%	-0.712%	0.944%	200	214	OK	OK	OK	OK
15	7+199.992	882.319	7+413.975	880.795	7+513.975	881.610	7+696.355	885.891	-0.712%	2.347%	3.060%	214	182	OK	OK	OK	OK
16	7+513.975	881.610	7+696.355	885.891	7+796.355	889.022	8+046.072	898.799	2.347%	3.915%	1.568%	182	250	OK	OK	OK	OK
17	7+796.355	889.022	8+046.072	898.799	8+246.072	899.558	8+602.202	888.321	3.915%	-3.155%	-7.071%	250	356	OK	error	OK	OK
18	8+246.072	899.558	8+602.202	888.321	8+752.202	887.239	8+760.000	887.323	-3.155%	1.077%	4.233%	356	8	OK	OK	OK	OK
19	8+752.202	887.239	8+760.000	887.323	8+960.000	885.538	9+110.000	880.216	1.077%	-3.548%	-4.625%	8	150	OK	OK	OK	OK
20	8+960.000	885.538	9+110.000	880.216	9+210.000	879.541	9+690.799	890.111	-3.548%	2.198%	5.746%	150	481	OK	error	OK	OK
21	9+210.000	879.541	9+690.799	890.111	9+890.799	889.063	9+919.287	888.138	2.198%	-3.247%	-5.445%	481	28	OK	OK	OK	OK
22	9+890.799	889.063	9+919.287	888.138	10+019.287	886.820	10+288.757	888.464	-3.247%	0.610%	3.857%	28	269	OK	OK	OK	OK
23	10+019.287	886.820	10+288.757	888.464	10+388.757	889.895	10+560.000	893.749	0.610%	2.251%	1.641%	269	171	OK	OK	OK	OK
24	10+388.757	889.895	10+560.000	893.749	10+760.000	898.641	11+128.000	908.359	2.251%	2.641%	0.390%	171	368	OK	OK	OK	OK
25	10+760.000	898.641	11+128.000	908.359	11+328.000	908.784	11+368.239	907.893	2.641%	-2.214%	-4.855%	368	40	OK	OK	OK	OK
26	11+328.000	908.784	11+368.239	907.893	11+518.239	908.535	11+735.000	915.193	-2.214%	3.072%	5.286%	40	217	OK	OK	OK	OK
27	11+518.239	908.535	11+735.000	915.193	12+035.000	922.749	12+435.000	930.612	3.072%	1.966%	-1.106%	217	400	OK	OK	OK	OK
28	12+035.000	922.749	12+435.000	930.612	12+635.000	930.278	12+864.224	925.005	1.966%	-2.300%	-4.266%	400	229	OK	OK	OK	OK
29	12+635.000	930.278	12+864.224	925.005	12+964.224	923.838	13+965.914	923.504	-2.300%	-0.033%	2.267%	229	1002	OK	OK	OK	OK
30	12+964.224	923.838	13+965.914	923.504	14+125.914	920.773	14+230.000	917.254	-0.033%	-3.381%	-3.348%	1002	104	OK	OK	error	error
31	14+125.914	920.773	14+230.000	917.254	14+390.000	913.480	15+570.000	897.694	-3.381%	-1.338%	2.043%	104	1180	OK	error	OK	OK
32	14+390.000	913.480	15+570.000	897.694	15+730.000	895.196	16+100.000	888.594	-1.338%	-1.784%	-0.447%	1180	370	OK	OK	OK	OK
33	15+730.000	895.196	16+100.000	888.594	16+260.000	889.845	16+505.000	898.050	-1.784%	3.349%	5.133%	370	245	OK	OK	OK	OK
34	16+260.000	889.845	16+505.000	898.050	16+665.000	901.752	17+260.000	909.361	3.349%	1.279%	-2.070%	245	595	OK	error	OK	OK
35	16+665.000	901.752	17+260.000	909.361	17+360.000	908.663	17+695.000	899.702	1.279%	-2.675%	-3.954%	595	335	OK	OK	OK	OK
36	17+360.000	908.663	17+695.000	899.702	17+795.000	899.371	18+296.223	909.455	-2.675%	2.012%	4.687%	335	501	OK	OK	OK	OK
37	17+795.000	899.371	18+296.223	909.455	18+496.223	909.472	18+520.000	908.998	2.012%	-1.994%	-4.005%	501	24	OK	OK	OK	OK

Source: JICA Experts

(2) Conclusion

It was agreed that application of 4.0% for maximum gradient and 0.3% for minimum gradient would be considered in accordance with the requirement of IRC SP 23-1993.

BDA/STUP explained the requirement of the railway crossing, which was determined based on the results of discussions with railway authorities providing 2.5% of the maximum gradient.

The vertical alignment indicated in Table 2.1.11 needs to be corrected.

Table 2.1.11 Amendment for Each Gradient

Start		End		Gradient	Amendment
Chainage	Elevation	Chainage	Elevation		
2+265.000	858.676	2+339.898	858.790	0.152%	Gradient revise to be 0.3%
4+312.000	873.401	4+416.000	869.976	-3.293%	Gradient revise to be 2.5%
21+420.472	915.189	21+520.826	915.230	0.041%	Gradient revise to be 0.3%
27+520.076	899.614	27+980.000	900.753	0.248%	Gradient revise to be 0.3%
32+105.000	870.945	33+200.391	870.647	-0.027%	Gradient revise to be -0.3% from CH:32+105 to CH:32+480 and 0.3% from CH:32+480 to CH:33+200 Add new VIP at CH:32+480
41+707.891	856.590	42+391.026	856.586	-0.001%	Gradient revise to be -0.3% from CH:41+707 to CH:42+050 and 0.3% from CH:42+050 to CH:42+391 Add new VIP at CH:42+050
44+700.000	856.386	45+078.192	856.625	0.063%	Gradient revise to be 0.3%
45+701.335	859.384	46+468.807	858.171	-0.158%	Gradient revise to be -0.3% from CH:45+701 to CH:46+055 and 0.3% from CH:46+055 to CH:46+468 Add new VIP at CH:46+055
47+247.186	856.010	47+455.000	856.125	0.055%	Gradient revise to be 0.3%
49+383.762	875.454	48+093.015	874.708	0.058%	VIP moves to 49+430. Gradient revise to be -0.3%
60+240.000	895.791	63+629.621	890.641	-0.152%	Gradient revise to be -0.3%
64+720.000	915.100	65+290.911	915.100	0.000%	Gradient revise to be 0.3%

Source: JICA Experts

2.1.7.2 Length of Vertical Curve

(1) Comments and Suggestions on DPR

In the DPR, the minimum length of curve adopted is 100 m. In the DPR drawings, all of the length is designed over 100 m. But, to maintain stopping sight distance, the JICA Experts recommended determining the length of vertical curves based on the formulae shown below.

According to IRC SP 23-1993, length of vertical curves shall be determined as:

Summit Curve

1) When the length of the curve exceeds the required sight distance:

$$L = \frac{NS^2}{4.4}$$

S = stopping sight distance in metres (120 m for speed of 80 km/h)

N = deviation angle, i.e. the algebraic difference between the two grades

2) When the length of the curve is less than the required sight distance:

$$\mathrm{L} = 2\mathrm{S} - \frac{4.4}{\mathrm{N}}$$

Valley Curve

1) When the length of the curve exceeds the required sight distance:

$$\mathrm{L} = \frac{\mathrm{NS}^2}{1.5 + 0.035\mathrm{S}}$$

2) When the length of the curve is less than the required sight distance:

$$\mathrm{L} = 2\mathrm{S} - \frac{1.50 + 0.035\mathrm{S}}{\mathrm{N}}$$

The JICA Experts reviewed the drawings based on the above formulae. The JICA Experts have pointed out that there are many sections that do not fulfill the requirement for length of vertical curves as presented in Table 2.1.12.

Table 2.1.12 Review on Vertical Curves of Vertical Alignment of BPRR

	Elements on DPR														Check				
	Tangent 1		VCR				Tangent 2		Gradient			Tangent		VCR				
			Start		End									Min. L	Stopping Sight Distance			
														IRC 86	Required L by IRC 86		Check	
	Ch.	Elev	Ch.	Elev	Ch.	Elev	Ch.	Elev	i1	i2	i1-i2	L1	L2	(L>50m)	Summit VCR	Valley VCR	Summit VCR	Valley VCR
1	0+100.000	859.528	0+470.000	850.045	0+570.000	849.885	1+400.000	868.504	-2.563%	2.243%	4.806%	370	830	OK	-	121.404	-	error
2	0+570.000	849.885	1+400.000	868.504	1+700.000	868.876	2+165.000	859.597	2.243%	-1.995%	-4.239%	830	465	OK	138.722	-	OK	-
3	1+700.000	868.876	2+165.000	859.597	2+265.000	858.676	2+339.898	858.790	-1.995%	0.152%	2.148%	465	75	OK	-	-25.401	-	OK
4	2+265.000	858.676	2+339.898	858.790	2+439.898	860.142	2+700.000	866.775	0.152%	2.550%	2.398%	75	260	OK	-	2.297	-	OK
5	2+439.898	860.142	2+700.000	866.775	3+000.000	871.282	3+079.087	871.642	2.550%	0.455%	-2.095%	260	79	OK	68.562	-	OK	-
6	3+000.000	871.282	3+079.087	871.642	3+179.087	872.301	3+510.000	875.161	0.455%	0.864%	0.409%	79	331	OK	-	-1153.368	-	OK
7	3+179.087	872.301	3+510.000	875.161	3+610.000	875.495	4+245.000	874.253	0.864%	-0.196%	-1.060%	331	635	OK	-175.147	-	OK	-
8	3+610.000	875.495	4+245.000	874.253	4+345.000	872.473	4+416.000	870.086	-0.196%	-3.362%	-3.166%	635	71	OK	101.040	-	error	-
9	4+345.000	872.473	4+416.000	870.086	4+516.000	867.830	4+711.214	865.588	-3.362%	-1.148%	2.213%	71	195	OK	-	-17.512	-	OK
10	4+516.000	867.830	4+711.214	865.588	4+811.214	865.173	5+650.000	867.841	-1.148%	0.318%	1.467%	195	839	OK	-	-148.664	-	OK
11	4+811.214	865.173	5+650.000	867.841	5+750.000	867.208	5+822.574	866.058	0.318%	-1.585%	-1.903%	839	73	OK	8.746	-	OK	-
12	5+750.000	867.208	5+822.574	866.058	5+922.574	866.636	6+600.000	885.191	-1.585%	2.739%	4.324%	73	677	OK	-	108.166	-	error
13	5+922.574	866.636	6+600.000	885.191	6+900.000	886.816	7+099.992	883.503	2.739%	-1.657%	-4.396%	677	200	OK	143.856	-	OK	-
14	6+900.000	886.816	7+099.992	883.503	7+199.992	882.319	7+413.975	880.795	-1.657%	-0.712%	0.944%	200	214	OK	-	-363.583	-	OK
15	7+199.992	882.319	7+413.975	880.795	7+513.975	881.610	7+696.355	885.891	-0.712%	2.347%	3.060%	214	182	OK	-	53.695	-	OK
16	7+513.975	881.610	7+696.355	885.891	7+796.355	889.022	8+046.072	898.799	2.347%	3.915%	1.568%	182	250	OK	-	-123.535	-	OK
17	7+796.355	889.022	8+046.072	898.799	8+246.072	899.558	8+602.202	888.321	3.915%	-3.155%	-7.071%	250	356	OK	231.400	-	error	-
18	8+246.072	899.558	8+602.202	888.321	8+752.202	887.239	8+760.000	887.323	-3.155%	1.077%	4.233%	356	8	OK	-	106.927	-	OK
19	8+752.202	887.239	8+760.000	887.323	8+960.000	885.538	9+110.000	880.216	1.077%	-3.548%	-4.625%	8	150	OK	151.370	-	OK	-
20	8+960.000	885.538	9+110.000	880.216	9+210.000	879.541	9+690.799	890.111	-3.548%	2.198%	5.746%	150	481	OK	-	140.808	-	error
21	9+210.000	879.541	9+690.799	890.111	9+890.799	889.063	9+919.287	888.138	2.198%	-3.247%	-5.445%	481	28	OK	178.213	-	OK	-
22	9+890.799	889.063	9+919.287	888.138	10+019.287	886.820	10+288.757	888.464	-3.247%	0.610%	3.857%	28	269	OK	-	92.219	-	OK
23	10+019.287	886.820	10+288.757	888.464	10+388.757	889.895	10+560.000	893.749	0.610%	2.251%	1.641%	269	171	OK	-	-107.452	-	OK
24	10+388.757	889.895	10+560.000	893.749	10+760.000	898.641	11+128.000	908.359	2.251%	2.641%	0.390%	171	368	OK	-	9.857	-	OK
25	10+760.000	898.641	11+128.000	908.359	11+328.000	908.784	11+368.239	907.893	2.641%	-2.214%	-4.855%	368	40	OK	158.892	-	OK	-
26	11+328.000	908.784	11+368.239	907.893	11+518.239	908.535	11+735.000	915.193	-2.214%	3.072%	5.286%	40	217	OK	-	133.537	-	OK
27	11+518.239	908.535	11+735.000	915.193	12+035.000	922.749	12+435.000	930.612	3.072%	1.966%	-1.106%	217	400	OK	36.191	-	OK	-
28	12+035.000	922.749	12+435.000	930.612	12+635.000	930.278	12+864.224	925.005	1.966%	-2.300%	-4.266%	400	229	OK	139.618	-	OK	-
29	12+635.000	930.278	12+864.224	925.005	12+964.224	923.838	13+965.914	923.504	-2.300%	-0.033%	2.267%	229	1002	OK	-	-11.431	-	OK
30	12+964.224	923.838	13+965.914	923.504	14+125.914	920.773	14+230.000	917.254	-0.033%	-3.381%	-3.348%	1002	104	OK	109.555	-	OK	-
31	14+125.914	920.773	14+230.000	917.254	14+390.000	913.480	15+570.000	897.694	-3.381%	-1.338%	2.043%	104	1180	OK	-	51.614	-	OK
32	14+390.000	913.480	15+570.000	897.694	15+730.000	895.196	16+100.000	888.594	-1.338%	-1.784%	-0.447%	1180	370	OK	14.614	-	OK	-
33	15+730.000	895.196	16+100.000	888.594	16+260.000	889.845	16+505.000	898.050	-1.784%	3.349%	5.133%	370	245	OK	-	129.683	-	OK
34	16+260.000	889.845	16+505.000	898.050	16+665.000	901.752	17+260.000	909.361	3.349%	1.279%	-2.070%	245	595	OK	67.751	-	OK	-
35	16+665.000	901.752	17+260.000	909.361	17+360.000	908.663	17+695.000	899.702	1.279%	-2.675%	-3.954%	595	335	OK	128.713	-	error	-
36	17+360.000	908.663	17+695.000	899.702	17+795.000	899.371	18+296.223	909.455	-2.675%	2.012%	4.687%	335	501	OK	-	118.382	-	error
37	17+795.000	899.371	18+296.223	909.455	18+496.223	909.472	18+520.000	908.998	2.012%	-1.994%	-4.005%	501	24	OK	131.086	-	OK	-

Source: JICA Experts

(2) Conclusion

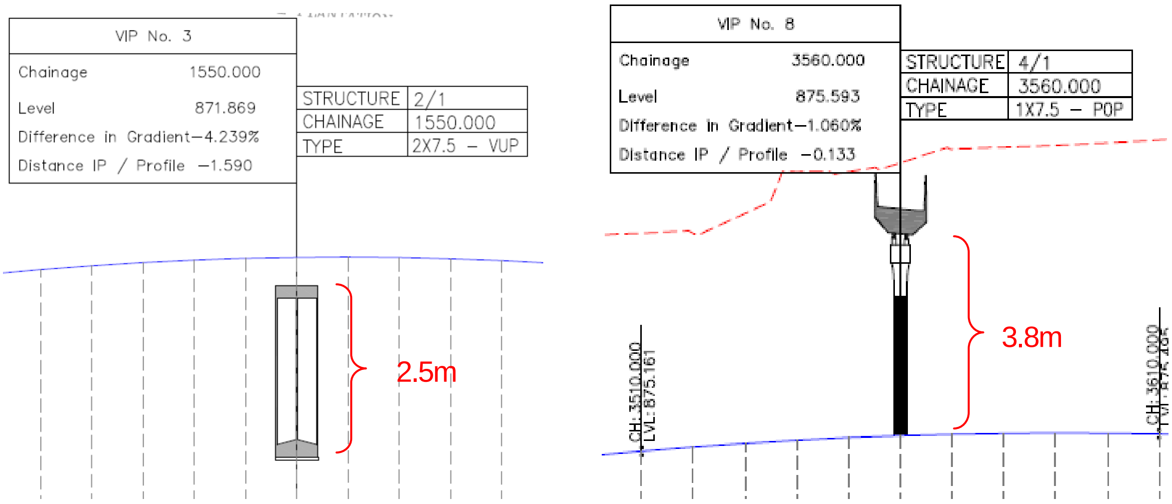
BDA/STUP explained that the length was determined using an abbreviated application table (Table 6) in IRC SP 23-1993 and the JICA Experts confirmed that there were no major differences between figures in the table and the calculated value by formula in IRCs. Accordingly, the length of curves is not necessary to be changed.

2.1.7.3 Clearance for Intersection

(1) Comments and Suggestions on DPR

Vertical clearance shall be determined as 5.5 m for vehicular underpasses and 4.5 m for pedestrian underpasses in the final DPR. However, several underpasses in the drawings did not showed the clearance as written in the final DPR.

The JICA Experts reviewed the drawings based on the above standard. The JICA Experts pointed out that there were many sections not fulfilling the requirement for clearance as presented in Table 2.1.13.



Source: JICA Experts

Figure 2.1.12 Insufficient Vertical Clearance for VUP/POP

Table 2.1.13 Review on the Vertical Clearance of VUP, VOP, PUP and POP

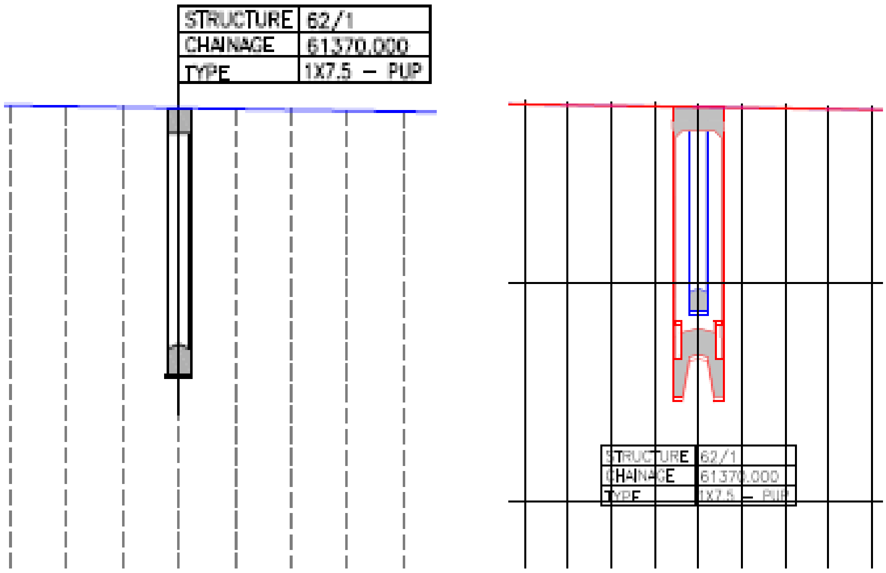
Chainage	Type	Clearance (m)	IRC86-1993 5.5 m vehicular road Final DPR 4.5 m pedestrian road
1+550.000	VUP	2.5	error
2+270.000	PUP	2.1	error
3+560.000	POP	3.8	error
4+950.000	PUP	4.0	error
5+700.000	PUP	3.5	error
6+750.000	VUP	4.5	error
8+860.000	VUP	5.5	OK
10+700.000	VUP	4.4	error
11+700.000	PUP	3.1	error
12+550.000	VUP	4.8	error
14+800.000	POP	3.9	error
15+600.000	POP	4.1	error
17+310.000	VUP	4.4	error
20+269.000	VUP	5.5	OK
21+200.000	PUP	3.0	error
23+400.000	VOP	5.3	error
27+145.000	POP	4.5	error
28+080.000	VUP	4.4	error
29+700.000	VOP	5.5	OK
31+500.000	VUP	5.5	OK
33+620.000	VUP	4.4	error
37+760.000	VOP	3.9	error
41+344.000	PUP	3.7	error
44+382.000	VUP	5.0	error
45+445.000	VUP	4.6	error
49+430.000	POP	2.1	error
50+360.000	VUP	5.0	error
51+430.000	VUP	5.5	OK
54+580.000	POP	3.7	error
61+370.000	PUP	3.5	error
62+900.000	VUP	3.8	error

Source: JICA Experts

(2) Conclusion

It was agreed to modify the drawings properly, reflecting the required clearance height for the overpass locations.

Revising clearance for each VUP, VOP, PUP, and POP needs modification of the vertical alignment. The JICA Experts showed sample drawings of vertical alignment as presented in Figure 2.1.13 and in the appendix.



Source: Left : DPR Drawing; Right : JICA Experts

**Figure 2.1.13	Modification for Box Culvert**

In addition to crossing road of BPRR main line, several sections in the BPRR main line are designed as bridge structures and box culverts. Those sections will be needed to consider the vertical clearance based on elevation of crossing road of BPRR main line.

The JICA Experts calculated the necessary clearance for bridge structure based on bridge plan as shown in Table 2.1.14.

In the section where the main line is designed as a box culvert, a 6.5 m clearance should be considered including pavement and thickness of floor slab from elevation of road crossing. Table 2.1.14 shows the sections of box culvert in main line.

The JICA Experts showed sample drawings as attached in the appendix 1-C considering the above requirements.

Table 2.1.14 Required Height of Centerline from Service Road

No.	Station	Bridge Category	Location	Cross Object	Width1)	Clearance (under BR)		Bridge Length2)	Span Arrange.	Girder Height	Width	Superelevation	Slab		Pevement	Structure Height	Clearance under Bridge	Margin	Required Height of CL from service road
						Vertical	Horizontal						Thickness	@ haunch					
1	KM00+000	Flyover	Main Road	NH-4	2@4m	5.5m	Existing BR	60m	2@30m	2	4	2.0%	0.22	0.27	0.065	2.42	5.5	0.5	8.42
2	KM03+560	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
3	KM04+212	ROB, Flyover	Main Road, Service Road	Bangalore-Tumkur Railway Line, SH39	8.5m,2@17.75m,8.5m	Rail: 8.14m Road: 5.5m	Rail: 60m Road: 40m	195m	1@60m+3@45m	3	17.75	3.9%			0.065	3.76	8.14	0.5	12.4
4	KM14+435	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@12m	5.5m	Service Road	120m	4@30m	2	12	2.0%	0.22	0.27	0.065	2.58	5.5	0.5	8.58
5	KM14+800	POP	Cross Road (Local Road)	Main Road, Service Road (Underpass, TP Section)	8.5m	5.5m	Service Road	80m	2@40m	2	8.5	2.0%			0.065	2.24	5.5	0.5	8.24
6	KM15+600	POP	Cross Road (Local Road)	Main Road, Service Road (Underpass, TP Section)	8.5m	5.5m	Service Road	120m	2@60m	3	8.5	2.0%			0.065	3.24	5.5	0.5	9.24
7	KM23+400	VOP	Cross Road (SH104)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
8	KM25+604	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@8.5m	5.5m	Service Road	120m	4@30m	2	8.5	2.0%	0.22	0.27	0.065	2.51	5.5	0.5	8.51
9	KM27+145	VOP	Cross Road (Local Road)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
10	KM29+770	VOP	Cross Road (Local Road)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
11	KM36+323	Flyover	Main Road	NH-4	8.5m,2@17.75m,8.5m	5.5m	NH-4: 60m	60m	1@60m	3	17.75	5.0%			0.065	3.96	5.5	0.5	9.96
12	KM37+760	VOP	Cross Road (SH35)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
13	KM38+769	Flyover	Main Road	Cross Road (Local Road) (Underpass)	2@17.75m	5.5m	Cross Road	140m	40m+60m+40m	3	17.75	2.0%			0.065	3.42	5.5	2.3 * +pier head height	11.22
14	KM43+125	ROB	Main Road, Service Road	Bangalore-Chennai Railway Line	8.5m,2@17.75m,8.5m	Rail: 8.14m	Rail: 70m	810m3)	11@30m, 40m+70m+40m, 11@30m	2 2.8 2	17.75 17.75 17.75	2.0% 2.0% 2.0%	0.22 0.35 0.22	0.27 0.4 0.27	0.065 0.065 0.065	2.69 3.62 2.69	5.5 8.14 5.5	0.5 0.5 0.5	8.69 12.26 8.69
15	KM49+430	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
16	KM53+221	Flyover	Main Road	Cross Road (SH35) (Underpass)	2@17.75m	5.5m	Cross Road	90m	3@30m	2	17.75	2.0%	0.22	0.27	0.065	2.69	5.5	0.5	8.69
17	KM54+580	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	1.6	8.5	2.0%	0.22	0.27	0.065	2.11	5.5	0.5	8.11
18	KM55+911	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@8.5m	5.5m	Service Road	120m	4@30m	2	8.5	2.0%	0.22	0.27	0.065	2.51	5.5	0.5	8.51
19	KM59+198	ROB	Main Road, Service Road	Bangalore-Hosur Railway Line	8.5m,2@17.75m,8.5m	Rail: 8.14m	Rail: 60m	790m3)	11@30m, 35m+60m+35m, 11@30m	2 2.4 2	17.75 17.75 17.75	2.0% 2.0% 2.0%	0.22 0.35 0.22	0.27 0.4 0.27	0.065 0.065 0.065	2.69 3.22 2.69	5.5 8.14 5.5	0.5 0.5 0.5	8.69 11.86 8.69
20	KM64+751	Flyover	Main Road	NH-7	2@4m	5.5m	Existing BR	60m	2@30m	2	4	2.0%	0.22	0.27	0.065	2.42	5.5	0.5	8.42

1) Road Width in the Final DPR (To be followed discussion result in DP-R02)

2) Approximate Bridge Length (It is necessary to determine in detail in the D/D stage)

3) Bridge length (abutment locations) is temporary extended by 5m height of MSE Wall in this JICA Technical Review Stage

Source: JICA Experts

Table 2.1.15 Main Line Designed as Box Culvert

Start	End	Cross section		Type
		start	end	
14+380.000	14+490.000	14+390.000	14+450.000	Junction
15+140.000	15+230.000	15+158.000		Railway
16+010.000	16+090.000	16+061.000		Railway
18+615.000	18+685.000	18+620.000	18+670.000	Junction
25+570.000	25+630.000	25+580.000	25+620.000	Junction
56+680.116	56+730.116	55+890.000	55+940.000	Junction

Source: JICA Experts

2.1.8 Quantity of Earthwork

(1) Comments and Suggestions on DPR

The JICA Experts suggest modifying the vertical alignment. Along with modification, the volume of earthwork will change from the BOQ.

(2) Conclusion

The JICA Experts calculated the quantity of earthwork based on the reviewed drawing that satisfies vertical restriction.

Although quantity in BOQ was estimated both mainline and service road, quantity of JICA experts drawing was estimated only the mainline due to the lack of elevation of service road. The JICA Experts suggested reconsidering the BOQ in the detailed design stage.

The quantity is calculated only for the main line, and did not consider the quantity for service road.

Table 2.1.16 Quantity of Earth work

	Quantity in BOQ (m3)		JICA Experts drawing (m3)	
	fill	cut	fill	cut
Section 1	2,814,307	2,327,899	1,278,560	1,414,758
Section 2	1,615,359	1,351,276	931,707	1,340,846
Section 3	4,333,079	1,322,323	2,303,398	1,150,510
Total	**8,762,746**	**5,001,498**	**4,513,665**	**3,906,114**

Source: JICA Experts

2.1.9 Quantity of Retaining Wall

(1) Comments and Suggestions on DPR

The JICA Experts suggested modifying the vertical alignment. Along with modification, the quantity of retaining wall was changed from the BOQ.

(2) Conclusion

The JICA Experts calculated the quantity of retaining wall based on reviewed drawings in Appendix 1-C that satisfies vertical restriction.

Method of calculation is in accordance with the calculation method of STUP.

However, compared with BOQ and recalculation based on JICA Experts drawing, the quantity of retaining wall considering the JICA Experts drawing was increased. The JICA Experts suggested reconsidering the BOQ in the detailed design stage.

Table 2.1.17 Quantity of Retaining Wall

Quantity in BoQ (m2)	Section 1	58,957
	Section 2	35,100
	Section 3	82,118
	Total	**176,175**
STUP re-caluculated (m2)	Section-1	99,901
	Section-2	63,500
	Section-3	66,254
	Total	**229,655**
JICA Experts drawing (m2)	Section-1	106,575
	Section-2	70,661
	Section-3	90,627
	Total	**267,863**

Source: JICA Experts

2.1.10 Cancellation of ROB and VOP for Service Road

(1) Comments and Suggestions on DPR

In the design of DPR, the service road can also cross the railway lines and National Highways by using the proposed new bridges in parallel with BPRR main line.

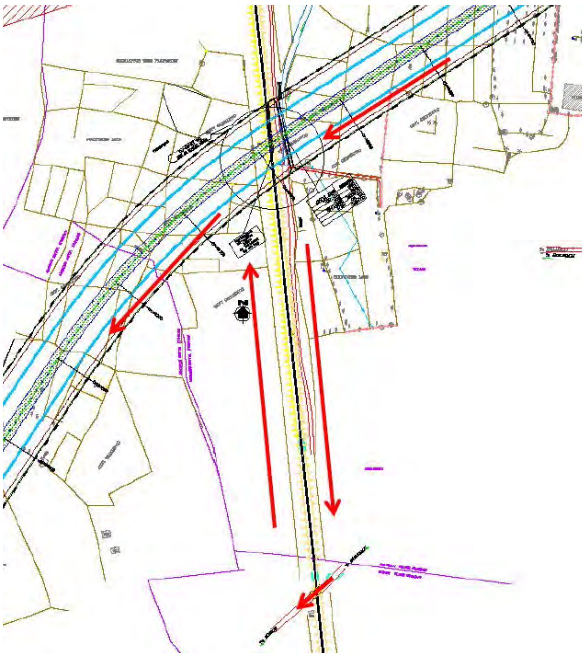
Such convenient configuration will encourage the usage of the service road without any toll fee and the toll revenue of BPRR will be reduced.

The road network of the service road shall ensure certain convenience to the premises/enterprises along BPRR but the network shall be strategically minimized.

Otherwise, the road user will choose the service road easily because there is no toll charge and the toll revenue of BPRR will be reduced.

In this review study by the JICA Experts, several cost-increased modification have been proposed. To absorb these increases of the cost, the cancellation of the overpass structure for the service road will be effective.

To encourage the usage of BPRR as a toll road, it is recommended not to provide overpass structure for the service road. The service road could be connected with existing secondary road network to cross the railway and main roads.



Source : JICA Experts

Figure 2.1.14 Example of how to cross the railway line if ROB and VOP were cancelled

(2) Conclusion

BDA informed that the railway authorities will not accept at-grade railway crossing by any roads. The JICA Experts agreed the service road also should overpass the railway line in parallel with BPRR main line.

2.1.11 Widening of Carriageway on Curves

(1) Comments and Suggestions on DPR

Widening of carriageway is needed on curve sections to cover the tracking of the rear wheels and easiness of turning curve as written in IRC 86-1983. However, widening is not considered in the DPR.

Therefore, the JICA Experts recommended the introduction of widening carriageway at four junctions such as Tumkur Road Crossing, Hosur Road Crossing, Old Madras Road Crossing and Bellary Road Junction.

Table 2.1.18 Widening of Carriageway

Radius of Curve (m)	Up to 20	21 to 40	41 to 60	61 to 100	100 to 300	Above 300
Extra width (m) Two-lane	1.5	1.5	1.2	0.9	0.6	Nil
Extra width (m) Single-lane	0.9	0.6	0.6	Nil	Nil	Nil

Source: IRC 86-1983

2.2 Junction Design

BPRR is a full access controlled road and drivers will tend to drive as they do on expressways. The most special characteristic of expressways compared with regular highways are restrictions on margining and diverting which occur at the junction areas. Therefore, junction areas need to utilize expressway design standard to reduce accidents although DPR designed these based on urban road (IRC 86-1983). In addition, there are no descriptions about junction in IRC 86-1983. Under this circumstance, BDA,DULT, STUP and the JICA Experts agreed to use IRC SP 99-2013 at the junction areas as much as possible.

2.2.1 Interval of JCTs and Recommendation of Additional JCTs

(1) Comments and Suggestions on DPR

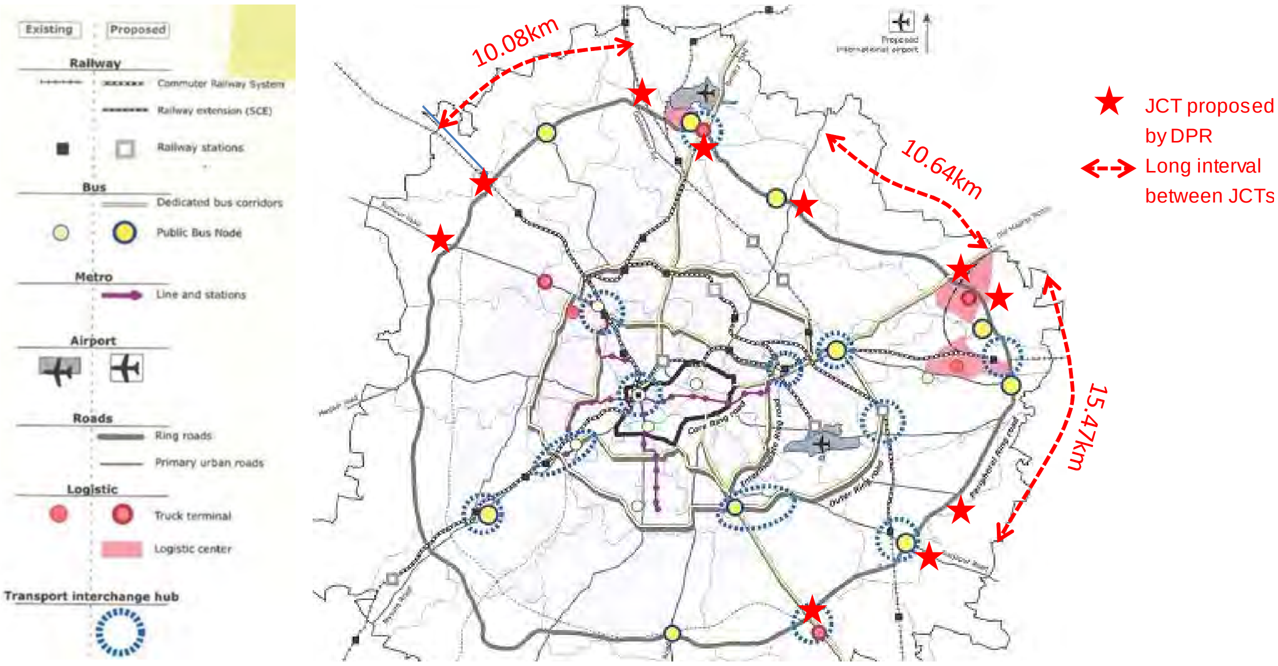
In the DPR, there are three sections having long interval of JCTs (more than 10 km).

- Hessarghatta Junction – Doddaballapura : 10.08 km
- Hennur Junction – Old Madras Road Junction : 10.64 km
- Whitefield Junction – Hoskote-Anekal Junction : 15.47 km

Construction of new junctions for above three sections which have more than 10 km interval of JCTs, should be considered in the detailed design stage.

The interval between Whitefield JCT and Hoskote-Anekal JCT is more than 15 km and Whitefield is one of the most chronically congested area in Bengaluru.

According to the “Bengalore Master Plan - 2015 Vision”, the Whitefield area is strategically selected as “Logistics Center” and “Public Bus Node”.



Source: JICA Experts based on Bangalore Master Plan-2015 vision

Figure 2.2.1 Bangalore Master Plan and JCT Interval over 10 km

Since BPRR is a part of the ring road laid down in Bengaluru metropolitan area, interval of adjacent junctions should not be too long in terms of user's convenience.

Table 2.2.1 shows JCT interval of three ring roads i.e., BPRR, Tokyo PRR, and Tokyo ORR. Average radius of Tokyo PRR is around 50 km from the center and BPRR is around 17 km from the center. Although Tokyo ORR is bigger than BPRR, JCT interval does not exceed 10 km.

Table 2.2.1 Comparison of JCT Interval of Three Ring Roads

BPRR (65km)		Tokyo PRR (300km ring) 220km is on service		Tokyo ORR (85km ring) 34km is on service	
JCT Name	Distance	JCT Name	Distance	JCT Name	Distance
Tumkur	4.34	Ebina	4.9	Oizumi	3.4
Hessarghatta	10.08	Kenou-atsugi	5.2	Wako	2.1
Doddaballapura	4.22	Sagamiwara-aikawa	8.9	Wako-kita	2.1
Bellary	6.96	Sagamiwara	5.9	Toda-nishi	2.3
Hennur	10.64	Takaosan	6.4	Toda-higashi	2.4
Old Madras	2.33	Hachioouji-nishi	5.2	Gaikan-urawa	1.7
Whitefirld	15.47	Akiruno	2.0	Kawaguchi-nishi	2.8
Hoskote-Anekal	2.69	Hinode	8.7	Kawaguchi-cyuo	2.2
Sajapur	8.83	Oume	4.8	Kawaguchi-higashi	3.4
Hosur		Iruma	6.0	Souka	6.0
Average interval of ICs	**7.3**	Sayamashidaka	6.8	Misato-nishi	5.3
		Kenou-tsurugashima	7.4	Misato-minami	
		Sakato	2.5	**Average interval of ICs**	**3.1**
		Kawashima	5.7		
		Okegawa-kitamoto	🟩		
		🟩	🟩		
		Tsukuba-cyuo	5.8		
		Tsukuba-ushiku	6.1		
		Ushiku-ami	5.9		
		Ami-higashi	6.0		
		Inashiki	6.0		
		Inashiki-higashi	4.6		
		Kanzaki			
		Average interval of ICs	**5.7**		

These sections are under construction

Source: JICA Experts

(2) Conclusion

Additional ON/OFF ramps between the above three sections which has more than 10 km distance will be reconsidered during the detailed design stage.

The required number of toll lanes of additional junctions should be finalized to comply with traffic volume which are calculated based on the traffic study result.

2.2.2 Design Speed of Ramp Terminal Area

2.2.2.1 Design Speed of Ramp

(1) Comments and Suggestions on DPR

There is no description on the DPR about ramp design speed.

In BPRR, only cloverleaf-type JCT has ramps with connecting access toward the service road. According to the “Manual of Specification and Standard for Expressways” (IRC SP 99-2013), ramp speed of BPRR loop is in the range of 60-80 km/h. However, as a result of discussion among DULT, BDA, STUP, and the JICA Experts, 40 km/h, which is a minimum ramp design speed as per IRC SP 99-2013, was agreed as the design ramp speed.

(2) Conclusion

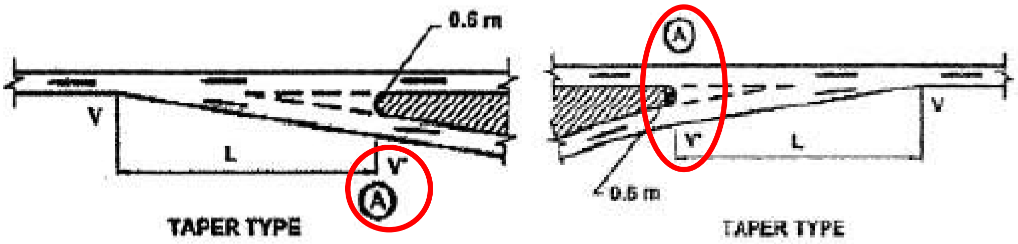
The design ramp speed is at 40 km/h.

2.2.2.2 Design Speed of Ramps from Toll Gate to Nose

(1) Comments and Suggestions on DPR

There is no description on the DPR about ramp design speed from toll gate to nose.

To finalize the length of acceleration/deceleration lane, design speed of V’ (shown in Figure 2.2.2) needs to be decided as per IRC SP 99-2013. Since most of the vehicles, except ETC users, have to stop at the toll gates for both entry and exit, design speed of V’ at location Ⓐ,which is located near the toll plaza, is decided as 40 km/h.



Source: IRC SP-99

Figure 2.2.2 Design Speed of Nose Position in IRC

(2) Conclusion

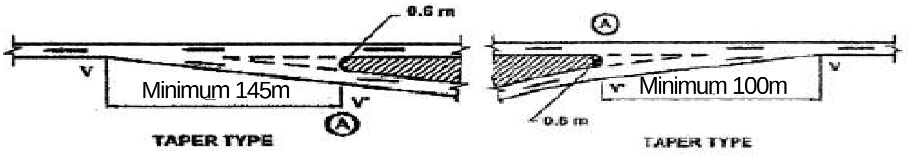
Design speed from toll gate to nose is 40 km/h.

2.2.3 Required Length for Acceleration/Deceleration Lanes on Margining/Departing of Mainline

(1) Comments and Suggestions on DPR

In DPR, there is no description of the required length from nose position to the end of taper for both acceleration/deceleration lanes.

According to IRC SP 99-2013, minimum length of acceleration and deceleration lanes were described as 145 m and 100 m, respectively. However, there are no adjustment factors for longitudinal gradient of the main line. In this chapter, the JICA Experts selected the adequate criteria of lane length by comparison of three standards, which are IRC, Japanese inter-city expressway (NEXCO), and Tokyo metropolitan expressway.



Source: IRC SP-99

Figure 2.2.3 Minimum Required Taper Length in IRC

(2) Conclusion

After comparison of three standards as per the following chapters (2.2.3.1, 2.2.3.2, and 2.2.3.3), the JICA Experts recommended to adopt the length of acceleration/deceleration and adjustment factors as described below. Detailed explanation of evaluation process is stated in Chapter 2.2.3.4.

- Acceleration Lane : 240 m
- Deceleration Lane : 170 m

Table 2.2.2 Adjustment Factor of Acceleration/Deceleration Lane Length for BPRR

Longitudinal Gradient	0 < λ ≦2	2 < λ ≦3	3 < λ ≦4	4 < λ ≦6
Deceleration Lane (Downgrade)	1.00	1.10	1.20	1.30
Acceleration Lane (Upgrade)	1.00	1.20	1.40	1.50

Source:JICA Experts

2.2.3.1 IRC Guidelines for Expressways

In the last version of IRC standard which is the “Guidelines for Expressways (IRC, April 2010)”, the adjustment factors of acceleration/deceleration length by gradient of main line are described in the table below.

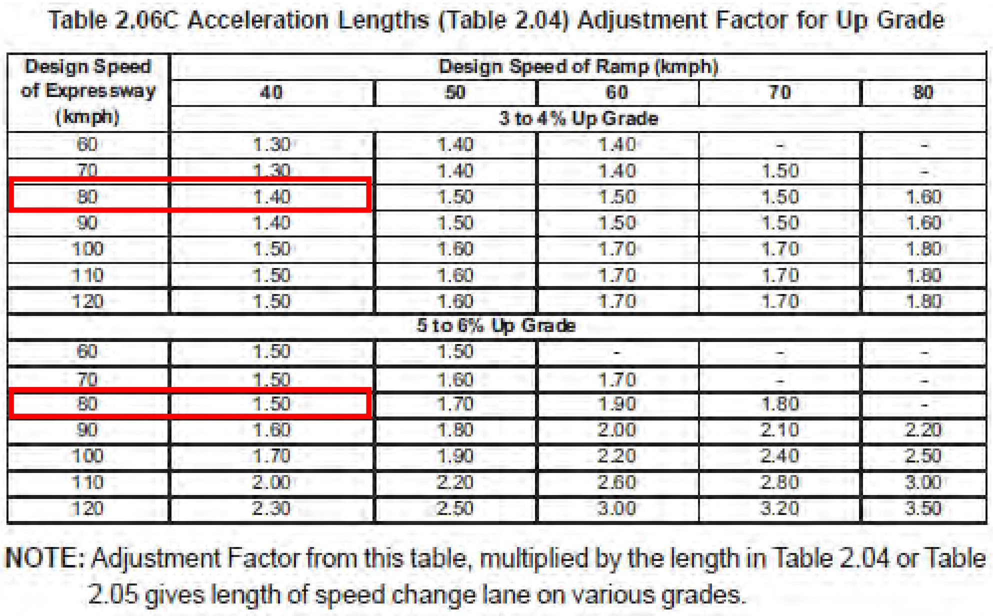


Table 2.06C Acceleration Lengths (Table 2.04) Adjustment Factor for Up Grade

Design Speed of Expressway (kmph)	Design Speed of Ramp (kmph)				
	40	50	60	70	80
	3 to 4% Up Grade				
60	1.30	1.40	1.40	-	-
70	1.30	1.40	1.40	1.50	-
80	1.40	1.50	1.50	1.50	1.60
90	1.40	1.50	1.50	1.50	1.60
100	1.50	1.60	1.70	1.70	1.80
110	1.50	1.60	1.70	1.70	1.80
120	1.50	1.60	1.70	1.70	1.80
5 to 6% Up Grade					
60	1.50	1.50	-	-	-
70	1.50	1.60	1.70	-	-
80	1.50	1.70	1.90	1.80	-
90	1.60	1.80	2.00	2.10	2.20
100	1.70	1.90	2.20	2.40	2.50
110	2.00	2.20	2.60	2.80	3.00
120	2.30	2.50	3.00	3.20	3.50

NOTE: Adjustment Factor from this table, multiplied by the length in Table 2.04 or Table 2.05 gives length of speed change lane on various grades.

Table 2.2.3 Adjustment Factors for Ramp Length of IRC

Source: Guidelines for Expressways, IRC, 2010

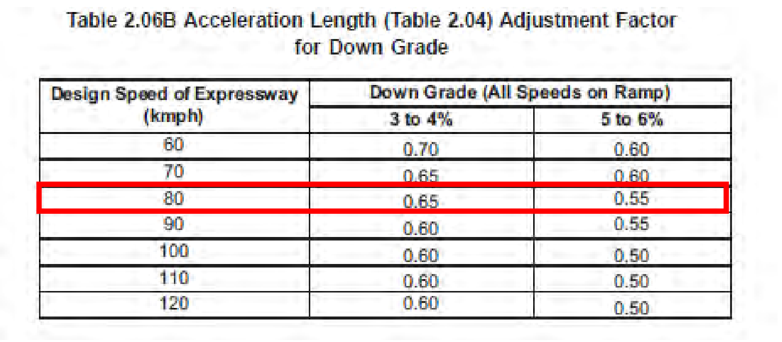


Table 2.06B Acceleration Length (Table 2.04) Adjustment Factor for Down Grade

Design Speed of Expressway (kmph)	Down Grade (All Speeds on Ramp)	
	3 to 4%	5 to 6%
60	0.70	0.60
70	0.65	0.60
80	0.65	0.55
90	0.60	0.55
100	0.60	0.50
110	0.60	0.50
120	0.60	0.50

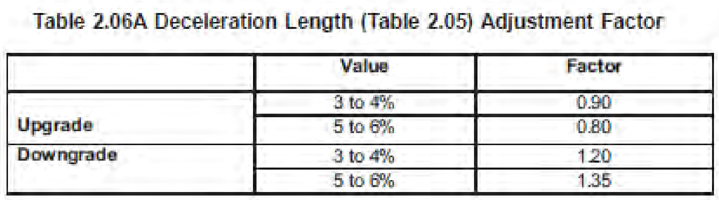


Table 2.06A Deceleration Length (Table 2.05) Adjustment Factor

	Value	Factor
Upgrade	3 to 4%	0.90
	5 to 6%	0.80
Downgrade	3 to 4%	1.20
	5 to 6%	1.35

Source: IRC Guidelines for Expressways

IRC Guidelines for Expressway stated the required length of acceleration/deceleration lane with adjustment factors for different grades of main line. However, adjustment factors of IRC Guidelines for Expressway indicates only 3<λ≦4%, 5<λ≦6%, but no indication of adjustment factors for 0<λ≦3%, 4< λ ≦ 5%. Furthermore, there is no description of required length for two-way acceleration/deceleration lane.

2.2.3.2 Criteria of Japanese Inter-city Expressways

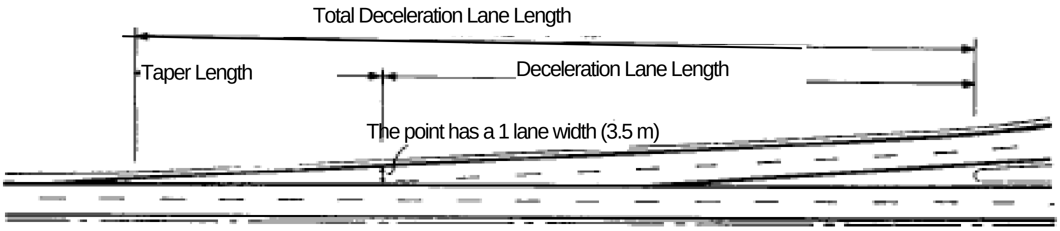
The criteria of Japanese Inter-city Expressways are stated below.

Table 2.2.4 Length of Acceleration/Deceleration Lane Length

Design Speed of Expressway (km/ph)		120	100	80	60
Deceleration Lane Length : Excluding Taper length (m)	1-way ramp	100	90	80	70
	2-way ramp	150	130	110	90
Acceleration Lane Length : Excluding Taper length (m)	1-way ramp	200	180	160	120
	2-way ramp	300	260	220	160
Exit Taper Rate		1/25		1/20	1/15
Entry Taper Rate		1/40		1/30	1/20

Source: NEXCO East Design Standard

According to the above criteria, the deceleration lane length of two-way lanes will be calculated as below.



Source: NEXCO East Design Standard

Figure 2.2.4 Typical Two-way Deceleration Lane

In the above case, deceleration lane length is 110 m as per Table 2.2.4. Then, taper length will be calculated using the following formula:

3.5 m (width of 1 lane) × 20 = 70 m

Therefore, total deceleration length will be 110 m + 70 m = 180 m

Required total lengths for two-way acceleration and deceleration lanes are shown in the table below.

Table 2.2.5 Required Length for Two-way Lane

(Design Speed of Expressway: 80 km/h, Lane width: 3.5 m)

	Changing Speed Lane Length	Taper Length		Total Length
		Taper Rate	Calculated Length	
Acceleration Lane	220 m	1/30	105 m	325 m
Deceleration Lane	110 m	1/20	70 m	180 m

Source: NEXCO East Design Standard

Adjustment factors by longitudinal gradient are indicated in Table below.

Table 2.2.6 Adjustment Factor by Longitudinal Gradient

Longitudinal Gradient	0 < λ ≦2	2 < λ ≦3	3 < λ ≦4	4 < λ ≦6
Deceleration Lane (Down Grade)	1.00	1.10	1.20	1.30
Acceleration Lane (Up Grade)	1.00	1.20	1.30	1.40

Source: NEXCO East Design Standard

2.2.3.3 Criteria of Tokyo Metropolitan Expressway

Length of acceleration/deceleration lane and taper are shown in Table below.

Table 2.2.7 Length of Acceleration/Deceleration Lane and Taper

Design Speed of Expressway (km/h)		80	60	50	40
Acceleration Lane Length (Including Taper Length) (m)	1-way ramp	160	120	90	50
	2-way ramp	240	180	140	90
Deceleration Lane Length (Including Taper Length) (m)	1-way ramp	110	90	70	80
	2-way ramp	170	140	110	40

Source: Tokyo Metropolitan Expressway

Adjustment factors by longitudinal gradient are indicated in Table below.

Table 2.2.8 Adjustment Factor by Longitudinal Gradient

Longitudinal Gradient	0 < λ ≦2	2 < λ ≦3	3 < λ ≦4	4 < λ
Deceleration Lane (Down Grade)	1.00	1.10	1.20	1.30
Acceleration Lane (Up Grade)	1.00	1.20	1.30	1.40

Source: Tokyo Metropolitan Expressway

2.2.3.4 Recommended Length for Acceleration/Deceleration Lane

There is no description of required length of two-way ramp for both acceleration and deceleration lane. As the characteristics of BPRR are similar to Tokyo metropolitan expressways, the JICA Experts recommended the use of the criteria of Tokyo metropolitan expressways. In addition to this, some gradients of adjustment factors for length of acceleration and deceleration lanes are also not indicated in the IRC. So, in order to fill the missing parts, adjustment factors for Tokyo metropolitan expressways are also recommended to use.

It is noted that adjustment factors for downgrade of acceleration/deceleration lane which reduce the length should not be utilized since the revised IRC does not indicate them and any other compared criteria are not recommended for reducing the length even in downgrade condition.

Minimum required length of ramp terminals for BPRR from nose position to end of taper, which the JICA Experts recommends, are indicated below.

- Acceleration Lane : 240 m
- Deceleration Lane : 170 m

Table 2.2.9 Adjustment Factor of Acceleration/Deceleration Lane Length for BPRR

Longitudinal Gradient	0 < λ ≦2	2 < λ ≦3	3 < λ ≦4	4 < λ ≦6
Deceleration Lane (Down Grade)	1.00	1.10	1.20	1.30
Acceleration Lane (Up Grade)	1.00	1.20	1.40	1.50

Source: JICA Experts

Adjustment factors of longitudinal gradient for acceleration lane in the case of 3< λ ≦4% and 4< λ ≦ 6% utilize IRC since these adjustment factors make the lane length longer; and longer means safer.

2.2.4 Transition Section of Main Line and Acceleration/Deceleration Lane

(1) Comments and Suggestions on DPR

The value of radius of curve or gradient in the DPR drawings are not considered for the required visibility for drivers driving on full access controlled toll roads.

Even if not described in IRC SP 99-2013, the alignment of connecting section of main line with ramp (acceleration/deceleration lane) needs to ensure the driver’s good visibility since accidents tend to occur in this section. To avoid accidents in this section, drivers need to recognize that the margining or diverting section is getting closer from a long distance.

The JICA Experts indicated the alignment criteria of full access controlled highways for Tokyo metropolitan expressways for the section which connects the main line and ramp for merging/diverging lanes below (speed of main line: 80 km/h).

- Radius of Horizontal Curve (shall be more than 500 m※)
- Radius of Vertical Curve of Summit-type (shall be more than 4,500 m※)
- Radius of Vertical Curve of Valley-type (shall be more than 3,000 m※)
- Vertical Gradient (4%※)

※This is the value that shall be followed under any conditions for full access controlled highways in Tokyo metropolitan expressways.

(2) Conclusion

After comparison with the required value of Tokyo metropolitan expressways, only the radius of vertical curve of summit type on mainline where connecting acceleration/deceleration lanes were observed smaller than 4500 m in some sections and they need to change from the DPR design according to the table below.

Table 2.2.10 Alignment Violating the Criteria of Full Access Controlled Highways for Tokyo Metropolitan Expressways

IC Name	Toward to	Entry /Exit	Old Chainage	New Chainage	Chainage difference	Horizontal Curve Radius (500m)	Vertical Curve Radius SummitType (4500m)	Vertical Curve Radius Valley Type (3000m)	Vertical Gradient (4%)	Remark
Hessarghatta	Hosur	Entry		5,500					0.3	
	Tumkur	Exit		5,500					-0.3	
	Tnmkur	Entry								
	Hosur	Exit								
Doddaballapura	Hosur	Entry		15,900					-1.8	
	Tumkur	Exit		15,900					1.8	
	Tnmkur	Entry		13,250			12,300			
	Hosur	Exit		13,250			12,300			
Ballary	Hosur	Entry		19,900		835			-1.9	
	Tumkur	Exit		19,900		835	5,100		1.9	There is a summit at nose.
	Tnmkur	Entry		17,450					2.7	
	Hosur	Exit		17,450			2,500		-2.7	There is a summit at beginning of taper.
Hennur	Hosur	Entry		26,800			3,600		1.5	There is a too sharp summit at end of tapar.
	Tumkur	Exit		26,800			3,600		-1.5	There is a too sharp summit at beginning of tapar.
	Tnmkur	Entry		24,200					-0.4	
	Hosur	Exit		24,200					0.4	
Old Madras	Hosur	Entry		37,400				10,000		
	Tumkur	Exit		37,400				10,000		
	Tnmkur	Entry		34,700		785			-1.5	
	Hosur	Exit		34,700		785			1.5	
Whitefield	IC Center			38.747						Corrected channage seems wrong
	Hosur	Entry		40,100		800	6,938			
	Tumkur	Exit		39,950					-1.9	Deceleration length is too short. Less than 200m
	Tnmkur	Entry		37,850				3,000	-3.2	There is a valley at the end of taper.
	Hosur	Exit		38,000			3,500		-1.0	There is a too sharp summit before tapar. Deceleration length is less than 200m
Hoskote-Anekal	IC Center		53,200	54,014	814					
	Hosur	Entry	54,186	55,000	814		4,250		2.6	There is a too sharp summit at end of tapar.
	Tumkur	Exit	54,186	55,000	814		4,250		-2.6	There is a too sharp summit at beginning of tapar.
	Tnmkur	Entry	51,986	52,800	814				1.5	
	Hosur	Exit	51,986	52,800	814				-1.5	
Sarjapur	IC Center		55,890	56,705	815					
	Hosur	Entry	57,285	58,100	815		21,209		2.9	
	Tumkur	Exit	57,285	58,100	815		20,209		-2.9	
	Tnmkur	Entry	54,585	55,400	815	1,175			0.9	
	Hosur	Exit	54,585	55,400	815	1,175			-0.9	

Source: JICA Experts

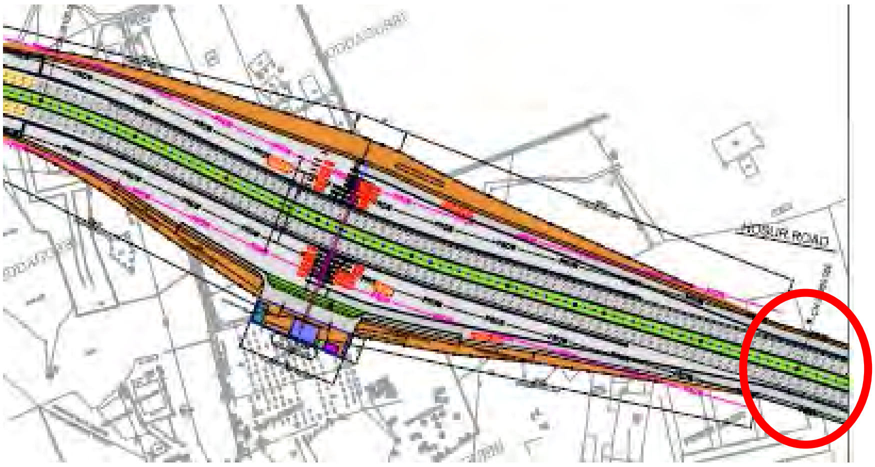
Ballary Road

Source: DPR Drawings

Figure 2.2.5 Sharp Summit at Ballary Road Junction

Sharp summit at Ch. 17+310 which causes poor visibility for cars exiting toward Hosur.

Hennur JCT

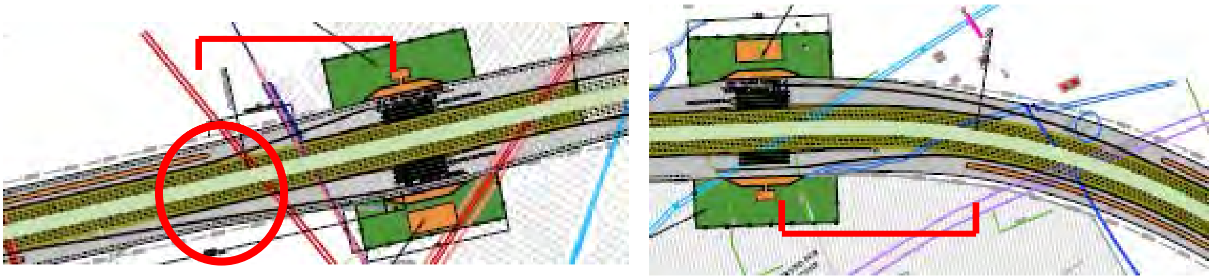


Source: DPR Drawings

Figure 2.2.6 Sharp Summit at Hennur Junction

Sharp summit at Ch. 26+934 which causes poor visibility for cars entering toward Hosur and exiting toward Tumkur.

Whitefield Road

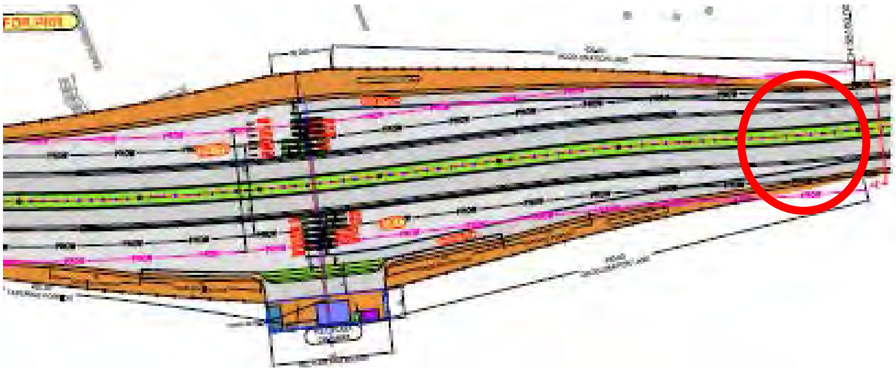


Source: DPR Drawings

Figure 2.2.7 Sharp Summit on White Field Road Junction

Sharp summit at Ch. 37+987 which causes poor visibility for cars exiting toward Hosur.Deceleration length of both exits is too short.

Hoskote-Anekal JCT



Source:DPR Drawings

Figure 2.2.8 Sharp Summit at Hoskote-Anekal Junction

Sharp summit at Ch. 54+917 which causes poor visibility for cars entering toward Hosur and exiting toward Tumkur.

The problem sections which are violating the criteria of radius of vertical curve of summit shall be changed to the minimum 4500 m.

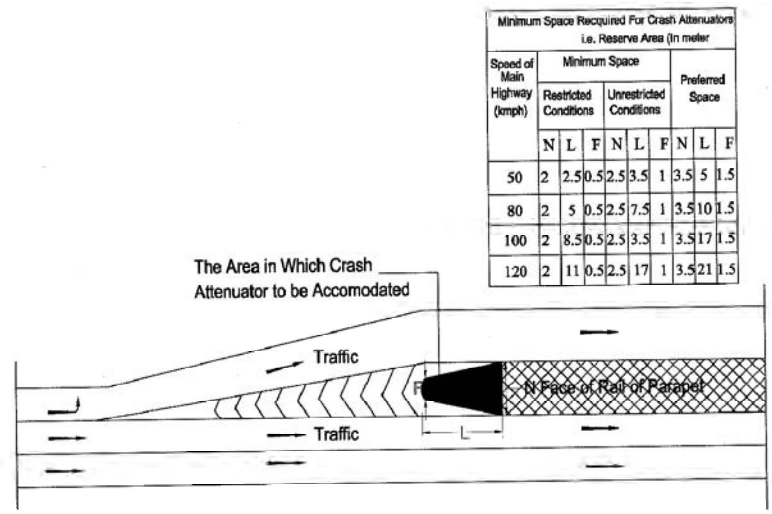
2.2.5 Measures Minimizing Accidents at Section Connecting Main Line and Acceleration/Deceleration Lane

(1) Comments and Suggestions on DPR

There are no detailed descriptions on the DPR. Every measure needs to focus on the improvement of recognition of junctions for drivers coming from upstream from a long distance.

- Enlargement of radius of vertical curve (especially at summit section)
- Expansion of margining/diverting length
- Clear segregation between main line and acceleration/deceleration lane
  (Wide dot marking, arrow marking, lettering marking, colored pavement, grooving pavement, cat eye, etc.)
- Guide signs for notifying junctions ahead to drivers (2 km, 1 km, 500 m upstream)
- Nose protection

IRC SP 99-2013 indicates the necessity of placing crash attenuator at the nose. Since accidents of crashing nose have a high potential to cause fatalities, the JICA Experts recommended ensuring the space to accommodate crash attenuator at nose position.



Minimum Space Recquired For Crash Attenuators i.e. Reserve Area (In meter									
Speed of Main Highway (kmph)	Minimum Space						Preferred Space		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
50	2	2.5	0.5	2.5	3.5	1	3.5	5	1.5
80	2	5	0.5	2.5	7.5	1	3.5	10	1.5
100	2	8.5	0.5	2.5	3.5	1	3.5	17	1.5
120	2	11	0.5	2.5	17	1	3.5	21	1.5

Source: IRC SP 99-2013

Figure 2.2.9 Space Required to Place Crash Attenuators

(2) Conclusion

The above measures are recommended to consider in the detailed design stage.

2.3 Toll Plaza Design

The toll plaza is the only place where drivers need to stop or reduce the speed to crawl level in full access controlled toll road. It also tends to cause the traffic congestion because of the following reasons:

- Trouble of transaction process of toll fee
- Corresponding trouble or claim from drivers
- Accidental contact with facilities on the toll island
- Accidental contact of vehicles in the vicinity of the toll island area

Design criteria of toll plaza area shall consider minimizing the above situations.

2.3.1 Alignment of Toll Plaza Area

(1) Comments and Suggestions on DPR

There is no detailed description on the DPR drawings.

Since all vehicles that want to use BPRR are coming into toll plaza and vehicles without ETC embedded have to stop at the toll gates, the gradient and radius of curvature of toll plaza area cannot be too steep. Another important consideration is the drainage system since there are various equipment installed. Therefore, in designing toll plaza area, the following noted in NEXCO East Design Standard shall be considered:

- Straight line is the best for toll plaza area but if horizontal curve is impossible to avoid, minimum radius of horizontal curve shall be 200 m.
- Minimum radius of vertical curve shall be 700 m.
- Gradient of toll plaza area shall be not more than 2%.
- Cross fall of toll plaza area shall be not more than 2%.

(2) Conclusion

The above design concepts are recommended to be adopted in the detailed design.

2.3.2 Width and Length of Toll Lane

(1) Comments and Suggestions on DPR

In the DPR drawing, 3.5 m for ETC and 3.2 m for manual lane are described as per IRC SP 99-2013. However, considering increasing ETC users in the future, width should be uniformed at 3.5 m. IRC also described 25 m for toll island length and there is no description about ETC lane length. ETC lane needs a longer island than manual lane since ETC lane requires a communication zone between antenna and OBU. Therefore, all lanes shall be 35 m (including 5 m for communication zone).

Adopting this concept is for avoiding any major reconstruction of toll gate when changing manual lane to ETC lane.

(2) Conclusion

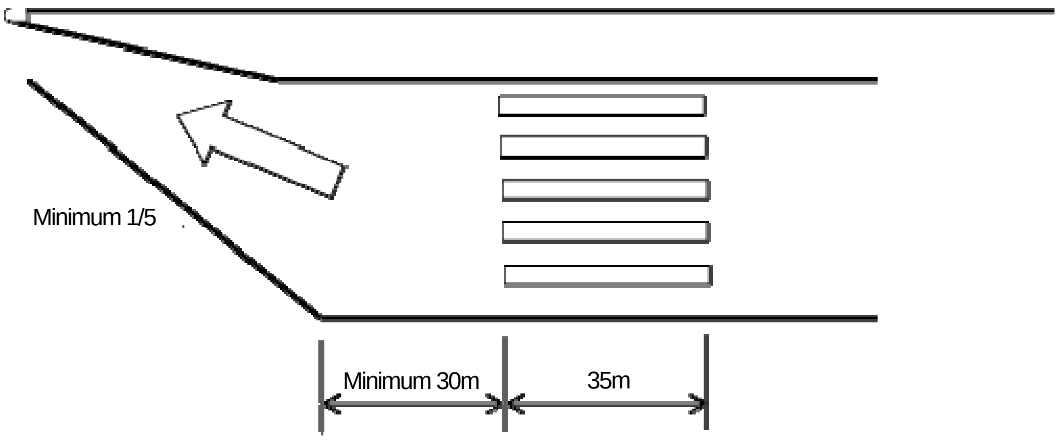
Every toll lane width is 3.5 m and length is 35 m.

2.3.3 Alignment from Toll Island to Nose Position

(1) Comments and Suggestions on DPR

There is no description on the DPR drawing.

The JICA Experts recommended to compile the figure below as the alignment of transition from toll island to the positon where the width transitions to the required two-lane ramps.



Source: JICA Experts

Figure 2.3.1 Example of Alignment of Area from Toll Island to Nose Position

After passing through the entry toll island or before exiting the toll island, at least 30 m of straight line is required to ensure that the full body of multi-axle vehicles coming out from the island does not hit the island or any facilities. Transition alignment from toll plaza area to nose position requires a minimum 1/5 taper ratio.

(2) Conclusion

The JICA Experts recommended adopting the above concept in the detailed design.

2.3.4 Toll Gate Facilities

2.3.4.1 Tunnel

(1) Comments and Suggestions on DPR

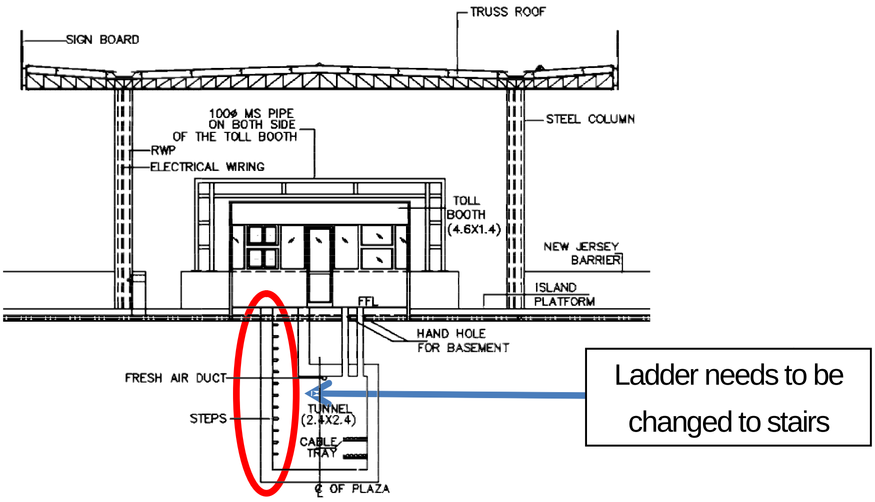
DPR drawings are showing tunnel under toll lanes except Whitefield JCT and one of Doddabalapura JCT. Tunnel for toll management is required for all toll plazas.

JICA Experts confirmed most of the toll plazas have a plan of tunnels However, ladder has planned for connecting toll booth to tunnel. The ladder may cause or inflict injury on staff working for toll management. In particular, toll collectors need to carry cash box from the toll booth to the cash room and it will be difficult to go up and down a ladder while carrying a cash box. Gurugaon, which is the largest toll plaza in India, as well as Hyderabad ORR, has a toll management tunnel and the booth is connected to the tunnel by stairs.

Space for stairs

Source: JICA Experts

Figure 2.3.2 Stairs Space of Toll Booth at Gurugaon Toll Plaza



Ladder needs to be changed to stairs

Source: JICA Experts

Figure 2.3.3 Ladder of BPRR (current drawing)

(2) Conclusion

All toll plazas should have a tunnel and steps that connect the toll booth to the tunnel in order to ensure the safety of toll collectors.

2.3.4.2 Width for Large Sized Vehicle Lane

(1) Comments and Suggestions on DPR

DPR drawings are showing 5.5 m width for large sized vehicle toll lanes even though IRC SP 99-2013 shows only 4.5 m.

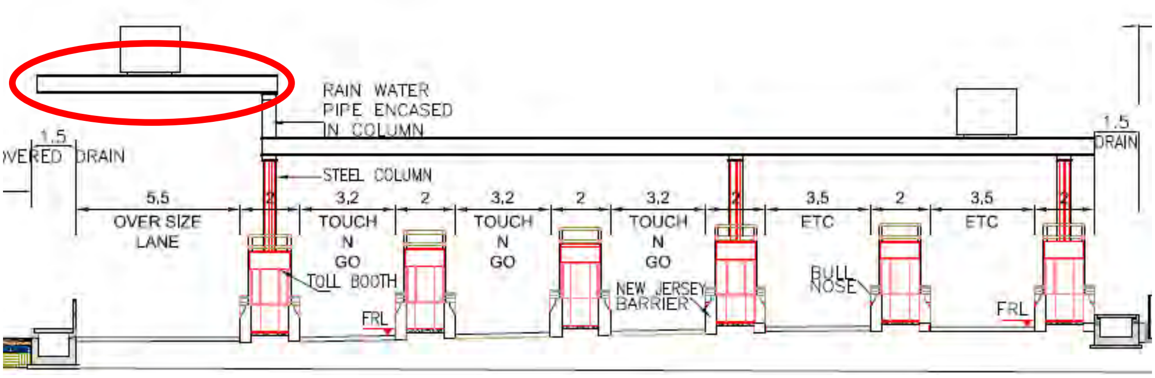
(2) Conclusion

As a result, the necessity of 5.5 m large sized vehicle lane was agreed among BDA and the JICA Experts for safer passage of vehicles considering local conditions.

2.3.4.3 Canopy

(1) Comments and Suggestions on DPR

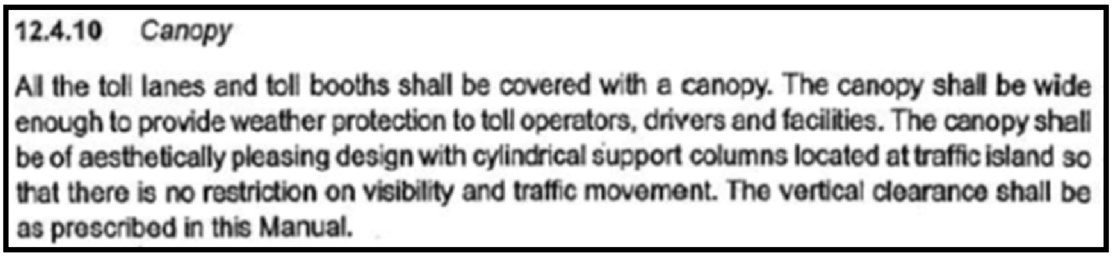
In the DPR drawing, clearance of canopy is not consistent and extra clearance is planned only for large sized vehicle lane. In addition, canopy for large sized vehicle was planned as cantilever. Since canopy has to be robust enough to bear overhead traffic light and VMS (it may be required in the future), cantilever should be avoided.



Source: DPR Drawing

Figure 2.3.4 Current Canopy Plan of BPRR

IRC SP 99-2013 description regarding canopy design is shown below.



12.4.10 *Canopy*

All the toll lanes and toll booths shall be covered with a canopy. The canopy shall be wide enough to provide weather protection to toll operators, drivers and facilities. The canopy shall be of aesthetically pleasing design with cylindrical support columns located at traffic island so that there is no restriction on visibility and traffic movement. The vertical clearance shall be as prescribed in this Manual.

Source: IRC SP:99-2013

(2) Conclusion

As a result, canopy design will be reconsidered as a consistent roof at the detailed design stage.

2.3.5 Number of Required Toll Lanes

2.3.5.1 Capacity of Toll Lane by Each System

(1) Comments and Suggestions on DPR

The number of toll lanes in the DPR drawing does not consider the capacity of each tolling system such as ETC, T&G, and manual.

As per IRC SP 99-2013, the capacities of lane of different systems are described below.

- Semiautomatic toll lane (manual cash transaction) : 240 vehicles/h
- Smart card lane (T&G) : 360 vehicles/h
- ETC lane : 1200 vehicles/h

In the case of T&G and ETC, the processing time for both entry and exit are the same. However, the processing time for entry and exit will be different for a manual lane. When a vehicle comes to the manual entry gate, the driver receives a transit card from the toll collector and leaves for the main line. On the other hand, when that vehicle comes to the exit gate, the driver gives the transit card to the toll collector and pays the travel fee after the toll collector has checked the amount. Therefore, the processing time for exit lane takes more time than entry lane.

The capacity of manual lane described in IRC SP 99-2013 is the capacity for entry lane only since almost an equal number (230 vehicles/h) is described in the Japanese manual. IRC SP 99-2013 also described that toll lane shall ensure a service time of not more than 10 seconds. Therefore, the JICA Experts recommended to utilize 180 vehicles/h for manual exit lane since it used the Japanese design in the case of 10 seconds service time.

Capacity of each system for both entry and exit are summarized in Table 2.3.1 below.

Table 2.3.1 Capacity of Entry/Exit Lane by Each System

Lane Type	Manual	T & G	ETC
Entry	240v/h	360v/h	1200v/h
Exit	180v/h	360v/h	1200v/h

Source: IRC SP 99-2013

It is noted that as the number of lanes increase, the processing capacity will be more than the capacity of one lane multiplied by the number of lanes, since incoming vehicle can enter any vacant lane.

(2) Conclusion

The JICA Experts recommended to adopt the above capacity for each tolling system.

2.3.5.2 Transition of Capacity of Toll Lane by Increasing the Number of Lanes

(1) Comments and Suggestions on DPR

There is no description and consideration of capacity of toll procedure on DPR.

It is noted that if the number of lanes increase, the capacity of processing will be more than the capacity that is multiplied number of lanes by the capacity of one lane, since coming vehicle can enter any vacant lanes.

With reference to the Japanese Design Standard (NEXCO-East), capacity indicated in Table 2.3.2 below can be used for calculation of the required number of toll lanes.

Table 2.3.2 Transition of Capacity of Toll Lane by Increasing the Number of Lanes

V/h by No. of Lane		1 Lane	2 Lanes	3 Lanes	4 Lanes	5 Lanes	6 Lanes	7 Lanes	8 Lanes
Manual	Entry	240	640	1,070	1,500	1,940	2,380	2,830	3,270
	Exit	180	510	850	1,200	1,550	1,910	2,260	2,620
T&G	Entry/Exit	360	850	1,420	2,000	2,590	3,180	3,770	4,360

Source: JICA Experts

(2) Conclusion

The JICA Experts recommended to use the above table for finding the capacity of each junction.

2.3.5.3 Transition of Usage Ratio of Each System

(1) Comments and Suggestions on DPR

There is no description or consideration of usage ratio of each tolling system on the DPR.

In order to calculate the required number of toll lanes of each system, the JICA Experts presented the following three cases as indicated in Table 2.3.3.

Case 1 is the case where ETC users started from 2% of all vehicles on BPRR and gradually increases to 34% in 2040. Case 2 and Case 3 are where ETC users started at 5% and usage ratios will be 46% and 50% in 2040, respectively. Regarding smartcard users (T&G) are set up with higher usage ratio since ITS master plan recommended disseminating intermodal smartcard. So, in the first year of BPRR service introduction, it is possible that many users will already hold smartcards for T&G.

Table 2.3.3 Transition of Usage Ratio of ETC and T&G (%)

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Remark
Case-1																				
ETC usage ratio	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	In any case, some OBU and smartcard need to be disseminated by Gov side before opening of PRR for promotion of ETC and T&G.
Accumulated total	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	31	32	33	34	
T&G usage ration	8	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Accumulated total	8	11	14	17	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Card Accumulated total	10	15	20	25	30	33	36	39	42	45	48	51	54	57	60	62	64	66	68	
Case-2																				
ETC usage ratio	5	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	In addition to case -1, some special discout terms in first 10 years are considered to increase ETC users.
Accumulated total	5	8	11	14	17	20	23	26	29	32	34	36	38	40	42	43	44	45	46	
T&G usage ration	8	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Accumulated total	8	11	14	17	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Card Accumulated total	13	19	25	31	37	41	45	49	53	57	60	63	66	69	72	74	76	78	80	
Case-3																				
ETC usage ratio	5	5	5	3	3	3	3	3	3	3	2	2	2	2	2	1	1	1	1	In addition to case -2, delivering subsidies for OBU is considered for 3 years after opening of PRR.
Accumulated total	5	10	15	18	21	24	27	30	33	36	38	40	42	44	46	47	48	49	50	
T&G usage ration	8	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Accumulated total	8	11	14	17	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Card Accumulated total	13	21	29	35	41	45	49	53	57	61	64	67	70	73	76	78	80	82	84	

Source: JICA Experts

(2) Conclusion

The JICA Experts recommended to adopt this transition of usage ratio to calculate the required number of toll lanes.

2.3.5.4 Required Number of Toll Lanes for Each Case

(1) Comments and Suggestions on DPR

There is no consideration for deciding the required number of toll lanes of each junction on the DPR. Required number of toll lanes is estimated from daily traffic volume calculated based on traffic demand forecast.

Table 2.3.4 Year 2022, Case 1 (ETC: 2%, T&G: 8%, Manual: 90%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	17,132	1,199	1,191	8	24	1,175	1,113	1	4	5	
	Nice Rd	Exit	11,786	825	819	6	16	809	760	1	3	4	
Hessaraghatta	Hosur	Entry	2,654	186	186	0	4	182	173	1	1	2	
	Tumkur	Exit	1,851	129	129	0	3	126	119	1	1	2	
Additional IC No.1	Hosur	Entry	3,907	273	273	0	5	268	253	1	2	3	
	Tumkur	Exit	3,913	273	273	0	5	268	251	1	2	3	
	Tumkur	Entry	3,584	251	250	1	5	246	233	1	1	2	
	Hosur	Exit	6,829	477	475	2	10	468	439	1	2	3	
Doddaballapur	Hosur	Entry	3,606	252	251	1	5	247	234	1	1	2	
	Tumkur	Exit	2,891	202	202	0	4	198	186	1	2	3	
	Tumkur	Entry	2,975	207	205	2	4	203	192	1	1	2	
	Hosur	Exit	3,283	230	228	2	5	225	212	1	2	3	
Bellary	Hosur	Entry	3,491	245	245	0	5	240	227	1	1	2	
	Tumkur	Exit	4,166	292	292	0	6	286	269	1	2	3	
	Tumkur	Entry	3,367	236	232	4	5	231	219	1	1	2	
	Hosur	Exit	4,987	349	344	5	7	342	321	1	2	3	
Hennur	Hosur	Entry	4,457	312	311	1	6	306	289	1	2	3	
	Tumkur	Exit	4,451	311	310	1	6	305	286	1	2	3	
	Tumkur	Entry	1,169	82	82	0	2	80	76	1	1	2	
	Hosur	Exit	1,158	81	80	1	2	79	75	1	1	2	
Additional IC No2	Hosur	Entry	1,304	91	91	0	2	89	84	1	1	2	
	Tumkur	Exit	1,357	95	95	0	2	93	87	1	1	2	
	Tumkur	Entry	3,095	217	217	0	4	213	201	1	1	2	
	Hosur	Exit	3,043	213	213	0	4	209	196	1	2	3	
Old Madras Road	Hosur	Entry	1,038	73	73	0	1	72	68	1	1	2	
	Tumkur	Exit	1,044	74	74	0	1	73	68	1	1	2	
	Tumkur	Entry	7,039	493	492	1	10	483	457	1	2	3	
	Hosur	Exit	7,291	510	509	1	10	500	470	1	2	3	
Whitefield	Hosur	Entry	3,918	274	269	5	5	269	254	1	2	3	
	Tumkur	Exit	3,975	278	273	5	5	273	256	1	2	3	
	Tumkur	Entry	3,053	213	213	0	4	209	198	1	2	3	
	Hosur	Exit	3,411	238	238	0	5	233	219	1	2	3	
Additional IC No3	Hosur	Entry	6,297	441	435	6	9	432	409	1	2	3	
	Tumkur	Exit	6,365	445	439	6	9	436	410	1	2	3	
	Tumkur	Entry	411	28	28	0	1	27	26	1	1	2	
	Hosur	Exit	319	22	22	0	0	22	20	1	1	2	
Hoskote-Anekal Rd	Hosur	Entry	2,598	182	180	2	4	178	169	1	1	2	
	Tumkur	Exit	5,785	405	403	2	8	397	373	1	2	3	
	Tumkur	Entry	4,846	339	337	2	7	332	315	1	2	3	
	Hosur	Exit	2,638	184	182	2	4	180	169	1	1	2	
Sarjapur	Hosur	Entry	5,303	371	370	1	7	364	344	1	2	3	
	Tumkur	Exit	1,777	124	121	3	2	122	114	1	1	2	
	Tumkur	Entry	2,177	153	150	3	3	150	142	1	1	2	
	Hosur	Exit	5,372	375	374	1	7	368	345	1	2	3	
Hosur	Tumkur	Entry	18,274	1,279	1,266	13	25	1,254	1,187	1	4	5	
	Nice Rd	Exit	19,354	1,355	1,342	13	27	1,328	1,248	1	5	6	

Source: JICA Experts

Table 2.3.5 Year 2022, Case 2 and Case 3 (ETC: 5%, T&G: 8%, Manual: 87%)

In 2022, usage ratios of ETC and T&G are the same.

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	17,132	1,199	1,191	8	60	1,139	1,079	1	4	5	
	Nice Rd	Exit	11,786	825	819	6	41	784	737	1	3	4	
Hessaraghatta	Hosur	Entry	2,654	186	186	0	9	177	167	1	1	2	
	Tumkur	Exit	1,851	129	129	0	6	123	115	1	1	2	
Additional IC No.1	Hosur	Entry	3,907	273	273	0	14	259	246	1	2	3	
	Tumkur	Exit	3,913	273	273	0	14	259	244	1	2	3	
	Tumkur	Entry	3,584	251	250	1	13	239	226	1	1	2	
	Hosur	Exit	6,829	477	475	2	24	453	426	1	2	3	
Doddaballapur	Hosur	Entry	3,606	252	251	1	13	239	227	1	1	2	
	Tumkur	Exit	2,891	202	202	0	10	192	180	1	1	2	
	Tumkur	Entry	2,975	207	205	2	10	197	152	1	1	2	
	Hosur	Exit	3,283	230	228	2	11	219	205	1	2	3	
Bellary	Hosur	Entry	3,491	245	245	0	12	233	220	1	1	2	
	Tumkur	Exit	4,166	292	292	0	15	277	261	1	2	3	
	Tumkur	Entry	3,367	236	232	4	12	224	212	1	1	2	
	Hosur	Exit	4,987	349	344	5	17	332	312	1	2	3	
Hennur	Hosur	Entry	4,457	312	311	1	16	296	281	1	2	3	
	Tumkur	Exit	4,451	311	310	1	16	296	278	1	2	3	
	Tumkur	Entry	1,169	82	82	0	4	78	74	1	1	2	
	Hosur	Exit	1,158	81	80	1	4	77	72	1	1	2	
Additional IC No2	Hosur	Entry	1,304	91	91	0	5	86	82	1	1	2	
	Tumkur	Exit	1,357	95	95	0	5	90	85	1	1	2	
	Tumkur	Entry	3,095	217	217	0	11	206	195	1	1	2	
	Hosur	Exit	3,043	213	213	0	11	202	190	1	2	3	
Old Madras Road	Hosur	Entry	1,038	73	73	0	4	69	66	1	1	2	
	Tumkur	Exit	1,044	74	74	0	4	70	66	1	1	2	
	Tumkur	Entry	7,039	493	492	1	25	468	443	1	2	3	
	Hosur	Exit	7,291	510	509	1	25	485	455	1	2	3	
Whitefield	Hosur	Entry	3,918	274	269	5	13	261	247	1	2	3	
	Tumkur	Exit	3,975	278	273	5	14	264	248	1	2	3	
	Tumkur	Entry	3,053	213	213	0	11	202	192	1	1	2	
	Hosur	Exit	3,411	238	238	0	12	226	212	1	2	3	
Additional IC No3	Hosur	Entry	6,297	441	435	6	22	419	397	1	2	3	
	Tumkur	Exit	6,365	445	439	6	22	423	398	1	2	3	
	Tumkur	Entry	411	28	28	0	1	27	25	1	1	2	
	Hosur	Exit	319	22	22	0	1	21	20	1	1	2	
Hoskote-Anekal Rd	Hosur	Entry	2,598	182	180	2	9	173	164	1	1	2	
	Tumkur	Exit	5,785	405	403	2	20	385	362	1	2	3	
	Tumkur	Entry	4,846	339	337	2	17	322	305	1	2	3	
	Hosur	Exit	2,638	184	182	2	9	175	164	1	1	2	
Sarjapur	Hosur	Entry	5,303	371	370	1	19	353	334	1	2	3	
	Tumkur	Exit	1,777	124	121	3	6	118	111	1	1	2	
	Tumkur	Entry	2,177	153	150	3	8	146	138	1	1	2	
	Hosur	Exit	5,372	375	374	1	19	356	335	1	2	3	
Hosur	Tumkur	Entry	18,274	1,279	1,266	13	63	1,216	1,151	1	4	5	
	Nice Rd	Exit	19,354	1,355	1,342	13	67	1,288	1,210	1	5	6	

Source: JICA Experts

Table 2.3.6 Year 2030, Case 1 (ETC: 18%, T&G: 24%, Manual: 58%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large- sized							
Tumkur	Hosur	Entry	38,295	2,680	2,661	19	479	2,201	1,849	1	5	6	
	Nice Rd	Exit	30,965	2,168	2,153	15	388	1,780	1,458	1	5	6	
Hessaraghatta	Hosur	Entry	4,255	297	296	1	53	244	205	1	1	2	
	Tumkur	Exit	3,609	252	251	1	45	207	169	1	1	2	
Additional IC No.1	Hosur	Entry	7,221	506	505	1	91	415	349	1	2	3	
	Tumkur	Exit	6,539	458	457	1	82	376	308	1	2	3	
	Tumkur	Entry	7,269	509	508	1	91	418	351	1	2	3	
	Hosur	Exit	9,214	645	641	4	115	530	434	1	2	3	
Doddaballapur	Hosur	Entry	6,021	422	420	2	76	346	291	1	2	3	
	Tumkur	Exit	4,827	338	336	2	60	278	227	1	2	3	
	Tumkur	Entry	4,998	350	347	3	62	288	242	1	2	3	
	Hosur	Exit	6,733	472	469	3	84	388	317	1	2	3	
Bellary	Hosur	Entry	6,671	466	459	7	83	383	322	1	2	3	
	Tumkur	Exit	5,468	383	378	5	68	315	258	1	2	3	
	Tumkur	Entry	9,057	634	626	8	113	521	438	1	2	3	
	Hosur	Exit	7,250	508	500	8	90	418	342	1	2	3	
Hennur	Hosur	Entry	5,558	389	388	1	70	319	268	1	2	3	
	Tumkur	Exit	5,898	414	413	1	74	340	278	1	2	3	
	Tumkur	Entry	3,625	254	254	0	46	208	175	1	1	2	
	Hosur	Exit	3,350	234	233	1	42	192	157	1	1	2	
Additional IC No2	Hosur	Entry	2,444	171	171	0	31	140	118	1	1	2	
	Tumkur	Exit	2,409	168	168	0	30	138	113	1	1	2	
	Tumkur	Entry	6,223	436	435	1	78	358	300	1	2	3	
	Hosur	Exit	6,214	435	434	1	78	357	292	1	2	3	
Old Madras Road	Hosur	Entry	3,179	223	222	1	40	183	154	1	1	2	
	Tumkur	Exit	2,618	183	183	0	33	150	123	1	1	2	
	Tumkur	Entry	8,441	591	588	3	106	485	408	1	2	3	
	Hosur	Exit	8,437	591	588	3	106	485	397	1	2	3	
Whitefield	Hosur	Entry	7,394	517	511	6	92	425	357	1	2	3	
	Tumkur	Exit	7,562	530	524	6	94	436	357	1	2	3	
	Tumkur	Entry	5,299	371	368	3	66	305	256	1	2	3	
	Hosur	Exit	6,390	448	442	6	80	368	302	1	2	3	
Additional IC No3	Hosur	Entry	2,204	154	151	3	27	127	107	1	1	2	
	Tumkur	Exit	9,525	667	663	4	119	548	448	1	2	3	
	Tumkur	Entry	2,470	173	172	1	31	142	119	1	1	2	
	Hosur	Exit	10,306	722	721	1	130	592	485	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	8,457	591	588	3	106	485	408	1	2	3	
	Tumkur	Exit	4,746	332	328	4	59	273	224	1	2	3	
	Tumkur	Entry	6,863	480	478	2	86	394	331	1	2	3	
	Hosur	Exit	8,632	604	599	5	108	496	406	1	2	3	
Sarjapur	Hosur	Entry	6,672	467	466	1	84	383	322	1	2	3	
	Tumkur	Exit	2,675	188	185	3	33	155	127	1	1	2	
	Tumkur	Entry	8,497	595	589	6	106	489	411	1	2	3	
	Hosur	Exit	4,786	335	335	0	60	275	225	1	2	3	
Hosur	Tumkur	Entry	27,290	1,911	1,893	18	341	1,570	1,319	1	4	5	
	Nice Rd	Exit	27,331	1,913	1,895	18	341	1,572	1,287	1	5	6	

Source: JICA Experts

Table 2.3.7 Year 2030, Case 2 (ETC: 29%, T&G: 24%, Manual: 47%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	38,295	2,680	2,661	19	772	1,908	1,603	1	5	6	
	Nice Rd	Exit	30,965	2,168	2,153	15	624	1,544	1,264	1	5	6	
Hessaraghatta	Hosur	Entry	4,255	297	296	1	86	211	177	1	1	2	
	Tumkur	Exit	3,609	252	251	1	73	179	147	1	1	2	
Additional IC No.1	Hosur	Entry	7,221	506	505	1	146	360	302	1	2	3	
	Tumkur	Exit	6,539	458	457	1	133	325	267	1	2	3	
	Tumkur	Entry	7,269	509	508	1	147	362	304	1	1	2	
	Hosur	Exit	9,214	645	641	4	186	459	376	1	2	3	
Doddaballapur	Hosur	Entry	6,021	422	420	2	122	300	252	1	2	3	
	Tumkur	Exit	4,827	338	336	2	97	241	197	1	2	3	
	Tumkur	Entry	4,998	350	347	3	101	249	209	1	1	2	
	Hosur	Exit	6,733	472	469	3	136	336	275	1	2	3	
Bellary	Hosur	Entry	6,671	466	459	7	133	333	280	1	2	3	
	Tumkur	Exit	5,468	383	378	5	110	273	224	1	2	3	
	Tumkur	Entry	9,057	634	626	8	182	452	380	1	2	3	
	Hosur	Exit	7,250	508	500	8	145	363	297	1	2	3	
Hennur	Hosur	Entry	5,558	389	388	1	113	276	232	1	1	2	
	Tumkur	Exit	5,898	414	413	1	120	294	241	1	2	3	
	Tumkur	Entry	3,625	254	254	0	74	180	151	1	1	2	
	Hosur	Exit	3,350	234	233	1	68	166	136	1	1	2	
Additional IC No2	Hosur	Entry	2,444	171	171	0	50	121	102	1	1	2	
	Tumkur	Exit	2,409	168	168	0	49	119	98	1	1	2	
	Tumkur	Entry	6,223	436	435	1	126	310	260	1	2	3	
	Hosur	Exit	6,214	435	434	1	126	309	253	1	2	3	
Old Madras Road	Hosur	Entry	3,179	223	222	1	64	159	133	1	1	2	
	Tumkur	Exit	2,618	183	183	0	53	130	106	1	1	2	
	Tumkur	Entry	8,441	591	588	3	171	420	353	1	2	3	
	Hosur	Exit	8,437	591	588	3	171	420	344	1	2	3	
Whitefield	Hosur	Entry	7,394	517	511	6	148	369	310	1	2	3	
	Tumkur	Exit	7,562	530	524	6	152	378	310	1	2	3	
	Tumkur	Entry	5,299	371	368	3	107	264	222	1	1	2	
	Hosur	Exit	6,390	448	442	6	128	320	262	1	2	3	
Additional IC No3	Hosur	Entry	2,204	154	151	3	44	110	93	1	1	2	
	Tumkur	Exit	9,525	667	663	4	192	475	389	1	2	3	
	Tumkur	Entry	2,470	173	172	1	50	123	103	1	1	2	
	Hosur	Exit	10,306	722	721	1	209	513	420	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	8,457	591	588	3	171	420	353	1	2	3	
	Tumkur	Exit	4,746	332	328	4	95	237	194	1	2	3	
	Tumkur	Entry	6,863	480	478	2	139	341	287	1	2	3	
	Hosur	Exit	8,632	604	599	5	174	430	352	1	2	3	
Sarjapur	Hosur	Entry	6,672	467	466	1	135	332	279	1	2	3	
	Tumkur	Exit	2,675	188	185	3	54	134	110	1	1	2	
	Tumkur	Entry	8,497	595	589	6	171	424	356	1	2	3	
	Hosur	Exit	4,786	335	335	0	97	238	195	1	2	3	
Hosur	Tumkur	Entry	27,290	1,911	1,893	18	549	1,362	1,144	1	4	5	
	Nice Rd	Exit	27,331	1,913	1,895	18	550	1,363	1,116	1	4	5	

Source: JICA Experts

Table 2.3.8 Year 2030, Case 3 (ETC: 33%, T&G: 24%, Manual: 43%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	38,295	2,680	2,661	19	878	1,802	1,514	1	5	6	
	Nice Rd	Exit	30,965	2,168	2,153	15	710	1,458	1,194	1	4	5	
Hessaraghatta	Hosur	Entry	4,255	297	296	1	98	199	167	1	1	2	
	Tumkur	Exit	3,609	252	251	1	83	169	139	1	1	2	
Additional IC No.1	Hosur	Entry	7,221	506	505	1	167	339	285	1	2	3	
	Tumkur	Exit	6,539	458	457	1	151	307	252	1	2	3	
	Tumkur	Entry	7,269	509	508	1	168	341	287	1	2	3	
	Hosur	Exit	9,214	645	641	4	212	433	355	1	2	3	
Doddaballapur	Hosur	Entry	6,021	422	420	2	139	283	238	1	1	2	
	Tumkur	Exit	4,827	338	336	2	111	227	186	1	2	3	
	Tumkur	Entry	4,998	350	347	3	115	235	198	1	1	2	
	Hosur	Exit	6,733	472	469	3	155	317	260	1	2	3	
Bellary	Hosur	Entry	6,671	466	459	7	151	315	264	1	2	3	
	Tumkur	Exit	5,468	383	378	5	125	258	211	1	2	3	
	Tumkur	Entry	9,057	634	626	8	207	427	359	1	2	3	
	Hosur	Exit	7,250	508	500	8	165	343	281	1	2	3	
Hennur	Hosur	Entry	5,558	389	388	1	128	261	219	1	1	2	
	Tumkur	Exit	5,898	414	413	1	136	278	227	1	2	3	
	Tumkur	Entry	3,625	254	254	0	84	170	143	1	1	2	
	Hosur	Exit	3,350	234	233	1	77	157	129	1	1	2	
Additional IC No2	Hosur	Entry	2,444	171	171	0	56	115	96	1	1	2	
	Tumkur	Exit	2,409	168	168	0	55	113	92	1	1	2	
	Tumkur	Entry	6,223	436	435	1	144	292	246	1	2	3	
	Hosur	Exit	6,214	435	434	1	143	292	239	1	2	3	
Old Madras Road	Hosur	Entry	3,179	223	222	1	73	150	126	1	1	2	
	Tumkur	Exit	2,618	183	183	0	60	123	100	1	1	2	
	Tumkur	Entry	8,441	591	588	3	194	397	333	1	2	3	
	Hosur	Exit	8,437	591	588	3	194	397	325	1	2	3	
Whitefield	Hosur	Entry	7,394	517	511	6	169	348	293	1	2	3	
	Tumkur	Exit	7,562	530	524	6	173	357	292	1	2	3	
	Tumkur	Entry	5,299	371	368	3	121	250	210	1	1	2	
	Hosur	Exit	6,390	448	442	6	146	302	247	1	2	3	
Additional IC No3	Hosur	Entry	2,204	154	151	3	50	104	88	1	1	2	
	Tumkur	Exit	9,525	667	663	4	219	448	367	1	2	3	
	Tumkur	Entry	2,470	173	172	1	57	116	98	1	1	2	
	Hosur	Exit	10,306	722	721	1	238	484	396	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	8,457	591	588	3	194	397	333	1	2	3	
	Tumkur	Exit	4,746	332	328	4	108	224	183	1	2	3	
	Tumkur	Entry	6,863	480	478	2	158	322	271	1	2	3	
	Hosur	Exit	8,632	604	599	5	198	406	333	1	2	3	
Sarjapur	Hosur	Entry	6,672	467	466	1	154	313	263	1	2	3	
	Tumkur	Exit	2,675	188	185	3	61	127	104	1	1	2	
	Tumkur	Entry	8,497	595	589	6	194	401	337	1	2	3	
	Hosur	Exit	4,786	335	335	0	111	224	184	1	2	3	
Hosur	Tumkur	Entry	27,290	1,911	1,893	18	625	1,286	1,081	1	4	5	
	Nice Rd	Exit	27,331	1,913	1,895	18	625	1,288	1,054	1	4	5	

Source: JICA Experts

Table 2.3.9 Year 2040, Case 1 (ETC: 34%, T&G: 34%, Manual: 32%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	42,302	2,961	2,917	44	992	1,969	1,523	1	5	6	
	Nice Rd	Exit	52,825	3,698	3,651	47	1,241	2,457	1,826	2	5	7	
Hessaraghatta	Hosur	Entry	13,339	934	927	7	315	619	479	1	2	3	
	Tumkur	Exit	5,677	398	392	6	133	265	197	1	2	3	
Additional IC No.1	Hosur	Entry	7,700	539	535	4	182	357	276	1	2	3	
	Tumkur	Exit	6,468	452	449	3	153	299	223	1	2	3	
	Tumkur	Entry	6,731	471	467	4	159	312	241	1	2	3	
	Hosur	Exit	10,094	706	701	5	238	468	348	1	2	3	
Doddaballapur	Hosur	Entry	5,690	398	395	3	134	264	204	1	1	2	
	Tumkur	Exit	8,429	590	586	4	199	391	290	1	2	3	
	Tumkur	Entry	4,559	319	315	4	107	212	164	1	1	2	
	Hosur	Exit	4,548	319	316	3	107	212	157	1	1	2	
Bellary	Hosur	Entry	4,079	286	260	26	88	198	153	1	1	2	
	Tumkur	Exit	4,134	289	264	25	90	199	148	1	1	2	
	Tumkur	Entry	12,028	842	825	17	281	562	434	1	2	3	
	Hosur	Exit	9,657	676	664	12	226	450	335	1	2	3	
Hennur	Hosur	Entry	9,336	653	647	6	220	433	335	1	2	3	
	Tumkur	Exit	8,172	572	569	3	193	379	281	1	2	3	
	Tumkur	Entry	4,239	297	296	1	101	196	152	1	1	2	
	Hosur	Exit	4,403	308	306	2	104	204	152	1	1	2	
Additional IC No2	Hosur	Entry	5,537	388	387	1	132	256	198	1	1	2	
	Tumkur	Exit	4,379	306	305	1	104	202	150	1	1	2	
	Tumkur	Entry	6,657	466	464	2	158	308	238	1	1	2	
	Hosur	Exit	6,341	444	442	2	150	294	218	1	2	3	
Old Madras Road	Hosur	Entry	2,903	203	203	0	69	134	104	1	1	2	
	Tumkur	Exit	3,498	245	245	0	83	162	120	1	1	2	
	Tumkur	Entry	9,018	631	624	7	212	419	324	1	2	3	
	Hosur	Exit	8,235	576	568	8	193	383	285	1	2	3	
Whitefield	Hosur	Entry	6,083	426	422	4	143	283	218	1	1	2	
	Tumkur	Exit	5,798	406	401	5	136	270	200	1	2	3	
	Tumkur	Entry	10,881	761	751	10	255	506	391	1	2	3	
	Hosur	Exit	14,114	988	974	14	331	657	488	1	2	3	
Additional IC No3	Hosur	Entry	10,117	708	700	8	238	470	363	1	2	3	
	Tumkur	Exit	9,422	659	651	8	221	438	325	1	2	3	
	Tumkur	Entry	9,741	682	678	4	231	451	349	1	2	3	
	Hosur	Exit	7,459	522	519	3	176	346	257	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	6,428	450	445	5	151	299	231	1	1	2	
	Tumkur	Exit	5,647	395	391	4	133	262	195	1	2	3	
	Tumkur	Entry	11,563	809	803	6	273	536	414	1	2	3	
	Hosur	Exit	5,081	355	351	4	119	236	175	1	1	2	
Sarjapur	Hosur	Entry	11,700	819	792	27	269	550	425	1	2	3	
	Tumkur	Exit	3,615	253	250	3	85	168	125	1	1	2	
	Tumkur	Entry	1,972	138	136	2	46	92	71	1	1	2	
	Hosur	Exit	11,061	775	747	28	254	521	387	1	2	3	
Hosur	Tumkur	Entry	39,626	2,774	2,746	28	934	1,840	1,423	1	4	5	
	Nice Rd	Exit	35,082	2,455	2,427	28	825	1,630	1,212	1	5	6	

Source: JICA Experts

Table 2.3.10 Year 2040, Case 2 (ETC: 46%, T&G: 34%, Manual: 20%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	42,302	2,961	2,917	44	1,342	1,619	1,252	2	4	6	
	Nice Rd	Exit	52,825	3,698	3,651	47	1,679	2,019	1,501	2	5	7	
Hessaraghatta	Hosur	Entry	13,339	934	927	7	426	508	393	1	2	3	
	Tumkur	Exit	5,677	398	392	6	180	218	162	1	1	2	
Additional IC No.1	Hosur	Entry	7,700	539	535	4	246	293	227	1	1	2	
	Tumkur	Exit	6,468	452	449	3	207	245	182	1	2	3	
	Tumkur	Entry	6,731	471	467	4	215	256	198	1	1	2	
	Hosur	Exit	10,094	706	701	5	322	384	285	1	2	3	
Doddaballapur	Hosur	Entry	5,690	398	395	3	182	216	167	1	1	2	
	Tumkur	Exit	8,429	590	586	4	270	320	238	1	2	3	
	Tumkur	Entry	4,559	319	315	4	145	174	135	1	1	2	
	Hosur	Exit	4,548	319	316	3	145	174	129	1	1	2	
Bellary	Hosur	Entry	4,079	286	260	26	120	166	129	1	1	2	
	Tumkur	Exit	4,134	289	264	25	121	168	125	1	1	2	
	Tumkur	Entry	12,028	842	825	17	380	463	358	1	2	3	
	Hosur	Exit	9,657	676	664	12	305	371	275	1	2	3	
Hennur	Hosur	Entry	9,336	653	647	6	298	355	275	1	2	3	
	Tumkur	Exit	8,172	572	569	3	262	310	231	1	2	3	
	Tumkur	Entry	4,239	297	296	1	136	161	124	1	1	2	
	Hosur	Exit	4,403	308	306	2	141	167	124	1	1	2	
Additional IC No2	Hosur	Entry	5,537	388	387	1	178	210	162	1	1	2	
	Tumkur	Exit	4,379	306	305	1	140	166	123	1	1	2	
	Tumkur	Entry	6,657	466	464	2	213	253	195	1	1	2	
	Hosur	Exit	6,341	444	442	2	203	241	179	1	1	2	
Old Madras Road	Hosur	Entry	2,903	203	203	0	93	110	85	1	1	2	
	Tumkur	Exit	3,498	245	245	0	113	132	98	1	1	2	
	Tumkur	Entry	9,018	631	624	7	287	344	266	1	2	3	
	Hosur	Exit	8,235	576	568	8	261	315	234	1	2	3	
Whitefield	Hosur	Entry	6,083	426	422	4	194	232	179	1	1	2	
	Tumkur	Exit	5,798	406	401	5	184	222	165	1	1	2	
	Tumkur	Entry	10,881	761	751	10	345	416	321	1	2	3	
	Hosur	Exit	14,114	988	974	14	448	540	401	1	2	3	
Additional IC No3	Hosur	Entry	10,117	708	700	8	322	386	299	1	2	3	
	Tumkur	Exit	9,422	659	651	8	299	360	267	1	2	3	
	Tumkur	Entry	9,741	682	678	4	312	370	286	1	2	3	
	Hosur	Exit	7,459	522	519	3	239	283	211	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	6,428	450	445	5	205	245	190	1	1	2	
	Tumkur	Exit	5,647	395	391	4	180	215	160	1	1	2	
	Tumkur	Entry	11,563	809	803	6	369	440	340	1	2	3	
	Hosur	Exit	5,081	355	351	4	161	194	144	1	1	2	
Sarjapur	Hosur	Entry	11,700	819	792	27	364	455	352	1	2	3	
	Tumkur	Exit	3,615	253	250	3	115	138	103	1	1	2	
	Tumkur	Entry	1,972	138	136	2	63	75	58	1	1	2	
	Hosur	Exit	11,061	775	747	28	344	431	321	1	2	3	
Hosur	Tumkur	Entry	39,626	2,774	2,746	28	1,263	1,511	1,168	2	4	6	
	Nice Rd	Exit	35,082	2,455	2,427	28	1,116	1,339	995	1	4	5	

Source: JICA Experts

Table 2.3.11 Year 2040, Case 3 (ETC: 50%, T&G: 34%, Manual: 16%)

IC	Toward	Entry /Exit	Daily Traffic Volume	Peak Hours Traffic Volume (7%)			No. of Vehicles with ETC	No. of Vehicles with Manual and T&G	Modified No. of Vehicles with Considering T&G on Mix Lanes	Required No. of ETC Lane	Required No. of Manual, T&G Lane	Total No. of required lane	Remark
			Total	Total	Regular -sized	Large-sized							
Tumkur	Hosur	Entry	42,302	2,961	2,917	44	1,459	1,503	1,162	2	4	6	
	Nice Rd	Exit	52,825	3,698	3,651	47	1,826	1,873	1,392	2	5	7	
Hessaraghatta	Hosur	Entry	13,339	934	927	7	464	471	364	1	2	3	
	Tumkur	Exit	5,677	398	392	6	196	202	150	1	1	2	
Additional IC No.1	Hosur	Entry	7,700	539	535	4	268	272	210	1	1	2	
	Tumkur	Exit	6,468	452	449	3	225	228	169	1	1	2	
	Tumkur	Entry	6,731	471	467	4	234	238	184	1	1	2	
	Hosur	Exit	10,094	706	701	5	351	356	264	1	2	3	
Doddaballapur	Hosur	Entry	5,690	398	395	3	198	201	155	1	1	2	
	Tumkur	Exit	8,429	590	586	4	293	297	221	1	2	3	
	Tumkur	Entry	4,559	319	315	4	158	162	125	1	1	2	
	Hosur	Exit	4,548	319	316	3	158	161	120	1	1	2	
Bellary	Hosur	Entry	4,079	286	260	26	130	156	121	1	1	2	
	Tumkur	Exit	4,134	289	264	25	132	157	117	1	1	2	
	Tumkur	Entry	12,028	842	825	17	413	430	332	1	2	3	
	Hosur	Exit	9,657	676	664	12	332	344	256	1	2	3	
Hennur	Hosur	Entry	9,336	653	647	6	324	330	255	1	2	3	
	Tumkur	Exit	8,172	572	569	3	285	288	214	1	2	3	
	Tumkur	Entry	4,239	297	296	1	148	149	115	1	1	2	
	Hosur	Exit	4,403	308	306	2	153	155	115	1	1	2	
Additional IC No2	Hosur	Entry	5,537	388	387	1	194	195	150	1	1	2	
	Tumkur	Exit	4,379	306	305	1	153	154	114	1	1	2	
	Tumkur	Entry	6,657	466	464	2	232	234	181	1	1	2	
	Hosur	Exit	6,341	444	442	2	221	223	166	1	1	2	
Old Madras Road	Hosur	Entry	2,903	203	203	0	102	102	78	1	1	2	
	Tumkur	Exit	3,498	245	245	0	123	123	91	1	1	2	
	Tumkur	Entry	9,018	631	624	7	312	319	247	1	2	3	
	Hosur	Exit	8,235	576	568	8	284	292	217	1	2	3	
Whitefield	Hosur	Entry	6,083	426	422	4	211	215	166	1	1	2	
	Tumkur	Exit	5,798	406	401	5	201	206	153	1	1	2	
	Tumkur	Entry	10,881	761	751	10	376	386	298	1	2	3	
	Hosur	Exit	14,114	988	974	14	487	501	372	1	2	3	
Additional IC No3	Hosur	Entry	10,117	708	700	8	350	358	277	1	2	3	
	Tumkur	Exit	9,422	659	651	8	326	334	248	1	2	3	
	Tumkur	Entry	9,741	682	678	4	339	343	265	1	2	3	
	Hosur	Exit	7,459	522	519	3	260	263	195	1	2	3	
Hoskote-Anekal Rd	Hosur	Entry	6,428	450	445	5	223	228	176	1	1	2	
	Tumkur	Exit	5,647	395	391	4	196	200	148	1	1	2	
	Tumkur	Entry	11,563	809	803	6	402	408	315	1	2	3	
	Hosur	Exit	5,081	355	351	4	176	180	133	1	1	2	
Sarjapur	Hosur	Entry	11,700	819	792	27	396	423	327	1	2	3	
	Tumkur	Exit	3,615	253	250	3	125	128	95	1	1	2	
	Tumkur	Entry	1,972	138	136	2	68	70	54	1	1	2	
	Hosur	Exit	11,061	775	747	28	374	402	298	1	2	3	
Hosur	Tumkur	Entry	39,626	2,774	2,746	28	1,373	1,401	1,083	2	4	6	
	Nice Rd	Exit	35,082	2,455	2,427	28	1,214	1,242	923	2	4	6	

Source: JICA Experts

Table 2.3.12 Required Number of Lanes in 2022 and 2040

IC +A2:L43	Toward	Entry /Exit	Year of 2022			Year of 2030			Year of 2040			Difference (2040-2022)		
			Case-1	Case-2	Case-3	Case-1	Case-2	Case-3	Case-1	Case-2	Case-3	Case-1	Case-2	Case-3
Tumkur	Hosur	Entry	5	5	5	6	6	6	6	6	6	1	1	1
	Nice Rd	Exit	4	4	4	6	6	5	8	7	7	4	3	3
Hessaraghatta	Hosur	Entry	2	2	2	2	2	2	3	3	3	1	1	1
	Tumkur	Exit	2	2	2	2	2	2	3	2	2	1	0	0
Additional IC No.1	Hosur	Entry	3	3	3	3	3	3	3	2	2	0	-1	-1
	Tumkur	Exit	3	3	3	3	3	3	3	3	2	0	0	-1
	Tumkur	Entry	2	2	2	3	2	3	3	2	2	1	0	0
	Hosur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
Doddaballapur	Hosur	Entry	2	2	2	3	3	2	2	2	2	0	0	0
	Tumkur	Exit	3	2	2	3	3	3	3	3	3	0	1	1
	Tumkur	Entry	2	2	2	3	2	2	2	2	2	0	0	0
	Hosur	Exit	3	3	3	3	3	3	2	2	2	-1	-1	-1
Bellary	Hosur	Entry	2	2	2	3	3	3	2	2	2	0	0	0
	Tumkur	Exit	3	3	3	3	3	3	2	2	2	-1	-1	-1
	Tumkur	Entry	2	2	2	3	3	3	3	3	3	1	1	1
	Hosur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
Hennur	Hosur	Entry	3	3	3	3	2	2	3	3	3	0	0	0
	Tumkur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
	Tumkur	Entry	2	2	2	2	2	2	2	2	2	0	0	0
	Hosur	Exit	2	2	2	2	2	2	2	2	2	0	0	0
Additional IC No2	Hosur	Entry	2	2	2	2	2	2	2	2	2	0	0	0
	Tumkur	Exit	2	2	2	2	2	2	2	2	2	0	0	0
	Tumkur	Entry	2	2	2	3	3	3	2	2	2	0	0	0
	Hosur	Exit	3	3	3	3	3	3	3	2	2	0	-1	-1
Old Madras Road	Hosur	Entry	2	2	2	2	2	2	2	2	2	0	0	0
	Tumkur	Exit	2	2	2	2	2	2	2	2	2	0	0	0
	Tumkur	Entry	3	3	3	3	3	3	3	3	3	0	0	0
	Hosur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
Whitefield	Hosur	Entry	3	3	3	3	3	3	2	2	2	-1	-1	-1
	Tumkur	Exit	3	3	3	3	3	3	3	2	2	0	-1	-1
	Tumkur	Entry	3	2	2	3	2	2	3	3	3	0	1	1
	Hosur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
Additional IC No3	Hosur	Entry	3	3	3	2	2	2	3	3	3	0	0	0
	Tumkur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
	Tumkur	Entry	2	2	2	2	2	2	3	3	3	1	1	1
	Hosur	Exit	2	2	2	3	3	3	3	3	3	1	1	1
Hoskote-Anekal Rd	Hosur	Entry	2	2	2	3	3	3	2	2	2	0	0	0
	Tumkur	Exit	3	3	3	3	3	3	3	2	2	0	-1	-1
	Tumkur	Entry	3	3	3	3	3	3	3	3	3	0	0	0
	Hosur	Exit	2	2	2	3	3	3	2	2	2	0	0	0
Sarjapur	Hosur	Entry	3	3	3	3	3	3	3	3	3	0	0	0
	Tumkur	Exit	2	2	2	2	2	2	2	2	2	0	0	0
	Tumkur	Entry	2	2	2	3	3	3	2	2	2	0	0	0
	Hosur	Exit	3	3	3	3	3	3	3	3	3	0	0	0
Hosur	Tumkur	Entry	5	5	5	5	5	5	5	6	6	0	1	1
	Nice Rd	Exit	6	6	6	6	5	5	6	5	6	0	-1	0

Source: JICA Experts

Yellow hatching means the changing number of toll lanes for each case in the same year. Blue hatching of Tumkur JCT means the highest number of toll lanes across all JCTs of all years. This number can be avoided by increasing ETC usage ratio such as Case 2 and Case 3.

In any case, both ends, which are Tumkur and Hosur toll barrier, tend to require more number of lanes. In particular, Tumkur must construct seven lanes for both directions in Cases 2 or 3 but not for Case 1. Other junctions located between ends need three lanes. In addition, it was found that bigger traffic volume in additional junctions such as the additional junction No. 3 will use more numbers than many other junctions.

The key factor that corresponds to estimated traffic volume is the increase in usage ratio of ETC.

(2) Conclusion

The JICA Experts recommended the following number of toll lanes for each JCT as minimum.

Table 2.3.13 Number of Toll Lanes for Each JCT

Tumkur	Hosur	Entry	7
	Nice Rd	Exit	7
Hessaraghatta	Hosur	Entry	3
	Tumkur	Exit	3
Additional IC No.1	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Doddaballapur	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Bellary	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Hennur	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Additional IC No2	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Old Madras Road	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Whitefield	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Additional IC No3	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Hoskote-Anekal Rd	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Sarjapur	Hosur	Entry	3
	Tumkur	Exit	3
	Tumkur	Entry	3
	Hosur	Exit	3
Hosur	Tumkur	Entry	7
	Nice Rd	Exit	7

Source: JICA Experts

2.4 Rest Area

(1) Comments and Suggestions on DPR

There is no description of rest area on the DPR.

The total length of ring road, which is composed of BPRR and NICE Road, will be 106 km of full access controlled highway. If some freight trucks drive from Mysore Road to Old Madras Road, the driver has to drive about half of the entire stretch without taking a rest. In order to consider the driver's mental fatigue, call of nature, and refueling petroleum, having a rest area along the BPRR can improve driver's convenience and safety. Therefore, the JICA Experts recommended to construct a rest area somewhere along the BPRR.

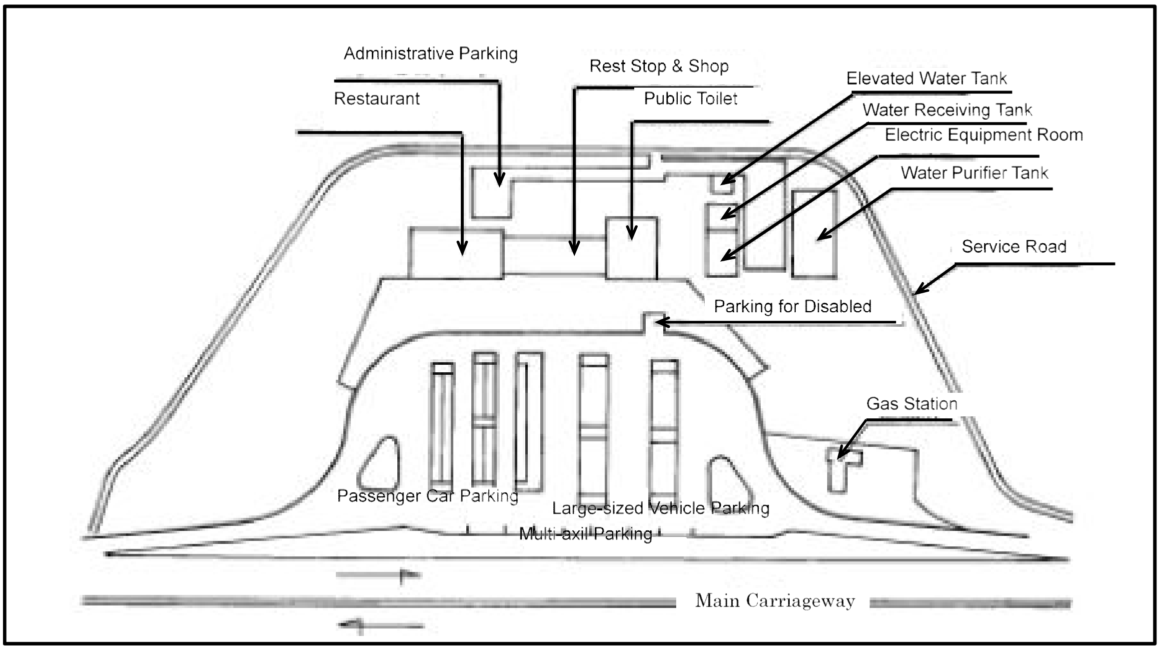
Minimum requirement of rest area are shown below.

- Parking lots (passenger car, truck, multi-axial vehicle)
- Toilet
- Small shop

In addition to the above, many facilities such as those listed below can be prepared depending on users' requirements within land limitation.

- Restaurant
- Petroleum stand
- Repair shop
- Garden

Rest areas can produce some revenue by charging rent for tenants of the restaurant and the shop. If many farmers are near the rest area, a market can be opened for them in some extra space.



Source: NEXCO East Design Standard

Figure 2.4.1 Typical Layout of Rest Area in Japan

(2) Conclusion

Rest area will be reconsidered after the opening of BPRR, since land acquisition takes a long time to complete. Accordingly, the service road shall be re-aligned along the outer edge of the rest area.

CHAPTER 3 STRUCTURAL DESIGN

3.1 General

The JICA Experts reviewed the structural design under the Final Detailed Project Report (R(5) of the Bengaluru Peripheral Ring Road (BPRR) Project.

Based on the review results, the JICA Experts provided the Directorate of Urban Land Transport (DULT), Bengaluru Development Authority (BDA), and STUP with comments and suggestions on several items through discussion papers as listed in Table 3.1.1.

According to the discussion results, the JICA Experts prepared the following reference drawings:

- Typical Cross Sections of Bridge Structure (Appendix 1-A)
- Typical Cross Sections of Box Culvert Structure (Appendix 1-A)
- Structural Layout Plan on Road Profile Drawings (Appendix 1-C)

Table 3.1.1 Items Commented by the JICA Experts

No.	Contents (This Technical Review Report (Draft))			Reference (Discussion Papers)	
1	3.2 Bridge Structure	3.2.1 Planning Criteria and Conditions	3.2.1.1 Geotechnical Conditions	Section 1.1.1.1	DP-S01 (06052015)
2			3.2.1.2 Cross Roads and Railways	Section 1.1.1.2	
3			3.2.1.3 Clearance	Section 1.1.1.3	
4			3.2.1.4 Substructure Locations	Section 1.1.1.4	
5			3.2.1.5 Requirements for Erection Work	Section 1.1.1.5	
6			3.2.1.6 Pier Locations of VOP/POP	Section 1.1.1.1	DP-S02 (13052015)
7			3.2.1.7 Maximum Height of Retaining Wall	Section 1.1.1.2	DP-S02 (13052015)
				Section 1.1.1.1	DP-S03 (18052015)
8			3.2.1.8 Cross Sections (Bridge Width)	Section 1.1.1.2	DP-S03 (18052015)
9		3.2.2 Design Criteria and Conditions	3.2.2.1 Applicable Design Standards	Section 1.1.2.1	DP-S01 (06052015)
10			3.2.2.2 Design Life	Section 1.1.2.2	
11			3.2.2.3 Operational (Importance) Category	Section 1.1.2.3	
12			3.2.2.4 Range of Effective Bridge Temperature	Section 1.1.2.4	
13			3.2.2.5 Design Horizontal Seismic Force	Section 1.1.2.5	
14		3.2.3 Bridge Planning	3.2.3.1 Superstructure Type	Section 1.1.2.1	DP-S02 (13052015)
15			3.2.3.2 Substructure Type	Section 1.1.2.2	
16			3.2.3.3 Foundation Type	Section 1.1.2.3	
17			3.2.3.4 Skew Angle	Section 1.1.2.4	
18			3.2.3.5 Bridge Planning	Section 1.1.2.5	
19			3.2.3.6 Bridge Accessory Planning	Section 1.1.2.6	
20			3.2.3.7 Structural Dimensions	Section 1.1.1.3	DP-S03 (18052015)
21	3.3 Box Culvert Structure	3.3.1 Plan of Box Culvert		Section 1.2.1	
22		3.3.2 Construction Method		Section 1.2.2	
				Section 1.3	DP-C01 (18052015)
				Section 1.4	
23		3.3.3 Thickness of Box Culvert		Section 1.2.3	DP-S03 (18052015)
24		3.3.4 Drainage Pump at Underpass		Section 1.2.4	

Source: JICA Experts

Notes:

- For work efficiency, “Bridge” and “Box Culvert” were categorized by structural type. (Did not follow the categories determined in the Indian Regulations).
- Chainage (KM) has discrepancies across the drawings in the Final DPR R(5) and the chainage on the Road Plan and Profile Drawings was followed in this report.

3.2 Bridge Structure

3.2.1 Planning Criteria and Conditions

3.2.1.1 Geotechnical Conditions

(1) Comments and Suggestions on DPR

Geotechnical conditions at BPRR are uncertain in the Final DPR.

During the kick-off meeting on 28th April, 2015, it was confirmed that geotechnical investigations were not conducted in the DPR stage due to land properties.

Geotechnical investigations are however necessary even in the DPR stage to conduct preliminary structural planning and estimation of work quantities; otherwise, the construction cost may overrun the Project budget in the detailed design (D/D) stage.

The JICA Experts recommended confirming the geotechnical conditions by collecting the existing geotechnical boring logs and laboratory test results at or near BPRR in other projects.

(2) Conclusion

The DULT, BDA, and STUP agreed to conduct geotechnical investigations during the D/D stage.

Based on past experiences, DULT, BDA, and STUP explained that depth of bearing layer is expected to be 2 m to 13 m from the existing ground level in the Bengaluru area.

The DULT, BDA, and STUP provided the past geotechnical investigation report at KM16+100 of the Bangalore - Nelamangala section of NH-4 as shown in Appendix 1-E.

3.2.1.2 Cross Roads and Railways

(1) Comments and Suggestions on DPR

Cross roads and railways are listed in Tables 6-1 to 6-6, Main Report, Final DPR; however, the existing conditions and future plan are not mentioned.

It seems that these are properly mentioned in the drawings of the Final DPR; however, the detailed cross sections and the minutes of meeting with relevant organizations are not included.

Therefore, the JICA Experts explained to conduct the technical review works based on the existing conditions and future plan of cross roads and railways in the drawings of the Final DPR.

Furthermore, the JICA Experts recommended confirming the existing conditions and future plan with relevant organizations and signing by their authorized representatives on the minutes of meeting at the beginning of the D/D stage to avoid re-design works.

(2) Conclusion

It was confirmed that the Final DPR was prepared based on the topographic survey data in 2007 and reflected the future plan at major cross locations on the drawings.

The DULT, BDA, and STUP agreed to confirm the existing conditions and future plan with relevant organizations at the beginning of the D/D stage.

3.2.1.3 Clearance

(1) Comments and Suggestions on DPR

The vertical clearance is determined to be 5.5 m at VOP/VUP and 4.5 m at POP/PUP in the Final DPR; however, the clearance on the main road and service road is not determined.

Furthermore, the vertical clearance at railway crossing locations in consideration of existing and future electrification is also not determined.

The JICA Experts recommended determining the clearance at all locations.

Furthermore, it is necessary to confirm the vertical clearance at railway crossing locations with the railway company.

(2) Conclusion

It was confirmed that the vertical clearance on the main road and service road was planned at 5.5 m in the Final DPR.

As for the vertical clearance at railway crossing locations, it was designated as 6.575 m at the minimum and 8.14 m at the maximum under the Indian Regulations.

The BDA agreed to confirm the required vertical clearance with the railway company soon.

3.2.1.4 Substructure Locations

(1) Comments and Suggestions on DPR

The planning criteria for substructure location are very important in bridge planning; however, it is not clearly determined in the Final DPR.

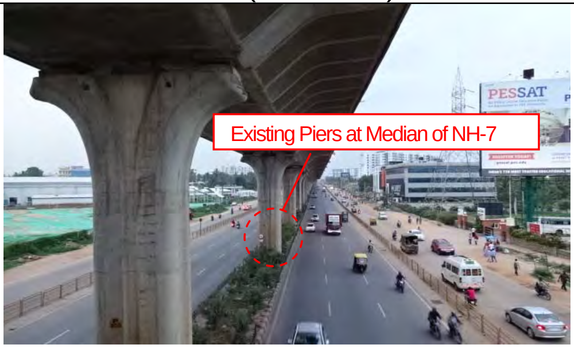
The JICA Experts understand that substructure locations are acceptable at most of the planned bridge locations in case of planning outside the cross roads.

However, in consideration of economy and constructability, the JICA Experts recommended confirming the possible substructure locations on the national highways and railways with the relevant organizations.

NH-4 (KM00+000)

NH-7 (KM18+637)

NH-4 (KM36+233)



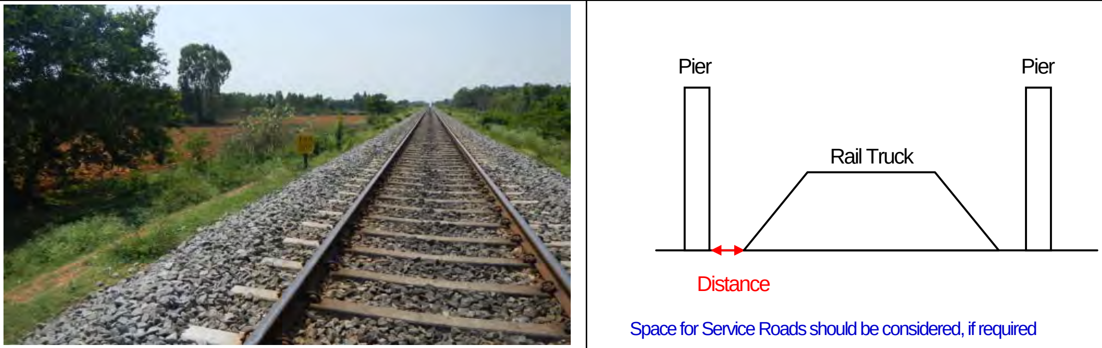
NH-7 (KM65+538)

Source: JICA Experts

Figure 3.2.1 Substructure Locations at National Highways

Tumkur Railway Line (KM04+212) Doddaballapur Railway Line (KM15+158)

Chikkaballapura Railway Line (KM16+061) Chennai Railway Line (KM43+125)



Hosur Railway Line (KM59+198) Image of Possible Pier Location

Source: JICA Experts

Figure 3.2.2 Substructure Locations at Railways

(2) Conclusion

1) At National Highways

The followings were confirmed as possible substructure locations at national highways:

- KM00+000 (NH-4), KM65+538 (NH-7): Allowed at medians
- KM18+637 (NH-7): Planned as an underpass.
- KM36+233 (NH-4): Not allowed on NH-4

2) At Railways

It was confirmed that the substructure locations are not allowed inside the railway right of way (ROW) in consideration of future railway widening.

The ROW width at each railway location is as follows:

- KM04+212 (Tumkur), KM59+198 (Hosur): 60 m
- KM15+158 (Doddaballapur), KM16+061 (Chikkaballapur): 60m
- KM43+125 (Chennai): 70 m

3.2.1.5 Requirements for Erection Work (Superstructure)

(1) Comments and Suggestions on DPR

The requirements for erection work (superstructure) are not determined in the Final DPR.

Based on the site surveys by the JICA Experts, the requirements at the state highways and lower class roads are not difficult.

However, bridge planning seriously affects the national highways and railways; therefore, the JICA Experts recommended confirming the following requirements with relevant organizations:

- Traffic Regulation on Cross Roads (Detour/Lane Numbers, Time/Duration)
- Time/Duration of Erection Works on Cross Roads and Railways
- Erection Method on Cross Roads and Railways during Construction Works

 CIP with Temporary Support/Form	 Crane Erection w/ Temporary Placing
 Span by Span	 Large-block Erection

Source: Japan Prestressed Concrete Contractors Association, Japan Bridge Association Inc.

Figure 3.2.3 Erection Methods

(2) Conclusion

1) At National Highways

It was confirmed that the cast-in-place (CIP) with temporary support/form (with detour) erection method was allowed in past projects in the Bengaluru area.

2) At Railways

It was confirmed that the CIP with temporary support/form (with reduced speed operation) erection method was allowed in past projects in the Bengaluru area.

In addition, it was also confirmed that temporary support beside the railway track is allowed under the Indian Standards in case of ensuring 3.5 m between the temporary support and center of track.

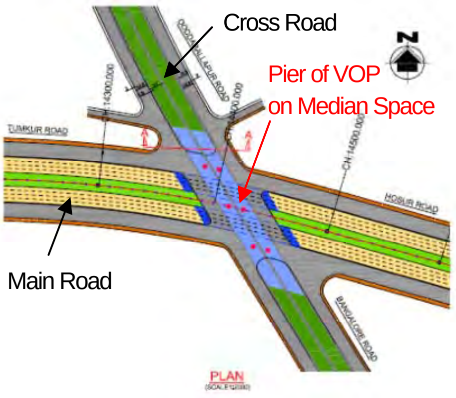
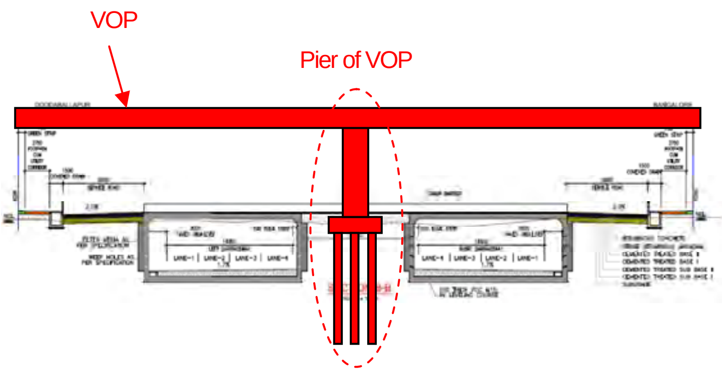
Therefore, the JICA Experts agreed to apply the CIP with temporary support/form (with reduced speed operation) erection method at low embankment locations of railway.

3.2.1.6 Pier Locations of VOP/POP

(1) Comments and Suggestions on DPR

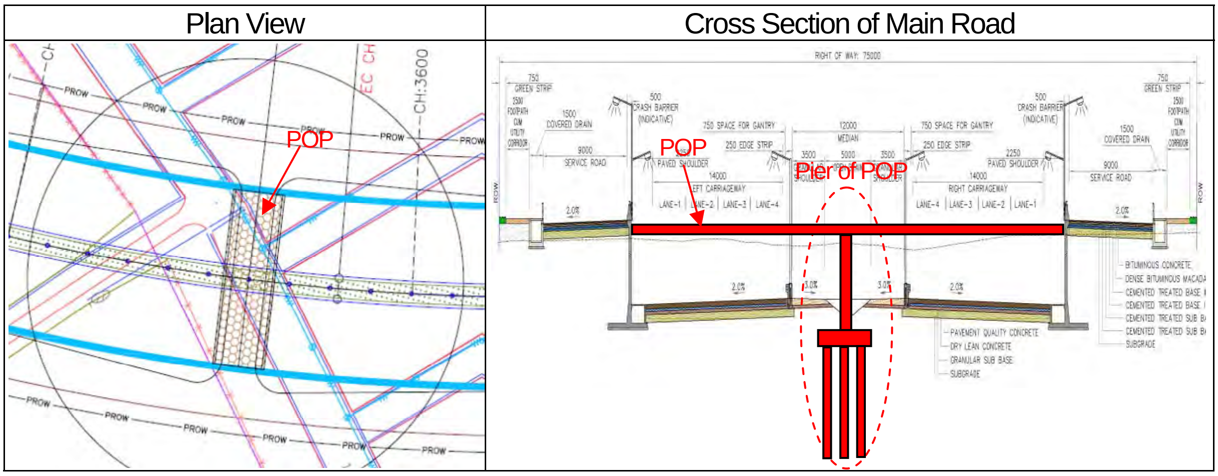
The median of BPRR (w=12 m) is planned to be utilized for bus rapid transit (BRT) or metro in the future.However, piers of VOP are planned on the median space in the Final DPR.

Moreover, it seems that piers of POP are also planned on the median space.

Plan View	Cross Section of Main Road
	

Source: Final DPR

Figure 3.2.4 Example: Pier on Median Space (VOP: KM14+400)


Plan View

Cross Section of Main Road

Source: Final DPR

Figure 3.2.5 Example: Pier on Median Space (POP: KM03+600)

The JICA Experts recommend deciding the possibility of pier planning at the median space of the main road in consideration of the following aspects:

<u>VOP</u>

In case of planning piers on the median space, construction cost may be made reasonable by applying shorter span length; however, BRT or metro should be arranged above VOP in the future.

Moreover, in case of planning piers on the median space, practical construction methods and procedures including neighboring construction between the pier and underpass of the main road should be carefully studied.

<u>POP</u>

In case of planning piers on the median space, construction cost may be made reasonable by applying typical girders with low girder depth (i.e., PC-I Girder, PC Void Slab); however, BRT or metro should be arranged above VOP or beside the piers on the ground in the future.

(2) Conclusion

It was confirmed that the existing metro lines were constructed using high-elevated structures.

Moreover, the maximum gradient of the future metro line on the median of BPRR will be smaller than that of BPRR and it is difficult to follow the same profile of BPRR at the underpass sections.

Therefore, the future metro line will be planned using elevated structures at least in the underpass sections of BPRR.

Accordingly, it was confirmed that the piers of VOP/POP at the median of BPRR will not affect the planning of the future metro line.

3.2.1.7 Maximum Height of Retaining Wall

(1) Comments and Suggestions on DPR

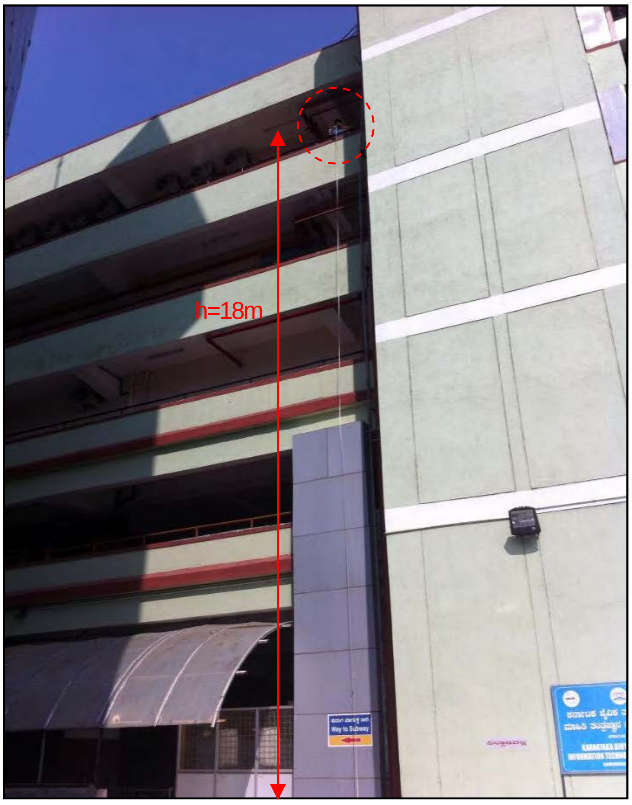
Mechanical stabilized earth (MSE) wall is planned in the embankment slope sections of the mainline and service road including the following high embankment locations:

- KM43+100 (ROB at Chennai Railway Line): 16 m on the center line
- KM59+200 (ROB at Hosur Railway Line): 15 m on the center line

It is noted that the above height is scaled on the centerline and the actual maximum height of the MSE wall at both edges of the road might be <u>further increased to 18m-20m height.</u>

Figure 3.2.6 shows 18 m height at the DULT office.

The 18 m height will reach to the 4th floor (actually 5 storeys high) of the DULT office.



Source: JICA Experts

Figure 3.2.6 Example: Height of 18 m at the DULT Office

Actually, there are some cases of tall MSE wall construction around the world as listed below; however, certain settlement was observed even using high-performance filling material (strictly selected granular or soil) and inextensible reinforcement (steel reinforcement).

Table 3.2.1 List of Tall MSE Walls Around the World

Location	*Max. Height(m)*	*No. of Tiers*	*Year Complete*	*Comments (Supplier)*
Crushing System Expansion, Victor, Colorado USA	32	1	2001	Mine wall supporting bridge crane. (Hilfiker)
Route 288, Richmond, Virginia USA	24	2	2002	High friction (gravel) backfill. (RECo)
Springfield Interchange, Virginia USA	20	1	2002	High friction (gravel) backfill. (RECo)
Hartsfield Airport Runway, Georgia USA	20	1	2003	Maximum total settlement of 600 mm during construction. (RECo)

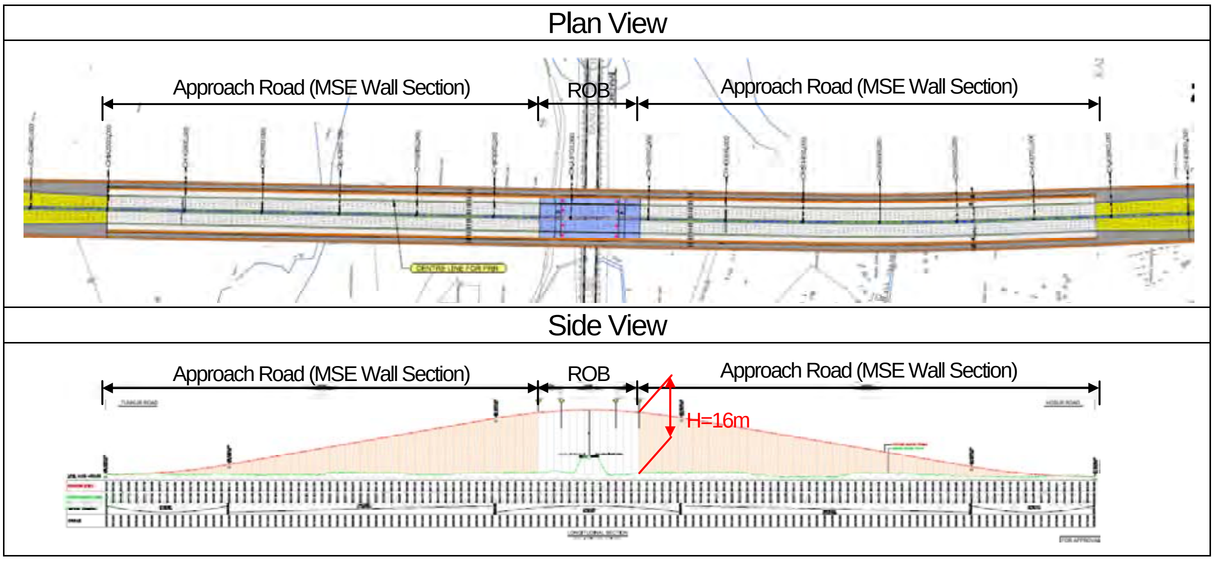
Source: www.reinforcedearth.com

The following photo in Figure 3.2.7 shows the actual deformation (settlement) of the 6 m high MSE wall in the Bengaluru area.

Source: JICA Experts

Figure 3.2.7 Example: Deformation at MSE Wall (NH-7 in Bengaluru)

This exceeds an experimental standard height (maximum 12 m in general); therefore, structural measures or optional structure type are necessary to be considered.



Source: Final DPR

Figure 3.2.8 Height of MSE Wall at Chennai Railway Line (KM 43+100)

The JICA Experts recommend applying the standard height of MSE wall by setting back the abutment locations (extending the ROB length) to assure structural aspects.

In case of applying tall MSE wall, the following technical measures are necessary to assure structural aspects during the design life:

- Considering as critical structure during design life,
- Conducting detailed geotechnical investigations at the planned locations,
- Conducting stability/deformation analyses by finite element method (FEM) under static/seismic conditions,
- Conducting consolidation analysis in detail,
- Using specific reinforcement such as metallic/geosynthetic reinforcement, and
- Conducting deformation and settlement monitoring during construction and operation periods.

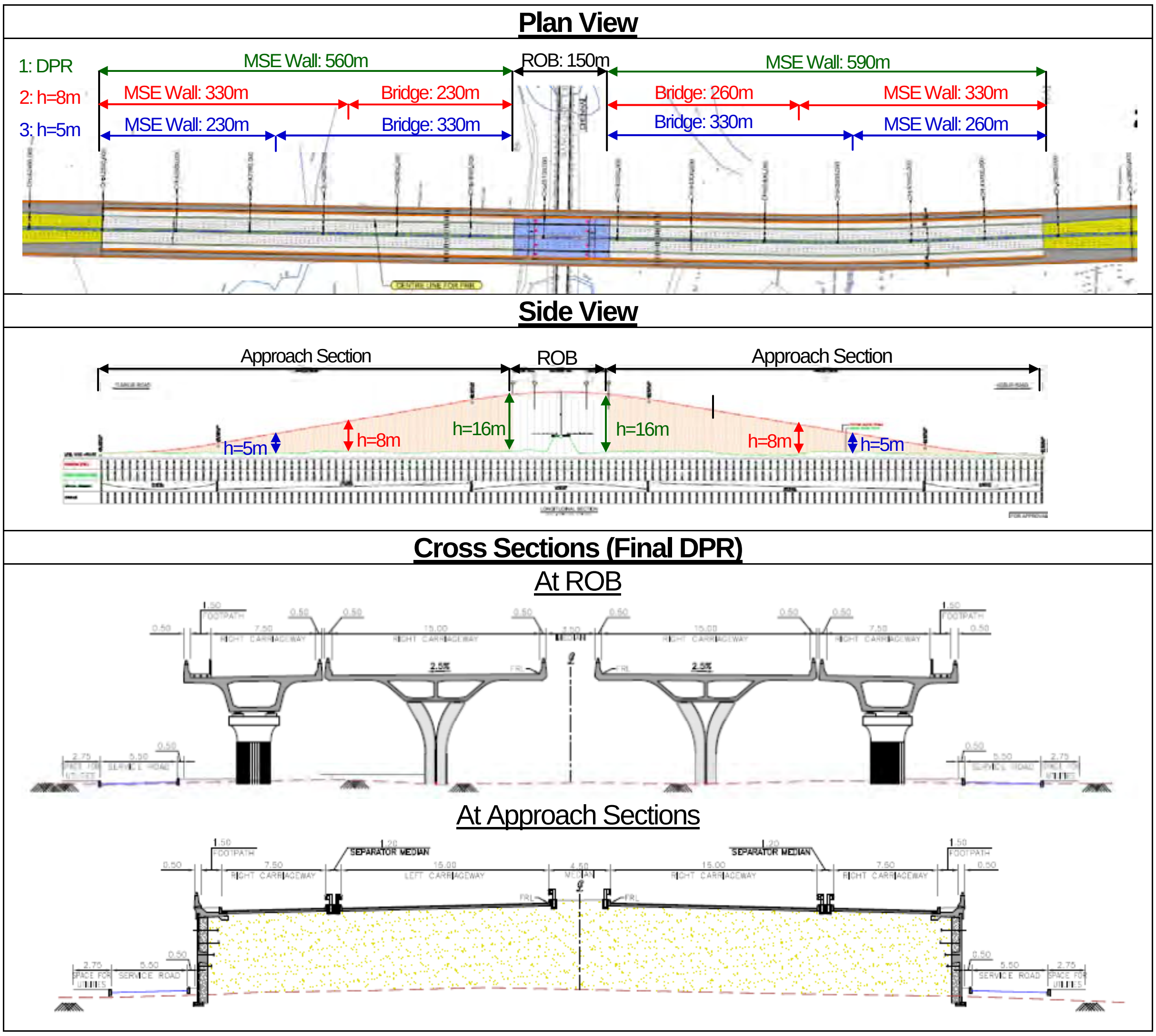
Furthermore, in case of applying high MSE wall, environmental and social conditions are significantly changed; therefore, it is necessary to get consent from the neighborhood.

However, this revision will have an impact of cost increase; therefore, it is necessary to have an agreement among DULT, BDA, STUP, and the JICA Experts regarding the revised abutment locations.

At present, the extent of geotechnical conditions is uncertain due to lack of survey data; therefore, it is necessary to be on the conservative side when deciding the abutment locations to avoid cost overrun during the implementation stage.

The JICA Experts conducted a preliminary cost evaluation at the Chennai Railway Line (KM43+100) in case the abutment height is reduced to 5 m and 8 m.

For avoiding cost overrun during the implementation stage, the JICA Experts recommend applying an abutment height of 5 m at 2 ROBs in this technical review stage.



Source: Final DPR

Figure 3.2.9 Abutment Locations at Chennai Railway Line (KM43+100)

Table 3.2.2 Preliminary Cost Evaluation (Approach Sections at Chennai Railway Line)

Item	1: DPR	2: h=8 m	3: h=5 m
Features of Approach Section	Approach Section L=1,150 m BP Side MSE Wall: 560 m Bridge: 0 m EP Side MSE Wall: 590 m Bridge: 0 m	Approach Section L=1,150 m BP Side MSE Wall: 330 m Bridge (PC-I): 230 m EP Side MSE Wall: 330 m Bridge (PC-I): 260 m	Approach Section L=1,150 m BP Side MSE Wall: 230 m Bridge (PC-I): 330 m EP Side MSE Wall: 260 m Bridge (PC-I): 330 m
Preliminary Cost Evaluation (Million Rs)			
1.PC-I Girder 1)	0	2,332	3,142
2.MSE Wall 2)	804	246	117
3.Soft Soil Treatment 3)	214	123	91
Total	**1,018**	**2,701**	**3,350**

Source: JICA Experts

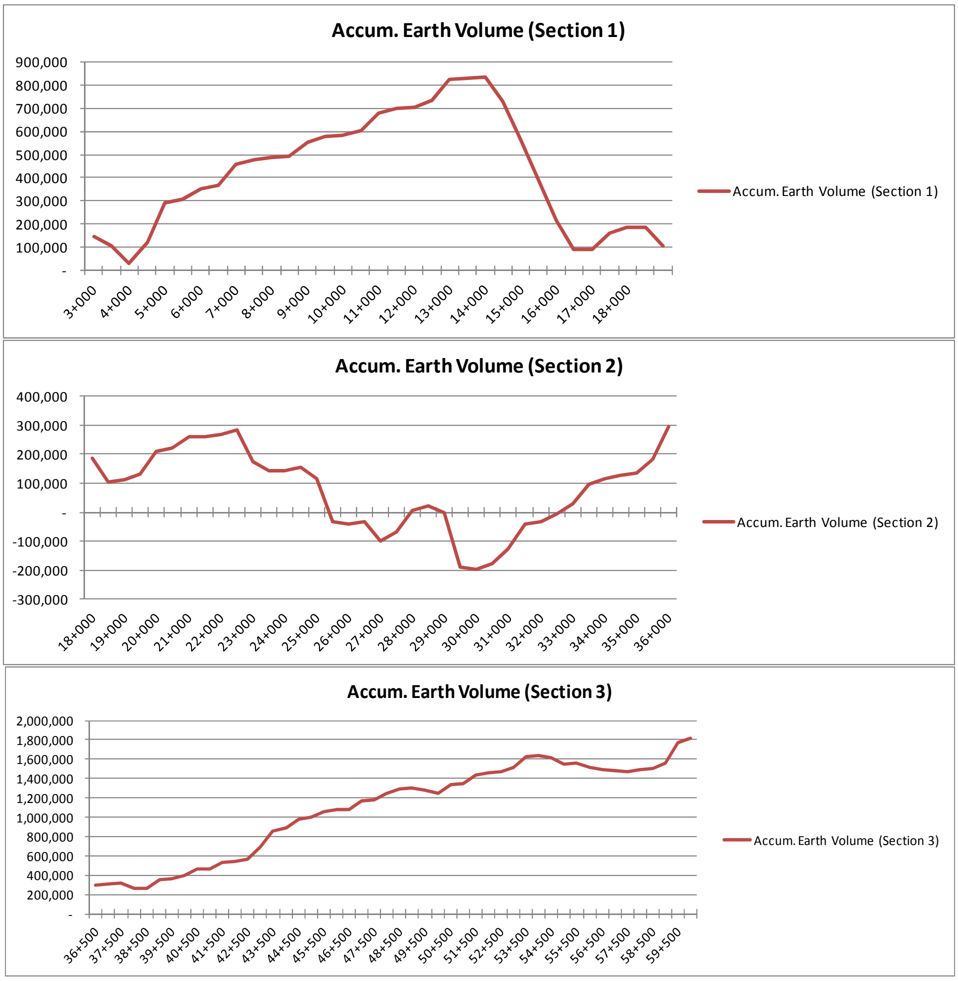
1) *Bridge Width: Main Road: w=2@17.75 m, Service Road: w=2@12 m, Unit Rate: Rs80,000/m^2*
2) *Using the Unit Rate in the Final DPR*
3) *Not estimated in DPR, Assume Soil Replacement (D=5 m), Unit Rate: Rs500/m^3*

Notes: Above costs are estimations for approach section; therefore, the costs of ROB are excluded. Also, from the “earth balance (cut and fill)” point of view, the volume of the earthfill in Section 3 shall be reduced.

Figure 3.2.10 below indicates the earth balance of each section calculated by the JICA Experts.

Huge amount of borrowed earthfill shall be required for Section 3.

On the other hand, the earth volume in Section 1 and Section 2 is well balanced.



Source: JICA Experts

Figure 3.2.10 Earth Balance of Each Section

(2) Conclusion

It was confirmed that geotechnical survey and structural analysis were not conducted in the DPR stage.

The DULT, BDA, and STUP agreed to set back the abutment location by a height of 5 m at 2 ROBs (Chennai and Hosur Lines) to reduce the height of MSE wall at swamp areas.

However, the DULT, BDA, and STUP suggested to revise the unit price of approach bridge (PC-I Girder) from Rs80,000/m^2 to Rs50,000/m^2 in consideration of construction prices in India.

The JICA Experts agreed and re-estimated the preliminary costs for approach section as follows:

Table 3.2.3 Revised Preliminary Cost (Million Rs)

Item	1: DPR	2: h=8 m	3: h=5 m (Agreed)
1.PC-I Girder	0	1,286	1,733
2.MSE Wall	804	246	117
3.Soft Soil Treatment	214	123	91
Total	1,018	1,655	1,941

Bridge Width: Main Road: w=2@17.75 m, Service Road: w=2@8.5 m, Unit Price: Rs50,000/m^2
Red: Revised

Notes

Above costs are estimations for approach section; therefore, the costs of ROB are excluded.

These are temporary solutions under this JICA Technical Review stage to ensure that the project budget is on a safe side.

Final cost will be decided in the D/D stage based on geotechnical survey and structural analysis results.

3.2.1.8 Cross Sections (Bridge Width)

(1) Comments and Suggestions on DPR

Bridge plan of service road at flyover sections is different by location in the Final DPR.

The JICA Experts clarify the bridge plan of the service road at flyover sections as follows:

- Existence or non-existence of flyover at intersections on service road
- Bridge width of flyover on service road

The cross section of service road (road section) is shown in Figure 3.2.11 below.

Source: Final DPR

Figure 3.2.11 Cross Section of Service Road (Road Section)

(2) Conclusion

The JICA Experts confirmed the bridge width of flyovers on the service road with DULT, BDA, and STUP and it was planned to be 8.5 m (0.5 m + 2@3.75 m + 0.5 m) in the Final DPR.

3.2.2 Design Criteria and Conditions

3.2.2.1 Applicable Design Standards

(1) Comments and Suggestions on DPR

The main design criteria for structural design are described in Section 3, Main Report, Final DPR; however, applicable design standards are not clearly determined.

The JICA Experts understand that a series of the Indian Road Congress (IRC) is the primary design standards; however, additional standards supplementing the IRC may be necessary.

In case of applying additional standards in the Project, the background and basic conditions must be same with IRC to ensure design requirements.
The JICA Experts recommend confirming the following design standards:

- Primary Design Standards
- Supplemental Design Standards (i.e., international design standards)
- Standards for Technical Specifications (construction works)

(2) Conclusion

The following were confirmed among the DULT, BDA, STUP, and the JICA Experts:

- IRC covers all of the necessary items in bridge design.
- Technical specifications are determined in the MORTH standards.

Accordingly, the JICA Experts understood the unnecessity of supplemental standards in the Project.

3.2.2.2 Design Life

(1) Comments and Suggestions on DPR

The main design criteria for structural design are described in Section 3, Main Report, Final DPR; however, design life for bridges is not determined.

The JICA Experts recommend determining the design life of bridges in the Project.

(2) Conclusion

The DULT, BDA, and STUP explained that the design life is determined to be 100 years in IRC.

3.2.2.3 Operational (Importance) Category

(1) Comments and Suggestions on DPR

Existence or non-existence of operational (importance) category in IRC is not described in the Final DPR.

In the American Association of State Highway and Transportation Officials (AASHTO), the operational category of road is determined in consideration of social importance.

Operational category is divided into the following three types:

- Critical Bridges
- Essential Bridges
- Other Bridges

The following points vary across the different categories:

- Adjustment Factor of Design Loads
- Return Period of Design Horizontal Seismic Coefficient

The JICA Experts recommend determining the operational category, if required in IRC.

(2) Conclusion

It was confirmed that the importance factor is classified in Table 8, Clause 219.5.1.1, IRC: 6-2014.

The DULT, BDA, and STUP explained that “Important Bridges” is applicable for the BPRR Project.

3.2.2.4 Range of Effective Bridge Temperature

(1) Comments and Suggestions on DPR

The main design criteria are described in Section 3, Main Report, Final DPR; however, the range of effective bridge temperature in the BPRR Project is not determined.

The JICA Experts recommend determining the maximum and minimum temperatures for applying bridge design in the BPRR Project.

(2) Conclusion

It was confirmed that the maximum and minimum temperatures by area are determined based on Figures 8 to 9, Clause 215.2, IRC: 6-2014.

The maximum and minimum temperatures in the BPRR Project area are as follows:

- Maximum Temperature: 45 degrees C (Celsius)
- Minimum Temperature: 10 degrees C

In accordance with Section 215.2, IRC: 6-2104, the range of effective bridge temperature in the BPRR Project is determined as follows:

- Concrete Bridge: 37.5 degrees C to 17.5 degrees C (Mean Temperature ± 10 degrees C)
- Steel Bridge: 60 degrees C to 0 degree C (Maximum + 15 degrees C to Minimum - 10 degrees C)

3.2.2.5 Design Horizontal Seismic Force

(1) Comments and Suggestions on DPR

The main design criteria are described in Section 3, Main Report, Final DPR; however, the design horizontal seismic coefficient in the BPRR Project is not determined.

The JICA Experts recommend determining the design horizontal seismic coefficient for applying bridge design in the BPRR Project.

(2) Conclusion

It was confirmed that the seismic zone in the BPRR Project is classified as Zone II (lowest class) based on Figure 11, Clause 219.1.2, IRC: 6-2014.

Accordingly, the zone factor (Z) for determining the horizontal seismic design force is 0.10 in the BPRR Project area based on Table 7, Clause 219.2, IRC: 6-2014.

In addition, DULT, BDA, and STUP explained that the zone factors in Table 7, Clause 219.2, IRC: 6-2014 consider a 75-year return period.

Figure 11 and Table 7, Clause 219.1.2, IRC:6-2014 are shown below.

IRC:6-2014

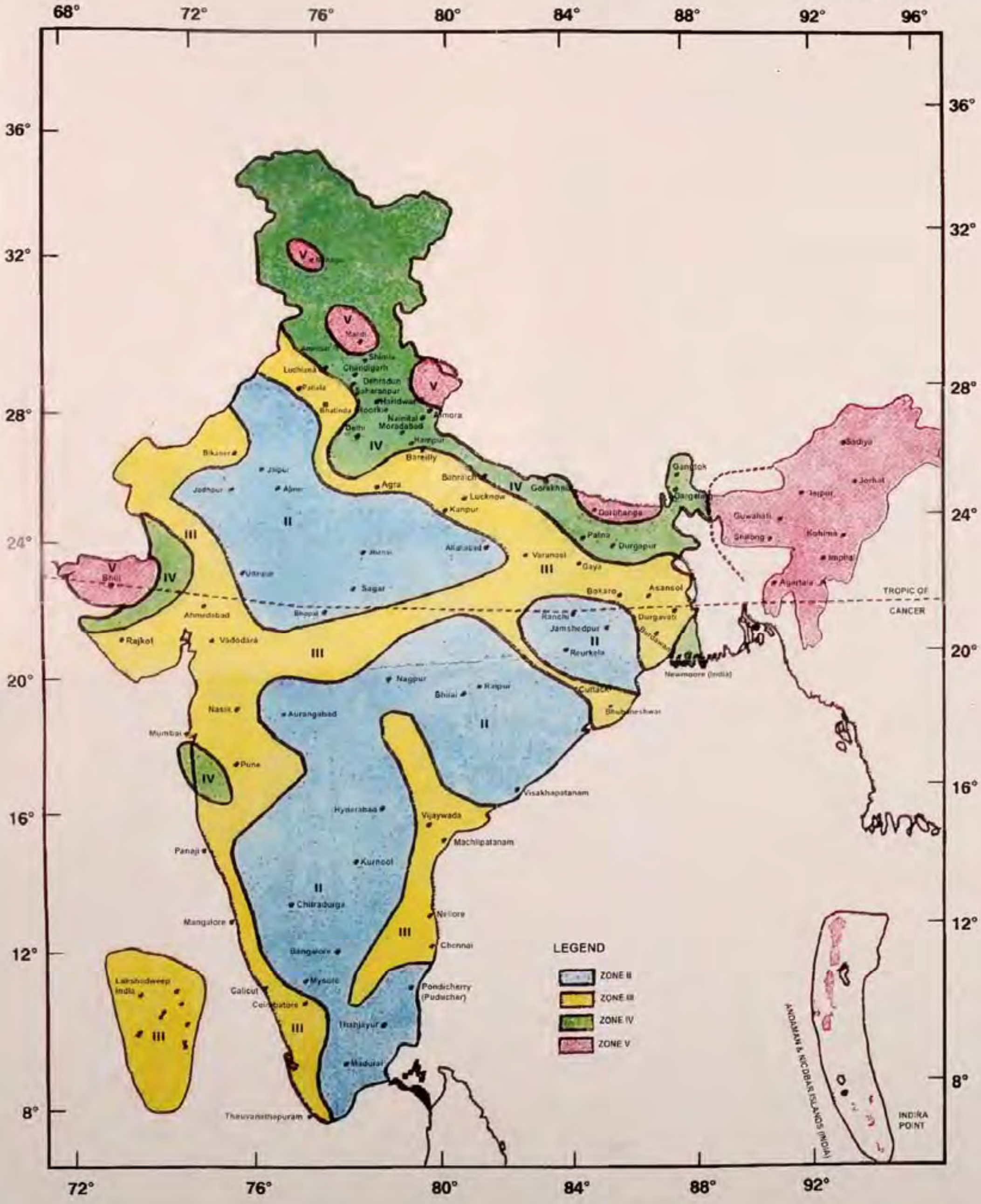
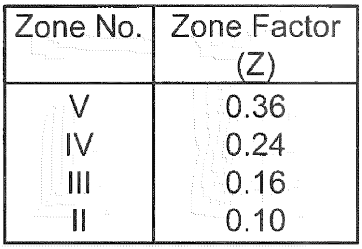


Fig. 11 Seismic Zones of India (IS 1893 (Part I):2002)

NOTE: Bridge locations and towns falling at the boundary line demarcating two zones shall be considered in the higher zone

Table 7 Zone Factor (Z)



Zone No.	Zone Factor (Z)
V	0.36
IV	0.24
III	0.16
II	0.10

Source : IRC:6-2014

3.2.3 Bridge Planning

3.2.3.1 Superstructure Type

(1) Comments and Suggestions on DPR

Span length is planned from 30 m to 70 m in the Final DPR; however, the superstructure type applied is pre-cast PC box girder (constant height type) only.

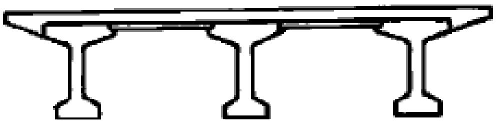
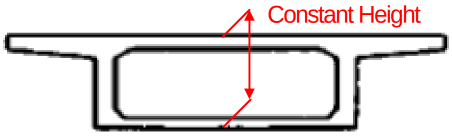
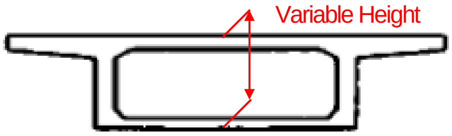
In consideration of economy, reducing girder height, and dead load, several superstructure types with various span lengths and erection methods are necessary.

The JICA Experts conducted site investigations at the existing bridges in the Bengaluru area.

In consideration of the general practices in the Bengaluru area, the JICA Experts recommend applying the following superstructure types in the BPRR area.

However, ROBs and flyovers at national highways should be separately planned.

Table 3.2.4 Superstructure Type (Recommended)

Span Length	Sections (Image)	Erection Method
35 m	PC-I Girder 	Pre-cast (Truck Crane) 
35 m (Locations where there is a need to reduce girder height)	PC Void Slab 	CIP (Staging) 
From 40 m to 60 m	PC Box Girder (Constant Height)  	CIP (Staging) 
Over 60 m	PC Box Girder (Variable Height)  	CIP (Balanced Cantilever) 

Source: Japan Prestressed Concrete Contractors Association

(2) Conclusion

The DULT, BDA, and STUP agreed with the superstructure types proposed by the JICA Experts.

<u>Notes:</u>

- It was confirmed that other superstructure types such as RC-I girder and PC hollow slab (pre-tension) with a span length of 20 m are also common in India.
- The JICA Experts recommended applying PC void slab at VOPs/POPs to reduce girder height; however, the non-existence of critical profile locations on the main road was confirmed, after profile of main carriageway was rectified to secure minimum (vertical) limit clearance under any VOPs/POPs/ROBs. Therefore, it was agreed to apply PC-I girder at VOPs/POPs for ensuring the quality of the construction works.
- It was confirmed that PC box girder with 40 m span length using the CIP method is appropriate instead of the pre-cast method because of the non-existence of long bridges in the BPRR Project.

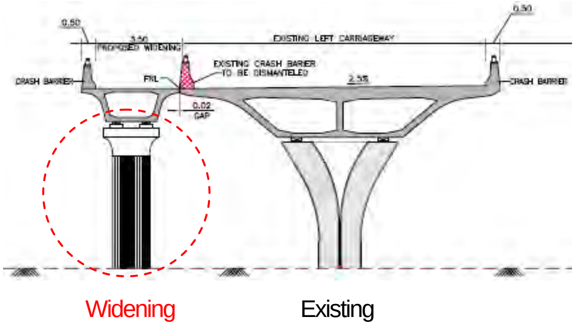
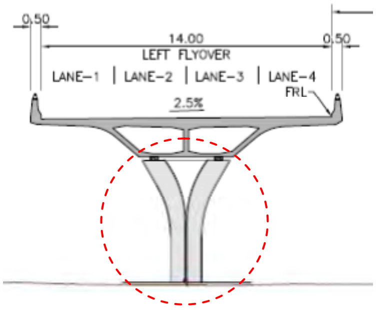
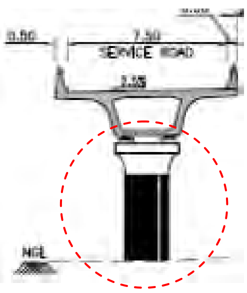
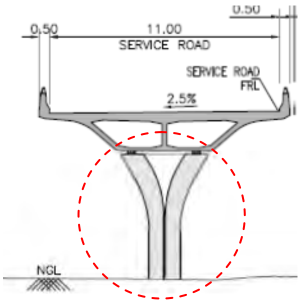
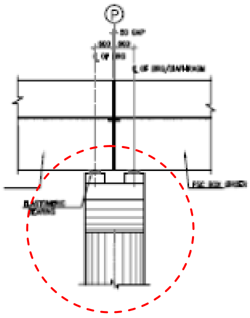
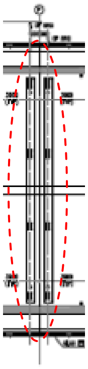
3.2.3.2 Substructure Type

(1) Comments and Suggestions on DPR

Various types of concrete pier are planned by location and road width in the Final DPR.

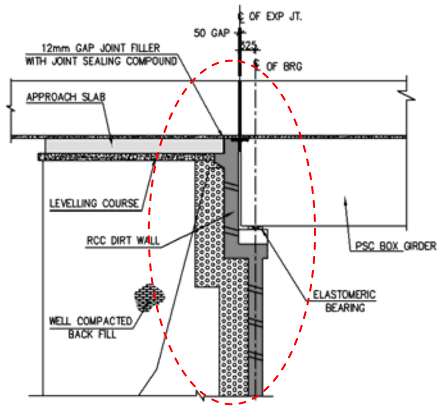
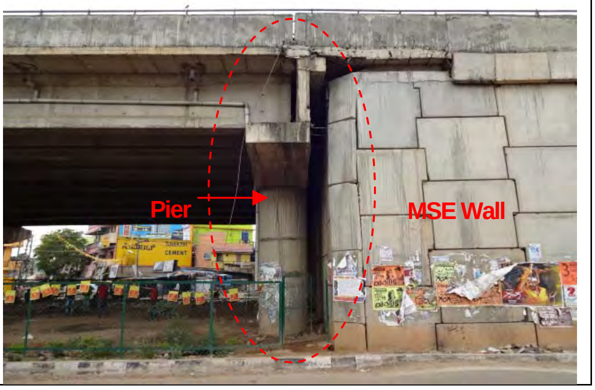
Abutment types are not clearly mentioned in the Final DPR; however, it seems that RC retaining wall abutment (VOP/POP) and mixed abutment (other bridges) are planned.

Table 3.2.5 Image of Piers

<table>
<tr><td colspan="2"><u>Main Road</u></td></tr>
<tr><td>Widening: Round Shape</td><td>Typical: Y Shape</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2"><u>Service Road</u></td></tr>
<tr><td>Road Width≤8.5 m: Round Shape</td><td>Road Width>8.5 m: Y Shape</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2"><u>VOP/POP</u></td></tr>
<tr><td colspan="2">Oval Shape</td></tr>
<tr><td>Side View</td><td>Plan View</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Source: Final DPR

Table 3.2.6 Image of Abutments

RC Retaining Wall Abutment: VOP/POP	Mixed Abutment: Other Bridges
	

Source: Final DPR, JICA Experts

Pier types in the Final DPR are reasonable considering economy and general practices in the Bengaluru area; however, it is necessary to review and analyze the column width of Y-shape piers in consideration of the design loads.

As for the abutment types, the JICA Experts recommend applying inverted T-shape.

In case of applying the RC retaining wall abutment and mixed abutment, the JICA Experts recommend the following solutions:

- Applying RC retaining wall abutment at cut locations (POP and some VOP) only in order to avoid settlement at bridge structures.
- Applying mixed abutment at embankment locations.

(2) Conclusion

The JICA Experts confirmed appropriateness of substructure types in the Final DPR.

The DULT, BDA, and STUP explained that the RC retaining wall abutment will be applied as one of the authorized types in the IRC.

3.2.3.3 Foundation Type

(1) Comments and Suggestions on DPR

Foundation types are not mentioned in the Final DPR.

It may not have been planned in the DPR stage due to lack of geotechnical information.

However, the variation of foundation type and size will largely affect the project cost during the implementation stage; therefore, it is necessary to plan before the JICA appraisal based on the existing geotechnical information at/around the BPRR Project.

In consideration of the geotechnical conditions around the BPRR Project (see Appendix 1-E), the JICA Experts recommend applying the following foundation types in the BPRR Project:

- Cast-in-Place RC Bored Pile (common diameter in the Bengaluru area to be confirmed)
- Spread Foundation (at shallow depth of bearing layer (i.e., 5 m))

However, in case of applying the above foundation types, it is necessary to consider appropriate countermeasures at neighboring construction locations (near existing houses and structures).

(2) Conclusion

It was confirmed that CIP RC bored pile and spread foundations are common types in India.

Notes:

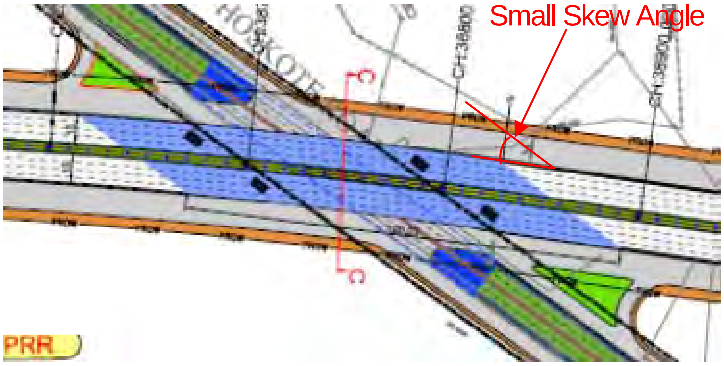
- Possible Diameter of Bored Pile: 1.0 m, 1.2 m, 1.5 m, 2.0 m (Common: 1.0 m and 1.2 m)
- Maximum Pitch between Bored Piles: 3D (for Rock), 2D (for Soil)

3.2.3.4 Skew Angle

(1) Comments and Suggestions on DPR

Some bridges are planned with quite small skew angles in the Final DPR.

A bridge with small skew angle has several technical issues in terms of design and durability.



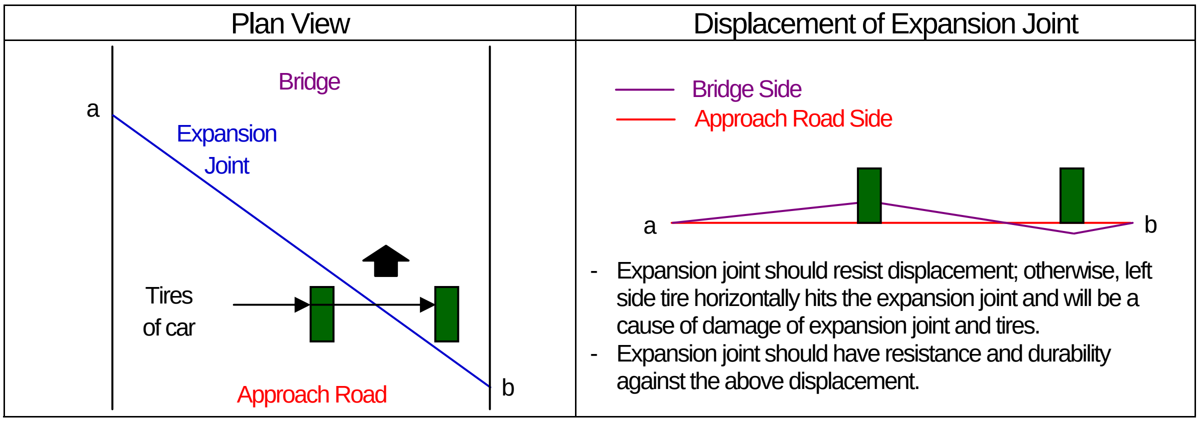
Source: Final DPR

Figure 3.2.12 Example: Small Skew Angle (KM38+700)

The JICA Experts recommend improving the skew angle to 90 degrees (70 degrees at the minimum) to avoid torsional force and unsymmetrical earth pressure at the abutment.

In case of applying small skew angles (less than 70 degrees), the following technical issues are necessary to be solved in the design stage:

- Considering torsional force in structural design.
- Considering unsymmetrical earth pressure in abutment design.
- Applying durable expansion joint to resist displacement along expansion joint.



- Expansion joint should resist displacement; otherwise, left side tire horizontally hits the expansion joint and will be a cause of damage of expansion joint and tires.
- Expansion joint should have resistance and durability against the above displacement.

Source: JICA Experts

Figure 3.2.13 Image: Displacement along Expansion Joint

(2) Conclusion

The DULT, BDA, and STUP agreed to improve bridge skew angles in the D/D stage.

<u>Notes:</u>

- Small bridge skew angle is not common in India (exceptional case only).

It is necessary to avoid extension of bridge length by improving bridge skew angles.

3.2.3.5 Bridge Planning

(1) Comments and Suggestions on DPR

Bridge planning is not clearly mentioned in the Final DPR.

Variation of bridge type and length will have huge effect to the project cost during the implementation stage; therefore, the JICA Experts recommended conducting bridge planning before the JICA appraisal in accordance with Sections 3.2 to 3.2.3.4 of this report.

(2) Conclusion

The DULT, BDA, STUP, and the JICA Experts discussed the bridge plan based on the proposal by the JICA Experts and agreed as shown in Table 3.2.7 in the next page.

The Structural Layout Plan on Road Profile Drawings is shown in Attachment 1-C.

<u>Main Revision Points in the Proposal by the JICA Experts:</u>

- According to the opinion of the DULT, BDA, and STUP, piers on service roads were considered for applying typical girder types as much as possible.
- According to past experiences of DULT, BDA, and STUP, it was assumed that temporary support structures inside the railway ROW with reduced speed operation would be allowed by the railway operator.
- In consideration of high railway embankment, it is difficult to apply temporary support structures inside the railway ROW and three spans of steel box girder using rapid erection method were planned at Chennai and Hosur Railway Lines.

<u>Notes:</u>

- The DULT, BDA, and STUP will discuss with and obtain approvals from the national highway and railway operators regarding clearance, structure type, and erection method.
- Superstructure plan at Chennai and Hosur Railway Lines may be revised to ordinal structure plan like other bridges in BPRR during the D/D stage after verifying technical validity and obtaining approval from the railway operator.
- Other superstructure plan may also be revised during the D/D stage after verifying economical and technical validity in accordance with geotechnical investigations/structural analysis results.

Table 3.2.7 Bridge Plan

No.	Station	Bridge Category	Location	Cross Object	Width1)	Clearance (under BR)		Bridge Length2)	Span Arrange.	Bridge Skew Angle	Superstructure	Erection Method	Substructure		Remarks
						Vertical	Horizontal						Abutment	Pier	
1	KM00+000	Flyover	Main Road	NH-4	4m	5.5m	Existing BR	60m	2@30m	82.8	PC-I	Truck Crane	Mixed	Round	Widening of Existing Bridge at Tumkur Road JCT
2	KM03+560	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Truck Crane	RC Retaining Wall	Oval	Planned Pier on Median of BPRR
3	KM04+212	ROB, Flyover	Main Road, Service Road	Bangalore-Tumkur Railway Line, SH39	8.5m,2@17.75m,8.5m	Rail: 8.14m Road: 5.5m	Rail: 60m Road: 40m	195m	1@60m+3@45m	75.1	PC Box (Constant)	CIP (Staging)	Mixed	Main Road: Y Service Road: Round	Assumed to allow temporary support structure inside railway ROW with reduced speed operation by railway operator
4	KM14+435	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@12m	5.5m	Service Road	120m	4@30m	90.0	PC-I	Track Crane	Mixed	Y	Planned Piers on Median of BPRR Planned Piers on Service Road
5	KM14+800	POP	Cross Road (Local Road)	Main Road, Service Road (Underpass, TP Section)	8.5m	5.5m	Service Road	80m	2@40m	90.0	PC Box (Constant)	CIP (Staging)	RC Retaining Wall	Oval	Temporary Plan To be updated in the beginning of D/D stage with the taper design at toll plaza section.
6	KM15+600	POP	Cross Road (Local Road)	Main Road, Service Road (Underpass, TP Section)	8.5m	5.5m	Service Road	120m	2@60m	90.0	PC Box (Constant)	CIP (Staging)	RC Retaining Wall	Oval	
7	KM23+400	VOP	Cross Road (SH104)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Piers on Median of BPRR
8	KM25+604	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@8.5m	5.5m	Service Road	120m	4@30m	90.0	PC-I	Track Crane	Mixed	Round	Planned Piers on Median of BPRR Planned Piers on Service Road
9	KM27+145	VOP	Cross Road (Local Road)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Pier on Median of BPRR
10	KM29+770	VOP	Cross Road (Local Road)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Piers on Median of BPRR
11	KM36+323	Flyover	Main Road	NH-4	8.5m,2@17.75m,8.5m	5.5m	NH-4: 60m	60m	1@60m	73.4	PC Box (Constant)	CIP (Staging)	Mixed	-----	Assumed to allow temporary support structure inside NH-4 ROW with detour roads by national highway operator
12	KM37+760	VOP	Cross Road (SH35)	Main Road (Underpass)	2@8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Piers on Median of BPRR
13	KM38+769	Flyover	Main Road	Cross Road (Local Road) (Underpass)	2@17.75m	5.5m	Cross Road	140m	40m+60m+40m	90.0	PC Box (Constant)	CIP (Staging)	Mixed	T (Round Column)	Planned Piers on Service Road of Cross Road Left Carrigeway: Pier on CH:38+660, 38+700, 38+760, Right Carrigiway: Pier on CH:38+698, 38+738, 38+798,
14	KM43+125	ROB	Main Road, Service Road	Bangalore-Chennai Railway Line	8.5m,2@17.75m,8.5m	Rail: 8.14m	Rail: 70m	810m3)	11@30m, 40m+70m+40m, 11@30m	90.0	PC-I, Steel Box, PC-I	Truck Crane, Rapid Erection, Truck Crane	Mixed	Main Road: T (Round Column) Service Road: Round	Planned steel box girder by reason of difficulty for applying temporary support structure inside railway ROW.
15	KM49+430	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Pier on Median of BPRR
16	KM53+221	Flyover	Main Road	Cross Road (SH35) (Underpass)	2@17.75m	5.5m	Cross Road	90m	3@30m	90.0	PC-I	Track Crane	Mixed	Y	Planned Piers on Service Road of Cross Road
17	KM54+580	POP	Cross Road (Local Road)	Main Road (Underpass)	8.5m	5.5m	Main Road	46.5m	2@23.25m	90.0	PC-I	Track Crane	RC Retaining Wall	Oval	Planned Pier on Median of BPRR
18	KM55+911	VOP	Cross Road (Local Road)	Main Road (Underpass), Service Road	2@8.5m	5.5m	Service Road	120m	4@30m	90.0	PC-I	Track Crane	Mixed	Round	Planned Piers on Median of BPRR Planned Piers on Service Road
19	KM59+198	ROB	Main Road, Service Road	Bangalore-Hosur Railway Line	8.5m,2@17.75m,8.5m	Rail: 8.14m	Rail: 60m	790m3)	11@30m, 35m+60m+35m, 11@30m	90.0	PC-I, Steel Box, PC-I	Truck Crane, Rapid Erection, Truck Crane	Mixed	Main Road: T (Round Column) Service Road: Round	Planned steel box girder by reason of difficulty for applying temporary support structure inside railway ROW.
20	KM64+751	Flyover	Main Road	NH-7	4m	5.5m	Existing BR	60m	2@30m	66.4	PC-I	Truck Crane	Mixed	Round	Widening of Existing Bridge at Hosur Road JCT

1) Road Width in the Final DPR (To be followed discussion result in DP-R02)

2) Approximate Bridge Length (It is necessary to determine in detail in the D/D stage)

3) Bridge length (abutment locations) is temporary extended by 5m height of MSE Wall in this JICA Technical Review Stage

Red: To be confirmed with Railway Operator

Blue: To be confirmed with Road Operator

Source: JICA Experts

3.2.3.6 Bridge Accessory Planning

(1) Comments and Suggestions on DPR

Bridge accessories plan is not clearly mentioned in the drawings of the Final DPR; however, the plan of bridge bearings and expansion joint is described in the Main Report.

- Bridge Bearing: Pot Bearings
- Expansion Joint: Modular Joints

The JICA Experts understand that pot bearings and modular joints are appropriate due to their high performance and durability.

(2) Conclusion

The appropriateness of expansion joint and bearing types was confirmed in the Final DPR.

- Expansion Joint: Modular Joint
  (Bridge Length (L) ≥ 60 m: Multi-strip Type, L < 60 m: Single-strip Type)
- Bearing: Pot Bearing

3.2.3.7 Structural Dimensions

(1) Comments and Suggestions on DPR

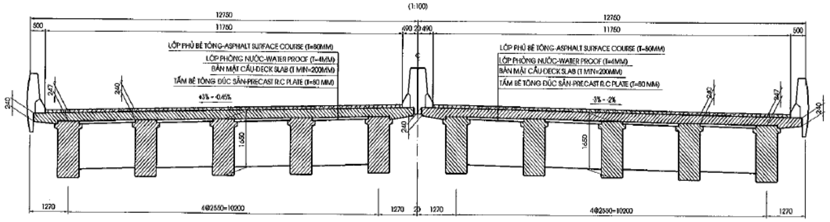
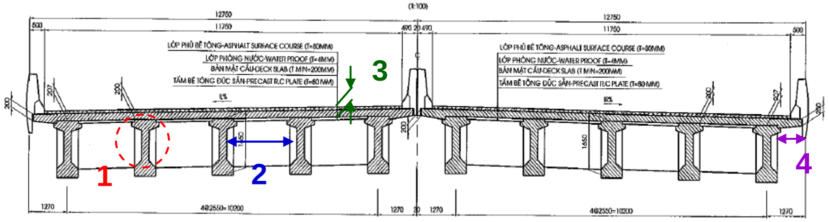
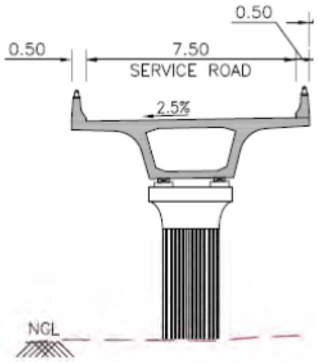
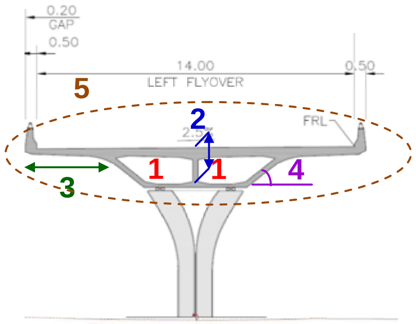
Preliminary study of bridge cross sections is included in the scope of works in the contract between JICA and the JICA Experts; however, the JICA Experts understand that the details of bridge cross sections will be determined in the beginning of the D/D stage.

Therefore, the JICA Experts confirmed the main points of bridge cross sections based only on IRC and general practices in the Bengaluru area.

The JICA Experts prepared inquiries on main points of bridge cross sections as shown in Tables 3.2.8 and 3.2.9.

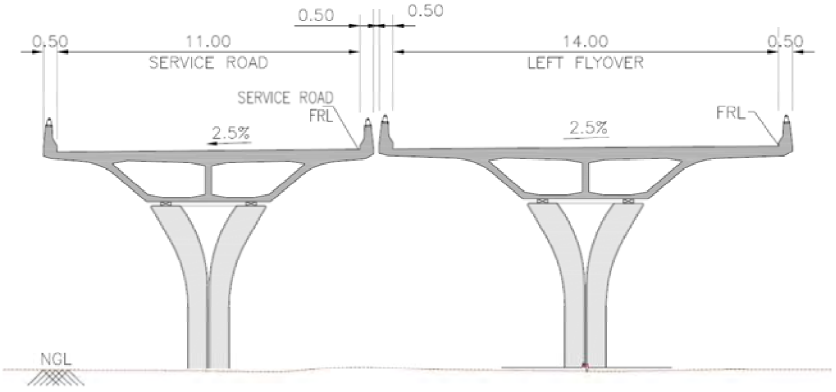
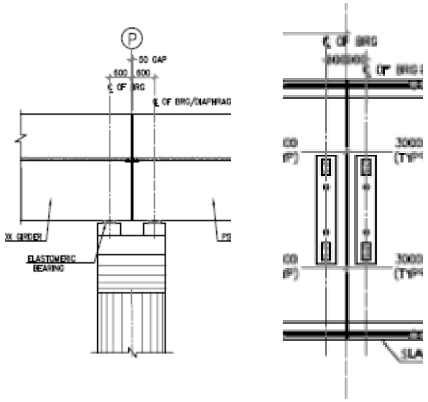
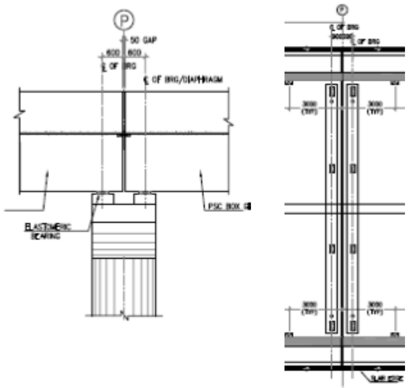
The JICA Experts requested DULT, BDA, and STUP to provide answers and relevant materials.

Table 3.2.8 Inquiries on Bridge Cross Sections (Superstructure)

No.	Structure			Inquiries by JICA Experts
1	Super structure	PC-I Girder	Image: At Abutment  Image: At Pier  	1 Size of PC-I Girder by Girder Length 2 Typical, Maximum, and Minimum Distance between Girders 3 Typical and Minimum Thickness of Slab 4 Typical and Maximum Cantilever Length
2		PC Box Girder (Constant Height)	Bridge Width: 8.5 m  Bridge Width: 12 m, 17.75 m  	1 Nos. of Cells for Bridge Width of 8.5 m, 12 m and 17.75 m 2 Girder Height for Span Length of 40 m, 45 m and 60 m 3 Typical and Maximum Cantilever Length for Bridge Width of 8.5 m, 12 m and 17.75 m 4 Web Angle for Bridge Width of 8.5 m, 12 m and 17.75 m 5 Typical and Minimum Thickness of Components for Bridge Width of 8.5 m, 12 m and 17.75 m

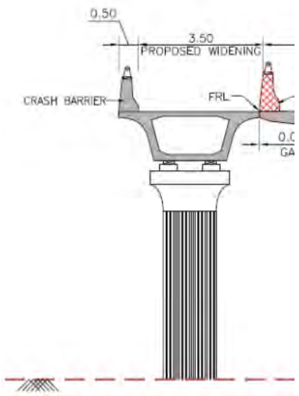
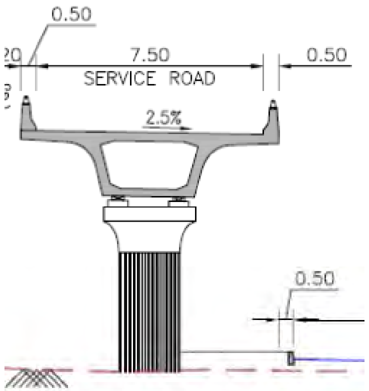
Source: JICA Experts

Table 3.2.9 Inquiries on Bridge Cross Sections (Substructure)

No.	Structure			Inquiries by JICA Experts
3	Substructure	Wall (Y) Shape Pier	Bridge Width: 12 m Bridge Width: 17.75 m 	Dimension of Substructure
4		Wall (Oval) Shape Pier	Bridge Width: 8.5 m Side View Plan View  Bridge Width: 19.6 m Side View Plan View 	

Source: JICA Experts

Table 3.2.10 Inquiries on Bridge Cross Sections (Substructure)

No.	Structure			Inquiries by JICA Experts
5	Substructure	Round Shape Pier	<u>Bridge Width: 4 m</u>  <u>Bridge Width: 8.5 m</u>  	Dimension of Substructure

Source: JICA Experts

(2) Conclusion

The JICA Experts confirmed with DULT, BDA, and STUP that the details of bridge cross sections will be determined in the beginning of the D/D stage according to general practices in India.

Therefore, the JICA Experts confirmed the expected structural dimensions on the main points with DULT, BDA, and STUP while referring to relevant project data.

The DULT, BDA, and STUP explained the following structural dimensions in the technical discussion:

Superstructure

PC-I Girder

- Slab Thickness: 22 cm
- Girder Height: 1.45 m (Span Length = 20 m)

PC Box Girder (Constant Height)

- Structure Height: 2.1 m (Span Length = 35 m), 2.4 m (Span Length = 60 m)
- Cantilever Length: 3.5 to 4.0 m (Bridge Width = 17.75 m)
- Web Angle: 47 degrees (acceptable from 42 to 47 degrees)
- Width of Bottom Slab: 6 m (Bridge Length: 17.75 m)

Substructure

Wall (Y) Shape Pier

- Column Width (Bottom): 1.85 m (Transverse Axis)*2.25 m (Bridge Axis) (Bridge Width: 17.75 m)

Foundation

CIP RC Bored Pile

- Pile Arrangement: 2 nos. on transverse axis in case of influence to local road
  (4 nos. on transverse axis are also acceptable in this Project, if required)

Reference Drawings

The DULT, BDA, and STUP provided reference drawings in past projects to the JICA Experts.

Sample Drawings Prepared by the JICA Experts

The JICA Experts prepared the following sample drawings on the main points in consideration of the above information and relevant experiences in Japan.

- Typical Cross Sections of Bridge Structure (Attachment 1-A)

3.3 Box Culvert Structure

3.3.1 Plan of Box Culvert

(1) Comments and Suggestions on DPR

The JICA Experts reviewed the plan of box culverts based on the drawings of the Final DPR.

The JICA Experts recommended confirming the plan of box culverts with DULT, BDA, and STUP.

(2) Conclusion

The JICA Experts confirmed the plan of box culvert with DULT, BDA, and STUP.

The list of box culverts is shown in Table 3.3.1 in the next page.

The Structural Layout Plan on Road Profile Drawings is shown in Attachment 1-C.

Table 3.3.1 List of Box Culverts

No.	Category	Station	Location	Cross Objects	Length	Skew (Degree)	Size Span Nos.@(W*H)	Remark
1	DC	KM00+525	Main Road, Service Road	Waterway	133.1m	34.3	2@(3.0m*2.0m)	
2	VUP	KM01+550	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
3	DC	KM02+215	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
4	PUP	KM02+270	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
5	DC	KM02+643	Main Road, Service Road	Waterway	77.6m	75.0	2@(2.0m*2.0m)	
6	VUP	KM02+850	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
7	DC	KM04+593	Main Road, Service Road	Waterway	78.3m	73.2	1@(3.0m*2.0m)	
8	PUP	KM04+950	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
9	PUP	KM05+700	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
10	DC	KM05+806	Main Road, Service Road	Waterway	83.9m	63.4	2@(2.0m*2.0m)	
11	VUP	KM06+750	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
12	DC	KM07+413	Main Road, Service Road	Waterway	87.5m	59.0	1@(2.0m*2.0m)	
13	DC	KM07+720	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
14	DC	KM08+720	Main Road, Service Road	Waterway	111.4m	42.3	1@(2.0m*2.0m)	
15	VUP	KM08+850	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
16	DC	KM09+100	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
17	DC	KM09+389	Main Road, Service Road	Waterway	91.6m	55.0	1@(3.0m*2.0m)	
18	DC	KM10+223	Main Road, Service Road	Waterway	106.1m	45.0	1@(2.0m*2.0m)	
19	DC	KM10+636	Main Road, Service Road	Waterway	103.9m	46.2	1@(2.0m*2.0m)	
20	VUP	KM10+700	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
21	PUP	KM11+230	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
22	DC	KM11+350	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
23	VUP	KM12+550	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
24	DC	KM12+790	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
25	DC	KM14+400	Main Road, Service Road	Waterway	103.6m	46.4	1@(2.0m*2.0m)	
26	Underpass	KM14+435	Main Road	Cross Road	81.7m	47.2	2@(16.5m*5.5m)	Doddaballapura JCT (SH-9)
27	DC	KM15+120	Main Road, Service Road	Waterway	110.2m	42.9	1@(2.0m*2.0m)	
28	RUB	KM15+158	Main Road, Service Road	Cross Railway	90.6m	41.5	1@(7.5m*5.5m), 2@(16.5m*5.5m), 1@(7.5m*5.5m)	Doddaballapur Railway
29	RUB	KM16+061	Main Road, Service Road	Cross Railway	70.5m	58.3		Chikkaballapur Railway
30	DC	KM16+190	Main Road, Service Road	Waterway	75.0m	90.0	2@(2.0m*2.0m)	
31	VUP	KM17+310	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
32	DC	KM17+786	Main Road, Service Road	Waterway	75.0m	90.0	1@(3.0m*2.0m)	
33	Underpass	KM18+651	Main Road, Service Road	Cross Road	62.0m	90.0	1@(7.5m*5.5m), 2@(16.5m*5.5m), 1@(7.5m*5.5m)	Bellary JCT (NH-7)
34	DC	KM20+040	Main Road, Service Road	Waterway	75.0m	90.0	1@(3.0m*2.0m)	
35	VUP	KM20+260	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
36	PUP	KM21+200	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
37	DC	KM22+213	Main Road, Service Road	Waterway	85.3m	61.6	1@(3.0m*2.0m)	
38	DC	KM24+320	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
39	DC	KM25+220	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
40	Underpass	KM25+604	Main Road	Cross Road	52.0m	57.6	2@(16.5m*5.5m)	Hennur JCT
41	DC	KM26+520	Main Road, Service Road	Waterway	118.2m	39.4	1@(2.0m*2.0m)	
42	DC	KM27+250	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
43	VUP	KM28+080	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
44	DC	KM29+065	Main Road, Service Road	Waterway	80.7m	68.3	2@(3.0m*2.0m)	

No.	Category	Station	Location	Cross Objects	Length	Skew (Degree)	Size Span Nos.@(W*H)	Remark
45	DC	KM30+883	Main Road, Service Road	Waterway	116.2m	40.2	1@(2.0m*2.0m)	
46	VUP	KM31+500	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
47	DC	KM31+703	Main Road, Service Road	Waterway	96.5m	51.0	1@(2.0m*2.0m)	
48	DC	KM32+233	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
49	DC	KM32+480	Main Road, Service Road	Waterway	81.4m	67.1	1@(2.0m*2.0m)	
50	DC	KM33+250	Main Road, Service Road	Waterway	86.3m	60.4	2@(3.0m*2.0m)	
51	VUP	KM33+620	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
52	DC	KM33+704	Main Road, Service Road	Waterway	75.0m	90.0	1@(3.0m*2.0m)	
53	DC	KM34+725	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
54	DC	KM35+732	Main Road, Service Road	Waterway	96.6m	50.9	1@(2.0m*2.0m)	
55	DC	KM36+300	Main Road, Service Road	Waterway	78.1m	73.7	1@(2.0m*2.0m)	
56	DC	KM36+400	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
57	DC	KM37+420	Main Road, Service Road	Waterway	75.0m	90.0	2@(2.0m*2.0m)	
58	Underpass	KM38+769	Cross Road	Main Road, Service Road	175.5m	90.0	2@(9.0m*5.5m)	
59	DC	KM38+840	Main Road, Service Road	Waterway	100.3m	48.4	1@(2.0m*2.0m)	
60	DC	KM39+644	Main Road, Service Road	Waterway	94.2m	52.8	1@(2.0m*2.0m)	
61	DC	KM39+993	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
62	VUP	KM40+060	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
63	DC	KM40+884	Main Road, Service Road	Waterway	118.4m	39.3	1@(2.0m*2.0m)	
64	DC	KM41+060	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
65	PUP	KM41+344	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
66	MB	KM42+783	Main Road, Service Road	Waterway	75.0m	90.0	2@(5.0m*5.0m)	
67	DC	KM43+100	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
68	DC	KM43+525	Main Road, Service Road	Waterway	75.9m	81.1	3@(2.0m*2.0m)	
69	DC	KM44+356	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
70	VUP	KM44+382	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
71	DC	KM45+025	Main Road, Service Road	Waterway	76.7m	78.0	1@(2.0m*2.0m)	
72	VUP	KM45+445	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
73	DC	KM46+056	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
74	DC	KM46+304	Main Road, Service Road	Waterway	80.7m	68.3	1@(2.0m*2.0m)	
75	DC	KM46+719	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
76	VUP	KM46+815	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
77	DC	KM46+895	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
78	DC	KM47+244	Main Road, Service Road	Waterway	78.6m	72.7	3@(2.0m*2.0m)	
79	DC	KM47+832	Main Road, Service Road	Waterway	75.5m	83.6	1@(2.0m*2.0m)	
80	DC	KM47+997	Main Road, Service Road	Waterway	146.9m	30.7	1@(2.0m*2.0m)	
81	VUP	KM48+100	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
82	DC	KM48+890	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
83	DC	KM50+065	Main Road, Service Road	Waterway	75.5m	83.1	1@(2.0m*2.0m)	
84	MB	KM50+240	Main Road, Service Road	Waterway	75.0m	90.0	4@(5.0m*5.0m)	
85	VUP	KM50+360	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
86	DC	KM50+539	Main Road, Service Road	Waterway	75.0m	90.0	1@(3.0m*2.0m)	
87	MB	KM51+165	Main Road, Service Road	Waterway	76.5m	78.5	2@(10.0m*5.0m)	
88	DC	KM51+410	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
89	VUP	KM51+430	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
90	DC	KM51+480	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
91	DC	KM51+990	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	

No.	Category	Station	Location	Cross Objects	Length	Skew (Degree)	Size Span Nos.@(W*H)	Remark
92	DC	KM52+510	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
93	DC	KM52+608	Main Road, Service Road	Waterway	91.9m	54.7	1@(2.0m*2.0m)	
94	Underpass	KM53+221	Cross Road	Main Road, Service Road	82.4m	90.0	2@(9.0m*5.5m)	Hoskote - Anekal JCT
95	DC	KM53+420	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
96	DC	KM55+298	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
97	MB	KM55+460	Main Road, Service Road	Waterway	80.4m	68.9	3@(10.0m*5.0m)	
98	DC	KM55+780	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
99	Underpass	KM55+911	Main Road	Cross Road	45.2m	85.8	2@(16.5m*5.5m)	Barjapur JCT
100	DC	KM56+610	Main Road, Service Road	Waterway	75.0m	90.0	1@(3.0m*2.0m)	
101	VUP	KM57+300	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
102	DC	KM58+515	Main Road, Service Road	Waterway	80.0m	69.7	1@(2.0m*2.0m)	
103	DC	KM59+178	Main Road, Service Road	Waterway	80.7m	68.3	1@(2.0m*2.0m)	Bangalore - Hosur Railway
104	DC	KM60+600	Main Road, Service Road	Waterway	128.5m	35.7	3@(2.0m*2.0m)	
105	PUP	KM61+370	Cross Road	Main Road	46.5m	90.0	1@(10.5m*4.5m)	
106	DC	KM61+637	Main Road, Service Road	Waterway	84.3m	62.8	1@(2.0m*2.0m)	
107	DC	KM61+796	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	
108	VUP	KM62+900	Cross Road	Main Road	46.5m	90.0	2@(9.0m*5.5m)	
109	DC	KM64+165	Main Road, Service Road	Waterway	75.7m	82.0	1@(2.0m*2.0m)	
110	DC	KM64+578	Main Road, Service Road	Waterway	75.0m	90.0	1@(2.0m*2.0m)	

DC: Drainage Culvert
VUP: Vehicular Underpass
PUP: Pedestrian Underpass
RUB: Railway Under Bridge
MB: Minor Bridge

Source: JICA Experts

3.3.2 Construction Method

(1) Comments and Suggestions on DPR

The construction method for box culverts is not clearly explained in the Final DPR.

At least, it is necessary to clarify at cross locations with national highways and RUBs.

The JICA Experts understand that construction methods at cross locations with national highways and RUBs are planned as follows:

- At Cross Locations with National Highway: Open and Cut Method with Detour
- At 2 RUBs: Box Pushing Method

For box pushing, it is necessary to confirm the following technical background:

- Technical Certification by IRC
- Maximum Pushing Length and Size (Possibility, Past Experience)
- Details of Construction Method
- Structural Details of Box Culvert

(2) Conclusion

The DULT, BDA, and STUP explained that all box culverts including at cross locations with national highways and railways are planned by applying open and cut method with detour road in the Final DPR in accordance with the past experiences in the Bengaluru area.

<u>Notes:</u>

For reference, the DULT, BDA, and STUP introduced the box pushing method as explained below.

- The DULT, BDA, and STUP explained that box pushing was applied to many projects in India even when the dimensions of underpass are larger than that for BPRR.
- The DULT, BDA, and STUP explained that box pushing was originally developed in the UK (Skanska) and exported to Thailand (ITD) and it was simplified by IRC.
- The DULT, BDA, and STUP explained that reduced speed operation of railway would be required during construction in case of applying box pushing method.
- The DULT, BDA, and STUP explained that box pushing has no conflict in patent.
- The DULT, BDA, and STUP explained that the underpass structure in case of applying box pushing is the same as standard box culverts.
- The DULT, BDA, and STUP agreed to provide more technical information as requested by the JICA Experts.

3.3.3 Thickness of Box Culvert

(1) Comments and Suggestions on DPR

Preliminary study of cross sections of box culverts is included in the scope of works in the contract between JICA and the JICA Experts; however, the JICA Experts understand that the details of the cross sections of box culverts will be determined in the beginning of the D/D stage.

Some large-sized box culverts are planned in the Final DPR; therefore, it is necessary to confirm the thickness of the components of large box culverts based on IRC or past experiences.

(2) Conclusion

The JICA Experts confirmed with the DULT, BDA, and STUP that the details of box culvert sections will be determined in the beginning of the D/D stage according to general practices in India.

Therefore, the JICA Experts confirmed the expected structural dimensions on main points with the DULT, BDA, and STUP while referring to relevant project data.

The structural dimensions confirmed in the technical discussion are as follows:

Thickness of Box Culvert (2@12.5 m)

- Upper Slab: 40 cm
- Bottom Slab: 45 cm
- Outer Wall: 35 cm
- Intermediate Wall: 30 cm

Reference Drawings

The DULT, BDA, and STUP provided reference drawings in past projects to the JICA Experts.

Sample Drawings Prepared by the JICA Experts

The JICA Experts prepared the following sample drawings on the main points in consideration of the above information and standard design in Japan.

- Typical Cross Sections of Box Culvert Structure (Attachment 1-A)

3.3.4 Drainage Pump at Underpass

(1) Comments and Suggestions on DPR

It seems that drainage pump at underpass is not planned in the Final DPR; therefore, it is necessary to clarify the plan of the drainage pump.

The JICA Experts recommended confirming the capacity, pitch, and installation space of the drainage pump at underpass with the DULT, BDA, and STUP based on IRC and past experiences.

(2) Conclusion

The DULT, BDA, and STUP explained the general practices of drainage system at underpass as follows:

- At Plains (i.e., Chennai): Drainage pump
- At Hilly Areas (i.e., Bengaluru): Gravity drain with plumbing for terminal treatment of drainage water, manhole: 30 m pitch with diameter of 1.2 m for maintenance works.

Accordingly, drainage pump was not planned in the Final DPR as natural drainage is facilitated.

CHAPTER 4 TRAFFIC DEMAND FORECAST

4.1 Basic Idea of Traffic Demand Forecast

4.1.1 Basic Idea

The purpose of the technical review on the traffic demand forecast is to obtain the future traffic volume on the BPRR and this result will be referred to in the detailed design for determination of the number of lanes and interchange booths, analysis of effect of development and to obtain the data for economic and financial analysis.

The Japan International Cooperation Agency (JICA) Experts applied the method of traffic demand forecast considering some important points as listed below as these were not considered in detail on the detailed project report (DPR) by the Bengaluru Development Authority (BDA).

The major consideration points for the traffic demand forecast are the following:

- Applying a method based on traffic engineering
- Traffic demand forecast for obtaining the design traffic volume of target year
- Traffic assignment considering the wide area of road network including NH 207
- Traffic assignment considering the road fee impact
- Providing appropriate data for the economic and financial analysis

4.1.2 Target Years

The target year for the traffic demand forecast is the year of 2040 as the design year of the BPRR. The year 2040 is set as 20 years after 2021 that is the opening year of BPRR. And also, the interim year reviews were set up taking into consideration the timing of the opening to traffic.

The target years for the traffic demand forecast:

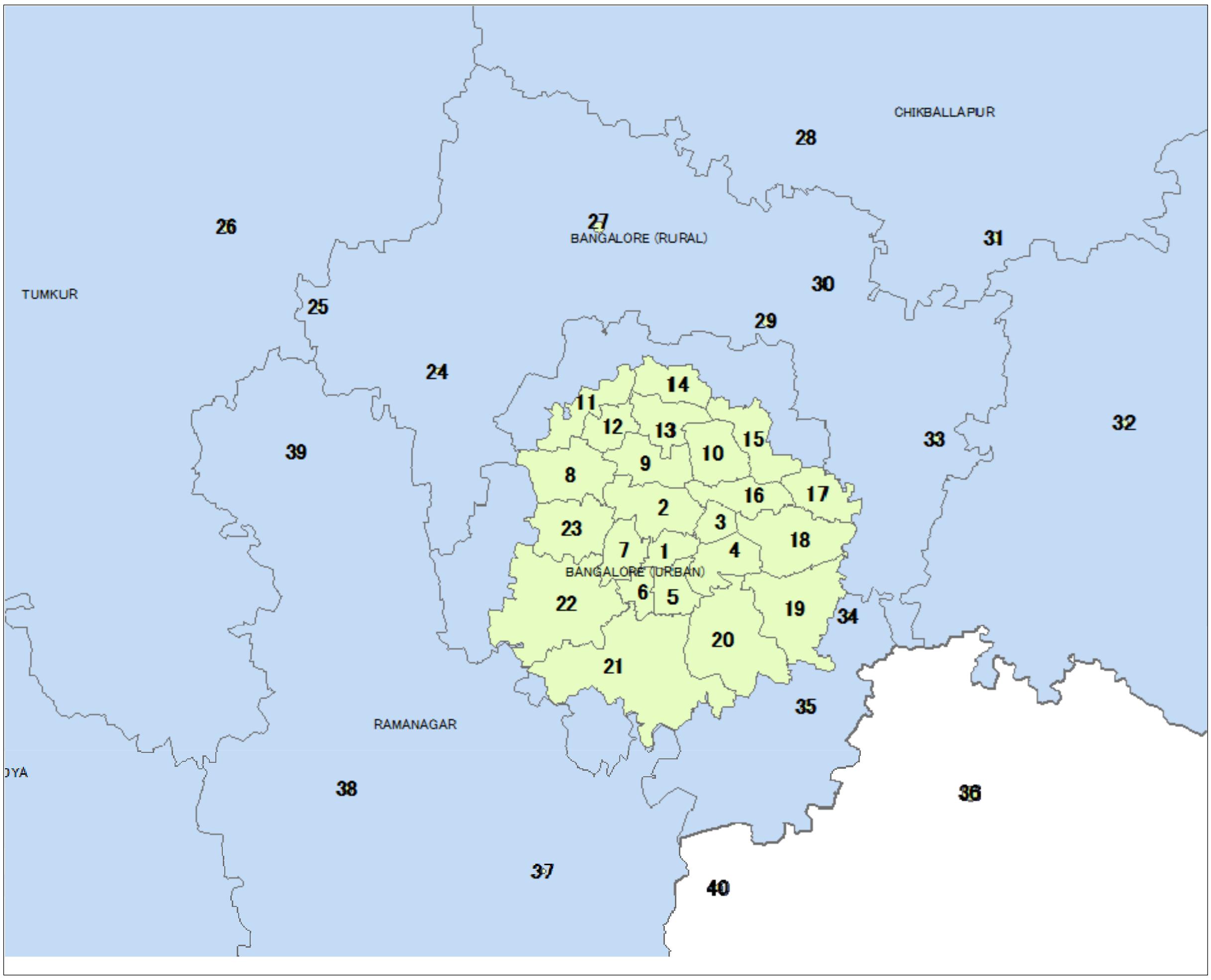
- Base year : 2014
- Interim year : 2022 and 2030
- Target year : 2040

4.1.3 Study Area

The study area is the administrative area of BDA, which includes the BPRR and its surrounding area. In this study, the traffic demand forecast is examined based on the traffic zones that have divided the study area. The zoning area includes the area of BDA and its surrounding states. There are 40 zones in total; 23 zones within the BDA area, and 17 zones outside the BDA area.

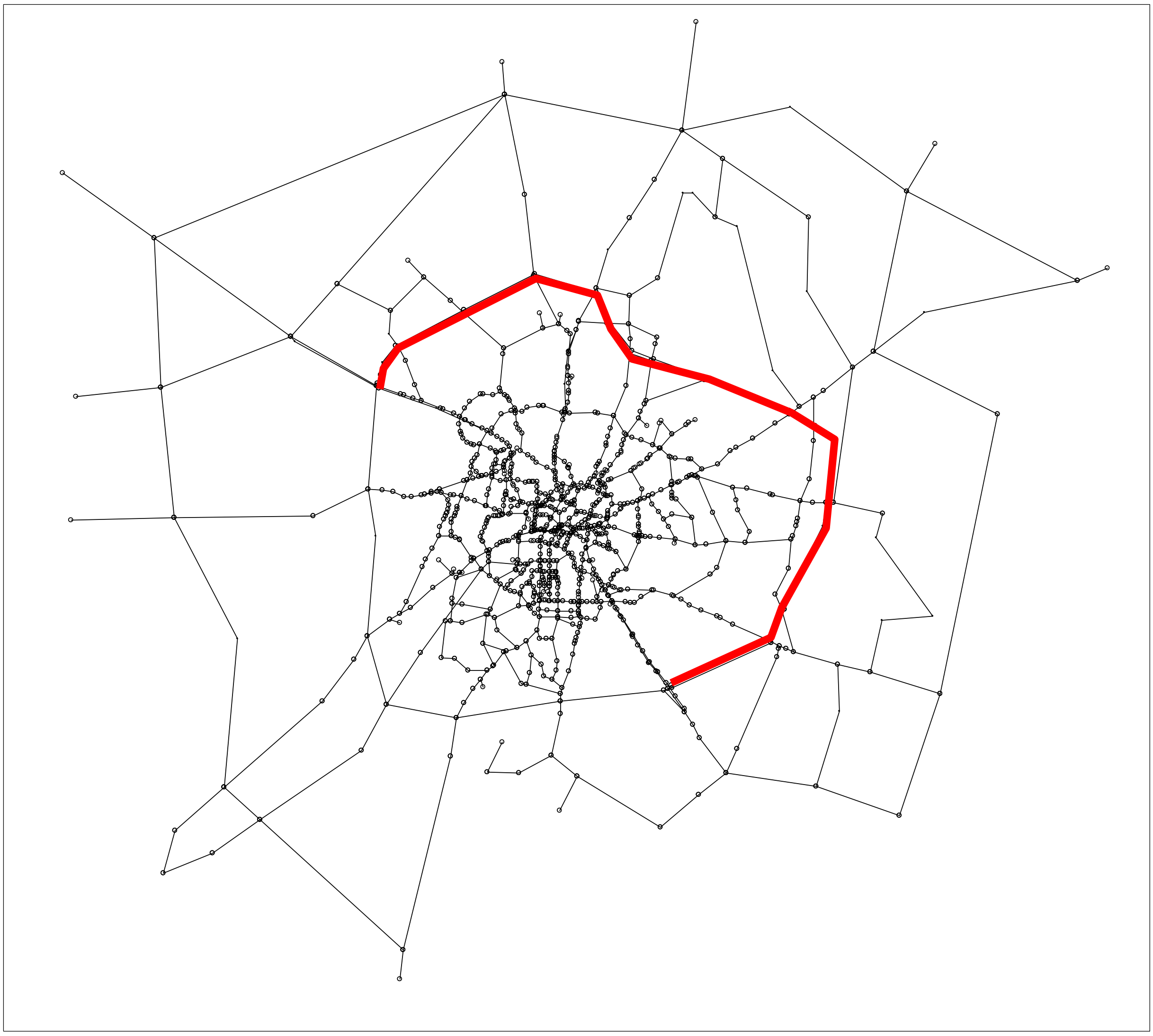
Although the traffic zone is considered in the DPR and the Bengaluru ITS Master Plan project (JICA, 2015), the JICA Experts judged that the zonings are not suitable for the BPRR study. To be concrete, the zones in the former are large zoning. A detailed calculation such as traffic volume on service roads is not possible. On the other hand, the zoning in the latter was too finely subdivided for the analysis of the ITS measure impact and needed to be integrated for the BPRR study so that it should be considered from the viewpoint of the wide area. For the abovementioned reasons, a new zoning was proposed as shown in Figure 4.1.1.

As for the road network for the demand forecast, it is taken to be the national roads, state roads, and main roads within BDA, and its surrounding areas. However, the road management system has no classification for main roads. The main road for traffic demand forecast was made up through the discretion of the JICA Experts. The road network in this study is shown in Figure 4.1.2.



Source: JICA Experts

Figure 4.1.1 Zoning of Traffic Analysis



Note: The red line is the BPRR

Source: JICA Experts

Figure 4.1.2 Road Network for Traffic Demand Forecast

4.2 Procedure for the Traffic Demand Forecast

In the DPR, the future traffic demand was estimated by multiplying the current traffic volume by the traffic growth rate calculated using state level socio-economic indicators. However, this method is not enough for the requirements mentioned in Chapter 4.1.1.

Therefore, the method based on traffic engineering, namely the three-step method set out below, were utilized based on the vehicle origin-destination (OD) matrix.

Step 1 Forecasting Trip Generation and Attraction

- Establishment of socio-economic framework
- Building the trip generation and attraction model

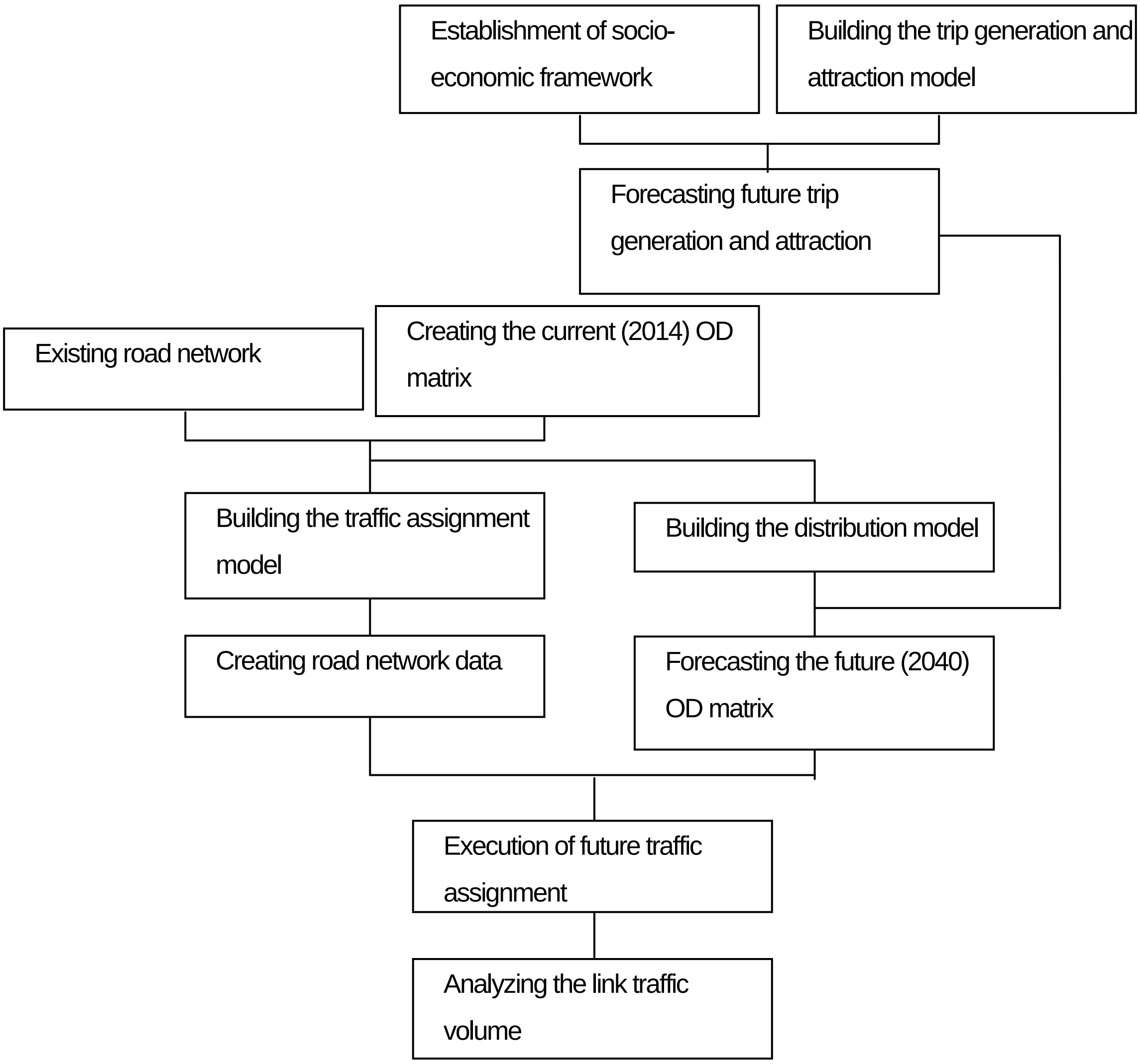
- Forecasting future trip generation and attraction

Step 2 Forecasting Trip Distribution

- Creating the current (2014) OD matrix
- Building the distribution model
- Forecasting the future (2040) OD matrix

Step 3 Traffic Assignment and Forecasting the Future Road Traffic

- Creating road network data
- Building the traffic assignment model
- Execution of future traffic assignment
- Analyzing the link traffic volume



Source: JICA Experts

Figure 4.2.1 Procedure for the Traffic Demand Forecast

4.3 Forecasting Trip Generation and Attraction

4.3.1 Basic Approach

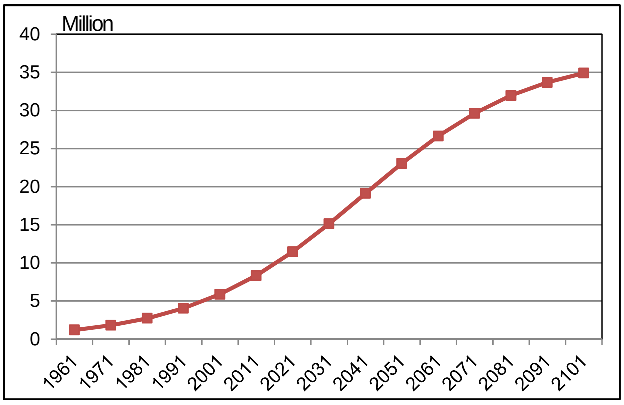
The trip generation by zone was estimated through the creation of a trip generation and attraction model explicated from the current population and economic indicators for each zone. The traffic volume made use of the trip generation calculated from the current OD matrix that was drawn up separately. The predictor variables, on the other hand, made use of values based on the population census. The socio-economic framework was estimated by the Karnataka Directorate of Economics and Statistics and by the JICA Experts.

4.3.2 Establishment of the Socio-economic Framework

The Karnataka Directorate of Economics and Statistics has released the estimated values for the population framework up to 2021, but it has made no long-term forecasts after that time. Thus, the JICA Experts established a long-term framework up to 2040 using the existing population census and the estimated values up to 2021 of the Karnataka Directorate of Economics and Statistics based on the logistics curve model. The simplex method, as logistics curve, which is y = a/(1+b*exp(-c*x)), is adopted. The estimated result is shown in Figure 4.3.1. Although the population in the Bengaluru urban area was 8.4 million in 2008, it is expected to increase to around 11 million in 2021, around 15 million in 2031, and around 19 million in 2041. The average annual growth rate will gradually decline during this period from 3.22% in 2011.

Regarding the socio-economy by district level such as the estimation of population and the net district domestic product (NDDP), the logistics curve was not applied due to the lack of available long-term historical data. So, the JICA Experts set the growth rate after 2021 based on the historical performance of growth rate. Specifically, the annual growth rate between 2011 and 2020 is set at 80% of that between 2007 and 2011. The rate between 2020 and 2030 is made 70% of the rate applied in the previous decade. Correspondingly, the rate for the next decade is 60% of that in the previous decade.

Year	Population	Annual Growth Rate
1961	1,207,300	4.22%
1971	1,825,398	4.13%
1981	2,736,030	4.00%
1991	4,049,264	3.81%
2001	5,885,847	3.56%
2011	8,347,051	3.22%
2021	11,463,265	2.82%
2031	15,137,072	2.36%
2041	19,120,855	1.89%



*The simplex method : y = a/(1+b*exp(-c*x)), a=37416964, b=46, c=0.431*

Source: JICA Experts, based on population census in India

Figure 4.3.1 Framework of Population in Bengaluru

Table 4.3.1 Framework of Population by District

	Dostrict	2011	2015	2020	2025	2030	2035	2040	AAGR 2011-2020	AAGR 2020-2030	AAGR 2030-2040	AAGR 2015-2040
1	Bagalkote	1,890,826	1,997,786	2,141,784	2,263,935	2,393,054	2,501,753	2,615,390	1.4%	1.1%	0.9%	1.1%
2	Bangalore Urban	9,588,910	11,202,014	13,626,081	15,938,839	18,644,142	21,143,685	23,978,332	4.0%	3.2%	2.5%	3.1%
3	Bangalore Rural	987,257	1,051,034	1,139,694	1,214,918	1,295,107	1,363,142	1,434,751	1.6%	1.3%	1.0%	1.3%
4	Belgaum	4,778,439	5,025,974	5,354,714	5,633,028	5,925,807	6,171,203	6,426,760	1.3%	1.0%	0.8%	1.0%
5	Bellary	2,532,383	2,768,888	3,096,512	3,386,713	3,704,111	3,979,826	4,276,064	2.3%	1.8%	1.4%	1.8%
6	Bidar	1,700,018	1,787,244	1,903,546	2,001,785	2,105,093	2,191,654	2,281,775	1.3%	1.0%	0.8%	1.0%
7	Bijapur	2,175,102	2,343,080	2,571,844	2,771,052	2,985,689	3,169,590	3,364,819	1.9%	1.5%	1.2%	1.5%
8	Chamarajanagar	1,020,962	1,044,812	1,076,085	1,101,545	1,127,608	1,148,911	1,170,617	0.6%	0.5%	0.4%	0.5%
9	Chickballapur	1,254,377	1,301,294	1,364,310	1,416,262	1,470,193	1,514,846	1,560,856	0.9%	0.8%	0.6%	0.7%
10	Chickmagalur	1,137,753	1,137,024	1,136,558	1,136,027	1,135,497	1,135,073	1,134,649	0.0%	0.0%	0.0%	0.0%
11	Chitradurga	1,660,378	1,722,033	1,803,209	1,870,635	1,940,583	1,998,462	2,058,068	0.9%	0.7%	0.6%	0.7%
12	Dakshina Kannada	2,083,625	2,184,209	2,335,183	2,456,684	2,584,507	2,691,648	2,803,231	1.3%	1.0%	0.8%	1.0%
13	Davangere	1,946,905	2,014,141	2,102,415	2,175,524	2,251,175	2,313,629	2,377,815	0.9%	0.7%	0.5%	0.7%
14	Dharwad	1,846,993	1,954,921	2,099,469	2,222,672	2,353,104	2,463,068	2,578,171	1.4%	1.1%	0.9%	1.1%
15	Gadag	1,065,235	1,105,112	1,157,112	1,200,491	1,245,496	1,282,740	1,321,098	0.9%	0.7%	0.6%	0.7%
16	Gulbarga	2,564,892	2,740,160	2,976,434	3,180,290	3,398,109	3,583,308	3,778,600	1.7%	1.3%	1.1%	1.3%
17	Hassan	1,776,221	1,802,746	1,840,223	1,869,415	1,899,071	1,923,141	1,947,516	0.4%	0.3%	0.3%	0.3%
18	Haveri	1,598,506	1,667,743	1,759,087	1,835,624	1,915,492	1,981,938	2,050,690	1.1%	0.9%	0.7%	0.8%
19	Kodagu	554,762	557,387	560,797	563,501	566,217	568,400	570,591	0.1%	0.1%	0.1%	0.1%
20	Kolar	1,540,231	1,607,204	1,695,959	1,770,215	1,847,723	1,912,221	1,978,971	1.1%	0.9%	0.7%	0.8%
21	Koppal	1,391,292	1,478,042	1,594,147	1,693,710	1,799,492	1,888,965	1,982,887	1.5%	1.2%	1.0%	1.2%
22	Mandya	1,808,680	1,827,434	1,851,525	1,870,897	1,890,471	1,906,281	1,922,223	0.3%	0.2%	0.2%	0.2%
23	Mysore	2,994,744	3,155,734	3,374,961	3,559,344	3,753,801	3,917,165	4,087,639	1.3%	1.1%	0.9%	1.0%
24	Raichur	1,924,773	2,037,388	2,187,486	2,315,667	2,451,360	2,565,750	2,685,477	1.4%	1.1%	0.9%	1.1%
25	Ramnagara	1,082,739	1,107,041	1,140,574	1,167,276	1,194,603	1,216,935	1,239,685	0.6%	0.5%	0.4%	0.5%
26	Shimoga	1,755,512	1,803,025	1,864,370	1,914,928	1,966,857	2,009,435	2,052,935	0.7%	0.5%	0.4%	0.5%
27	Tumkur	2,681,449	2,725,093	2,784,099	2,830,993	2,878,678	2,917,416	2,956,675	0.4%	0.3%	0.3%	0.3%
28	Udupi	1,177,908	1,225,363	1,307,243	1,369,268	1,434,236	1,488,473	1,544,762	1.2%	0.9%	0.7%	0.9%
29	Uttara Kannada	1,436,847	1,471,589	1,516,250	1,552,957	1,590,552	1,621,298	1,652,637	0.6%	0.5%	0.4%	0.5%
30	Yadagiri	1,172,985	1,273,658	1,412,445	1,534,273	1,666,609	1,780,844	1,902,910	2.1%	1.7%	1.3%	1.6%

Source: JICA Experts, based on the Karnataka Directorate of Economics and Statistics

Table 4.3.2 Framework of Net District Domestic Product (NDDP)

	Dostrict	2007	2011	2015	2020	2025	2030	2035	2040	AAGR (2007-2011)	AAGR (2011-2020)	AAGR (2020-2030)	AAGR (2030-2040)
										Ffactor	80%	70%	60%
1	Bagalkote	29,529	46,350	68,199	107,580	148,654	205,408	250,016	304,312	11.9%	9.5%	6.7%	4.0%
2	Bangalore Urban	114,339	183,607	275,522	444,866	625,096	878,343	1,080,177	1,328,390	12.6%	10.1%	7.0%	4.2%
3	Bangalore Rural	54,499	94,124	150,421	261,681	388,019	575,351	731,457	929,920	14.6%	11.7%	8.2%	4.9%
4	Belgaum	28,745	48,619	76,307	129,936	189,710	276,982	348,782	439,193	14.0%	11.2%	7.9%	4.7%
5	Bellary	49,404	66,038	84,618	113,343	139,322	171,256	194,028	219,828	7.5%	6.0%	4.2%	2.5%
6	Bidar	21,193	35,526	55,327	93,351	135,395	196,375	246,269	308,840	13.8%	11.0%	7.7%	4.6%
7	Bijapur	26,608	41,347	59,053	92,201	126,465	173,462	210,176	254,659	11.6%	9.3%	6.5%	3.9%
8	Chamarajanagar	24,003	35,720	49,246	73,570	97,765	129,917	154,382	183,453	10.4%	8.4%	5.9%	3.5%
9	Chickballapur	27,022	41,176	57,875	88,574	119,759	161,923	194,471	233,561	11.1%	8.9%	6.2%	3.7%
10	Chickmagalur	34,510	57,926	88,122	148,885	216,153	313,812	393,782	494,132	13.8%	11.1%	7.7%	4.6%
11	Chitradurga	27,782	39,728	53,022	76,059	98,178	126,730	147,936	172,691	9.4%	7.5%	5.2%	3.1%
12	Dakshina Kannada	54,625	87,012	126,814	203,074	283,655	396,212	485,477	594,852	12.3%	9.9%	6.9%	4.1%
13	Davangere	30,490	48,453	70,481	112,593	156,998	218,916	267,950	327,967	12.3%	9.8%	6.9%	4.1%
14	Dharwad	43,355	70,233	103,780	169,077	239,114	338,163	417,527	515,518	12.8%	10.3%	7.2%	4.3%
15	Gadag	27,992	43,224	61,416	95,275	130,078	177,594	214,570	259,245	11.5%	9.2%	6.4%	3.9%
16	Gulbarga	24,623	40,622	60,928	101,133	144,962	207,786	258,689	322,061	13.3%	10.7%	7.5%	4.5%
17	Hassan	27,053	47,691	75,531	134,196	202,038	304,178	390,372	500,991	15.2%	12.2%	8.5%	5.1%
18	Haveri	24,124	40,092	60,496	101,174	145,809	210,135	262,491	327,890	13.5%	10.8%	7.6%	4.5%
19	Kodagu	60,252	102,074	156,466	266,871	390,105	570,244	718,593	905,535	14.1%	11.3%	7.9%	4.7%
20	Kolar	32,174	50,665	73,151	115,774	160,356	222,104	270,733	330,008	12.0%	9.6%	6.7%	4.0%
21	Koppal	25,356	46,975	77,499	144,905	226,384	353,678	464,437	609,882	16.7%	13.3%	9.3%	5.6%
22	Mandya	25,119	40,631	59,966	97,546	137,801	194,669	240,194	296,366	12.8%	10.2%	7.2%	4.3%
23	Mysore	34,068	65,703	112,047	218,358	351,555	566,003	757,288	1,013,221	17.8%	14.3%	10.0%	6.0%
24	Raichur	24,689	37,977	53,791	83,119	113,161	154,061	185,815	224,113	11.4%	9.1%	6.4%	3.8%
25	Ramnagara	36,316	64,454	102,647	183,642	277,872	420,454	541,277	696,822	15.4%	12.3%	8.6%	5.2%
26	Shimoga	36,923	50,800	65,703	90,624	113,746	142,767	163,825	187,989	8.3%	6.6%	4.6%	2.8%
27	Tumkur	27,839	43,687	62,898	99,195	137,043	189,332	230,424	280,435	11.9%	9.5%	6.7%	4.0%
28	Udupi	47,918	75,885	110,072	175,216	243,697	338,943	414,211	506,193	12.2%	9.7%	6.8%	4.1%
29	Uttara Kannada	31,001	50,598	75,227	123,502	175,628	249,755	309,424	383,347	13.0%	10.4%	7.3%	4.4%
30	Yadagiri	-	33,895	41,858	54,493	65,639	79,065	88,478	99,013	6.8%	5.4%	3.8%	2.3%

Source: JICA Experts, based on the Karnataka Directorate of Economics and Statistics

4.3.3 Building the Trip Generation and Attraction Model

A trip generation model was created for the 23 zones within BDA. The model equation applied was of simple linear type. The data used to create the model was the 2014 population figures and number of workers. These numbers were derived from the population census values. The trip generation model equation is as follows:

$$\boldsymbol{Y = a \cdot x1 + b \cdot x2 + c}$$

Where:

Y = Traffic volume generated/attracted traffic volume per zone

X_1 = Population per zone

X_2 = Employment population per zone

a, b = Parameters, c = Constant term

The result of the calculation is shown in Table 4.3.3. The goodness of fit of each model is appropriate due to the high multiple correlation coefficient. Judging from this result, these parameters are used as coefficients of trip generation and attraction model.

Table 4.3.3 Parameters of Trip Generation and Attraction Model

	Model	Coefficient			Correlation Coefficient
		Population	Employment	Constant	
2W	Generation	3.93	6.77	155.3	0.85
	Attraction	4.07	6.30	157.7	0.85
Auto	Generation	-	2.53	21.5	0.74
	Attraction	-	2.52	21.6	0.74
Car	Generation	2.46	9.33	187.0	0.85
	Attraction	2.46	9.28	188.3	0.85
Bus	Generation	0.39	0.85	10.0	0.75
	Attraction	0.86	0.39	9.9	0.75
LCV	Generation	-	0.84	9.0	0.79
	Attraction	-	0.84	9.0	0.79
Truck	Generation	-	0.62	11.0	0.79
	Attraction	-	0.62	11.0	0.79

2W: Two-wheeler; Auto: auto rickshaw; LCV: light commercial vehicle

Source: JICA Experts

4.3.4 Forecasting Future Trip Generation and Attraction

The future traffic volume was calculated on the basis of the trip generation model created in the previous section. The input data in the model, the number of population and of employment population per zone in 2040 were determined taking into consideration the future land use plan. According to BDA, the revised Master Plan 2015 is about halfway complete, and the land use in the suburbs will proceed. At the present time, the planning is progressing on the revision of the development plan covering progressive urbanization for the planning period of up to 2031. In this study, the population placement assumed that with regard to land use in 2040, the development of the fringe areas of BDA would be accelerated beyond even the revised Master Plan 2015. As for the current land use of the areas bordering the BPRR, most of the lands are undeveloped farmland and vacant land. However, it is anticipated that land use in 2040 will certainly have progressed, in particular, the development of residential areas.

Based on the above concept, the trip generation and attraction by zone was estimated. Table 4.3.4 is the summary of the trip generation and annual average growth rate of all zones from 2014 to 2040. The traffic growth rate is 3.0% between 2014 and 2022, and that of the next decade is 2.3% (2022-2030) and finally, 1.9% (2030-2040). As a result, the rate of increase shows that the traffic volume in 2040 is 1.8 times of that in 2014.

Table 4.3.4 Trip Generation Volume and Annual Average Growth Rate

Classification	Traffic Volume (1000 trip/day)				Annual Average Growth Rate			Rate of Increase (2040/2014)
	2014	2022	2030	2040	2014-2022	2022-2030	2030-2040	
2W	1,983	2,501	2,983	3,587	2.9%	2.2%	1.9%	1.8
Auto	301	353	437	541	2.0%	2.7%	2.2%	1.8
Car	2,143	2708	3262	3,955	3.0%	2.4%	1.9%	1.8
Bus	206	253	327	419	2.6%	3.3%	2.5%	2.0
LCV	134	184	222	269	3.8%	2.4%	1.9%	2.0
Truck	122	170	197	230	4.2%	1.9%	1.6%	1.9
MAV	18	25	29	34	4.2%	1.9%	1.6%	1.9
Total	4,888	6,194	7,457	9,035	3.0%	2.3%	1.9%	1.8

**Traffic Volume: Trip End*

2W: Two-wheeler; Auto: auto rickshaw; LCV: light commercial vehicle; MAV: multi-axle vehicle (four-wheel axle or more)

Source: JICA Experts

4.4 Forecasting Trip Distribution

4.4.1 Basic Approach

The purpose of the estimation of trip distribution is to estimate the trip pattern between zones based on trip generation/attraction and the inter-zone distance. As a result, the OD matrix in the present and target years is outputted as base data for the traffic assignment. The current OD matrix was created using the current OD patterns in the metropolitan area prepared in the Bengaluru ITS Master Plan Project and the current OD patterns prepared in the DPR of BPRR. The future OD matrix is created based on the distribution model created by the JICA Experts.

4.4.2 Creating the Current OD Matrix

For the 23 zones within BDA, the current OD patterns in the metropolitan area that were prepared in the ITS master plan were used to create the current OD matrix on vehicles/day basis. The seven vehicle types were classified as two-wheeler, auto rickshaw, passenger car, bus, light commercial vehicle, truck, and multi axle vehicle (four-wheel axle or more).

For the 17 zones outside of BDA, the current OD matrix was created by combining the current OD patterns prepared in the ITS master plan project and that in the DPR of BPRR. Specifically, for the zones on the outer part of the BPRR area, the results of the DPR OD survey were used. However, for the zones beside the NICE road, the current OD matrix was supplemented with the current OD patterns prepared in the ITS master plan project based on the Comprehensive Traffic and Transportation Study (CTTS).

4.4.3 Building the Distribution Model

The distribution models were constructed on the basis of the current OD matrix using the gravity model shown below. A distribution model was drawn up for each vehicle type. However, as medium-size trucks and heavy trucks were considered to have similar distribution characteristics, a common model was prepared. Regarding the internal impedance, the time and distance between zones were applied to the model calibration. The calculated parameters are shown in Table 4.4.1. The goodness of fit of each model is appropriate due to the result of multiple correlation coefficients. Although the rate of commercial vehicle is a bit low, the Study Team judged it reasonable for this study. Judging from this result, these parameters are used as coefficients of trip distribution model.

$$\boldsymbol{T_{ij} = k \cdot \frac{G_i^{\alpha} \cdot A_j^{\beta}}{d_{ij}^{\gamma}}}$$

Where:

T_{ij} = Inter-zonal trip volume

G_i = Generated trip volume

A_j = Attracted trip volume

d^{ij} = Inter-zonal impedance (time distance)

k, α, β, γ = parameters

Table 4.4.1 Parameters of Distribution Model

	Two-wheeler	Auto Rickshaw	Car	Bus	Light Truck	Truck
K	0.000001	0.00066	0.00022	0.00040	0.00046	0.00026
Α	1.23	0.71	0.69	0.73	0.73	0.76
Β	1.22	0.69	0.69	0.71	0.73	0.76
Γ	0.21	0.85	0.45	0.37	0.37	0.03
R^2	0.87	0.64	0.78	0.73	0.68	0.67

Source: JICA Experts

4.4.4 Forecasting the Future OD Matrix

The future OD matrix in 2040 was created using the future trip generation and the distribution model.

4.5 Traffic Assignment and Forecasting the Future Road Traffic

4.5.1 Method for Traffic Volume Assignment

In this study, the incremental assignment method adapted the traffic assignment method using the JICA System for Traffic Demand Analysis (STRADA). The traffic assignment calculation needs the OD matrix data, road network data, and parameters for controlling the calculation of assignment.

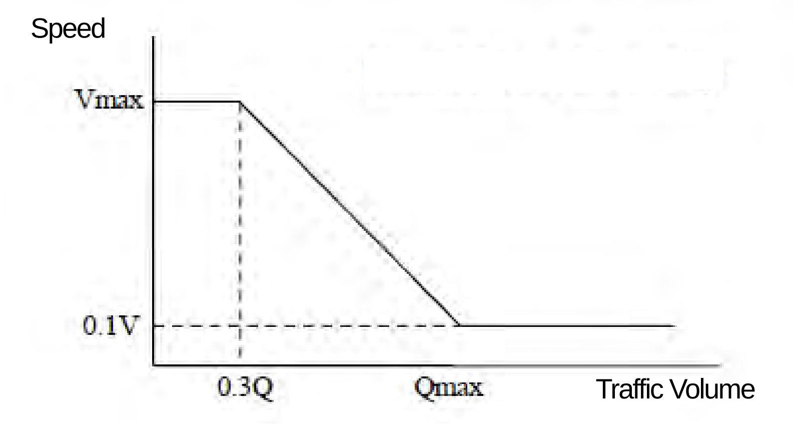
The OD matrix data created in Chapter 4.4 was used. The future road network is shown in Figure 4.1.2., while the road conditions are shown in Table 4.5.1. These figures were established based on the traffic capacity of IRC64-1990. Although the road conditions were based on the results of the road inventory in the Comprehensive Traffic and Transportation Plan (CTTP), the conditions of the major roads were established based on the results of field surveys carried out by the JICA Experts. The QV type, relation of capacity and travel speed is shown in Figure 4.5.1 was applied. The standard toll fees decided by the government were applied for link conditions of PRR shown in Table 4.5.2.

In order to reproduce the share of the use of toll roads and ordinary roads, time value was applied as a parameter shown in Table 4.6.3. The value of time is a numerical value calculated on the basis of the results of road user questionnaire surveys carried out in this study. The details will be explained in Chapter 4.6.

Table 4.5.1 Road Link Conditions

SN	Type of Road	No. of Lane	Road Capacity (Q_{max}: PCU/hr)	Free Flow Speed (V_{max}: km/hr)
1	2 lane-1way - undivided	2	58,000	50
2	2 lane-2way - undivided	2	36,000	50
3	3 lane-1 way - undivided	3	86,000	50
4	4 lane-1 way - undivided	4	116,000	50
5	4 lane-2 way - undivided	4	72,000	50
6	4 lane-2 way - divided	4	86,000	50
7	6 lane-2way - divided	6	130,000	60
8	8 lane-2way - divided	8	173,000	80

Source: JICA Experts



Source: JICA Experts

Figure 4.5.1 QV Type

Table 4.5.2 Toll Fee of PRR for Traffic Assignment

Type	Toll Fee (Rs/km)	Type	Toll Fee (Rs./km)
Passenger Car	0.97	LCV	1.56
Bus	3.28	Truck	3.28
-	-	MAV	5.14

LCV: Light Commercial Vehicle, MAV: Multi Axle Vehicle (four wheel-axles or more)

Source: IRC 64-1990

The incremental assignment is a method of dividing the OD traffic volume and assigning the divided traffic volume, one by one, to the route with the smallest general cost (impedance made up of time, distance, etc.). It was decided to divide the traffic volume five times by 20% for each time. The QV model type and link condition shown in Figure 4.5.1 and Table 4.5.1 were applied. The assignment calculation was carried out for each of the seven vehicle types. The steps of the assignment per increment are as follows:

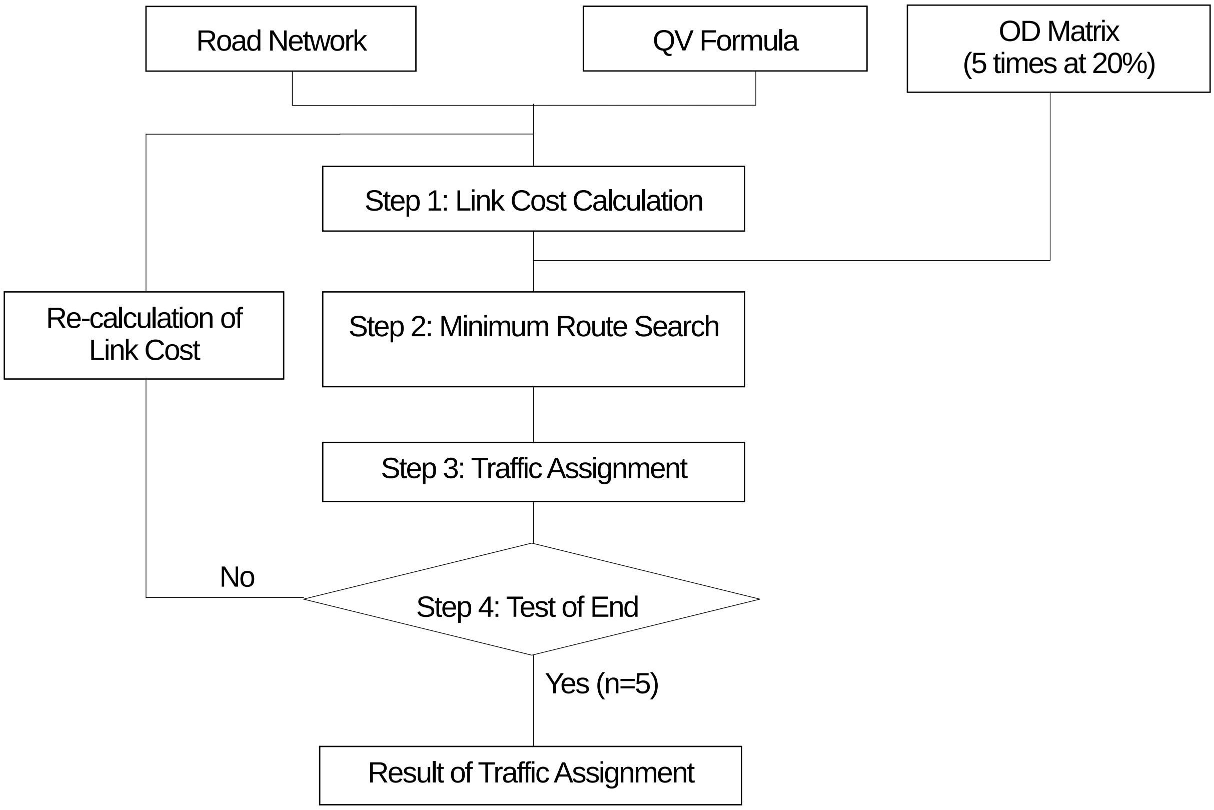
[Step 0] Initialize: Set the increment $n=0$ and the link traffic pattern $X^{(0)} = 0$.

[Step 1] Link cost calculation: Calculate the link cost $t^{(n)}$ by the traffic pattern.

[Step 2] Minimum route search: Search the minimum route under the link cost of $t^{(n)}$. The minimum route search uses the Dijkstra algorithm.

[Step 3] Traffic assignment to road network: Assignment of the traffic of OD matric on it to obtain the new traffic pattern $X^{(n)}$. The split rate of OD matrix was five times per 20% in common for all types of vehicles.

[Step 4] Test of end: If it is the last increment, stop. Otherwise, set the increment $n=n+1$ and go to Step 1.



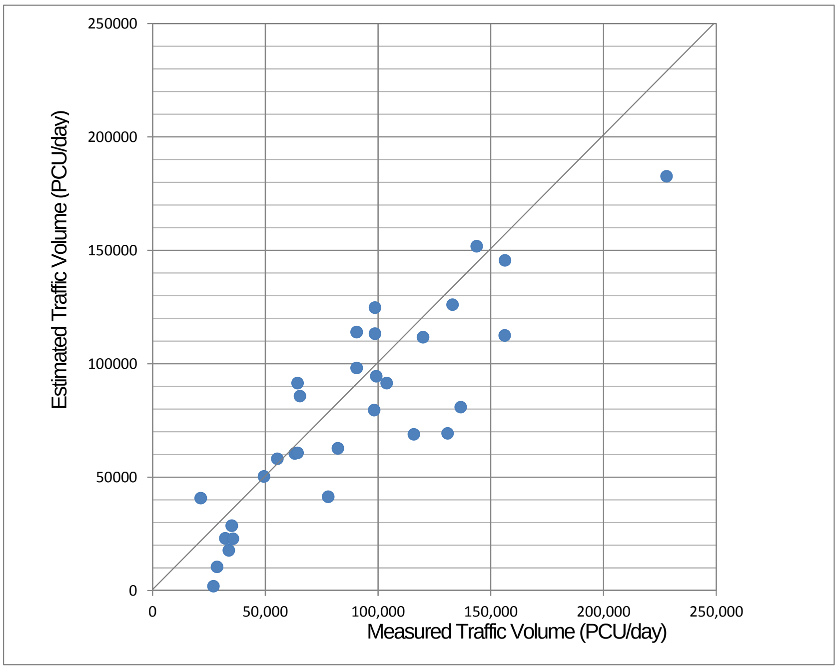
Source: JICA Experts

Figure 4.5.2 Traffic Assignment Procedure

4.5.2 Confirmation of Reproducibility of Current Conditions

For traffic volume assignment, the reproducibility of current conditions is confirmed using an incremental assignment method to assign future traffic volume.

The results of the reproduction of current conditions are shown in Figure 4.5.3 and Table 4.5.3. For a total of 32 major cross sections, the correlation coefficient of the actual value and estimated value was 0.86, from which it was judged that the reproducibility of current conditions was assured. Based on the above parameter conditions, an estimate of future traffic volume is carried out.



(Vertical Axis: Estimated Value x Horizontal Axis: Measured Value)

Source: JICA Experts

Figure 4.5.3 Results of Reproduction of Current Conditions

Table 4.5.3 Comparison of Measured Traffic Volume and Estimated Value

Road Name	Traffic Volume		Gap (100 PCU/day)	Ratio of Gap
	Measured (100 PCU/day)	Estimated (100 PCU/day)		
NH17 Mysore Rd.	992	945	48	5%
NH7 Hosur Rd.	1,331	1,260	71	5%
NH4 Old Madras Rd.	2,280	1,826	454	20%
NH7 Bellary Rd.	1,563	1,455	108	7%
NH4 Tumkur Rd.	1,437	1,518	-81	-6%
Outer Ring Rd.	906	981	-75	-8%
White Field Rd.	822	627	195	24%

Source: JICA Experts

4.5.3 Results of Future Traffic Volume Assignment

The results of the forecasting of traffic volume for the year 2040 are shown in Table 4.5.4. From these results, the design daily volume for the main lane is 128,000 PCU/day in 2040. This traffic volume is the distance weighted average of BPRR. Based on the traffic count survey result conducted in 2014 shown in Table 4.5.6, the peak hour ratio of BPRR will be more than 7%. On the other hand, the design standard for expressways in India, which is IRC (SP: 99-2013), indicates that the road capacity of six lanes to keep the level of service B is around 114,000 PCU/day in the peak hour ratio of 7% as shown in Table 4.5.7. Based on the standard therefore, it can be said that the main lane of BPRR needs to be an eight-lane road in order to ensure the level of service B.

At the same time, the design traffic volume for service roads is 33,000, which is lower than the road capacity of 60,000 PCU/day for a four-lane road set out in IRC (64-1990). It is reasonable that the service roads be four-lane roads. However, the traffic volume of the service road shown here is the traffic volume estimated by the traffic assignment between the zones. In fact, traffic is expected by a short trip user in the internal zone. Even if twice the traffic was generated due to the internal zone traffic, the road capacity of four lanes could manage the generated traffic. If more than the expected development was advanced, the new road should be planned depending on the progress speed of development of land use or growth of population.

Table 4.5.4 Result of Traffic Assignment and Design Daily Volume

S.N.	Name of JCT	Main Lane		Service Road
		Traffic Volume (PCU/day)	Ratio of Large-size Vehicle	Traffic Volume (PCU/day)
1	Tumkur Rd. JCT	130,300	16%	21,700
2	Hessarghatta JCT	153,200	15%	31,500
A1	Aditional IC No. 1	148,000	14%	30,300
3	Doddaballapura JCT	152,600	14%	31,000
4	Bellary JCT	135,700	14%	32,200
5	Hennur JCT	146,600	14%	21,400
A2	Aditional IC No. 2	142,800	14%	48,100
6	Old Madras Rd JCT	127,700	14%	36,200
7	Whitefield JCT	111,400	14%	25,600
A3	Aditional IC No. 3	115,800	15%	28,600
8	Hoskote-Anekal JCT	116,900	12%	51,900
9	Sajapur JCT	90,000	9%	41,600
10	Hosur Rd JCT			
Average (Design Daily Volume)		*128,000*	*14%*	*33,000*

Note: Average is the distance weighted average

Source: JICA Experts

Table 4.5.5 Result of Traffic Demand Forecast on Main Lane of BPRR by Section

Year	Section 1 (0-18 km)	Section 2 (18-36 km)	Section 3-1 (36-50 km)	Section 3-2 (50-65 km)	Total (PCU/day)
2022	39,000	41,000	40,000	39,000	42,000
2030	84,000	78,000	69,000	64,000	74,000
2040	146,000	141,000	116,000	105,000	128,000

Source: JICA Experts

Table 4.5.6 Result of Traffic Demand Forecast on Service Road of BPRR by Section

Year	Section 1 (0-18 km)	Section 2 (18-36 km)	Section 3-1 (36-50 km)	Section 3-2 (50-65 km)	Total (PCU/day)
2022	11,000	23,000	14,000	15,000	15,000
2030	23,000	30,000	20,000	24,000	25,000
2040	29,000	36,000	28,000	37,000	33,000

Source: JICA Experts

Table 4.5.7 Design Service Volume for Expressways in Plain and Rolling Terrain (in PCU/day) for LOS B

Design Service Volume in PCU/day for Level of Service B		
4-Lane	6-Lane	8-Lane
86,000 for PHF (6%) 75,500 for PHF (7%) 65,000 for PHF (8%)	130,000 for PHF (6%) 114,000 for PHF (7%) 98,000 for PHF (8%)	173,000 for PHF (6%) 151,500 for PHF (7%) 130,000 for PHF (8%)

PHF: Peak hour factor

Note: PHP 7% is an estimation by the JICA Experts

Source: IRC: SP:99-2013

Table 4.5.8 Peak Hour Volume and Ratio

	Old Madras	Bellary	Tumkur	Whitefield
Peak traffic volume	14,168	11,675	7,142	5,578
Daily traffic volume	198,303	153,291	105,232	78,642
Hourly peak %	7.1%	7.6%	6.8%	7.1%

Source: Results of Bengaluru ITS Master Plan Traffic Survey

Table 4.5.9 Passenger Car Unit

Type	PCU Factor	Type	PCU Factor
Two-Wheeler	0.5	LCV	1.5
Auto Rickshaw	1.0	Truck	3.0
Passenger Car	1.0	MAV	4.5
Bus	3.0	-	-

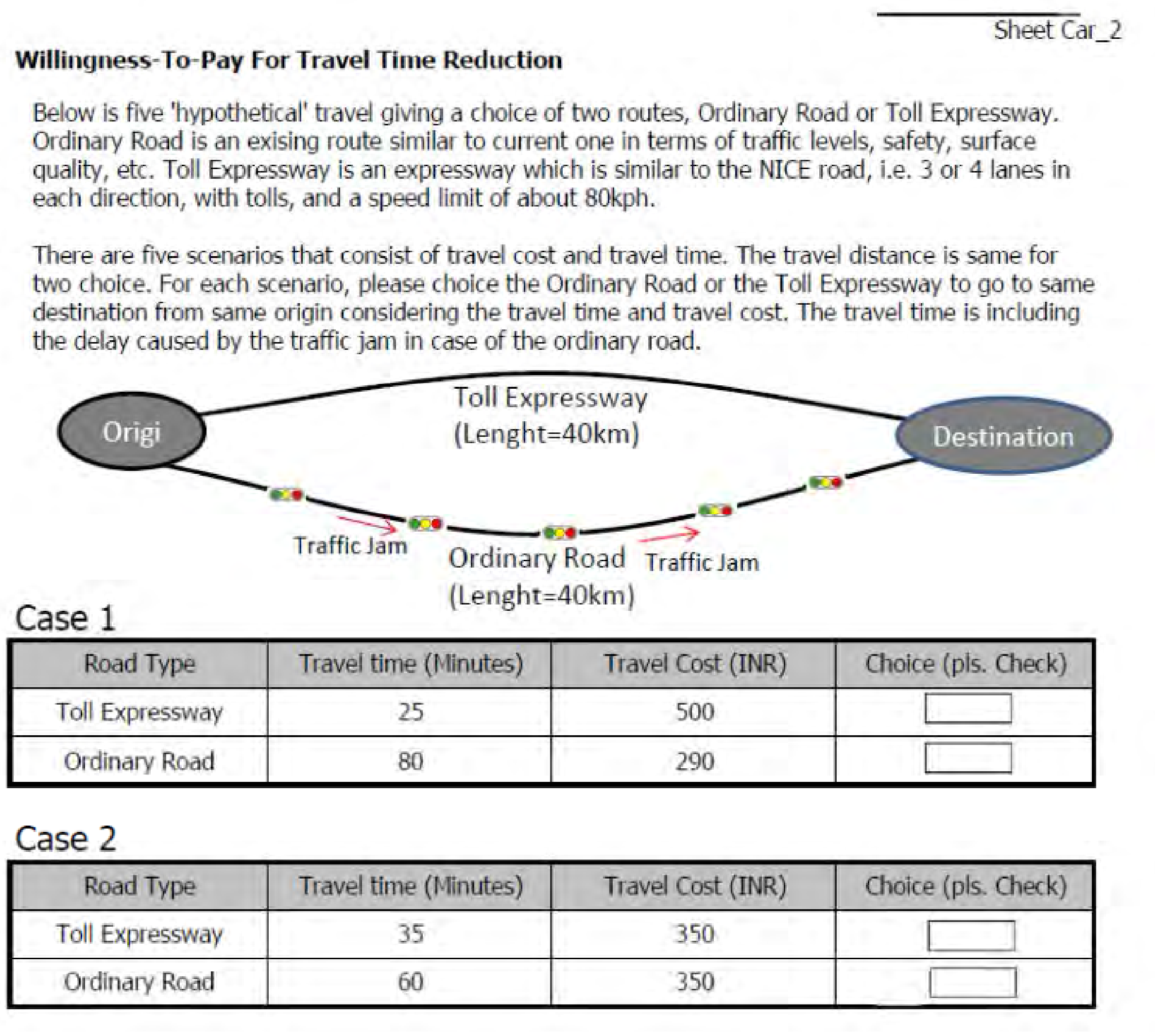
LCV: Light Commercial Vehicle, MAV: Multi Axle Vehicle (four wheel-axle or more)

Source: IRC 64-1990

4.6 Implementation of Road User Interview Survey

The questionnaire surveys to road users were carried out targeting the vehicle drivers at the gasoline fuel stations and truck parking areas located along Tumkur Road and Old Madras Road, and carriers of truck. This survey is aimed to carry out sensitivity analysis of the relationship between toll fee and travel time. The two types of questionnaires are prepared for passenger car and truck, each shown in Figure 4.6.1and Figure 4.6.2. The questionnaire has five cases consisting of the variable of toll fee and travel time for the 40-km drive by toll expressway or ordinary road. The level of toll fee and travel time in the base case was set referring to the toll fee of NICE Road and current traffic situation from the site survey.

The summary of the survey is shown in Table 4.6.1. The number of respondents collected was 776 in total that consists of 470 respondents as passenger car users and 306 respondents as truck users or carriers. The percentage of valid samples was 68% in passenger cars and 99% in trucks. The number of samples is obtained from the multiplication of the number of respondents and the five cases in the questionnaire. The valid samples, which consists of 1,600 samples of car and 1,515 samples of truck were used in the analysis.



Sheet Car_2

Willingness-To-Pay For Travel Time Reduction

Below is five 'hypothetical' travel giving a choice of two routes, Ordinary Road or Toll Expressway. Ordinary Road is an exising route similar to current one in terms of traffic levels, safety, surface quality, etc. Toll Expressway is an expressway which is similar to the NICE road, i.e. 3 or 4 lanes in each direction, with tolls, and a speed limit of about 80kph.

There are five scenarios that consist of travel cost and travel time. The travel distance is same for two choice. For each scenario, please choice the Ordinary Road or the Toll Expressway to go to same destination from same origin considering the travel time and travel cost. The travel time is including the delay caused by the traffic jam in case of the ordinary road.

Case 1

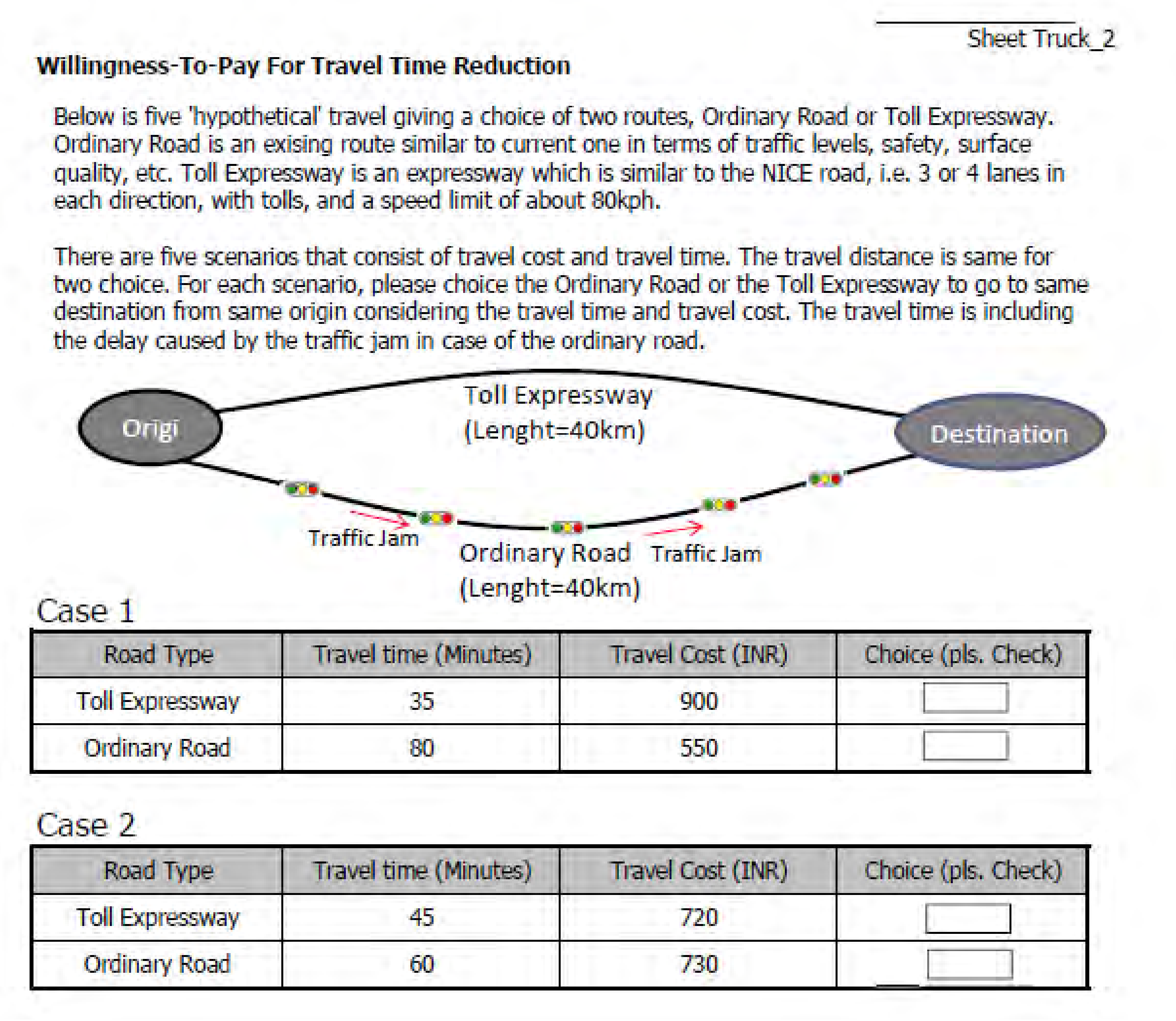
Road Type	Travel time (Minutes)	Travel Cost (INR)	Choice (pls. Check)
Toll Expressway	25	500	☐
Ordinary Road	80	290	☐

Case 2

Road Type	Travel time (Minutes)	Travel Cost (INR)	Choice (pls. Check)
Toll Expressway	35	350	☐
Ordinary Road	60	350	☐

Source: JICA Experts

Figure 4.6.1 Questionnaire Road User Interview Survey for Passenger Car



Sheet Truck_2

Willingness-To-Pay For Travel Time Reduction

Below is five 'hypothetical' travel giving a choice of two routes, Ordinary Road or Toll Expressway. Ordinary Road is an exising route similar to current one in terms of traffic levels, safety, surface quality, etc. Toll Expressway is an expressway which is similar to the NICE road, i.e. 3 or 4 lanes in each direction, with tolls, and a speed limit of about 80kph.

There are five scenarios that consist of travel cost and travel time. The travel distance is same for two choice. For each scenario, please choice the Ordinary Road or the Toll Expressway to go to same destination from same origin considering the travel time and travel cost. The travel time is including the delay caused by the traffic jam in case of the ordinary road.

Case 1

Road Type	Travel time (Minutes)	Travel Cost (INR)	Choice (pls. Check)
Toll Expressway	35	900	☐
Ordinary Road	80	550	☐

Case 2

Road Type	Travel time (Minutes)	Travel Cost (INR)	Choice (pls. Check)
Toll Expressway	45	720	☐
Ordinary Road	60	730	☐

Source: JICA Experts

Figure 4.6.2 Questionnaire Road User Interview Survey for Truck

Table 4.6.1 Summary of Questionnaire Surveys

Classification		Number of Samples	Number of Respondents	Percentage of Valid Samples
Car	Number of valid samples	1,600	320	68%
	Number of samples collected	2,350	470	100%
Truck	Number of valid samples	1,515	303	99%
	Number of samples collected	1,530	306	100%

Source: JICA Experts

The analysis of route choice based on the disaggregated analysis was carried out applying the logit model shown in the formula below. The data obtained from the road user survey was used as the input data. A logit model was created using two variables, travel time and toll fee as travel cost.

$$V = \alpha t + \beta c + \gamma$$

$$P = \frac{\exp(V)}{\sum_{k=1,2} \exp(V_k)}$$

Where:

P = Choice probability

t = Travel time (min)

c = Toll fee (Rs)

k = Choice of route (expressway or ordinary road)

α,β,γ = Parameters

From the calculation, the parameters shown in Table 4.6.2 were obtained. The results for both the likelihood ratio (0.25 or higher) and the accuracy rate (70% or higher) are satisfactory. Moreover, the signs of the parameters were reasonable.

The time value was estimated from the result of calculation by logit model. The time value per vehicle to be applied to the traffic volume assignment obtained from an analysis of the results are shown in Table 4.6.3.

Table 4.6.2 Results of Disaggregated Analysis

Item	Unit	Car	Truck
Constant Term	-	4.876	6.446
Travel Cost (Toll fee)	Rs	-0.030	-0.019
Travel Time	min	-0.047	-0.051
Value of Time	Rs/min-person	1.59	2.65
	Rs/hr-person	95.11	159.03
Adjusted Likelihood Ratio	-	0.29	0.43
Accuracy Rate (Cost)	-	75.1	83.9
Accuracy Rate (time)	-	68.0	76.0

Source: JICA Experts

Table 4.6.3 Time Value per Vehicle

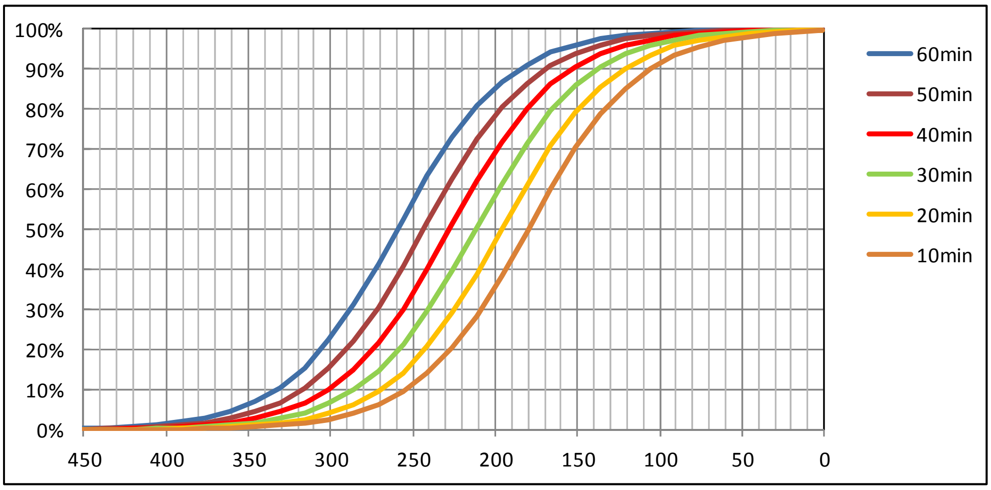
Vehicle Type	2014 (Rs/min)	2040 (Rs/min)
Two-wheeler	1.6	3.3
Car	4.0	8.3
Bus	10.3	21.6
Light Truck	2.1	4.4
Truck	5.3	11.1

**An annual increase of 3% in the value of time was anticipated.*

Source: JICA Experts

Figures 4.6.2 and 4.6.3 show the choice probability of expressway with the travel time difference between the expressway use and ordinary road use in the case of 40-km travel distance route. The JICA Experts can understand the sensitivity between the toll fee level and travel time.

This result shows the behavior of car users below. For example, in the case of the 40 minutes of travel time difference for the 40 km road distance between expressway use and ordinary road use, if the toll fee is Rs 230, which is nearly Rs 5.7/km, 50% of car users will use the expressway. If the toll fee is Rs 150, which is nearly Rs 3.7/km, 90% of the car users will use the expressway (see the red line). On the other hand, in the case of truck users shown in Figure 4.6.3, if there is 40-minute travel time difference, 70% of truck users will use the expressway with a toll fee of Rs 400.

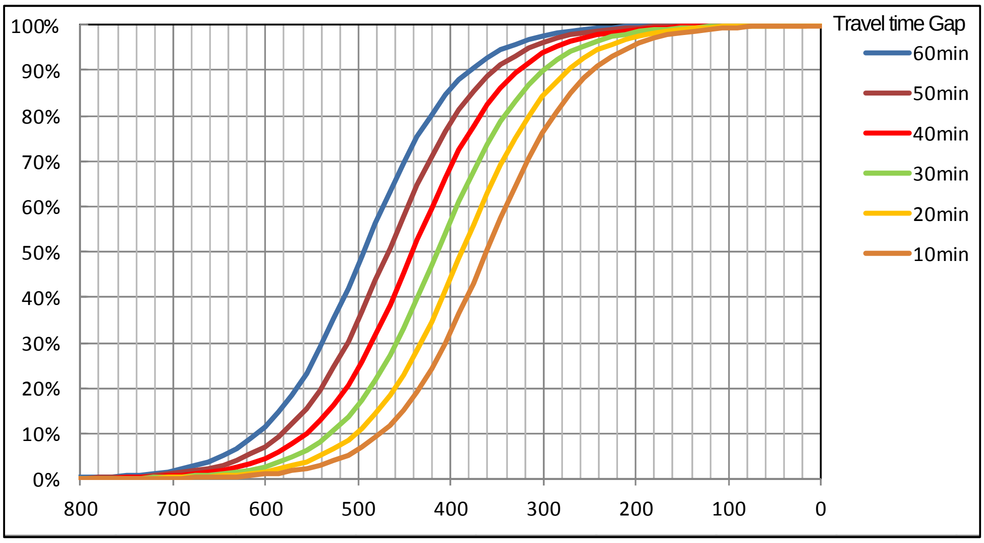


**Horizontal Axis: Toll Fee (Rs)*

***Driving distance: 40 km*

Source: JICA Experts

Figure 4.6.3 Choice Probability of Expressway by Travel Time Difference (Car Users)



**Horizontal Axis: Toll Fee (Rs)*

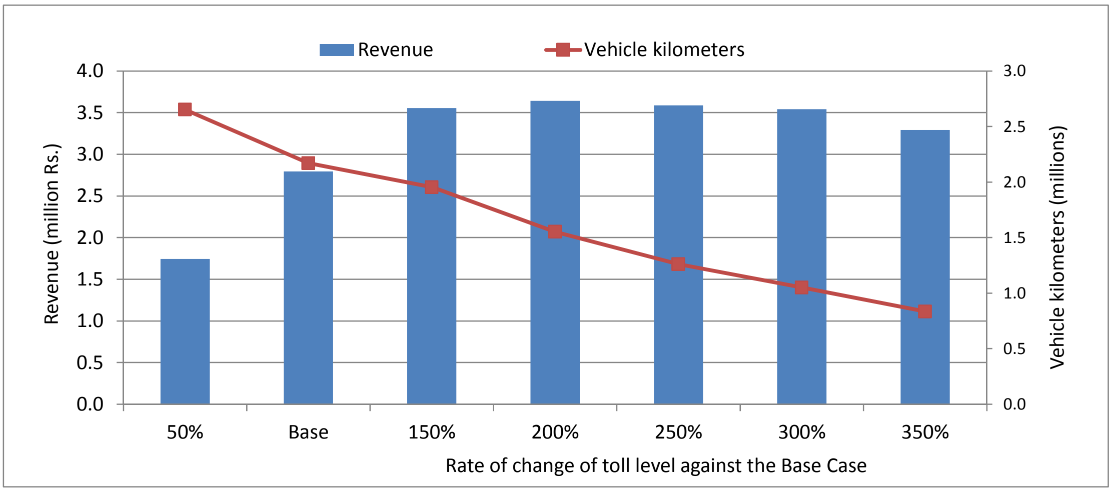
***Driving distance: 40 km*

Source: JICA Experts

Figure 4.6.4 Choice Probability of Expressway by Travel Time Difference (Truck Users)

4.6.1 Analysis of the pricing sensitivity

The sensitivity analysis of toll revenue per day was carried out in the case of changing the toll level of PRR. This analysis was performed by changing of 50% of the price level on PRR as one of the conditions of traffic assignment. The toll fee level in the base case was applied fee shown in Table 8.2.3 in Chapter 8. Figure 4.6.5 shows the relation between the change of PRR toll level and the toll revenue per day, and also the vehicle kilometers. As the result, In the case of abound 1.5 times or 2.0 times of tool level against the base case, the revenue is maximum.



Source: JICA Experts

Figure 4.6.5 Relation between the change of PRR toll level and the toll revenue per day, and also the vehicle kilometers

4.7 Analysis on the project effect

4.7.1 Operation and effect indicators

The operation and effect indicators are indicated in two years after commercial operation of PRR in table 4.7.1. For the approx. 35km of road distance between Tumkur Road JCT and Old madras road JCT road, it is expected that the travel time saving of 26 minutes from 54 minutes of travel time to 28 minutes of travel time. And also, regarding the travel speed for this distance, the current speed is 39 km/hr. but it would be upgrade to 75 km/hr by using the PRR. The relieve traffic congestion in city center is expected by the shifting of traffic that passed go to the city center.

Table 4.7.1 Operation and effect indicators

Indicator	Category	Original (Y2014)	Target（Y2024） 2 years after commercial operation
Annual average daily traffic（PCU/day）		－	88,000
Daily Average Travel Time (min) *1	PRR	－	28 min
	Local roads	54 min	47 min
Traffic speed (km/h) *1	PRR	－	75 km/hr
	Local roads	39 km/hr	44 km/hr
Cost Saving (million Rs./year) *2	VOC	－	4,900
	TTC	－	12,300

*1: Tumkur Road (JCT) - Old Madras Road (JCT) Road distance is approx. 35km

*2: All study area of traffic demand forecast and economic analysis

Source: JICA Experts

4.7.2 Effect of ITS measures implementation

In this section, the effect by the implementation of ITS measures that is explained in Chapter 5 was analyzed. The target component for evaluation here is the traffic information dissemination system and the advanced signal system that is the subject of the yen loan project. The spec and detail of ITS components is mentioned in Chapter 5.

The effect indicator is directed to a reduction in travel time by the implementation of ITS measures. The benefit by the travel time saving were calculated by the multiplication of reductions of total vehicle-hour realize by measures introduced and travel time cost.

The effect of reduction of vehicle-kilometers was calculated base on the traffic demand forecast. Note that the estimation was analyzed utilizing the study result in Bengaluru ITS Master Plan project by JICA. The basic idea of estimation of effect of ITS measures implementation on that master plan project is presented below.

Regarding the project evaluation for the traffic information dissemination, it is calculated based on the traffic demand forecast. The basic case of traffic demand forecast was estimated by the five step traffic assignment method. For the analysis of effect of ITS implementation, we conducted the road assignment under the assumption which is realized the system optimum state of traffic flow on all target road network. And then, the gap of total vehicle-hour was calculated as the reduction effect by the implementation of ITS measure. The hunting reaction is not considered here. The effect indicator is directed to a reduction in travel time.

On the other hand, the advanced signal system is expected to reduce delay time at intersection to coordinate the optimal cycle time of signal and timing of green light time. As a result, the traffic capacity at intersection is increased. In this study, it is assumed that the implementation of advanced signal system allows the increase of link capacity of 10%. The calculation is conducted by traffic assignment.

The travel time cost applied for the project evaluation is shown in Table 4.7.2. And, the calculation result of benefit is shown in Table 4.7.3. Based on this result, the economic analysis will be conducted in Chapter 8.

Table 4.7.2 Travel Time Cost (2015)

Vehicle Type	Time Cost (Rs./hr./veh)
Two-wheeler	71.7
Car	448.2
Bus	2794.3
LCV	7.2
MAV	41.5

Source: JICA Experts

Table4.7.3 Benefit by ITS Measure Implementation

ITS Measure	Benefit (Billion Rs.)
Traffic Information Dissemination(B-TIC)	0.57
advanced signal system	1.53
Total	2.10

Source: JICA Experts

CHAPTER 5 INTELLIGENT TRANSPORT SYSTEMS (ITS)

5.1 ITS Components Funded by the Grant and Loan Projects

(1) Explanation by JICA Experts

ITS Master Plan for Bengaluru Metropolitan Area (referred to as 'ITS Master Plan' hereinafter) was finalised and the Study was completed on 30th June 2015.

Japanese grant project (referred to as 'the grant project' hereinafter) and Japanese loan project (referred to as 'the loan project' hereinafter) are planned for development of ITS which are proposed by ITS Master Plan.

The table below shows ITS components which will be developed by the grant and loan projects.

The centre systems and roadside equipment at the important locations of Bengaluru Traffic Information System (referred to as 'B-TIC' hereinafter) and Area Traffic Signal Control System (referred to as 'ATCS' hereinafter) will be prepared by the grant project. The coverage area of B-TIC and ATCS will be expanded by the loan project.

The involved Indian organisations in Bengaluru for the development of these ITS components are DULT, BDA and Bengaluru Traffic Police. (The details as to how they are involved are described in the later sections.)

JICA Experts explained the ITS components which will be developed by the grant and loan projects to DULT, BDA and Bengaluru Traffic Police.

Table 5.1.1 ITS Components by the Grant and Loan Projects

ITS Component			Grant	Loan
City ITS	Bengaluru Traffic Information System (B-TIC)	Centre System (including Probe Car System)	●	●
		Queue Length Measurement System		
		Automatic Traffic Counter-Cum Classifier (ATCC) System		
		Variable Message Sign (VMS) System		
		Internet System		
	Area Traffic Signal Control System (ATCS) (*1)		●	●
	Clearinghouse for Common Smartcard			●
ITS for PRR	Highway Traffic Management System (HTMS)			●
	Toll Management System (TMS)			●

Source: JICA Expert

*Note (*1): Additional ATCS will be installed by Indian government after the loan project implementation.*

(2) Conclusion

DULT, BDA and Bengaluru Traffic Police understood the ITS components which will be developed by the grant and loan projects.

5.2 Phased-wise Installation of City ITS by the Grant and Loan Projects

5.2.1 Policy of Coverage Area by the Grant and Loan Projects

(1) Explanation by JICA Experts

ITS Master Plan proposes that ITS components of City ITS be implemented in a phased manner. Under the situation that the grant project will be carried out followed by the loan project, JICA experts further considered the quantity of equipment of ITS components of City ITS covered by the grant project and the loan project in line with the phasing policy of ITS Master Plan.

The policy of the coverage area is set out and explained to DULT, BDA and Bengaluru Traffic Police. The policy of the coverage area is shown in the table on the next page.

Table 5.2.1 Policy of Coverage Area of ITS Components (City ITS)

ITS Component (City ITS)		Grant (Phase-1)	Loan (Phase-2)
Bengaluru Traffic Information System (B-TIC)	Centre System including Probe Car System (*1)	Centre Setup	Centre Upgrade
	Queue Length Measurement System (*2)	Inside ORR	-
	Automatic Traffic Counter-Cum Classifier (ATCC) System	Inside ORR	Inside ORR/PRR
	Variable Message Sign (VMS) System	Inside ORR	Inside ORR/PRR
	Internet System	Inside ORR	Inside ORR/PRR
Area Traffic Signal Control System (ATCS) (*3)		Selected intersections on major road	Inside ORR
Clearinghouse for Common Smartcard		-	Bengaluru Metropolitan Area

Source: JICA Expert

*Note (*1): Probe Car System: Phase-1 (Grant) BMTC probe data, Phase-2(Loan) KSRTC and other probe data.*

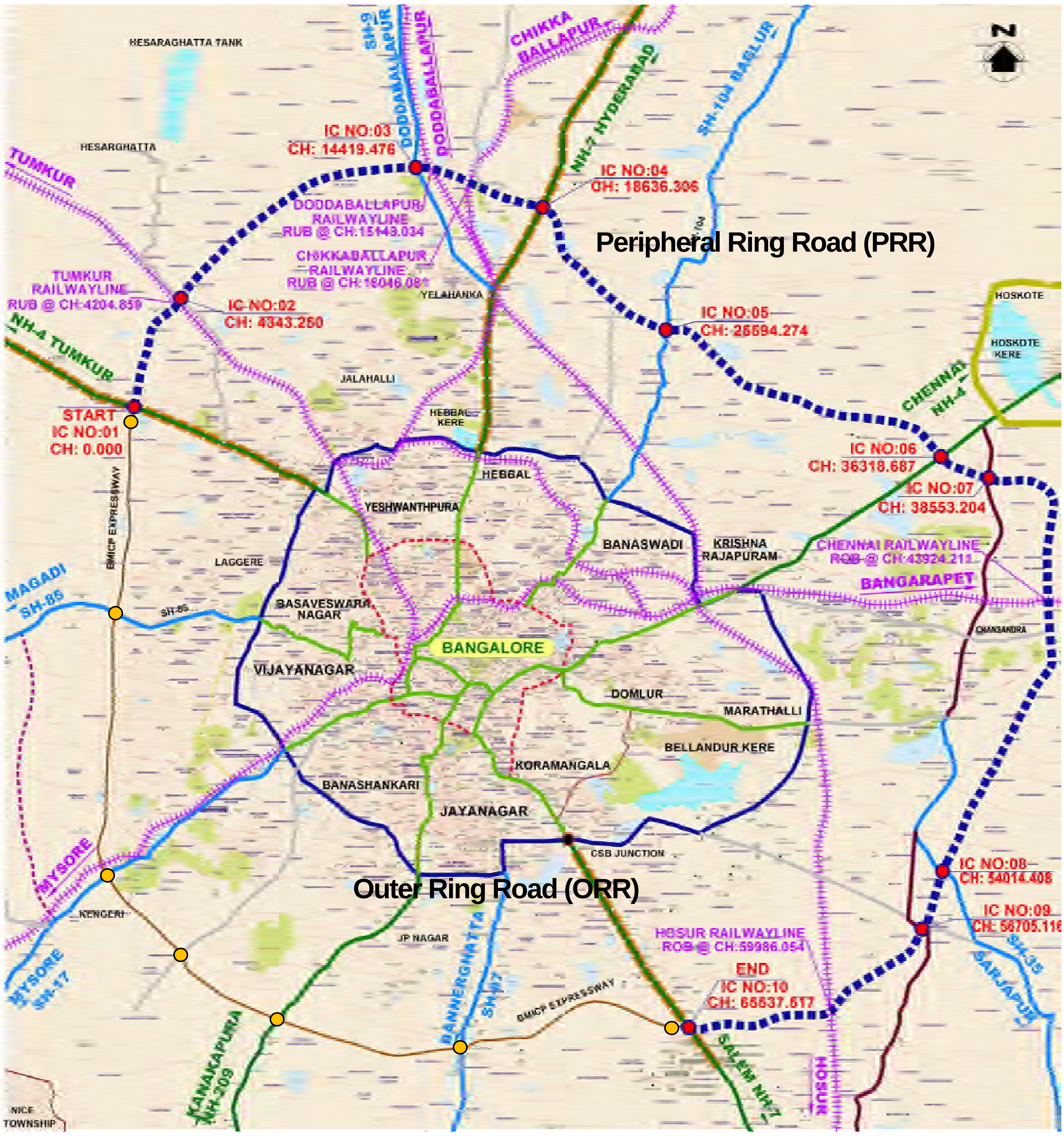
*Note (*2): All equipment at 13 locations will be covered by the grant project.*

*Note (*3): Further phases of ATCS can be considered by Indian government, evaluating the situation after the loan project implementation.*

The location map of Outer Ring Road (ORR) and Peripheral Ring Road (PRR) is shown on the next page.

(2) Conclusion

DULT, BDA and Bengaluru Traffic Police understood the policy of the coverage area explained by JICA Experts.



Source: ITS Master Plan for Bengaluru edited by JICA Expert

Figure 5.2.1 Location Map: Outer Ring Road (ORR) and Peripheral Ring Road (PRR)

5.2.2 Details of Phased-wise Installation by the Grant and Loan Projects

Area Traffic Signal Control System (ATCS)

(1) Explanation by JICA Experts

Under the situation where the grant project is planned, followed by the loan project for ATCS, the phased-wise proposal made by ITS Master Plan needs to be re-considered taking into consideration of budget and installation period of the projects. JICA Experts investigated and proposed as follows:

- Grant (Phase-1): 20 intersections along the major road inside ORR,
- Loan (Phase-2): 180 intersections inside ORR, and
- Remaining ATCS: Future phases can be considered by Indian government based on evaluation after the loan project implementation

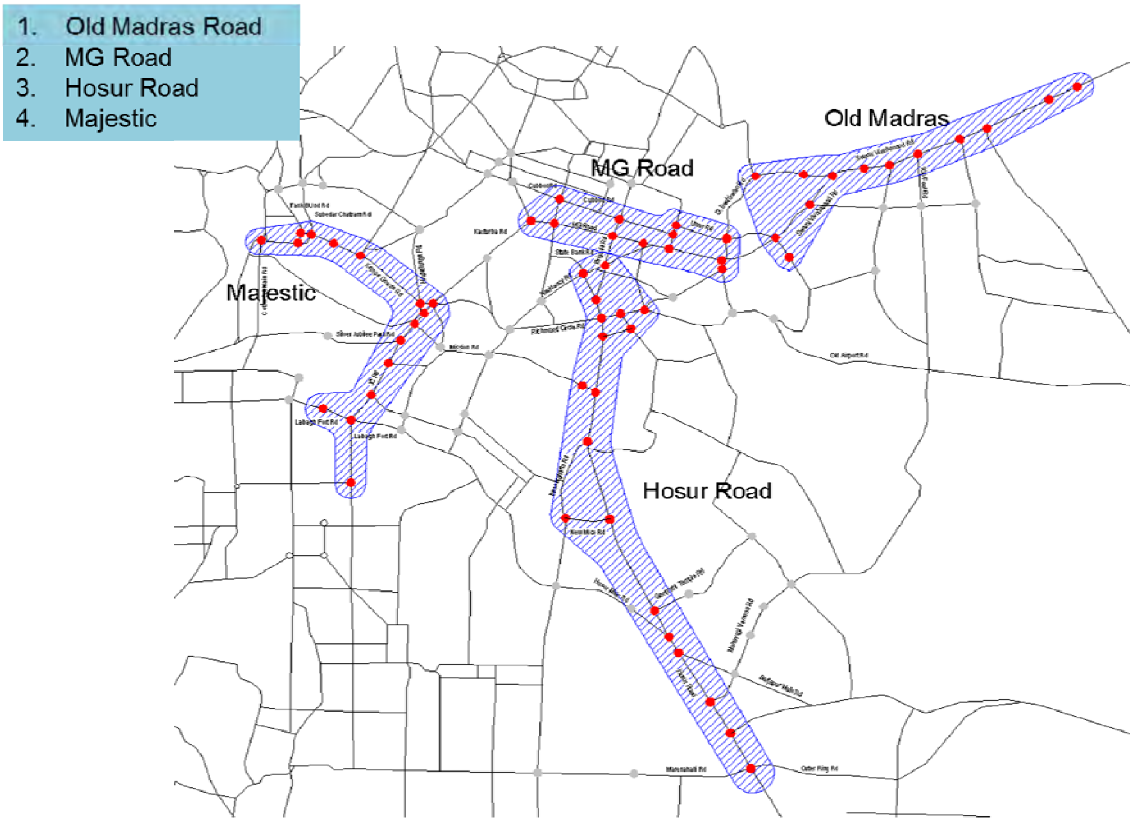
JICA Experts explained the proposed phased-wise installation of ATCS to DULT, BDA and Bengaluru Traffic Police. The details are explained below.

<Grant (Phase-1)>

The proposed intersections and corridors of ATCS for the grant project are shown in the figure on the next page. These are grouped, for signal coordination, by the major roads in the city which are Old Madras Road, MG Road, Hosur Road and the roads in the area of Majestic. It is likely that one of these groups (or combination) will be selected for the grant project.

JICA Experts for this review study assumed approximately 20 intersections for the grant project.

It is noted that the target corridors and intersections will be finalised with the consensus with Bengaluru Traffic Police during the grant project.



Source: JICA Expert

Figure 5.2.2 Proposed Intersections and Corridors of ATCS for the Grant Project

<Loan (Phase-2)>

The general practice is that installation at 150 intersections takes 24 months. (Example: It generally takes approximately 0.7 month per intersection for signal construction. Five (5) parties (each party per intersection) work in parallel, and then 21 months are required for completion of construction. It takes one (1) to two (2) months for preparation for commencement of construction after contracting. It also takes one (1) to two (2) months for calibration/trial run after completion. Thus it becomes 24 months in total. This includes minimum civil works for intersection improvement such as pavement, lane marking, preparation of median, etc.)

The installation period for ATCS for the loan project is drawn for 33 months (explained later). The last three (3) months are for system calibration. Thus, a total of 30 months will be spent for installation.

Considering the proposal made by ITS Master Plan and possible numbers of the intersections within the installation period for the loan project, it is proposed to cover by the loan project as:

- Remaining 80 intersections in the core area, and
- 100 intersections inside ORR (to be selected in the design stage), totalling 200 intersections.

(2) Conclusion

ATCS by the Grant Project:

DULT and Bengaluru Traffic Police understood the explanation of JICA Experts and agreed with the proposal.

ATCS by the Loan Project:

DULT wishes, if possible, that the number of ATCS for the loan project be increased, adding from ATCS to be developed by State budget. They stated that the cost of consultant fee is currently estimated at 300 crore on which DULT does not agree. This amount could be utilised for ATCS.

JICA Experts explained that the number of ATCS for the loan project was drawn considering the construction period.

DULT further stated that it could be arranged as stage-1 and stage-2.

JICA Experts suggested that this matter be finalised during the next meeting with JICA together with the matter of the consultant fee and with consideration of the allowed period of the construction after the year of 2021 for JICA loan.

Bengaluru Traffic Information System (B-TIC)

B-TIC comprises the sub-systems with the purposes as shown in table below.

Table 5.2.2 Sub-systems and Purposes: B-TIC

Category of Function	Sub-system	Purpose
Data Processing	a) Centre System	To process and cummulate collected data and provide information
Data Collection	b) Probe Car System	To collect probe data to generate congestion information
	c) Queue Length Measurement System	To measure queue length to generate congestion information (supplement to Probe Car System)
	d) Automatic Traffic Counter-Cum Classifier (ATCC) System)	To measure traffic volume (for road management purpose)
Information Provision	e) Variable Message Sign (VMS) System	To provide dynamic traffic information to road users
	f) Internet System	To provide dynamic traffic information to road users

(1) Explanation by JICA Experts

JICA Experts elaborated the development plans for B-TIC for the grant and loan projects in line with the basic concept of ITS Master Plan. They are proposed below.

1) Centre System

<Grant (Phase-1)>

The central server and servers for the sub-systems will be prepared in B-TIC centre.

B-TIC centre will be prepared on the 2nd floor of the existing DULT office building (already decided during ITS Master Plan Study).

<Loan (Phase-2)>

The software of the central server and servers for the sub-systems in B-TIC centre will be modified as the coverage area of the sub-systems are expanded.

2) Probe Car System

< Grant (Phase-1)>

Bengaluru Metropolitan Transport Corporation (referred to as 'BMTC' hereinafter), a governmental city bus operator, plans to develop a bus monitoring system installing GPS devices on their 6700 city buses. (The bus monitoring system is under trial as of July 2015.)

The probe car system for B-TIC is proposed to utilise the probe data obtained from the GPS devices on these city buses to cover the major roads in the city, mainly inside ORR.

< Loan (Phase-2)>

The routes on which BMTC city buses run concentrate inside ORR (although they cannot be clearly divided in terms of area as these are roads.)

Karnataka State Road Corporation (referred to as 'KSRTC' hereinafter) is a governmental inter-city bus operator. They operate approximately 8,000 buses departing/arriving from/to Bengaluru city.

It is proposed that the probe data be obtained mainly from KSRTC buses and other vehicles in phase-2 to increase density of data collection and cover up to PRR area.

3) Queue Length Measurement System

<Grant (Phase-1)>

The roadside equipment for queue length measurement system will be installed at the intersections where severe congestion frequently occurs to supplement to the probe car system. ITS Master Plan indentified 13 locations (100 units) in the city.

It is proposed that the grant project covers all these 13 locations.

In combination with the above probe car system, the data collection will cover the major roads in the city.

4) Automatic Traffic Counter-Cum Classifier (ATCC) System

<Grant (Phase-1)>

ITS Master Plan proposes to install ATCC roadside equipment at 40 locations (80 units: 2 units at one location) in total in Bengaluru (on the midpoint between major intersections of major roads). Installing them at all these locations by the grant project is not practical considering the budget and installation period. It is also considered that the number of installation locations can be compromised to the practical level in consideration of the purpose of the sub-system, which is not for congestion information generation as described in the table on the previous page.

The candidate corridors for ATCS for the grant project are shown in Figure 5.2.2.

It is assumed that any of Old Madras Road, MG Road or Hosur Road (or combination) would be selected as the target roads for ATCS for the grant project, not from Majestic area. This is because that a large number of bus depot (BMTC and KSRTC) and suburban train stations exist in Majestic area with higher number of illegal parking on the road than other areas. The traffic is consequently more saturated in Majestic area compared to other three (3) candidate areas. It is considered that more demonstration effectiveness of ATCS in these three (3) candidate areas than Majestic area can be achieved.

JICA Experts recommend that the roadside equipment of other sub-systems be also deployed along the target roads of the grant project.

Based on the above considerations, the coverage area of ATCC is delineated as shown in the figure on the next page.

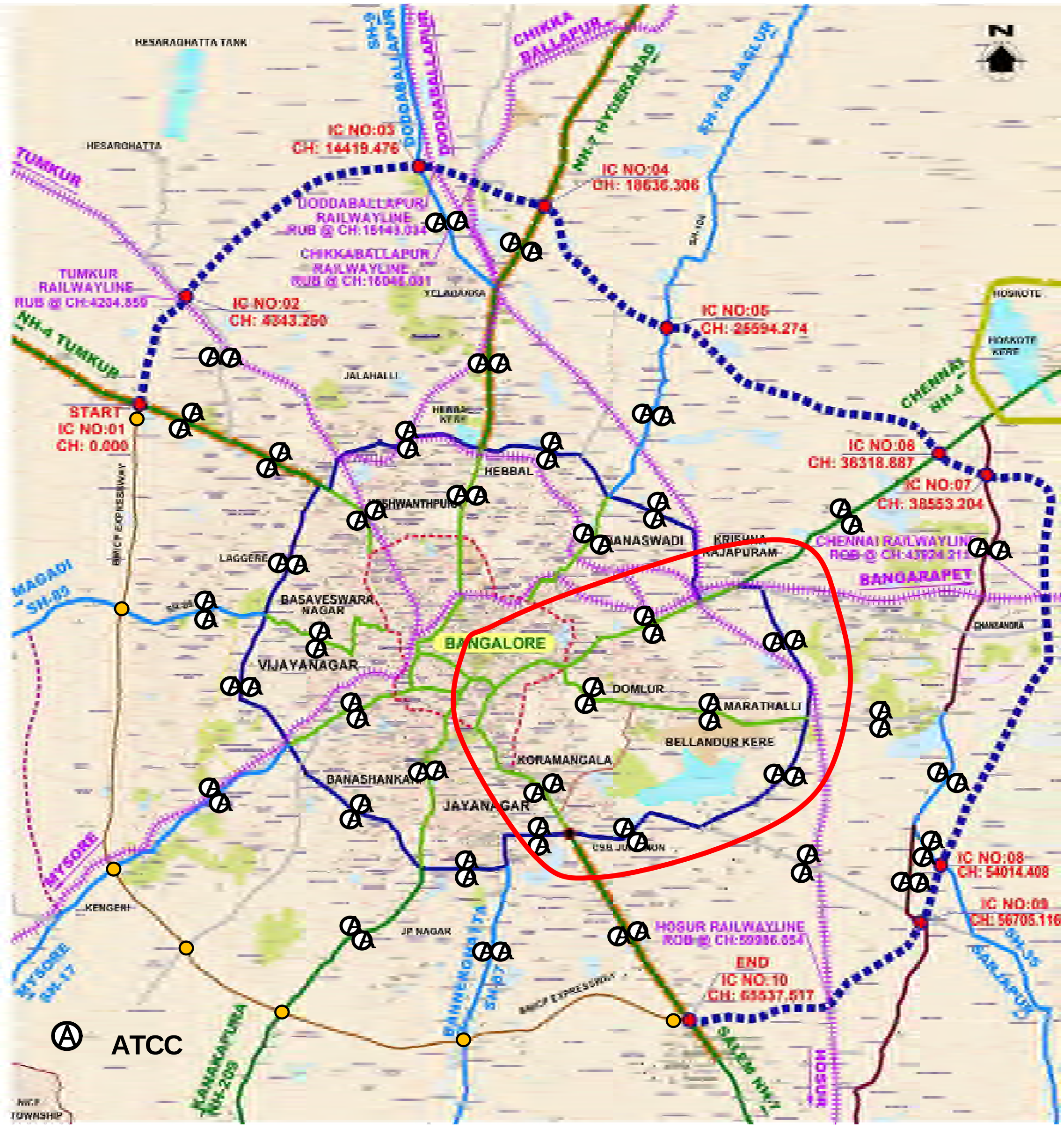
The red-encircled area in the figure includes Old Madras Road, MG Road, Hosur Road and ORR.

It includes eight (8) locations of ATCC (16 units: 2 units at one location at midpoint of major roads in the area).

It is noted that the above considerations are assumption of JICA Experts as of July 2015 and the details will be finalised during the grant project.

<Loan (Phase-2) >

ATCC will be installed at the remaining 32 locations (64 units) to cover the entire Bengaluru as shown in the figure on the next page.



Source: ITS Master Plan for Bengaluru edited by JICA Expert

Grant Project: ATCCs inside the red-circled area

Loan Project: Remaining ATCCs on the map

Figure 5.2.3 Location Map of ATCC in Bengaluru

5) Variable Message Sign (VMS) System

<Grant (Phase-1) >

The dynamic congestion information generated from probe car system and queue length measurement system will be provided by Variable Message Sign (VMS) board.

ITS Master Plan proposes to install VMS Board at 20 locations in total in Bengaluru. Likewise ATCC, installing them at all these locations by the grant project is not practical considering the budget and installation period.

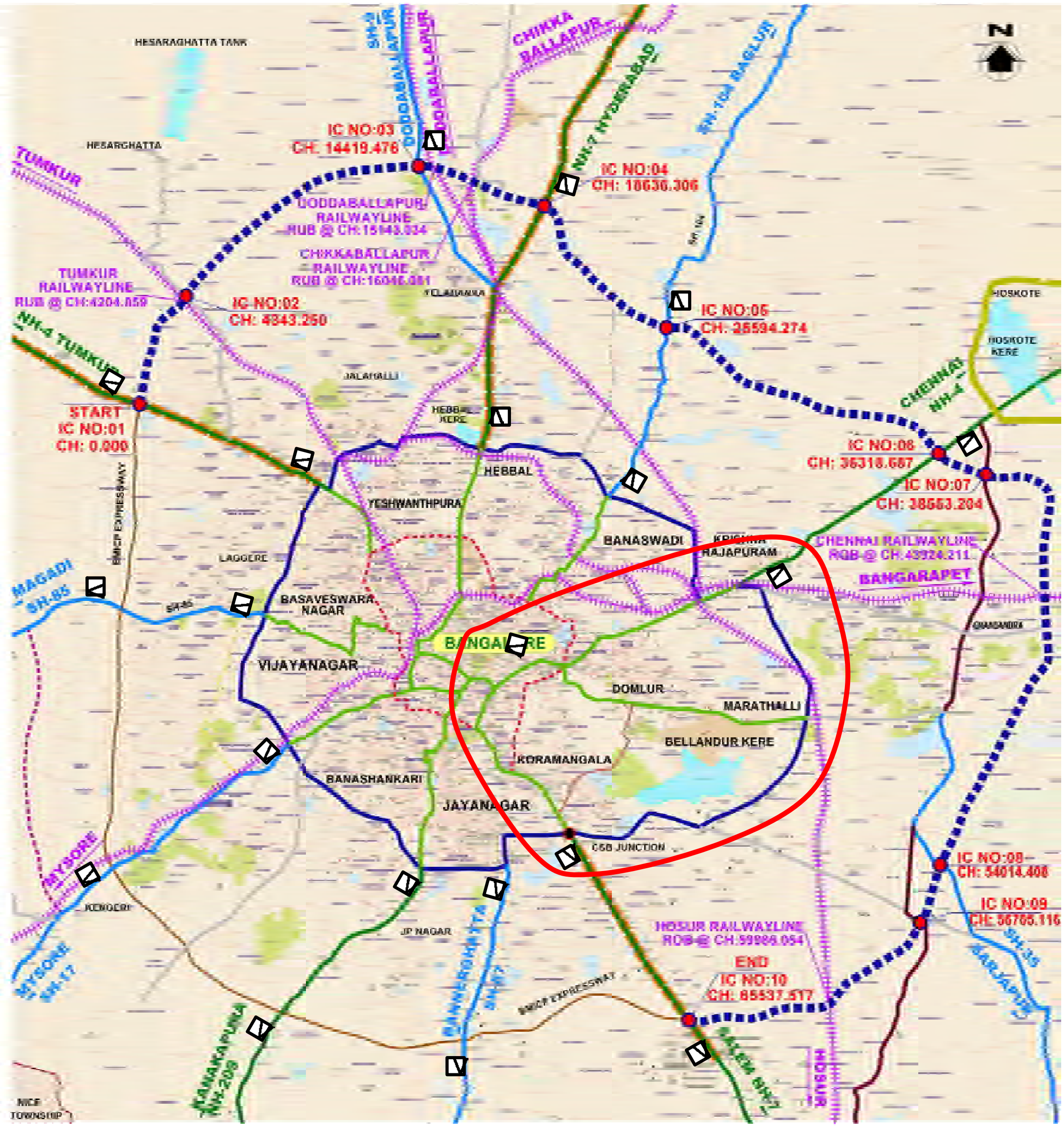
Based on the same considerations made for ATCC explained above, the coverage area of VMS board is delineated as shown in the figure on the next pate.

It includes three (3) locations of VMS board (3 units) in the area.

It is also noted that the above considerations are assumption of JICA Experts as of July 2015 and the details will be finalised in the design of the grant project.

<Loan (Phase-2) >

VMS board will be installed at the remaining 17 locations (17 units) to cover the entire Bengaluru as shown in the figure on the next page.



Source: ITS Master Plan for Bengaluru edited by JICA Expert

Grant Project: VMSs inside the red-circled area

Loan Project: Remaining VMSs on the map

Figure 5.2.4 Location Map of VMS in Bengaluru

6) Web based Interface (Internet System)

<Grant (Phase-1) >

The dynamic congestion information generated from probe car system and queue length measurement system will be provided by Web based Interface (Internet System).

The Web based Interface (Internet System) covers the major roads on which BMTC buses run and queue length measurement system are installed, mainly inside ORR in the grant project.

<Loan (Phase-2) >

The server software of the Web based Interface (Internet System) will be modified to cover the roads on which KSRTC buses and other vehicles run in the loan project.

(2) Conclusion

DULT, BDA and Bengaluru Traffic Police understood the proposal explained by JICA Experts and agreed.

5.3 Number of Equipment of ITS Component by the Grant and Loan Project

(1) Explanation by JICA Experts

JICA Experts considered the number of equipment of ITS components based on the considerations made in the previous clauses. They are as shown in the table on the next page.

Three (3) interchanges were added and the number of toll lanes at the interchange for PRR was adjusted during the PRR Review Study. The number of equipment for PRR ITS (Highway Traffic Management System: HTMS and Toll Management System: TMS) was adjusted accordingly.

JICA Experts explained the proposed number of equipment of ITS components by the grant and loan projects to DULT, BDA and Bengaluru Traffic Police.

Table 5.3.1 Number of Equipment of ITS Component by the Grant Project and Loan Project

Unit=Set

	ITS Component		Grant	Loan
City ITS	Bengaluru Traffic Information System (B-TIC)	Centre System including Probe Car System	1	Upgrade
		Queue Length Measurement System	100	
		Automatic Traffic Counter-Cum Classifier (ATCC) System	16	64
		Variable Message Sign (VMS) System	3	17
		Web based Interface (Internet System)	1	Upgrade
	Area Traffic Signal Control System (ATCS)		20	180
	Clearinghouse for Common Smartcard			1
ITS for PRR	Highway Traffic Management System (HTMS)	Centre System (Traffic Control Centre)		1
		Automatic Traffic Counter-Cum Classifier (ATCC) System		24
		CCTV System		24
		Variable Message Sign (VMS) System		50
		Internet System		1
	Toll Management System (TMS)	Centre System (Toll Mangement Centre)		1
		Toll Plaza System		13
		Electronic Toll Collection (ETC) System		46
		Mannual and Touch & Go System		108

Source: JICA Expert

(2) Conclusion

DULT, BDA and Bengaluru Traffic Police understood the proposal explained JICA Experts and agreed.

5.4 Cost of Equipment of ITS Component by the Grant and Loan Projects

(1) Explanation by JICA Experts

JICA Experts calculated the cost of equipment of ITS components as shown in the next page. The cost shown in the table is divided into the grant and loan projects based on the cost made by ITS Master Plan according to the number of the equipment presented in the previous clause.

JICA Experts explained the cost of equipment of ITS components to DULT and BDA.

Table 5.4.1 Cost of Equipment of ITS Component by the Grant and Loan Projects

Unit=INR

ITS Component		Equipment	
		Grant	Loan
Bengaluru Traffic Information System (B-TIC)	Centre System (including Probe Car System)	557,546,250	271,476,000
	Queue Length Measurement System	63,640,500	
	Automatic Traffic Counter-Cum Classifier (ATCC) System	34,317,360	137,269,440
	Variable Message Sign (VMS) System	42,124,005	238,702,695
	Internet System	60,060,000	1,155,000
Subtotal		**757,688,115**	**648,603,135**
ITS for Peripheral Ring Road	Highway Traffic Management System (HTMS)		791,903,340
	Toll Management System (TMS)		572,029,950
Subtotal			**1,363,933,290**
Area Traffic Signal Control System (ATCS)		207,510,300	1,321,563,900
Electronic Road Pricing (ERP) System			
Clearinghouse for Common Smartcard			389,620,800
Grand Total		**965,198,415**	**3,723,721,125**

Source: JICA Expert

Note: The costs for contingency and consultant were excluded from the cost estimate made by ITS Master Plan because they were considered separately in the PRR Review Study.

(2) Conclusion

DULT and BDA understood the cost explained by JICA Experts and agreed.

5.5 Information Provision by Bengaluru Traffic Police

(1) Explanation by JICA Experts

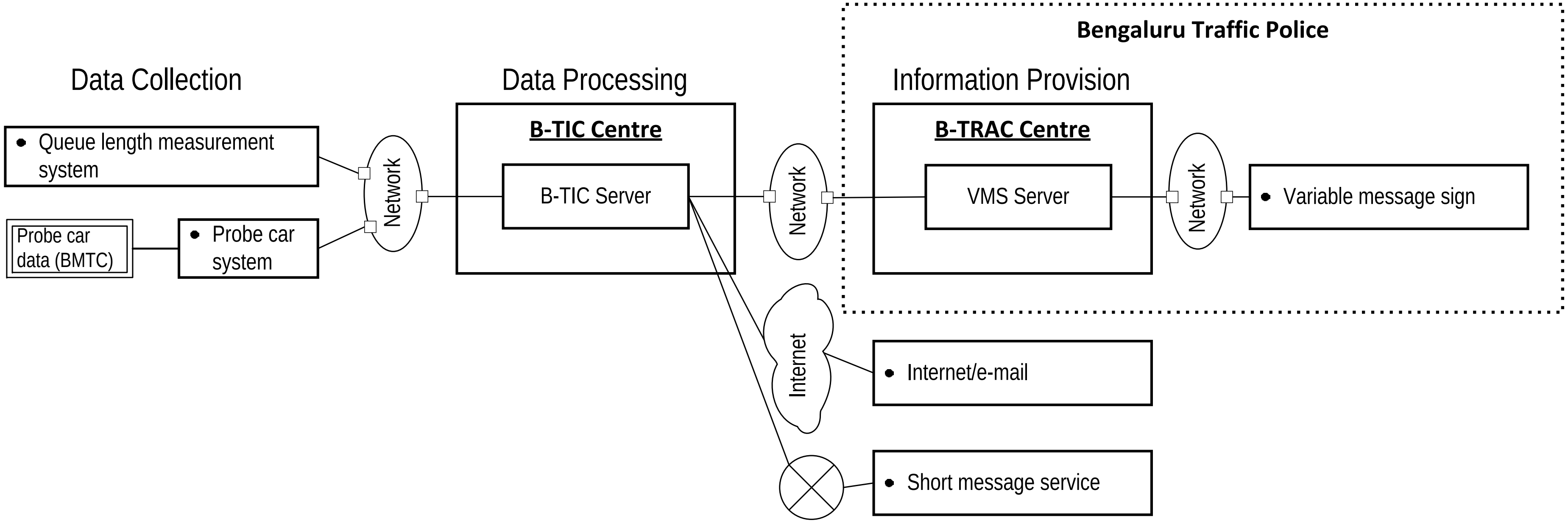
The following considerations were made during the meeting with DULT and explained to Bengaluru Traffic Police by JICA Experts.

B-TIC will be developed as 'Data Centre'. It collects, processes, analyses the traffic data and shares the result of processing to the relevant organisations. It is considered that the data on dynamic congestion information will be transmitted from B-TIC to B-TRAC centre of Bengaluru Traffic Police. This is because that the existing VMS are operated by Bengaluru Traffic Police as part of traffic management.

The dynamic traffic congestion information will be generated from probe car system and queue length measurement system. The collected data from these sub-systems will be processed at B-TIC centre. The result will be transmitted to B-TRAC centre and the information will be provided through VMS.

The system configuration of B-TIC in relation with B-TRAC is depicted in the figure on the next page.

(It is noted that the below figure shows only the sub-systems which are related to Bengaluru Traffic Polic).



Source: JICA Expert

Figure 5.5.1 System Configuration of B-TIC in Relation with Bengaluru Traffic Police

(2) Conclusion

Bengaluru Traffic Police understood and agreed.

5.6 Organisations for ITS

(1) Explanation by JICA Experts

The different ITS components will be prepared by the grant project and loan project. The responsible organisation for each ITS component needs to be clarified and determined. The organisation also needs to be clarified by the project stage: implementation and operation, and for ownership and management of equipment.

(2) Conclusion

JICA Experts held discussions with DULT, BDA and Bengaluru Traffic Police and confirmed the responsible organisations as shown in the table below.

Table 5.6.1 Responsible Organisations for ITS

ITS Component		JICA Project	Project Stage		Equipment	
			Implementation (Procurement/ Installation)	Operation	Ownership	Management
B-TIC	(*1)	Grant Project	DULT	DULT	DULT	DULT
		Loan Project	BDA	DULT	DULT	DULT
	VMS	Grant Project	DULT	Traffic Police	Traffic Police	Traffic Police
		Loan Project	BDA	Traffic Police	Traffic Police	Traffic Police
ATCS		Grant Project	DULT	Traffic Police	Traffic Police	Traffic Police
		Loan Project	BDA	Traffic Police	Traffic Police	Traffic Police
Clearinghouse		Loan Project	BDA	DULT	DULT	DULT
HTMS for PRR		Loan Project	BDA	BDA	BDA	BDA
TMS for PRR		Loan Project	BDA	BDA	BDA	BDA

Note (*1): Queue Length Measurement System, ATCC and Centre

Source : JICA Experts

(3) JICA Experts' Recommendation: Formulation of ITS Society

Several organisations are involved in implementing ITS. It is important to ensure those organisations to work together in a coordinated manner.

JICA Experts strongly recommend formulating a governing body that will be responsible for overall implementation of ITS components by the grant and loan projects. ITS Master Plan proposed to establish "ITS Society"[1] by Karnataka government to oversee all activities of ITS in Bengaluru. It is suggested to form the ITS society and to be organised by senior official of the stakeholder organisations, headed by DULT as proposed by ITS Master Plan. It shall function as a body for monitoring, coordinating and making decisions by incorporating views of the constituent members. It shall be formed sufficiently prior to the initiation of ITS projects.

The constituent members of the ITS Society shall include the major stakeholder organisations in urban transport sector in Bengaluru such as Bangalore Traffic Police, road administrators, city/inter-city public bus operators, metro rail operator, Department of Transport, and etc.

The details of ITS Society can be found in ITS Master Plan.

5.7 Scope of Contractor and Consultant

5.7.1 Scope of Contractor for Installation and Operation

(1) Explanation by JICA Experts

It needs to be confirmed whether the contract for supplier includes operation or not.

In the case of ITS projects in Hyderabad Metropolitan Area in India, the contract for the supplier includes the operation. The ITS projects are i) ITS for Outer Ring Road (Highway Traffic Management System and Toll Management System) and ii) City ITS (Traffic Information System). Both projects are funded by Japanese loan.

In the case of Bengaluru, Area Traffic Signal Control System (ATCS) and clearinghouse are included in addition to the ITS components in Hyderabad.

JICA Experts held discussion with DULT, BDA and Bengaluru Traffic Police as to whether the operation shall be included or not.

(2) Comments by Indian Side

They mentioned as follows:

---

[1] The 'Society' is a body which is entitled with legal authority and responsibility to achieve the objectives of the society. It is to be formed under Indian Society Act 1860 and registered in the Register of Society. A memorandum of association is signed by the constituent members of the society. The memorandum of association contains the name of the society, its objectives, details of the constituent members, and etc. Once registered, the society will be legally responsible for making decisions and implementing as per the objectives.

- DULT opined that inclusion of operation in the contract for the supplier is required. DULT considers that this shall be applied to all ITS components of the grant project and loan project, except ATCS.
- BDA opined that that the contract of the supplier shall include the operation for all ITS components (City ITS and PRR ITS: HTMS and TMS), except ATCS. They mentioned that the inclusion of the operation is a preferable option for them in view that:
  - ✓ The systems can be stabilised during the operation period, being taken care by the operators who are familiar with the systems,
  - ✓ The operation period is considered a preferable learning opportunity for the government organisations in charge of operation, e.g. DULT and BDA, and
  - ✓ BDA opined that three (3) years would be appropriate for the operation period, and it could be extended as required.
- Bengaluru Traffic Police informed that the operation of the traffic single is not outsourced to the private company. They operate. Thus, it is not applicable to the ATCS.
- In regard of the grant project, DULT and BDA expressed their wish that the operation is included in the contract scope of the supplier as well.

(3) Conclusion

The above matters will be finalised in line with JICA’s view point. (It is noted that this matter excludes the case of ATCS.)

5.7.2 Scope of Contractor for ITS Component for PRR ITS and City ITS

(1) Explanation by JICA Experts

The scope of the contractor in terms of ITS components for the loan project shall be determined. The components of the loan project are shown in the table below.

Table 5.7.1 ITS Components to Be Covered by the Loan Project

Category	ITS Component
City ITS	Bengaluru Traffic Information System (B-TIC)
	Area Traffic Signal Control System (ATCS)
	Clearinghouse for Common Smartcard
ITS for PRR	Highway Traffic Management System (HTMS)
	Toll Management System (TMS)

Source : JICA Experts

(2) Conclusion

JICA Experts held discussions with DULT and BDA, and agreed:

- Two (2) contractors: one for City ITS and the other for ITS for PRR

Separating the contractors between City ITS and ITS for PRR is intended to avoid dependency of the progress of the civil works of PRR.

5.7.3 Scope of Consultant for ITS Component

(1) Explanation by JICA Experts

The scope of the consultant in terms of ITS components for the loan project shall be determined.

JICA Experts recommend a single consultant for City ITS and PRR ITS due to the following advantages:

- The coordination amongst ITS components is required. In particular, the traffic control centre of HTMS for PRR and the centre for traffic information system (B-TIC) exchange the data each other. Assuring compatibility will be easier.
- The implementation schedules for City ITS and PRR ITS are almost same.

(2) Conclusion

DULT and BDA understood and agreed. They mentioned that the respective groups under the single consultant can be formed if required.

5.8 Design and Contract Document

5.8.1 Design of the Grant and Loan Projects

(1) Explanation by JICA Experts

JICA Experts explained to BDA the reason of choosing the ITS component/coverage area/number of equipment of the grant project in relation with design aspects of the grant and loan projects as follows:

- The basic ITS component including centre and minimum number of roadside equipment will be prepared by the grant project.
- These basic components will be designed and specification will be prepared during the grant project.
- The basic components prepared by the grant project will be expanded by the loan project in terms of function and area.
- Therefore, the design specification prepared by the grant project will be referred and utilised during the design stage of the loan project so that the basic system concept and compatibility will be assured and the loan project can be smoothly implemented.

(2) Conclusion

BDA understood the explanation of JICA Experts and agreed.

5.8.2 Contract Document: FIDIC Suite for the Loan Project

(1) Explanation by JICA Experts

JICA Experts explained about the contract document for the loan project as follows:

- The Yellow Book has been prepared for Design Build Project where the contractors carry out the detailed design so that it meets the outline or performance specification prepared by the employer.
- The Silver Book has been prepared for EPC/Turnkey Project where the contractor provides a completed facility to the employer that is ready to be operated at 'the turn of a key'. This is not relevant to ITS projects planned in Bengaluru.
- The Gold Book has been prepared for Design Build Project and it includes the operation. However, the operation period is intended for e.g. 20 years. FIDIC states that Gold Book may not be suitable if the operation period significantly differs.
- The Red Book has been prepared for the project where most of the works are designed by the employer. The Pink Book is a variant of the Red Book and for the projects that are funded by Multilateral Development Banks ('MDBs') such as the World Bank.

- The Yellow Book is considered most suitable with additional provision of the clause of the operation. It will be determined in line with JICA's point of view.

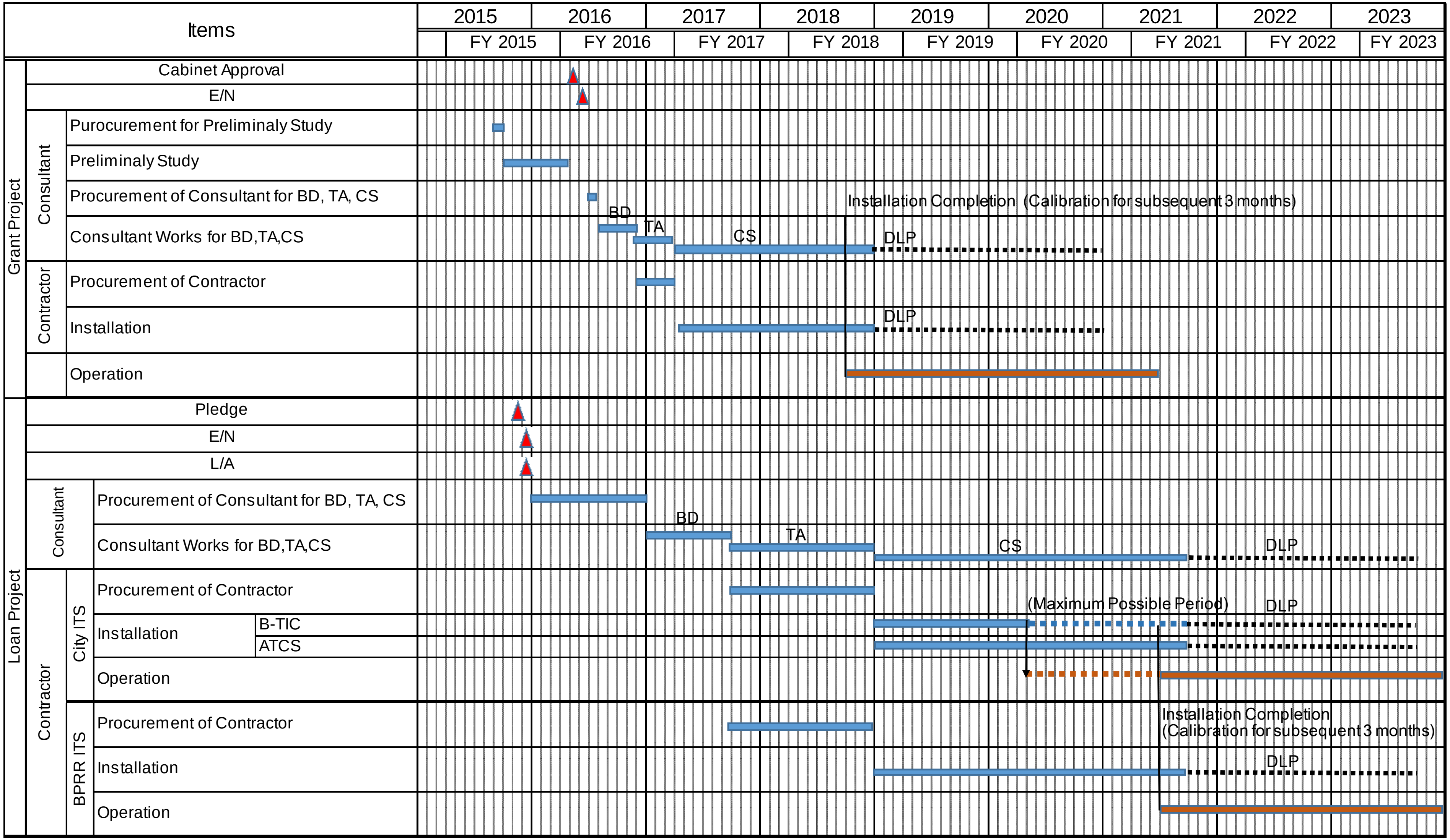
(2) Conclusion

BDA understood the explanation of JICA Experts.

5.9 Schedule of ITS Works for the Grant and Loan Projects

(1) Explanation by JICA Experts

The schedule of ITS works for the grant and loan projects was prepared by JICA Experts , as shown on the next page, and explained to DULT and BDA.



BD: Basic Design, TA: Tendering Assistance, CS: Construction Supervision

Source : JICA Experts

Figure 5.9.1 Schedule of ITS Works

(2) Conclusion

DULT commented that the commencement of operation of City ITS in the loan project is too late. They requested JICA Experts to consider making it earlier because that the City ITS in the loan project is expansion of the equipment.

JICA Experts explained that the dotted line of installation of B-TIC of the schedule for City ITS shown in the table is a maximum possible time available for the implementation of City ITS components and actual schedule will be detailed at the time of the basic design stage.

5.10 Important Notice for Implementation of ITS

5.10.1 GPS Device for Probe System for B-TIC for the Grant Project

(1) Explanation by JICA Experts

B-TIC will generate congestion information on the road from probe data and will provide the generated information to the road users. Thus the probe data is a critical factor for B-TIC and the data transmission from the probe car needs to be assured.

In the grant project as the first phase, it is planned that B-TIC will utilise the probe data transmitted from GPS devices installed on the city buses of Bengaluru Metropolitan Transport Corporation (BMTC).

A bus monitoring system is now being developed by BMTC and its trial is underway. The entire project was originally planned to complete by August in 2015.

According to the latest information from BMTC as of June 2015, the trial for the bus monitoring system has not been successful. The data from the GPS devices on the buses is not stably obtained by the centre system of the bus monitoring system and the investigation is now underway.

(2) Countermeasure Proposed by JICA Experts

In regard of importance of the probe data for B-TIC and the current situation of the above project, JICA Experts recommend to install the GPS devices on their buses by the grant project to minimise the dependency of the system.

The followings need to be confirmed and agreed with BMTC:

- Whether it is acceptable for BMTC to install GPS devices on their buses by the grant project or not,
- In such case, BMTC is required to bear the communication cost from GPS device to their bus monitoring server because the grant project does not include the operation cost,
- BMTC is required to take care of the maintenance of the GPS devices, and
- BMTC is required to develop the centre-side subsystem of the bus monitoring system because the development of this subsystem is out of scope of the grant project.

JICA Experts requested DULT to obtain the information from BMTC as soon as possible.

(3) Conclusion

Based on the explanation of JICA Experts, DULT issued an official letter to BMTC to clarify the current situation of their project and enquire the possibility of provision of GPS by the grant project. DULT hold the discussion with BMTC and informed to JICA Experts that the situation of the project has been improved and the installation of GPS on 6700 buses is expected to complete in a year. BMTC replied that GPS will be installed by themselves.

It is noted that the situation needs to be further updated during the grant project.

(4) JICA Experts' Recommendation

As stated in the clause of conclusion above, BMTC showed their willingness to install the GPS devices by themselves. Nevertheless, if possible, JICA Experts recommend providing the GPS devices by the grant project to ensure the data collection as the probe data is indispensable data source for B-TIC for generation of congestion information.

The congestion information by B-TIC in the grant project will cover the major roads in the city. Therefore it is recommended that the GPS devices be installed at least on the buses which run on the major roads in the city, if not all buses, by the grant project.

5.10.2 Information Exchange between NICE Road and PRR and ITS Facilities on NICE Road

The consideration is made to the information exchange between NICE Road (Nandi Infrastructure Corridor Enterprise Road) and PRR and ITS facilities on NICE Road as follows:

The planned PRR will be connected with NICE Road and form a full circle ring road. ITS facilities are studied on this PRR Review Study. It is preferable from the point of view of ITS that ITS be implemented together with the section of NICE Road as a whole.

However, NICE Road has been constructed and operated under BOT (Build, Operate and Transfer) scheme whereas PRR and ITS facilities on PRR will be constructed under Japanese loan and it will be operated by BDA. The concession period of NICE Road is for 40 years from 1994. None of ITS facilities (Highway Traffic Management System nor Toll Management System) has been introduced on the section of NICE Road now. Therefore any information cannot be exchanged as of now. If ITS facilities are introduced to the section of NICE Road in the future, it is advised that ITS be implemented considering the following points:

HTMS (Highway Traffic Management System): The traffic control centre and roadside equipment will be introduced to the section of NICE Road and the necessary information will be exchanged between the centres for PRR and NICE Road. The necessary information includes the information on congestion, accident, road/IC closures, and etc on their own sections. The centre for either PRR or NICE Road which receives the information will provide the information to the road users on their own section as the information on traffic event occurred ahead. Which information is to be automatically exchanged by the system (called 'on-line exchange') and which information is to be manually exchanged by human (called 'off-line exchange') need to be determined beforehand for the information exchange. Further, such factors as transmission method, data format, data exchange frequency and etc also need to be determined for the on-line exchange.

It would also be possible that the centre for PRR handles all information including the section of NICE Road as one centre and only the roadside equipment will be introduced to the section of NICE Road. However, the operation of the control centre is closely related to the operation of the expressway. Thus the above mentioned method is considered more realistic, considering such factors as the difference of implementing scheme of PRR and NICE Road, organisations involved and etc.

TMS (Toll Management System): It is considered realistic that the toll management systems are introduced and operated separately because toll fare is to be managed individually by PRR and NICE Road. In view of convenience of the road users, it is recommended that the same type of ETC and smartcard for ETC and Touch & Go which will be commonly used for NICE Road and PRR be introduced to the section of NICE Road. It is noted that the clearinghouse will be required in this case.

5.10.3 Clearinghouse and Smartcard for PRR TMS

The ITS Master Plan proposed the development of the clearinghouse for common smartcard for Bengaluru. The common smartcard is proposed to be a multi-purpose smartcard. The clearinghouse will take care of transaction settlement amongst different transport operators and services.

Toll Management System (TMS) will be introduced to Peripheral Ring Road (PRR). Three toll collection methods will be adopted; (i) Cash, (ii) Touch and Go using prepaid smartcard, and (iii) Electronic Toll Collectin (ETC) using prepaid smartcard on on-board unit. Thus the smartcard system needs to be designed along with TMS system for PRR and the prepaid smartcard shall be available by the time of commencement of operation of TMS.

On the other hand, the city transport operators (Bengaluru city bus operator and Bengaluru metro operator) are implementing the smartcard. The smartcard is already available on Bengaluru metro and introduction of the smartcard is planned for Bengaluru city bus (as detailed later). They are considering the possibility of making their smartcards multi-purpose. This is still under discussion and it is not clear when it will be realised.

The preparations of the smartcard system for TMS and the clearinghouse are closely related to the aspects of the smartcards which will be introduced by the city transport operators. Therefore, JICA Experts included the discussion items of the clearinghouse and smartcard system for TMS for PRR under PRR Review Study.

(1) Current Situation of Smartcard in Bengaluru

1) Bengaluru Metro

The smartcard has already been introduced to Bengaluru metro by Bengaluru Metro Rail Corporation Limited (referred to as ‘BMRCL’ hereinafter), a metro rail operator, and it is in use for the fare payment of Bengaluru Metro. The metro smartcard is Mifare type which is widely used in the world. The metro smartcard system can be used only for the metro fare payment.

2) Bengaluru City Bus

Bengaluru Metropolitan Transport Corporation (BMTC), a governmental city bus operator in Bengaluru, is planning to introduce the smartcard payment system.

The progress of their plan has been updated for this review study as follows:

The project for the introduction of the smartcard is now underway. The project consists of two components: (i) Electronic Ticketing Automation System[2] and (ii) Smartcard System. BMTC smartcard is considered to be NPCI type[3] and will be used only for bus fare payment. NPCI recently released the standard framework of NPCI.

These components under the project are being implemented by two different contractors: (i) TRIMAX for Electronic Ticketing Automation System (ETAS), and (ii) Axis Bank for Smartcard System. The contractor of Smartcard System, Axis Bank, started the design work of the smart card. Axis Bank appointed their sub-contractor, “Cartec”(Turkish) for card supplier and “Verifone”(U.S.) for card reader supplier.

The handy terminal for ETAS will be equipped with the smartcard reader. Technical test for ETAS together with the smartcard reader is planned to complete by the end of 2015 and the pilot will start after completion of the technical test.

The outline of smartcard in Bengaluru is summarised in the table below.

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[2] It is a system to issue a paper ticket from a handy-terminal held by the bus crew on the bus upon cash payment made by the passenger. It also manages the collected bus fares for BMTC bus operation.

[3] NPCI: National Payment Corporation of India (NPCI) is a financial agency under Indian Central Bank called ‘Reserve Bank of India (RBI). It is responsible for all electronic payment frameworks, policies and settlement amongst involved agencies and banks in India.

NPCI recently launched ‘Rupay’, which is an Indian standard for e-transaction of credit card and debit card. It is a standard similar to EMV which is a de-facto global standard of e-transaction of VISA International, Mastercard International and Europay.

Table 5.10.1 Outline of Situation of Smartcard in Bengaluru

No.	Item	BMRCL (Metro)	BMTC (City Bus)
(1)	Current Situation of Smartcard	In use for metro fare payment	Planned to introduce
(2)	Smartcard Type	Mifare DESFire (ISO 1443 Type A)	Decided to adopt NPCI framework
(3)	Smartcard Contractor	Samsung (Korea)	Axis Bank
(4)	Contract Period	Till the end of phase I of metro construction (Tentatively till the end of 2016)	5 years from 2014 to the end of 2019
(5)	Card Issuer	BMRCL	Axis Bank
(6)	Value Issuer	BMRCL	Axis Bank

Source: JICA Expert

3) Current Situation for Integration of Smartcard between BMTC and BMRCL

The technical meetings on the integration of the smartcard were held between BMTC and BMRCL, chaired by Commissioner of DULT in 2015 under ITS Master Plan study works. The purpose of the meetings were to enable to introduce a single smartcard across different transport operators and services. It was tentatively agreed that BMTC and BMRCL would make efforts on making their smartcard interoperable by exchanging technical details each other. However any final decisions were not made during the previous meetings. Thus for this review study, the situation has been updated as follows:

- BMRCL is now considering the possibility of making their existing smartcard system interoperable with NPCI based BMTC smartcard by modifying their system during the phase I of the metro project. Their current contract of the smartcard with the contractor, Samsung, is until the end of 2016 (till the completion of the metro phase I).
- BMRCL agreed to review NPCI smartcard specification to investigate the impact in terms of cost, system modification, and etc. of making BMTC smartcard interoperable for metro fare payment. For this purpose, NPCI technical details will be shared to BMRCL by BMTC.

It is noted that the integration of the smartcard between BMRCL and BMTC is still under the stage of consideration and further discussions and investigations between two agencies will be required.

(2) Suggestion of JICA Experts

Considering the current situation of the smartcard in Bengaluru, the following two (2) options are considered.

- Option-1: Prepare the smartcard system for PRR as a multi-purpose and clearinghouse
- Option-2: Prepare the smartcard system for PRR as a single-purpose for PRR toll collection

These are further explained below.

Option-1:

Smartcard Design

If the specification of the smartcard of BMTC based on NPCI type is finalised by the design stage of TMS for PRR, the smartcard system of PRR will be prepared based on the same type and as multi-purpose. This is also due to the consideration that there is a possibility that this type may be used for metro. The following aspects shall be noted:

- The smartcard of BMTC based on NPCI type shall be designed as multi-purpose usage.
- The technical details shall be shared by BMTC for the design of the smartcard system of TMS for PRR in the design stage.
- The feasibility of the NPCI based smartcard needs to be confirmed before the design of TMS for PRR because there have not been any cases where the NPCI based smartcard is introduced.

If the specification of the smartcard of BMTC based on NPCI type is not finalised by the design stage of TMS for PRR, the smartcard type shall be decided at the time of design considering the related surrounding aspects in Bengaluru. The multi-purpose smartcard system shall be designed with close coordination amongst related organisations such as DULT, BDA, BMTC, Bangalore metro, and etc.

Clearinghouse

The common smartcard will be used for different modes of transport and services. They may be issued by different card/value issuers. Under such condition, a central agency which handles transaction data and settlement amongst various services will be required. Thus, the clearinghouse needs to be established.

As per the discussions with DULT and BDA under PRR Review Study, it was confirmed that the clearinghouse will be procured and installed by BDA as a loan project and it will be operated under the jurisdiction of DULT.

As per the regulation of Indian Central Bank, the clearinghouse will be categorised into ‘Semi-Open System’ from the standpoint that the common smartcards are used at the locations where the card readers are installed by different card/value issuers. The regulations stipulate that the banking license is required for the settlement for the Semi-Open System. Thus it is suggested that the operation of the clearinghouse be tied up with bank.

(The corresponding section of the regulation is summarised by JICA Experts and provided in the clause later.)

The details of establishment of the clearinghouse and other necessary steps can be found in ITS Master Plan for Bengaluru.

Option-2:

If the specification of the smartcard of BMTC based on NPCI type is not finalised by the design stage of TMS for PRR, there is also an option to prepare the smartcard system for PRR as a single-purpose. The smartcard type will be decided at the time of design considering the related surrounding aspects in Bengaluru.

The implementation agency for PRR ITS is BDA. Therefore in this case, BDA issues the smartcard. BDA will be the card issuer and value issuer of the smartcard for PRR. It is suggested that the operation of the smartcard be taken care by the supplier as the card management requires special skill sets.

In the case of option-2, the clearinghouse is not required because the payment is confined to the toll collection of PRR. However the modification of the system of PRR and establishment of the clearinghouse will be required if the smartcard for PRR is used as multi-purpose for other services in the future.

The advantages and disadvantages for the option-1 and option-2 are shown on the table below.

Table 5.10.2 Advantages and Disadvantages of the Option-1 and Option-2

	Advantage	Disadvantage
Option-1	- More contribution to user convenience than option-2 - Thus, more contribution to card dissemination, consequently T&G and ETC usage on PRR than option-2 - No need of (or minimal) system modification for multi-purpose usage	- Design and implementation are more complex than option-2 - Close coordination amongst involved agencies is required
Option-2	- Design and implementation are more simple than option-1	- Less contribution to user convenience than option-1 - Thus, less contribution to card dissemination, consequently T&G and ETC usage on PRR than option-1 - System modification is required for multi-purpose usage in the future

Source: JICA Expert

(3) Conclusion

DULT understood. They expressed their view that the introduction of the smartcard based on NPCI type of BMTC may be completed in 2016.

(4) JICA Experts' Recommendation

The option-1 is recommended particularly because of requirement of system modification of PRR for multi-purpose usage in the future. However, the introduction of the multi-purpose smartcard and establishment of the clearinghouse requires close coordination amongst the involved agencies such as BDA, BMTC, BMRCL and etc. It is also expected that finalising the related aspects as detailed above in this section may take a certain period. JICA Experts therefore recommend forming ITS Society as stated in the prior corresponding section and it shall take care of the matters of the smartcard and clearinghouse.

<Supplement>

Regulation of Indian Central Bank (Reserve Bank of India: RBI) for Prepaid Fare Payment Systems

RBI published the regulations for prepaid fare payment. It stipulates that the agencies which introduce or join the prepaid fare payment system shall follow the regulations. It categorises the prepaid fare payment system into four (4) types. The followings are summary of the regulation related to this aspect:

(i) Closed System :

It means the system with a prepaid smartcard which can be used only within the organisation. For example, the prepaid smartcard as a coupon issued by the employer to the employees for purchasing lunch, stationeries and etc. available within the organisation is called the closed system.

(ii) Semi-closed System

It means the system with a prepaid smartcard, issued by an organisation (called card/value issuer), which are used at the locations where the card readers are installed by the same card/value issuer. For example, if BMTC (card/value issuer) issues the smartcard and install the card readers at BMTC buses (for bus fare payment), metro stations (for metro fare payment) and parking lots (for parking payment), it is called the semi-closed system.

(iii) Semi-Open System

It means the system with a smartcard, issued by organisations (called card/value issuers), which can be used at the locations where the card readers are installed by different card/value issuers. For example, if the smartcard issued by BMTC (card/value issuer) can be used at the locations e.g. metro stations, parking, kiosks where the card readers are installed by the different card/value issuers e.g. metro, bank and etc., it is called the semi-open system.

(iv) Open System

It means the system with a card which can be used for the fare payment and as Bank card. For example, a combo-card which has both smartcard and Bank debit card is called the open system. This card can be issued only by Bank.

The regulation stipulates that the banking license is required for the settlement for the above (iii) semi-open system and (iv) open system.

Note: The above descriptions are explanation simplified by JICA Experts. The corresponding sections of the guideline are attached.

CHAPTER 6 IMPLEMENTATION PLAN

The implementation plan of DPR was prepared to confirm the financial viability of the Project under the DBOT scheme and requires to be modified based on the latest conceivable financial resource of the Project.

6.1 Financial Resources

The Project was originally planned to apply DBOT scheme as mentioned in the Project Feasibility Report in 2012. Since the DPR concluded that the Project could not generate the threshold return and is not financially viable, DULT/BDA requested JICA to consider financing the Project through a loan. Although an official decision or commitment by JICA to extend the loan has not been made yet, the JICA Experts prepared the implementation plan in this report assuming the loan funding will be given due consideration by JICA. The timing of the Loan Agreement (L/A) is tentatively set out as December 2015.

6.2 Engineering Services

The DPR was prepared to check the financial viability of the Project under DBOT and the detailed design is not included in the implementation plan of the DPR. DULT/BDA informed that the detailed design would be conducted by STUP with funding by BDA and the period of the detailed design would be 12 months after the commitment of the financial resource of the Project. In the implementation plan in this report, the detailed design is tentatively scheduled from January 2016, immediately after L/A (timing of L/A is also still tentative). Accordingly, the scope of the engineering services under the loan consists of the post-detailed design and pre-construction activities such as 1) Review of Detailed Design, 2) Basic Design of ITS, 3) Tender Assistance, and post-construction activity such as 4) Construction Supervision for both civil works and ITS works.

6.3 Tender Period

The period of the tendering of construction works was set out as 12 months as directed by JICA.

6.4 Construction Works (Civil Works)

6.4.1 Tender Packaging

In the DPR, the Project was split into three sections and the amount of Section 3 is much larger than other sections. Furthermore, the cost of Section 3 will be increased due to the modification of the railway crossings. The JICA Experts proposed the repackaging of the Project dividing Section 3 into two packages and DULT/BDA understood the proposal as recorded in the Minutes of Meeting of the "Technical Review Wrap-up Meeting" held on 21 May 2015.

Table 6.4.1 Proposed Repackaging

Section	DPR	Proposed by the JICA Experts	
Section 1 (L=18 km)	1,145 Crore	1,145 Crore	
Section 2 (L=17 km)	951 Crore	951 Crore	
Section 3 (L=29 km)	1,624 Crore	Section 3-1	1,624 Crore++ =2 x 812 Crore++
		Section 3-2	
ITS	800 Crore	800 Crore	
Total	4,519 Crore	4,519 Crore++	

++ : due to modification of railway crossings (extension of bridge length and supply of steel bridge)

Note: The above cost is based on the DPR (not the reviewed cost by the JICA Experts).

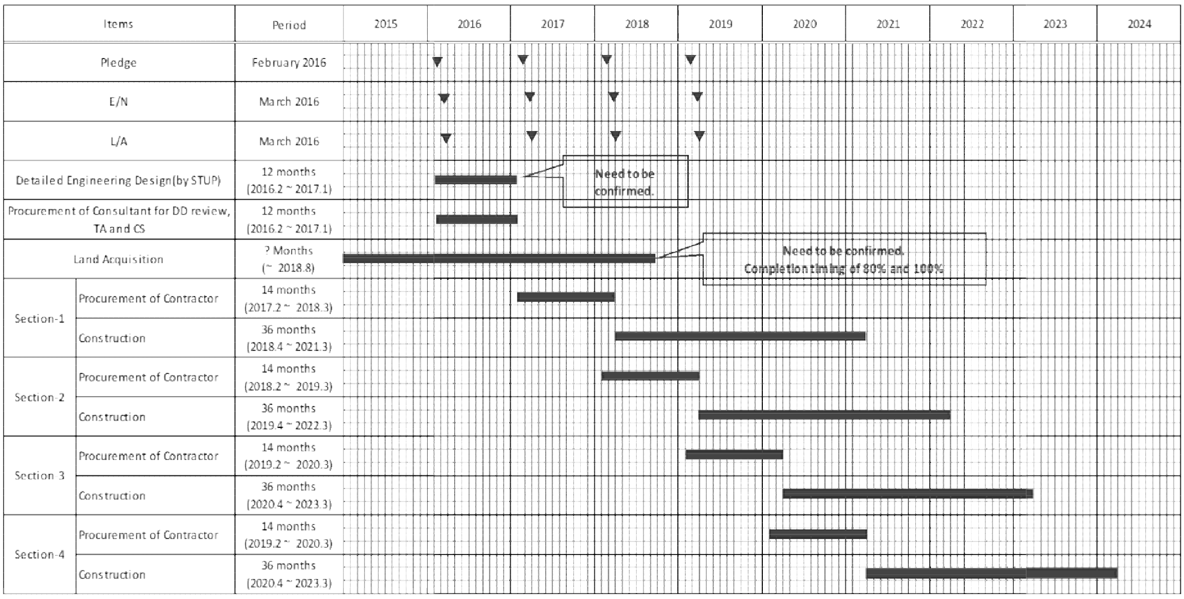
Source: JICA Experts

The break point in Section 3 has been tentatively set out by the JICA Experts as proposed in Chapter 7 (Cost Estimate).

6.4.2 Construction Period

The JICA Experts referred the construction period of 36 months for each section based on the DPR. The detailed construction period shall be further studied during the detailed design stage.

Initially, the JICA Experts recommended the step-wise commencement of the Project for 72 months as shown below.



Items		Period
Pledge		February 2016
E/N		March 2016
L/A		March 2016
Detailed Engineering Design(by STUP)		12 months (2016.2 ~ 2017.1)
Procurement of Consultant for DD review, TA and CS		12 months (2016.2 ~ 2017.1)
Land Acquisition		? Months (~ 2018.8)
Section-1	Procurement of Contractor	14 months (2017.2 ~ 2018.3)
	Construction	36 months (2018.4 ~ 2021.3)
Section-2	Procurement of Contractor	14 months (2018.2 ~ 2019.3)
	Construction	36 months (2019.4 ~ 2022.3)
Section 3	Procurement of Contractor	14 months (2019.2 ~ 2020.3)
	Construction	36 months (2020.4 ~ 2023.3)
Section-4	Procurement of Contractor	14 months (2019.2 ~ 2020.3)
	Construction	36 months (2020.4 ~ 2023.3)

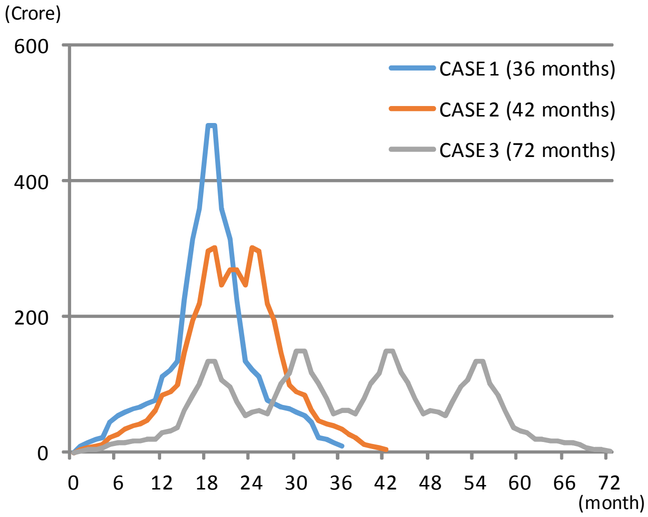
Need to be confirmed.

Need to be confirmed.
Completion timing of 80% and 100%

Source: JICA Experts (Wrap-up Meeting on 21 May 2015)

Figure 6.4.1 Implementation Plan Proposed in Wrap-up Meeting

DULT/BDA requested the JICA Experts to change the commencement of the construction works of all sections simultaneously. The JICA Experts explained that the simultaneous commencement might not be practical due to limited capacity of resources of the implementing agency, disbursement of the project cost, and progress of land acquisition.



Source: JICA Experts

Figure 6.4.2 Monthly Disbursement Schedule by Construction Periods

After several discussions between DULT/BDA and the JICA Mission, it was determined that all sections would be commenced simultaneously.

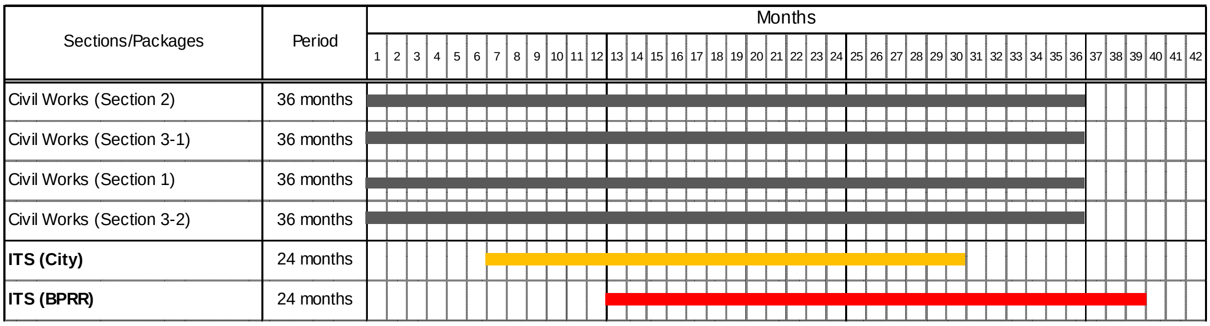
Accordingly, 36 months of the construction period to complete all sections by mid 2021 was selected.

6.5 Construction Works (ITS Works)

ITS works consist of "City ITS" and "BPRR ITS" under the Project.

The construction period (manufacturing and installing) of ITS Works has been set out as 33 months including three months of the commissioning period of the ITS equipment of BPRR after the completion of the civil works.

The basic design of ITS Works shall be conducted prior to the commencement of the procurement for the construction. Accordingly, the commencement of ITS Works will be 6 months later than that of the Civil Works.

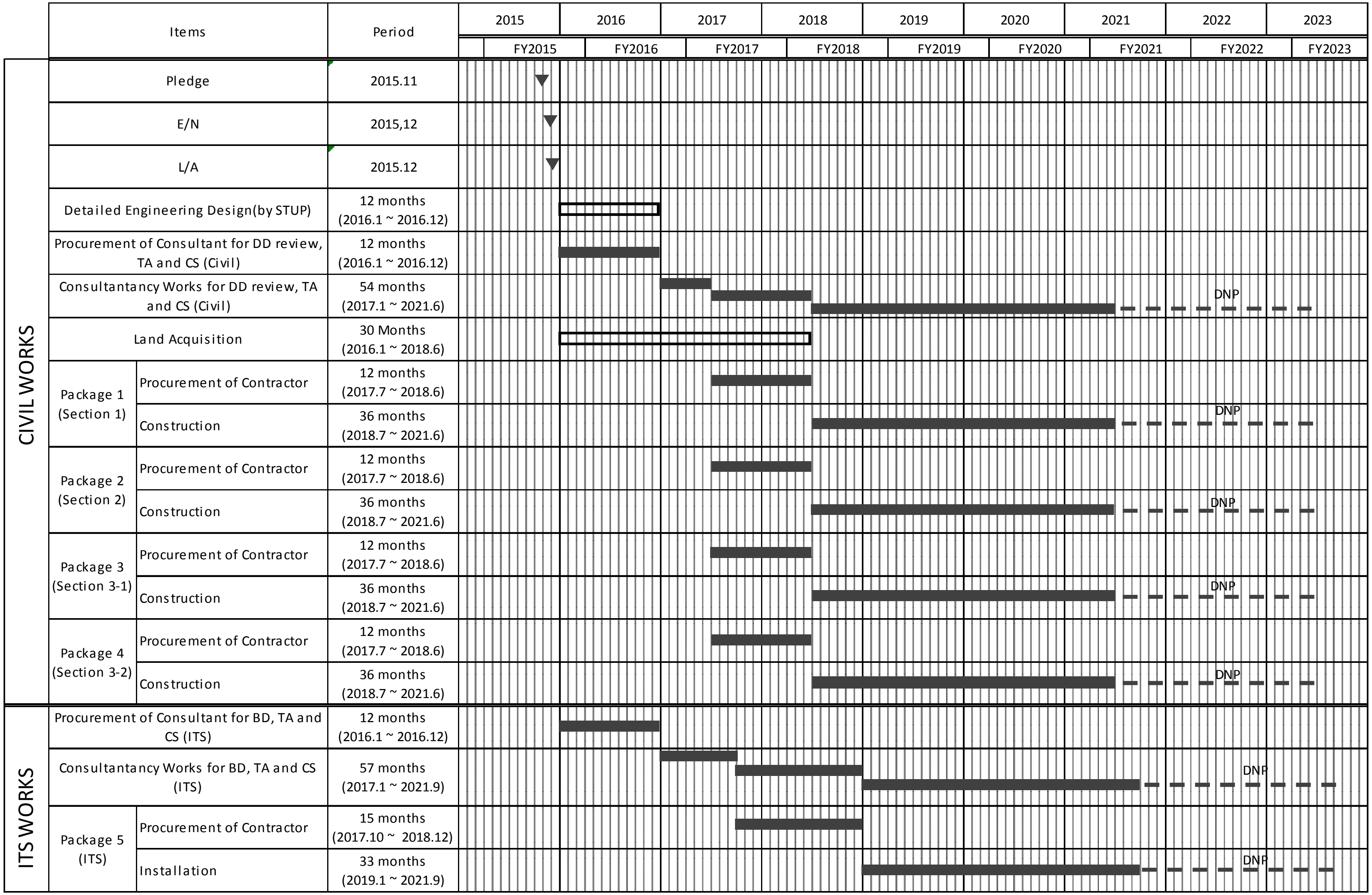


Source: JICA Experts

Figure 6.5.1 Implementation Period of ITS Works

6.6 Overall Implementation Plan

Accordingly, the overall implementation plan is presented in the next page.



	Items		Period
CIVIL WORKS	Pledge		2015.11
	E/N		2015,12
	L/A		2015.12
	Detailed Engineering Design(by STUP)		12 months (2016.1 ~ 2016.12)
	Procurement of Consultant for DD review, TA and CS (Civil)		12 months (2016.1 ~ 2016.12)
	Consultantancy Works for DD review, TA and CS (Civil)		54 months (2017.1 ~ 2021.6)
	Land Acquisition		30 Months (2016.1 ~ 2018.6)
	Package 1 (Section 1)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 2 (Section 2)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 3 (Section 3-1)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
	Package 4 (Section 3-2)	Procurement of Contractor	12 months (2017.7 ~ 2018.6)
		Construction	36 months (2018.7 ~ 2021.6)
ITS WORKS	Procurement of Consultant for BD, TA and CS (ITS)		12 months (2016.1 ~ 2016.12)
	Consultantancy Works for BD, TA and CS (ITS)		57 months (2017.1 ~ 2021.9)
	Package 5 (ITS)	Procurement of Contractor	15 months (2017.10 ~ 2018.12)
		Installation	33 months (2019.1 ~ 2021.9)

Source: JICA Experts

Figure 6.6.1 Overall Implementation Plan

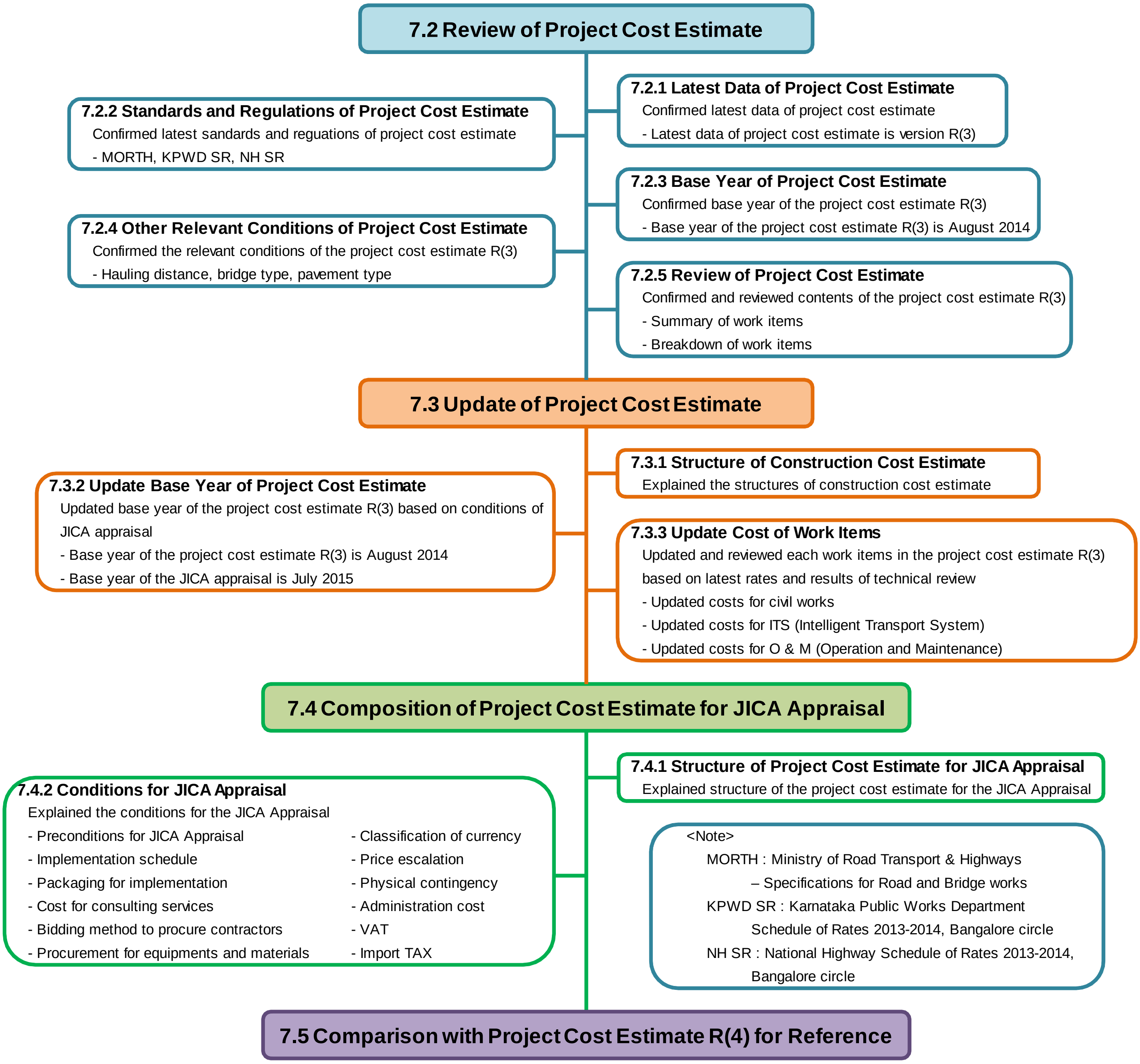
CHAPTER 7 COST ESTIMATE

7.1 General

The JICA Experts reviewed and updated the project cost estimate (Version R(3)) of the Bengaluru Peripheral Ring Road (BPRR) Project based on the final detailed project report (DPR) R(5).

7.1.1 Methodology for Review and Update of Project Cost Estimate

The JICA Experts reviewed and updated the project cost estimate R(3) by methodology as shown in Figure 7.1.1.



7.2 Review of Project Cost Estimate

7.2.1 Latest Data of Project Cost Estimate
Confirmed latest data of project cost estimate
- Latest data of project cost estimate is version R(3)

7.2.2 Standards and Regulations of Project Cost Estimate
Confirmed latest sandards and reguations of project cost estimate
- MORTH, KPWD SR, NH SR

7.2.3 Base Year of Project Cost Estimate
Confirmed base year of the project cost estimate R(3)
- Base year of the project cost estimate R(3) is August 2014

7.2.4 Other Relevant Conditions of Project Cost Estimate
Confirmed the relevant conditions of the project cost estimate R(3)
- Hauling distance, bridge type, pavement type

7.2.5 Review of Project Cost Estimate
Confirmed and reviewed contents of the project cost estimate R(3)
- Summary of work items
- Breakdown of work items

7.3 Update of Project Cost Estimate

7.3.1 Structure of Construction Cost Estimate
Explained the structures of construction cost estimate

7.3.2 Update Base Year of Project Cost Estimate
Updated base year of the project cost estimate R(3) based on conditions of JICA appraisal
- Base year of the project cost estimate R(3) is August 2014
- Base year of the JICA appraisal is July 2015

7.3.3 Update Cost of Work Items
Updated and reviewed each work items in the project cost estimate R(3) based on latest rates and results of technical review
- Updated costs for civil works
- Updated costs for ITS (Intelligent Transport System)
- Updated costs for O & M (Operation and Maintenance)

7.4 Composition of Project Cost Estimate for JICA Appraisal

7.4.1 Structure of Project Cost Estimate for JICA Appraisal
Explained structure of the project cost estimate for the JICA Appraisal

7.4.2 Conditions for JICA Appraisal
Explained the conditions for the JICA Appraisal
- Preconditions for JICA Appraisal
- Implementation schedule
- Packaging for implementation
- Cost for consulting services
- Bidding method to procure contractors
- Procurement for equipments and materials
- Classification of currency
- Price escalation
- Physical contingency
- Administration cost
- VAT
- Import TAX

<Note>
MORTH : Ministry of Road Transport & Highways
– Specifications for Road and Bridge works
KPWD SR : Karnataka Public Works Department
Schedule of Rates 2013-2014, Bangalore circle
NH SR : National Highway Schedule of Rates 2013-2014, Bangalore circle

7.5 Comparison with Project Cost Estimate R(4) for Reference

Source: JICA Experts

Figure 7.1.1 Methodology for Review and Update of Project Cost Estimate

7.2 Review of Project Cost Estimate

The JICA Experts reviewed the project cost estimate R(3) based on the final DPR R(5).

7.2.1 Latest Data of Project Cost Estimate

It was confirmed that the latest official project cost estimate is version R(3).

7.2.2 Standards and Regulations of Project Cost Estimate

References for unit rates of each work item in the project cost estimate R(3) are KPWD SR 2013-2014 (Karnataka Public Works Department Schedule of Rates 2013-2014, Bangalore circle) and NH SR 2013-2014 (National Highway Schedule of Rates 2013-2014, Bangalore circle).

The latest standards and regulations are shown in Table 7.2.1 below.

Table 7.2.1 Latest Standards and Regulations of Project Cost Estimate

Item	Name
Specifications	Ministry of Road Transport and Highways – Specifications for Road and Bridge Works (Fifth Revision) (hereinafter MORTH (R5))
Schedule of Rates	Karnataka Public Works Department Schedule of Rates 2014-2015, Bangalore Circle (hereinafter KPWD SR 2014-2015)
	National Highway Schedule of Rates 2014-2015, Bangalore Circle (hereinafter NH SR 2014-2015)

Source: JICA Experts

7.2.3 Base Year of Project Cost Estimate

The base year of the project cost estimate R(3) is August 2014.

7.2.4 Other Relevant Conditions of Project Cost Estimate

The relevant conditions of the project cost estimate R(3) are summarized in Table 7.2.2 below.

Table 7.2.2 Other Relevant Conditions of Project Cost Estimate

Item	Description
Hauling Distance	➢ Project cost estimate R(3) considered the hauling costs in consideration of the distance to/from potential borrow pits, disposal sites, etc. ➢ Sand material is not available inside Bengaluru City (Estimated hauling distance: 100 km)
Bridge Type	Bridge structures are estimated as PC box girder.
Pavement Type	Main road and bridges: concrete pavement Service road and bridges: asphalt pavement

Source: JICA Experts

7.2.5 Review of Project Cost Estimate

The JICA Experts reviewed the project cost estimate R(3) based on the final DPR R(5).

7.2.5.1 Summary of Work Items

Table 7.2.3 shows the schedule of summary work items.

Table 7.2.3 Schedule of Summary Work Items

Summary of Work Items

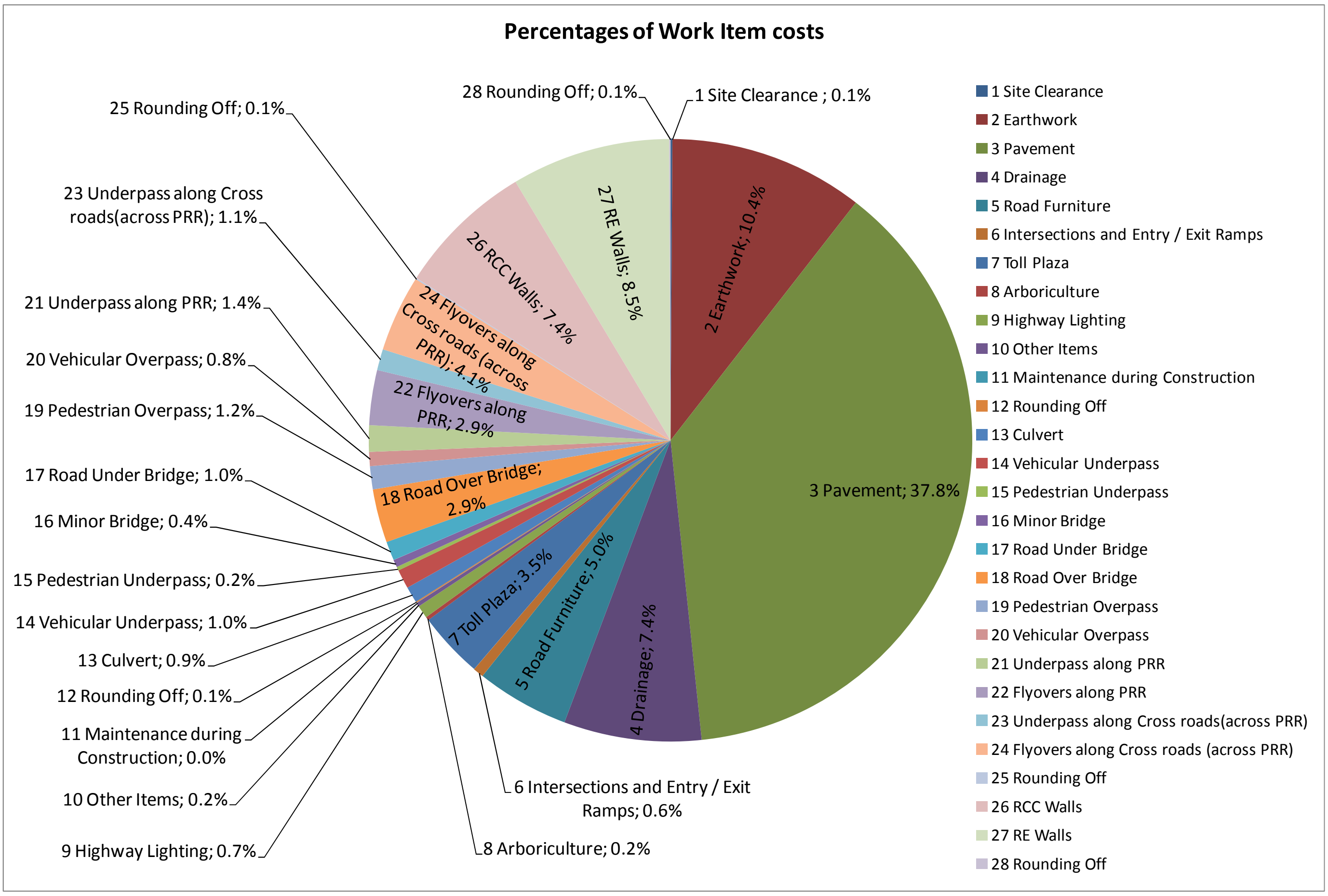
Sl no	Description	Total Amount (Rs)	
A	ROAD WORKS	13,690,000,000	66.0%
1	Site Clearance	21,161,009	0.1%
2	Earthwork	2,164,241,771	10.4%
3	Pavement	7,841,361,243	37.8%
4	Drainage	1,531,558,297	7.4%
5	Road Furniture	1,035,192,545	5.0%
6	Intersections and Entry / Exit Ramps	118,236,045	0.6%
7	Toll Plaza	734,940,241	3.5%
8	Arboriculture	40,856,994	0.2%
9	Highway Lighting	143,420,920	0.7%
10	Other Items	43,271,120	0.2%
11	Maintenance during Construction	1,559,011	0.0%
12	Rounding Off	14,200,803	0.1%
B	STRUCTURE WORKS	3,740,000,000	18.0%
13	Culvert	180,692,176	0.9%
14	Vehicular Underpass	211,558,947	1.0%
15	Pedestrian Underpass	42,331,149	0.2%
16	Minor Bridge	83,618,827	0.4%
17	Road Under Bridge	211,357,592	1.0%
18	Road Over Bridge	594,629,691	2.9%
19	Pedestrian Overpass	256,624,861	1.2%
20	Vehicular Overpass	156,820,799	0.8%
21	Underpass along PRR	293,352,081	1.4%
22	Flyovers along PRR	610,439,258	2.9%
23	Underpass along Cross roads(across PRR)	235,710,948	1.1%
24	Flyovers along Cross roads (across PRR)	849,539,635	4.1%
25	Rounding Off	13,324,037	0.1%
C	EARTH RETAINING STRUCTURES	3,310,000,000	16.0%
26	RCC Walls	1,525,659,858	7.4%
27	RE Walls	1,770,266,283	8.5%
28	Rounding Off	14,073,859	0.1%
D	TOTAL (A+B+C)	20,740,000,000	100.0%

Source: JICA Experts

7.2.5.2 Breakdown of Each Work Item

The JICA Experts reviewed the breakdown of major work items.

The proportion and ratio of each work item is shown in Figure 7.2.1 below.



Source: JICA Experts

Figure 7.2.1 Proportion and Ratio of Each Work Item

(1) Revision on Reinforcing Works

It was confirmed that the appropriate unit cost for reinforcing works should be Rs68,990/ton instead of Rs68.99/ton. The JICA Experts revised the costs for reinforcing works in structure works.

Table 7.2.4 shows the comparison of structure work costs.

Table 7.2.4 Comparison of Structure Work Costs

Sl no	Description	Total Amount (Rs)		Difference
		Cost Estimate R(3)	Revised by the JICA Experts	
B	STRUCTURE WORKS			
12	Culvert	180,692,176	327,435,045	146,742,869
13	Vehicular Underpass	211,558,947	419,507,860	207,948,913
14	Pedestrian Underpass	42,331,149	82,308,069	39,976,921
15	Minor Bridge	83,618,827	173,015,492	89,396,666
16	Railway Under Bridge	211,357,592	479,547,589	268,189,997
17	Railway Over Bridge	594,629,691	1,120,472,321	525,842,629
18	Pedestrian Overpass	256,624,861	451,822,515	195,197,654
19	Vehicular Overpass	156,820,799	304,892,139	148,071,340
20	Underpass along PRR	293,352,081	528,566,936	235,214,855
Total		2,030,986,122	3,887,567,966	1,856,581,844

Source: JICA Experts

The revised cost breakdowns of structure works are shown in Table 7.2.5 to Table 7.2.13 below.

Table 7.2.5 Revised Cost Breakdown of Culverts

BILL NO 12 : STRUCTURES - CULVERTS											
Item	**Description**	**Unit**	**Culvert**			**Total Qty**	**Rate (Rs)**	**Amount (Rs)**			**Total Amount (Rs)**
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**	
	Number of structures	**Nos**	**18**	**17**	**34**			**18**	**19**	**32**	
12.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	19,229	17,432	30,533	67,194	47	907,508	822,721	1,441,035	3,171,264
12.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.										
	a) PCC M15 below foundation	cum	960	870	1,524	3,355	4,271	4,101,398	3,717,827	6,511,322	14,330,547
	RCC M35 for structure	cum	8,011	7,266	12,715	27,992	5,612	44,952,363	40,774,467	71,352,511	157,079,341
	RCC M40 for crash barrier	cum	86	55	93	234	7,575	654,793	414,208	706,607	1,775,608
12.03	Back filling with approved soil	cum	6,400	5,802	10,164	22,366	187	1,198,541	1,086,552	1,903,433	4,188,526
12.04	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**										
	For structure	MT	612	551	965	2,129	68,995	42,238,568	38,043,689	66,607,503	146,889,759
SUB TOTAL								**94,053,171**	**84,859,462**	**148,522,411**	**327,435,045**
GRAND TOTAL								**327,435,045**			
Box culvert for water supply & sewage line crossings is also included											

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.6 Revised Cost Breakdown of VUP

BILL NO 13: STRUCTURES- VUP

Item	**Description**	**Unit**	**VUP**			**Total QTY**	**Rate (Rs.)**	**Amount (Rs)**			**Total Amount (Rs)**
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**	
	Number of structures	**Nos**	**7**	**5**	**9**						
13.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	10,143	7,038	13,834	31,015	47	478,709	332,165	652,909	1,463,784
13.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.										
	a) PCC M15 below foundation	cum	507	352	692	1,551	4,271	2,165,600	1,503,533	2,955,809	6,624,941
	b)PCC M15 in approach slab	cum	264	189	371	824	4,779	1,261,656	903,231	1,773,009	3,937,896
13.03	Providing and laying Cement Concrete in **foundation/ substructure /super structure** including centering and shuttering and **Excluding the cost of reinforcement**.										
	RCC M35 for structure	cum	8,718	5,462	10,737	24,917	5,612	48,922,626	30,650,996	60,252,608	139,826,231
	RCC M40 for crash barrier	cum	221	154	302	677	7,575	1,674,102	1,166,568	2,287,686	5,128,356
13.04	Back filling with approved soil	cum	3,381	2,346	4,611	10,338	187	633,167	439,340	863,511	1,936,018
13.05	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	1,822	1,302	2,558	5,682	940	1,711,951	1,223,359	2,403,497	5,338,807
13.06	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**										
	For structure	MT	1,048	664	1,305	3,017	68,995	72,306,467	45,812,494	90,038,110	208,157,070
13.07	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	1,786	1,275	2,507	5,568	164	293,190	209,304	411,549	914,043
13.08	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	3,623	2,588	5,086	11,297	953	3,452,260	2,466,036	4,846,313	10,764,609
13.09	Approach slab M30 including reinforcement	Cum	536	383	753	1,672	10,568	5,664,341	4,047,467	7,957,553	17,669,362
13.10	Anti Carbonation Painting to the exposed surface of concrete	Sqm	10,083	7,202	14,157	31,442	67	675,158	482,246	947,953	2,105,356
13.11	PCC M -30 filling at top of PUP base	Cum	725	518	1,017	2,260	5,921	4,292,406	3,066,850	6,021,210	13,380,466
13.12	RCC M25 at Drain side walls cover slab kerb near median	Cum	116	83	163	362	6,246	724,494	518,388	1,018,039	2,260,922
SUB TOTAL								**144,256,125**	**92,821,979**	**182,429,756**	**419,507,860**
GRAND TOTAL								**419,507,860**			

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.7 Revised Cost Breakdown of PUP

BILL NO 14 : STRUCTURES - PUP

Item	**Description**	**Unit**	**PUP**			**Total Qty**	**Rate (Rs)**	**Amount (Rs)**			**Total Amount (Rs)**
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**	
	Number of structures	**Nos**	**4**	**1**	**2**						
14.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	3229	807	1615	5651	47.20	152,396	38,087	76,222	266704.596
14.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.										
	a) PCC M15 below foundation	cum	161	40	81	282	4271.40	687,695	170,856	345,983	1204534.8
	b)PCC M15 in approach slab	cum	151	38	76	265	4779.00	721,629	181,602	363,204	1266435
14.03	Providing and laying Cement Concrete in **foundation/ substructure /super structure** including centering and shuttering and **Excluding the cost of reinforcement**.										
	RCC M35 for structure	cum	2636	659	1318	4613	5611.68	14,792,388	3,698,097	7,396,194	25886679.84
	RCC M40 for crash barrier	cum	66	17	33	116	7575.12	499,958	128,777	249,979	878713.92
14.04	Back filling with approved soil	cum	1076	269	538	1883	187.27	201,505	50,376	100,752	352633.176
14.05	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	977	244	489	1710	939.60	917,989	229,262	459,464	1606716
14.06	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**										
	For structure	MT	331	83	166	580	68994.72	22,837,252	5,726,562	11,453,124	40016937.6
14.07	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	843	211	422	1476	164.16	138,387	34,638	69,276	242300.16
14.08	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	1035	259	518	1812	952.87	986,224	246,794	493,588	1726606.238
14.09	Approach slab M30 including reinforcement	Cum	306	77	153	536	10567.80	3,233,747	813,721	1,616,873	5664340.8
14.10	Anti Carbonation Painting to the exposed surface of concrete	Sqm	2746	687	1373	4806	67	183,872	46,002	91,936	321809.76
						0					
14.11	PCC M -30 filling at top of PUP base	Cum	207	52	104	363	5921	1,225,556	307,869	615,738	2149163.28
						0					
14.12	RCC M25 at Drain side walls cover slab kerbnear median	Cum	66	17	33	116	6246	412,212	106,176	206,106	724494.24
SUB TOTAL								**46,990,811**	**11,778,819**	**23,538,440**	**82,308,069**
GRAND TOTAL								**82,308,069**			

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.8 Revised Cost Breakdown of Minor Bridge

BILL NO 15: STRUCTURES - MINOR BRIDGE

Item	**Description**	**Unit**	**Minor Bridge**			**Total QTY**	**Rate (Rs)**	**Amount (Rs)**			**Total Amount (Rs)**
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**	
	Number of structures	**Nos**	**0**	**0**	**4**						
15.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum			46,746	46,746	47			2,206,224	2,206,224
15.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.										
	a) PCC M15 below foundation	cum			779	779	4,271			3,327,421	3,327,421
	RCC M35 for structure	cum			12,974	12,974	5,612			72,805,936	72,805,936
15.03	Back filling with approved soil	cum			15,582	15,582	187			2,918,072	2,918,072
15.04	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum			2,033	2,033	940			1,910,207	1,910,207
15.05	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**										
	For structure	MT			1,297	1,297	68,995			89,486,152	89,486,152
15.06	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.			2,202	2,202	164			361,480	361,480
SUB TOTAL								**0**	**0**	**173,015,492**	**173,015,492**
GRAND TOTAL								**173,015,492**			

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.9 Revised Cost Breakdown of RUB

BILL NO 16 ; STRUCTURES -RUB										
Item	**Description**	**Unit**	**RUB**		**Total QTY**	**Rate (Rs.)**	**Amount (Rs)**			**Total Amount (Rs)**
			Str 1 : Main Carriage way	**Str 1 : Service Road**			**Str 1**	**Str 2**	**Str 3**	
	Number of structures	**Nos**	**2**	**2**						
16.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	83,200	128,000	211,200	47	9,967,795			9,967,795
16.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.									
	a) PCC M15 below foundation	cum	1,040	400	1,440	4,271	6,150,816			6,150,816
	RCC M35 for structure	cum	22,362	8,400	30,762	5,612	172,626,500			172,626,500
16.03	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	3,600	2,640	6,240	940	5,863,104			5,863,104
16.04	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**									
	For structure	MT	2,819	1,072	3,891	68,995	268,458,456			268,458,456
16.05	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	3,900	2,860	6,760	164	1,109,722			1,109,722
16.06	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	8,600	1,500	10,100	953	9,624,019			9,624,019
16.07	Anti Carbonation Painting to the exposed surface of concrete	Sqm	18,000	10,000	28,000	67	1,874,880			1,874,880
16.08	RCC M25 at Drain side walls cover slab kerbnear median	Cum	320	300	620	6,246	3,872,297			3,872,297
SUB TOTAL							**479,547,589**	**0**	**0**	**479,547,589**
GRAND TOTAL							**479,547,589**			

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.10 Revised Cost Breakdown of ROB

BILL NO 17 : STRUCTURES - ROB

Item	Description	Unit	QUANTITY- ROB		Total Qty	Rate (Rs.)	Amount (Rs)		Total Amount (Rs)
			Str 1	Str 3			Str 1	Str 3	
	Number of structures	**Nos**	**1**	**2**					
17.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	11,470	15,332	26,802	47	541,338	723,609	1,264,947
17.02	Pile Boring M35								
	a)1000mm dia	Rm	3,520	3,696	7,216	8,262	29,082,240	30,536,352	59,618,592
17.03	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.								
	a) PCC M15 below pile cap	cum	638	613	1,251	3,856	2,459,873	2,363,483	4,823,356
	b)PCC M15 in approach slab	cum	57	137	194	5,921	337,472	811,117	1,148,589
	f) RCC M35 for Pilecaps	cum	2,703	1,989	4,692	5,627	15,209,240	11,191,705	26,400,946
17.04	Providing and laying Cement Concrete in **Sub-structure** including centering and shuttering etc. and **Excluding cost of steel**)								
	a) RCC M35 for pier , Piercap Dirtwall and pedestal upto 10m ht	cum	891	1,069	1,960	6,486	5,778,973	6,930,616	12,709,589
17.05	Providing and laying Reinforced Cement Concrete in **Super structure** including centering and shuttering and **Excluding cost of steel.**								
	a) RCC M35	cum	936	6,552	7,488	6,780	6,346,305	44,424,132	50,770,437
	b) PSC M45	cum	10,462	11,138	21,600	8,757	91,617,617	97,540,974	189,158,591
17.06	Providing and laying Reinforced Cement Concrete M-30 grade for **approach slabs including cost of reinforcement**	cum	115	115	230	10,568	1,215,297	1,215,297	2,430,594
17.07	Providing and laying 40**mm Modified Bituminous concrete with 25mmthick Mastic Asphalt wearing course** on struction portion including approach slab	sqm	13,884	15,288	29,172	953	13,229,692	14,567,525	27,797,217
17.08	Providing and constructing **RCC crash barrier** M 40 grade including cost of centering, shuttering and **Excluding the Cost of reinforcement.**	cum	406	212	618	5,612	2,277,444	1,187,880	3,465,325
17.09	Providing and fixing the **expansion joints**								
	a) Asphaltic Plug Joint between approach slab and dirt wall.	RM	120	240	360	1,459	175,090	350,179	525,269
	b) Elastomeric type Joint	RM							
	c) Strip Seal type Joint	RM	468	437	905	16,798	7,861,614	7,337,506	15,199,120
17.10	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum				940			
17.11	Providing and fixing galvanized **Drainage Spouts** along with drain pipes.	Nos.	720	403	1,123	1,700	1,223,942	685,408	1,909,350
17.12	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**								
	For structure	MT	3,035	4,594	7,629	68,995	209,429,333	316,939,665	526,368,998
17.13	HTS for Prestressing	MT	434	589	1,023	170,380	73,944,798	100,353,655	174,298,454
17.14	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.				164			

17.15	**Elastomeric bearings**	cu.cm	140,400	590,100	730,500	1	98,561	414,250	512,811
17.16	**Pot cum PTFE Bearings**								
	a) 750 MT Capacity	Nos	8	16	24	317,520	2,540,160	5,080,320	7,620,480
	b) 450 MT Capacity	Nos	40		40	190,512	7,620,480	0	7,620,480
17.17	Anti Carbonation Painting to the exposed surface of concrete	Sqm	23,457	31,508	54,965	67	1,570,681	2,109,802	3,680,483
17.18	110 mm dia HDPE Rain water down take pipes	Rmt	1,500	1,440	2,940	510	764,640	734,054	1,498,694
17.09	Pile load test - Initial	No	1	2	3	300,000	300,000	600,000	900,000
17.20	Pile load test - Routine	No	1	2	3	250,000	250,000	500,000	750,000
SUB TOTAL							**473,874,789**	**646,597,532**	**1,120,472,321**
GRAND TOTAL							**1,120,472,321**		

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.11 Cost Breakdown of POP

BILL NO 18 : STRUCTURES - POP

Item	**Description**	**Unit**	**POP**			**Total Qty**	**Rate (Rs.)**	**Amount (Rs)**		
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**
	Number of structures	**Nos**	**3**	**0**	**2**					
18.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	495,000	0	330,000	825,000	47	23,362,020	0	15,574,680
18.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.									
	a) PCC M15 below foundation	cum	1,730	0	1,153	2,883	4,271	7,389,522	0	4,925,778
	b)PCC M15 in approach slab	cum	26	0	18	44	5,921	155,592	0	103,728
18.03	Providing and laying Cement Concrete in **Sub-structure** including centering and shuttering etc. and **Excluding cost of steel**)									
	a) RCC M35 for Retaining Wall, footing, pier,	cum	13,428	0	8,952	22,380	6,486	87,093,202	0	58,062,135
18.04	Providing and laying Reinforced Cement Concrete in **Super structure** including centering and shuttering and **Excluding cost of steel.**									
	a) RCC M35	cum	1,817	0	1,211	3,028	6,780	12,318,340	0	8,212,227
18.05	Providing and laying Reinforced Cement Concrete M-30 grade for **approach slabs including cost of reinforcement**	cum	62	0	41	103	10,568	655,204	0	433,280
18.06	Providing and laying 40**mm Modified Bituminous concrete with 25mmthick Mastic Asphalt wearing course** on struction portion including approach slab	sqm	1,080	0	720	1,800	953	1,029,103	0	686,069
18.07	Providing and constructing **RCC crash barrier** M 40 grade including cost of centering, shuttering and **Excluding the Cost of reinforcement.**	cum	1,440	0	960	2,400	5,612	8,080,819	0	5,387,213
18.08	Providing and fixing the **expansion joints**									
	a) Asphaltic Plug Joint between approach slab and dirt wall.	RM	500	0	333	833	1,459	729,540	0	485,874
18.09	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	10,289	0	6,860	17,149	940	9,667,544	0	6,445,656
18.10	Providing and fixing galvanized **Drainage Spouts** along with drain pipes.	Nos.	102		68	170	1,700	173,392	0	115,595
18.11	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**									
	For structure	MT	1,668	0	1,164	2,832	68,995	115,083,193	0	80,309,854
18.12	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	11,147	0	7,431	18,578	164	1,829,892	0	1,219,873
18.13	**Elastomeric bearings**	cu.cm	315,900		210,600	526,500	1	221,762	0	147,841
18.14	Anti Carbonation Painting to the exposed surface of concrete	Sqm	2,670	0	1,780	4,450	67	178,783	0	119,189
18.15	Footpath at bridge deck top	Sqm	405	0	270	675	916	370,915	0	247,277
18.16	HandRail at deck edge	Rm	288		192	480	2,099	604,454	0	402,970
SUB TOTAL								**268,943,278**	**0**	**182,879,237**
GRAND TOTAL								**451,822,515**		

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.12 Cost Breakdown of VOP

BILL NO 19 : STRUCTURES - VOP

Item	Description	Unit	VOP			Total Qty	Rate (Rs.)	Amount (Rs)		
			Str 1	Str 2	Str 3			Str 1	Str 2	Str 3
	Number of structures	**Nos**	**0**	**2**	**1**			**1**	**0**	**0**
19.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	0	330,000	165,000	495,000	47	0	15,574,680	7,787,340
19.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.									
	a) PCC M15 below foundation	cum	0	1,153	577	1,730	4,271	0	4,925,778	2,464,598
	b)PCC M15 in approach slab	cum	0	36	18	54	5,921	0	213,939	106,570
19.03	Providing and laying Cement Concrete in **Sub-structure** including centering and shuttering etc. and **Excluding cost of steel**)									
	a) RCC M35 for Retaining Wall, footing, pier, piercap & Dirt wall	cum	0	8,952	4,476	13,428	6,486	0	58,062,135	29,031,067
19.04	Providing and laying Reinforced Cement Concrete in **Super structure** including centering and shuttering and **Excluding cost of steel.**									
	a) RCC M35	cum	0	2,273	1,136	3,409	6,780	0	15,408,773	7,704,387
19.05	Providing and laying Reinforced Cement Concrete M-30 grade for **approach slabs including cost of reinforcement**	cum	0	85	43	128	10,568	0	898,263	454,415
19.06	Providing and laying 40**mm Modified Bituminous concrete with 25mmthick Mastic Asphalt wearing course** on struction portion including approach slab	sqm	0	1,440	720	2,160	953	0	1,372,137	686,069
19.07	Providing and constructing **RCC crash barrier** M 40 grade including cost of centering, shuttering and **Excluding the Cost of reinforcement.**	cum	0	960	480	1,440	5,612	0	5,387,213	2,693,606
19.08	Providing and fixing the **expansion joints**									
	a) Asphaltic Plug Joint between approach slab and dirt wall.	RM	0	164	82	246	1,459	0	239,289	119,645
19.09	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	0	6,860	3,430	10,290	940	0	6,445,656	3,222,828
19.10	Providing and fixing galvanized **Drainage Spouts** along with drain pipes.	Nos.	0	68	34	102	1,700	0	115,595	57,797
19.11	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**									
	For structure	MT	0	1,339	669	2,008	68,995	0	92,383,930	46,157,468
19.12	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	0	7,431	3,716	11,147	164	0	1,219,873	610,019
19.13	**Elastomeric bearings**	cu.cm	0	315,900	157,950	473,850	1	0	221,762	110,881
19.14	Anti Carbonation Painting to the exposed surface of concrete	Sqm	0	2,400	1,200	3,600	67	0	160,704	80,352
19.15	Footpath at bridge deck top	sqm	0	270	135	405	916	0	247,277	123,638
19.16	HandRail at deck edge	Rm	0	192	96	288	2,099	0	402,970	201,485
SUB TOTAL								**0**	**203,279,974**	**101,612,165**
GRAND TOTAL								**304,892,139**		

Source: JICA Experts based on cost estimate R(3) in DPR

Table 7.2.13 Cost Breakdown of Underpass

BILL NO 20 : STRUCTURES - UNDER PASS										
Item	**Description**	**Unit**	**QUANTITY- ROB**			**Total Qty**	**Rate (Rs.)**	**Amount (Rs.)**		
			Str 1	**Str 2**	**Str 3**			**Str 1**	**Str 2**	**Str 3**
	Nos		**2**	**1**	**1**			**2**	**1**	**1**
20.01	Earthwork in excavation for structures **in all types of soil**	cum	297,660	141,570	200,000	639,230	47	14,048,361	6,681,538	9,439,200
20.02	Providing and laying Plain cement concrete M15 for leveling course									
	PCC M15 below foundation 100 thick	cum	2,508	2,016	500	5,023	4,271	10,710,749	8,609,946	2,135,700
20.03	Providing Reinforced cement concrete for following concrete works (Rate shall exclude for HYSD Reinforcement.)									
	RCC M35 for retaining walls	cum	7,874	3,826	4,000	15,701	6,486	51,071,589	24,817,801	25,943,760
20.04	Providing **M40** grade reinforced cement concrete **crash barrier**	cum	656	312	400	1,368	5,612	3,681,262	1,750,844	2,244,672
20.05	Providing and fixing the **expansion joints of various types as below**									
	Joints in side walls of retaining walls (premoulded joint filler &compound)	RM	237	70	170	477	193	45,765	13,540	32,883
20.06	Providing **filter media** behind retaining	cum	6,917	3,456	3,500	13,873	940	6,499,307	3,247,539	3,288,600
20.07	Supplying, cutting, bending,fitting placing TMT Fe500 HYSD reinforcement									
	a) In Approach retaining walls	MT	781	382	350	1,513	68,995	53,907,300	26,340,459	24,148,152
	b) For crash barrier	MT	105	50	70	225	68,995	7,241,686	3,444,216	4,829,630
20.08	Providing and fixing **100mm dia PVC weep holes** in retaining walls	Nos.	7,494	3,744	3,800	15,038	164	1,230,137	614,668	623,808
20.09	Providing anti carbonation treatment to exposed concrete surface	Sq.m	11,529	5,761	5,800	23,089	67	771,948	385,723	388,368
	Bridge crossing at Existing road level									
20.10	M35 concrete for footing	cum	910	640	270	1,820	5,612	5,106,629	3,591,475	1,515,154
20.11	M35 concrete in pier	cum	410	250	160	820	6,486	2,659,235	1,621,485	1,037,750
20.12	M35 concrete for piercap and pedestal	cum	293	180	113	585	6,780	1,983,220	1,220,443	762,777
20.13	RCC M35 for Dirt wall	cum	154	64	90	308	6,780	1,042,462	432,240	610,222
20.14	Superstructure RCC M35	cum	4,116	2,604	1,512	8,232	6,780	27,907,468	17,655,745	10,251,723
20.15	Elastomeric Bearings	cucm	819,000	468,000	351,000	1,638,000	1	574,938	328,536	246,402
20.16	HYSD Fe500									
a	For footing	MT	91	64	27	182	68,995	6,278,520	4,415,662	1,862,857
b	For pier	MT	41	25	16	82	68,995	2,828,784	1,724,868	1,103,916
c	For piercap	MT	59	36	23	117	68,995	4,036,191	2,483,810	1,552,381
d	For superstructure	MT	617	391	227	1,235	68,995	42,597,340	26,949,338	15,648,002
e	For dirt wall	MT	15	6	9	31	68,995	1,060,794	439,841	620,952
f	For crash Barrier	MT	14	7	7	28	68,995	967,803	484,840	482,963
20.17	Drainage Spouts	Nos	73	42	31	146	1,700	124,094	71,397	52,698
20.18	Strip seal Expansion Joint	RM	435	255	180	870	16,798	7,307,269	4,283,572	3,023,698
20.19	Wearing coat	sqm	6,240	3,660	2,580	12,480	953	5,945,929	3,487,516	2,458,413
20.20	Footpath at bridge deck top	sqm	157	92	65	314	916	143,787	84,257	59,530
20.21	Crash Barrier at edge of carriageway	cum	75	44	31	150	5,612	420,876	246,914	173,962
20.22	Handrail at deck edge	Rm	104	61	43	208	2,099	218,275	128,027	90,248
20.23	Anticarbonate Painting	sqm	7,233	4,234	2,999	14,466	67	484,322	283,509	200,813
20.24	Asphaltic Joint	Rm	194	170	24	388	1,459	283,062	248,044	35,018
20.25	Approach slab M30 including	cum	305	179	126	609	10,568	3,217,895	1,886,352	1,331,543
SUB TOTAL								**264,396,996**	**147,974,146**	**116,195,795**
GRAND TOTAL								**528,566,936**		

Source: JICA Experts based on cost estimate R(3) in DPR

(2) Revision on Earthwork

The JICA Experts reviewed the quantities of earthwork in the project cost estimate R(3) based on the drawings of the final DPR R(5).

The JICA Experts conducted a preliminary calculation of the earthwork quantities of mainline based on the profile drawings of the final DPR R(5).

The calculation results of quantities by the JICA Experts are considered only for the mainline. Therefore, the JICA Experts deemed that total quantities included the mainline and the service road are double of calculation results.

Table 7.2.14 shows the comparison of earthwork quantities.

Table 7.2.14 Comparison of Earthwork Quantities

Item	Quantities of Earthwork (cu. m)	
	Cost Estimate R(3)	Reviewed by the JICA Experts
Excavation	5,001,498	2,009,750 x 2 = 4,019,500
Embankment	8,762,746	3,829,899 x 2 = 7,659,798

Source: JICA Experts

The quantities of both R(3) and the review made by the JICA Experts are different. However the JICA Experts assessed that the difference could not be resolved since the estimation of the JICA Experts is a rough figure only based on the quantity estimation of the mainline.

Therefore, the JICA Experts determined that total quantities of earthwork in the project cost estimate R(3) are properly estimated under the feasibility study stage.

The JICA Experts compared unit rates of earthwork with KPWD SR 2014-2015 and NH SR 2014-2015.

The comparison of earthwork unit rates is shown below.

Table 7.2.15 Comparison of Earthwork Unit Rates

Bill No.2 : Earthwork

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (Rs)		DPR	KPWD SR 2014-15		NH SR 2014-15	
					DPR	JICA Review	Unit Cost	Unit Cost	Reference Sl.No.	Unit Cost	Reference Sl.No.
2.01	Earthwork in excavation necessary for construction of roadway in all types of soil all complete as per Technical Specifications Clause 301.										
	(a) Excavation in ordinary soil	Cu.m	4,651,374	37.04	172,305,498.46	187,357,344.72	37.04			40.28	Sl. No. 3.06
	(b) Excavation of Soft Rock (for GSB/ Concrete)	Cu.m	250,074	49.03	12,261,628.37	13,519,000.44	49.03			54.06	Sl. No. 3.07
	(c) Excavation of Hard Rock requiring controlled blasting (for GSB/BT/Concrete works)	Cu.m	100,050	249.48	24,960,474.00	25,346,667.00	249.48			253.34	Sl. No. 3.05
2.02	Construction of embankment with suitable material from **borrow areas** including cover to fly ash core with all leads and lifts, compacting to 95% of modified proctor density, all complete as per drawings and Technical Specifications, Clause 305 (20 KM lead)	Cu.m	3,865,164	288.79	1,116,228,441.89	1,116,228,441.89	288.79	220.32	Sl. No. 19.6		
2.03	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, Clause 305	Cu.m	1,032,964	316.87	327,317,368.61	327,317,368.61	316.87	252.72	Sl. No. 19.62		
2.05	Filling in median/island/footpath with ***approved borrow material*** (selected earth and agricultural soil) with all leads and lifts complete as per Technical Specification Clauses 305 & 407.	Cu.m	376,088	238.03	89,520,978.82	89,520,978.82	238.03	252.72	Sl. No. 19.62		
2.06	Construction of embankment with suitable material obtained from ***roadway*** including cover to fly ash core with all leads and lifts, compacting to 95% of modified proctor density, all complete as per drawings all complete as per Technical Specifications, Clause 305	Cu.m	2,558,255	57.65	147,484,424.05	174,063,670.20	57.65	68.04	Sl. No. 19.61		
2.07	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from ***roadway*** with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, Clause 305	Cu.m	930,274	67.82	63,094,903.78	63,295,842.96	67.82	68.04	Sl. No. 19.61		
2.1	Loosening and recompacting sub-grade in all kinds of soil, compacting to 97% of modified proctor density, all complete as per Technical Specifications Clauses 301 & 305.	Cu.m	103,328	51.84	5,356,523.52	5,412,320.64	51.84	52.38	Sl. No. 19.65		
2.11	Transportation and disposal of surplus rock between for use in road construction lead of 20 Km	Cu.m	350,103	180.79	63,295,821.58	63,295,821.58	180.79	176.04	Sl. No. 17.00 17.05		
2.12	Transportation and disposal of surplus earth between lead of 15 Km and 20 Km	Cu.m	1,162,843	122.47	142,415,707.90	179,589,472.92	122.47	154.44	Sl. No. 17.00 17.04		
TOTAL					**2,164,241,771**	**2,244,946,930**					
DIFFERENCE					**80,705,159**		4%				

Source: JICA Experts

Some unit rates in the project cost estimate R(3) are lower than the unit rates in KPWD SR 2014-2015 or NH SR 2014-2015; however, differences of total cost are not much.

The JICA Experts assessed that unit rates in costs of earthwork are the proper rates.

(3) Revision on Pavement

The JICA Experts received the final plan of pavement structure from DULT, BDA, and STUP in the technical meeting on 10 July 2015.

The final plan of pavement structure is not in conformity to the pavement structure in the drawings of the DPR. However, it was confirmed that the drawings will be revised based on the final plan of pavement structure by STUP.

Therefore, the JICA Experts applied the final plan of pavement structure.

Table 7.2.16 shows the final plan of pavement structure.

Table 7.2.16 Final Plan of Pavement Structure

Structure of Pavement	
Main Road	Pavement Quality Concrete (PQC)
	Dry Lean Concrete (DLC)
	Granular Subbase (GSB)
Service Road	Bituminous Concrete Course (BMC)
	Dense Bituminous Macadam (DBM)
	Wet Mix Macadam (WMM)
	Granular Subbase (GSB)

Source: JICA Experts

It is noted that the final plan of pavement structure is in conformity to the unit items in the project cost estimate R(3).

Also, the JICA Experts reviewed the unit rates of pavement works based on KPWD SR 2014-2015 and NH SR 2014-2015.

Some unit rates in the project cost estimate R(3) are lower than the unit rates in KPWD SR 2014-2015. However, differences of total cost are not much.

The JICA Experts assessed that the unit rates in costs of pavement are the proper rates.

Table 7.2.17 shows the comparison of pavement quantities and unit rates.

Table 7.2.17 Comparison of Pavement Quantities and Unit Rates

Bill No.3 : Pavement

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (Rs)		DPR	KPWD SR 2014-15	
					DPR	JICA Review	Unit Cost	Unit Cost	Reference Sl.No.
3.01	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading –I (Table:400-1).	Cu.m.	826,728	1,149	950,009,679	1,150,011,717	1,149	1,391	Sl. No. 20.4.1
3.02	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading –I (Table:400-2).	Cu.m.							
3.03	Providing and laying Wet Mix Macadam base and profile correction course of required thickness complete as per Technical Specifications Clause 406.(10 km lead)	Cu.m.	277,027	1,173	324,994,225	398,519,961	1,173	1,439	Sl. No. 20.18
3.07	Providing bituminous primer coat over granular surface with bitumen emulsion of low porosity complete as per Technical Specifications Clause 502 @ 7.5 to 9.8 kg/10 sq.m.	Sq.m.	1,092,588	80.78	88,263,629	88,263,629	80.78		
3.08	Providing tack coat with bituminous Emulsion all complete as per Technical Specifications Clause 503								
	(i) On granular surface treated with primer and on hungry bituminous surface @3.0 Kg /10 sq.m.	Sq.m.	1,092,588	21.71	23,717,900	23,717,900	21.71		
	(ii) On Bituminous surface @ 2.0 Kg/10 sq.m.	Sq.m.	1,092,588	11.99	13,097,945	13,097,945	11.99		
3.10	Providing & laying Dense Bituminous Macadam course of required thickness on prepared surface complete as per Technical Specifications Clause 507	Cu.m.	54,629	9,198	502,452,959	505,978,168	9,198	9,262	Sl. No. 21.17.2
3.11	Providing & laying Bituminous Concrete course with CRMB of required thickness on prepared surface complete as per Technical Specifications Clause 509 with modified bituminous binder	Cu.m.	43,703	9,798	428,203,305	476,901,121	9,798	10,912	Sl. No. 21.22.1
3.14	Providing & laying Dry Lean Concrete subbase in M15 cc in service road locations at underpass area as per Technical Specifications Clause 601 and as approved by the Engineer.	Cu.m.	333,085	3,489.75	1,162,383,379	1,247,909,614	3,489.75	3,747	Sl. No. 22.1
3.15	Providing & laying Pavement Quality Concrete of M45 Grade of specified thickness in service road locations at underpass area using minimum cement content 350 kg/cu.m. with slip form paver as per Technical Specifications Clause 602 and as approved by the Engineer.	Cu.m.	658,809	6,600.15	4,348,238,221	4,543,726,616	6,600.15	6,897	Sl. No. 22.2.1
	TOTAL				**7,841,361,243**	**8,448,126,672**			
DIFFERENCE					**606,765,429**		8%		

Source: JICA Experts

(4) Revision on Drainage

The JICA Experts reviewed the quantities of major drainage structures (Item 4.01 and Item 4.03) in the project cost estimate R(3) based on the final DPR R(5) and determined that the quantities of these items seems to be the proper quantities (approximately double the total PRR length).

Furthermore, the JICA Experts reviewed the unit rates of drainage works in the project cost estimate R(3) based on KPWD SR 2014-2015/NH SR 2014-2015 and determined that the unit rates of drainage works are appropriate.

Table 7.2.18 shows the comparison of drainage unit rates.

Table 7.2.18 Comparison of Drainage Unit Rates

Bill No.4 : Drainage

Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (Rs)**	
					DPR	**JICA Review**
4.01	Construction of precast RCC drain at edge of ROW complete (Unit Qty: Excavation = 0.5 Cum / Rm ; RCC = 0.20 Cum /Rm ; Steel = 0.011 Mt/Rm)	Lm	131025	1978	**259,167,450**	**267,498,732**
4.03	Construction of covered rectangular drains along service roads and between main road and service road (Unit qty: Excavation = 0.533 Cum/Rm ; RCC M20 =0.675 Cum/Rm ; PCC M15= 0.17 Cum/Rm ; Rebar =60 Kg/Cum ; Precast cover (150mm thick) = 0.23 Cum/Rm ; Shuttering = 6.0 Sqm/ Rm ; Weepholes, 100 dia = 4no/10 Rm ; Backfill = 0.15 Cum/Rm ; Edge Angles ISA 50x50x6; 4No/Rm	Lm	124190	9762	**1,212,386,853**	**1,279,438,105**
4.05	Construction of sumps complete as per specifications and drawings in central median at superelevated sections (size 1.0 x 1.0 m x 1.0 m 200 mm wall thickness) at end of median(Unit qty: Excavation = 0.5 cum ; RCC M20 =1.16cum ; PCC M15 = 0.28cum ; Rebar =75kg/cum ; Precast cover (150mm thick) =0.18 cum ; Shuttering = 8.8 sqm ; backfill = 0.2 cum/Rm)	Nos	72	15335	**1,104,146**	**1,156,093**
	a) Connecting drains on service roads due to change in C/s.	Lm	1966	9836.8	**19,339,149**	**19,339,149**
4.08	Providing water downtakes to drain from underpass/flyover approaches.	Lm	8235	1620	**13,340,700**	**13,340,700**
4.1	Providing rain water harvesting facilities on project road complete as per typical detail in Technical schedule	Nos	2622	10000	**26,220,000**	**26,220,000**
	TOTAL				**1,531,558,297**	**1,606,992,779**
DIFFERENCE					**75,434,481**	

5%

Unit Rate Breakdown (for JICA Review)

Item	Total Unit Rate (Rs)	Exc	PCC	RCC M20	RCC M20 Cover Slab	Rebar	Weep Hole / Grating	Backfill	Edge Angles
		NH	NH	KPWD	KPWD	NH	KPWD5	NH	DPR
4.01	2,042	18.44		1145.02		762.56			
4.03	10,302	19.66	814.50	4797.41		3764.29	154.00	43.65	708.75
4.05	16,057	18.44	1341.54	6641.09	1030.51	6967.06		58.20	
Reference Sl.No.		3.13(i)	9.01	28.7.2	28.7.2	9.09	28.1	12.01VI	

KPWD : KPWD SR, Bangalore circle 2014-15
NH : NH SR, Bangalore Circle 2014-15

Source: JICA Experts

(5) Revision on Retaining Wall

The JICA Experts confirmed the quantities of retaining wall in the project cost estimate R(3) with DULT, BDA, and STUP.

The JICA Experts reported that there is a difference between the quantity calculation by the JICA Experts and the quantity in the project cost estimate R(3) on RE wall area (RE wall: Reinforced Earth wall).

DULT, BDA, and STUP provided the JICA Experts the revised quantities of RE wall on 19 June 2015.

Table 7.2.19 shows the comparison of retaining wall quantities.

Table 7.2.19 Comparison of Retaining Wall Quantities

Item	Quantities of Retaining Wall (sq. m)		
	Cost Estimate R(3)	Reviewed by the JICA Experts	Revised by STUP
RCC Wall	98,986	108,184	-
RE Wall	176,175	339,680	229,655

Source: JICA Experts

The JICA Experts updated the quantity of RE wall in the project cost estimate R(3) by using the quantity of STUP since it is assumed that BDA/STUP would adjust the quantity during the detailed design stage.

Table 7.2.20 shows the updated cost estimate of RE wall.

Table 7.2.20 Updated Cost Estimate of RE Wall

BILL NO 25: RE WALL							
Item		**Unit**	**Total Quantity**		**Rate (Rs)**	**Total Amount (Rs)**	
SI NO	**Structures**		**Cost Estimate R(3)**	**Revise by STUP**		**Cost Estimate R(3)**	**Revise by STUP**
	RE PANEL						
25.01	Area of RE wall - RE Panel	Sqm	176175	229655	5,500.00	968,962,500	1,263,100,080
25.02	Area of RE wall, - (Friction slab, Crash barrier, Filter media, HDPE pipe etc.)	Sqm	176175	229655	3,500.00	616,612,500	803,790,960
	RCC WALL						
	Length		12620	12620			
25.03	EARTH WORK	Cum	47325	47325	47.20	2,233,551	2,233,551
25.04	Back fill	Cum	27764	27764	187.27	5,199,420	5,199,420
25.05	PCC	Cum	3155	3155	4,271.40	13,476,267	13,476,267
25.06	RCC - M35	Cum	16406	16406	6,485.94	106,408,332	106,408,332
25.07	Steel	MT	738	738	68,994.72	50,936,732	50,936,732
25.08	Weep holes	Nos	6300	6300	164.16	1,034,208	1,034,208
25.09	Filter media	Cum	5300	5300	939.60	4,980,256	4,980,256
25.10	Painting	Sqm	6310	6310	66.96	422,518	422,518
Total						**1,770,266,283**	**2,251,582,323**
Difference						**481,316,040**	

Source: JICA Experts

7.3 Update of Project Cost Estimate

The JICA Experts updated the project cost estimate R(3) based on the latest rates and results of the technical review.

7.3.1 Structure of Construction Cost Estimate

The structures of construction cost estimate for civil works, intelligent transport system (ITS), and operation and maintenance (O&M) cost are shown below.

Table 7.3.1 Structure of Construction Cost Estimate for Civil Works

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
A. Road Works	**14,649,051,849**	**A. Road Works**	**13,690,000,000**	**959,051,849**
1. Site Clearance	21,330,297	1. Site Clearance	21,161,009	169,288
2. Earthwork	2,181,555,705	2. Earthwork	2,164,241,771	17,313,934
3. Pavement	7,904,092,133	3. Pavement	7,841,361,243	62,730,890
4. Drainage	1,543,810,764	4. Drainage	1,531,558,297	12,252,466
5. Road Furniture	1,043,474,085	5. Road Furniture	1,035,192,545	8,281,540
6. Intersections and Entry/Exit Ramps	119,240,605	6. Intersections and Entry/Exit Ramps	118,236,045	1,004,560
7. Toll Plaza	1,612,053,535	7. Toll Plaza	734,940,241	877,113,293
8. Arboriculture	41,183,850	8. Arboriculture	40,856,994	326,856
9. Highway Lighting	144,568,287	9. Highway Lighting	143,420,920	1,147,367
10. Other Items	35,996,809	10. Other Items	43,271,120	-7,274,311
11. Maintenance during Construction	1,745,778	11. Maintenance during Construction	1,559,011	186,767
		12. Rounding Off	14,200,803	-14,200,803
B. Structure Works	**9,099,701,822**	**B. Structure Works**	**3,740,000,000**	**5,359,701,822**
12. Culvert	330,054,525	13. Culvert	180,692,176	149,362,349
13. Vehicular Underpass	422,863,923	14. Vehicular Underpass	211,558,947	211,304,976
14. Pedestrian Underpass	82,966,534	15. Pedestrian Underpass	42,331,149	40,635,385
15. Minor Bridge	174,399,616	16. Minor Bridge	83,618,827	90,780,790
16. Railway Under Bridge	483,383,969	17. Railway Under Bridge	211,357,592	272,026,378
17a. Bridge Structures	6,211,526,000	18. Railway Over Bridge	594,629,691	4,478,056,931
		19. Pedestrian Overpass	256,624,861	
		20. Vehicular Overpass	156,820,799	
		22. Flyovers along PRR	610,439,258	
		21. Underpass along PRR (Bridge Structure of	114,954,460	
20. Underpass along PRR	300,574,666	21. Underpass along PRR (Exclede Bridge	178,397,621	122,177,045
22. Underpass along Cross road	237,596,636	23. Underpass along Cross road	235,710,948	1,885,688
23. Flyover along Cross road (Exclude bridge	856,335,952	24. Flyover along Cross road	849,539,635	6,796,317
		25. Rounding Off	13,324,037	-13,324,037
C. Earth Rtaining Structures	**3,807,460,118**	**C. Earth Rtaining Structures**	**3,310,000,000**	**497,460,118**
24. RCC Wall	1,537,865,137	26. RCC Wall	1,525,659,858	12,205,279
25. RE Wall	2,269,594,981	27. RE Wall	1,770,266,283	499,328,699
		28. Rounding Off	14,073,859	-14,073,859
D. Other Works	**2,859,599,486**	**F. Other Items of Work**	**3,208,260,000**	**-348,660,514**
1. Environmental Mitigation Plan	90,200,000	2. Environmental Mitigation Plan	90,200,000	0
2. Capacity Building (A+B+C) X 0.30%	82,668,641	4. Capacity Building (A+B+C) X 0.5%	103,700,000	-21,031,359
3. Shifting of Utilities after LA (A+B+C) X 5.00%	1,377,810,689	5. Shifting of Utilities after LA (A+B+C) X 7.5%	1,555,500,000	-177,689,311
4. Safety & Occupational Health, Risc Coverage (A+B+C) X 4.75%	1,308,920,155	10. Safety & Occupational Health, Risc Coverage (A+B+C) X 7.0%	1,451,800,000	-142,879,845
		13. Rounding Off	7,060,000	-7,060,000
Total	**30,415,813,275**	**Total**	**23,948,260,000**	**6,467,553,275**

Source: JICA Experts

Table 7.3.2 Structure of Construction Cost Estimate for ITS

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	item	Total Amount (Y) (INR)	
E. Intelligent Transport System	**3,723,721,125**	**G. Intelligent Transport System**	**8,000,000,000**	**-4,276,278,875**
1. ITS for Peripheral Ring Road	1,363,933,290	1. PRR - ITS	1,464,000,000	-100,066,710
2. Bengaluru Traffic Information System (B-TIC)	648,603,135	2. Bangalor City - ITS	6,468,000,000	-4,108,212,165
3. Area Traffic Signal Control System (ATCS)	1,321,563,900			
4. Electronic Road Pricing (ERP) System	0			
5. Clearinghouse for Common Smartcard	389,620,800			
		3. Rounding Off	68,000,000	-68,000,000
Total	**3,723,721,125**	**Total**	**8,000,000,000**	**-4,276,278,875**

Source: JICA Experts

Table 7.3.3 Structure of O&M Cost for Civil Works

Update by JICA Experts			Project Cost Estimate R(3) in DPR			Difference (INR)
item		Total Amount (INR)	item		Total Amount (INR)	
K1. Routine O & M (per 1 year)		**131,431,514**	**K1. Routine O & M (per 1 year)**		**75,205,843**	**56,225,670**
a. Roads	0.201	71,503,020	a. Roads		39,955,843	31,547,177
b. Structures	(Cr/Yr/Km)	59,928,494	b. Structures	(B+C) X 0.5%	35,250,000	24,678,494
K2. Periodic O & M (per 5 years)		**844,916,875**	**K2. Periodic O & M (per 5 years)**		**1,498,523,564**	**-653,606,690**
a. Roads	1.289	459,662,272	a. Roads		1,423,723,564	-964,061,292
b. Structures	(Cr/Yr/Km)	385,254,603	b. Structures	B X 2.0%	74,800,000	310,454,603

Source: JICA Experts

Table 7.3.4 Structure of O&M Cost for ITS

Update by JICA Experts		Project Cost Estimate R(3) in DPR			Difference (INR)
item	Total Amount (INR)	item		Total Amount (INR)	
K3. Routine O & M for ITS (per 1 year)	**1,082,350,438**	**K1. Routine O & M for ITS (per 1 year)**		**960,000,000**	**122,350,438**
1. ITS for Peripheral Ring Road	814,696,502	c. PRR ITS	(G1+G3) X 12%	183,840,000	630,856,502
2. Bengaluru Traffic Information System (B-TIC)	50,281,440	d. City ITS	G2 X 12%	776,160,000	-508,506,064
3. Area Traffic Signal Control System (ATCS)	133,660,208				
4. Electronic Road Pricing (ERP) System	72,822,288				
5. Clearinghouse for Common Smartcard	10,890,000				
Total	**1,082,350,438**	**Total**		**960,000,000**	**122,350,438**

Source: JICA Experts

7.3.2 Update Base Year of Project Cost Estimate

The JICA Experts updated the base year of the project cost estimate R(3) based on conditions of the JICA appraisal.

The base years of the project cost estimate R(3) and JICA appraisal are shown below.

- Base year of the project cost estimate R(3): August 2014
- Base year of the JICA appraisal: July 2015

In accordance with updating the base year of the project cost estimate, the JICA Experts updated the unit rates in the project cost estimate R(3) by using the construction cost index (CCI) in India.

The JICA Experts calculated the annual price escalation based on the CCI in India, and used 0.8% rate of year 2014 based on the discussion with JICA headquarters.

Table 7.3.5 shows the price escalation of each category.

Table 7.3.5 Price Escalation of Each Category

Category	Annual Price Escalation of year 2014		
	CCI		Price Escalation
	Jan. 2014 (A)	Dec. 2014 (B)	B / A - 1
Building	139.90	141.06	0.8%
Roads	143.98	145.17	0.8%
Bridges	136.48	137.62	0.8%
Power	140.99	142.16	0.8%
Urban Infra	133.54	134.65	0.8%
Maintenance	133.09	134.19	0.8%

Source: JICA Experts

(Refer to the Construction Cost Index (CCI) by the Construction Industry Development Council)

7.3.3 Update Cost of Work Items

The JICA Experts reviewed and updated each work item in the project cost estimate based on latest rates and results of JICA technical review.

7.3.3.1 Civil Works

(1) Road Works

Table 7.3.6 shows the comparison of the cost estimate for the road works.

Table 7.3.6 Comparison of Cost Estimate for Road Works

Update by JICA Experts		**Project Cost Estimate R(3) in DPR**		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
A. Road Works	**14,649,051,849**	**A. Road Works**	**13,690,000,000**	**959,051,849**
1. Site Clearance	21,330,297	1. Site Clearance	21,161,009	169,288
2. Earthwork	2,181,555,705	2. Earthwork	2,164,241,771	17,313,934
3. Pavement	7,904,092,133	3. Pavement	7,841,361,243	62,730,890
4. Drainage	1,543,810,764	4. Drainage	1,531,558,297	12,252,466
5. Road Furniture	1,043,474,085	5. Road Furniture	1,035,192,545	8,281,540
6. Intersections and Entry/Exit Ramps	119,240,605	6. Intersections and Entry/Exit Ramps	118,236,045	1,004,560
7. Toll Plaza	1,612,053,535	7. Toll Plaza	734,940,241	877,113,293
8. Arboriculture	41,183,850	8. Arboriculture	40,856,994	326,856
9. Highway Lighting	144,568,287	9. Highway Lighting	143,420,920	1,147,367
10. Other Items	35,996,809	10. Other Items	43,271,120	-7,274,311
11. Maintenance during Construction	1,745,778	11. Maintenance during Construction	1,559,011	186,767
		12. Rounding Off	14,200,803	-14,200,803

Source: JICA Experts

1) Major Contents of Cost Update

Major contents of the cost update for the road works are summarized below.

- Update the unit rates of each work by using 0.8% rate of annual price escalation in year 2014.
- Update the toll plaza costs based on the technical review results.

2) Toll Plaza

The JICA Experts updated the costs of the toll plaza based on the technical review and the results are summarized as shown below.

- Update the costs of additional three toll plazas (additional interchanges).
- Update the costs of additional and missing toll booth tunnels.
- Update the costs of additional and missing ducts and junction boxes for electric cable.

Unit rates of toll booth tunnels were calculated by using cost per cu. m of Bill No.12 Culvert (shown in Table 7.3.7).

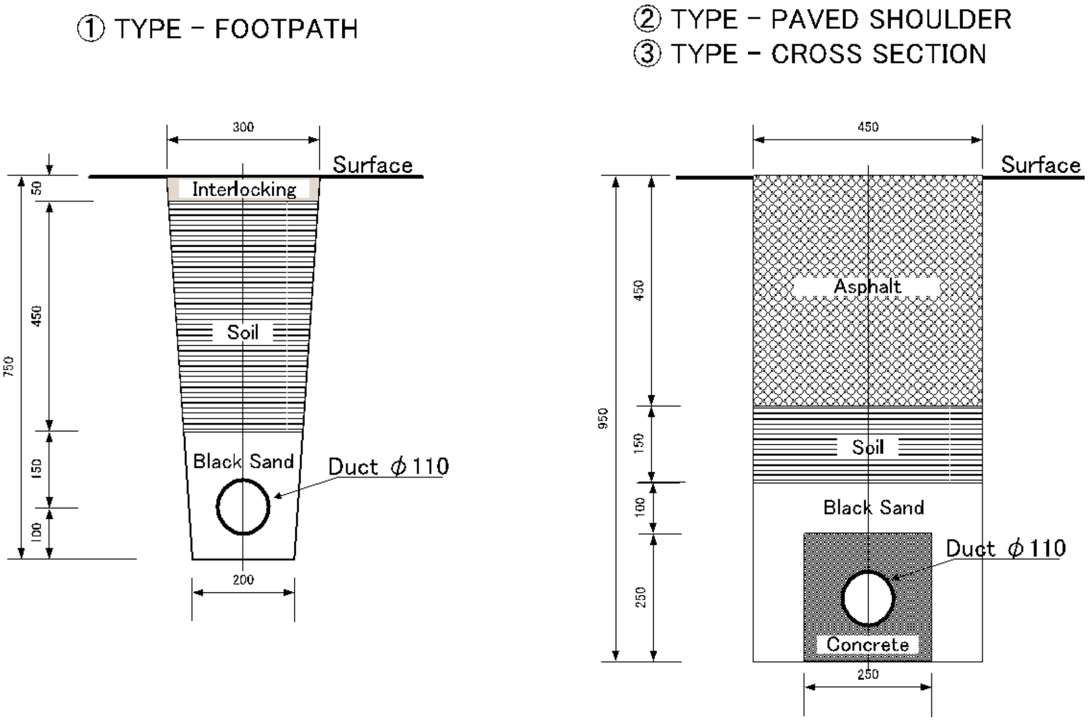
Table 7.3.7 Calculation of Unit Rate for Tunnel of Toll Booth

A) Total Cost of Culvert (update cost, exclude cost of crash barrier)	Rs	28,264,712
B) Total Volume of Culvert	m^3	27,992
C) Cost of Culvert per cu. m (A / B)	Rs / m^3	1,727
D) Area of Tunnel	m^2	2.36
E) Unit Cost of Tunnel (C * D)	Rs / m	27,676
Applicable Unit Cost of Tunnel	Rs / m	30,000

Source: JICA Experts

Unit rates of ducts and junction boxes for electric cable were estimated based on KPWD SR2014-2015.

The typical drawings are shown in Figures 7.3.1 and 7.3.2; and the calculation of ducts and junction boxes are shown in Tables 7.3.8 and 7.3.9.



Source: JICA Experts

Figure 7.3.1 Typical Drawings of PVC Ducts

Table 7.3.8 Cost Estimate for Unit Rate of PVC Ducts

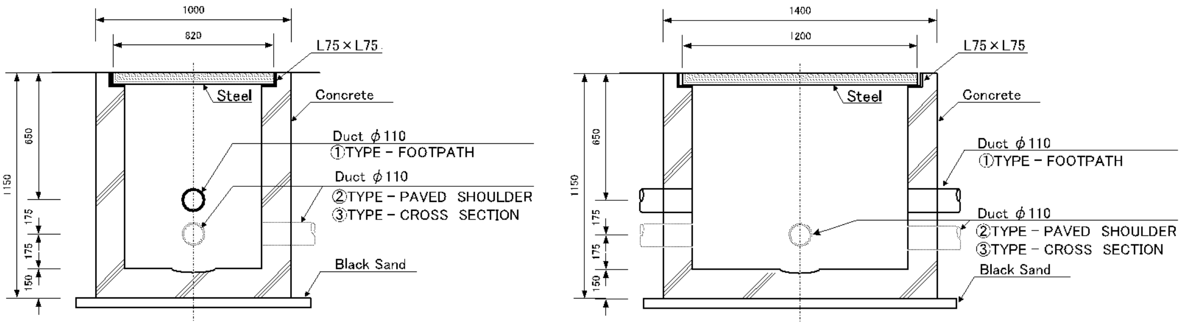
Cost Calculation for Duct D110mm under Paved Shoulder

Item no	Description	Unit	No	Length (m)	Breadth (m)	Height (m)	Quantity	Rate (Rs)	Amount (Rs)
1	Earthwork excavation for foundation of structures	Cum	1	1	0.45	0.95	0.428	138	59
2	Construction of embankment	Cum	1	1	0.45	0.15	0.068	67	5
3	Providing and laying in position reinforced cement concrete	Cum	1	1	0.25	0.25	0.063	5953	372
4	Providing and removing centering, shuttering, strutting, propping etc., and removal of form work for foundations, footings	Sqm	1	3		0.25	0.750	232	174
5	KSRB 4.9.2: Providing T.M.T steel reinforcement for R.C.C work	Sqm	1				0.003	77334	266
6	Sand	MT	1	1	0.95	0.1	0.095	1537	146
7	PVC Pipes 10kg/Sqm 110mm outerdia	Rm	1	1			1.000	541	541
GRAND TOTAL Per m									1562

Cost Calculation for Duct D110mm under Footpath

Item no	Description	Unit	No	Length (m)	Breadth (m)	Height (m)	Quantity	Rate (Rs)	Amount (Rs)
1	Earthwork excavation for foundation of structures	Cum	1	1	0.25	0.75	0.188	138	26
2	Construction of embankment	Cum	1	1	0.267	0.45	0.120	67	8
6	Sand	MT	1	1	0.217	0.25	0.045	1537	69
7	PVC Pipes 10kg/Sqm 110mm outerdia	Rm	1	1			1.000	541	541
Grand Total per m									643

Source: JICA Experts (Refer to KPWD SR 2014-2015)



Source: JICA Experts

Figure 7.3.2 Typical Drawings of Junction Box

Table 7.3.9 Cost Estimate for Unit Rate of Junction Box

Cost Calculation for Junction Box of size 1.4x1.0x1.15 m									
Item no	Description	Unit	No	Length (m)	Breadth (m)	Height (m)	Quantity	Rate (Rs)	Amount (Rs)
1	Earthwork excavation for foundation of structures	Cum	1	2.4	2	1.2	5.76	138	797
2	Providing and laying in position plain cement concrete	Cum	1	1.6	1.2	0.1	0.192	5144	988
3	Providing and laying in position reinforced cement concrete								
	Walls	Cum	1	4.2	0.15	0.9	0.567		
	Bottom Slab	Cum	1	1.4	1	0.15	0.21		
	Top Slab	Cum	1	1.4	1	0.1	0.14		
	TOTAL						0.917	5953	5459
4	Providing and removing centering, shuttering, strutting, propping etc.	Sqm	1						
	TOTAL						11.060	232	2567
5	Providing T.M.T steel reinforcement for R.C.C work	MT	1				0.05	77334	3900
6	ISA for cover slab 75x75x6 mm @6.8kg/ m	kg	1	5			34	58.3	1982
Grand Total per Nos									15694

Source: JICA Experts (Refer to KPWD SR 2014-2015)

3) Other Items

Item Nos.10.01 to 10.03 are vehicles and mobile phones for client during construction, therefore, the JICA Experts deducted these items from other items and included these in the administration cost.

Table 7.3.10 shows the items deducted from other items.

Table 7.3.10 Items Deducted from Other Items

BILL NO 10 : Other Items					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
10.01	Provision for two nos new 4x4 driven AC Vehicle (Travera - 1 nos and Tata Sumo - 1 no) to PIU including vehicle management, fuel charges, driver salary)	Veh month	72	60,480.00	4,354,560
10.02	Provision of two mobile phones with connection	Month	72	5,040.00	362,880
10.03	Maintenance of Vehicles provided to client including driver, operation costs, fuel etc, complete (4000 km/month)	Veh month	72	40,320.00	2,903,040

Source: JICA Experts

4) Cost Breakdown of Road Works

The updated cost breakdowns of the road works are shown below.

Table 7.3.11 Updated Cost Breakdown of Site Clearance

BILL NO 1 : Site Clearance

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
1.01	Clearing and grubbing road land for project road complete as per Technical Specifications Clause 201.	Ha.	541	26,426.74	14,296,864
1.02	Dismantling including disposal of unserviceable material and stacking the serviceable material complete as per Technical Specifications Clause 202.				0
	a) Brick/Stone Structures.	Cu.m.	**525**	259.10	136,026
	b)Plain Concrete/Reinforced concrete/ Prestressed concrete structures including cleaning, straightening & cutting of bars and separating them out from RCC/PSC.	Cu.m.	**1067**	387.56	413,522
	c) Bituminous Pavement	Cu.m.	**3908**	220.99	863,644
	d) Granular Material / shoulder	Cu.m.		388.64	0
	e) Retaining walls	Rm	**195**	380.51	74,199
	f) Pedestian Guard raill	Rm		70.76	0
	g) Metal crash barrier	Rm		65.32	0
1.03	Shifting of Utilities complete as per Technical Specifications Clause 201.				0
1	Electrical poles	Nos.	**658**	163.30	107,449
2	Electric junction box	Nos.	**0**	1,197.50	0
3	Transformer	Nos.	**7**	348,364.80	2,438,554
4	Telepphone pole	Nos.	**5**	1,069.92	5,350
5	Telephone junction box	Nos.	**4**	598.75	2,395
6	Lamp post	Nos.	**45**	123.45	5,555
7	Water post	Nos.	**0**		0
8	Hand pump	Nos.	**2**	348.36	697
9	Manhole	Nos.	**36**	5,007.74	180,279
10	Valve	Nos.	**0**		0
11	Sign board	Nos.	**0**	146.97	0
12	Borewell	Nos.	**136**	653.18	88,833
13	Km stones	Nos.	**3**	258.66	776
14	OFC stones	Nos.	**4**	258.66	1,035
15	Boundary stones	Nos.	**5**	566.09	2,830
16	HT Tower within ROW	Nos.	**4**	1,306.37	5,225
17	Bus stop / shelter	Nos.	**0**		0
18	Signal posts	Nos.	**0**	136.08	0
19	Name boards / gantry	Nos.	**0**	136.08	0
1.04	Cutting of trees including cutting of trunks, branches and removal of stumps of felled trees above 300 mm girth complete as per Technical Specifications Clause 201.		**0**		0
	a) above 300m upto 600mm	Nr.	**3018**	152.41	459,972
	b) above 600m upto 900mm	Nr.	**1811**	305.91	553,999
	c) above 900mm upto 1800mm	Nr.	**1207**	765.31	923,734
	d) above 1800mm	Nr.	**603**	1,275.89	769,359
	TOTAL				**21,330,297**

Source: JICA Experts

Table 7.3.12 Updated Cost Breakdown of Earthworks

BILL NO 2 : Earthwork					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
2.01	Earthwork in excavation necessary for construction of roadway in all types of soil all complete as per Technical Specifications Clause 301.				
	(a) Excavation in ordinary soil	Cu.m	4,651,374	37.34	173,683,942
	(b) Excavation of Soft Rock (for GSB/ Concrete)	Cu.m	250,074	49.42	12,359,721
	(c) Excavation of Hard Rock requiring controlled blasting (for GSB/BT/Concrete works)	Cu.m	100,050	251.48	25,160,158
	(d) Excavation of Hard Rock - Open blasting	Cu.m		104.51	0
2.02	Construction of embankment with suitable material from **borrow areas** including cover to fly ash core with all leads and lifts, compacting to 95% of modified proctor density, all complete as per drawings and Technical Specifications, Clause 305 (20 KM lead)	Cu.m	3,865,164	291.10	1,125,158,269
2.03	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, Clause 305	Cu.m	1,032,964	319.41	329,935,908
2.04	Construction of hard shoulder satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, Clause 307	Cu.m		319.41	0
2.05	Filling in median/island/footpath with ***approved borrow material*** (selected earth and agricultural soil) with all leads and lifts complete as per Technical Specification Clauses 305 & 407.	Cu.m	376,088	239.94	90,237,147
2.06	Construction of embankment with suitable material obtained from ***roadway*** including cover to fly ash core with all leads and lifts, compacting to 95% of modified proctor density, all complete as per drawings all complete as per Technical Specifications, Clause 305	Cu.m	2,558,255	58.11	148,664,299
2.07	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from ***roadway*** with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, Clause 305	Cu.m	930,274	68.37	63,599,663
2.08	Construction of hard shoulder satisfying the requirements of minimum CBR value as indicated in the specification with approved material from ***roadway and drainage excavation etc***., with all leads & lifts, compacting to 97% of modified proctor density, as per Technical Specification Technical Specifications, Clause 307	Cu.m		68.37	0
2.09	Construction of Median with suitable materials deposited at site from ***roadway and drainage excavation*** including all leads and lifts etc., complete as per Technical Specification Clause 305.	Cu.m		118.66	0
2.10	Loosening and recompacting sub-grade in all kinds of soil, compacting to 97% of modified proctor density, all complete as per Technical Specifications Clauses 301 & 305.	Cu.m	103,328	52.25	5,399,376
2.11	Transportation and disposal of surplus rock between for use in road construction lead of 20 Km	Cu.m	350,103	182.24	63,802,188

BILL NO 2 : Earthwork					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
2.12	Transportation and disposal of surplus earth between lead of 15 Km and 20 Km	Cu.m	1,162,843	123.45	143,555,034
2.13	Scarifying Existing Bituminous Surface layer(s) as per Technical Specifications Clause 305. lead of 20 Km	Sqm		3.16	0
2.14	Excavating the Existing Pavement surface and disposal lead of 20 Km	Cum		335.83	0
TOTAL					**2,181,555,705**

Source: JICA Experts

Table 7.3.13 Updated Cost Breakdown of Pavement

BILL NO 3 : Pavement

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
3.01	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading–I (Table:400-1).	Cu.m.	826,728	1,158.31	957,609,757
3.02	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading–I (Table:400-2).	Cu.m.			
3.03	Providing and laying Wet Mix Macadam base and profile correction course of required thickness complete as per Technical Specifications Clause 406.(10 km lead)	Cu.m.	277,027	1,182.54	327,594,179
3.04	Providing and Construction of Cement Treated Sub base as per Technical Specifications Clause 403	Cu.m.			
3.05	Providing and Construction of Cement Treated Sub Base with open graded material as per Technical Specifications Clause 403	Cu.m.			
3.06	Providing and Construction of Cement Treated Base as per Technical Specifications Clause 403	Cu.m.			
3.07	Providing bituminous primer coat over granular surface with bitumen emulsion of low porosity complete as per Technical Specifications Clause 502 @ 7.5 to 9.8 kg/10 sq.m.	Sq.m.	1,092,588	81.43	88,969,738
3.08	Providing tack coat with bituminous Emulsion all complete as per Technical Specifications Clause 503				
	(i) On granular surface treated with primer and on hungry bituminous surface @3.0 Kg /10 sq.m.	Sq.m.	1,092,588	21.88	23,907,644
	(ii) On Bituminous surface @ 2.0 Kg/10 sq.m.	Sq.m.	1,092,588	12.08	13,202,729
3.09	Providing & laying Bituminous Macadam course of required thickness for main road and on prepared surface as profile corrective course complete as per Technical Specifications Clause 504	Cu.m.			
3.10	Providing & laying Dense Bituminous Macadam course of required thickness on prepared surface complete as per Technical Specifications Clause 507	Cu.m.	54,629	9,271.13	506,472,583
3.11	Providing & laying Bituminous Concrete course with CRMB of required thickness on prepared surface complete as per Technical Specifications Clause 509 with modified bituminous binder	Cu.m.	43,703	9,876.41	431,628,932
3.12	Providing & laying Semi Dense Bituminous Concrete course of required thickness on prepared surface complete as per Technical Specifications Clause 511 with polymer modified bituminous binder	Cu.m.			
3.13	Providing & laying aggregates for SAMI as crack prevention layer as per Technical specifications Clause 510 (Table 500-21)	Sq.m.		65.97	
3.14	Providing & laying Dry Lean Concrete subbase in M15 cc in service road locations at underpass area as per Technical Specifications Clause 601 and as approved by the Engineer.	Cu.m.	333,085	3,517.67	1,171,682,446
3.15	Providing & laying Pavement Quality Concrete of M45 Grade of specified thickness in service road locations at underpass area using minimum cement content 350 kg/cu.m. with slip form paver as per Technical Specifications Clause 602 and as approved by the Engineer.	Cu.m.	658,809	6,652.95	4,383,024,127
TOTAL					**7,904,092,133**

Source: JICA Experts

Table 7.3.14 Updated Cost Breakdown of Drainage

BILL NO 4 : Drainage					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
4.01	Construction of precast RCC drain at edge of ROW complete (Unit Qty: Excavation = 0.5 Cum / Rm ; RCC = 0.20 Cum /Rm ; Steel = 0.011 Mt/Rm)	Lm	131025	1,993.82	261,240,790
4.02	Construction of lined ROW Drains at edge of ROW (Unit Qty: Excavation = 0.144 Cum / Rm ; PCC M15= 0.1 Cum/Rm ; Rebar =60 Kg/Cum ; Precast cover (150mm thick) = 0.12Cum/Rm;RCC M20 =0.39 Cum/Rm ;Shuttering = 2.8 Sqm/ Rm	Lm	0	5,255.52	0
4.03	Construction of covered rectangular drains along service roads and between main road and service road (Unit qty: Excavation = 0.533 Cum/Rm ; RCC M20 =0.675 Cum/Rm ; PCC M15= 0.17 Cum/Rm ; Rebar =60 Kg/Cum ; Precast cover (150mm thick) = 0.23 Cum/Rm ; Shuttering = 6.0 Sqm/ Rm ; Weepholes, 100 dia = 4no/10 Rm ; Backfill = 0.15 Cum/Rm ; Edge Angles ISA 50x50x6; 4No/Rm	Lm	124190	9,840.45	1,222,085,947
4.04	Construction of Covered rectangular drains in the central median at superelevated sections (Unit qty: PCC M15= 0.125 Cum/Rm ; RCC M15= 0.383 Cum/Rm ; Rebar =60 Kg/Cum Shuttering = 3 Sqm/ Rm ; Inlet opening with Grating @ 10 m c/c = 1nos.; GI pipe of length 2.25m @ 10m c/c = 1 nos)	Lm		4,470.74	0
4.05	Construction of sumps complete as per specifications and drawings in central median at superelevated sections (size 1.0 x 1.0 m x 1.0 m 200 mm wall thickness) at end of median(Unit qty: Excavation = 0.5 cum ; RCC M20 =1.16cum ; PCC M15 = 0.28cum ; Rebar =75kg/cum ; Precast cover (150mm thick) =0.18 cum ; Shuttering = 8.8 sqm ; backfill = 0.2 cum/Rm)	Nos	72	15,458.04	1,112,979
4.06	Providing and laying 1000mm dia NP4 RCC pipes for		0		0
	a) Connecting drains on service roads due to change in C/s.	Lm	1966	9,915.49	19,493,862
	b) Outlet from RCC drain to brick masonry head wall	Lm	0		0
4.07	Providing drain inlets for collection of surface run off from main road and service road	Nos	0	604.80	0
4.08	Providing water downtakes to drain from underpass/flyover approaches.	Lm	8235	1,632.96	13,447,426
4.09	Toe walls in Random Rubble stone masonry laid in PCC M15 leveling course complete as per drawing and Technical Specifications Section 1400	Cum			0
4.10	Providing rain water harvesting facilities on project road complete as per typical detail in Technical schedule	Nos	2622	10,080.00	26,429,760
4.11	Construction of 300 mm dia semi-circular drainage chute in cement concrete M-15 with M-15 foundation concrete as per drawings and Technical Specifications Sections 1500 and 1700 including construction of bell mouth at entry at high embankment locations	Lm			0
4.12	Construction of energy dissipation basin at toe of chutes in M-15 as per drawing and Technical Specifications Sections 1500 & 1700.	Nr.			0
4.13	Construction of uncovered trapezoidal lined drain in central median . Excavation 2.75m3/Rm lined area 5.22 sqm Rm	Lm		5,087.38	0
TOTAL					**1,543,810,764**

Source: JICA Experts

Table 7.3.15 Updated Cost Breakdown of Road Furniture

BILL NO 5 : Road Furniture					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
5.01	Pavement marking with hot applied thermoplastic paints conforming to ASTM D36/BS-3262 (Part - I) as per drawing & Technical Specifications Clause 803.	Sq.m.	123217	475.74	58,618,723
5.02	Painting concrete Kerb complete with suitable paint	Sq.m.	57818	58.79	3,398,921
5.03	Supplying and fixing at site retro-reflectorised type sign boards/signs made of encapsulated lense type of reflective sheeting fixed over aluminum sheeting 2.0 mm thick with minimum coefficient of retro-reflection (determined in accordance with ASTM Stan		0	0.00	0
	A) Mandatory /Regulatory Signs of Size.		0	0.00	0
	i) Circular 600 mm dia.	Nr.	98	3,464.05	339,477
	B) Cautionary/Warning Signs-Triangular 900mm size	Nr.	126	4,135.74	521,104
	C) Informatory Signs		0	0.00	0
	a) Direction and Place Identification sign		0	0.00	0
	i) Advance Direction/Destination signs	Nr.	110	7,333.95	806,734
	ii) Direction signs 1200 x 700 mm	Nr.	110	7,333.95	806,734
	iii) Reassurance signs	Nr.	110	7,333.95	806,734
	iv) Place Identification Signs	Nr.	100	7,333.95	733,395
	b) Facility and Other Useful information Signs	Nr.	75	7,333.95	550,046
	c) Route Marker Signs		0	0.00	0
	i) PRR Route marker signs of size 450x600mm	Nr.	94	2,357.34	221,590
	ii) SH/MOR Route marker signs	Nr.	94	2,357.34	221,590
5.04	Providing and fixing retro-reflectorised road delineators complete as per drawing and Technical Specifications Clause 805.		0	0.00	0
	a) Cluster of Red Reflectors.	Nr.	1008	1,411.20	1,422,490
	b) Road way delineators.		0	0.00	0
	i) Chevron marker boards	Nr.	934	3,628.80	3,389,299
	ii) Road Delineators on curves	Nr.	3908	382.11	1,493,296
	c) Cats eye - Ordinary	Nr.	58348	382.11	22,295,508
	d) Cats eye - solar studs	Nr.	71315	544.32	38,818,181
5.05	Construction of plain cement concrete kerb M-20 grade complete as per drawing & Technical Specifications Clause 408.		0	0.00	0
	a) Kerb. (unit Qty: Concrete M20 - 0.07 cum/Lm)	Lm	191060	377.59	72,143,259
	b) Kerb with Channel (unit Qty:Concrete M20 - 0.13 cum/Lm)	Lm	31220	701.25	21,892,946
5.06	For foundations of kerbs M-15 grade		0	0.00	0
	a) Kerb. (unit Qty:PCC M15 - 0.037 Cum/Lm)	Lm	175032	159.31	27,883,671
	b) Kerb with Channel (unit Qty: 0.07 Cum/Lm)	Lm	31220	301.39	9,409,395
5.07	Providing and fixing reinforced cement concrete M-15 grade stones including excavation, foundation concrete and reinforcement inscription etc. all complete as per Technical Specifications Section 800.		0	0.00	0
	i) Hectometer stones.	Nr.	512	592.22	303,217
	ii) 5th km. stone.	Nr.	28	2,991.58	83,764
	iii) km. stone.	Nr.	110	1,873.55	206,090
5.08	Providing and fixing M-20 guard post 250mm dia x 1.25m long including reinforcement 4 Nos. 12mm dia vertical bars and 5 No. stirrups 6mm dia, duly embedded in cement concrete grade M-15, 550mm x 550mm x 650mm	Nr.	0		0

BILL NO 5 : Road Furniture

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
5.09	Providing and laying Road land (ROW) boundary pillars at 50m spacing in M-20, 200mm dia x 0.9m long including reinforcement 4 Nos. 6mm dia vertical bars and 5 No. stirrups 6mm dia, duly embedded in cement concrete grade M-15, 500mm x 500mm x 750mm.	Nr.	2590	366.87	950,198
5.10	Providing and laying utility ducts in RCC M 20 concrete at sides of service road (1.5m wide x 0.75m deep) including provision of utility racks	Lm	0	0.00	0
5.11	Construction of New Concrete Crash Barrier in M-30 grade for roadway as per Technical Specifications Clause 408 (unti quantities: Concrete: 0.4 Cum/Rm ; Shuttering : 1.75 Sqm/Rm ; Reinf: 80 Kg/Cum).	Lm	0	4,169.49	0
5.12	Providing and installing Pedestrian Guard rail at central median locations as per drawings and Technical Specifications Clause 808	Lm	118210	1,663.44	196,635,469
5.13	Providing, fabricating and fixing W shaped Metal beam Crash Barrier channel on main road, bridge approaches and sharp curve locations as per Technical specifications Clause 810	Lm	153138	2,724.87	417,280,517
5.14	Provision of Overhead Signs		0	0.00	0
	a) Cantilver Type (4m x 1.2m)	Nr.	28	211,680.00	5,927,040
	b) Overhead signs 6m height and 12m wide	Nr.	4	636,048.00	2,544,192
5.15	Providing, fabricating and fixing W shaped Metal beam Crash Barrier at high embankment locations as per Technical specifications Clause 810	Lm	0	2,724.87	0
5.16	Providing and installing chain link fence with L angles complete with gate, painting, concrete base and foundation complete as per Technical Specification Clause 807	Lm	58530	1,415.23	82,833,529
5.17	Providing utility ducts in NP 3 pipes, 2 rows of 300mm dia for the project road	Lm	5704	3,199.51	18,250,022
5.18	Use existing Pedestrian guard rail with repairs and rehabilitations	Lm	0	0.00	0
5.19	Use existing Metal crash barrier with repairs and rehabilitations	Lm	0	0.00	0
5.20	Noise barriers	Lm	0	0.00	0
5.21	Providing Traffic beacons at important cross roads, pedestrain crossings, educational institutions, minor junctions	No	84	3,225.60	270,950
5.22	Providing Bus shelters at bus stops	No	65	806,400.00	52,416,000
5.23	Providing 160 mm dia HDPE pipes along service roads (3 rows each)	Lm	0	1,208.39	0
TOTAL					**1,043,474,085**

Source: JICA Experts

Table 7.3.16 Updated Cost Breakdown of Intersections and Entry/Exit Ramps

BILL NO 6 : Intersections and Entry/Exit Ramps

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
6.01	Clearing and grubbing road land for project road complete as per Technical Specifications Clause 201.	Ha	1	26,426.74	24,677
6.02	Construction of embankment with approved material from **borrow areas** with all leads and lifts, compacting to 95% of modified proctor density, all complete as per drawings and Technical Specifications Clause 305.	Cu.m	23863	291.10	6,946,575
6.03	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specification Clause 305	Cum	14915	319.41	4,763,955
6.04	Construction of Earthern shoulder satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specification Clause 401	Cum	9545	319.41	3,048,740
	Filling in median/island/footpath with ***approved borrow material*** (selected earth and agricultural soil) with all leads and lifts complete as per Technical Specification Clauses 305 & 407.	Cum	0	239.94	0
	Providing and laying cement treated base Clause 403. Grading–I (Table:400-1).	Cum	0	984.13	0
	Providing and laying cement treated base Clause 403. Grading–I (Table:400-1).	Cum	0	984.13	0
6.05	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading–I (Table:400-2).	Cu.m.	16287	1,158.31	18,865,443
6.06	Providing and laying Wet Mix Macadam base and profile correction course of required thickness complete as per Technical Specifications Clause 406.(10 km lead)	Cu.m.	0	1,182.54	0
6.07	Providing & laying Dry Lean Concrete subbase in M15 cc in service road locations at underpass area as per Technical Specifications Clause 601 and as approved by the Engineer.	Cu.m.	9257	3,517.67	32,563,053
6.08	Providing & laying Pavement Quality Concrete of M45 Grade of specified thickness in service road locations at underpass area using minimum cement content 350 kg/cu.m. with slip form paver as per Technical Specifications Clause 602 and as approved by the Engineer.	Cu.m.	4475	6,652.95	29,771,957
6.09	Providing bituminous primer coat over granular surface with bitumen emulsion complete as per Technical Specifications Clause 502 @ 6.0 to 9.0 kg/10 sq.m.	Sq.m.	0	81.43	0
6.10	Providing tack coat with bituminous Emulsion all complete as per Technical Specifications Clause 503		0	0.00	0
6.11	(i) On granular surface treated with primer and on hungry bituminous surface @2.5 to 3.0/10 sq.m.	Sq.m.	0	21.88	0
6.12	(ii) On Bituminous surface @ 2.0 to 2.5 Kg/10 sq.m.	Sq.m.	0	12.08	0
6.13	Providing & laying Dense Bituminous Macadam course of required thickness on prepared surface complete as per Technical Specifications Clause 507	Cu.m.	0	9,271.13	0

BILL NO 6 : Intersections and Entry/Exit Ramps					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
6.14	Providing & laying Bituminous Concrete course of required thickness on prepared surface complete as per Technical Specifications Clause 509 with polymer modified bituminous binder	Cu.m.	0	9,876.41	0
6.15	Pavement marking with hot applied thermoplastic paints conforming to ASTM D36/BS-3262 (Part - I) as per drawing & Technical Specifications Clause 803.	Sq.m.	0	475.74	0
6.16	Painting concrete Kerb complete with suitable paint	Sq.m.	0	58.79	0
6.17	Supplying and fixing at site retro-reflectorised type sign boards/signs made of encapsulated lense type of reflective sheeting fixed over aluminum sheeting 2.0 mm thick with minimum coefficient of retro-reflection (determined in accordance with ASTM Stan		0	0.00	0
	A) Mandatory /Regulatory Signs of Size.		0	0.00	0
	i) Circular 900 mm dia.	Nr.	16	3,464.05	55,425
	ii) Octagon 900 mm height (for “STOP”).	Nr.	0	0.00	0
	iii) Triangular 900 mm size (for “GIVE WAY”).	Nr.	0	0.00	0
	B) Cautionary/Warning Signs-Triangular 900mm size	Nr.	16	4,135.74	66,172
	C) Informatory Signs		0	0.00	0
	a) Direction and Place Identification sign		0	0.00	0
	i) Advance Direction/Destination signs	Nr.	4	7,333.95	29,336
	ii) Direction signs 1200 x 700 mm	Nr.	28	7,333.95	205,351
	iii) Reassurance signs	Nr.	4	7,333.95	29,336
	iv) Place Identification Signs	Nr.	0	0.00	0
	v) Speed breaker signs	Nr.	0	0.00	0
	b) Facility and Other Useful information Signs	Nr.	12	12,096.00	145,152
	c) Overhead Gantry marker sign, 1.5m height	Rm	0	0.00	0
6.18	Providing and fixing retro-reflectorised road delineators complete as per drawing and Technical Specifications Clause 805.		0	0.00	0
	a) Cluster of Red Reflectors.	Nr.	34	1,209.60	41,126
	b) Road way delineators.	Nr.	0	0.00	0
	c) Cats eye	Nr.	0	0.00	0
6.19	Construction of plain cement concrete kerb M-20 grade complete as per drawing & Technical Specifications Clause 408.		0	0.00	0
	a) Kerb. (unit Qty: Concrete M20 - 0.065 cum/Lm)	Lm	0	377.59	0
	b) Kerb with Channel (unit Qty:Concrete M20 - 0.12 cum/Lm)	Lm	0	0.00	0
6.20	For foundations of kerbs M-15 grade		0	0.00	0
	a) Kerb. (unit Qty:PCC M15 - 0.06 Cum/Lm)	Lm	0	159.31	0
	b) Kerb with Channel (unit Qty: 0.07 Cum/Lm)	Lm	0	0.00	0
6.21	Providing and laying 25 mm thick precast cement concrete chequered tiles of grade M-20 in ordinary grey cement without chips laid in cement mortar 1:3 over 50 mm thick cement concrete M-15 grade and 150 mm thick granular sub-base including pointing of tiles	Sq.m.	0	923.17	0
6.22	Providing and installing Pedestrian Guard rail at intersection locations as per drawings and Technical Specifications Clause 808	Rm	0	1,663.44	0
6.23	Landscaping	LS	0	0.00	0
6.24	Providing and fixing Litter bins complete as per Technical Specifications.	Nr	0	0.00	0

BILL NO 6 : Intersections and Entry/Exit Ramps					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
6.25	Providing and installation of traffic signals at major intersections	Nr	10	100,800.00	1,008,000
6.26	Providing and installation of LED Traffic beacons at intersections for minor intersections	Nr	0	60,480.00	0
6.27	Providing speed breakers at cross roads (avg length 10m)	No	0	0.00	0
6.28	Providing, fabricating and fixing W shaped Metal beam Crash Barrier at high embankment locations as per Technical specifications Clause 810	Lm	7955	2,724.87	21,676,308
TOTAL					**119,240,605**

Source: JICA Experts

Table 7.3.17 Updated Cost Breakdown of Toll Plaza

BILL NO 7 : Toll Plaza					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
7.01	Providing & laying Pavement Quality Concrete of M45 Grade of specified thickness in at toll plaza area using minimum cement content 350 kg/cu.m. with slip form paver as per Technical Specifications Clause 602 and as approved by the Engineer.	Cum	53762	6,652.95	357,675,962
7.02	Providing & laying Dry Lean Concrete subbase in M15 cc at toll plaza area as per Technical Specifications Clause 601 and as approved by the Engineer.	Cum	26881	3,517.67	94,558,434
7.03	Providing and Construction of Cement Treated Sub base as per Technical Specifications Clause 403	Cum	39591	984.13	38,962,713
7.04	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, clause 305	Cum	48596	291.10	14,146,409
7.05	Providing and laying Wet Mix Macadam base and profile correction course of required thickness complete as per Technical Specifications Clause 406.	Cum			
7.06	Providing bituminous primer coat over granular surface with bitumen emulsion complete as per Technical Specifications Clause 502 @ 6.0 to 9.0 kg/10 sq.m.	Sq.m			
7.07	Providing tack coat with bituminous Emulsion all complete as per Technical Specifications Clause 503				
	(i) On granular surface treated with primer and on hungry bituminous surface @2.5 to 3.0/10 sq.m.	Sq.m			
	(ii) On Bituminous surface @ 2.0 to 2.5 Kg/10 sq.m.	Sq.m			
7.08	Providing & laying Bituminous Macadam course of required thickness for main road, service road and on prepared surface as profile corrective course complete as per Technical Specifications Clause 504	Cum			
7.09	Providing & laying Dense Bituminous Macadam course of required thickness on prepared surface complete as per Technical Specifications Clause 507	Cum			
7.10	Providing & laying Bituminous Concrete course of required thickness on prepared surface complete as per Technical Specifications Clause 509 with polymer modified bituminous binder	Cum			
7.11	Filling in median/island/footpath with ***approved borrow material*** (selected earth and agricultural soil) with all leads and lifts complete as per Technical Specification Clauses 305 & 407.	Cum	5853	239.94	1,404,347
7.12	Pavement marking with hot applied thermoplastic paints conforming to ASTM D36/BS-3262 (Part - I) as per drawing & Technical Specifications Clause 803.	Sq.m.	8737	475.74	4,156,503
7.13	Supplying and fixing at site retro-reflectorised type sign boards/signs made of encapsulated lense type of reflective sheeting fixed over aluminum sheeting 2.0 mm thick with minimum coefficient of retro-reflection (determined in accordance with ASTM Standard E:810) as indicated in Table 800-1 complete including vertical pipes/ angles/ posts etc. all complete as per drawing and Technical Specification Clause 801.				

BILL NO 7 : Toll Plaza

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
7.13	**A) Mandatory /Regulatory Signs of Size.**				
	i) Circular 600 mm dia.	Nr.			
	ii) Octagon 900 mm height (for "STOP").	Nr.			
	B) Cautionary/Warning Signs-Triangular 900mm size	Nr.			
	C) Informatory Signs				
	i) Toll plaza signs	Nr.	256	45,360.00	11,612,160
7.14	Providing and fixing retro-reflectorised road delineators complete as per drawing and Technical Specifications Clause 805.				
	a) Cluster of Red Reflectors.	Nr.			
	b) Cats eye	Nr.	640	544.32	348,365
7.15	Construction of New Jersey Crash Barrier in M-30 grade complete as per drawing & Technical Specifications Clause 408.				
	a) Concrete in M 30 CC with 80 Kg/Cum steel	Cu.m.	3909	11,134.44	43,524,509
	b) Shuttering	Sqm		above rate including shuttering	
	c) Object marking	Sqm	10359	58.79	608,970
7.16	Kerbs				
	a) Kerb. (unit Qty:PCC M20 - 0.11 Cum/Lm)	Lm			
	b) PCC Kerb (M 15 : unit Qty: 0.065 Cum/Lm)	Lm			
7.17	Providing and laying 25 mm thick precast cement concrete chequered tiles of grade M-20 in ordinary grey cement without chips laid in cement mortar 1:3 over 50 mm thick cement concrete M-15 grade and 150 mm thick granular sub-base including pointing of tiles with neat cement as per drawing and Tech. Specification clause 409.	Sq.m.	11520	923.17	10,634,881
7.18	Overhead Lane Control Sign Board (Full Width)	Rm	695	22,176.00	15,412,320
7.19	Covered Drains for Toll Plaza (Unit Qty.Excavation=1.25 Cum/Rm ; RCC in M20 cc - 0.5 cum/Rm ; PCC M15 cc = 0.12 Cum/Rm ; Shuttering = 2.65 Sqm / Rm ; ISA 75 x 75 x 6 = 4no/Rm ; Reinforcement = 80 Kg/cum ; Heavy Duty grating = 0.85 Wide / Rm)	Lm	855	7,056.00	6,032,880
7.20	Toll Plaza - Administrative Building and O&M base camp	Sq.m.	3780	16,269.12	61,497,274
7.21	Rest area	No			
7.22	Toll Booths including protection	No	128	30,240.00	3,870,720
7.23	Hardware and Software for Toll collection system	Ls			
7.24	Toll Plaza Canopy	Sqm	17361	3,427.20	59,499,619
7.25	Maintenance Building with separate storage area for inflammable materials	Ls			
7.26	Plantation of trees	Ls			
7.27	Landscaping	Ls			
7.28	Providing and fixing Litter bins complete as per Technical Specifications.	Nr.	32	2,016.00	64,512
7.29	Construction of tube wells and water supply system complete	Nr.	9	201,600.00	1,814,400
7.30	Construction Toilet complexes complete	Nr.	9	504,000.00	4,536,000
7.31	Petrol / Diesel Filling station	Nr.			
7.32	Automatic Vehicle Traffic Counter	Nr.	32	201,600.00	6,451,200
7.33	150mm dia PVC duct for conduits	Rm	695	1,415.23	983,586
7.34	Provision and installation of one no of ATMS facility (Advanced Traffic Management Systems) on project road consisting of Automatic traffic counter cum classifier and Weigh in motion	Ls	3	1,008,000.00	3,024,000

BILL NO 7 : Toll Plaza

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
7.35	Provision of tunnel below toll booths 2.4m wide & 2.4m clear height.	Rm			
SUB TOTAL (A)					**740,819,763**

BILL NO 7a : Additional Items of Toll Plaza

Item	Description	Unit	Total Qty	Rate (Rs)	Total Amount (INR)
7a.01	Providing & laying Pavement Quality Concrete of M45 Grade of specified thickness in at toll plaza area using minimum cement content 350 kg/cu.m. with slip form paver as per Technical Specifications Clause 602 and as approved by the Engineer.	Cum	48502	6,652.95	322,682,438
7a.02	Providing & laying Dry Lean Concrete subbase in M15 cc at toll plaza area as per Technical Specifications Clause 601 and as approved by the Engineer.	Cum	24251	3,517.67	85,307,231
7a.03	Providing and laying Granular Sub-base as pavement and drainage layer complete as per Technical Specifications Clause 401. Grading–I (Table:400-1).	Cum	24251	1,158.31	28,090,335
7a.04	Construction of subgrade satisfying the requirements of minimum CBR value as indicated in the specification with approved material from **borrow areas**, with all leads & lifts, compacting to 97% of modified proctor density, all complete as per Technical Specifications, clause 305	Cum	80837	291.10	23,531,815
7a.05	Filling in median/island/footpath with ***approved borrow material*** (selected earth and agricultural soil) with all leads and lifts complete as per Technical Specification Clauses 305 & 407.	Cum	2088	239.94	500,987
7a.06	Pavement marking with hot applied thermoplastic paints conforming to ASTM D36/BS-3262 (Part - I) as per drawing & Technical Specifications Clause 803.	Sq.m.	3204	475.74	1,524,257
7a.07	Supplying and fixing at site retro-reflectorised type sign boards/signs made of encapsulated lense type of reflective sheeting fixed over aluminum sheeting 2.0 mm thick with minimum coefficient of retro-reflection (determined in accordance with ASTM Standard E:810) as indicated in Table 800-1 complete including vertical pipes/ angles/ posts etc. all complete as per drawing and Technical Specification Clause 801.				
	A) Mandatory /Regulatory Signs of Size.				
	i) Circular 600 mm dia.	Nr.			
	ii) Octagon 900 mm height (for “STOP”).	Nr.			
	B) Cautionary/Warning Signs-Triangular 900mm size	Nr.			
	C) Informatory Signs				
	i) Toll plaza signs	Nr.	96	45,360.00	4,354,560
7a.08	Providing and fixing retro-reflectorised road delineators complete as per drawing and Technical Specifications Clause 805.				
	a) Cluster of Red Reflectors.	Nr.			
	b) Cats eye	Nr.	240	544.32	130,637
7a.09	Construction of New Jersey Crash Barrier in M-30 grade complete as per drawing & Technical Specifications Clause 408.				
	a) Concrete in M 30 CC with 80 Kg/Cum steel	Cu.m.	5567	11,134.44	61,989,256

BILL NO 7a : Additional Items of Toll Plaza					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
7a.09	b) Shuttering	Sqm		above rate including shuttering	
	c) Object marking	Sqm	11803	58.79	693,844
7a.10	Providing and laying 25 mm thick precast cement concrete chequered tiles of grade M-20 in ordinary grey cement without chips laid in cement mortar 1:3 over 50 mm thick cement concrete M-15 grade and 150 mm thick granular sub-base including pointing of tiles with neat cement as per drawing and Tech. Specification clause 409.	Sq.m.	3240	923.17	2,991,060
7a.11	Overhead Lane Control Sign Board (Full Width)	Rm	264	22,176.00	5,854,464
7a.12	Toll Plaza - Administrative Building and O&M base camp	Sq.m.	3000	16,269.12	48,807,360
7a.13	Toll Booths including protection	No	36	30,240.00	1,088,640
7a.14	Toll Plaza Canopy	Sqm	3402	3,427.20	11,659,334
7a.15	Providing and fixing Litter bins complete as per Technical Specifications.	Nr.	12	2,016.00	24,192
7a.16	Construction of tube wells and water supply system complete	Nr.	6	201,600.00	1,209,600
7a.17	Construction Toilet complexes complete	Nr.	6	504,000.00	3,024,000
7a.18	Automatic Vehicle Traffic Counter	Nr.	12	201,600.00	2,419,200
7a.18	Provision of tunnel below toll booths 2.4m wide & 2.4m clear height.	Rm	3,433	30,000	102,981,000
7a.19	110mm dia PVC duct for electric cable under footpath	Rm	130,000	643	83,590,000
7a.19	110mm dia PVC duct for electric cable under paved syoulder and cross section	Rm	43,000	1,562	67,166,000
7a.20	Junction box W1.4m L1.4m H1.15m	Nr.	740	15,694	11,613,560
SUB TOTAL (B)					**871,233,771**
TOTAL (A+B)					**1,612,053,535**

Source: JICA Experts

Table 7.3.18 Updated Cost Breakdown of Arboriculture

BILL NO 8 : Arboriculture					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
8.01	Plantation of trees as per MOEF guidelines in one/two rows depending upon space available on either side of road within ROW & central median (including planting with manure, gardening and maintenance)	No	6063	595.49	3,610,432
8.02	Providing 300 mm thick stone pitching for high embankment (height >3m) including 150mm granular fill all complete as per Technical Specifications Section 307	Sqm.			
8.03	Turfing of embankment slopes with grass sods all complete as per Technical Specifications Clause 307.	Sqm.			
8.04	Turfing of central median, entry, exit ramps and underpass locations with grass sods all complete as per Technical Specifications Clause 307.	Sqm.	733832	49.64	36,428,876
8.05	Plantation of shrubs in central median including planting with manure, gardening and maintenance @ 15m	Km	65	17,744.83	1,144,542
TOTAL					**41,183,850**

Source: JICA Experts

Table 7.3.19 Updated Cost Breakdown of Highway Lighting

BILL NO 9 : Highway Lighting					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
9.01	Highmast lighting at major junctions, Toll plaza, Truck laybye, Interchanges,ROB, Rest Areas - 40 lux	Nr.	22	604,800.00	13,305,600
9.02	Street lighting in urban areas - 40 lux	Nr.	5183	14,152.32	73,351,475
9.03	Illumination at toll plaza approach - 40 lux	Nr.	340	14,152.32	4,811,789
9.04	Lighting at approach to bus bay, truck laybye and Junction portions, Curve locations - 40 lux	Nr.	625	14,152.32	8,845,200
9.05	Lighting at Toll plaza central section (roof) - 100 lux	Nr.	489	7,056.00	3,450,384
9.06	Lighting for toll plaza tunnel section, VUP and PUP/CUP	Nr.	1096	5,040.00	5,523,840
9.07	Feeder Pillar	Nr.	30	504,000.00	15,120,000
9.08	Cables Lumpsum	LS	1		20,160,000
TOTAL					**144,568,287**

Source: JICA Experts

Table 7.3.20 Updated Cost Breakdown of Other Items

BILL NO 10 : Other Items					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
10.01	Provision for two nos new 4x4 driven AC Vehicle (Travera - 1 nos and Tata Sumo - 1 no) to PIU including vehicle management, fuel charges, driver salary)	Veh month	72	60,480.00	4,354,560
10.02	Provision of two mobile phones with connection	Month	72	5,040.00	362,880
10.03	Maintenance of Vehicles provided to client including driver, operation costs, fuel etc, complete (4000 km/month)	Veh month	72	40,320.00	2,903,040
10.04	Facilities to NHAI / Client				
	a) Desktop computer with software	Ls			
	b) Laptop with necessary software	Ls			
	c) Internet Broadband connection	Ls			
	d) Laser printer, fax, copier	Ls			
	e) Junior clerks - 2 nos	Ls			
	f) Data Operator - 2 nos	Ls			
	g) Peon - 2 nos	Ls			
10.05	Providing and installation one no of highway / material engineering laboratory with stand by power system	Nr.	3	1,512,000.00	4,536,000
10.06	Provision of highway patrolling system	Nr.	3	2,419,200.00	7,257,600
10.07	Provision of Traffic aid post	Nr.	3	201,600.00	604,800
10.08	Provision of medical aid post	Nr.	3	201,600.00	604,800
10.09	Provision of crane	Nr.	3	403,200.00	1,209,600
10.10	Rest area	Ha	6	50,400.00	302,400
10.11	Vehicle rescue post	Nr.	3	201,600.00	604,800
10.12	Operation and maintance centre	Nr.	3	504,000.00	1,512,000
10.13	Provision for traffic diversion & Safety				
	a) Barricading	m	6000	900.67	5,404,009
	b) Reflecor tapes	m	6000	100.80	604,800
	c) Safety display boards	Nr.	110	8,064.00	887,040
	d) Traffic signs	Nr.	130	4,032.00	524,160
10.14	Topographic Survey	Km	79	151,200.00	11,944,800
10.15	Field Investigations (Topo survey, Traffic Surveys, Geo Tech, hydrological investigation, Axle load surveys)	Ls			
10.16	Detailed Engineering	Ls			
10.17	Project Management	Ls			
10.18	Independent Engineer Fees	Ls			
SUB TOTAL (A)					**43,617,289**

BILL NO 10a : Items Deducted from Other Items (These items are included in administration cost)					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
10a.01	Provision for two nos new 4x4 driven AC Vehicle (Travera - 1 nos and Tata Sumo - 1 no) to PIU including vehicle management, fuel charges, driver salary)	Veh month	-72	60,480.00	-4,354,560
10a.02	Provision of two mobile phones with connection	Month	-72	5,040.00	-362,880
10a.03	Maintenance of Vehicles provided to client including driver, operation costs, fuel etc, complete (4000 km/month)	Veh month	-72	40,320.00	-2,903,040
SUB TOTAL (B)					**-7,620,480**
TOTAL (A+B)					**35,996,809**

Source: JICA Experts

Table 7.3.21 Updated Cost Breakdown of Maintenance During Construction

BILL NO 11 : Maintenance during Construction					
Item	**Description**	**Unit**	**Total Qty**	**Rate (Rs)**	**Total Amount (INR)**
	MAINTENANCE DURING CONSTRUCTION				
11.01	Pothole filling and patching work	Sqm	2840	413.68	1,174,860
11.02	Crack sealing	Sqm	2130	20.16	42,941
11.03	Earthen shoulder maintenance including filling with select soil	Cum	2080	223.78	465,454
11.04	Road marking	Sqm	24	475.74	11,418
11.05	Maintenance of existing road signs	Nr	45	504.00	22,680
11.06	Maintenance of existing guard posts, crash barriers etc.	Nr	47	604.80	28,426
TOTAL					**1,745,778**

Source: JICA Experts

(2) Structure Works

Table 7.3.22 shows the comparison of the cost estimate for the structure works.

Table 7.3.22 Comparison of Cost Estimate for Structure Works

Update by JICA Experts		**Project Cost Estimate R(3) in DPR**		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
B. Structure Works	**9,099,701,822**	**B. Structure Works**	**3,740,000,000**	**5,359,701,822**
12. Culvert	330,054,525	13. Culvert	180,692,176	149,362,349
13. Vehicular Underpass	422,863,923	14. Vehicular Underpass	211,558,947	211,304,976
14. Pedestrian Underpass	82,966,534	15. Pedestrian Underpass	42,331,149	40,635,385
15. Minor Bridge	174,399,616	16. Minor Bridge	83,618,827	90,780,790
16. Railway Under Bridge	483,383,969	17. Railway Under Bridge	211,357,592	272,026,378
17a. Bridge Structures	6,211,526,000	18. Railway Over Bridge	594,629,691	4,478,056,931
		19. Pedestrian Overpass	256,624,861	
		20. Vehicular Overpass	156,820,799	
		22. Flyovers along PRR	610,439,258	
		21. Underpass along PRR (Bridge Structure of Cross Road)	114,954,460	
20. Underpass along PRR	300,574,666	21. Underpass along PRR (Exclede Bridge Structure of Cross Road)	178,397,621	122,177,045
22. Underpass along Cross road	237,596,636	23. Underpass along Cross road	235,710,948	1,885,688
23. Flyover along Cross road (Exclude bridge structure)	856,335,952	24. Flyover along Cross road	849,539,635	6,796,317
		25. Rounding Off	13,324,037	-13,324,037

Source: JICA Experts

1) Major Contents of Update

Table 7.3.23 shows the major contents of the cost update for the structure works.

Table 7.3.23 Major Contents of Cost Update for Structure Works

Item	Description	Difference
		Million INR
Review of Reifocing Works	68.99 Rs → 68.99 Thousand Rs	1,857
Update of Base Year for Cost Estimate	August 2014 → June 2015	73
Review of Bridge Area	Apply PC-I girder bridge on behalf of RE-wall of approach section at Chennai ROB and Hosur ROB	2,119
	Other bridge areas are not changed	0
Review of Bridge Type	Apply Steel-Box girder bridge on behalf of PC-Box girder bridge	1,553
	Apply PC-I girder bridge on behalf of PC-Box girder bridge	-241
Total		5,360

Source: JICA Experts

- Review of reinforcing works: The cost for reinforcing works of the structure works in the project cost estimate R(3) is Rs68.99/t. However, it was confirmed that the cost of reinforcing works should be Rs68,990/t.

- Update the unit rates of each work by using 0.8% rate of annual price escalation in year 2014.

- Review of bridge area: the JICA Experts applied PC-I girder bridges instead of RE-wall at the approach section of Chennai ROB and Hosur ROB; therefore, areas of PC-I girder bridge were increased.
- The JICA Experts applied PC-I girder and steel-box girder bridge on behalf of PC-box girder bridge depending on construction conditions.

2) Bridge Structure

The JICA Experts reviewed the types of bridge structures.

In the drawings of the final DPR R(5), all of the bridges of the Project are designed as PC-box girder bridges even though the span length of bridges varies from 23 m to 60 m.

The JICA Experts set bridge types based on the span length as shown in Table 7.3.24 below.

Table 7.3.24 Bridge Types Based on Span Length

Bridge Type	Span Length (m)	Remarks
PC-I Girder Bridge	L ≦ 30 m	
PC-Box Girder Bridge	30 m < L ≦ 60 m	
Steel-Box Girder Bridge	L ≧ 60 m	Chennai ROB, Hosur ROB

Source: JICA Experts

PC-I girder bridge was applied in the case where the span length is less or equal 30 m because the cost of PC-I girder bridge is lower than the cost of PC-box girder bridge.

The steel-box girder bridge was applied in the case where fast erection is necessary, as in a railway over a bridge.

In accordance with reviewing bridge type, the JICA Experts reviewed the costs of bridge structures.

The costs of bridge structures were applied as unit price per sq. m (including substructure and foundation), because this stage is the feasibility engineering stage.

The unit price of PC-box girder bridge was calculated by using the costs of bridge in the project cost estimate R(3).

Table 7.3.25 shows the costs and areas of bridge structures in the project cost estimate R(3).

Table 7.3.25 Costs and Areas of Bridge Structures in Project Cost Estimate R(3)

Item		Total Amount (INR)	Area of Bridge (sq. m)
Bridge (PC-BOX Girder)	ROB	1,129,436,099	34,268
	Bridge of Cross Road	232,220,805	
	POP	455,437,095	1,920
	VOP	307,331,276	2,376
	Flyover	615,322,772	7,480
Total		2,739,748,047	46,044
Price of PC-Box Girder Bridge per sq. m. (Rs / sq. m.)			59,503

Source: JICA Experts

The unit price of PC-I girder bridge was referred to the unit price of PC-I girder bridge of Hyderabad Outer Ring Road Construction Project.

Note: Hyderabad Outer Ring Road Construction Project means "Construction of Eight-lane Access Controlled Expressway as Outer Ring Road to Hyderabad City in the State of Andhra Pradesh, India in the Stretches from Shamirpet to Pedda Amberpet – From Km.61.700 to Km.95.000 (Northern Arc)"

The unit price of steel-box girder bridge was referred to the unit price of plate girder bridge of Hyderabad Outer Ring Road Construction Project.

The JICA Experts calculated the unit price of steel-box girder bridge applying the ratio of steel weight between steel-box girder and steel-plate girder as shown in Table 7.3.26.

Table 7.3.26 Calcuration for Unit Rate of Steel Box Girder Bridge

Item	Plate Girder Bridge	Steel Box Girder Bridge
General Steel Weight	0.4 t/sq. m	0.45 t/sq. m
Rate of Steel Weight	1.0	1.13
Unit Rate of Bridge	Rs130,000/sq. m	Rs146,900/sq. m

Source: JICA Experts

The unit prices of bridge structures adopted by the JICA Experts are summarized in Table 7.3.27.

Table 7.3.27 Unit Prices of Bridge Structures Based on Experiences in Relevant Projects

Bridge Type	Unit Price of Bridge (Rs/sq. m) (Including Substructure and Foundation)
PC-I Girder Bridge	34,000
PC-box Girder Bridge	59,000
Steel-box Girder Bridge	146,000

Source: JICA Experts

3) Underpass along PRR

Item Nos. 20.10 to 20.25 of underpass along PRR are bridge costs of a crossroad; therefore, these items are included in the bridge costs as shown in Table 7.3.28.

Table 7.3.28 Deducted Items of Underpass along PRR

BILL NO 20 : Underpass along PRR					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
	Bridge crossing at Existing road level				
20.10	M35 concrete for footing	cum	1820	5,656.57	10,294,964
20.11	M35 concrete in pier	cum	820	6,537.83	5,361,019
20.12	M35 concrete for piercap and pedestal	cum	585	6,834.48	3,998,172
20.13	RCC M35 for Dirt wall	cum	308	6,834.48	2,101,603
20.14	Superstructure RCC M35	cum	8232	6,834.48	56,261,455
20.15	Elastomeric Bearings	cucm	1638000	0.71	1,159,075
20.16	HYSD Fe500				
a	For footing	MT	182	69,546.68	12,657,495
b	For pier	MT	82	69,546.68	5,702,828
c	For piercap	MT	117	69,546.68	8,136,961
d	For superstructure	MT	1235	69,546.68	85,876,238
e	For dirt wall	MT	31	69,546.68	2,138,560
f	For crash Barrier	MT	28	69,546.68	1,951,090
20.17	Drainage Spouts	Nos	146	1,713.52	250,174
20.18	Strip seal Expansion Joint	RM	870	16,932.71	14,731,455
20.19	Wearing coat	sqm	12480	960.50	11,986,992
20.20	Footpath at bridge deck top	sqm	314	923.17	289,874
20.21	Crash Barrier at edge of carriageway	cum	150	5,656.57	848,486
20.22	Handrail at deck edge	Rm	208	2,115.59	440,043
20.23	Anticarbonate Painting	sqm	14466	67.50	976,393
20.24	Asphaltic Joint	Rm	388	1,470.75	570,652
20.25	Approach slab M30 including reinforcement	cum	609	10,652.34	6,487,277

Source: JICA Experts

4) Flyover along Crossroad

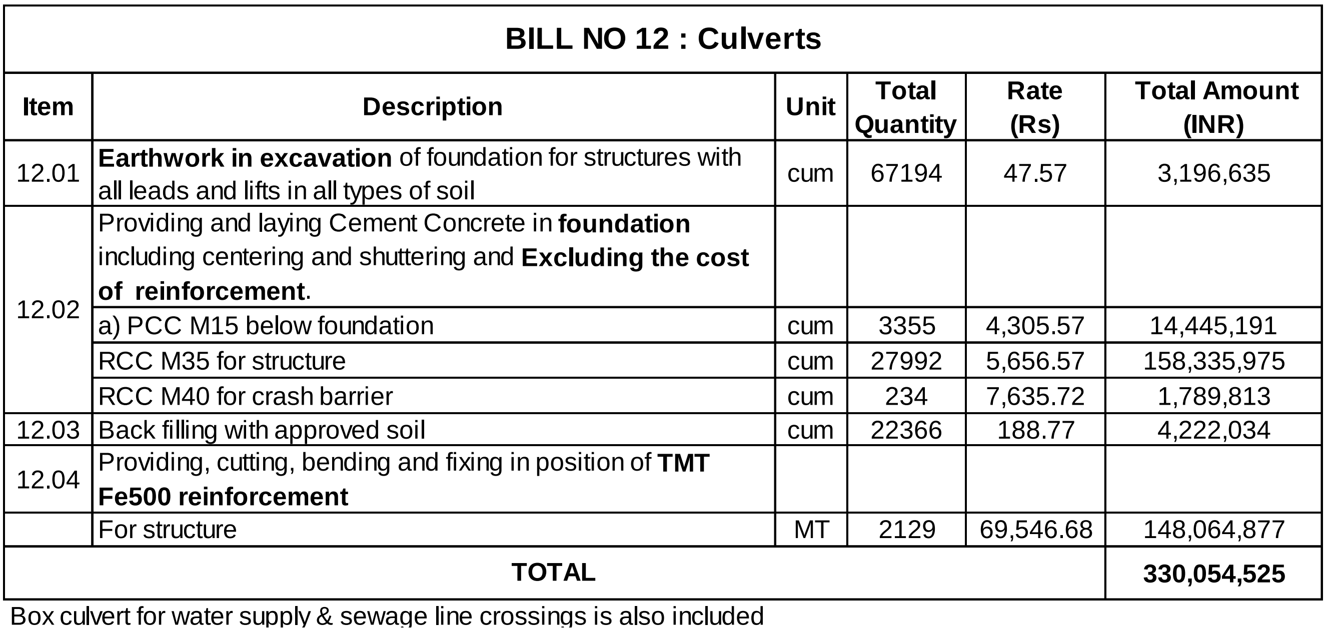
This item consists of retaining walls, pavements, etc., and the cost of flyover is included in the VOP.

Therefore, the JICA Experts updated the unit rates of this item by using 0.8% rate of annual price escalation in year 2014.

5) Cost Breakdown of Structure Works

Updated cost breakdowns of the structure works are shown below.

Table 7.3.29 Updated Cost Breakdown of Culvert



BILL NO 12 : Culverts

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
12.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	67194	47.57	3,196,635
12.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.				
	a) PCC M15 below foundation	cum	3355	4,305.57	14,445,191
	RCC M35 for structure	cum	27992	5,656.57	158,335,975
	RCC M40 for crash barrier	cum	234	7,635.72	1,789,813
12.03	Back filling with approved soil	cum	22366	188.77	4,222,034
12.04	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**				
	For structure	MT	2129	69,546.68	148,064,877
TOTAL					**330,054,525**

Box culvert for water supply & sewage line crossings is also included

Source: JICA Experts

Table 7.3.30 Updated Cost Breakdown of VUP

BILL NO 13: Vehicular Underpass

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
13.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	31015	47.57	1,475,494
13.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.				
	a) PCC M15 below foundation	cum	1551	4,305.57	6,677,941
	b)PCC M15 in approach slab	cum	824	4,817.23	3,969,399
13.03	Providing and laying Cement Concrete in **foundation/ substructure /super structure** including centering and shuttering and **Excluding the cost of reinforcement**.				
	RCC M35 for structure	cum	24917	5,656.57	140,944,840
	RCC M40 for crash barrier	cum	677	7,635.72	5,169,383
13.04	Back filling with approved soil	cum	10338	188.77	1,951,506
13.05	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	5682	947.12	5,381,518
13.06	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**				
	For structure	MT	3017	69,546.68	209,822,327
13.07	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	5568	165.47	921,355
13.08	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	11297	960.50	10,850,725
13.09	Approach slab M30 including reinforcement	Cum	1672	10,652.34	17,810,716
13.10	Anti Carbonation Painting to the exposed surface of concrete	Sqm	31442	67.50	2,122,199
13.11	PCC M -30 filling at top of PUP base	Cum	2260	5,967.92	13,487,509
13.12	RCC M25 at Drain side walls cover slab kerb near median	Cum	362	6,295.61	2,279,009
TOTAL					**422,863,923**

Source: JICA Experts

Table 7.3.31 Updated Cost Breakdown of PUP

BILL NO 14 : Pedestrian Underpass

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
14.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	5651	47.57	268,838
14.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.				
	a) PCC M15 below foundation	cum	282	4,305.57	1,214,171
	b)PCC M15 in approach slab	cum	265	4,817.23	1,276,566
14.03	Providing and laying Cement Concrete in **foundation/ substructure /super structure** including centering and shuttering and **Excluding the cost of reinforcement**.				
	RCC M35 for structure	cum	4613	5,656.57	26,093,773
	RCC M40 for crash barrier	cum	116	7,635.72	885,744
14.04	Back filling with approved soil	cum	1883	188.77	355,454
14.05	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	1710	947.12	1,619,570
14.06	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**				
	For structure	MT	580	69,546.68	40,337,073
14.07	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	1476	165.47	244,239
14.08	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	1812	960.50	1,740,419
14.09	Approach slab M30 including reinforcement	Cum	536	10,652.34	5,709,656
14.10	Anti Carbonation Painting to the exposed surface of concrete	Sqm	4806	67.50	324,384
14.11	PCC M -30 filling at top of PUP base	Cum	363	5,967.92	2,166,357
14.12	RCC M25 at Drain side walls cover slab kerbnear median	Cum	116	6,295.61	730,290
TOTAL					**82,966,534**

Source: JICA Experts

Table 7.3.32 Updated Cost Breakdown of Minor Bridge

BILL NO 15: Minor Bridge					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
15.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	46746	47.57	2,223,874
15.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.				
	a) PCC M15 below foundation	cum	779	4,305.57	3,354,040
	RCC M35 for structure	cum	12974	5,656.57	73,388,384
15.03	Back filling with approved soil	cum	15582	188.77	2,941,417
15.04	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	2033	947.12	1,925,488
15.05	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**				
	For structure	MT	1297	69,546.68	90,202,041
15.06	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	2202	165.47	364,372
TOTAL					**174,399,616**

Source: JICA Experts

Table 7.3.33 Updated Cost Breakdown of RUB

BILL NO 16 : Railway Under Bridge					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
16.01	**Earthwork in excavation** of foundation for structures with all leads and lifts in all types of soil	cum	211200	47.57	10,047,538
16.02	Providing and laying Cement Concrete in **foundation** including centering and shuttering and **Excluding the cost of reinforcement**.				
	a) PCC M15 below foundation	cum	1440	4,305.57	6,200,023
	RCC M35 for structure	cum	30762	5,656.57	174,007,512
16.03	Providing **filter media** behind RE panels, abutments, wing walls, retaining walls and return walls.	cum	6240	947.12	5,910,009
16.04	Providing, cutting, bending and fixing in position of **TMT Fe500 reinforcement**				
	For structure	MT	3891	69,546.68	270,606,123
16.05	Providing and fixing **100mm dia PVC weep holes** in abutments, wing walls and return walls.	Nos.	6760	165.47	1,118,599
16.06	Wearing coat -Tack coat, BC-40mm & Mastic asphalt 25 mm	Sqm	10100	960.50	9,701,011
16.07	Anti Carbonation Painting to the exposed surface of concrete	Sqm	28000	67.50	1,889,879
16.08	RCC M25 at Drain side walls cover slab kerbnear median	Cum	620	6,295.61	3,903,275
TOTAL					**483,383,969**

Source: JICA Experts

Table 7.3.34 Updated Cost Breakdown of Bridge Structure

BILL NO 17a : Bridge Structures					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
17a.01	PC-I Girder Bridge	Sqm	84,762.75	34,000	2,881,933,500
17a.02	PC-Box Girder Bridge	Sqm	20,057.50	59,000	1,183,392,500
17a.03	Steel-Box Girder Bridge	Sqm	14,700.00	146,000	2,146,200,000
TOTAL					**6,211,526,000**

Source: JICA Experts

Table 7.3.35 Updated Cost Breakdown of Underpass along PRR

BILL NO 20 : Underpass along PRR					
Item	**Description**	**Unit**	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
20.01	Earthwork in excavation for structures **in all types of soil**	cum	639230	47.57	30,410,452
20.02	Providing and laying Plain cement concrete M15 for leveling course				
	PCC M15 below foundation 100 thick	cum	5023	4,305.57	21,628,047
20.03	Providing Reinforced cement concrete for following concrete works (Rate shall exclude for HYSD Reinforcement.)				
	RCC M35 for retaining walls	cum	15701	6,537.83	102,647,815
20.04	Providing **M40** grade reinforced cement concrete **crash barrier**	cum	1368	5,656.57	7,738,192
20.05	Providing and fixing the **expansion joints of various types as below**				
	Joints in side walls of retaining walls (premoulded joint filler &compound)	RM	477	194.98	92,925
20.06	Providing **filter media** behind retaining walls	cum	13873	947.12	13,139,730
20.07	Supplying, cutting, bending,fitting placing TMT Fe500 HYSD reinforcement				
	a) In Approach retaining walls	MT	1513	69,546.68	105,231,078
	b) For crash barrier	MT	225	69,546.68	15,639,657
20.08	Providing and fixing **100mm dia PVC weep holes** in retaining walls	Nos.	15038	165.47	2,488,362
20.09	Providing anti carbonation treatment to exposed concrete surface	Sq.m	23089	67.50	1,558,408
	Bridge crossing at Existing road level				
20.10	M35 concrete for footing	cum	1820	5,656.57	10,294,964
20.11	M35 concrete in pier	cum	820	6,537.83	5,361,019
20.12	M35 concrete for piercap and pedestal	cum	585	6,834.48	3,998,172
20.13	RCC M35 for Dirt wall	cum	308	6,834.48	2,101,603
20.14	Superstructure RCC M35	cum	8232	6,834.48	56,261,455
20.15	Elastomeric Bearings	cucm	1638000	0.71	1,159,075
20.16	HYSD Fe500				
a	For footing	MT	182	69,546.68	12,657,495
b	For pier	MT	82	69,546.68	5,702,828
c	For piercap	MT	117	69,546.68	8,136,961
d	For superstructure	MT	1235	69,546.68	85,876,238
e	For dirt wall	MT	31	69,546.68	2,138,560
f	For crash Barrier	MT	28	69,546.68	1,951,090
20.17	Drainage Spouts	Nos	146	1,713.52	250,174
20.18	Strip seal Expansion Joint	RM	870	16,932.71	14,731,455
20.19	Wearing coat	sqm	12480	960.50	11,986,992
20.20	Footpath at bridge deck top	sqm	314	923.17	289,874
20.21	Crash Barrier at edge of carriageway	cum	150	5,656.57	848,486
20.22	Handrail at deck edge	Rm	208	2,115.59	440,043
20.23	Anticarbonate Painting	sqm	14466	67.50	976,393
20.24	Asphaltic Joint	Rm	388	1,470.75	570,652
20.25	Approach slab M30 including reinforcement	cum	609	10,652.34	6,487,277
SUB TOTAL (A)					**532,795,472**

BILL NO 20a : Deducted Items of Bridge crossing at Existing road level (These items are included in bridge structure cost)

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
	Bridge crossing at Existing road level				
20a.01	M35 concrete for footing	cum	-1820	5,656.57	-10,294,964
20a.02	M35 concrete in pier	cum	-820	6,537.83	-5,361,019
20a.03	M35 concrete for piercap and pedestal	cum	-585	6,834.48	-3,998,172
20a.04	RCC M35 for Dirt wall	cum	-308	6,834.48	-2,101,603
20a.05	Superstructure RCC M35	cum	-8232	6,834.48	-56,261,455
20a.06	Elastomeric Bearings	cucm	-1638000	0.71	-1,159,075
20a.07	HYSD Fe500				
a	For footing	MT	-182	69,546.68	-12,657,495
b	For pier	MT	-82	69,546.68	-5,702,828
c	For piercap	MT	-117	69,546.68	-8,136,961
d	For superstructure	MT	-1235	69,546.68	-85,876,238
e	For dirt wall	MT	-31	69,546.68	-2,138,560
f	For crash Barrier	MT	-28	69,546.68	-1,951,090
20a.08	Drainage Spouts	Nos	-146	1,713.52	-250,174
20a.09	Strip seal Expansion Joint	RM	-870	16,932.71	-14,731,455
20a.10	Wearing coat	sqm	-12480	960.50	-11,986,992
20a.11	Footpath at bridge deck top	sqm	-314	923.17	-289,874
20a.12	Crash Barrier at edge of carriageway	cum	-150	5,656.57	-848,486
20a.13	Handrail at deck edge	Rm	-208	2,115.59	-440,043
20a.14	Anticarbonate Painting	sqm	-14466	67.50	-976,393
20a.15	Asphaltic Joint	Rm	-388	1,470.75	-570,652
20a.16	Approach slab M30 including reinforcement	cum	-609	10,652.34	-6,487,277
SUB TOTAL (B)					**-232,220,805**
TOTAL (A+B)					**300,574,666**

Source: JICA Experts

Table 7.3.36 Updated Cost Breakdown of Underpass along Crossroad

BILL NO 22 : Underpass along Cross roads

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
22.01	PRR crossing				
22.02	Cross road as				
22.03	ROW	m			
22.04	Cross Section width	m			
22.05	Turning spans	m			
22.06	Total length	m			
22.07	Area of covered portion	Sqm	4040	18,144.00	73,301,760
22.08	Height	m			
22.09	Length of approach	m			
22.1	Restriction of RE wall	m			
22.11	Length of RCC wall	m	163	15,686.90	2,553,345
22.12	Length of RE wall	m			
22.13	Area of RE wall, 4 sides - RE Panel	Sqm	6226	5,040.00	31,378,652
22.14	Area of RE wall, 4 sides- (Friction slab, Crash barrier, Filter media, HDPE pipe etc.)	Sqm	6226	3,528.00	21,965,057
22.15	Crust + subgrade	m			
22.16	Embankment Height	m			
22.17	Embankment, 2 sides	Cum	57703	291.10	16,797,571
22.18	Subgrade	Cum	10686	319.41	3,413,119
22.19	GSB	Cum	4274	1,158.31	4,951,000
22.2	WMM	Cum	5343	1,182.54	6,318,167
22.21	Prime	Sqm	21372	81.43	1,740,295
22.22	Tack	Sqm	21372	21.88	467,646
22.23	DBM	Cum	2137	9,271.13	19,813,889
22.24	Tack	Sqm	21372	12.08	258,252
22.25	BC	Cum	1069	9,876.41	10,553,739
	Surface Level Road				
22.26	Length	m			
22.27	Width	m			
22.28	Area	Sqm			
22.29	Sides	No			
22.3	Total Area	Sqm			
22.31	Embankment	Cum	10935	291.10	3,183,204
22.32	Subgrade	Cum	10935	319.41	3,492,715
22.33	GSB	Cum	4374	1,158.31	5,066,461
22.34	WMM	Cum	5468	1,182.54	6,465,511
22.35	Prime	Sqm	21870	81.43	1,780,880
22.36	Tack	Sqm	21870	21.88	478,552
22.37	DBM	Cum	1094	9,271.13	10,137,981
22.38	Tack	Sqm	21870	12.08	264,275
22.39	BC	Cum	875	9,876.41	8,639,887
22.40	Drain at surface level - Trapezoidal unlined - 45 Sqm Area including Turfing	Rm	2916	1,512.00	4,408,992
22.41	Lane marking	No	20	475.74	9,515
22.42	Road signs	No	20	7,808.45	156,169
TOTAL					**237,596,636**

Source: JICA Experts

Table 7.3.37 Updated Cost Breakdown of Flyover along Crossroad

BILL NO 23 : Flyovers along Cross roads
(Costs of Flyovers are included in VOP)

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
23.01	PRR crossing				
23.02	Cross road as				
23.03	ROW	m			
23.04	Cross Section width	m			
23.05	Turning spans	m			
23.06	Total length	m			
23.07	Area of covered portion	Sqm	13248	25,200.00	333,849,600
23.08	Height	m			
23.09	Length of approach	m			
23.1	Restriction of RE wall	m			
23.11	Length of RCC wall	m	327	15,490.58	5,071,798
23.12	Length of RE wall	m			
23.13	Area of RE wall, 4 sides - RE Panel	Sqm	22346	5,040.00	112,623,099
23.14	Area of RE wall, 4 sides- (Friction slab, Crash barrier, Filter media, HDPE pipe etc.)	Sqm	22346	3,528.00	78,836,169
23.15	Crust + subgrade	m			
23.16	Embankment Height	m			
23.17	Embankment, 2 sides	Cum	214950	291.10	62,572,453
23.18	Subgrade	Cum	29047	319.41	9,277,910
23.19	GSB	Cum	11619	1,158.31	13,458,346
23.2	WMM	Cum	14524	1,182.54	17,174,727
23.21	Prime	Sqm	58095	81.43	4,730,659
23.22	Tack	Sqm	58095	21.88	1,271,207
23.23	DBM	Cum	5809	9,271.13	53,860,261
23.24	Tack	Sqm	58095	12.08	702,010
23.25	BC	Cum	2905	9,876.41	28,688,317
	Surface Level Road				
23.26	Length	m			
23.27	Width	m			
23.28	Area	Sqm			
23.29	Sides	No			
23.3	Total Area	Sqm			
23.31	Embankment	Cum	33723	291.10	9,816,699
23.32	Subgrade	Cum	33723	319.41	10,771,202
23.33	GSB	Cum	13489	1,158.31	15,624,484
23.34	WMM	Cum	16861	1,182.54	19,939,022
23.35	Prime	Sqm	67445	81.43	5,492,065
23.36	Tack	Sqm	67445	21.88	1,475,809
23.37	DBM	Cum	3372	9,271.13	31,264,569
23.38	Tack	Sqm	67445	12.08	814,999
23.39	BC	Cum	2698	9,876.41	26,644,590
23.40	Drain at surface level - Trapezoidal unlined - 45 Sqm Area including Turfing	Rm	7966	1,512.00	12,044,592
23.41	Lane marking	No	40	475.74	19,029
23.42	Road signs	No	40	7,808.45	312,338
TOTAL					**856,335,952**

Source: JICA Experts

(3) Earth Retaining Structures

Table 7.3.38 shows the comparison of the cost estimate for earth retaining structures.

Table 7.3.38 Comparison of Cost Estimate for Earth Retaining Structures

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
C. Earth Rtaining Structures	**3,807,460,118**	**C. Earth Rtaining Structures**	**3,310,000,000**	**497,460,118**
24. RCC Wall	1,537,865,137	26. RCC Wall	1,525,659,858	12,205,279
25. RE Wall	2,269,594,981	27. RE Wall	1,770,266,283	499,328,699
		28. Rounding Off	14,073,859	-14,073,859

Source: JICA Experts

1) Major Contents of Update

Major contents of the cost update for the earth retaining structures are shown below.

- Update the quantities of RE wall (shown in Chapter 7.2.5.2 Breakdown of Each Work Item).
- Update the unit rates of each work by using 0.8% rate of annual price escalation in year 2014.

2) Cost Breakdown of Earth Retaining Structures

Updated cost breakdowns of the earth retaining structures are shown below.

Table 7.3.39 Updated Cost Breakdown of RCC Wall

BILL NO 24 : RCC WALL					
Item	**Description**	Unit	**Total Quantity**	**Rate (Rs)**	**Total Amount (INR)**
	RCC WALL				
	Length		65490		
24.01	EARTH WORK	Cum	253176	47.57	12,044,486
24.02	Back fill	Cum	146097	188.77	27,578,681
24.03	PCC	Cum	16878	4,305.57	72,671,153
24.04	RCC - M35	Cum	90201	6,537.83	589,718,580
24.05	Steel	MT	4289	69,546.68	298,258,230
24.06	Weep holes	Nos	37792	165.47	6,253,566
24.07	Filter media	Cum	31676	947.12	30,000,682
24.08	Painting	Sqm	98986	67.50	6,681,127
24.09	Crash Barrier M40	Cum	26196	7,625.92	199,768,684
24.10	Steel Crash Barrier	MT	4191	70,356.63	294,889,948
Total					**1,537,865,137**

Source: JICA Experts

Table 7.3.40 Updated Cost Breakdown of RE Wall

BILL NO 25: RE WALL

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
	RE PANEL				
25.01	Area of RE wall - RE Panel	Sqm	176175	5,544.00	976,714,200
25.02	Area of RE wall, - (Friction slab, Crash barrier, Filter media, HDPE pipe etc.)	Sqm	176175	3,528.00	621,545,400
	RCC WALL				
	Length		12620		
25.03	EARTH WORK	Cum	47325	47.57	2,251,419
25.04	Back fill	Cum	27764	188.77	5,241,015
25.05	PCC	Cum	3155	4,305.57	13,584,077
25.06	RCC - M35	Cum	16406	6,537.83	107,259,598
25.07	Steel	MT	738	69,546.68	51,344,226
25.08	Weep holes	Nos	6300	165.47	1,042,482
25.09	Filter media	Cum	5300	947.12	5,020,098
25.10	Painting	Sqm	6310	67.50	425,898
Sub Total (A)					**1,784,428,413**

BILL NO 25a: RE WALL (Update of Area of RE Wall)

Item	Description	Unit	Total Quantity	Rate (Rs)	Total Amount (INR)
	RE PANEL				
25a.01	Area of RE wall - RE Panel	Sqm	-176175	5,544.00	-976,714,200
			229655	5,544.00	1,273,204,881
25a.02	Area of RE wall, - (Friction slab, Crash barrier, Filter media, HDPE pipe etc.)	Sqm	-176175	3,528.00	-621,545,400
			229655	3,528.00	810,221,288
Sub Total (B)					**485,166,568**
Total (A+B)					**2,269,594,981**

Source: JICA Experts

(4) Other Works

Table 7.3.41 shows the comparison of the cost estimate for other works.

Table 7.3.41 Comparison of Cost Estimate for Other Works

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
D. Other Works	**2,859,599,486**	**F. Other Items of Work**	**3,208,260,000**	**-348,660,514**
1. Environmental Mitigation Plan	90,200,000	2. Environmental Mitigation Plan	90,200,000	0
2. Capacity Building (A+B+C) X 0.30%	82,668,641	4. Capacity Building (A+B+C) X 0.5%	103,700,000	-21,031,359
3. Shifting of Utilities after LA (A+B+C) X 5.00%	1,377,810,689	5. Shifting of Utilities after LA (A+B+C) X 7.5%	1,555,500,000	-177,689,311
4. Safety & Occupational Health, Risc Coverage (A+B+C) X 4.75%	1,308,920,155	10. Safety & Occupational Health, Risc Coverage (A+B+C) X 7.0%	1,451,800,000	-142,879,845
		13. Rounding Off	7,060,000	-7,060,000
Total	**30,415,813,275**	**Total**	**23,948,260,000**	**6,467,553,275**

Source: JICA Experts

1) Major Contents of Update

Major contents of the cost update for the other works are shown below.

- The JICA Experts has been reviewing the project cost estimate R(3) which was officially provided by BDA and JICA in May 2015 as a base of the review works. On 6 July 2015, BDA provided (via e-mail) the project cost estimate R(4). However, the JICA Experts found major errors even in the summary of the amount on the project cost estimate R(4). Therefore, the JICA Experts decided to keep referring to the cost estimate R(3) as a base of the review works by the JICA Experts.
- In the cost estimate R(4), the ratios of items in the "Other Works" were revised by BDA/STUP as shown in Table 7.3.42. BDA/STUP proposed that the ratios are to be properly calculated based on past or ongoing project experiences of BDA. Accordingly, the JICA Experts accepted to apply the ratios in the project cost estimate R(4).

Table 7.3.42 Comparison of Ratios of Other Works

Item	Ratio of Other Works	
	Cost Estimate R(3)	Cost Estimate R(4)
F-1) Preparatory Works like Topography, Soil Investigation, Construction Material Assessment & Test, etc.	2.0%	0.25%
F-4) Capacity Building	0.5%	0.3%
F-5) Shifting of Utilities after LA	7.5%	5.0%
F-8) Design Fee	0.75%	0.3%
F-10) Safety & Occupational Health, Risk Coverage, etc.	7.0%	4.75%

Source: JICA Experts

- SI No.F-1 Preparatory works like topography, soil investigation, construction material assessment & test, etc. were included in the detailed design by STUP under "non-eligible" items.
- SI No.F-3 Rehabilitation and resettlement cost was included in the land acquisition cost.
- SI No.F-6 Feasibility engineering cost was cost for the DPR; therefore, it was deducted in the cost estimate.
- SI No.F-7 Supervision consultancy was rearranged by the JICA Experts.
- SI No.F-8 Design fee was changed and named as detailed design by STUP.
- SI No.F-9 Approvals were included in the administration cost.

It is noted that capacity building (SI No.F-4) is the item for capacity building program of the BDA in the project management area; however, the contents were not determined in detail.

The JICA Experts recommended DULT and BDA to discuss with JICA in the appraisal stage.

7.3.3.2 Intelligent Transport System (ITS)

The JICA Experts revised the cost estimate of ITS works based on JICA ITS Master Plan Study.

Table 7.3.43 shows the cost estimate for ITS works.

Table 7.3.43 Cost Estimate for ITS Works

ITS Component		Equipment				O&M (Annual)
		Grant	Loan	State	Total	
ITS for Peripheral Ring Road	Highway Traffic Management System (HTMS)		791,903,340		1,583,806,680	39,551,318
	Toll Management System (TMS)		572,029,950		1,011,047,752	775,145,184
Subtotal			**1,363,933,290**		**2,594,854,432**	**814,696,502**
Bengaluru Traffic Information System (B-TIC)	Centre System (including Probe Car System)	557,546,250	271,476,000		1,100,498,250	**50,281,440**
	Queue Length Measurement System	63,640,500	0		63,640,500	
	Automatic Traffic Counter-Cum Classifier (ATCC) System	34,317,360	137,269,440		308,856,240	
	Variable Message Sign (VMS) System	42,124,005	238,702,695		519,529,395	
	Internet System	60,060,000	1,155,000		62,370,000	
Subtotal		**757,688,115**	**648,603,135**		**2,054,894,385**	
Area Traffic Signal Control System (ATCS)		**207,510,300**	**1,321,563,900**	**1,461,975,600**	**3,011,763,968**	**133,660,208**
Electronic Road Pricing (ERP) System			**0**	**928,524,288**	**928,524,288**	**72,822,288**
Clearinghouse for Common Smartcard			**389,620,800**		**779,241,600**	**10,890,000**
Grand Total		**965,198,415**	**3,723,721,125**	**2,390,499,888**	**7,079,419,428**	**1,082,350,438**

Source: JICA Experts

The costs for ITS works consist of grant aided portion (J-ODA), loan portion, and state budget portion. The JICA Experts counted the costs of the loan portion in the project cost estimate of BPRR.

Table 7.3.44 shows the comparison of the cost estimate for ITS works.

Table 7.3.44 Comparison of Cost Estimate for ITS Works

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (X - Y) (INR)
item	Total Amount (X) (INR)	item	Total Amount (Y) (INR)	
E. Intelligent Transport System	**3,723,721,125**	**G. Intelligent Transport System**	**8,000,000,000**	**-4,276,278,875**
1. ITS for Peripheral Ring Road	1,363,933,290	1. PRR - ITS	1,464,000,000	-100,066,710
2. Bengaluru Traffic Information System (B-TIC)	648,603,135	2. Bangalor City - ITS	6,468,000,000	-4,108,212,165
3. Area Traffic Signal Control System (ATCS)	1,321,563,900			
4. Electronic Road Pricing (ERP) System	0			
5. Clearinghouse for Common Smartcard	389,620,800			
		3. Rounding Off	68,000,000	-68,000,000
Total	**3,723,721,125**	**Total**	**8,000,000,000**	**-4,276,278,875**

Source: JICA Experts

7.3.3.3 Operation and Maintenance (O&M)

(1) O&M Cost for Civil Works

The O&M cost consists of routine (once a year) and periodic (once every five years) maintenance works.

It was confirmed that the O&M cost for civil works was calculated based on the official formula issued by the National Highways Authority of India (NHA) as shown below. (Refer to NHA Letter No. NHAI/11033/CGM(Fin)/2011 dated 29 May 2011.)

- Routine Maintenance: Rs7 lakhs/km/year for 2010-11
- Periodic Maintenance: Rs45 lakhs/km/year for 2010-11

Since the above formulas are prepared for 4-lane highway projects, the JICA Experts applied the adjustment rate of a 2-lane increase of 150%.

The base year of the O&M cost is adjusted by wholesale price index.

Table 7.3.45 shows the comparison of the O&M cost for the civil works.

Table 7.3.45 Comparison of O&M Cost for Civil Works

Update by JICA Experts			Project Cost Estimate R(3) in DPR			Difference (INR)
item		Total Amount (INR)	item		Total Amount (INR)	
K1. Routine O & M (per 1 year)		**131,431,514**	**K1. Routine O & M (per 1 year)**		**75,205,843**	**56,225,670**
a. Roads	0.201	71,503,020	a. Roads		39,955,843	31,547,177
b. Structures	(Cr/Yr/Km)	59,928,494	b. Structures	(B+C) X 0.5%	35,250,000	24,678,494
K2. Periodic O & M (per 5 years)		**844,916,875**	**K2. Periodic O & M (per 5 years)**		**1,498,523,564**	**-653,606,690**
a. Roads	1.289	459,662,272	a. Roads		1,423,723,564	-964,061,292
b. Structures	(Cr/Yr/Km)	385,254,603	b. Structures	B X 2.0%	74,800,000	310,454,603

Source: JICA Experts

(2) O & M Cost for ITS

The JICA Experts revised the O&M cost for ITS based on JICA ITS Master Plan Study.

Table 7.3.46 shows the comparison of O&M costs for ITS.

Table 7.3.46 Comparison of O&M Costs for ITS

Update by JICA Experts		Project Cost Estimate R(3) in DPR		Difference (INR)
item	Total Amount (INR)	item	Total Amount (INR)	
K3. Routine O & M for ITS (per 1 year)	**1,082,350,438**	**K1. Routine O & M for ITS (per 1 year)**	**960,000,000**	**122,350,438**
1. ITS for Peripheral Ring Road	814,696,502	c. PRR ITS (G1+G3) X 12%	183,840,000	630,856,502
2. Bengaluru Traffic Information System (B-TIC)	50,281,440	d. City ITS G2 X 12%	776,160,000	-508,506,064
3. Area Traffic Signal Control System (ATCS)	133,660,208			
4. Electronic Road Pricing (ERP) System	72,822,288			
5. Clearinghouse for Common Smartcard	10,890,000			
Total	**1,082,350,438**	**Total**	**960,000,000**	**122,350,438**

Source: JICA Experts

7.4 Composition of Project Cost Estimate for JICA Appraisal

In JICA Appraisal, the project cost estimate should be composed as JICA format for appraisal.

Therefore, the JICA Experts composed work items of the project cost estimate based on the JICA format for appraisal by JICA.

7.4.1 Structure of Project Cost Estimate for JICA Appraisal

The structure of the project cost estimate based on the JICA format for appraisal is shown below.

Table 7.4.1 Structure of Project Cost Estimate for JICA Appraisal

Structure of Project Cost Estimate for JICA Appraisal			Structure of Project Cost Estimate R(3) in DPR	
Item		Total Amount	Item	Total Amount
		million INR		million INR
A. ELIGIBLE PORTION				
I)	Procurement / Construction	38,018	A. Road Works, B. Structure Works, C. Earth Retaining Structures, F. Other Items of Work	37,557
i)	Package-1 (Section-1 : KM00+000-KM18+367)	8,797	A, B, C, F) Strech-1 (KM00+000-KM18+367)	7,604
ii)	Package-2 (Section-2 : KM18+367-KM36+323)	6,386	A, B, C, F) Strech-2 (KM18+367-KM36+323)	6,120
iii)	Package-3 (Section-3-1 : KM36+323-KM50+000)	7,611	A, B, C, F) Strech-3 (KM36+323-KM65+538)	10,648
iv)	Package-4 (Section3-2 : KM50+000-KM65+538)	7,623		
v)	Package-5 (ITS : BPRR & Bengaluru City)	3,724	G) ITS	8,000
vi)	Dispute Boards (Package-2&3)	0	-	
vii)	Dispute Boards (Package-1&4&5)	0	-	
	Base Cost for JICA Financing (i+ii+iii+iv+v+vi+vii)	34,140	Sub Total （A+B+C+F+G）	32,372
	Price Escalation	2,069	F-12) Price Escalation (a) for Year 2014-15	2,074
			F-12) Price Escalation (b) for Year 2015-16	2,074
	Physical Contingency	1,810	F-11) Contingency	1,037
II)	Consulting Services	2,995	F-7) Supervision Consultancy	604
	Consulting Services for Civil Works	1,780	a. PRR - Civil Construction	207
	Consulting Services for ITS Works	922	b. PRR - ITS Implementation	73
			c. City - ITS Implementation	323
	Base Cost	2,703	Sub Total (a+b+c)	604
	Price Escalation	150	-	0
	Physical Contingency	143	-	0
Total (I+II)		41,014	Total	38,161
B. NON ELIGIBLE PORTION				
a	Procurement / Construction	0	Procurement / Construction	0
	Base Cost for GoI Financing	0	-	0
	Price Escalation	0	-	0
	Physical Contingency	0	-	0
b	Consulting Services	161	Consulting Services	156
	Base Cost (Detailed Design by STUP)	152	F-8) Design Fee	156
			F-1) Preparatory works like Topography, Soil Investigation, Construction Material assessment & test. etc.	415
	Price Escalation	1	-	0
	Physical Contingency	8	-	0
c	Land Acquisition	81,000	Land Acquisisition Cost	57,500
	Base Cost	81,000	E) Land Acquistion Cost (excl Rehabilitation / resettlement cost)	53,800
			F-3) Rehabilitation and Resettlement Cost	3,700
	Price Escalation	0	-	0
	Physical Contingency	0	-	0
d	Administration Cost	104	F-9) Approvals	176
			A-10) Provision and Maintenance of Vehicles and Mobile	8
e	VAT	5,970	-	0
f	Import Tax	437	-	0
Total (a+b+c+d+e+f)		87,671	Total	57,839
TOTAL (A+B)		128,685	**TOTAL**	96,000
C. Interest during Construction		553	-	0
	Interest during Construction(Const.)	537	-	0
	Interest during Construction (Consul.)	16	-	0
D. Front End Fee		82	-	0
GRAND TOTAL (A+B+C+D)		129,320	GRAND TOTAL	96,000
E. JICA Finance Portion (A)		41,014		38,161

Source: JICA Experts

7.4.2 Conditions for JICA Appraisal

The conditions for JICA Appraisal are explained as follows.

7.4.2.1 Preconditions for JICA Appraisal

Table 7.4.2 shows the preconditions for JICA Appraisal provided by JICA.

Table 7.4.2 Preconditions for JICA Appraisal

Item	Preconditions
Exchange Rate	USD = JPY 120.7
	USD = INR 63.8
	INR = JPY 1.89
Rate of Price Escalation	Foreign Currency (JPY) : 1.8%
	Local Currency (INR) : 1.3%
Rate of Physical Contingency	Construction: 5.0%
	Consultant: 5.0%
Base Year for Cost Estimate	July 2015
Billing Rate of Consultant	Professional (A): JPY 3,049,000
	Professional (B): INR 320,000
	Supporting Staff: INR 80,000
Rate of Administration Cost	0.085%
Rate of Interest During Construction	Construction: 0.3%
	Consultant: 0.1%
Rate of Front End Fee	0.2%

Source: JICA Experts

7.4.2.2 Implementation Schedule

As mentioned in Chapter 6 in this report.

7.4.2.3 Packaging for Implementation

The JICA Experts sorted project sections based on the implementation schedule as mentioned in Chapter 6.

The project packaging (sections) in the DPR are divided into three sections at the points of intersection with National Highways. The project scale of Section 3 is quite larger than other sections.

Therefore, the JICA Experts proposed to divide Section 3 into two sections (namely Section 3-1 and Section 3-2) as explained in Chapter 6.

In dividing Section 3, the JICA Experts considered the following conditions:

- Costly Chennai Railway over bridge and Hosur Railway over bridge were separated.
- Selection point of low excavations and embankments.

Table 7.4.3 shows the project packaging for implementation of the Project.

Table 7.4.3 Project Packaging for Implementation

Section	Chainage	Length (km)
Section 1	KM 0.000 (Tumkur Road) - KM 18.367 (Bellary Road)	18.367
Section 2	KM 18.367 (Bellary Road) - KM 36.323 (Old Madras Road)	17.956
Section 3-1	KM 36.323 (Old Madras Road) - KM 50.000	13.677
Section 3-2	KM 50.000 - KM 65.538 (Hosur Road)	15.538

Source: JICA Experts

7.4.2.4 Cost for Consulting Services

The cost breakdowns for the consulting services estimated by the JICA Experts are shown below.

Table 7.4.4 Cost Breakdown for Consulting Services of Civil Works and ITS

Description	Unit	Qty.	Foreign Portion		Local Portion		Combined Total	
			JPY		INR			
			Rate	Amount	Rate	Amount	JPY	INR
A Remuneration								
1 Professional (A)	M/M	499	3,049,000	1,521,451,000	0	0	1,521,451,000	804,213,536
2 Professional (B)	M/M	4538	0	0	320,000	1,452,160,000	2,747,268,213	1,452,160,000
3 Supporting Staffs	M/M	1374	0	0	80,000	109,920,000	207,952,100	109,920,000
Subtotal of A				1,521,451,000		1,562,080,000	4,476,671,313	2,366,293,536
B Direct Cost								
1 International Airfare	Trip	41.58	400,000	16,633,333		0	16,633,333	8,792,102
2 Domestic Travel (Bengaluru<>Delhi)		20		0	25,000	500,000	945,925	500,000
3 Accommodation Allowance	Month	499		0	127,600	63,672,400	120,458,600	63,672,400
	Month	4538		0	20,000	90,760,000	171,704,263	90,760,000
	Month	1374		0	20,000	27,480,000	51,988,025	27,480,000
4 Vehicle Rental	Month	1679		0	55,000	92,345,000	174,702,845	92,345,000
5 Office Rental (Core Office)	M/M	60		0	100,000	6,000,000	11,351,097	6,000,000
Office Rental (Section 1 Office)	M/M	36		0	50,000	1,800,000	3,405,329	1,800,000
Office Rental (Section 2 Office)	M/M	36		0	50,000	1,800,000	3,405,329	1,800,000
Office Rental (Section 3-1 Office)	M/M	36		0	50,000	1,800,000	3,405,329	1,800,000
Office Rental (Section 3-2 Office)	M/M	36		0	50,000	1,800,000	3,405,329	1,800,000
6 International Communications	M/M	204		0	10,000	2,040,000	3,859,373	2,040,000
7 Domestic Communications	M/M	204		0	20,000	4,080,000	7,718,746	4,080,000
8 Office Supplies, Utilities, Communication (Core Office)	month	60		0	40,000	2,400,000	4,540,439	2,400,000
Office Supplies, Utilities, Communication (Section 1 Office)	month	36		0	40,000	1,440,000	2,724,263	1,440,000
Office Supplies, Utilities, Communication (Section 2 Office)	month	36		0	40,000	1,440,000	2,724,263	1,440,000
Office Supplies, Utilities, Communication (Section 3-1 Office)	month	36		0	40,000	1,440,000	2,724,263	1,440,000
Office Supplies, Utilities, Communication (Section 3-2 Office)	month	36		0	40,000	1,440,000	2,724,263	1,440,000
9 Office Furniture and Equipment (Core Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 1 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 2 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 3-1 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 3-2 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
10 Report Preparation	Month	60		0	50,000	3,000,000	5,675,549	3,000,000
11 Overseas Training Cost	LS	1	4,100,000	4,100,000	1,300,000	1,300,000	6,559,404	3,467,191
12 Hotel Cost during DLP								
13 Survey	Ns	280			50,000	14,000	26,486	14,000,000
Subtotal of B				20,733,333		325,537,400	636,601,110	336,496,693
Total				1,542,184,333		1,887,617,400	5,113,272,424	2,702,790,229

Source: JICA Experts

Table 7.4.5 Cost Breakdown for Consulting Services of Civil Works

Description	Unit	Qty.	Foreign Portion		Local Portion		Combined Total	
			JPY		INR			
			Rate	Amount	Rate	Amount	JPY	INR
A Remuneration								
1 Professional (A)	M/M	248	3,049,000	756,152,000	0	0	756,152,000	399,689,292
2 Professional (B)	M/M	3393	0	0	320,000	1,085,760,000	2,054,094,545	1,085,760,000
3 Supporting Staffs	M/M	993	0	0	80,000	79,440,000	150,288,527	79,440,000
Subtotal of A				756,152,000		1,165,200,000	2,960,535,072	1,564,889,292
B Direct Cost								
1 International Airfare	Trip	20.67	400,000	8,266,667		0	8,266,667	4,369,622
2 Domestic Travel (Bengaluru<>Delhi)		14.46		0	25,000	361,425	683,763	361,425
3 Accommodation Allowance	Month	248		0	127,600	31,644,800	59,867,200	31,644,800
	Month	3393		0	20,000	67,860,000	128,380,909	67,860,000
	Month	993		0	20,000	19,860,000	37,572,132	19,860,000
4 Vehicle Rental	Month	877		0	55,000	48,235,000	91,253,362	48,235,000
5 Office Rental (Core Office)	M/M	43		0	100,000	4,300,000	8,134,953	4,300,000
Office Rental (Section 1 Office)	M/M	26		0	50,000	1,300,000	2,459,404	1,300,000
Office Rental (Section 2 Office)	M/M	26		0	50,000	1,300,000	2,459,404	1,300,000
Office Rental (Section 3-1 Office)	M/M	26		0	50,000	1,300,000	2,459,404	1,300,000
Office Rental (Section 3-2 Office)	M/M	26		0	50,000	1,300,000	2,459,404	1,300,000
6 International Communications	M/M	147		0	10,000	1,470,000	2,781,019	1,470,000
7 Domestic Communications	M/M	147		0	20,000	2,940,000	5,562,038	2,940,000
8 Office Supplies, Utilities, Communication (Core Office)	month	43		0	40,000	1,720,000	3,253,981	1,720,000
Office Supplies, Utilities, Communication (Section 1 Office)	month	26		0	40,000	1,040,000	1,967,524	1,040,000
Office Supplies, Utilities, Communication (Section 2 Office)	month	26		0	40,000	1,040,000	1,967,524	1,040,000
Office Supplies, Utilities, Communication (Section 3-1 Office)	month	26		0	40,000	1,040,000	1,967,524	1,040,000
Office Supplies, Utilities, Communication (Section 3-2 Office)	month	26		0	40,000	1,040,000	1,967,524	1,040,000
9 Office Furniture and Equipment (Core Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 1 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 2 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 3-1 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
Office Furniture and Equipment (Section 3-2 Office)	LS	1		0	1,000,000	1,000,000	1,891,850	1,000,000
10 Report Preparation	Month	43		0	50,000	2,150,000	4,067,476	2,150,000
11 Overseas Training Cost	LS	1	2,000,000	2,000,000	970,000	970,000	3,835,094	2,027,167
12 Hotel Cost during DLP								
13 Survey	Ns	280			50,000	14,000,000	26,485,893	14,000,000
Subtotal of B				10,266,667		209,871,225	407,311,446	215,298,014
Total				766,418,667		1,375,071,225	3,367,846,518	1,780,187,306

Source: JICA Experts

Table 7.4.6 Cost Breakdown for Consulting Services of ITS

Description	Unit	Qty.	Foreign Portion		Local Portion		Combined Total	
			JPY		INR			
			Rate	Amount	Rate	Amount	JPY	INR
A Remuneration								
1 Professional (A)	M/M	251	3,049,000	765,299,000	0	0	765,299,000	404,524,244
2 Professional (B)	M/M	1145	0	0	320,000	366,400,000	693,173,668	366,400,000
3 Supporting Staffs	M/M	381	0	0	80,000	30,480,000	57,663,574	30,480,000
Subtotal of A				765,299,000		396,880,000	1,516,136,241	801,404,244
B Direct Cost								
1 International Airfare	Trip	20.92	400,000	8,366,667		0	8,366,667	4,422,480
2 Domestic Travel (Bengaluru<>Delhi)		5.54		0	25,000	138,575	262,162	138,575
3 Accommodation Allowance	Month	251		0	127,600	32,027,600	60,591,400	32,027,600
	Month	1145		0	20,000	22,900,000	43,323,354	22,900,000
	Month	381		0	20,000	7,620,000	14,415,893	7,620,000
4 Vehicle Rental	Month	802		0	55,000	44,110,000	83,449,483	44,110,000
5 Office Rental (Core Office)	M/M	17		0	100,000	1,700,000	3,216,144	1,700,000
Office Rental (Section 1 Office)	M/M	10		0	50,000	500,000	945,925	500,000
Office Rental (Section 2 Office)	M/M	10		0	50,000	500,000	945,925	500,000
Office Rental (Section 3-1 Office)	M/M	10		0	50,000	500,000	945,925	500,000
Office Rental (Section 3-2 Office)	M/M	10		0	50,000	500,000	945,925	500,000
6 International Communications	M/M	57		0	10,000	570,000	1,078,354	570,000
7 Domestic Communications	M/M	57		0	20,000	1,140,000	2,156,708	1,140,000
8 Office Supplies, Utilities, Communication (Core Office)	month	17		0	40,000	680,000	1,286,458	680,000
Office Supplies, Utilities, Communication (Section 1 Office)	month	10		0	40,000	400,000	756,740	400,000
Office Supplies, Utilities, Communication (Section 2 Office)	month	10		0	40,000	400,000	756,740	400,000
Office Supplies, Utilities, Communication (Section 3-1 Office)	month	10		0	40,000	400,000	756,740	400,000
Office Supplies, Utilities, Communication (Section 3-2 Office)	month	10		0	40,000	400,000	756,740	400,000
9 Office Furniture and Equipment (Core Office)	LS	0		0	1,000,000	0	0	0
Office Furniture and Equipment (Section 1 Office)	LS	0		0	1,000,000	0	0	0
Office Furniture and Equipment (Section 2 Office)	LS	0		0	1,000,000	0	0	0
Office Furniture and Equipment (Section 3-1 Office)	LS	0		0	1,000,000	0	0	0
Office Furniture and Equipment (Section 3-2 Office)	LS	0		0	1,000,000	0	0	0
10 Report Preparation	Month	17		0	50,000	850,000	1,608,072	850,000
11 Overseas Training Cost	LS	1	2,100,000	2,100,000	330,000	330,000	2,724,310	1,440,025
12 Hotel Cost during DLP								
13 Survey	Ns	0			50,000	0	0	0
Subtotal of B				10,466,667		115,666,175	229,289,665	121,198,679
Total				775,765,667		512,546,175	1,745,425,906	922,602,923

Source: JICA Experts

7.4.2.5 Bidding Method to Procure Contractors

To procure contractor, the bidding method is used the international competitive bidding (ICB).

7.4.2.6 Procurement for Equipment and Materials

The JICA Experts confirmed the procurement for equipment and materials with DULT, BDA, and STUP.

It was confirmed that almost all construction materials and equipment for civil works can be procured in India.

Some parts of equipment for ITS (advanced signal control system and ETC lane controller system, ETC antenna) were procured from a foreign country and other equipment for ITS can be procured in India.

7.4.2.7 Classification of Currency

In this report, it has been assumed that the Project will be financed by JICA loan.

Therefore, JPY was used as foreign currency and INR (Rs) was used as local currency.

(1) Direct Cost

The costs of materials and equipment for civil works were estimated in local currency.

Imported equipment for ITS works were estimated in foreign currency and other commonly procured equipment for ITS works were estimated in local currency.

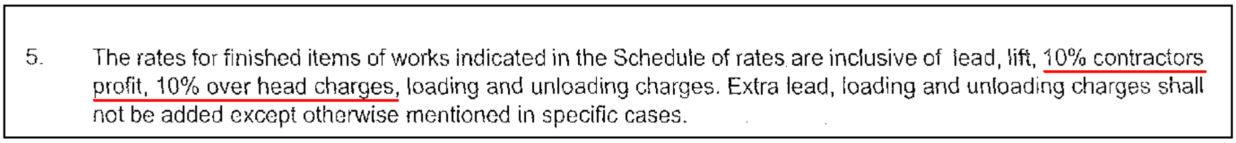
(2) Indirect Cost

The JICA Experts divided the indirect costs into foreign currency and local currency by considering foreign contractors because of ICB.

The basic concept of the proportion of indirect cost is presented below.

- 10% contractors profit and 10% overhead charges are included in unit rates of KPWD SR 2014-2015 (shown in Figure 7.4.1).

Figure 7.4.1 General Note in KPWD SR 2014-2015



5. The rates for finished items of works indicated in the Schedule of rates are inclusive of lead, lift, 10% contractors profit, 10% over head charges, loading and unloading charges. Extra lead, loading and unloading charges shall not be added except otherwise mentioned in specific cases.

Source: KPWD SR 2014-2015 Bangalore Circle

- Contractors profit was in foreign currency, because it is a budget for head office of foreign contractor.

- Overhead charges were divided into 50% foreign currency and 50% local currency, because these consisted of salaries and travel expenses for foreign workers and salaries for local workers.

The cost breakdowns by each section after division into foreign currency and local currency are shown below.

Table 7.4.7 Cost Breakdown of Construction for Section 1 (Package 1)

Package-1 (Section-1 : KM00+000-KM18+367)				
item	Cost		Total	
	Foreign	Local		
	JPY	INR	JPY	INR
A. Road Works	**1,203,244,814**	**3,604,085,405**	**8,021,632,093**	**4,240,100,476**
1. Site Clearance	1,496,385	4,482,128	9,975,897	5,273,092
2. Earthwork	181,438,744	543,464,407	1,209,591,627	639,369,890
3. Pavement	633,004,877	1,896,042,776	4,220,032,512	2,230,638,560
4. Drainage	116,904,226	350,163,833	779,361,510	411,957,451
5. Road Furniture	78,370,761	234,744,346	522,471,741	276,169,818
6. Intersections and Entry/Exit Ramps	16,837,986	50,434,906	112,253,239	59,335,184
7. Toll Plaza	155,439,994	465,590,217	1,036,266,627	547,753,196
8. Arboriculture	3,287,411	9,846,799	21,916,074	11,584,470
9. Highway Lighting	13,110,880	39,271,085	87,405,864	46,201,277
10. Other Items	3,200,026	9,585,056	21,333,510	11,276,536
11. Maintenance during Construction	153,524	459,851	1,023,493	541,001
B. Structure Works	**636,946,928**	**1,907,850,423**	**4,246,312,855**	**2,244,529,910**
12. Culvert	26,903,688	80,584,757	179,357,923	94,805,596
13. Vehicular Underpass	41,264,125	123,598,648	275,094,169	145,410,174
14. Pedestrian Underpass	13,441,611	40,261,727	89,610,739	47,366,737
15. Minor Bridge	0	0	0	0
16. Railway Under Bridge	137,173,460	410,876,374	914,489,735	483,383,969
17a. Bridge Structures	236,100,267	707,192,350	1,574,001,782	831,991,000
20. Underpass along PRR	42,680,627	127,841,504	284,537,516	150,401,769
22. Underpass along Cross road	0	0	0	0
23. Flyover along Cross road (Exclude bridge structure)	139,383,148	417,495,064	929,220,989	491,170,664
C. Earth Rtaining Structures	**421,652,750**	**1,262,978,658**	**2,811,018,330**	**1,485,857,245**
24. RCC Wall	145,166,182	434,817,015	967,774,547	511,549,429
25. RE Wall	276,486,567	828,161,643	1,843,243,783	974,307,816
D. Other Works	**0**	**826,312,523**	**1,563,258,959**	**826,312,523**
1. Environmental Mitigation Plan	0	25,278,516	47,823,149	25,278,516
2. Capacity Building	0	23,911,463	45,236,890	23,911,463
3. Shifting of Utilities after LA	0	398,524,382	753,948,164	398,524,382
4. Safety & Occupational Health, Risc Coverage	0	378,598,162	716,250,756	378,598,162
Total	**2,261,844,492**	**7,601,227,010**	**16,642,222,236**	**8,796,800,155**

Source: JICA Experts

Table 7.4.8 Cost Breakdown of Construction for Section 2 (Package 2)

Package-2 (Section-2 : KM18+367-KM36+323)				
item	Cost		Total	
	Foreign	Local		
	JPY	INR	JPY	INR
A. Road Works	**1,092,819,475**	**3,273,327,817**	**7,285,463,166**	**3,850,973,902**
1. Site Clearance	1,892,508	5,668,638	12,616,717	6,668,985
2. Earthwork	105,361,285	315,589,200	702,408,564	371,281,411
3. Pavement	622,718,118	1,865,230,794	4,151,454,118	2,194,389,169
4. Drainage	124,921,762	374,178,800	832,811,748	440,210,353
5. Road Furniture	86,233,589	258,295,915	574,890,594	303,877,547
6. Intersections and Entry/Exit Ramps	8,449,644	25,309,263	56,330,961	29,775,603
7. Toll Plaza	125,391,621	375,586,169	835,944,138	441,866,081
8. Arboriculture	3,212,511	9,622,451	21,416,740	11,320,530
9. Highway Lighting	11,242,737	33,675,427	74,951,578	39,618,150
10. Other Items	3,200,026	9,585,056	21,333,510	11,276,536
11. Maintenance during Construction	195,675	586,106	1,304,499	689,536
B. Structure Works	**223,024,403**	**668,026,145**	**1,486,829,351**	**785,913,112**
12. Culvert	24,273,850	72,707,587	161,825,665	85,538,338
13. Vehicular Underpass	26,551,509	79,529,871	177,010,058	93,564,554
14. Pedestrian Underpass	3,369,303	10,092,092	22,462,023	11,873,049
15. Minor Bridge	0	0	0	0
16. Railway Under Bridge	0	0	0	0
17a. Bridge Structures	95,304,096	285,464,850	635,360,638	335,841,000
20. Underpass along PRR	21,712,812	65,036,497	144,752,078	76,513,526
22. Underpass along Cross road	0	0	0	0
23. Flyover along Cross road (Exclude bridge structure)	51,812,833	155,195,248	345,418,890	182,582,644
C. Earth Rtaining Structures	**324,373,308**	**971,597,045**	**2,162,488,720**	**1,143,055,347**
24. RCC Wall	160,518,137	480,800,806	1,070,120,915	565,648,007
25. RE Wall	163,855,171	490,796,239	1,092,367,805	577,407,340
D. Other Works	**0**	**605,597,064**	**1,145,698,521**	**605,597,064**
1. Environmental Mitigation Plan	0	24,712,857	46,753,006	24,712,857
2. Capacity Building	0	17,339,827	32,804,344	17,339,827
3. Shifting of Utilities after LA	0	288,997,118	546,739,062	288,997,118
4. Safety & Occupational Health, Risc Coverage	0	274,547,262	519,402,109	274,547,262
Total	**1,640,217,186**	**5,518,548,070**	**12,080,479,758**	**6,385,539,424**

Source: JICA Experts

Table 7.4.9 Cost Breakdown of Construction for Section 3-1 (Package 3)

Package-3 (Section-3-1 : KM36+323-KM50+000)				
item	Cost		Total	
	Foreign	Local		
	JPY	INR	JPY	INR
A. Road Works	**884,266,528**	**2,648,648,098**	**5,895,110,186**	**3,116,056,586**
1. Site Clearance	1,259,566	3,772,784	8,397,106	4,438,570
2. Earthwork	155,555,067	465,934,895	1,037,033,778	548,158,700
3. Pavement	462,194,655	1,384,414,036	3,081,297,697	1,628,722,395
4. Drainage	91,886,631	275,228,500	612,577,540	323,798,235
5. Road Furniture	61,683,663	184,761,394	411,224,419	217,366,346
6. Intersections and Entry/Exit Ramps	4,005,550	11,997,843	26,703,664	14,115,110
7. Toll Plaza	96,230,134	288,238,619	641,534,230	339,104,257
8. Arboriculture	2,428,971	7,275,510	16,193,141	8,559,423
9. Highway Lighting	7,908,130	23,687,264	52,720,869	27,867,369
10. Other Items	1,045,772	3,132,405	6,971,810	3,685,182
11. Maintenance during Construction	68,390	204,849	455,933	240,999
B. Structure Works	**859,605,134**	**2,574,779,696**	**5,730,700,891**	**3,029,152,584**
12. Culvert	19,891,951	59,582,462	132,613,004	70,097,015
13. Vehicular Underpass	24,432,324	73,182,268	162,882,163	86,096,785
14. Pedestrian Underpass	3,158,481	9,460,615	21,056,541	11,130,135
15. Minor Bridge	23,166,122	69,389,606	154,440,816	81,634,831
16. Railway Under Bridge	0	0	0	0
17a. Bridge Structures	755,243,974	2,262,186,175	5,034,959,825	2,661,395,500
20. Underpass along PRR	0	0	0	0
22. Underpass along Cross road	33,712,281	100,978,570	224,748,542	118,798,318
23. Flyover along Cross road (Exclude bridge structure)	0	0	0	0
C. Earth Rtaining Structures	**213,792,296**	**640,373,168**	**1,425,281,973**	**753,380,198**
24. RCC Wall	61,201,442	183,316,997	408,009,616	215,667,055
25. RE Wall	152,590,854	457,056,172	1,017,272,357	537,713,143
D. Other Works	**0**	**712,131,897**	**1,347,246,395**	**712,131,897**
1. Environmental Mitigation Plan	0	18,823,666	35,611,543	18,823,666
2. Capacity Building	0	20,695,768	39,153,279	20,695,768
3. Shifting of Utilities after LA	0	344,929,468	652,554,653	344,929,468
4. Safety & Occupational Health, Risc Coverage	0	327,682,995	619,926,920	327,682,995
				0
Total	**1,957,663,958**	**6,575,932,859**	**14,398,339,445**	**7,610,721,264**

Source: JICA Experts

Table 7.4.10 Cost Breakdown of Construction for Section 3-2 (Package 4)

Package-4 (Section3-2 : KM50+000-KM65+538)				
item	Cost		Total	
	Foreign	Local		
	JPY	INR	JPY	INR
A. Road Works	**976,739,461**	**2,925,632,752**	**6,511,596,407**	**3,441,920,884**
1. Site Clearance	1,404,599	4,207,203	9,363,993	4,949,650
2. Earthwork	176,721,175	529,333,848	1,178,141,167	622,745,704
3. Pavement	525,085,299	1,572,790,707	3,500,568,658	1,850,342,008
4. Drainage	104,386,030	312,668,016	695,906,870	367,844,725
5. Road Furniture	69,826,380	209,151,318	465,509,203	246,060,374
6. Intersections and Entry/Exit Ramps	4,544,613	13,612,502	30,297,419	16,014,708
7. Toll Plaza	80,402,659	240,830,500	536,017,727	283,330,000
8. Arboriculture	2,758,154	8,261,513	18,387,693	9,719,427
9. Highway Lighting	8,763,470	26,249,268	58,423,136	30,881,492
10. Other Items	2,769,257	8,294,771	18,461,716	9,758,554
11. Maintenance during Construction	77,824	233,106	518,825	274,242
B. Structure Works	**862,713,528**	**2,584,090,284**	**5,751,423,517**	**3,040,106,217**
12. Culvert	22,592,536	67,671,540	150,616,906	79,613,576
13. Vehicular Underpass	27,751,278	83,123,548	185,008,523	97,792,409
14. Pedestrian Underpass	3,574,634	10,707,121	23,830,896	12,596,613
15. Minor Bridge	26,324,552	78,850,068	175,497,016	92,764,786
16. Railway Under Bridge	0	0	0	0
17a. Bridge Structures	676,042,545	2,024,953,725	4,506,950,297	2,382,298,500
20. Underpass along PRR	20,902,867	62,610,466	139,352,447	73,659,371
22. Underpass along Cross road	33,712,281	100,978,570	224,748,542	118,798,318
23. Flyover along Cross road (Exclude bridge structure)	51,812,833	155,195,248	345,418,890	182,582,644
C. Earth Rtaining Structures	**120,652,892**	**361,392,230**	**804,352,611**	**425,167,329**
24. RCC Wall	69,525,654	208,250,550	463,504,358	245,000,647
25. RE Wall	51,127,238	153,141,680	340,848,253	180,166,682
D. Other Works	**0**	**715,558,002**	**1,353,728,069**	**715,558,002**
1. Environmental Mitigation Plan	0	21,384,961	40,457,129	21,384,961
2. Capacity Building	0	20,721,583	39,202,118	20,721,583
3. Shifting of Utilities after LA	0	345,359,722	653,368,627	345,359,722
4. Safety & Occupational Health, Risc Coverage	0	328,091,735	620,700,195	328,091,735
				0
Total	**1,960,105,880**	**6,586,673,267**	**14,421,100,604**	**7,622,752,432**

Source: JICA Experts

Table 7.4.11 Cost Breakdown of Construction for ITS (Package 5)

Package-5 (ITS : BPRR & Bengaluru City)				
item	Cost		Total	
	Foreign	Local		
	JPY	INR	JPY	INR
E. Intelligent Transport System				
1. ITS for Peripheral Ring Road	255,645,960	1,228,803,114	2,580,356,553	1,363,933,290
2. Bengaluru Traffic Information System (B-TIC)	0	648,603,135	1,227,059,536	648,603,135
3. Area Traffic Signal Control System (ATCS)	2,500,200,043	0	2,500,200,043	1,321,563,900
4. Electronic Road Pricing (ERP) System	0	0	0	0
5. Clearinghouse for Common Smartcard	0	389,620,800	737,103,927	389,620,800
Total	**2,755,846,003**	**2,267,027,049**	**7,044,720,059**	**3,723,721,125**

Source: JICA Experts

7.4.2.8 Price Escalation

Price escalation is added to the base cost (construction cost and cost of the consulting services, land acquisition cost) by year during the construction period, and the rates of price escalations are calculated using the following formula:

$((1 + A) ^ (B - C))-1$

A: Base rate (F/C: 1.8%, L/C: 1.3%)

B: Target year

C: Base year (2015)

Table 7.4.12 shows the annual price escalation rates.

Table 7.4.12 Annual Price Escalation Rates

Currency Portion	Price Escalation Rate							
	2016	2017	2018	2019	2020	2021	2022	2023
F/C (Foreign Currency)	1.8%	3.6%	5.5%	7.4%	9.3%	11.3%	13.3%	15.3%
L/C (Local Currency)	1.3%	2.6%	4.0%	5.3%	6.7%	8.1%	9.5%	10.9%

Source: JICA Experts

7.4.2.9 Physical Contingency

Physical contingency was added to the total of base costs and price escalations, and the rate of physical contingency was set at 5% as directed by JICA headquarters.

7.4.2.10 Administration Cost

Administration cost was added to the total of base costs, price escalations, and physical contingencies, and the rate of administration cost was set at 3% as directed by JICA headquarters.

SI. No. F-9 Approvals and Item Nos. 10.01 to 10.03 in SI. No. A-10 other Items are included in the administration cost.

7.4.2.11 Value Added Tax (VAT)

VAT was added to the total of base costs, price escalations and physical contingencies except the land acquisition cost, and the VAT rate is 14.5%.

The VAT rate was referred to the general rate of Karnataka Value Added TAX Act, 2013.

7.4.2.12 Import Tax

Import tax was referred to as the base tax of Customs Tariff 2013-14 and calculated by the way it is stated in the website of Japan External Trade Organization (JETRO).

Import tax was added to imported equipment of ITS.

Rate of import tax for ITS equipment is 26.4%.

Table 7.4.13 shows the calculation of import tax for ITS equipment.

Table 7.4.13 Calculation of Import Tax for ITS Equipment

<table>
<tr><td colspan="5">Basic Custom Duty</td></tr>
<tr><td colspan="2">Tariff Items</td><td>Import TAX (%)</td><td colspan="2">Reference</td></tr>
<tr><td>8530</td><td>Electrical signalling, safety or traffic control equipment for roads</td><td>7.5</td><td>Customs Tariff 2013-2014
(Central Board of Excise and Customs)</td><td>Chapter 85</td></tr>
<tr><td colspan="5">Reference: Customs Tariff 2013-14 by Central Board of Excise and Customs, Department of Revenue, Ministry of Finance</td></tr>
<tr><td colspan="5">Calculation of Import TAX</td></tr>
<tr><td>Item</td><td>Rate(%)</td><td>Cost</td><td colspan="2">Remarks</td></tr>
<tr><td>a. Imports</td><td></td><td>100.00</td><td colspan="2"></td></tr>
<tr><td>b. Basic Custom Duty</td><td>7.50</td><td>7.50</td><td colspan="2">a * 10.0%</td></tr>
<tr><td>c. Sub Total</td><td></td><td>107.50</td><td colspan="2">a + b</td></tr>
<tr><td>d. Additional Duty</td><td>12.5</td><td>13.44</td><td colspan="2">c * 12.5%</td></tr>
<tr><td>e. Education Cess</td><td>3.0</td><td>0.63</td><td colspan="2">(b + d) * 3.0%</td></tr>
<tr><td>f. Sub Total</td><td></td><td>121.57</td><td colspan="2">c + d + e</td></tr>
<tr><td>g. Special Additional Duty</td><td>4.0</td><td>4.86</td><td colspan="2">f * 4.0%</td></tr>
<tr><td>h. Total</td><td></td><td>126.43</td><td colspan="2">f + g</td></tr>
<tr><td>Priority Rate of Duty</td><td>26.43</td><td></td><td colspan="2">h - a</td></tr>
<tr><td colspan="5">Reference: Web site of JETRO (Japan External Trade Organization)</td></tr>
</table>

Source: JICA Experts

7.5 Comparison with Project Cost Estimate R(4) for Reference

As already mentioned in this section (page 7-54 in this Chapter), BDA/DULT provided the project cost estimate R(4) on 6 July 2015.

Although the JICA Experts still keep using the cost estimate R(3) as a base of the review works, the JICA Experts compared the summary of the project cost estimate between the cost estimate R(4) and the reviewed cost estimate by the JICA Experts (based on R(3)) as shown in Table 7.5.1.

It is noted that this comparison will be used for reference purpose only.

Table 7.5.1 Comparison with Project Cost Estimate R(4) for Reference

Update by JICA Experts		Project Cost Estimate R(4) in DPR		Difference X - Y (INR)
item	Total Amount (X) (INR)	Item	Total Amount (Y) (INR)	
Construction Cost for Civil Works				
A. Road Works	**14,649,051,849**	**A. Road Works**	**14,880,000,000**	**-230,948,151**
1. Site Clearance	21,330,297	1. Site Clearance	23,005,418	-1,675,121
2. Earthwork	2,181,555,705	2. Earthwork	2,494,931,844	-313,376,139
3. Pavement	7,904,092,133	3. Pavement	8,494,042,167	-589,950,035
4. Drainage	1,543,810,764	4. Drainage	1,624,392,826	-80,582,062
5. Road Furniture	1,043,474,085	5. Road Furniture	1,057,696,492	-14,222,407
6. Intersections and Entry/Exit Ramps	119,240,605	6. Intersections and Entry/Exit Ramps	127,823,118	-8,582,513
7. Toll Plaza	1,612,053,535	7. Toll Plaza	760,143,006	851,910,528
8. Arboriculture	41,183,850	8. Arboriculture	42,083,952	-900,102
9. Highway Lighting	144,568,287	9. Highway Lighting	216,470,505	-71,902,218
10. Other Items	35,996,809	10. Other Items	28,121,120	7,875,689
11. Maintenance during Construction	1,745,778	11. Maintenance during Construction	2,308,833	-563,054
		12. Rounding Off	8,980,719	-8,980,719
B. Structure Works	**9,099,701,822**	**B. Structure Works**	**5,909,999,999**	**3,189,701,823**
12. Culvert	330,054,525	13. Culvert	347,026,485	-16,971,960
13. Vehicular Underpass	422,863,923	14. Vehicular Underpass	444,510,788	-21,646,865
14. Pedestrian Underpass	82,966,534	15. Pedestrian Underpass	87,084,794	-4,118,260
15. Minor Bridge	174,399,616	16. Minor Bridge	182,975,458	-8,575,842
16. Railway Under Bridge	483,383,969	17. Railway Under Bridge	507,815,476	-24,431,507
17a. Bridge Structures	6,211,526,000	18. Railway Over Bridge	1,178,048,907	3,339,308,564
		19. Pedestrian Overpass	478,950,944	
		20. Vehicular Overpass	323,204,602	
		22. Flyovers along PRR	647,721,983	
		21. Underpass along PRR (Bridge Structure of Cross Road)	244,291,000	
20. Underpass along PRR	300,574,666	21. Underpass along PRR (Exclede Bridge Structure of Cross Road)	316,160,391	-15,585,724
22. Underpass along Cross road	237,596,636	23. Underpass along Cross road	246,968,150	-9,371,514
23. Flyover along Cross road (Exclude bridge structure)	856,335,952	24. Flyover along Cross road	886,125,614	-29,789,662
		25. Rounding Off	19,115,407	-19,115,407
C. Earth Rtaining Structures	**3,807,460,118**	**C. Earth Rtaining Structures**	**3,280,000,000**	**527,460,118**
24. RCC Wall	1,537,865,137	26. RCC Wall	1,608,913,943	-71,048,806
25. RE Wall	2,269,594,981	27. RE Wall	1,654,371,043	615,223,938
		28. Rounding Off	16,715,014	-16,715,014
D. Other Works	**2,859,599,486**	**E. Other Items of Work**	**2,511,570,000**	**348,029,486**
1. Environmental Mitigation Plan	90,200,000	1. Environmental Mitigation Plan	90,200,000	0
2. Capacity Building (A+B+C) X 0.30%	82,668,641	2. Capacity Building (A+B+C) X 0.30%	72,210,000	10,458,641
3. Shifting of Utilities after LA (A+B+C) X 5.00%	1,377,810,689	3. Shifting of Utilities after LA (A+B+C) X 5.00%	1,203,500,000	174,310,689
4. Safety & Occupational Health, Risc Coverage (A+B+C) X 4.75%	1,308,920,155	8. Safety & Occupational Health, Risc Coverage (A+B+C) X 4.75%	1,143,325,000	165,595,155
		13. Rounding Off	2,335,000	-2,335,000
Sub Total (Civil Works)	**30,415,813,275**	**Sub Total (Civil Works)**	**26,581,569,999**	**3,834,243,276**
Construction Cost for ITS				
E. Intelligent Transport System	**3,723,721,125**	**F. Intelligent Transport System**	**8,000,000,000**	**-4,276,278,875**
1. ITS for Peripheral Ring Road	1,363,933,290	1. PRR - ITS	1,464,000,000	-100,066,710
2. Bengaluru Traffic Information System (B-TIC)	648,603,135	2. Bangalor City - ITS	6,468,000,000	-4,108,212,165
3. Area Traffic Signal Control System (ATCS)	1,321,563,900			
4. Electronic Road Pricing (ERP) System	0			
5. Clearinghouse for Common Smartcard	389,620,800			
		3. Rounding Off	68,000,000	-68,000,000
Sub Total (ITS Works)	**3,723,721,125**	**Sub Total (ITS Works)**	**8,000,000,000**	**-4,276,278,875**
Grand Total (Civil Works & ITS Works)	**34,139,534,400**	**Grand Total (Civil Works & ITS Works)**	**34,581,569,999**	**-442,035,599**

Source: JICA Experts

CHAPTER 8 ECONOMIC AND FINANCIAL EVALUATION

8.1 Economic Evaluation

Although the economic analysis was conducted in the Detailed Project Report (DPR), there are some issues listed below.

- The Project cost was only for the construction cost, excluding the land acquisition cost. This proposed Bengaluru Peripheral Ring Road (BPRR) project is a green field project, thus the land acquisition cost should be included in the Project cost.

- Only the vehicle operation cost (VOC) benefit was estimated. Travel time cost saving was not mentioned. For a high standard urban road project, the benefit of travel time cost (TTC) saving is quite big. Thus, TTC saving should be fully considered for this Project.

Since the Project cost and estimate of attracted traffic along BPRR were reviewed by the JICA Expert, economic evaluation was also revised.

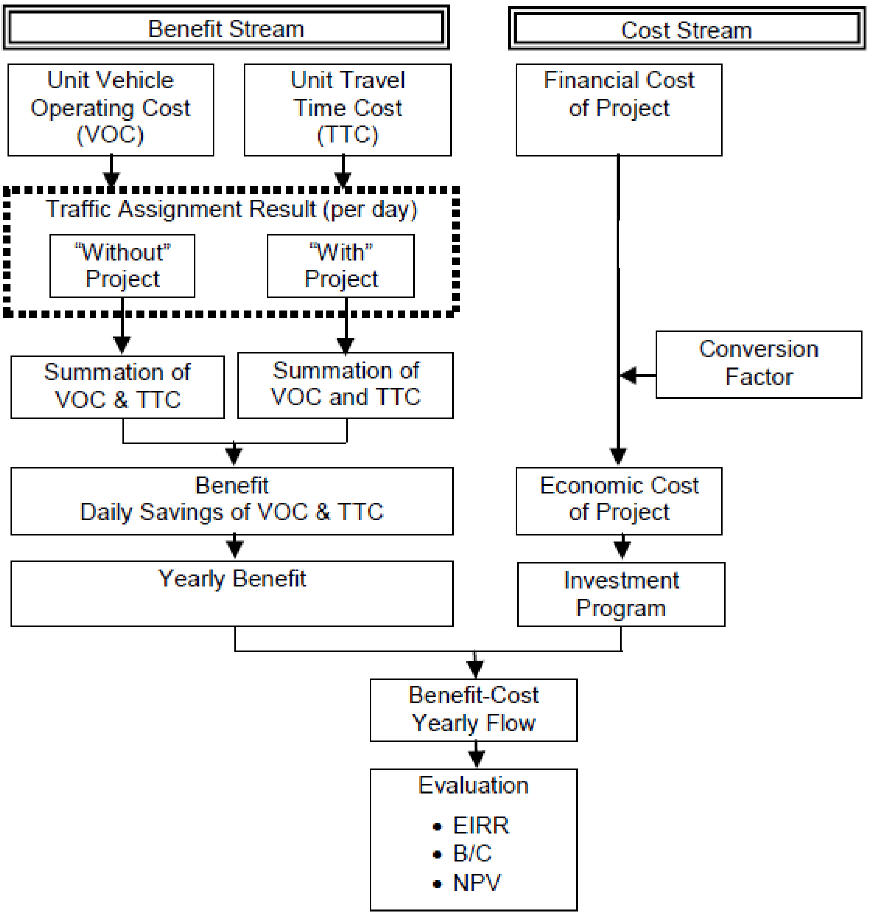
8.1.1 Methodology

The economic analysis shall determine whether the construction and operation of the proposed Project will be feasible based on the benefits and costs to be derived from the Project. Transport projects such as BPRR can play a very important role in strengthening the economic growth. It is required, however, that the Project must be economically viable, satisfying the government-prescribed hurdle rates.

The annual economic costs and benefits shall be estimated under the “with project” and “without project” scenarios. The difference in economic costs and benefits in both cases shall be attributed to the Project and subjected to economic feasibility measurement. The economic feasibility of the Project shall be indicated by the economic internal rate of return (EIRR), benefit-cost ratio (B/C), and net present value (NPV) at an assumed discount rate of 12%, which is the acceptable social discount rate for economic appraisal of public investment projects in the country. The hurdle rates for economic feasibility are the following: EIRR > 12%, B/C > 1.0, and NPV > 0. Sensitivity of the Project arising from adverse changes in costs and benefits shall be examined to establish the capacity of the Project to exhibit economic feasibility under these cases.

(1) General Work Flow of Economic Evaluation

Figure 8.1.1 shows the work flow of economic evaluation.



Source: JICA Experts

Figure 8.1.1 Work Flow of Economic Evaluation

(2) Indicators of Economic Evaluation

Economic costs and benefits throughout the project life period are compared using a discount cash flow analysis. The discount rate (hereinafter referred to as "DR") is at 12%, which is widely used in India as the social discount rate. For economic evaluation, three indicators are calculated i.e., economic internal rate of return (hereinafter referred to as "EIRR"), benefit/cost ratio (hereinafter referred to as "B/C"), and net present value (hereinafter referred to as "NPV"). In addition, the economic life is assumed to be 25 years, per IPC:SP 30-2009 Guideline published by the Indian Roads Congress 2009. Therefore, the pro-forma cash flow of a project evaluation will be prepared for 2015-2039. They are defined as shown in Table 8.1.1.

Table 8.1.1 Indicators of Economic Evaluation

No.	Indicators	Calculation Formula or Value
1	Discount rate (DR)	12% in India as a social discount rate
2	Economic Internal Rate of Return (EIRR)	r satisfying: *B*: benefit, *C*: Cost $\sum \frac{B_n}{(1+r)^n} = \sum \frac{C_n}{(1+r)^n}$
3	Benefit/Cost Ratio (B/C)	$\sum \frac{B_n}{(1+DR)^n} \div \sum \frac{C_n}{(1+DR)_n}$
4	Net Present Value (NPV)	$\sum \frac{B_n - C_n}{(1+DR)^n}$
5	Pro-forma cash flow of a project evaluation	For the period of 2015-2039

Source: JICA Experts

8.1.2 Economic Cost of the Project

(1) Initial Cost

The Project cost must be estimated by a shadow price in the cost benefit analysis. The Project cost of BPRR is estimated in market prices as mentioned in Chapter 7. The market price or financial price should be converted to economic cost for economic evaluation.

According to the “Manual on Economic Evaluation of Highway Projects in India”, a factor of 0.80-0.90 has been used to convert financial cost of road works to economic cost in India. Basically, the difference is mainly attributed to the value added tax (VAT) (14.5%), import tax (approx. 5%) and others.

In the Study, cost excluding VAT and import tax is assumed as the economic cost. Table 8.1.2 shows the estimated economic cost of the Project.

Table 8.1.2 Estimated Economic Cost (Year 2015 Price)

Rs in millions

Description	Economic Cost (Financial Cost - VAT and Import Tax)
1. Civil Work-Package-1	9,237.0
1. Civil Work-Package-2	6,706.0
1. Civil Work-Package-3	7,991.0
1. Civil Work-Package-4	8,004.0
2. ITS for Bengaluru Peripheral Ring Road	1,432.2
3. Land Acquisition	51,030.0
4.Detailed Design	100.0
5. Tender Assistant	149.0
6. Construction Supervision	1,859.0
7. Administration Cost	103.0
Total	86,611.2

Source: JICA Experts

Note: The estimated land acquisition cost is Rs81,000 million for 100 m width of right-of-way (ROW). Actually, a 100 m width is included as future LRT project (12 m width) and development area (25 m width). As the necessary road ROW is 63 m (=100 m-12 m-25 m) only, revised land acquisition cost is Rs51,030.0 million (= Rs81,000 million * 0.63)

Table 8.1.3 shows the implementation schedule and yearly initial cost flow.

Table 8.1.3 Implementation Schedule and Initial Cost (Economic Cost) Per Year

Rs in million

Description	Economic Cost	2016	2017	2018	2019	2020	2021
1. Civil Work Package 1	9,237.0	0.0	0.0	1,539.5	3,079.0	3,079.0	1,539.5
1. Civil Work Package 2	6,706.0	0.0	0.0	1,117.7	2,235.3	2,235.3	1,117.7
1. Civil Work Package 3	7,991.0	0.0	0.0	1,331.8	2,663.7	2,663.7	1,331.8
1. Civil Work Package 4	8,004.0	0.0	0.0	1,334.0	2,668.0	2,668.0	1,334.0
2. ITS for BPRR	1,432.2	0.0	0.0	0.0	0.0	954.8	477.4
3. Land Acquisition	51,030.0	20,412.0	20,412.0	10,206.0	0.0	0.0	0.0
4. Detailed Design	100.0	100.0	0.0	0.0	0.0	0.0	0.0
5. Tender Assistant	149.0	0.0	99.3	49.7	0.0	0.0	0.0
6. Construction Supervision	1,859.0	0.0	0.0	309.8	619.7	619.7	309.8
7. Administration Cost	103.0	18.7	18.7	18.7	18.7	18.7	9.4
Total	**86,611.2**	**20,530.7**	**20,530.1**	**15,907.2**	**11,284.4**	**12,239.2**	**6,119.6**

Source: JICA Experts

(2) Operation and Maintenance Cost

The operation and maintenance (O&M) cost was estimated. The operation cost is for the daily road/traffic management of the road facility and toll collection works. The maintenance cost consists of routine maintenance and periodic maintenance. The operation and maintenance costs was estimated based on the official formula issued by the NHA as shown in 7.3.3.3 (1) and shown in Table 8.1.4.

Table 8.1.4 Operation and Maintenance and Other Costs

Rs in million

Item		Economic Cost
1	O&M cost per year	131.4
2	Periodic maintenance cost every five years	844.9

Source: JICA Experts

8.1.3 Economic Benefits of the Project

The economic benefits of the Project are calculated by multiplying the estimated traffic volumes and unit vehicle operating cost (VOC) / travel time cost (TTC) respectively, and the amount of ‘without’ case minus ‘with’ case is considered as the benefit provided by the Project.

(1) Unit Vehicle Operating Cost (VOC) and Unit Travel Time Cost (TTC)

1) Unit Vehicle Operating Cost (VOC)

The VOC per unit distance is estimated by the type of vehicle which is composed of the following components; a) fuel cost, b) oil cost, c) tire cost, d) spare parts cost, e) maintenance labor cost, f) depreciation cost, g) crew cost, and h) fixed cost, including overhead administration, interest borrowed capitals, etc.

Although the “Manual on Economic Evaluation of Highway Projects in India” has the unit VOC, VOC has been determined by road roughness and road alignment (rise and fall, curvature of section, terrain, etc.) The unit VOC is usually prepared according to vehicle type and speed condition. In an Indian project, the Comprehensive Transportation Study for Mumbai Metropolitan Region (Technical Assistance by the World Bank) was used as the unit VOC of speed condition as shown in Table 8.1.5. Therefore, these data are revised and updated in accordance with the whole price index (WPI) as shown in Table 8.1.6.

Table 8.1.5 Unit VOC in 2005

Rs/km/vehicle

Speed (km/hr)	Two-wheeler	Passenger Car	Bus	Light Commercial Vehicle (LCV)	Truck/Multi Axle Vehicle (MAV)
10	2.49	6.61	26.06	18.30	25.41
20	1.89	4.11	17.92	12.31	17.67
30	1.74	3.29	16.40	10.00	15.04
40	1.55	2.88	14.63	8.78	13.65
50	1.57	2.82	13.58	8.08	12.25
60	1.63	3.05	15.47	8.20	12.57

Source: Mumbai Metropolitan Region Development Authority

Table 8.1.6 Whole Price Index in India (2008-2015)

Financial Year	Index
2005	100.0
2006	104.5
2007	111.4
2008	116.6
2009	126.0
2010	130.8
2011	143.3
2012	156.1
2013	167.6
2014	177.6
2015	188.3

Source: Office of the Economic Adviser, Government of India, Ministry of Commerce and Industry, Department of Industrial Policy and Promotion

The unit VOC of high speed range (60-80 km/h) was estimated to utilize the proportion of unit VOC of 2008 in the Ministry of Land, Infrastructure, Transport and Tourism in Japan. The unit VOC in 2015 was estimated (see Table 8.1.7).

Table 8.1.7 Unit VOC in 2015

Rs/km/vehicle

Speed (km/hr)	Two-wheeler	Passenger Car	Bus	LCV	Truck/MAV
10	4.69	12.44	49.06	34.45	47.84
20	3.56	7.74	33.74	23.17	33.27
30	3.28	6.19	30.87	18.83	28.31
40	2.92	5.42	27.54	16.53	25.70
50	2.96	5.31	25.57	15.21	23.06
60	3.07	5.74	29.12	15.44	23.66
70	3.22	5.88	29.89	15.83	24.88
80	3.46	6.15	31.27	16.58	27.29

Source: Revised by the JICA Experts

2) Unit Travel Time Cost (TTC)

The travel time saving cost (TTC) obtained from the "Manual on Economic Evaluation of Highway Projects in India" is as shown in Table 8.1.8.

Table 8.1.8 Unit Travel Time Cost for Passenger Vehicles in 2009

Vehicle Type	Value of Time by Passengers in Rs/hr(a)	Average Occupancy (b)	Value of Time by Vehicle Type in Rs/hr (a*b)
1.Two-wheelers	32.0	1.5	48.0
2. Cars	62.5	4.8	300.0
3. Bus	43.5	43.0	1870.5

Source: Manual on Economic Evaluation of Highway Projects in India 2009

In case of commodities, lesser travel time signifies smaller investment cost. Quick travel results in time savings to the vehicle crew. The estimated unit travel time cost is shown in Table 8.1.9.

Table 8.1.9 Unit Travel Time Cost for Commodity Vehicles in 2009

Vehicle Type	Commodity Holding Cost (Rs/day)(a)	Conversion Factor (b)[1]	Commodity Holding Cost (Rs/hr)(a*b)
1.Light Commercial Vehicle (LCV)	58.10	1/12	4.8
2. Multi Axle Vehicle (MAV)	333.0	1/12	27.8

Source: Manual on Economic Evaluation of Highway Projects in India 2009, JICA Experts

By utilizing the WPI as shown in Table 8.1.6, unit travel time cost in 2015 was estimated (see Table 8.1.10).

Table 8.1.10 Unit Travel Time Cost in 2015

Rs/hr./veh.

Vehicle Type	2015
Two-wheeler	71.7
Car	448.2
Bus	2794.3
LCV	7.2
MAV	41.5

Source: JICA Experts

(2) Estimation of Economic Benefit (VOC and TTC Saving)

As shown in Figure 8.1.1, traffic assignment was conducted for "with project" case and "without project" case. The difference of vehicle-km and vehicle-hour for both cases is mainly the economic benefit of the Project.

Based on the unit VOC by vehicle type, vehicle speed, and the total vehicle-km, daily VOC saving by year is estimated. The daily TTC saving by year is also estimated based on the unit TTC by vehicle type and total vehicle-hour. The economic benefit is shown in Table 8.1.11.

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[1] Daily moving time is assumed as 12hours due to working hours, traffic ban etc.

Table 8.1.11 Economic Benefit

Year	Economic Benefit (Rs1,000/day)		
	VOC	TTC	Total
2022	15,419	21,770	37,189
2030	13,025	69,663	82,688
2040	7,595	88,167	95,762

Source: JICA Experts

(3) Other Economic Benefits

With the increasing congestion on the existing road, there is a greater likelihood of accident occurrence due to conflicts between the pedestrian and the vehicle. It is anticipated that with the Project, accidents happening at-grade could be avoided. In this Study, however, the benefit from possible reduction of road accidents is not considered since there is no acceptable value assigned to traffic accidents in the country.

8.1.4 Results of Economic Analysis

The performance shown in Table 8.1.12 of the Project based on indicators of economic feasibility is:

EIRR	15.0%
B/C	1.33
NPV (Rs in million @ i = 12%)	21,214.0

The economic costs and benefits of the Project generated a positive NPV and an EIRR that are higher than the government-prescribed hurdle rate (12%). These values indicate that the Project is economically viable.

Table 8.1.12 Cost-Benefit Stream

Undiscounted Benefit Cost Stream Revenue

Million Rs

sq	Year	Construction Cost	Other Cost (ROW etc.)	Initial Cost	O &M	Cost Total	VOC Benefit	TTC Benefit	Benefit Total	Benefit - Cost
1	2015					0.0	0.0	0.0	0.0	0.0
2	2016	0.0	20,530.7	20,530.7		20,530.7	0.0	0.0	0.0	-20,530.7
3	2017	0.0	20,530.1	20,530.1		20,530.1	0.0	0.0	0.0	-20,530.1
4	2018	5,323.0	10,584.2	15,907.2		15,907.2	0.0	0.0	0.0	-15,907.2
5	2019	10,646.0	638.4	11,284.4		11,284.4	0.0	0.0	0.0	-11,284.4
6	2020	11,600.8	638.4	12,239.2		12,239.2	0.0	0.0	0.0	-12,239.2
7	2021	5,800.4	319.2	6,119.6	65.7	6,185.3	2,874.0	3,435.4	6,309.4	124.1
8	2022			0.0	131.4	131.4	5,628.0	7,946.0	13,574.0	13,442.6
9	2023			0.0	131.4	131.4	5,510.5	9,189.5	14,700.0	14,568.6
10	2024			0.0	131.4	131.4	5,395.5	10,627.6	16,023.1	15,891.7
11	2025			0.0	131.4	131.4	5,282.9	12,290.8	17,573.6	17,442.2
12	2026			0.0	976.3	976.3	5,172.6	14,214.2	19,386.8	18,410.5
13	2027			0.0	131.4	131.4	5,064.6	16,438.6	21,503.2	21,371.8
14	2028			0.0	131.4	131.4	4,958.9	19,011.2	23,970.0	23,838.6
15	2029			0.0	131.4	131.4	4,855.4	21,986.3	26,841.6	26,710.2
16	2030			0.0	131.4	131.4	4,754.0	25,427.0	30,181.0	30,049.6
17	2031			0.0	976.3	976.3	4,504.4	26,033.1	30,537.4	29,561.1
18	2032			0.0	131.4	131.4	4,267.8	26,653.6	30,921.4	30,790.0
19	2033			0.0	131.4	131.4	4,043.7	27,288.9	31,332.6	31,201.2
20	2034			0.0	131.4	131.4	3,831.4	27,939.4	31,770.7	31,639.3
21	2035			0.0	131.4	131.4	3,630.2	28,605.4	32,235.5	32,104.1
22	2036			0.0	976.3	976.3	3,439.5	29,287.2	32,726.7	31,750.4
23	2037			0.0	131.4	131.4	3,258.9	29,985.3	33,244.2	33,112.8
24	2038			0.0	131.4	131.4	3,087.8	30,700.0	33,787.8	33,656.4
25	2039			0.0	131.4	131.4	2,925.6	31,431.8	34,357.4	34,226.0
		33,370.2	53,241.0	86,611.2	4,965.6	91,576.8	82,485.5	398,491.1	480,976.6	389,399.8

Discounted Benefit Cost Stream Revenue

Million Rs

sq	Year	Discounted	Construction Cost	Other Cost (ROW etc.)	O &M	Cost Total	VOC Benefit	TTC Benefit	Benefit Total	Benefit - Cost
1	2015	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2016	1.12	0.0	18,331.0	0.0	18,331.0	0.0	0.0	0.0	-18,331.0
3	2017	1.25	0.0	16,366.4	0.0	16,366.4	0.0	0.0	0.0	-16,366.4
4	2018	1.40	3,788.8	7,533.6	0.0	11,322.5	0.0	0.0	0.0	-11,322.5
5	2019	1.57	6,765.7	405.7	0.0	7,171.4	0.0	0.0	0.0	-7,171.4
6	2020	1.76	6,582.6	362.2	0.0	6,944.8	0.0	0.0	0.0	-6,944.8
7	2021	1.97	2,938.7	161.7	33.3	3,133.7	1,456.1	1,740.5	3,196.5	62.9
8	2022	2.21	0.0	0.0	59.4	59.4	2,545.8	3,594.4	6,140.2	6,080.7
9	2023	2.48	0.0	0.0	53.1	53.1	2,225.6	3,711.5	5,937.1	5,884.0
10	2024	2.77	0.0	0.0	47.4	47.4	1,945.7	3,832.4	5,778.1	5,730.7
11	2025	3.11	0.0	0.0	42.3	42.3	1,700.9	3,957.3	5,658.2	5,615.9
12	2026	3.48	0.0	0.0	280.7	280.7	1,487.0	4,086.2	5,573.2	5,292.6
13	2027	3.90	0.0	0.0	33.7	33.7	1,300.0	4,219.4	5,519.3	5,485.6
14	2028	4.36	0.0	0.0	30.1	30.1	1,136.4	4,356.9	5,493.3	5,463.2
15	2029	4.89	0.0	0.0	26.9	26.9	993.5	4,498.8	5,492.3	5,465.4
16	2030	5.47	0.0	0.0	24.0	24.0	868.5	4,645.4	5,514.0	5,489.9
17	2031	6.13	0.0	0.0	159.3	159.3	734.8	4,246.6	4,981.3	4,822.1
18	2032	6.87	0.0	0.0	19.1	19.1	621.6	3,881.9	4,503.5	4,484.4
19	2033	7.69	0.0	0.0	17.1	17.1	525.8	3,548.6	4,074.5	4,057.4
20	2034	8.61	0.0	0.0	15.3	15.3	444.8	3,244.0	3,688.8	3,673.5
21	2035	9.65	0.0	0.0	13.6	13.6	376.3	2,965.4	3,341.8	3,328.1
22	2036	10.80	0.0	0.0	90.4	90.4	318.4	2,710.8	3,029.2	2,938.8
23	2037	12.10	0.0	0.0	10.9	10.9	269.3	2,478.1	2,747.4	2,736.5
24	2038	13.55	0.0	0.0	9.7	9.7	227.8	2,265.3	2,493.1	2,483.4
25	2039	15.18	0.0	0.0	8.7	8.7	192.7	2,070.8	2,263.5	2,254.9
			20,075.8	43,160.8	974.8	64,211.4	19,371.1	66,054.2	85,425.4	21,214.0

Net Present Value (Million Rs)	21,214.0
B/C Ratio	1.33
EIRR	15.0%

Source: JICA Experts

8.1.5 Project Sensitivity

The Project sensitivity to identified risks is shown in Table 8.1.13.

Table 8.1.13 Project Sensitivity

	NPV (Rs in million)	**B/C**	**EIRR**
Base case	21,214.0	1.33	15.02%
Cost plus 10%	14,792.9	1.21	13.99%
Cost plus 20%	8,371.7	1.11	13.06%
Benefit less 10%	12,671.5	1.20	13.88%
Benefit less 20%	4,128.9	1.06	12.64%
Cost plus 10%, Benefit less 10%	6,250.3	1.09	12.87%

Source: JICA Experts

Results showed that the Project is able to hurdle the minimum acceptance criteria of EIRR = 12% and NPV = 0 in all cases.

8.2 Financial Evaluation

The financial analysis was conducted in the Detailed Project Report (DPR) and it concluded that the Project IRR is negative, hence, not financially viable.

Since the Project cost and attracted traffic of BPRR were reviewed in the Study, the financial analysis was conducted based on the revised cost and revenue.

8.2.1 Case Study

Case 1: Pure BOT	Initial costs, such as the construction cost and consultancy cost, shall be funded by the private company. During the operation period, O&M cost shall be shouldered by the private company. Road ROW cost and administration cost shall be funded by the government. All tariffs will be received by the private company.
Case 2: BOT with Government Financial Support (GFS)	Same as above conditions excluding 40%[2] of initial cost shall be paid by the government as Viability Gap Fund (VGF)

8.2.2 Assumptions and Conditions for Financial Analysis

8.2.2.1 Input Data

Input data are shown in Table 8.2.1 and Table 8.2.2.

Table 8.2.1 Initial Cost

(at 2015 price level)(in Rs1,000)

1	Land / ROW Acquisition	81,000,000
2	Detailed Engineering Design Services	115,000
3	Civil Work	34,977,250
4	ITS(O&M Facility Installation)	1,568,523
5	Construction Supervision Services	2,309,200
6	Independent Consultation Fee	115,000
7	Insurance Cost	349,773
8	Physical Contingencies	1,971,737
9	Price Contingencies	17,982,880
10	Project Administration Costs	174,886
Total		140,564,249

Source: JICA Experts

Note: insurance cost and independent consultant fee each are assumed as 1.0% and 0.3% of construction cost.

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[2] 40% is the maximum VGF (Implementing agency 20% and Indian government 20%) in India (Guidelines for Financial Support to PPPs in Infrastructure (VGF Scheme)). PPP project with VGF is necessary for project approval from the Indian government in advance.

Table 8.2.2 O&M Cost (2021-2047)

(at 2015 price level)(in Rs1,000)

11	Operation Cost	4,284,816
12	Maintenance Cost	6,042,169
13	Insurance Fee	795,000
14	Independent Consultant Fee	67,500
Total		10,326,985

Source: JICA Experts

Note: O&M is estimated based on the Table 8.1.4 and Table 8.2.5.

Revenue is estimated by the total vehicle*km from traffic assignment result and toll rate.

Table 8.2.3 Estimated Daily Revenue in 2022 (After One Year of Operations)

Vehicle Type	Vehicle *km Along BPRR (a)	Toll Rate (Rs/km*veh.) (b)	Revenue (Rs/day) (a*b)
Car	1,868,271	1.48	2,765,041
Bus	122,607	4.88	598,322
LCV	41,053	2.36	96,885
TRUCK	125,612	4.88	612,987
MAV	12,838	4.88	62,649
Total			**4,135,884**

Source: JICA Experts

Note: Toll rate in 2022 is set based on the toll rate (car Rs1.0/km in 2014) and price escalation of 5%.

Price escalation is assumed at 5% for the future toll rate and the annual growth rate (AGR) of traffic volume of BPRR is estimated from the traffic assignment result (see Table 8.2.4).

Table 8.2.4 Annual Growth Rate of BPRR's Traffic

	2021-2030	2031-
AGR	9.00%	3.93%

Source: JICA Expert

Note: AGR is based on the traffic assignment result.

8.2.2.2 Parameters for Financial Evaluation

The parameters used for financial evaluation are in Table 7.2.5 below.

Table 8.2.5 Various Parameters for Financial Evaluation

Parameters:PRR to Bangalore

Base year for financial analysis		
Base year for financial analysis	2015	
Discount Rate	12%	
Implementation/Operation Period		
Beginning Year of the Concession	2018	
Concession Period	30	years
End Year of the Concession Period	2047	
Beginning Year of the Operation	2021	year
	6	month
Operation Period	27	
Costs		
Project Cost		
Base Year	2015	
Physical Contingency	5%	
Administration Costs	0.5%	of Civil Work Cost
Gov	50%	
Prv	50%	
Insurance Cost (Construction All Risk)	1.0%	of Civil Work Cost
O&M Cost		
Operation Period	27	years
Operating Cost to increase by	4.0%	every year due to increase in operations
Routine Maintenance Cost: to increase by	2.0%	every year due to wear and tear
Periodic Maintenance Cost: to increase by	5.0% 1	
Independent Consultant Fee	0.1%	of Civil Work Cost
Period	5	years
Gov	50%	
Prv	50%	
Other Cost Items		
Annual Insurance (O&M)	0.600%	of depreciable assets
Depreciation		
Life of Assets	30	years
Price Escalation	5.0%	pa
Financing Structure		
GFS for Main Civil Work	0%	of Civil Work Cost
GFS Provision Schedule		
1st year	2019	
proportion	23.6%	
2nd year	2020	
proportion	39.2%	
3rd year	2021	
proportion	37.2%	
Equity Ratio	30%	
Debt Ratio	70%	
Loan Tenure: Commercial Bank Loan		
Interest Rate	11.8%	
Grace Period	4	years
Loan Repayment Period	12	years
Beginning Year of Repayment	2018	
End Year of Repayment	2029	
Finance charge	0.3%	of Loan
IDC:Interest During Construction	11.8%	
Taxation		
Tax	32.40%	of Taxable Income

Source: JICA Experts

8.2.3 INDICATORS FOR FINANCIAL VIABILITY

(1) DEFINITION OF INDICATORS

The following three kinds of internal rate of return (IRR) as shown below are set to examine the financial viability of BPRR.

Project IRR:	It is calculated with toll tariff revenue and the whole Project cost including ROW acquisition, etc., actually funded by the government. It is the basic indicator for financial viability.
IRR for SPV:	It means an internal rate of return for private sector (Special Purpose Vehicle).
Equity IRR:	It means an internal rate of return against equity investments for the Project. (It means an IRR for equity investor.)

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Each IRR is the rate which satisfies the following formulae:

Project IRR

$$\sum \frac{R_i - I_i - C_i}{(1 + \text{Project IRR})^{\mathrm{i}}} = 0$$

Whereby:

R_i : Revenue from Toll Tariff at year i

I_i ; Whole invested project costs at year i

C_i : Whole operating costs at year i

IRR for SPV

$$\sum \frac{R_i - I'_i - C'_i}{(1 + \text{IRR for SPC})^{\mathrm{i}}} = 0$$

Whereby:

I'_i : Invested capital costs by SPV (the Concessionaire) at year i

C'_i : Operating costs paid by SPV at year I (including corporate income tax)

Equity IRR

$$\sum \frac{D_i - E_i}{(1 + \text{Equity IRR})^{\mathrm{i}}} = 0$$

Whereby:

D_i : Dividend for investor at year i (= Ri - I'i - C"i)

* C"i is including loan amortization

E_i : Equity investment from investor

(2) CRITERIA

The weighted average cost of capital (WACC) is calculated from the weighted average of interest-bearing debt cost and equity cost, and represents financing cost for private sector as criteria of Project IRR and IRR for SPV. Calculation formula of WACC is stated below.

$$WACC_{\text{after tax}} = r(E) \times \frac{E}{(D+E)} + r(D) \times (1-t) \times \frac{D}{(D+E)}$$

Whereby:

$r(E):$ cost of Equity (Return on Equity)

$r(D):$ cost of debt (interest rate)

$E:$ total value of equity

$D:$ total value of debt

$t:$ Corporate Income Tax Rate

WACC (after tax) is 11.6% in case of the conditions on financing by private sector shown in Table 8.2.6. Hurdle rate (cost of equity) to evaluate equity IRR is assumed to be 20.0% in this Study.

Table 8.2.6 Conditions for Calculation of WACC

Equity	Loan
-Share of equity is 30% -Cost of equity (Return on equity) is 20.0%	-Share of loan is 70% -Cost of debt (Interest rate) is 11.8% -Corporate income tax rate is 32.4%

Source: JICA Experts

The criteria for financial analysis for BPRR are shown in **Table 8.2.7.**

Table 8.2.7 Criteria of Financial Analysis for BPRR

Hurdle Rate of IRR for SPV	11.6%
Hurdle Rate of Equity IRR	20.0%

Source: JICA Experts

8.2.4 Evaluation Results

Table 8.2.8 shows the evaluation results of the financial analysis.

Project IRR

Project IRR, which considers all costs including construction cost, consultancy cost, ROW acquisition cost, and O&M cost, is 1.42%. This implies that the private sector investment is not financially viable. The Project up to the completion of facilities is planned to be invested by the government.

IRR for Special Purpose Vehicle (SPV)

IRR for SPV, which considers construction cost, consultancy cost and O&M cost to be invested by the private company, is 5.87% for Case 1 and 8.47% for Case 2. WACC is estimated to be 11.6%. Thus, the Project is not financially viable and will not be attractive to the private sector for both cases.

Equity IRR

Equity IRR is estimated to be at 4.50% for Case 1 and 7.88% for Case 2. This is considered low to attract the interest of the private sector.

Table 8.2.8 Results of the Financial Analysis for BPRR

Case	Results		
	Project IRR	IRR for SPV	Equity IRR
Case 1: Pure BOT	1.42%	5.87%	4.50%
Case 2: BOT with GFS		8.47%	7.88%

Source: JICA Experts

8.2.5 Sensitivity Analysis

According to the willingness-to-pay survey results, many road users will use the toll road even though the toll rate will be 1.5 or 2 times higher than the present rate. Estimated maximum revenue will be 1.5-2.0 times as that of the present toll rate (see Chapter 4).

As sensitivity analysis, financial analysis was done for 1.5 times the toll rate of base case (= maximum revenue case) as shown in Table 8.2.9. The revenue of the case is 1.27 times the base case.

Table 8.2.9 Results of the Financial Analysis for BPRR (Toll Rate 1.5 Times of Base Case)

Case	Result		
	Project IRR	IRR for SPV	Equity IRR
Case 1: Pure BOT	2.59%	7.37%	6.41%
Case 2: BOT with GFS		10.05%	9.89%

Source: JICA Experts

Although all indicators will be better than the base case, these values do not resolve the hurdle rate. It is found that it is difficult to apply the BOT scheme, even though the toll setting for maximum revenue is selected.

CHAPTER 9 CONCLUSION

The conclusion of the technical review is summarized below.

- ✧ This report will be referred by BDA for the detailed design of the Project.
- ✧ Also this report will be referred by the delegation of JICA to consider the formulating of the Project under JICA scheme.
- ✧ Technical suggestions and proposals by JICA Experts in this report have been discussed in the series of the technical discussions and accepted by the implementing authorities. BDA will prepare the detailed design of the Project referring to this report.
- ✧ Most of the elements of the horizontal alignment in DPR were properly designed based on IRC. Minor modifications of the horizontal alignment were proposed by JICA Experts as presented in this report. JICA Experts understood that the modification would be considered by BDA during the detailed design stage as much as practically possible within the constraint of ROW which was once already defined.
- ✧ JICA Experts reviewed the vertical alignment of the mainline of the Project in DPR. Due to limited data/information (i.e. missing and/or old topographic data), the vertical alignment of the mainline was tentatively designed in DPR. The detailed design of the vertical alignment shall be conducted referring the suggestions in this report. The vertical alignment of the service road is not available in DPR. The detailed design of the service road shall be conducted as well as the mainline after the topographic survey.
- ✧ Three (3) additional junctions have been proposed in this report for the sections with more than 10km interval between junctions proposed in DPR. The necessity of the additional junction has been confirmed by the traffic demand forecast too.
- ✧ JICA Experts proposed 3 types of the structure such as PC-I girder, PC-Box girder and Steel Box girder and the span layout of the bridges has been proposed in this report for a reference of the detailed design. The length of the bridges on 2 nos. of ROB was proposed to avoid high embankment. This modification will impact to the cost estimate largely and further detailed study shall be conducted in the detailed design stage discussing with the concerned railway authorities.
- ✧ Traffic demand forecast was conducted by JICA Experts and the justification of the number of lanes of the mainline (8-lane) and the service road (4-lane) has been confirmed. Also the required number of toll lanes on junctions and barriers were newly estimated for the reference of the detailed design by BDA.
- ✧ JICA reviewed the scope and the cost of ITS based on ITS MP for the basic design of ITS which will be conducted under the loan scheme of JICA.

- The cost estimate of the Project has been updated based on the above modifications and the newly obtained cost information. The cost estimate will be finalized by the detailed design. The cost estimate in this report will be referred by the delegation of JICA to consider the formulating of the Project under JICA scheme.

- The result of the economic analysis has indicated that the Project is economically viable. On the other hand, the financial viability of the Project has not been justified. Accordingly it is recommended to implement the Project as a public works by the government budget.