National Highways Authority of India

Sector 10, Dwarka, New Delhi

CONSULTANCY SERVICES FOR PREPARATION OF DETAILED PROJECT REPORT FOR REDESIGNING, REHABILITATION AND UP-GRADATION TO 4/6-LANE CONFIGURATION STRENGTHENING OF NEW NH-248A RAJASTHAN BORDER-NUH-GURGAON IN THE STATE OF HARYANA





REVISED FINAL FEASIBILITY REPORT

Package – II (From Ch. 9+282 to Ch.22+000)

Volume - I: Main Report

DELD16079-NHAI-FFR-RPT-0008(R2)

December 2017

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EXECUTIVE SUMMARY

0.1 BACKGROUND

The work for consultancy services for Consultancy Services for Preparation of Detailed Project Report for redesigning, rehabilitation and upgradation to four/six lane configuration & strengthening of new NH-248A Sohna – Nuh – Gurgaon in the state of Haryana. has been awarded to M/s. AECOM Asia Company Ltd., vide Public Works Department (B&R), Haryana commencement letter no. 63242 dated 23.05.2016. The agreement for the Consultancy Services was signed on 27th June 2016.

The project road section starts from PWD R.D. 2+400 at Rajiv Chowk, Gurgaon which is a 4 legged – grade separated junction at km. 32+650 of NH-8 and ends at PWD R.D. 95+985 of NH-248A i.e. at Rajasthan Border.

After the submission of Inception Report, the project has been transferred from PWD (B&R), Haryana to NHAI. Based on various interactions with NHAI, it was decided to divide the project road into three distinct construction packages, viz.

- **Package-I : PWD RD 2+400 to 11+682 and**
- **Package-II : PWD RD 11+682 to 24+400**
- **Package-III: PWD RD 24+400 to 95+985**

The proposed development including its cost and financial analysis presented in this report is for Package-II only.

The current traffic between Rajiv Chowk (km 0+000) to Ashram/Vatika Chowk (km 4+900) is 68760 PCU and between Ashram / Vatika Chowk (km 4+900) to Sohna (km 23+300) it is 23847 PCU. Thus with the traffic projection, it is apparent that traffic would exceed 25000 PCU for km 4+900 to km 23+300 section of the project road in 2017-18. Therefore considering the current traffic and rapid urbanization of the project influence area, NHAI has decided for 6-laning of the Package-II section of the project road with 6-lane service road.

In line with the work order the Revised Final Feasibility Report for Package-II was submitted on 12th September 2017. Now based on the discussions with NHAI, **Revised Final Feasibility Report (Revision No. - R2)** for **Package –II: Six laning and Strengthening of new NH-248A from existing km 11+682 to km 24+400 in the state of Haryana** is being submitted.

0.2 PROJECT DEVELOPMENT DESCRIPTIONS

0.2.1 General

The project road passes through Gurgaon district of Haryana.

Table 0.1: Details of Project District

Sl. No.	Name of Districts	Existing Chainage		Length (km)	Percentage
		From	To		
1	Gurgaon	11+682	24+400	12.718	100%

Table 0.2: Homogeneous Sections

Homogeneous Section	Description	Existing Length in Km
I	Km 11+682 to km 24+400	12.718

0.2.2 Nodal Points on the Project Road

Barring the built-up locations, agriculture is the predominant land use in some semi-arid areas while it is barren in the arid patches along the road. In the built-up areas both residential and commercial buildings have developed abutting the road corridor. The road is entirely in Haryana district. The list and locations of villages / towns noticed along the project road is tabulated in **Table 0.3** below:

Table 0.3: List of Settlements

Sl. No	Name of Built-up Area	Existing Chainage		Design Chainage		Length (Km)
		From	To	From	To	
1	Bhondsi	12+400	14+300	10+000	11+900	1.9
2	University Area	21+505	23+000	19+103	20+603	1.5
3	Sohna	23+000	24+400	20+603	22+000	1.397

0.2.3 Traffic Volume

Based on preliminary reconnaissance, the project road was divided into six homogenous sections in such a way that traffic intensity within a particular section will be more or less uniform. The homogenous sections (HS) identified and their estimated average annual daily traffic and PCU are listed below:

Table 0.4: Annual Average Daily Traffic

Homogenous section	Design Chainage	Section	Length (km)	Total Vehicles	Total (PCU)
HS-1	0+000 - 4+900	Rajiv Chowk - Ashram Chowk	4.9	**68923**	**68760**
HS-2	4+900 - 23+300	Ashram Chowk - Sohna	18.4	**18761**	**23847**
HS-3	23+300 - 42+630	Sohna - Nuh	19.33	**12579**	**18582**
HS-4	42+630 - 63+700	Nuh - Bhadas	21.07	**17349**	**23248**
HS-5	63+700 - 80+060	Bhadas - Firozpur Jhirka	16.36	**9975**	**15309**
HS-6	80+060 - 93+960	Firozpur Jhirka - Rajasthan Border	13.9	**8838**	**10755**

Based on the above Package II falls under one homogeneous section. As in this section traffic volume exceeds 25000 PCU in 2017-18, hence 6-laning is proposed for this section of project corridor.

0.2.4 Proposed Developmental Plan/Construction

Based on various interactions with clients, typical cross-section has been finalized to maintain the uniformity of the entire project road and to accommodate the typical cross section within the available ROW to the maximum possible extent. In general minimum ROW has been proposed to be 49 m. However in some stretches due to the restriction in availability of land in built up area, proposed ROW is kept ranging between 35-49 m. The existing project road section under Package-II in the State of Haryana has multi-dimensional facets with respect to land use and road geometry and considering all these aspects the section-wise policy adopted for widening based on the initial investigations is given in **Table: 0.5**. Considering the urban nature of the project corridor, the project road has been proposed to be upgraded to 6-lane configuration with 3-lane service road on either side.

Table 0.5: Summary of Development Scheme

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Applicable Typical cross section (TCS)	Remark	Village Name
	From	To	From	To				
1	11+682	11+806	9+282	9+406	124	TCS-6A	Approach	
2	11+806	12+166	9+406	9+766	360	TCS-4B	Viaduct	
3	12+166	12+870	9+766	10+470	704	TCS-5	Elevated structure	Maruti Kunj Road crossing
4	12+870	12+970	10+470	10+570	100	TCS-5A	Elevated structure	Bhondsi
5	12+970	13+034	10+570	10+634	64	TCS-5	Elevated structure	Bhondsi
6	13+034	13+394	10+634	10+994	360	TCS-4B	Viaduct	Bhondsi
7	13+394	13+528	10+994	11+128	134	TCS-8	Approach	Bhondsi
8	13+528	14+680	11+128	12+280	1152	TCS-2B		
9	14+680	15+040	12+280	12+640	361	TCS-3A		
10	15+040	15+790	12+640	13+390	750	Toll plaza		
11	15+790	16+253	13+390	13+853	463	TCS-3A		
12	16+253	16+710	13+853	14+310	457	TCS-7	Approach	
13	16+710	16+740	14+310	14+340	30	VUP		Ghamroj village
14	16+740	17+254	14+340	14+854	514	TCS-7	Approach	
15	17+254	17+810	14+854	15+410	556	TCS-3A		
16	17+810	18+271	15+410	15+871	461	TCS-7	Approach	
17	18+271	18+346	15+871	15+946	75	1×30+ 1×15+ 1×30 m span	Flyover	Alipur Village
18	18+346	18+822	15+946	16+422	476	TCS-7	Approach	
19	18+822	20+033	16+422	17+633	1211	TCS-3B		

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Applicable Typical cross section (TCS)	Remark	Village Name
	From	To	From	To				
20	20+033	21+100	17+633	18+700	1067	TCS-11A		
21	21+100	21+460	18+700	19+060	360	TCS-11B		
22	21+460	21+611	19+060	19+211	151	TCS-7	Approach	
23	21+611	22+325	19+211	19+925	714	TCS-4B	Viaduct (30m span at km 19+550)	University Area
24	22+325	22+472	19+925	20+072	147	TCS-7	Approach	
25	22+472	24+400	20+072	22+000	1928	TCS-2A		
Total length(m)					**12718**			

Note: All the given Design Chainages are with respect to the Right median edge (RME)
*Median width is inclusive of kerb shyness

0.2.5 Service Road/Slip Road

The summary of length of proposed service road/slip road is given below:

Table 0.5A: Summary of Service/slip road

Existing Chainage		Design Chainage		Length (m)	Details of Service Road		
From	To	From	To		Total width (m)	Side	Type
11+682	11+806	9+282	9+406	124	10.25	Both sides	Service Road/ Slip Road
11+806	13+394	9+406	10+994	1588	10.75	Both sides	Service Road
13+394	13+528	10+994	11+128	134	9.25	Both sides	Service Road/ Slip Road
13+528	14+680	11+128	12+280	1152	9.25	Both sides	Service Road
14+680	15+040	12+280	12+640	360	10.75	Both sides	Service Road
15+790	17+254	13+390	14+854	1464	10.75	Both sides	Service Road/ Slip Road
17+254	17+810	14+854	15+410	556	10.75	Both sides	Service Road
17+810	18+822	15+410	16+422	1012	10.75	Both sides	Service Road/ Slip Road
18+822	21+460	16+422	19+060	2638	10.75	Both sides	Service Road
21+460	21+611	19+060	19+211	151	10.75	Both sides	Service Road/ Slip Road
21+611	22+325	19+211	19+925	714	10.75	Both sides	Service Road
22+325	22+472	19+925	20+072	147	10.75	Both sides	Service Road/ Slip Road
22+472	23+100	20+072	20+700	628	10.25	Both sides	Service Road
23+100	24+400	20+700	22+000	1300	10.75	Both sides	Service Road

Note: The width of service /slip road is including the kerb shyness.

0.2.6 Proposed Pavement

The project road being heavily loaded in one direction (Sohna to Gurgaon – right carriageway) and lightly loaded on the other (Gurgaon to Sohna – left carriageway), Consultant has designed the pavement based on direction of travel.

Using the IITPAVE software, the flexible pavement thicknesses required for pavement widening and new pavement of stretches have been designed and is given in **Table 0.6**.

Consultant proposes flexible pavement with rigid base for construction of new and reconstruction of right carriageway of the project road section. However where existing right carriageway has been proposed for overlay and is being widened to accommodate paved shoulder, the same is proposed to be carried out using flexible base.

For left carriageway, Flexible pavement with flexible base is proposed. Hence based on the above the pavement thickness adopted for left and right carriageway is presented in **Table 0.6A and Table 0.6B** below.

Rigid pavement is proposed at Toll plaza location. The proposed thickness is presented in **Table 0.7.**

Table 0.6A: ADOPTED Flexible Pavement Thickness for Widening/New/Reconstruction of Left Carriageway (Gurgaon – Sohna)

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Design MSA	Pavement Thickness (mm)			
						Gurgaon - Raj Border (LEFT C/W)			
	From	To			15 years	BC	DBM	WMM	GSB
I	9+282	22+000	12.718	9%	51	40	95	250	200

Table 0.6B: ADOPTED Flexible Pavement Thickness for Widening/New/Reconstruction of Right Carriageway (Sohna - Gurgaon)

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Design MSA		Pavement Thickness (mm)								
							Raj Border - Gurgaon (RIGHT C/W)								
							Widening of Existing Right C/w with Overlay				New / Reconstruction of Right C/w				
	From	To			10 years	15 years	BC	DBM	WMM	GSB	BC	DBM	AIL	CTB	CTSB
I	9+282	22+000	12.718	9%	75	133	50	125	250	200	50	50	100	150	250

The rigid pavement thicknesses required is given in ***Table 0.7***

Table 0.7: Proposed Rigid Pavement thickness

Material Type	Thickness (mm)	
	Left Carriageway	Right Carriageway
Pavement Quality Concrete (M-40)	300	350
Dry Lean Concrete (M-10)	150	150
Granular Sub-base	200	150
Subgrade	500	500

0.2.7 Intersections

4 major and 10 minor junctions are proposed to be improved as a part of upgradation project. The improvement proposals of major and minor junctions are given respectively in **Table 0.8.**

Table 0.8: Existing junction Improvement Proposal

Sl. No.	PWD RD	Design Chainage	Junction Type		LHS				RHS				Remarks
					Type	Width	Leads	Proposal	Type	Width	Leads	Proposal	
1	12+181	9+781	T	Major	BT	4.50	Maruti Kunj	Flyover					Maruti Kunj road junction
2	13+019	10+619	T	Minor					BT	2x14.5	Bhondsi	Flyover	Bhondsi
3	14+150	11+750	T	Major	BT	5.30	Ritroj road	At grade					Proposed junction with Bhondsi-Silani permit line
4	16+305	13+905	T	Minor	BT	3.80	Mahendwara	At-grade					
5	16+725	14+325	T	Major					BT	3.90	Ghamroj	VUP	
6	18+286	15+886	Y	Minor					BT	3.70	Alipur	Flyover	Staggered junction
7	18+336	15+936	T	Minor	BT	5.00	Garhi Bazidpur	Flyover					
8	19+800	17+400	Y	Minor					BT	5.70	Raiseena	At-grade	
9	20+212	17+812	T	Minor	BT	3.80	Berka	At-grade					
10	21+950	19+550	T	Major					BT	5.30	Mohamadpur Gurjar	Flyover	
11	22+675	20+275	T	Minor	Gr.	3.00	Village	At-grade					
12	24+010	21+610	Y	Minor					BT	5.50	Sohna	At-grade	Maharaja Agrasen road
13	24+120	21+720	Y	Minor	BT	3.50	Berka	At-grade					
14	24+370	21+970	T	Minor					BT	5.20	Sohna	At-grade	

0.2.8 Proposal of Flyovers, Bridges, Culverts and other Structures

a) Bridges

There are no major bridge and 2 minor bridges on the project road. The existing bridges are on natural streams, nallahs and canals.

Table 0.9: Proposal of Minor Bridges

Sl. No.	Existing Chainage	Design Chainage	Proposed span arrangement (Clear span)	Proposed Structure type	Total Width
1	15+855	13+455	1 x 10.80m	RCC BOX	27.5 for Main Carriageway+ 2 x 15.25 m for Service Road Bridges (Service road bridge includes service road of 10.75m width,3.5m wide footpath, pedestrian guard rail and crash barrier)
2	19+095	16+695	1x7.6m	RCC BOX	27.5 for Main Carriageway+ 2 x 15.25 m for Service Road Bridges (Service road bridge includes service road of 10.75m width,3.5m wide footpath, pedestrian guard rail and crash barrier)

b) Elevated Structure/ Flyover/VUPs

The proposed Elevated Structure/ Flyover/VUPs are tabulated in ***Table 0.10.***

Table 0.10: Proposal for Elevated Structure/ Flyover/VUP

Sl. No.	Design Chainage		Length (m)	Proposed Span (m)	Proposed Structure	Total Width (m)	Vertical Clearance (m)	Remark
	From	To						
1	9+406	9+766	360	10x36.0m	Viaduct	25.5	As per Design Profile	Bhondsi
	9+781		30	1x30.0m	Elevated Structure	25.5	5.5	Bhondsi
	9+796	10+604	808	1x26.0+ 21x36.0+ 1x26.0m	Elevated Structure	25.5	5.5	Bhondsi
	10+619		30	1x30.0m	Elevated Structure	25.5	5.5	Bhondsi
	10+634	10+994	360	10x36.0m	Viaduct	25.5	As per Design Profile	Bhondsi
2	14+310	14+340	30	1x30.0m	VUP	25.5	5.5	Ghamroj Village
3	15+871	15+946	75	1x30.0+ 1x15.0+ 1x30.0m	Flyover	25.5	5.5 m	Alipur Villlage
4	19+211	19+535	324	9x36.0m	Viaduct	25.5	As per Design Profile	University area
	19+550		30	1x30.0m	Flyover	25.5	5.5 m	University area
	19+565	19+925	360	10x36.0m	Viaduct	25.5	As per Design Profile	University area

c) Pedestrian Facilities

The details of proposed FOB are given below:

Table 0.11A: Proposal for Foot Over Bridge (FOB)

Sl. No.	Existing Chainage	Design Chainage	Type of Structure	Overall Length (m)	Clear Width of FOB (m)	Vertical Clearance (m)	Remarks
1	21+100	18+700	Steel Structure with Ramps and elevators on both sides	71.0	5.0 (3m – Walkway + 2m-Bike lane)	5.5	Near under construction Residential Housing Society
2	22+500	20+100	Steel Structure with Ramps and elevators on both sides	65.0	5.0 (3m – Walkway + 2m-Bike lane)	5.5	Near GD Goenka University

Footpath shall be provided at locations given in Table 0.11B.

Table 0.11B: Footpath Location

Sl. No.	Design Chainage		Length (m)	Facilities	Width (m)	Side	Remarks
	From	To					
1	9+282	10+470	1188	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
2	10+470	10+570	100	Utility corridor-cum-Drain Cum Footpath	3.5 on RHS /1.5 m LHS	Both side	
3	10+570	10+994	424	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
4	10+994	11+128	134	Utility corridor-cum-Drain Cum Footpath	2.0	Both side	
5	11+128	12+640	1512	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
6	12+640	13+390	750	Utility corridor-cum-Drain Cum Footpath	2.0	Both side	Toll plaza
7	13+390	13+853	463	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
8	13+853	14+100	247	Utility corridor-cum-Drain Cum Footpath	4.5	Both side	
9	14+100	14+854	754	Utility corridor-cum-Drain Cum Footpath	3.0	Both side	
10	14+854	15+410	556	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
11	15+410	15+480	70	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
12	15+480	15+624	144	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
13	15+624	16+186	562	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
14	16+186	16+297	111	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	

Sl. No.	Design Chainage		Length (m)	Facilities	Width (m)	Side	Remarks
	From	To					
15	16+297	16+422	125	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
16	16+422	19+060	2638	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
17	19+060	19+105	45	Utility corridor-cum-Drain Cum Footpath	5.5	Both side	
18	19+105	19+211	106	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
19	19+211	19+925	714	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
20	19+925	19+990	65	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
21	19+990	20+700	710	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
22	20+700	21+700	1000	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
23	21+700	22+000	300	Utility corridor-cum-Drain Cum Footpath	5.5	Both side	

d) Culvets

There are total 13 culverts existing on the project road section. All existing culverts are either slab, box or pipe culverts having overall width equal or more than 12.0m. The detailed development proposal is presented in **Table 0.12**.

Table 0.12: Summary of Development Proposal for Culverts

Sl. No	Existing km/PWD RD	Design Chainage	Existing			Development Proposed			
			Existing Structure	Total width (m)	Span (m)	(Retained / Widened / Reconstruction / New Construction)	Proposed Structure Type	Span Arrangement	Total Width (m)
1	13+130	10+730	Slab	30.1	1x4.0	Concentric Widening	Box	1x4.0m	55
2	14+268	11+868	Slab	20.5	1x1.5	Concentric Widening	Box	1x1.5m	53
3	14+736	12+336	Slab	20.5	1x1.5	Concentric Widening	Box	1x1.5m	56
4	16+500	14+100	Slab	20.5	1x1.5	Reconstruction	Box	1x1.5m	57
5	17+168	14+768	Slab	22	1x3.25	Reconstruction	Box	1x 3.5m	54
6	18+250	15+850	Slab	20.5	1x1.3	Reconstruction	Box	1x1.5m	58
7	18+357	15+957	RCC Box	20.5	1x1.2	Reconstruction	Box	1x1.5m	58

Sl. No	Existing km/PWD RD	Design Chainage	Existing			Development Proposed			
			Existing Structure	Total width (m)	Span (m)	(Retained / Widened / Reconstruction / New Construction)	Proposed Structure Type	Span Arrangement	Total Width (m)
8	19+521	17+121	Slab	23.5	1x3.0	Concentric Widening	Box	1x3.0	60
9	20+313	17+913	Slab	23.5	1x3.0	Concentric Widening	Box	1x3.0	60
10	21+568	19+168	Slab	20.5	1x1.2	Reconstruction	Box	1x1.5m	58
11	22+585	20+185	Slab	20.5	1x1.3	Concentric Widening	Box	1x1.3	55
12	22+868	20+468	Slab	20.5	1x1.3	Concentric Widening	Box	1x1.3	55
13	23+768	21+368	Slab	36.5	1x1.5	Concentric Widening	Box	1x1.5	59

e) Toll plaza

Location of toll plaza has been proposed based on the traffic dispersal pattern at the respective homogenous sections, road geometry and vertical profile of the road and the surrounding area. The location and details of the toll plaza is given in **Table 0.13.**

Table 0.13: Details of Toll Plaza

Sl. No.	Existing Chainage (Km)	Design Chainage (Km)	Length(m)	Section for toll plaza	No. of lanes
1	15+400	13+000	Tapering length-203m Straight length of Toll plaza- 313m Tapering length-234m	From km 9+282 to km 22+000	24 (12 lanes in each direction)

0.2.9 Proposal for Rainwater Harvesting

Rain water harvesting system shall be provided along the project highway at the following locations as per MOEF guidelines and IRC:SP:50-2013 and IRC:SP:42-2014.

Table 0.14: Location of Rain Water Harvesting

Sl. No.	Details Such as Location/Interval/ Size	Remarks
1	At 500m interval staggered on both sides	

Sl. No.	Details Such as Location/Interval/ Size	Remarks
2	At 500 m interval beneath the Elevated structure between the design chainage 9+796 to 10+994 (at Bhondsi). The location shall be decided in consultation with NHAI / IE.	
3	In rest area	

0.2.10 Proposal of Noise barriers

Noise / sound barrier shall be provided on both sides of the main carriageway at following locations:

Table 0.15: Location of Noise / Sound Barrier

Sl. No.	Design Chainage		Length (m)	Side	Built up	Remarks
	From	To				
1	9+282	11+128	1846	Both	Bhondsi	Along both side of the elevated corridor including its approaches
2	19+112	20+021	909	Both	University	Along both side of the elevated corridor including its approaches
	Total		**2755**			

0.3 PRELIMINARY COST ESTIMATE

The project cost on above items has been worked out for the year 2017-18 based on development proposal. Total civil cost is assessed at this stage is given in **Table 0.16**.

Table 0.16: Total Civil cost

Sl. No.	Bill No	Description	Amount
			Package-II
1	Bill No 1	Site clearance and dismantling	4,599,947
			0.09%
2	Bill No 2	Earth work	414,436,015
			8.49%
3	Bill No 3	Granular sub-base and base courses	433,440,282
			8.88%
4	Bill No 4	Bituminous courses	435,520,026
			8.92%
5	Bill No 5	Cross drainage works	48,208,000
			0.99%

Sl. No.	Bill No	Description	Amount
			Package-II
6	Bill No 6	Bridge's, underpass, flyover & rob etc.	2,406,263,721
			49.29%
7	Bill No 7	Drainage and protective works	610,505,620
			12.51%
8	Bill No 8	Traffic signs, markings and road appurtences	172,453,329
			3.53%
9	Bill No 9	Miscellaneous items	112,385,630
			2.30%
10	Bill No 10	Electrical works	34,323,000
			0.70%
11	Bill No 11	Toll plaza	150,000,000
			3.07%
12	Bill No 12	Traffic management including traffic diversion and safety during construction	59,366,580
			1.22%
Total Cost			4,881,502,150
Total Cost (in Cr.)			**488.15**

The total project cost for Package-II is given below:

Table 0.17: Total Civil cost

Estimated Project Cost	
Particulars	**Amount (in Cr.)**
1) Base Civil Construction Cost	488.15
2) Escalation @ 5% upto Bid Due Date	-
3) Civil Construction Cost on Bid Date (1+2)	488.15
4) Contingencies @ 1% of Civil Construction Cost as mentioned in (3) above	4.88
5) Total EPC Cost (3+4)	493.03
6) IC/Pre-Operative Expenses @ 1% of Total EPC Cost mentioned in (5) above	4.93
7) O&M during Development Period	-
8) Total Cost (5+6+7)	**497.96**
9) Financing Expenses	3.88
10) Project Cost without IDC (8+9)	**501.85**
11) Interest During Construction (IDC) @ 10.10% p.a.	22.33
12) Estimated Project Cost as on Bid Date (10+11)	**524.17**
Cost of Preconstruction Activities (Rs. in Crores)	

Estimated Project Cost	
Land Acquisition	340.60
Utility Shifting (Electrical Overhead & Underground, Water supply, Sewarage) Lump sum	135.0
Total Capital Cost (Rs. in Crores)	**1689.01**

0.4 FINANCIAL ANALYSIS

The main objective of financial analysis is to assess the likely returns to the investors under realistic conditions/assumptions.

The total landed costs for the proposed road at the end of the construction period has been estimated by adding the capitalized interest during construction (IDC). Considering both Package-I and Package-II, the total landed cost at the time of commissioning (start of 2020-21) is thus estimated is given in **Table 0.18**.

Table 0.18 Total Landed Cost including IDC

Sl. No.	Particulars		Amount (Rs in Cr.)
A	**Concessionaire Cost**	Package -I: 643.99 Cr	1132.14
		Package -II: 488.15 Cr	
1	Civil Construction Cost base year (2017-18)		1132.14
	Escalation for one year (Civil Cost in 2018-19)		**1188.75**
2	Physical Contingencies Charges (1% Civil Construction Cost)		11.89
3	**Estimated Project Cost (EPC), base year**		**1200.63**
4	IC & Preoperative Expenses (1% of EPC)		12.01
5	Interest During Construction, IDC		57.5
6	Finance Charges (1.0% of Debt)		9.08
7	Escalation @ 5.0% per annum (on TPC)		83.30
8	Viability Gap Funding VGF		0.0
9	**Concessionaire Cost of Project after Grant**		**1362.54**

Based on the project structure traffic study and toll rate analysis, financial feasibility analysis has been carried out as per the methodology outlined in earlier sections. The minimum Equity IRR (Return on Equity) considered for the project is 15%. As per current scenario, existing traffic is low. Financial indicators are presented in **Table 0.19** below.

Table 0.19: Financial Indicators

S. No.	Particulars	Results (At 15% Equity IRR)	Results (At Maximum Permissible VGF of 10% of TPC as per clause 25.2.2 of DCA)
1.	Equity IRR	15.0%	12.6%
2.	Expected VGF (in %)	29%	10%
3.	Expected VGF (Rs. in Crore)	389	135
4.	Total Project Cost (Rs. in Crore)	1,340	1,355
5.	NPV of the Equity @ 12% discount rate (Rs. in Crore)	238	50

From the above table it can be concluded that the project is financially **Not Viable** on BOT (Toll) basis with 10% Grant permissible for as per clause 25.2.2 of DCA and 30 years Concession Period. **Hence the project is recommended to be taken up on Hybrid Annuity or EPC mode**.

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CHAPTER-1: INTRODUCTION AND OVERVIEW OF NHAI

1.1 BACKGROUND

The Public Works Department (B&R), Haryana has been entrusted with the assignment of Preparation of Detailed Project Report (DPR) for redesigning, rehabilitation and up-gradation to four/six lane configuration & strengthening of Gurgaon – Nuh - Rajasthan Border section of new NH-248A in the state of Haryana. As part of this endeavour, PWD (B&R), Haryana has decided to rehabilitate and upgrade the existing newly declared National Highway section from Gurgaon – Nuh – Rajasthan border of NH-248A in the State of Rajasthan to four/six lane configuration. This segment of NH-248A, from Gurgaon to Rajasthan Border via Nuh, hereafter termed as Project Highway.

The work for consultancy services for Consultancy Services for Preparation of Detailed Project Report for redesigning, rehabilitation and upgradation to four lane configuration & strengthening of new NH-248A Rajasthan Border – Nuh – Gurgaon in the state of Haryana. has been awarded to M/s. AECOM Asia Company Ltd., vide Public Works Department (B&R), Haryana commencement letter no. 63242 dated 23.05.2016. The agreement for the Consultancy Services was signed on 27th June 2016. As instructed vide PWD (B&R) and NHAI letter, the project road has been transferred to NHAI and hence NHAI shall be the executing agency of the project.

1.2 PROJECT OBJECTIVE

The main objective of the Consultancy services is to establish the technical, economical and financial viability of the project development proposals. Based on the findings of the feasibility of improvement proposals, detailed project reports and bidding documents for redesigning, rehabilitation and upgrading of the existing road to 6 lane shall be prepared.

The viability of the project will be established taking into account the requirements with regard to rehabilitation, upgrading and improvement based on highway design, pavement design, provision of service roads wherever necessary, type of intersections, rehabilitation and widening of existing and /or construction of new bridges and structures, road safety features, quantities of various items of works and cost estimates and economic analysis.

The Detailed Project Report would inter-alia include detailed highway design, design of pavement and overlay with options for flexible or rigid pavements, design of bridges and cross drainage structures and grade separated structures, design of service roads, quantities of various item, detailed working drawings, detailed cost estimates, economic and financial viability analyses, environmental and social feasibility, social and environmental action plans as appropriate and documents required for tendering the project on commercial basis for international / local competitive bidding.

1.3 SCOPE OF SERVICES

Detailed scope of works for this project is listed in the Terms of Reference (TOR) of the Contract. An abstract of the scope is presented below:

- As far as possible, the widening/improvement work to 6 laning will be carried out within the existing right of way avoiding land acquisition. At locations having inadequate width provisions of short bypasses, service roads, alignment corrections, improvement of Intersections will be considered as necessary and feasible. However, bypass proposal will also be considered, wherever improvement to two lanes of the existing road is not possible.
- Provide land acquisition details as per revenue records/maps for further processing of Land Acquisition papers. Submit 3(a), 3(A) and 3(D) draft notification for acquisition of land.
- Study the possible locations and design of toll plaza.
- Wayside amenities, such as rest area, bus bays, bus shelters and truck lay-byes will also be planned.
- The local and slow traffic may need segregation from the main traffic and provision of service roads and fencing may be considered, wherever necessary to improve efficiency and safety.
- Make suitable proposals for widening/improvement of the existing road to 6 lane and strengthening of the carriageways, as required at the appropriate time to maintain the level of service over the design period.
- Prepare documents for EPC contracts.
- Make provision of adequate safety features like safety barriers, retro-reflective and adequate road signs to ease driving, pedestrian facilities at urban sections, etc.
- All ready to implement "good for construction" drawings will be prepared.
- Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) and Rehabilitation and Resettlement Studies will be carried out meeting the requirements of the Government of India or lending agencies like ADB/ World Bank etc.
- Liaise with different stakeholders in the project, viz. electrical, telephone, OFC, Public Health, Forest etc. and obtain necessary estimates for utility shifting and tree cutting.
- Approval of all drawings of Railway Over Bridges (ROB) including GAD and detail engineering drawings will be got done by the consultant from the Railways.
- Obtain 'No Objection Certificate' from Ministry of Environment and Forest.
- Obtain all types of necessary clearances required for implementation of the project on the ground from the concerned agencies. The client will provide the necessary supporting letters and any official fees as per the demand note issued by such concerned agencies from whom the clearances are being sought to enable implementation.

1.4 REVISED FINAL FEASIBILITY REPORT

In line with Terms of references (TOR) and based on the Revised Final Feasibility Report submitted vide our letter dated 12th September 2017, the **Revised Final Feasibility Report**

(Revision no. - R2) for Package-II : Six laning and Strengthening of new NH-248A from existing km 11+682 to km 24+400 in the State of Haryana is now being submitted. The Detailed Project Report would inter-alia include detailed highway design, design of pavement and overlay with options for flexible or rigid pavements, design of bridges and cross drainage structures and grade separated structures, design of service roads, quantities of various item, detailed working drawings, detailed cost estimates, economic and financial viability analyses, environmental and social feasibility, social and environmental action plans as appropriate and documents required for tendering the project on commercial basis for international / local competitive bidding.

1.5 REPORT STRUCTURE

The structure of the Revised Feasibility Study report is presented as below:

- ✓ *Executive Summary*
- ✓ *Chapter -1: Introduction and Overview of NHAI*
- ✓ *Chapter -2: Project Road Description*
- ✓ *Chapter -3: Methodology for Feasibility study*
- ✓ *Chapter- 4: Socio economic profile*
- ✓ *Chapter- 5:Traffic Survey and Analysis*
- ✓ *Chapter -6:Engineering surveys and investigations*
- ✓ *Chapter- 7: Design Standards*
- ✓ *Chapter- 8: Development Proposals*
- ✓ *Chapter-9: Environmental Screening and Preliminary Environmental Assessment*
- ✓ *Chapter-10: Initial social assessment and preliminary land acquisition*
- ✓ *Chapter-11: Cost Estimate*
- ✓ *Chapter-12: Financial Analysis*
- ✓ *Chapter-13: Conclusion and Recommendation*

1.6 OVERVIEW OF NHAI

1.6.1 NHAI Establishment

The National Highways Authority of India (NHAI) was constituted by an act of Parliament, "the National Highways Authority of India, 1988". It is responsible for the development, maintenance and management of National Highways entrusted to it and for matters connected or incidental thereto. The Authority was operationalized in February 1995 with the appointment of full time Chairman and other Members.

1.6.2 NHAI Mandate

1. Primary mandate is time and cost bound implementation of National Highways Development Project (NHDP) through host of funding options including from external multilateral agencies like World Bank, Asian Development Bank, JBIC etc. Work mainly comprises of strengthening and 4/6 laning of high-density corridors around 13,146 kms.

The components are:

- Golden Quadrilateral – 5,846 kms connecting Delhi-Kolkata-Chennai-Mumbai.
- North-South-East-West Corridor – 7,300 kms connecting Kashmir to Kanyakumari and Silchar to Porbandhar.

2. Providing Road connectivity to major ports.
3. Involving the private sector in financing the construction, maintenance and operation of National Highways and wayside amenities.
4. Improvement, maintenance and augmentation of the existing National Highways network.
5. Implementation of road safety measures and environmental management.
6. Introducing Information Technology in Construction, maintenance and all operation of NHAI.

1.6.3 Organization

A full time Chairman heads NHAI. Member Finance, Member Administration, Member Technical head their respective departments and report to the Chairman. A detailed organization chart of NHAI is given in ***Figure 1.1.***

1.7 NATIONAL HIGHWAY DEVELOPMENT PROGRAM (NHDP)

The National Highways have a total length of 71,772 km to serve as the arterial network of the country. The development of National Highways is the responsibility of the Government of India. The Government of India has launched major initiatives to upgrade and strengthen National Highways through various phases of National Highways Development Project (NHDP) presented in ***Figure 1.2.*** National Highway Development Program is envisaged to plan, design and construct a network of world class highways to support the economic growth of the country. Infrastructure in India has been found to be a bottleneck/speed breaker for the trade and business, poverty alleviation and economic growth of the country. Advantages of providing well developed network of highways are as follows:

- Savings in vehicles operating costs by reduced fuel consumption and maintenance costs
- Travel time savings by faster and comfortable journeys
- Safer travel
- Benefits to trade especially in movement of perishable goods.
- Reduce demographic shift to urban areas
- Poverty alleviation and all round development of areas

NHDP's focus is on developing International standard roads with facilities for uninterrupted flow of traffic with:

- Enhanced safety features
- Better Riding Surface
- Better Traffic Management and Noticeable Signage
- Divided carriageways and service roads
- Grade separators
- Over bridges and Underpasses

- Bypasses
- Wayside amenities

National Highways Development Project is being implemented in 7 phases, which are briefly as under:

NHDP Phase I : NHDP Phase I was approved by Cabinet Committee on Economic Affairs (CCEA) in December 2000 at an estimated cost of Rs. 30,000 crores comprises mostly of GQ (5,846 km) and NS-EW Corridor (981 km), port connectivity (356 km) and others (315 km).

NHDP Phase II : NHDP Phase II was approved by CCEA in December 2003 at an estimated cost of Rs. 34,339 crores (2002 prices) comprises mostly NS-EW Corridor (6,161 km) and other National Highways of 486 km length, the total length being 6,647 km. The total length of Phase II is 6,647 km.

NHDP Phase III : Government approved on 5.3.2005 upgradation and 4 laning of 4,035 km of National Highways on BOT basis at an estimated cost of Rs. 22,207 crores (2004 prices). Government approved in April 2007 upgradation and 4 laning at 8074 km at an estimated cost of Rs. 54,339 crores.

NHDP Phase V : CCEA has approved on 5.10.2006 six laning of 6,500 km of existing 4 lane highways under NHDP Phase V (on DBFO basis). Six laning of 6,500 km includes 5,700 km of GQ and other stretches.

NHDP Phase VI : CCEA has approved on November 2006 for 1000 km of expressways at an estimated cost of Rs. 16680 crores.

NHDP Phase VII: CCEA has approved on December 2007 for 700 km of Ring Roads, Bypasses and flyovers and selected stretches at an estimated cost of Rs. 16680 crs.

Finance Mechanisms: NHAI proposes to finance its projects by a host of financing mechanisms. Some of them are as follows:

1. The Government of India – Budgetary Allocation

In a historic decision, the Government of India introduced a Cess on both Petrol and Diesel. This amount at that time (at 1999 prices) came to a total of approximately Rs. 2,000 crores per annum. Further, Parliament decreed that the fund so collected were to be put aside in a Central Road Fund (CEF) for exclusive utilization for the development of a modern road network. The developmental work that it could be tapped to fund, and the agencies to whom it was available were clearly defined as:

- Construction and Maintenance of State Highways by State Governments
- Development of Rural Roads by State Governments
- Construction of Rail Over Bridges by Indian Railways.
- Construction and Maintenance of National Highways by NHDP and Ministry of Road Transport & Highways.

Today, the Cess contributes between Rs. 5 to 6 Thousand crores per annum towards NHDP.

2. Loan Assistance from International Funding Agencies

Loan assistance is available from multilateral development agencies like Asian Development Bank and World Bank or Other overseas lending agencies like Japanese Bank of International Co-operation.

3. Market Borrowing

NHAI proposes to tap the market by securities cess receipts.

4. Private Sector Participation

Major policy initiatives have been taken by the Government to attract foreign as well as domestic private investments. To promote involvement of the private sector in construction and maintenance of National Highways, Projects are offered on Build, Operate and Transfer (BOT) basis to private agencies. After the concession period, which can range up to 30 years, this road is transferred back to NHAI by the Concessionaires. NHAI funds are also leveraged by the setting up of Special Purpose Vehicles (SPVs). The SPVs borrow funds and repay these through toll revenues in the future. Some more models have emerged for better leveraging of funds available with NHAI such as Annuity, which is a variant of BOT model.

Total cost of NHDP has been estimated to be Rs.54000 crores or US$ 13.2 billion whose components are as below:

Likely sources	***Rs.Cr.*** **(On 1999 prices)**	***US$ Billions*** **(On 1999 prices)**
Cess on Petrol and Diesel	20,000	4.90
External assistance	20,000	4.90
Market borrowings	10,000	2.40
Private Sector Participation	4,000	1.00

1.8 GOVERNMENT POLICY INITIATIVES

Policy Initiatives for Attracting Private Investment

- Government will carry out all preparatory work including land acquisition and utility removal. Right of Way (ROW) to be made available to concessionaires free from all encumbrances.
- NHAI / GOI to provide capital grant up to 40% of project cost to enhance viability on a case to case basis.
- 100% tax exemption for 5 years and 30% relief for next 5 years, which may be availed of in 20 years.
- Concession period allowed up to 30 years.
- Arbitration and Conciliation Act 1996 based on unicitral provisions

- In BOT projects entrepreneur are allowed to collect and retain tolls
- Duty free import of specified modern high capacity equipment for highway construction.

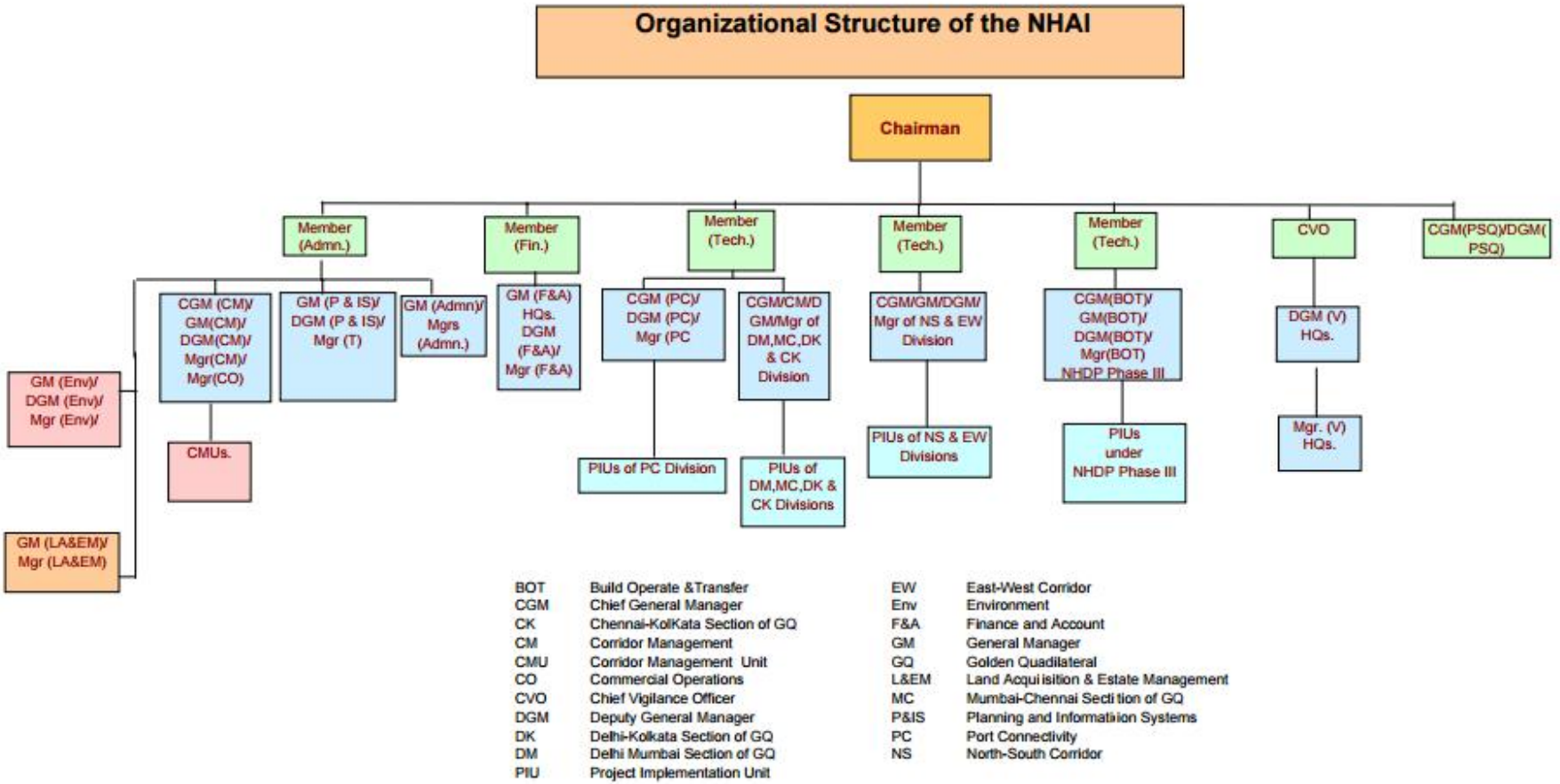
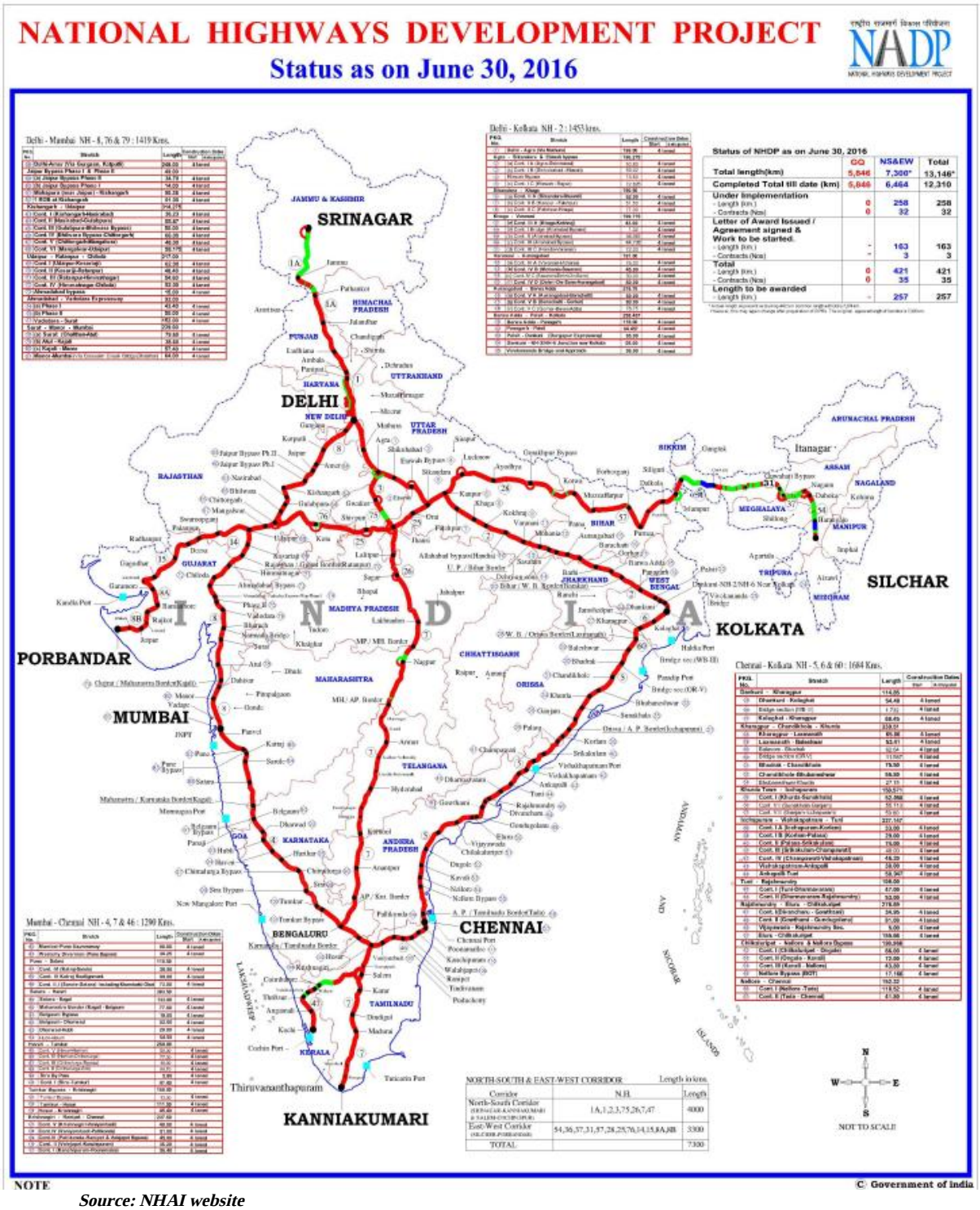


Fig. 1.1: Organization Structure of NHAI



Source: NHAI website

Fig. 1.2: NHDP Status as on June 30, 2016

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CHAPTER-2: PROJECT ROAD DESCRIPTIONS

2.1 GENERAL

The project road starts from Gurgaon city in the state of Haryana and ends at Haryana – Rajasthan border. The road section passes through Gurgaon district of Haryana. Gurgaon also known as Gurugram, is located in Gurgaon district in the state of Haryana and is situated in the south eastern part of the state, and northern part of the country. Once a small dusty agricultural village, Gurgaon has now emerged to become the city with the third highest per capita income in India.

Haryana is a landlocked state in northern India. The total geographical area of the state is 4.42 m ha, which is 1.4% of the geographical area of the country. Haryana has four main geographical features: the Yamuna-Ghaggar plain forming the largest part of the state, the Shivalik Hills to the northeast, Semi-desert sandy plain to the southwest and the Aravalli Range in the south.

The climate is arid to semi-arid with average rainfall of 354.5 mm in Haryana. There are two agro climatic zones in the state. The north western part is suitable for Rice, Wheat, Vegetable and temperate fruits and the south western part is suitable for high quality agricultural produce, tropical fruits, exotic vegetables and herbal and medicinal plants.

Haryanvi has traditionally been the dominant mother tongue in Haryana. As Haryanvi has no official status, as it is seen as a dialect of Hindi; thus Hindi is the official language and the most commonly spoken language in the state. Haryana has second largest Punjabi speaking population in India after the state of Punjab.

The state is divided into four divisions for administrative purposes: Ambala, Rohtak, Gurgaon and Hisar. Within these there are 21 districts.

National Highway 248A starts at Shahpura in Rajasthan and ends in Gurgaon, Haryana. The project road section of the highway starts from PWD R.D. 2+400 at Rajiv Chowk, Gurgaon which is a 4 legged – grade separated junction at km. 32+650 of NH-8 and ends at PWD R.D. 95+950. However during survey, linear measurement of the road reveals that the existing end R.D. of the road is 95+985 instead of 95+950. Hence the total actual existing length of the project road is 93.585 km.

The index map depicting the project road is presented in **Fig.2.1.**

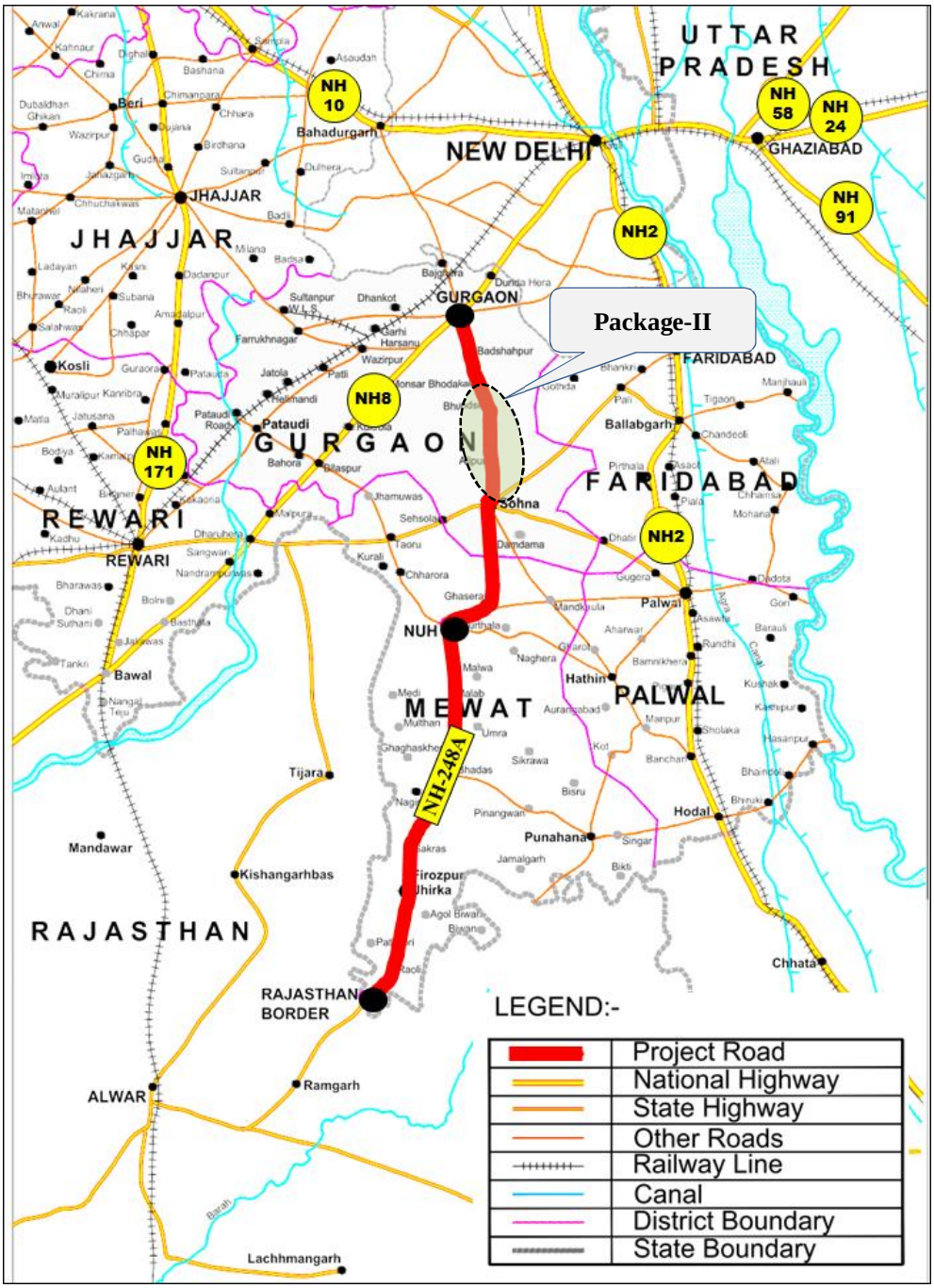


Fig 2.1: Index Map showing Project Road

2.2 PROJECT BACKGROUND

The work for consultancy services for Consultancy Services for Preparation of Detailed Project Report for redesigning, rehabilitation and upgradation to four lane configuration & strengthening of new NH-248A Rajasthan Border – Nuh – Gurgaon in the state of Haryana. has been awarded to M/s. AECOM Asia Company Ltd., vide Public Works Department (B&R), Haryana commencement letter no. 63242 dated 23.05.2016. The agreement for the Consultancy Services was signed on 27th June 2016.

After the submission of Inception Report, the project has been transferred from PWD (B&R), Haryana to NHAI. Subsequent to site visit and discussions with NHAI, the project has been divided into following three construction packages:

Package	Existing Chainage / PWD RD		Length (Km)	Remarks
	From	To		
I	2+400	11+682	9.282	Rajiv Chowk to Start of Bhondsi
II	11+682	24+400	12.718	Start of Bhondsi to Start of Sohna
III	24+400	95+985	71.585	Start of Sohna to Rajasthan Border

In line with the work order the Revised Final Feasibility Report for Package-II was submitted on 12th September 2017. Now based on discussion with NHAI**, Revised Final Feasibility Report (Revision No. – R2)** for **Package-II: Six laning and Strengthening of new NH-248A existing km 11+682 to existing km 24+400 in the state of Haryana** is being submitted.

2.3 PROJECT ROAD

The project road section under Package-II starts from PWD R.D. 11+682 (Fig.2.3A) of NH-248A and ends at PWD R.D. 24+400 near Sohna. The road passes through Gurgaon district of Haryana. The district-wise details are given in **Table 2.1** below:

Table 2.1: Details of Project District

Sl. No.	Name of Districts	Existing Chainage		Length (km)
		From	To	
1	Gurgaon	11+682	24+400	12.718
TOTAL				**12.718**

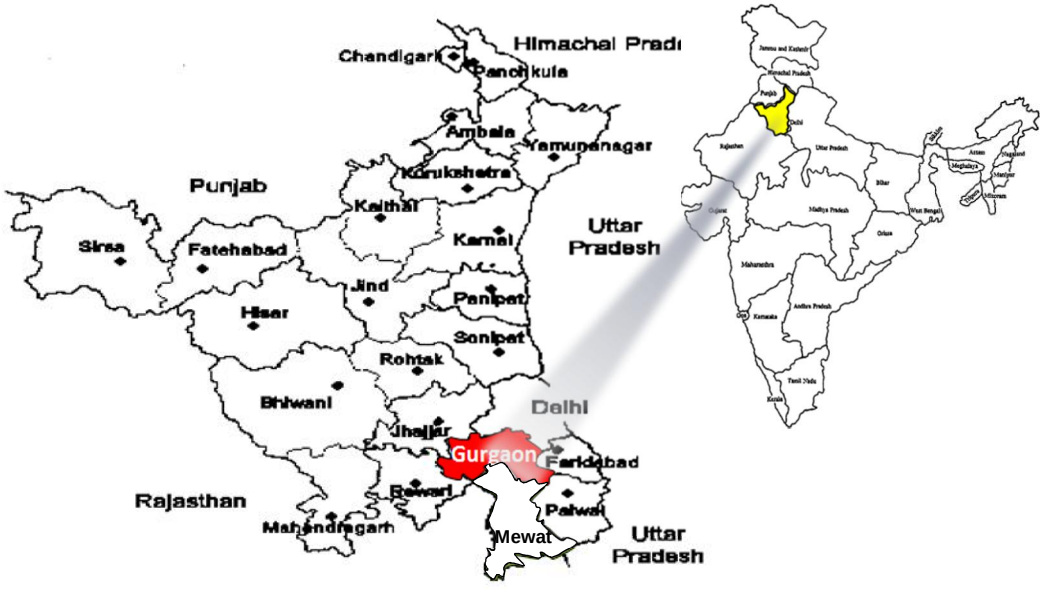


Fig 2.2: Project District of Haryana

Between start of the project road section under Package-II ,i.e PWD R.D. 11+682 and end of the project road section i.e PWD R.D 24+400, at Sohna, the existing NH-248A is of 2 x 2-lane configuration with median varying between 0.5m to 1.5m. The major settlements along the project corridors are Badshahpur and Bondsi. A line plan of the project road depicting its salient features is presented in **Fig. 2.4**:



Fig 2.3A: Start of the Project Road at km 11+682 (existing) of NH-248A



Fig 2.3B: End of the Project Road at km 24+400(existing) of NH-248A

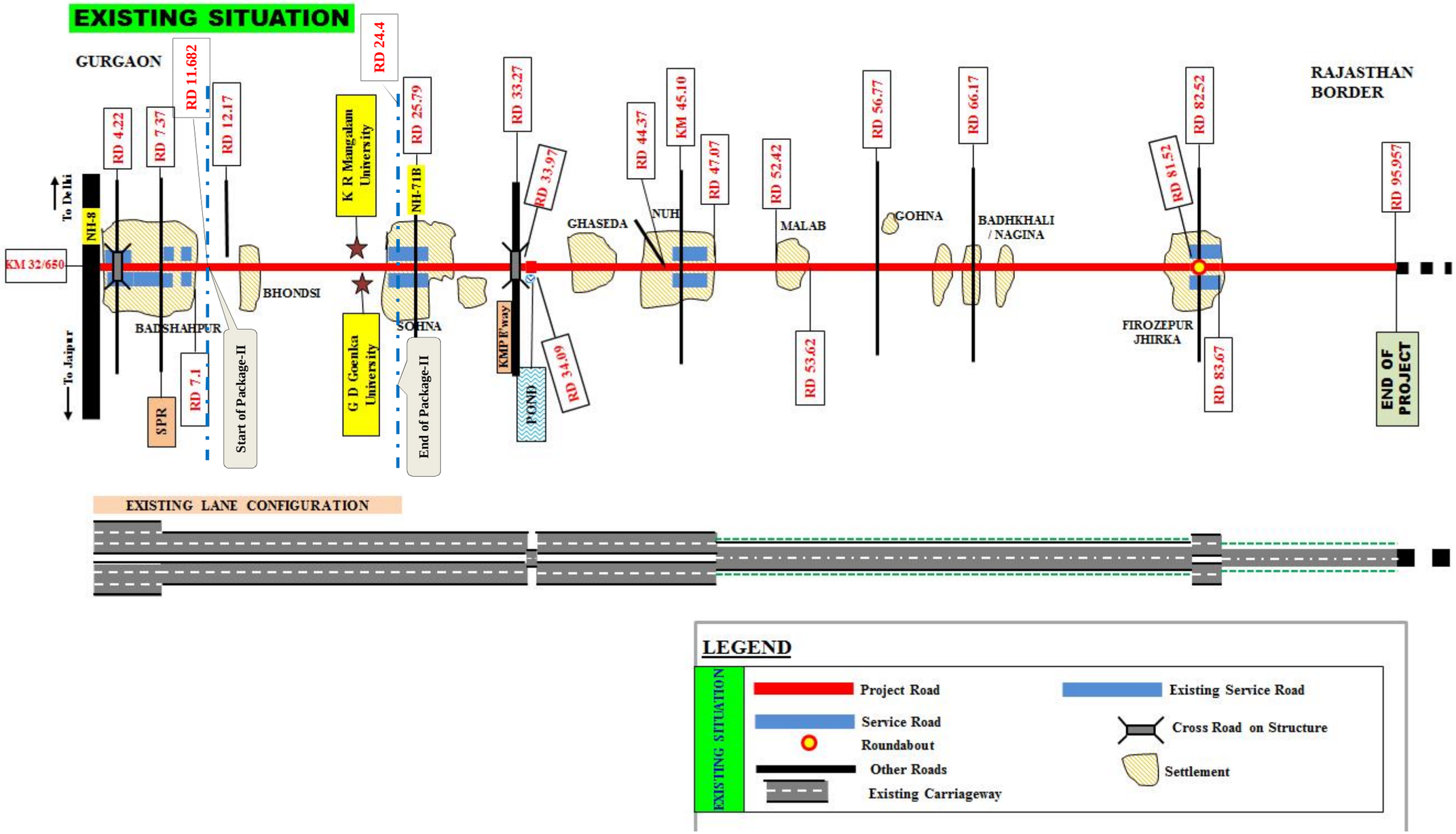


Fig 2.4: Schematic Line Plan of Project Road

2.4 STUDY OF PROJECT CORRIDOR

The consultant's team during their several site visits have collected field data to understand the project and its constraints which has been subsequently used to formulate the project improvement/ development proposals. The salient existing features of the project are discussed in the subsequent paragraphs to give an overview of the project corridor. The proper understanding of the existing project features and constraints form the basis of the design proposals to follow. The project features discussed are as follows:

- Terrain and Land use
- Climatic Conditions
- Physiographic Features
- Geological Features
- Existing Roadway
- Right of Way
- Cross-Drainage Structures
- Highway Geometrics
- Pavement Condition
- Major Developments
- Cross-road and Junctions
- Drainage Condition
- Railway Crossings
- Utility Lines
- Environmental and Social Status
- Alternate Routes

2.4.1 Terrain and Land use

The project road runs through plain terrain and semi-arid to sub humid region only.

Barring the built-up locations, agriculture is the predominant land use in some semi-arid areas while it is barren in the arid patches along the road. In the built-up areas both residential and commercial buildings have developed abutting the road corridor. The list and locations of villages / towns noticed along the project road is tabulated in **Table 2.2** below:

Table 2.2: List of Settlements

Sl. No.	Existing Chainage		Length (m)	Name of Settlement
	From	To		
1	12+700	14+600	1900	Bhondsi
2	21+900	22+900	1000	K R Mangalam University on Left G D Goenka University on Right

Sl. No.	Existing Chainage		Length (m)	Name of Settlement
	From	To		
3	22+900	24+400	1500	Sohna

2.4.2 Climatic Conditions

The climate of the state varies from sub-tropical, semi-arid to sub-humid, continental and monsoonal. Summers are very hot (up to a high of 47 degree Celsius)and winters are very cold (1˚ Celsius). The months of May and June are the hottest and the coldest months are December and January.

Rainfall recorded in the region is low and erratic in most parts excepting some areas of the Karnal and Ambala districts. Siwalik Hills region receives highest rainfall and the Aravalli Hills region records the least rainfall. Monsoon season normally spans from July to September and it sometimes causes local flooding. Winter rains are usually received between December and February. Maximum rainfall is recorded from Ambala area, being 47.16 inches (119.78cm) per annum, but it is sporadic in other areas. The average annual rainfall recorded from the state is about 650 mm and varies from less than 300 mm in southwester parts to over 1000 mm in the Siwalik Hills region. The three main climatic regions of the state are - hot arid region, hot semi-arid region and hot sub-humid region.

The mean rainfall (mm) recorded in hot arid region ranges from 300 mm-500 mm, whereas 500 mm - 750 mm in the hot semi-arid region and 750 mm - 1050 mm in the hot sub humid region of the state. The mean temperatures recorded in the three regions are 27 ˚C, 26˚ C, and 24˚C, respectively.

2.4.3 Geological Feature

The geology of Haryana is predominated by the Quaternary alluvium and aeolian sediments covering nearly 95% of area. The rest of the area comprises Proterozoic and Tertiary rocks exposed in the southern and northeastern extremities of the state, respectively.

Haryana state falls in three Seismic Zones viz. II, III and IV, creating low to moderate damage risk from earthquakes. Ambala, Sonepat, Rohtak, Karnal, Gurgaon, Mewat, Faridabad, Panipat, Rewari and Yamunanagar districts lie in Zone IV. The districts of Kurukshetra, Jind, Hissar, Bhiwani, Mahendragarh and Kaithal lie in Zone III while only Sirsa District lies in Zone II.

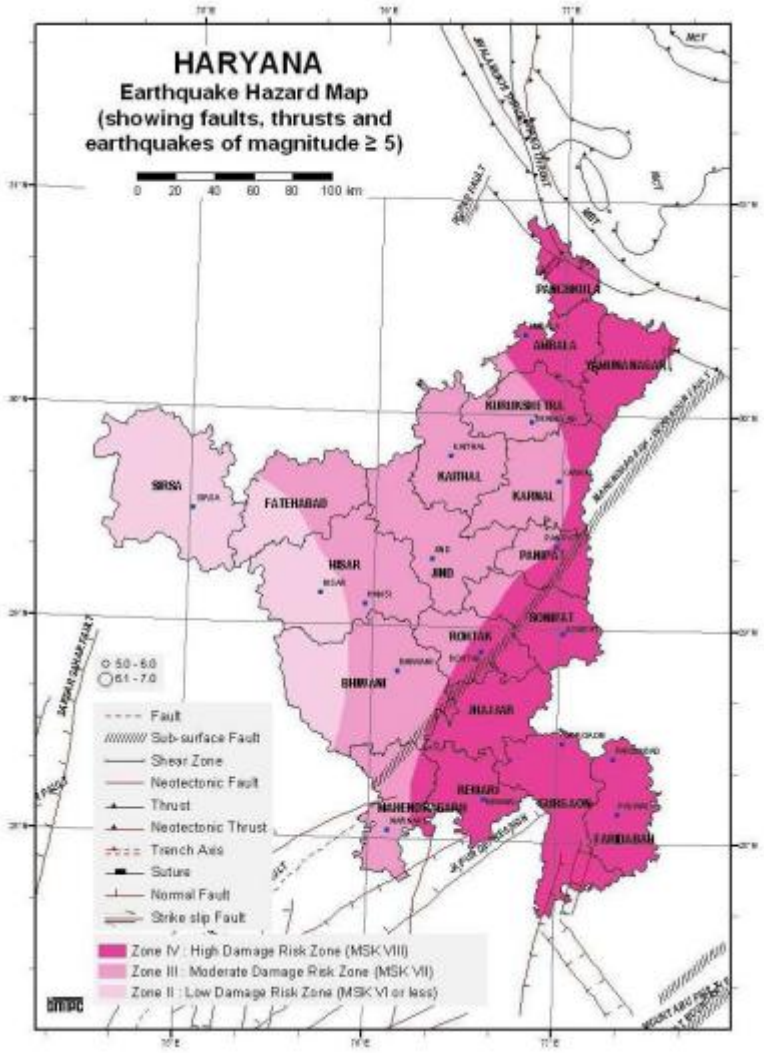


Fig 2.5: Seismic Zone Map of Haryana

2.4.4 Cross Drainage Structures

There are 2 Minor Bridges and no Major Bridge on the project road. The list of the bridges is presented in **Chapter 6: Survey and Investigation**.

Along with these bridges there are 13 culverts along the project road. The conditions of the culverts were observed to be generally fair to good. The inventory and condition survey of the culverts are discussed in **Chapter 6.**

The detailed improvement proposal of the cross drainage structures is discussed in **Chapter 8: Development Proposals.**

2.4.5 Highway Geometrics

The horizontal alignment of the project road is mostly straight and with flatter curves. Both the horizontal and vertical alignment of the road is apparently seems to meet the National Highway standards almost at all locations.

2.4.6 Pavement Condition

The pavement is of flexible type for the whole stretch. Although overall the pavement is in fair condition, however cracks and rutting are seen occasionally on the pavement. This is predominant on right carriageway / lane which is generally more loaded than the left carriageway / lane. Pavement condition is discussed in more detail in **Chapter 6.** The chainage wise details of pavement condition are given in ***Appendix 6.3***.

2.4.7 Major Developments along project road

The project road passes through number of urban and semi urban settlements, of which the important ones are viz. Bhondsi and Sohna. A detailed list of the village and town locations is presented in **Chapter-6** of this volume.

2.4.8 Cross Roads and Junctions

The identification of major junctions and category of road crossing the project road was done based on local enquiry and verification from secondary data, maps and consultation with competent authorities.

Considering only the bituminous cross roads, there are **4 nos. of major** and **10 nos. of minor junctions** exists along the project road.

2.4.9 Railway Crossings

Currently there is no railway crossing in the entire project corridor under Package-II.

2.4.10 Overpass

There is no overpass on the project road.

2.4.11 Utility Lines

Several utility lines cross and run parallel to the project road. The different types of utility lines observed are as given below:

- Electric Line
- High Tension Transmission lines
- Telephone lines
- OFC Lines (underground)

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CHAPTER-3: METHODOLOGY FOR FEASIBILITY STUDY

3.1 GENERAL

The Feasibility study consists of:

- Traffic Surveys
- Engineering Surveys and Investigations
- Environmental and Social Screening
- Assessment of required development
- Preliminary cost estimates
- Financial viability
- Economic viability
- Mode of Implementation and Packaging
- Feasibility report

The Approach and methodology adopted for each task mentioned above are described as under:

3.2 TRAFFIC SURVEYS

To appreciate the characteristics of traffic along the project road sections in terms of size, desire, speed, load and lead, number of surveys were carried out. Traffic surveys primarily consist of manual classified mid-block counts namely to determine the existing volume and composition of traffic using key links and nodes within the study area. All types of traffic surveys and studies done for feasibility study are discussed below:

3.3 CLASSIFIED TRAFFIC VOLUME COUNT

In addition to available present traffic data, traffic volume surveys have been conducted based on IRC: 102. The data collected from surveys has been used to establish accurate baseline traffic flows and the same has been used in forecasting the future traffic levels. These surveys have been undertaken at six identified locations based on the homogeneity of traffic volume and pattern as identified from reconnaissance survey and as intimated to PWD (B&R), Haryana and NHAI vide Inception Report. The locations of survey are presented in the **Table 3.1** below.

The survey was conducted for 24 hours for continuous 7 days to capture both the hourly and diurnal variation of traffic. Disaggregated classification system has been used due to the requirements of the vehicle operating cost modelling. As the inputs for modelling traffic congestion effects require an hourly distribution of traffic volume, the data was collected at 15-minute intervals and aggregated to hourly volumes, direction wise.

The monthly variation in the traffic volume has been studied using the monthly fuel sales data for a period of minimum 2 years collected from different fuel refilling stations available on the project corridor. From the data so collected, seasonal correction factor has been estimated and applied to convert the Average Daily Traffic (ADT) to Annual Average Daily Traffic (AADT).

All data will be stored in a database program and plotted on maps.

3.3.1 Origin- Destination and Commodity Movements Survey

These surveys have been conducted to anticipate the Origin-Destination (O-D) characteristic in order to establish the existing pattern of travel in the project influence area.

It is important to identify any trip patterns influenced by existing congestion levels or road condition. Hence O-D survey has been conducted at three locations on the project corridor. Roadside interviews have been conducted during survey to gather data on the trip purpose, trip length, socio-economic background of passengers, commodity type and value for commercial vehicles, and loading pattern of goods vehicles.

With the help of local police assistance, the survey at all locations was conducted for 24 hours using a systematic random sampling. The classified volume count carried out along with the O-D survey was used to arrive at the sample coverage/expansion factor. The objective was to sample as many vehicles as practical given the constraints of the storage capabilities of the interview bay.

A traffic zone system has been developed for coding and analyzing the O-D data. The zones have been defined based on the traffic on each linear and spatial segment. The data collected has been coded and processed to eliminate all illogical data and entry errors.

The processed data has been used to generate O-D matrices (by category, purpose, and overall). Desire line diagrams have been prepared to give an understanding of the travel pattern in the region and along the corridor. For each station a trip matrix has been prepared and merged to generate the global trip matrix. The data on the socio-economic and other related aspects have been used to enable an assessment of the travel characteristics on the project corridor.

3.3.2 Turning Movement Survey

The methodology for the surveys was as per IRC: SP: 41. The details including the locations and duration of surveys were finalized in consultation with PWD (B&R), Haryana /. Intersection movement count was done for estimation of peak hour traffic for the design of the major and minor junction.

3.3.3 Axle Load Surveys

The intensity of traffic loading and the corresponding damaging factor of different categories of vehicles are an important parameter for the design of pavement. An axle load survey in both directions was carried out at two suitable locations in the project road stretch. The loading characteristic was taken on random sample basis normally for trucks only for two normal days (24 hours). The axle load survey was done using portable weigh pad having capacity of 20 tonnes wheel load. The survey was conducted to cover both traffic direction and for empty as well as loaded commercial vehicles, i.e. Light Goods Vehicles, 2-Axle trucks, 3-Axle trucks, Multi-Axle trucks and Buses. The number of standard axles using the road derived from Axle load surveys is vital to the pavement design and economic analysis.

3.3.4 Survey Programme

The table below gives the details of the traffic surveys carried for the project road.

Table 3.1: Traffic Survey Locations

Type of Survey	Duration	Location	No. of Locations
Classified Traffic Volume Count	7 Days x 24 hrs	• Km 3+000 • Km 21+000 (before Sohna) • Km 30+000 (before junction with KMP Exp) • Km 46+000 (near Marora) • km 77+600 • km 84+000	6
Turning Movement Count	1 Day	• Km 1+750 • km 4+900 • km 9+700 • km 19+880 • km 23+300 • km 30+800 • km 42+630 • km 54+300 • km 63+700 • km 80+060	10
OD Survey	1 Day	• Km 21+000 • Km 77+600 • km 84+000	3
Axle Load Survey	48 hours	• km 77+600 • km 84+000	2

3.4 TRAFFIC FORECAST

Traffic Volume Characteristics

The traffic volume data has been compiled and processed in order to establish the link volumes in the base year. The daily and hourly fluctuations in the traffic flow has been examined, the peak hour factor has been determined and the volume capacity ratios at disaggregated links has been calculated (once the capacity of the different links of project road is estimated considering the pavement width and speed flow relationships). At this stage the road sections that are in distress from traffic point of view has been distinctly identified. Subsequently, the Uniformity in Capacity Utilization of the Road Sections has been studied and an estimation of the time-based users versus non-time based users and the local traffic versus the regional traffic is proposed. All these findings collectively contribute to the understanding of existing problems on the project corridor at a micro level and pave the way for suggesting

development measures related to geometric improvements and development of other road infrastructures such as Flyovers, VUPs, PUPs, Bypasses etc. In order to establish the base year link traffic volume in terms of ADT, the utmost care has been taken to reduce errors and variations.

Travel Desire Patterns

The traffic desire pattern, both for passenger vehicles and goods vehicles has been established through analysis and interpretation of the O-D matrix developed from the roadside interviews.

There has been a dual utility of this finding. Firstly, it helped to establish the level of interaction between different traffic zones in terms of trip ends, which enabled a subsequent development of the shortest path matrix and the traffic from other corridors to the project road. Secondly, it is used in assessing the benefits accrued in terms of transport cost, i.e. VOC; travel time, etc. after the improvement of the project road in a more realistic manner.

Trip Characteristics

This task was focused on understanding the travel characteristics by all vehicular modes which include purpose, frequency, trip distance, travel time, income of passengers etc. in the case of passenger vehicles, and type of commodity, value of commodity, loading pattern etc., for goods vehicles.

Forecasting Socio-Economic Base

The economic growth in the region has a major impact on the proposed facility. The impact is expected to be due to growth in local demand, development of industrial centres, and tourist centres. For this purpose the studies carried out/reports prepared by various Govt./Non Govt. agencies have been reviewed in order to get a realistic assessment of impact of town growth in the context of the present study.

The study also included reviewing the impact of plans, programmes and schemes with focus being primarily on appreciation of implications of envisaged development scenarios on the proposed project facility and on operationalisation of activities proposed in the region along the corridor. The review study had prime focus on the impact on travel demand levels in the corridor. In addition, the phasing, expected level and time of operation of these projects and consequent traffic generation levels were also evaluated. Based on the detailed review of the socio-economic parameters a set of economic indices per traffic zone was generated. On the basis of the expected economic growth for each traffic zone, these indicators have been projected annually up to the design year.

Estimate Generated and Induced Traffic

Some development activities in the project influence area of NH-248A are expected. The alignment is expected to yield benefits and might result in a rise in traffic demand on the surrounding roads. Keeping in view the large potential of development, information on related issues has been collected from concerned organizations and agencies to study likely traffic and to

arrive at realistic traffic projections. Generated traffic is also expected in the Influence Area by implementations of new town plans.

Estimate Diverted Traffic

A project of such nature is expected to attract a significant volume of traffic from other parallel corridors, once the proposed improvements are implemented. Hence, diverted traffic on the project corridor was also estimated based on shortest path route choice modelling after an in depth analysis of the journey speed and delay surveys and the Origin-Destination surveys. The divertible traffic has been projected independently and added to the stream flow of the project corridor at different phases of development.

Traffic Assignment

This most important task of assigning traffic on the corridor from other adjoining roads has been assessed by using the Capacity Restraint Assignment Technique. To establish the capacity of roads, the recommended capacity values in Indian Roads Congress (IRC: 64 and IRC: 106-1990) has been reviewed, and based on the speed-flow relations developed from the present study, the capacity values has been derived. The assessment of traffic load on the corridor has been made by mode and year. Travel time, distance and cost have been considered as affecting parameters for user assignment modelling. The traffic loads on the corridor has also been assessed with alternate toll structures. Further additional toll cost has been added to the Vehicle Operating Cost (VOC) for assignment purposes and traffic assignment has been estimated on the corridor.

Regional Traffic Components

The model has been able to replicate multi modal networks, there being a need to model the roads and the railways. This model uses “generalized costs” which embody not only vehicle operating costs and time costs but also factors reflecting levels of services. The standard categorization of traffic has been used, namely:

- Normal traffic;
- Diverted traffic; and
- Generated traffic, since the economic benefit to each type is calculated differently.

Normal traffic is the one whose travel does not change as a result of the network improvement. This traffic gains the value of the improvement in full measure. Generated traffic shifts modes because of the improvement. It gains by the cost margin between the modes.

3.5 ENGINEERING SURVEYS AND INVESTIGATIONS

3.5.1 Reconnaissance and Alignment

The consultant made an in-depth study of the available land width (ROW), topographic survey maps of the project area and other relevant information collected.

A detailed reconnaissance survey was conducted on the total section of the project road. Detailed information on existing features such as land use, habitation, water routes, canals, intersecting

roads, railway lines, utilities such as electrical lines (HT/LT), etc was collected from site. This enabled the Consultants to visualize the possible problems to be encountered while selecting the realignment. The detailed ground reconnaissance of project influence area is utilized for planning and programming the detailed surveys and investigations.

3.5.2 Topographic Surveys

Formulate Survey Program

The senior Survey Engineer visited the project corridors to gain knowledge on specific site problems, which enabled him to estimate the number of survey teams and survey equipments to be deployed.

Establish Horizontal and Vertical Controls

In order to ensure high degree of accuracy of survey, control points (cement concrete pillars) has been established at an interval of about 5 km apart along the road, using differential GPS techniques. Twin pillars has been fixed at these locations so as to enable further densification of control (200 to 300 m apart) along the road using total station traverse. Care was taken while establishing these points to locate them at safe places within the RoW and away from main construction area so that they can serve as permanent benchmarks for survey and layout at later stage.

The elevations (ellipsoidal heights) as obtained by GPS observations are not accurate for highway work and cannot be used. Therefore, the elevation of the control points has been established with respect to the GTS (Great Trigonometric Survey) benchmarks established by Survey of India. The exact elevations (RL) of these benchmarks were obtained, with the assistance of the client, and precision leveling was carried out by two leveling teams in fore and back direction and mean was taken to establish the elevation of all cement concrete pillars, and other control points using auto-levels.

For quick referencing additional benchmarks were established prior to initiation of the survey work and the intermediate distance between two BMs was kept not more than 250m, as specified in the ToR.

All these benchmarks will be tabulated with the following details and incorporated in the Final DPR for further reference during the construction period.

- Unique Identification Number
- Co-ordinates (X, Y and Z)
- Description of GPS Pillar/Bench Mark
- Sketch of GPS Pillar/Bench Mark with reference to permanent ground features

Collection of Cross Section Data

Collection of DTM data was started after completion of traversing and leveling as described in the previous activity. The data was collected using Total Station along the project corridor. The

survey corridor width was kept as 30m from the centre line on either side of road. The detailed field survey essentially covered the following:

All natural and manmade features such as buildings, trees, fences, transmission links, water lines, and others utility lines which fall within the RoW. As per requirements, intersections, bridges and culvert location survey data were collected as described below.

Intersection/Cross Roads: Where existing roads cross the alignment, the survey was extended till 100m on either side of the road centre line to allow improvements, including at grade intersections, to be designed.

Bridge Location Survey (Hydraulic Cross Section Surveys)

In the design of C.D structures, determination of waterways and span arrangements are important. In order to assess waterways and span arrangement, a hydraulic survey of CD structures is necessary. Hydraulic cross section survey was carried out as per the requirements of TOR and as procedure laid down in IRC: SP: 19.

Finalization of Strip Plans

The strip plans are updated based on the exact location of the physical features utility lines, property lines, location of CD structures, archaeological structures, bypass alignments etc., captured during the topographic survey.

3.5.3 Road and Pavement Investigations

Road Inventory

A detailed road inventory was carried out at 100 m intervals mainly for alternative alignments and visual inventory survey for other road network. Detail information was collected and utilized for planning, design and cost estimate.

Pavement Investigations

Pavement Composition: Besides collecting PWD data, trial pits were taken along the project road at every 2 km to ascertain pavement composition and subgrade type.

Pavement Condition Surveys: Detailed field studies were carried out to collect pavement condition, shoulder condition, embankment condition and drainage condition. The data has been analysed following IRC: 82.Benkelman Beam Deflection Survey: BBD Survey was conducted as per the requirement of TOR and procedure laid down in IRC: 81.

Subgrade Characteristics and Strength

Test pits were done for pavement investigation, soil samples were collected from these pits at every 5 Km intervals for laboratory investigations. Sand Replacement apparatus was used to derive the field density and Moisture meter was used for field moisture content.

3.5.4 Investigation of Quarry and Borrow Area Material

Samples were collected from the existing quarry and borrow area and appropriate tests as suggested in the ToR was carried out on the same to determine the suitability of the material to be used in embankment and pavement structures.

3.6 ENVIRONMENTAL AND SOCIAL SCREENING

Baseline Surveys

The baseline data required by Ministry of Environment & Forests, GoI includes the following components within the predefined study area (ROW and Adjacent areas):

- Water, land and air (natural physical resources);
- Fisheries, forestry, wildlife, and eco-systems (biological resources);
- Navigation, flood control and landuse (human use values); and
- Socio economic, aesthetic and cultural heritage (quality of life values)

The environmental resources and features will broadly cover the following:

Natural Physical Resources

Water includes:

- Location of principal watercourses, both perennial and seasonal
- Location of principal irrigation canals and drains
- The general drainage pattern in the vicinity of the route corridor
- The location of aquifer or recharge areas associated with potable water supply,
- The locations of lakes and reservoirs in the project area
- The presence of any areas where drainage is impeded, such as swampy areas, or where existing road embankments cut natural drainage patterns and there is upstream impedance to flow, etc.

Land includes:

- To identify whether erosion and land sliding will affect the route corridor,
- The availability of the soil survey maps of the area, etc.

Air includes:

- Information on current air quality from the Central Pollution Control Board or from regional offices, which maintain a network of monitoring stations established under the National Ambient Air Quality Monitoring (NAAQM) Programme.

Ecological Resources include:

- The location of any national parks, wildlife sanctuaries, nature reserves, biosphere reserves, primary forest, mangrove swamp other wetlands
- Information on any designated Ramsar sites

- Location of major concentrations of trees/green tunnel
- Location of any water bodies such as lakes, water courses (brackish, fresh water or tidal) where fisheries is important.

Human Use Values include:

- Navigation
- Landuse
- Services and other infrastructure

Quality of Life Values INCLUDE:

- Cultural heritage
- Noise climate
- Areas of particular scenic beauty and any tourist sites
- the information on the presence of any scheduled tribes and their particular lifestyle, characteristics etc.

Local Concerns include:

- Specific local environmental concerns to establish the nature and scale of any environmental problems which have occurred on recent road projects.

Identification of Issues and Hot Spots

For the project corridor, the environmental features have been tabulated along with their kilometer location and level of sensitivity. Using this approach, hotspots have been identified to help focus mitigation plans. This method will be used for all stretches that require future environmental analysis.

Pollution Indicators

Although virtually all of the information required establishing the environmental mapping of the project in the initial environmental screening is derived from secondary sources, the preliminary identification of the critical issues in the project area is understood more fully by carrying out well determined pollution monitoring. In addition, to review and assess the correctness of key information, it has to be checked through field observations.

Such pollution monitoring surveys were taken up at pre-selected locations (depending on the earlier established environmental capacity of road sections) with the objective of attaining a comprehensive picture of the whole corridor. Since this task is cost effective, the selectivity of the quantum of survey will be very important.

Following surveys were conducted:

- Air quality surveys which include monitoring pollution levels in terms of sulphur dioxide (SO2), oxides of nitrogen (NOx), Carbon monoxide (CO), lead (Pb), hydrocarbons (CHx).

- In particular near urban areas, a dust accumulation survey will be carried out with respect to total suspended particulate matter (SPM) and its respirable fraction (RPM).
- Noise level survey
- Water quality survey of important surface water bodies and drinking water sources

Environmental Impact Assessment

The Environmental Impact Assessment (EIA) is a valuable tool used to examine the potential adverse and beneficial consequences of a proposed development project, so that due consideration can be given to these aspects in further stages of project planning and design, and eventually during construction and operation.

The EIA involves identification and evaluation of the potential direct and indirect effects of a project on the individual environmental and social components, as well as any interactions between these. It also identifies ways and means through which unacceptable impacts can be avoided, offset, or minimized, and beneficial impacts enhanced.

The overall objective of the EIA is to ensure that potential environmental problems are recognized at an early stage in project preparation, so that these can be properly addressed during subsequent stages.

The EIA shall be used as a key management tool used to shape a project in such a way as to optimize its environmental performance in much the same way as engineering and economic studies are used in project preparation. It shall also play a major role in the decision-making process when project alternatives are being compared.

Social Impact Assessment

Data collected during the census and baseline socio - economic surveys was assessed.

A suitable methodology was evolved for the classification/ categorisation/ analysis of various impacts, as has been developed in house on similar projects.

The inventory of social resources in the probable impact zone will form the baseline for assessment of likely social impacts. Impacts were assessed in the immediate and extended influence zone of the road. Likely social impacts of the proposed project are:

- Loss of social resources such as trees, wells, temples, community space, etc.
- Loss of properties
- Loss of livelihood

Assessment of the impacts formed the basis of entitlement framework and the Resettlement Action Plan.

The census survey was undertaken as soon as adequate engineering details are known. A full census of all likely project affected persons (PAPs) within the area of direct influence (the existing RoW in most of the cases) was carried out along the highway corridor. This survey helped to identify in a comprehensive manner, the physical location of the PAPs.

Estimation of Costs and Budgeting for R&R

Market value assessment survey was conducted to estimate the market values of land, residential and commercial properties along the project corridor. To estimate the resettlement budget, the following costs apart from that of land acquisition were worked out:

- Inclusion of squatters and vulnerable groups in government housing schemes;
- Shifting assistance for properties needing relocation;
- Budget for vocational training and income generation schemes especially for the vulnerable groups;
- Contingency provision to accommodate any additional compensation assistance or land acquisition that was necessary.

3.7 ASSESSMENT OF REQUIRED DEVELOPMENT

From the existing field data a few scheme alternatives were evolved. This task made use of available data, site reconnaissance desk studies and preliminary findings. The standards, codes of practice and other relevant controlling documents were listed thereby establishing the procedures, design controls and general engineering practice required. In the review of project alignment due consideration was given to the environmental implications land take and impact on project affected people, using information provided in the discipline Desk Study Reports undertaken earlier.

3.7.1 Widening and Strengthening scheme

The project section under the scope of study has multidimensional facets in terms of geometry, pavement composition/ condition, existing utilities, religious structures, etc. and considering all these aspects the section-wise policy was adopted for strengthening and widening based on the initial investigations.

3.7.2 Bypasses and Realignments

The requirement of bypasses and realignments were assessed from detailed desk study, field and topographic survey and revenue data of existing ROW. An Alignment Option Study Report has been prepared and submitted for approval of the recommended option.

3.7.3 Homogeneous Section

The project road has been divided into homogeneous road sections on the basis of following and traffic generation, and dispersal nodes located along the project road.

- Traffic
- Pavement Composition and thicknesses

3.7.4 Pavement Design

Pavement is the most significant component of a road and therefore its design strengths must be assured to support the projected traffic loading throughout the design period. The pavement

option study consist of analysis of different pavement alternatives to provide a basis for selection of the most advantages solution, considering all costs occurring during the life of the pavement, viz., construction costs, future maintenance costs and future costs for the road users.

In pavement option study, following has been studied in detail:

- Flexible pavement over the existing pavement
- New flexible pavement with flexible hase (WMM + GSB)
- New flexible pavement with rigid base (CTB + CTSB)
- Flexible Pavement for full reconstruction stretches of existing pavement.
- New Rigid Pavement

Rigid Pavement has been proposed at Toll plaza location.

3.7.5 Bridges and Culverts

Wherever reconstructions of existing bridges are proposed, parallel bridges are proposed to be built either on upstream side or on downstream side as per site requirement. Either span arrangement will be kept similar to the existing bridges or a combination of two/three spans will be adopted. In some cases it is proposed to keep only one span to cover the stream.

3.8 PRELIMINARY COST ESTIMATES

Cost Estimates were made based upon the improvement proposals and rates mostly derived from **Basic Schedule of Rates, Haryana (2014)** but suitably modified to update with the existing market rates. Where alternatives have been identified within the design, each will be evaluated to an accuracy of +/- 15% so that a reasonable assessment can be made on the balance of costs against benefits. Cost estimates were compared with recent designed, ongoing and executed National Highways Projects.

3.9 FINANCIAL STUDY

The financial viability of each package depends on the working cash flows available to service the debt and equity. This working cash flow is basically dependent upon the following:-

a) Project Cost

b) Traffic & Traffic Growth

c) Toll Structure

d) Operation and Maintenance expenses

e) Interest on Debt

f) Tax

The main objective of Financial Analysis is to examine the viability of implementing the project on a BOT basis. The analysis attempts to ascertain the extent to which the investment can be recovered through toll revenue and the gap, if any, be funded through Grant / Subsidy. This covers aspects like financing through debt and equity, loan repayment, debt servicing, taxation, depreciation, etc. The viability of the project is evaluated on the basis of Project FIRR (Financial

Internal Rate of Return on total investment). The FIRR is estimated on the basis of cash flow analysis, where both costs and revenue have been indexed to take account of inflation. Financial analysis has been carried out for the one individual package with debt equity ratio of 70:30.

3.10 MODE OF IMPLEMENTATION AND PACKAGING

Based on the output of financial analysis the mode of implementation has been decided, i.e. whether to opt for BOT (Toll) mode or for EPC or for Hybrid Annuity.

Construction packages are decided based on ease of construction and the requirements of NHAI.

3.11 FEASIBILITY REPORT

The Feasibility Study culminates with the submission of the Revised Final Feasibility Report(Revision no. - R2).

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CHAPTER-4: SOCIO-ECONOMIC PROFILE OF THE PROJECT AREAS

4.1. INTRODUCTION

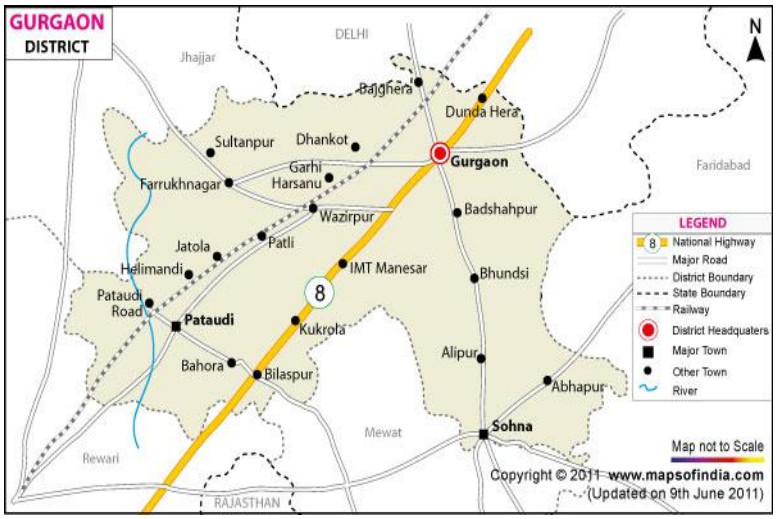
The project influence areas of the proposed project road are located in the districts of Gurgaon and Mewat in the state of Haryana. The project road in package-II starts from km 11+682 of NH-248A and ends at 24+400 of NH-248A. However the project road under Package –II falls in the Gurgaon district. In order to appreciate the socio-economic profile of the influence area of the project corridor, a micro-level analysis has been done.

The description of socio-economic features of the Gurgaon district comprises the demographic, social and economic aspect of the population, it includes the features of population distribution, density of population, workforce and share of workers in major economic categories; and the vulnerable groups.

The physical and socio-economic profile of both the districts concerned is illustrated separately in the following sections.

4.1.1 Gurugram (Gurgaon) - The Physical Features and the District Profile

Area and Location



Gurgaon district is situated in NCR of Delhi, the capital of India. It is just 10 kms away from Indira Gandhi International Airport, Delhi. The district derived its name from the name of Guru Dronacharya; the village was given as Gurudakshina to him by his students; the Pandavas and hence it came to be known as Guru-gram, which in course of time got distorted to Gurgaon. Thus the district has been existence since the times of Mahabharata. The district is surrounded by Delhi & Rajasthan.

Gurgaon district is the southern-most district of Haryana. The district lies between 27º39' and 28º32' 25" latitude, and 76º39' 30" and 77º20' 45" longitude. On its north, it is bounded by the district of Rohtak and the Union Territory of Delhi. Faridabad district lies to its east. On its south, the district shares boundaries with the states of Uttar Pradesh and Rajasthan. To its west lies the district of Rewari and the State of Rajasthan. Gurgaon town is about 32 km away from New Delhi, the National Capital of India.

Administratively, Gurgaon district is divided into 3 sub-divisions: Gurgaon North, Gurgaon South and Pataudi, which are further divided into five revenue tehsils, namely, Gurgaon, Sohna, Pataudi, Farukh Nagar, Manesar. It also comprises four rural development blocks, Pataudi, Sohna, Gurgaon and Farrukhnagar.

Climate and Rainfall

The district experiences four distinct seasons - spring (February - March), summer (April - August), fall/autumn (September - October) and winter (November - January), along with the monsoon season setting in towards the later half of the summer. Summers, from early April to mid-October, are typically hot and humid, with an average daily June high temperature of 40 °C (104 °F). The season experiences heat indices easily breaking 43 °C (109 °F). Winters are cold and foggy with few sunny days, and with a December daytime average of 3 °C (37 °F). The Western Disturbance brings some rain in winter that further adds to the chill. Spring and autumn are mild and pleasant seasons with low humidity. The monsoon season usually starts in the first week of July and continues till August. Thunderstorms are not uncommon during the Monsoon. The average annual rainfall is approximately 714 millimeters (28.1 in).

Agriculture

The main crops of Gurgaon district are Wheat, Bajra, Paddy, Rapeseed Mustard, vegetables (Chilli, tomato, etc.) Fruits (Guava, Aonla, etc.), and fodder crops etc. are chief cash crops of district. Some of the more enterprising formers have now taken to a crop each of Kharif onion which is providing to a very good in terms of yield and the returns for the formers.

The predominate farming system in Gurgaon district is Agriculture integrated with Animal Husbandry. The major cropping systems under the existing farming system are bajra, wheat, bajra-mustard guar-wheat and guar-mustard. Buffalo is the main component under animal husbandry. Wheat and Mustard are the main crops in rabi, which occupy 49,833 ha and 21,967 ha, respectively with an average productivity of 36.80 and 12.40 q/ha. In kharif, bajra is the major crop occupying 32,833 ha with the productivity of 14.25 q/ha.

Forest

The district is almost bereft of vegetation, as the area under forests in the district is merely 3000 hectare. There is 2.5% of total geographical area of district under forest cover. Mostly the xeric species dominates in the district. Tree species found are Prosopis, Acacia, Salvedora, Shisham, Albizia, Neem etc.

Industries

Gurgaon has now emerged to become the city with the third highest per capita income in India. Popularly known as Millennium City, Gurgaon has the presence of about 250 or 50% of the Fortune 500 companies. Gurgaon's proximity to Delhi means easy access to political decision makers. Maruti Suzuki Private Limited was the first company that set up a manufacturing unit in the city in 1970s making cars. Eventually, DLF Limited, a real estate company acquired vast stretches of land in the city. The first major American brand to set up a unit in Gurgaon was General Electric in 1997. GE's setup in Gurgaon prompted other companies, both international as

well as domestic, to follow suit. Today, Gurgaon has emerged as one of the most important offshoring centers in the world, providing outsourcing solutions in software, IT, service and sales through delivery facilities and call centers.

There are 22491 Registered Industrial Unit, out of that 436 are Medium & Large Unit, 2000 Engineering units, 1255 are Ready-made garments & embroidery, 1035 are Metal based (Steel Fab.) and 145 are Leather based industries.

Infrastructure in Gurgaon District

- **Education**

  The District, public school system, managed by the government of Haryana, is administered by Haryana Board of School Education. The city also has a large number of private schools, where education is often expensive and the quality usually better than the government schools. Schools like The Shri Ram School - Aravali, the Ardee World School, Sector 52, The Heritage School, DAV Public School Sector 14 and Amity International School are among the top 10 schools in the city, according to the 2013 Hindustan Times - C fore Top Schools Survey.

  There are several universities and institutes located in Gurgaon and its nearby areas, that form a part of Gurgaon district including Ansal Institute of Technology; ITM University, Sector 23A; GD Goenka University, Sohna Road; KR Mangalam University, Sohna Road; Amity University, Manesar; Apeejay Stya University, Sohna; BML Munjal University, NH8; Shree Guru Gobind Singh Tricentenary University, Budhera; and National Brain Research Centre, Manesar. Gurgaon is also home to one of India's top ranked business school, Management Development Institute.

  Gurgaon district has 599 Primary Schools, 186 Middle Schools, 263 Secondary & Senior Secondary Schools and 9 Colleges.

- **Health Services**

  Gurgaon has many hospitals and a number of medical research facilities within its city limits. Some of the private hospital include Fortis Hospital, Medanta, Max Hospital and Columbia Asia Hospital. Gurgaon has become an increasingly popular destination for medical tourism.

  The District has 6 Allopathic, 12 Ayurvedic, 12 Primary Health Center, 1 Community Health Center, 8 Sub Health Center and 71 Private Hospitals.

- **Airways**

  Gurgaon is served by Indira Gandhi International Airport, though the airport is just outside the city limits and located within the jurisdiction of Delhi near National Highway 8. The airport is one of the busiest airports in India and provides domestic and international air connectivity.

- **Railways**

  Intercity rail:

  Gurgaon railway station operated by Northern Railway of Indian Railways. The rail station that forms a part of the larger Indian railways network, where trains connect Gurgaon to Delhi and other important cities in India like Mumbai, Kolkata, Ahmadabad and Jaipur.

  Delhi Metro:

  There are five stations served by Delhi Metro located on the Yellow Line, which are HUDA City Centre, IFFCO Chowk, MG Road, Sikanderpur and Guru Droncharya.

  A line connecting HUDA City Centre Metro Station to Bawal via Kherki Daula has also been proposed.

  Rapid Metro:

  Currently Rapid Metro Gurgaon have six stations, connecting Yellow Line of Delhi Metro at Sikandarpur metro station, which are Sikanderpur, Phase 2, Vodafone Belvedere Towers, IndusInd Bank Cyber City, Micormax Moulsari Avenue and Phase 3. Two stations, Shankar Chowk and Gateway tower, are scheduled to become operational soon. The first phase of Rapid Metro became operational in November 2013 and covers a distance of 3.3 mi. Two more phases of the project are in the pipeline and would take the total number of subway stations in Gurgaon to 16. An estimated 33,000 people ride Rapid Metro everyday, which provides an exclusive elevated transit service with three coach trains that run in a loop.

- **Road System**

  The major highway that links Gurgaon is National Highway 8, the road that runs from Delhi to Mumbai. While the 27.7-kilometre (17.2 mi) Delhi-Gurgaon border-Kherki Dhaula stretch has been developed as an expressway, the rest is expanded to six lanes. The second Highway Is Dwarka Expressway, Which Starts from Gurgaon and linked to New Delhi's various major Inter cities.

- **Dedicated Freight Corridor**

  Western Dedicated Freight Corridor has been proposed to cross the project road in village Sohna of distric Gurgaon. It would cross the project road at PWD R.D. 27+170.

- **Intercity buses:**

  Gurgaon bus terminal, managed by Haryana Roadways, is a busy bus station in the city that provides bus connectivity, both private and government, to other cities in Haryana and neighboring states like Delhi, Uttar Pradesh and other cities like Chandigarh.

- **Places of Interest**

  Damdama Lake: Damadam Lake is a nice place to have day trips, picnic and family outings. The place is located near the Aravalli hills. It is one of the biggest lakes in Haryana. Boating is one of the most popular activities for tourists who visited the place; one can opt from the range of boats like row boats, paddle boats and motor boats, whichever is convenient for them. The place is also known for its various adventurous activities like rock climbing, hot

air ballooning, para sailing, cycling, trekking etc. Bungee jumping is also available by paying extra. Location: Gurgaon; 45 km From Dhaula Kuan, Delhi

Sheetala Devi Temple: Gurgaon has numerous temples but one of the most famous and most visited temples in Gurgaon is Sheetala Devi temple. The temple is situated on a side of a beautiful pond. The temple witnesses many visitors throughout the year, but is very much crowded during the month of Chitra, especially Mondays, as they are considered very auspicious. Different devotees have different reasons to come to the temple, sometimes the occasion can be the "mundan ceremony", or some come with a purpose of offering prayers to the goddess to protect them from the disease like small-pox. The infrastructure of the temple is commendable.

Sultanpur Bird Sanctuary: This is a small sanctuary that has a fresh water lake, and the rest of the area is surrounded by cultivated plains. The main "salt pan", dries up in the summers but get back to its normal state after a heavy monsoon and attracts number of migratory birds, most of the birds that are found here are: pelicans, flamingos, ducks, geese. Sunrise over the Sultanpur Lake is an experience that no one coming to Gurgaon should miss. Though the place is open all through the year the best time to visit is November to February and March to April if it has been a year of good rain.

Sohna: The place is situated at the foothills of Aravallis and is most famous for the Shiv temple and hot water springs. It is believed that the well was dug by one of the brothers of Pandavas named Arjun when he was feeling thirsty, the temperature of the water varies from 46 ° C to 51.7 ° C . The place also has a grand park which is situated at the top of the hills.

Kurukshetra: The land of Kurukshetra has got religious and spiritual importance. The place is considered to be very religious. Famous places to visit in Kurukshetra are: Jyotisar, Sannihit Sarovar, Brahma Sarovar, Krishna museum etc. The place is a real paradise for people who believe in spirituality.

Devi Art Foundation: The center is among the first few non-profit centers that showcase the creative talent from the Indian subcontinent. It gives an opportunity to the audiences to know more about modern and new technique of art.

Kingdom of Dreams: This six acre entertainment park is most famous for hosting the grandest Bollywood musical in the country. If you’re lucky, you’ll catch Zangoora, it's longest-running show. Other attractions include Culture Gully, a recreated Indian street with themed restaurants, a live arts and crafts village and 14 state pavilions; mythological shows at Showshaa Theatre and a Bollywood-themed restaurant.

4.2 DEMOGRAPHIC PROFILE OF THE DISTRICTS

Population

The project road under Package-II falls in the district of Gurugram (Gurgaon) in Haryana state and it is expected that about 6.0 % of the State population are likely to be directly or indirectly benefited by the project road under this package (**Table 4.1)**.

Table 4.1: Affected Population

State/ Districts	Population		
	Male	Female	Total
Haryana	**13,494,734**	**11,856,728**	**25,351,462**
Gurugram (Gurgaon)	816,690	697,742	1,514,432

Source: Census of India 2011

Population Density

Population density of the affected districts varies considerably as per the census data of 2011 which clearly suggests that the density of population in the project influenced area is greater than that of the state. Haryana has a population density of 573 persons/ sq. km. and in the affected districts about 1204 persons/ sq. km in Gurgaon district as detailed in **Table 4.2**.

Table 4.2: Population Density of the Affected Districts

State/ District	Population Density	
	2001	2011
Haryana	**478**	**573**
Gurugram (Gurgaon)	716	1204

Source: Census of India 2011

Rural and Urban Population

In the state of Haryana, 65.12% of total population is rural and 34.88% is urban. In Gurgaon district 68.82% is urban of total population and 31.18% is rural area. However, majority of the population in the affected Gurgaon district is dependent on other work. The figures make it evident that the proposed road will pass through and cater to the needs of highly ruralised parts of our country.

Sex-Ratio

Sex ratio of the influenced districts presents the scenario of state. Sex-ratio of Haryana is 879 female per thousand male. Sex-ratio of the influence in Gurgaon district is lower that the state as shown in **Table 4.3**.

Table 4.3: Sex ratio in the state and project district

States/District	Overall Sex Ratio	Child Sex Ratio (Age group of 0-6 yrs)
Haryana	**879**	**834**
Gurugram (Gurgaon)	854	830

Source: Census of India 2011

Decadal Growth Rate

It is evident from 2011 census the decadal growth rate for 2001-2011 of Haryana is about 19.90% which is less than the growth rate of 1991-01. Similarly, the growth rate in 2001-11 of the Gurgaon district is higher than the growth rate in 1991-01 as shown in **Table 4.4**.

Table 4.4: Decadal Growth Rate

State/ District	1991-2001	2001-2011
Haryana	**28.06**	**19.90**
Gurugram (Gurgaon)	44.15	73.96
Mewat	45.67	37.93

Source: Census of India 2011

Vulnerable Population

As per the Government of India guidelines, people belonging to Scheduled Castes & Scheduled Tribes, physically handicapped, women headed household, families below poverty line, disabled persons and destitute persons are to be considered as vulnerable population.

The census data, 2011 reveals that the percentage of Scheduled Caste in the influenced districts is less than that of the state. With respect to Schedule Tribe population, State has no ST population as detailed in **Table 4.5**.

Table 4.5: Total Schedule Caste and Schedule Tribe

State/ District	Total Population	SC Population	ST Population	Percentage of SC out of total population	Percentage of ST out of total population
Haryana	**0**	**5,113,615**	**0**	**20.17**	**0.00**
Gurugram (Gurgaon)	1,514,432	197,937	0	13.07	0.00

Source: Census of India 2011

4.3 THE SOCIAL SERVICES

Literacy and Education

Literacy rate of the influenced district Gurgaon is higher than the state. Gurgaon has the literacy rate of 84.70%.

Table 4.6: Literacy Rate

Sl. No.	District	Literates Population	Literacy Rate (in %age)
1	***Haryana***	**16,598,988**	**75.55**
2	Gurugram (Gurgaon)	1,111,116	84.70

Source: Census of India 2011

4.4 ECONOMIC FEATURES

Distribution of Population by Workers, Non-workers & Occupation

Other work is the main occupation of its inhabitants in the Gurgaon district. As evident from **Table 4.7**, non-workers exceed main-workers, showing relatively low dependency ratio.

Table 4.7: Distribution of Population by Workers and Non-Workers

State/ District	Population	Male	Female	Total
Haryana	Main Workers	5860600	1154683	7015283
	Marginal Workers	946036	955189	1901225
	Non- Workers	6688098	9746856	16434954
	Total	**13494734**	**11856728**	**25351462**
Gurugram (Gurgaon)	Main Workers	400386	87055	487441
	Marginal Workers	32070	25205	57275
	Non- Workers	384234	585482	969716
	Total	**27806158**	**24411198**	**52217356**

Source: Census of India 2011

Table 4.8 contains occupational structure of work force in the project affected districts. Occupation in Other Work is greater than other three sectors in Gurgaon. In the project affected district, higher percentage of workers are involved in other workers and rest of workers are involved in either cultivation or agriculture activities and few are involved in HH industries as shown in **Table 4.8**.

Table 4.8: Categories of Workers

State/ District	Categories	Male	Female	Total
Haryana	Cultivators	1789122	691679	2480801
	Agricultural Labourers	1041241	486892	1528133
	HH industries/	186533	75747	262280
	Other Workers	3789740	855554	4645294
	Total	**6806636**	**2109872**	**8916508**
Gurugram (Gurgaon)	Cultivators	41842	14204	56046
	Agricultural Labourers	19113	7984	27097
	HH industries	13764	4464	18228
	Other Workers	357737	85608	443345
	Total	**432456**	**112260**	**544716**

Source: Census of India 2011

4.5 SOCIAL AND DEMOGRAPHIC PROFILE OF THE AFFECTED VILLAGES

A social and demographic profile of the project-affected area/population is essential to create database and develop indicators for the evaluation of the SIA. To understand the social context of the proposed project and for providing necessary inputs for social analysis of the project, relevant baseline data on social and cultural conditions were collected from various available primary and secondary sources like personal observation and enquiry, consultation with knowledgeable persons of the villages etc. Due to the implementation of project several villages or urban settlements in the affected district of Gurgaon is likely to be affected. On the basis of social survey those settlements and villages have been identified and the same has been documented in the report. The important demographic features of the villages, i.e., population, social categories, literacy level and economy of the village are described as a part of baseline data in the following manner:

Population

The population composition of any village is important to anticipate the extent of project impact. Keeping in mind the importance of demographic profile, the population of the villages was computed.

The composition of population with respect to male and female population of potential affected villages/ settlements is shown in **Table 4.9**.

Table 4.9: Distribution of the Population of different villages with sex composition

Sr. No.	District	Village Name	Male	Female	Total
1	Gurgaon	Nurpur Jharsa(165)	595	538	1133
2	Gurgaon	Tikli(167)	3484	3156	6640
3	Gurgaon	Badshahpur (87)	8209	7384	15593
4	Gurgaon	Bhondsi (168)	10245	7165	17410
5	Gurgaon	Ghamroj(179)	2494	2303	4797
6	Gurgaon	Alipur(180)	1789	1609	3398

Source: Census of India 2011

Social Classification

It is very important to identify vulnerable population during Social Impact Assessment. Social survey data was applied to understand the social classification in affected settlements/ villages. The data reveals that the percentage of Schedule Tribes is very low in comparison to the Schedule Caste. The assessment of the population under different social categories in the concerned settlements/villages is discussed in **Table 4.10**.

Table 4.10: Social Classification in Villages

Sl. No.	Name	Scheduled Castes			Scheduled Tribes		
		Male	Female	Total	Male	Female	Total
1	Nurpur Jharsa(165)	45	39	84	0	0	0
2	Tikli(167)	851	796	1647	0	0	0
3	Badshahpur (87)	1488	1384	2872	0	0	0
4	Bhondsi (168)	948	751	1699	0	0	0
5	Ghamroj(179)	427	376	803	0	0	0
6	Alipur(180)	304	270	574	0	0	0

Source: Census of India 2011

Educational Status

As per the Census 2011 data, the number of male literates are higher that the female literates. The **Table 4.11** delineates the literate and illiterate population of the villages.

Table 4.11: Number of Literates and Illiterates in the Project Influence Villages

Sl. No.	Name	Literates			Illiterates		
		Male	Female	Total	Male	Female	Total
1	Nurpur Jharsa(165)	474	377	851	121	161	282
2	Tikli(167)	2773	2033	4806	711	1123	1834
3	Badshahpur (87)	6165	4646	10811	2044	2738	4782
4	Bhondsi (168)	8367	5078	13445	1878	2087	3965

Sl. No.	Name	Literates			Illiterates		
		Male	Female	Total	Male	Female	Total
5	Ghamroj(179)	1953	1506	3459	541	797	1338
6	Alipur(180)	1422	1031	2453	367	578	945

Source: Census of India 2011

Workforce in Project affected villages

Majority of work force belongs to the category of main workers followed by the category of marginal workforce. The details of the affected village wise are summarized in **Table 4.12**.

Table 4.12: Workers in the Project-Affected Villages

Sl. No.	Name	Main Workers			Marginal Workers			Total Workers
		Male	Female	Total	Male	Female	Total	
1	Nurpur Jharsa(165)	259	142	401	17	6	23	424
2	Tikli(167)	1531	545	2076	290	316	606	2682
3	Badshahpur (87)	3490	432	3922	371	48	419	4341
4	Bhondsi (168)	4582	301	4883	194	27	221	5104
5	Ghamroj(179)	1036	91	1127	75	126	201	1328
6	Alipur(180)	780	87	867	9	2	11	878

Source: Census of India 2011

Category wise Distribution of Workforce

It is well evident from the below table that people of the likely affected villages are either engaged in cultivation or in other work. Haryana is one of the industrial hub of the nation thus most of the people engaged in industrial as well as household activities. However, agriculture also plays an important sector in the engaging the workforce as is shown in **Table 4.13**.

Table 4.13: Distribution of Workforce in Project Affected Villages

Sl. No.	Name	Cultivators			Agricultural Labourers			Household Industries			Other Workers			Non Workers			Total		Total
		Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	
1	Nurpur Jharsa(165)	61	3	64	6	5	11	3	54	57	206	86	292	319	390	709	595	538	1133
2	Tikli(167)	622	409	1031	295	151	446	104	134	238	800	167	967	1663	2295	3958	3484	3156	6640
3	Badshahpur (87)	413	36	449	281	72	353	193	30	223	2974	342	3316	4348	6904	11252	8209	7384	15593
4	Bhondsi (168)	364	2	366	124	9	133	92	11	103	4196	306	4502	5469	6837	12306	10245	7165	17410
5	Ghamroj(179)	133	117	250	64	23	87	18	4	22	896	73	969	1383	2086	3469	2494	2303	4797
6	Alipur(180)	217	37	254	62	5	67	9	6	15	501	41	542	1000	1520	2520	1789	1609	3398

Source: Census of India 2011

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CHAPTER-5: TRAFFIC SURVEY & ANALYSIS

5.1 INTRODUCTION

Analysis of the existing traffic flow data is extremely important to understand the current travel characteristics along with its problems and constraints and also to identify future improvement requirements of the project corridor.

The present chapter covers traffic and travel characteristics of the vehicles moving on the project corridor.

Traffic and travel characteristics also vary spatially and temporally. To appreciate these, extensive traffic surveys at number of locations, covering the entire corridor, have been carried out. The list of traffic and travel surveys conducted is mentioned below:

- Classified Traffic Volume Count Survey
- Origin-Destination Survey
- Turning Movement Count Survey
- Axle Load Survey

5.2 HOMOGENOUS SECTIONS FOR TRAFFIC SURVEYS

Based on Preliminary Reconnaissance, the project road was divided into six traffic homogenous sections in such a way that traffic intensity within a particular section will be more or less uniform. The homogenous sections (HS) identified are listed below:

Table 5-1 : Details of Homogenous Sections

Homogenous section	From km to km	Length (km)	Remarks
HS-1	0+000 - 4+900	4.9	Rajiv Chowk – Ashram Chowk
HS-2	4+900 - 23+300	18.4	Ashram Chowk - Sohna
HS-3	23+300 - 42+630	19.33	Sohna - Nuh
HS-4	42+630 - 63+700	21.07	Nuh - Bhadas
HS-5	63+700 - 80+060	16.36	Bhadas - Firozpur Jhirka
HS-6	80+060 - 93+960	13.9	Firozpur Jhirka - Rajasthan Border

5.3 PRIMARY TRAFFIC SURVEYS

Different type of primary traffic surveys were conducted during the month of July 2016. Type of primary surveys conducted along with the survey locations and schedule of conducted surveys is mentioned in Table 5-2.

Table 5-2 : Traffic Survey Locations and Schedule

Survey ID	Type of Survey	Section/Location	Chainage	Date
T1	7-days Classified Traffic Volume Count Survey (TVC)	Rajiv Chowk – Ashram Chowk	3+000	31/07/16 – 02/08/16
T2		Ashram Chowk - Sohna	21+000	27/07/16 – 2/08/16
T3		Sohna – Nuh	30+000	22/07/16 – 28/07/16
T4		Nuh - Bhadas	46+000	21/07/16 – 27/07/16
T5		Bhadas - Firozpur Jhirka	77+000	21/07/16 – 27/07/16
T6		Firozpur Jhirka - Rajasthan Border	84+000	21/07/16 – 27/07/16
O1	1 day Origin-Destination Survey (OD)	Ashram Chowk - Sohna	21+000	02/08/16
O2		Bhadas - Firozpur Jhirka	77+000	27/07/16
O3		Firozpur Jhirka - Rajasthan Border	84+000	25/07/16
M1	1- day Turning Movement Count Survey (TMC)	Ashram Chowk - Sohna	9+700	03/08/16
M2		Ashram Chowk - Sohna	19+800	03/08/16
M3		Sohna – Nuh	30+800	29/07/16
M4		Nuh - Bhadas	41+200	29/07/16
M5		Nuh - Bhadas	42+630	29/07/16
M6		Nuh - Bhadas	54+300	27/07/16
M7		Bhadas - Firozpur Jhirka	63+700	26/07/16
M8		Firozpur Jhirka - Rajasthan Border	80+060	22/07/16
A1	1 day Axle Load Survey	Bhadas - Firozpur Jhirka	44+000	31/05/16
A2		Firozpur Jhirka - Rajasthan Border	85+000	30/05/16

Methodology adopted for conducting the surveys mentioned in the table above along with the location details is discussed in the following section.

5.4 SURVEY METHODOLOGY

5.4.1 Classified Traffic Volume Count

Classified Traffic volume survey is conducted to know the quantum of vehicles passing through a given section of road over a period of time. The survey is also important to understand the following:

- to determine the road widening and widening/strengthening requirement.
- to check the efficiency of the network by comparing existing traffic with LOS or with the capacity.
- to understand the improvement requirement of new/existing intersections.
- to estimate future traffic flows.
- To suggest traffic management measures like traffic signals, one-way road and no entry for certain class of vehicles etc.

Classified Traffic Volume surveys also help to appreciate the traffic characteristics in terms of total volume, hourly variation, volume/capacity (V/C) ratio, modal composition, peak hour traffic share and directional split of traffic at each survey locations.

The survey can be conducted by various methods like using automatic counter, Pneumatic tubes, inductive loops etc. but mainly manual counts are carried out considering variation in axle types moving on Indian roads.

For the present study, Manual Classified Traffic Volume Counts were conducted at Five locations along the project road i.e. one in each homogeneous section. The survey was conducted round-the-clock for 7 consecutive days. The count stations were selected away from any local hindrance and the results represent the actual traffic flow in each of the homogenous section. Average Daily Traffic (ADT) was obtained from the seven day count data. This value was then converted to Annual Average Daily Traffic (AADT) by applying the Seasonal Correction Factor (SCF). For recording classified traffic volume data, vehicles were grouped into the categories as mentioned in Table 5-3. Toll exempted vehicles were recorded separately to estimate the tollable traffic. This is important if the government agencies want to develop this road on Public Private Partnership (PPP) mode. Similarly, Non-motorized traffic modes were counted separately to estimate the specific requirement of these modes and to address the same during design of the project corridor.

Table 5-3 : Vehicle Classification System

Motorized Vehicle		**Non-motorized Vehicle**
2 wheelers		Bicycle
Auto Rickshaw, Auto Goods		Cycle Rickshaw
Passenger Car : Car, Van, Jeeps, Taxi		Animal Drawn/Hand Cart
Bus	Mini Bus, School Bus, Govt. Bus, Pvt. Bus	
Truck	Mini LCV, Light Commercial Vehicle (LCV), LCV (6 - Tyre)	
	2, 3 – Axle Rigid Chassis Truck (HCV)	
	(4 - 6 Axle) Multi Axle Truck(MAV), (=>7 Axle)MAV, HCM	
Tractor	Agriculture Tractor, Tractor & Trailer	
Toll Exempted Vehicles	Army vehicles, Fire tenders, Ambulances, selected Govt. vehicles	

Manual Classified Counts

Traffic volume counts were by trained enumerators using hand tally marks. The count data was recorded with 15-minute intervals for each vehicle group, for both directions. The counts were made separately for motorized and non-motorized traffic as per the vehicle classification system mentioned in Table 5.3. In addition, toll exempted vehicles, which include Government vehicles; ambulances, Military Vehicles, Fire Tender etc. were also recorded separately.

TVC survey locations with their respective chainage are mentioned in Table 5-4 and also showing in Figure 5-1. The questionnaire used to record the traffic volume data is presented in Appendix 5-1

Table 5-4 : TVC Survey Locations

Loc No.	Section	Location Name
1	Rajiv Chowk - Ashram Chowk	Tikri @3+000
2	Ashram Chowk – Sohna	G. D Goenka University @21+000
3	Sohna – Nuh	Kherli Kankar near KMP Expressway @30+000
4	Nuh – Bhadas	Nizampur Nuh @46+000
5	Bhadas - Firozpur Jhirka	Dhanwala @77+000
6	Firozpur Jhirka - Rajasthan Border	Maholi @84+000

5.4.2 Origin-Destination(OD) Survey

The objective of the OD survey was to assess the travel pattern of passenger and freight vehicles moving on the corridor and the desire of trips performed by these modes in terms of destined and through trips. OD survey record the trips in terms of its origin, destination, purpose, trip length of a trip in case of passenger vehicles and origin, destination, commodity carried, trip length in case of freight modes. The survey locations are shown in Figure 5-1. The questionnaire used to record the data for passenger and freight vehicles is given in Appendix 5-2

Survey Duration & Methodology: The survey was carried out on a working day for 24 hours by using road side interview method. Each motorized mode (passenger and freight) were stopped on a sample basis to record the information about the trip. On an average, a sample size of 20% or more as recommended in IRC-SP-19-1981 was achieved. The details of sample collected for different modes at each of the OD survey location are mentioned in Table 5-5.

Table 5-5 : Sample Size captured for Different Vehicles

Modes	Locations		
	G. D Goenka University (@km21+000)	Dhanwala (@km77+000)	Maholi (@km 84+000)
(Passenger Vehicles)			
Car/Jeep/Van	88%	95%	92%
Taxi (Yellow Board)	-	-	1%
Mini Bus	1%	-	-
Private Bus	11%	5%	7%

Modes	Locations		
(Freight Vehicles)			
L C V	1%	-	1%
2-axle Truck	41%	30%	35%
3-axle Truck	55%	48%	44%
4 – 6 axle	319%	22%	21%
7+ axle	1%	-	-

Vehicles moving in each direction were surveyed and the information was recorded by trained enumerators. OD Survey Locations were selected in such a way that they capture the travel pattern of the vehicles moving on the project corridor and its interaction with outside regions as well as on the places lying along the project corridor. The OD survey locations are listed in Table 5-6**.**

Table 5-6 : OD Survey Locations

Loc No.	Road Section	Location Name
1	Ashram Chowk - Sohna	G. D Goenka University (@21+000)
2	Bhadas -Firozpur Jirka	Dhanwala (@77+000)
3	Firozpur Jhirka - Rajasthan Border	Maholi (84+000)

5.4.3 Turning Movement Count Survey

Turning Movement Surveys were carried out to determine the directional movement of traffic at each intersection. Turning movement surveys were carried out at eight major intersections as mentioned in Table 5-1and shown in Figure 5-1. The questionnaire used to carry-out the survey is presented in Appendix 5-3. Enumerators were stationed at each arm of the junction to note the number of vehicles entering through each arm and the direction of their exit. Volume counts of all vehicle types were made separately for all directions. The survey was conducted for 24 hours at each of the survey locations.

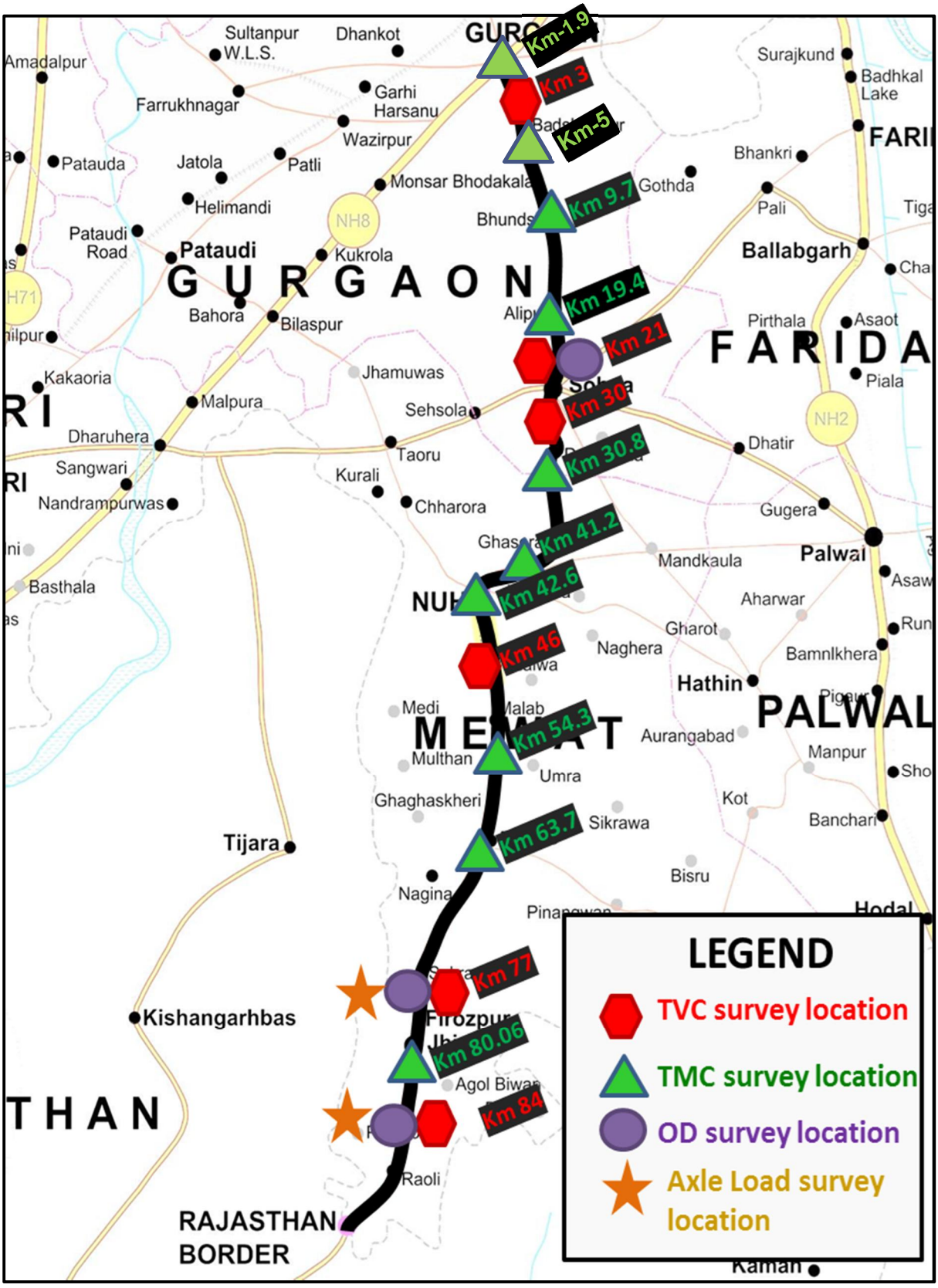


Figure 5-1 Traffic Survey Locations

5.5 DATA ANALYSIS

5.5.1 Traffic Characteristics

Traffic Characteristics obtained by analysing the survey data are expressed in terms of total flow, its modal composition, hourly variations and peak traffic flows.

As the counted traffic is composed of different type of vehicles, it is normal practice to convert the flow into equivalent Passenger Car Units (PCU) by using certain equivalence factors. The flow is then expressed as PCU per hour. PCU factors mentioned in IRC-64-1990,'Guidelines for capacity of Roads in Rural Areas' are used and these are presented in Table 5-7.

Table 5-7 : Passenger Car Unit Values Adopted

Vehicle Type	PCU		Vehicle Type	PCU
Car	1.0		Auto Rickshaw	1.0
Mini Bus	1.5		Van/Tempo	1.0
Standard Bus	3.0		Agricultural Tractor	1.5
LCV	1.5		Agricultural Tractor & Trailer	4.5
2 Axle Truck, Tipper	3.0		Animal Drawn	6.0
3 Axle Truck	3.0		Cycle	0.5
MAV	4.5		Cycle Rickshaw	2.0
Two Wheeler	0.5		Others	4.5

5.5.2 Average Daily Traffic(ADT)

Traffic volume count data collected from the survey locations tabulated and analysed further to obtain the Average Daily Traffic (ADT). Hourly data collected was summarized to obtain hourly variation of traffic. The summarized Average Daily Traffic data observed at all the location by each hour of the day is presented in Appendix 5-6 to Appendix 5-17. Average Daily Traffic (ADT) in term of Total Vehicles and Total PCU for each survey location is presented in Table 5-8.

Table 5-8 : Average Daily Traffic observed at different locations

Sl. No.	Location (Name & Chainage)	Road Section	Pass. Veh.	Freight Veh.	Non Moto. Veh.	Total (Veh)	Total (PCU)
1	Tikri (@Km3)	Rajiv Chowk - Ashram Chowk	69315	4980	75	74,370	73,753
2	G.D Goenka University (@Km21)	Ashram Chowk - Sohna	15834	3859	22	19,715	24,415
3	Kherli Kankar near KMP Expressway (@Km30)	Sohna – Nuh	8835	3987	36	12,859	18,431
4	Nizampur Nuh @Km46	Nuh – Bhadas	13203	4449	135	17,787	23,240
5	Dhanwala @Km77	Bhadas - Firozpur Jhirka	6547	3494	22	10,063	15,023
6	Maholi @Km84	Firozpur jhirka - Rajasthan Border	6772	2093	93	8,958	10,665

It is observed from the data that maximum ADT of 74,370 (73,753 PCU) was observed near Tikri @km 3 i.e between Rajiv Chowk to Ashram Chowk followed by G.D Goenka University @km21 i.e between Ashram Chowk to Sohna with traffic volume of 19,715 (24,415 PCU). Such a heavy flow of traffic observed on the section from Rajiv Chowk to Ashram Chowk is due to urban nature of development along the corridor . Mojor Residential and Commercial projects are coming up on this section and the traffic is expected to grow even higher once all the sectors planned along this section are fully developed.

Minimum volume of 8,958 vehciles (10,665 PCU) was observed on 'Firozpur Jhirka to Rajasthan Border ' section of the project road. This section caters mainly to regional traffic destined to Alwar and other areas in this region. Also this section has more freight vehicles than passeneger vehicles. This distribution suggest that regional movements are higher than local travel on this section of the project road.

Modewise ADT observed at each location is presented in the Table 5-9.

Table 5-9 : Modewise Traffic Composition at each location

Chainage	2-Wheeler	Auto Rick.	Car/ Jeep/ Van	Taxi	M. Bus	Bus	Goods Auto	Mini LCV	LCV Freight	2-x	3-x	MAV	HCM	Tract.	Tract. & Trailor	Total Non-Moto. Veh.	Total Moto. Veh.	Total Veh.	Total PCU
Rajiv chowk-Ashram Chowk (@Km3)	**16968**	**5997**	**40163**	**4961**	**566**	**660**	**179**	**1413**	**974**	**776**	**968**	**555**	**16**	**85**	**13**	**75**	**74295**	**74370**	**73753**
% Share	(22.8%)	(8.1%)	(54%)	(6.7%)	(0.7%)	(0.9%)	(0.2%)	(1.9%)	(1.3%)	(1.04%)	(1.3%)	(0.7%)	(0.02)%	(0.1%)	(0.02%)				
Ashram Chowk-Sohna (@KM21)	**4509**	**1282**	**8411**	**1030**	**105**	**495**	**63**	**726**	**683**	**689**	**1105**	**404**	**18**	**144**	**28**	**22**	**19693**	**19715**	**24415**
% Share	(22.9%)	(6.5%)	(42.7%)	(5.2%)	(0.5%)	(2.5%)	(0.3%)	(3.7%)	(3.5%)	(3.5%)	(5.6%)	(2.0%)	(0.09%)	(0.7%)	(0.1%)				
Sohna-Nuh (@Km 30)	**3742**	**839**	**3884**	**172**	**34**	**164**	**32**	**418**	**330**	**518**	**2292**	**298**	**4**	**73**	**21**	**36**	**12822**	**12859**	**18431**
% Share	(29.1%)	(6.5%)	(30.2%)	(1.3%)	(0.3%)	(1.3%)	(0.2%)	(3.3%)	(2.6%)	(4.03%)	(17.8%)	(2.3%)	(0.03%)	(0.6%)	(0.2%)				
Nuh-Bhadas (@km46)	**6124**	**1290**	**5223**	**266**	**53**	**248**	**71**	**528**	**346**	**662**	**2223**	**271**	**8**	**277**	**62**	**135**	**17652**	**17787**	**23240**
% Share	(34.4%)	(7.3%)	(29.4%)	(1.5%)	(0.3%)	(1.4%)	(0.4%)	(3.0%)	(1.9%)	(3.7%)	(12.5%)	(1.5%)	(0.05%)	(1.6%)	(0.3%)				
Bhadas- Firozpur Jhirka (@Km77)	**3409**	**592**	**2137**	**238**	**23**	**148**	**34**	**368**	**245**	**373**	**2052**	**269**	**2**	**119**	**31**	**22**	**10041**	**10063**	**15023**
% Share	(33.8%)	(5.9%)	(21.2%)	(2.4%)	(0.2%)	(1.5%)	(0.3%)	(3.7%)	(2.4%)	(3.71%)	(20.4%)	(2.7%)	(0.02%)	(1.2%)	(0.3%)				
Firozpur Jhirka-Rajasthan Border (@Km84)	**4454**	**259**	**1901**	**-**	**7**	**152**	**7**	**384**	**227**	**200**	**779**	**317**	**5**	**120**	**55**	**93**	**8865**	**8958**	**10665**
% Share	(49.7%)	(2.9%)	(21.2%)	-	(0.1%)	(1.7%)	(0.1%)	(4.3%)	(2.5%)	(2.2%)	(8.7%)	(3.5%)	(0.06%)	(1.3%)	(0.6%)				

Modewise Analysis

Mode wise analysis of Traffic composition shows that Cars (21%-61%) and 2- wheelers (23%-50%) are the predominant mode at each location. In case of Freight vehicles, 3-axle trucks are predominant mode having share varying from 1%-20%.

Traffic comoposition observed for each survey location is presented in the following sections:

Modewise analysis of traffic captured at Tikri (@ km3) shows that out of total traffic, 93% are passenger and 7% are Freight vehicles. In case of Passenger vehicles, Cars have the maximum share in overall traffic with 54% share followed by 2-W with 23% share. Auto Rickshaws also have a substantial share of 7% in overall traffic. Share of Buses and LCV Passenger vehicles (used to ferry passenger) is 1.7% and 1.2% respectively. This shows the absence of public transport on this corridor and cars being used as an alternate for the movement.

Freight vehicles including LCV & Truck (2-x, 3-x and MAV) have a share of 3% in overall traffic which is not substantial in overall traffic flow. Refer Fig 5-2.

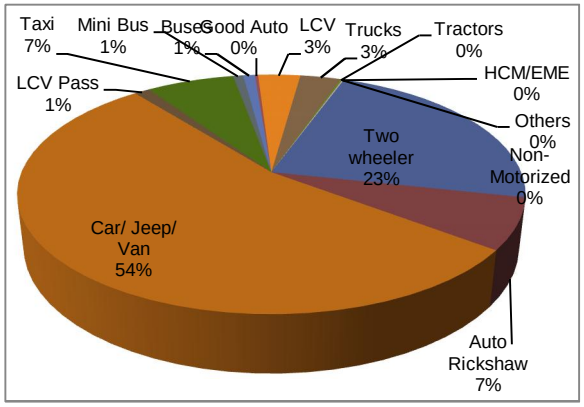


Figure 5-2 Traffic Composition at Tikri (@Km3)

Modewise analysis of traffic near G.D Goenka Univeristy (@km21) shows distribution between Passenger and Freight vehciles at 80%and 20% respectively. In Passenger vehicles, Cars have maximum share in overall traffic with 43% share followed by 2-W (23%) Auto-Rickshaws also have a substantial share (5%). Share of Buses is only 3% in overall traffic. Higher share of Car and Autorickshaws suggest that these modes are primarily used for local travel in the absence of reliable public transport system.

In Freight vehicles LCV & Trucks (2-axle, 3-axle and MAV) has share of 7% and 11% repectively. Refer Fig 5-3.

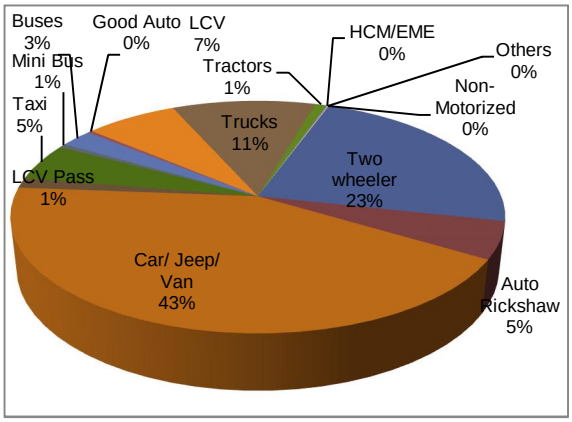


Figure 5-3 Traffic Composition near G.D Goenka University (@Km21)

Modewise analysis of traffic captured at Kherli Kankar (@km30) near KMP Expressway, suggest a distribution of 69%and 31% between Passenger and Freight vehicles. In Passenger vehicles, Cars and 2-W have a share of 30% and 29% respectively. Auto-Rickshaws have share of 7% and share of Buses is only 1%. This shows the lack of public buses and autos being used as mode of local transport in this section of the project corridor.

In Freight vehicles LCV & Trucks (2-axle, 3-axle and MAV) has share of 6% and 24% respectively. Refer Fig 5-4. Higher share of trucks in this section of the project corridor suggest the movement of regional traffic.

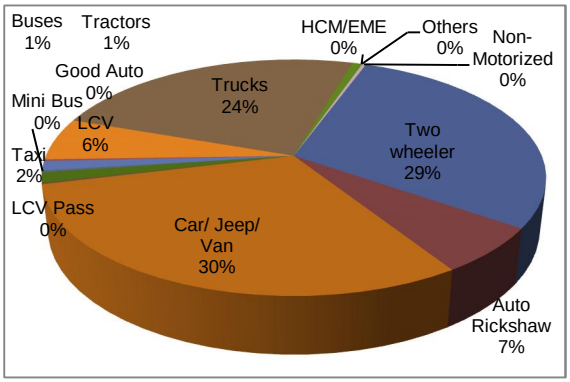


Figure 5-4 Traffic Composition at Kherli Kankar (@Km30)

Modewise analysis of traffic data near Nuh (@km 46) shows the distribution between Passenger and Freight vehicles at 75%and 25% respectively. In Passenger vehicles, 2-W have maximum share in overall traffic (35%) followed by Cars (29%). Higher share of 2-W suggest that this mode is primarily used for local movement. Share of Buses is only 1% . Low share of public buses and higher share of 2-W in this section of the project corridor suggest that 2W are primarily used for the local travel in the absence of buses.

In Freight vehicles LCV & Trucks (2-axle, 3-axle and MAV) has share of 5% & 18% respectively. Higher share of trucks on this section suggest that the corridor caters to the regional traffic movement. Refer Fig 5-5.

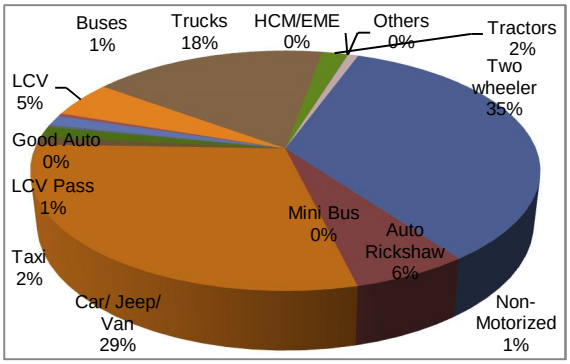


Figure 5-5 Traffic Composition at Nuh Rural (@Km 46)

Modewise analysis of traffic captured at Dhanwala (@km 77) near Firzopur Jhirka Rural, shows a distribution between Passenger and Freight vehicles at 65%and 35% respectively. In Passenger vehicles, 2-W have maximum share in overall traffic (34%) followed by Car (21%). Auto Rickshaws have a share of 6% in overall traffic; Buses share is 2% in overall traffic which is negligible.

In Freight vehicles LCV & Trucks (2-axle, 3-axle and MAV) has share of 6% & 27% respectively. Hgher share of freight vehicles means that this section of the corridor is catering to regional traffic. Refer Fig 5-6.

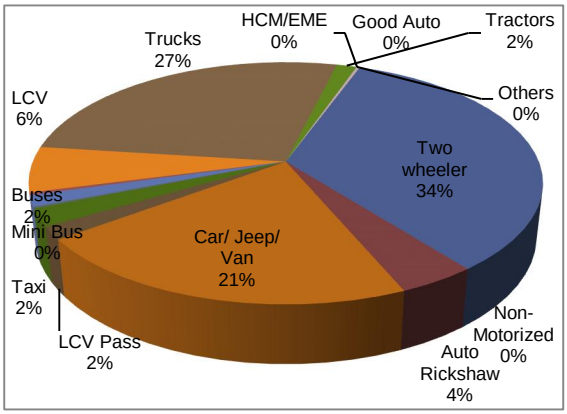


Figure 5-6 Traffic Composition at Dhanwala (@Km77)

Modewise analysis of traffic captured at Maholi (@ km 84) near Firozpur Jhirka, shows distribution between Passenger and Freight vehicles at 77%and 23% respectively. In Passenger vehicles, 2-W have maximum share in overall traffic (50%) followed by Car (21%). Buses on this section have a share of 2% only.

In Freight vehicles LCV & Trucks (2-axle, 3-axle and MAV) has share of 7% & 14%. Refer Fig 5-7.

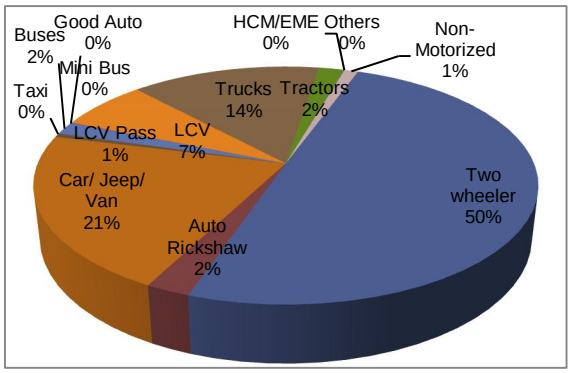


Figure 5-7 Traffic Composition at Maholi (@Km84)

Analysis of the data collected and its modal distribution suggest that:

- Share between Passenger and Freight Vehicles varies from (65% - 93%) and (7% -35%) respectively. Highest passenger vehicle share is observed near Tikri @ km 3 (93%) and minimum near Dhanwala @ km 77(65%) because road section at km 3 pass through Urban area and road section at Dhanwala (@km77) falls in rural area.
- Share of Auto-Rickshaws is highest near Tikri @ km 3(6.9%) and mimimum near Maholi @ km 84(2.4%). This is also because of urban influence of Gurgaon city at km3.
- Similarly share of Cars is also highest near Tikri @ km 3 (60.6%) and minimum near Dhanwala @ km 77(21%)
- Share of Buses varies from (1-3%) showing inadequacy of Public Transport along the project road.
- Share of 3-x trucks are highest near Dhanwala @ km 77 (20.4%) and minimum near Tikri @ Km 3 (1.3%)
- LCV share varies from 5%-7%. Highest share is observed near G.D Goenka University (@km21) because they are primarily used to supply goods for shorter distances in urban areas.

Also it is observed that, vehicle composition varies substantially at km3 and km77. This is due to nature of development along the corridor.

5.5.3 Seasonal Correction Factor (SCF)

ADT calculated needs to be converted into AADT to address the variation in traffic over various months in a year. For this purpose, seasonal traffic variations on the project road were analysed. In the present study, traffic characteristics along the project road vary considerably across the five homogeneous sections, thus establishing the need to have separate factors for each of these sections. SCF generally established from past traffic data or from the petrol/ diesel sales of the petrol stations along the project corridor.

Sales data for a complete calendar year was collected from the fuel stations along the corridor. The data along with arrived correction factors for the month of July (survey month) are presented in Table 5-10. These factors were used to arrive at the AADT values. As trucks and buses are diesel

driven vehicles, their monthly variations are corrected on the basis of HSD (diesel) sales data and for other vehicles it is estimated based on Petrol sales data. SCF worked out separately for diesel and petrol vehicles on two different sections of the project corridor is presented in the table below:

Table 5-10 : Seasonal Correction Factor

Sl. No.	Sections	SCF-Diesel Veh.	SCF-Petrol Veh.
1	Rajiv Chowk - Sohna	0.866	0.866
2	Sohna-Rajasthan Border	1.256	0.883
Adopted SCF		**1.06**	**0.87**

5.5.4 Annual Average daily Traffic

Average Annual Daily Traffic (AADT) at six locations along the project road was worked out by multiplying the respective SCF with the ADT values. AADT values worked out at all the locations are presented in the Table 5-11.

Table 5-11: AADT-Mode wise traffic at each location

Chainage	2-Wheeler	Auto Rick.	Car/ Jeep/ Van	Taxi	M. Bus	Bus	Goods Auto	Mini LCV	LCV Freight	2-x	3-x	MAV	HCM	Tract.	Tract. & Trailor	Total Non-Moto. Veh.	Total Moto. Veh.	Total Veh.	Total PCU
Rajiv chowk-Ashram Chowk (@Km3)	**16968**	**6049**	**34942**	**4316**	**600**	**700**	**190**	**1498**	**1032**	**823**	**1026**	**588**	**17**	**85**	**13**	**75**	**68848**	**68923**	**68760**
% Share	(25%)	(8.8%)	(50.7%)	(6.3%)	(1%)	(1%)	(0.3%)	(2.2%)	(1.5%)	(1%)	(1%)	(1%)	-	-	-				
Ashram Chowk-Sohna (@KM21)	**4509**	**1299**	**7318**	**896**	**111**	**525**	**67**	**770**	**724**	**730**	**1172**	**428**	**19**	**144**	**28**	**22**	**18739**	**18761**	**23847**
% Share	(24%)	(6.9%)	(39%)	(4.8%)	(1%)	(3%)	(0.4%)	(4.1%)	(3.9%)	(4%)	(6%)	(2%)	-	(1%)	-				
Sohna-Nuh (@Km 30)	**3742**	**841**	**3379**	**149**	**36**	**174**	**34**	**444**	**350**	**549**	**2430**	**316**	**4**	**73**	**21**	**36**	**12542**	**12579**	**18582**
% Share	(30%)	(6.7%)	(26.9%)	(1.2%)	(0.3%)	(1%)	(0.3%)	(3.5%)	(2.8%)	(4%)	(19%)	(3%)	-	(1%)	-				
Nuh-Bhadas (@km46)	**6124**	**1301**	**4544**	**232**	**56**	**263**	**76**	**559**	**367**	**702**	**2357**	**287**	**9**	**277**	**62**	**135**	**17214**	**17349**	**23248**
% Share	(35%)	(7.5%)	(26.2%)	(1.3%)	(0.3%)	(2%)	(0.4%)	(3.2%)	(2.1%)	(4%)	(14%)	(2%)	-	(2%)	-				
Bhadas- Firozpur Jhirka (@Km77)	**3409**	**602**	**1859**	**207**	**24**	**157**	**36**	**390**	**260**	**396**	**2175**	**286**	**2**	**119**	**31**	**22**	**9953**	**9975**	**15309**
% Share	(34%)	(6.4%)	(18.6%)	(2%)	(0.2%)	(2%)	(0.4%)	(3.9%)	(2.6%)	(4%)	(22%)	(3%)	-	(1%)	-				
Firozpur Jhirka-Rajasthan Border (@Km84)	**4454**	**262**	**1653**	**-**	**7**	**161**	**7**	**407**	**241**	**212**	**826**	**336**	**5**	**120**	**55**	**93**	**8745**	**8838**	**10755**
% Share	(50%)	(2.9%)	(18.7%)	-	-	(2%)	(0.1%)	(4.6%)	(2.7%)	(2%)	(9%)	(4%)	-	(1%)	(1%)				

5.5.5 Hourly variation and Directional Distribution of Traffic

5.5.5.1 Hourly Variation

Hourly Variation Analysis of the traffic data and hourly variation of traffic suggest that both passenger and freight traffic movement behavior is almost similar. Traffic on the corridor start building up in the morning hours and reaches at the peak during this period. After that the traffic flow start coming down and falls during the wee hours. Highest peak hour flows are observed in the morning hours from 9:00 am to 12:00 am. Only at km 30, an evening peak flow is observed. This is because the location is near KMP expressway and regional traffic start entering or leaving the project corridor at this location.

Hourly variation observed at different locations is presented in Fig 5-8 to Fig 5-13.

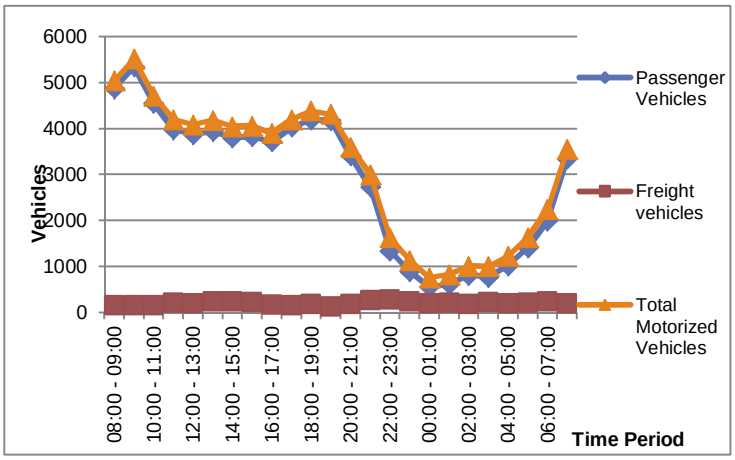


Figure 5-8 Hourly variation of traffic @Km3

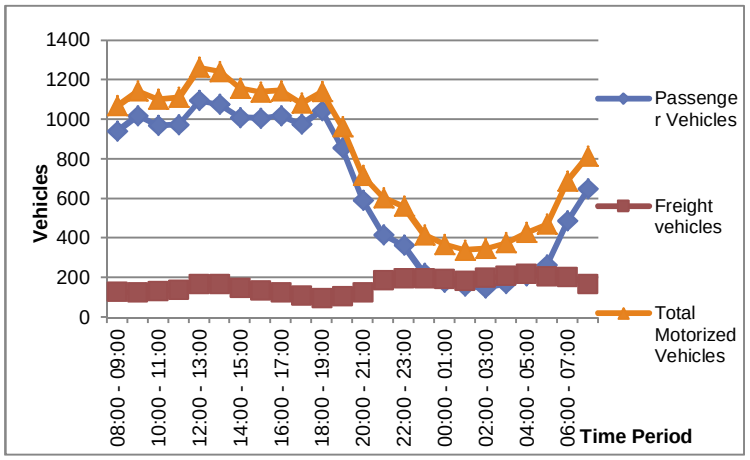


Figure 5-9 Hourly variation of traffic @Km21

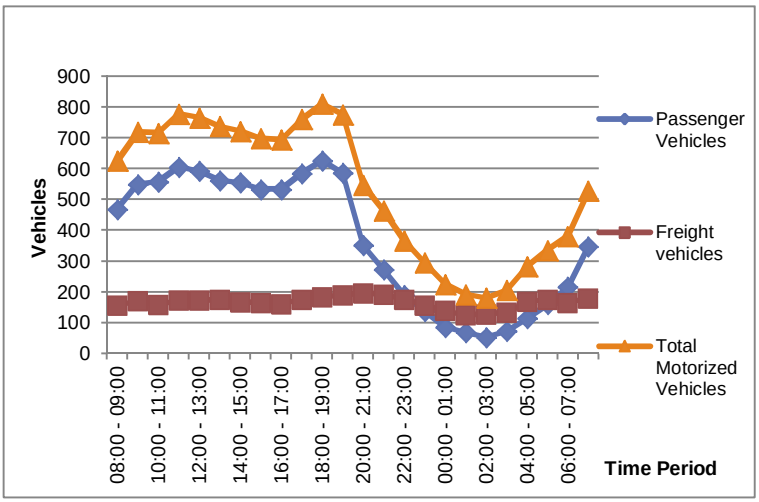


Figure 5-10 Hourly variation of traffic @Km30

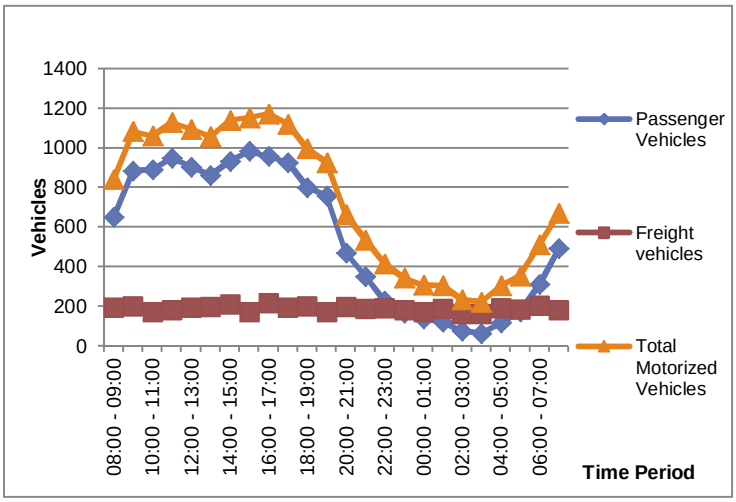


Figure 5-11 Hourly variation of traffic @Km46

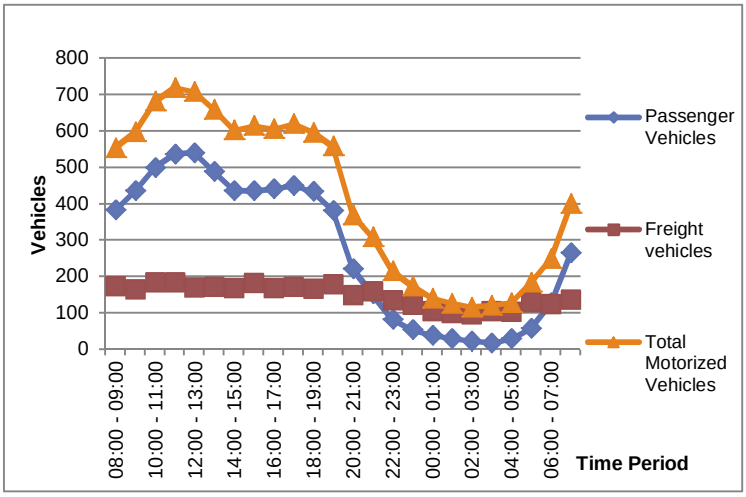


Figure 5-12 Hourly variation of traffic @Km77

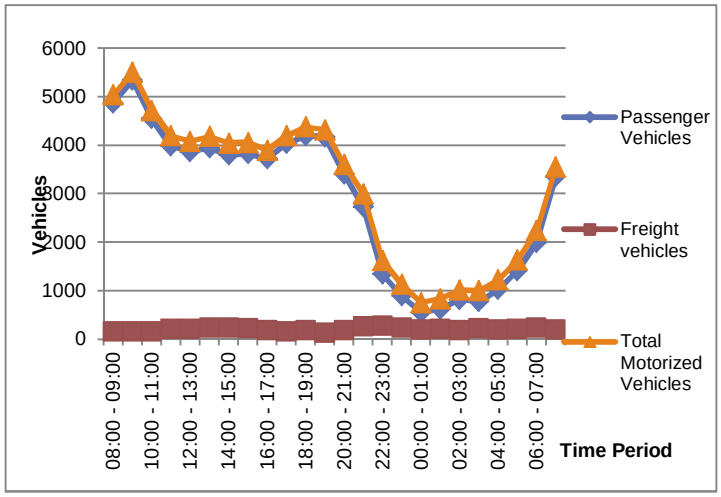


Figure 5-13 Hourly variation of traffic @Km84

5.5.5.2 Directional Distribution:

Directional Distribution of traffic at all the locations shows that traffic is evenly distributed in both directions i.e. from Gurgaon to Rajasthan and Rajasthan to Gurgaon. The directional distribution observed at all the locations is presented in the **Table 5-12.**

Table 5-12 : Directional Distribution of Traffic

Directional Distribution	Tikri (@km3)	G.D Goenka University (@km21)	Kherli Kankar (@km 30)	NUH Rural (@km46)	Dhanwala (@km77)	Maholi (@km84)
Rajiv Chowk -Rajasthan Border	49.7%	49.2%	49.1%	49.6%	48.1%	47.9%
Rajasthan Border -Rajiv Chowk	50.3%	50.8%	50.9%	50.4%	51.9%	52.1%

5.5.5.3 Peak Hour Factor

Share of Peak hour factor at all the location varies between 6.3 & 7.4. Highest peak hour factor has been observed near Tikri (@km 3) and near Maholi (@Km 84). Highest Peak Hour traffic has been observed between 9.00 – 10.00 am near Tikri (@km 3). Peak Hours and peak hour factor for different locations are mentioned in Table 5-13.

Table 5-13 : Peak Hour Factor

TVC	Traffic (PCU)	Peak Hour	P.H.F
Tikri (@Km3)	5,071	09:00 - 10:00	7.4
G.D Goenka University (@Km21)	1,396	12:00 - 13:00	6.4
Kherli Kankar near KMP Expressway (@Km30)	1,023	18:00 - 19:00	6.3
Nizampur Nuh @Km46	1,383	16:00 - 17:00	6.6
Dhanwala @Km77	905	11:00 - 12:00	7.2
Maholi @Km84	667	11:00 - 12:00	7.4

Morning peak hours are observed at the locations close to urban areas like Tikri (@km3) and evening peak hours at the location near to regional corridors like Kherli Kankar as this section is primarily serving to freight traffic.

5.5.6 Toll Exempted Vehicles

Toll exempted vehicles were counted separately during the surveys and their composition was found to be negligible at all locations. Mode-wise toll exempted vehicles captured at all the locations are shown in the Table 5-14.

Table 5-14 : Toll Exempted Vehicles at Different Locations

TVC	Car	Bus	LCV	Truck
Tikri (@Km3)	24	8	10	7
G.D Goenka University (@Km21)	70	14	21	3
Kherli Kankar near KMP Expressway (@Km30)	24	1	4	1
Nizampur Nuh @Km46	83	3	35	1
Dhanwala @Km77	18	2	5	0
Maholi @Km84	4	0	2	0

Maximum numbers of toll exempted vehicles are observed near Nuh (@km 46) followed by section near G.D Goenka University (@Km 21).

5.6 TRAVEL CHARACTERISTICS

Data Checking

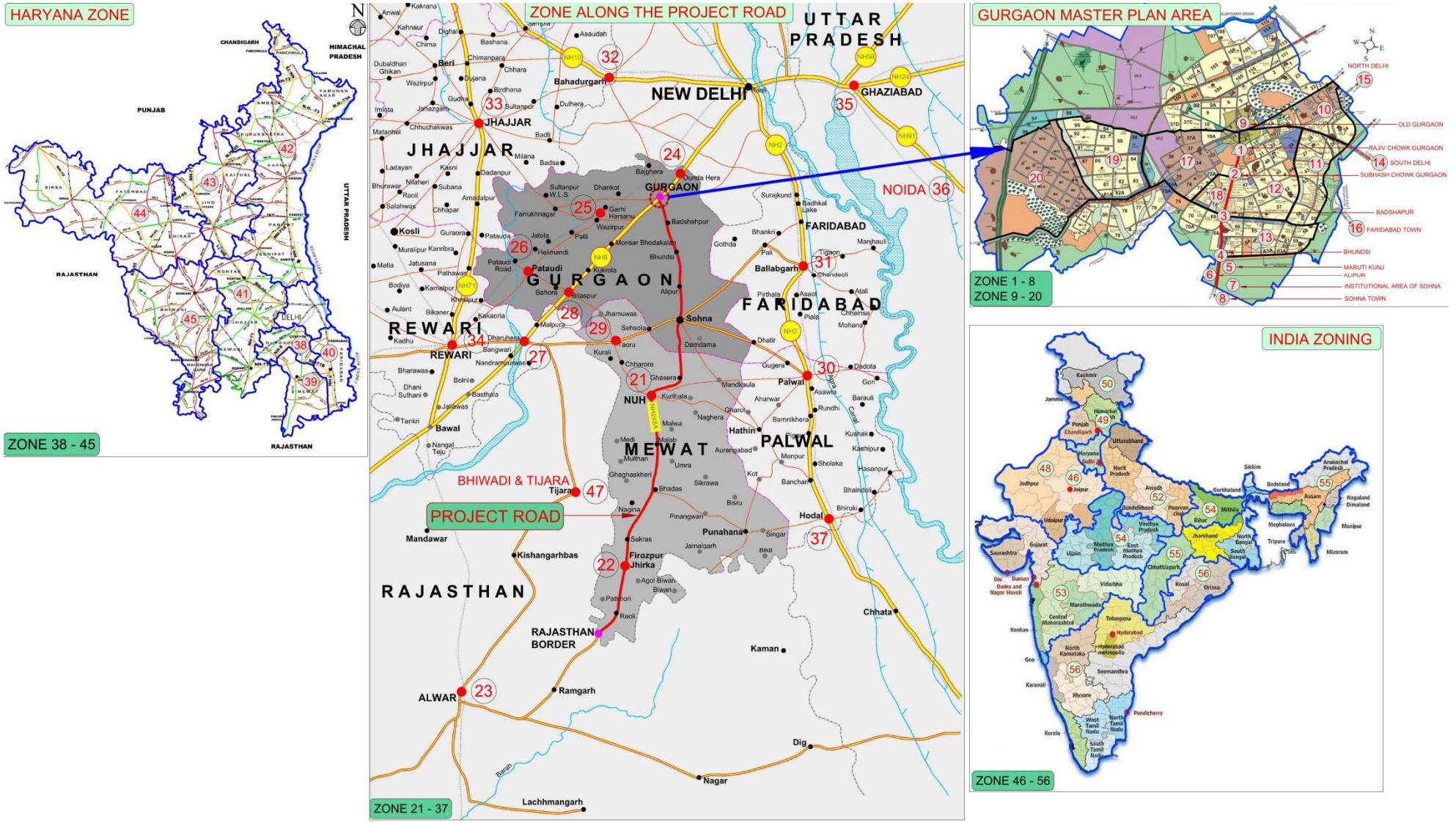
The field data collected was tabulated and punched for further analysis. Incorrect and inconsistent records were corrected by crosschecking it with original field data sheets. The checked and corrected data were used for final analysis.

Zoning System

For the analysis of O-D data and preparation of trip tables for studying the regional interaction, a zoning system was developed for the project influence area. The zoning system was developed at four levels. In first level, immediate influence areas of project road were assigned zone codes. Secondly, all-important towns located along the project corridor were considered. In third level, all nearby districts were grouped into zones. Finally, states beyond the influence area were aggregated broadly in terms of direction of travel. In all, a 56 zone system was evolved. These 56 zones were further clubbed into 20 zones based on the homogeneity of zones. The list of 56 and 20 traffic zones is given in Appendix 5-18 and presented in Figure 5-14.

Development of Origin-Destination Matrices

After coding of Origin and Destination data, expansion factors were calculated by comparing the sample size by vehicle type with the Annual Average Daily Traffic. Vehicle wise O-D matrices were developed using these expansion factors. O-D matrices for different locations along the project road are presented in Appendix 5-19 to Appendix 5-24. Desire line diagrams representing the travel desire for passenger at each location are presented in Figures 5-15 to 5-17 and desire line diagrams for freight vehicles are shown in Figures 5-18 to 5-20.Salient findings from the OD surveys are discussed in subsequent sections.


HARYANA ZONE
ZONE 38 - 45
ZONE ALONG THE PROJECT ROAD
ZONE 21 - 37
PROJECT ROAD
BHIWADI & TIJARA
RAJASTHAN BORDER
GURGAON MASTER PLAN AREA
ZONE 1 - 8
ZONE 9 - 20
INDIA ZONING
ZONE 46 - 56
NEW DELHI
GURGAON
FARIDABAD
NOIDA
GHAZIABAD
REWARI
MEWAT
PALWAL
JHAJJAR
NUH
RAJASTHAN
UTTAR PRADESH
HARYANA
PUNJAB
HIMACHAL PRADESH
CHANDIGARH
DELHI
OLD GURGAON
RAJIV CHOWK GURGAON
SUBHASH CHOWK GURGAON
SOUTH DELHI
BADSHAPUR
FARIDABAD TOWN
BHUNDSI
MARUTI KUNJ
ALIPUR
INSTITUTIONAL AREA OF SOHNA
SOHNA TOWN
NORTH DELHI

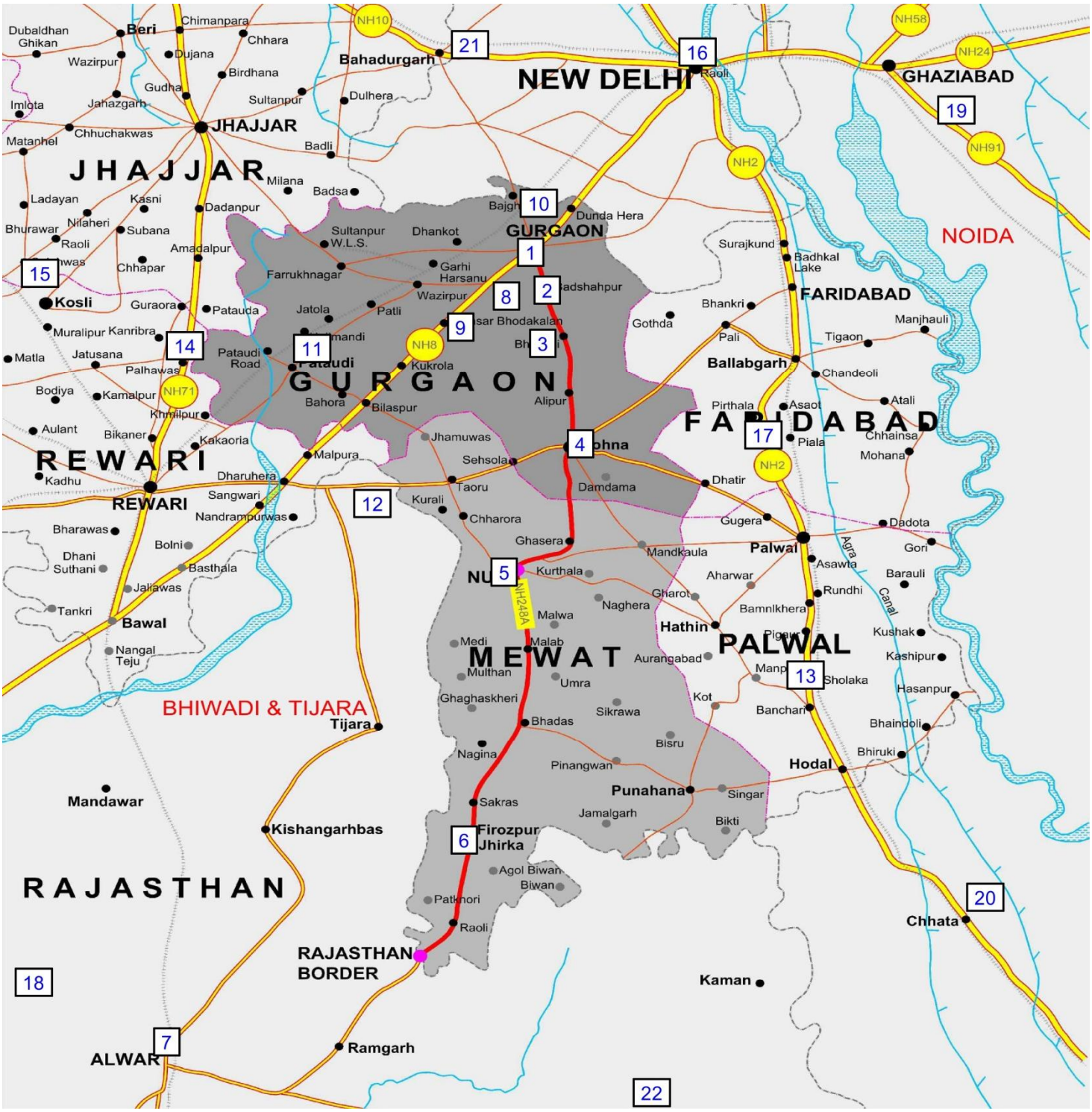


Figure 5-14 Traffic Zoning System

5.6.1 Travel Pattern-Passenger Vehicles

Travel pattern analysis of the passenger vehicles captured at all the locations was analyzed to understand the origin and destination of the trips. To understand the geographical allocation of trips performed, captured trips were clubbed in to the trips generating along the corridor, trips generating from rest of the state & trips from surrounding states and rest of India. Following table give the details of the pattern observed at different locations.

Table 5-15 : Travel Pattern – Passenger Vehicles

	Zone No.	Zones	G.D Goenka University (@km21)	Dhanwala (@km 77)	Maholi (@km 84)
Along the Project Corridor	1	Rajiv Chowk, Subhash Chowk, Alipur	0.8%	0.05%	-
	2	Badshapur	1.2%	0.3%	0.05%
	3	Bhondsi	1.1%	0.1%	-
	4	Sohna	27.7%	3.6%	0.9%
	5	Nuh	7.3%	10.7%	6%
	6	Firopur jhirka	3.9%	29.4%	29.4%
	7	Alwar	2.2%	17.7%	28.1%
Total along Project Corridor			**44.42%**	**62.07%**	**64.42%**
Regional Interaction	8	Old Gurgaon & Udyog Vihar	1.0%	0.3%	-
	9	Manesar	0.2%	0.4%	0.06%
	10	New Gurgaon	31.2%	9.5%	14%
	11	Pataudi	-	-	-
	12	Dharuhera and Bilapsur	1.3%	2.9%	1%
	13	Ballabgarh & Palwal	3.6%	9.1%	3%
	14	Jhajjar/Rewari	0.2%	0.3%	0.5%
	15	Rest of Haryana	0.5%	1.4%	0.5%
	16	Delhi	15.8%	5.7%	4.3%
	17	Faridabad	-	-	1%
	18	Rajasthan	0.4%	6.2%	8.8%
	19	U.P	0.11%	0.15%	0.2%
	20	Rest of UP	0.62%	0.53%	1.84%
	21	North India	0.34%	0.9%	0.2%
	22	Rest of India	0.05%	0.5%	0.0%

Key observations from the passenger trips observed at different locations are:

- 44-64% of passenger trips are originating or destining along the project road
- Share of trips generating from Delhi varies from 4% to 15%. The location near to border i.e. near Maholi (@km 84 has less share of traffic generating from Delhi while location near G.D Goenka University (@km 21) has maximum share generating from Delhi.

- Similarly near G.D Goenka University (@km 21), share of traffic generating from Gurgaon district is maximum (31.2%).
- Ballabgarh, Palwal and Hodal also have a subsequent share of passenger traffic which is either generating or destining to these areas with shares varying from 3% to 9%.
- Along the Project road, major contributors to the Passenger traffic are Sohna(@ km 21) with 28% share and Firozpur Jhirka and Alwar (@Km 77) and (@km 84) with share of 18%-20% respectively.
- Nuh is the next major contributor to the Passenger traffic along the Project Corridor.

OD Matrices for passenger vehicles are presented in Appendix 5- 19 to Appendix 5-21. Desire line of the passenger trips captured at different locations highlighting the areas of major interaction is presented in Figure 5.14-5.16.

It is observed from the desire line that areas in close proximity to Gurgaon has interaction between New Delhi and other parts of Haryana and areas away from Gurgaon has interaction with UP and Rajasthan.

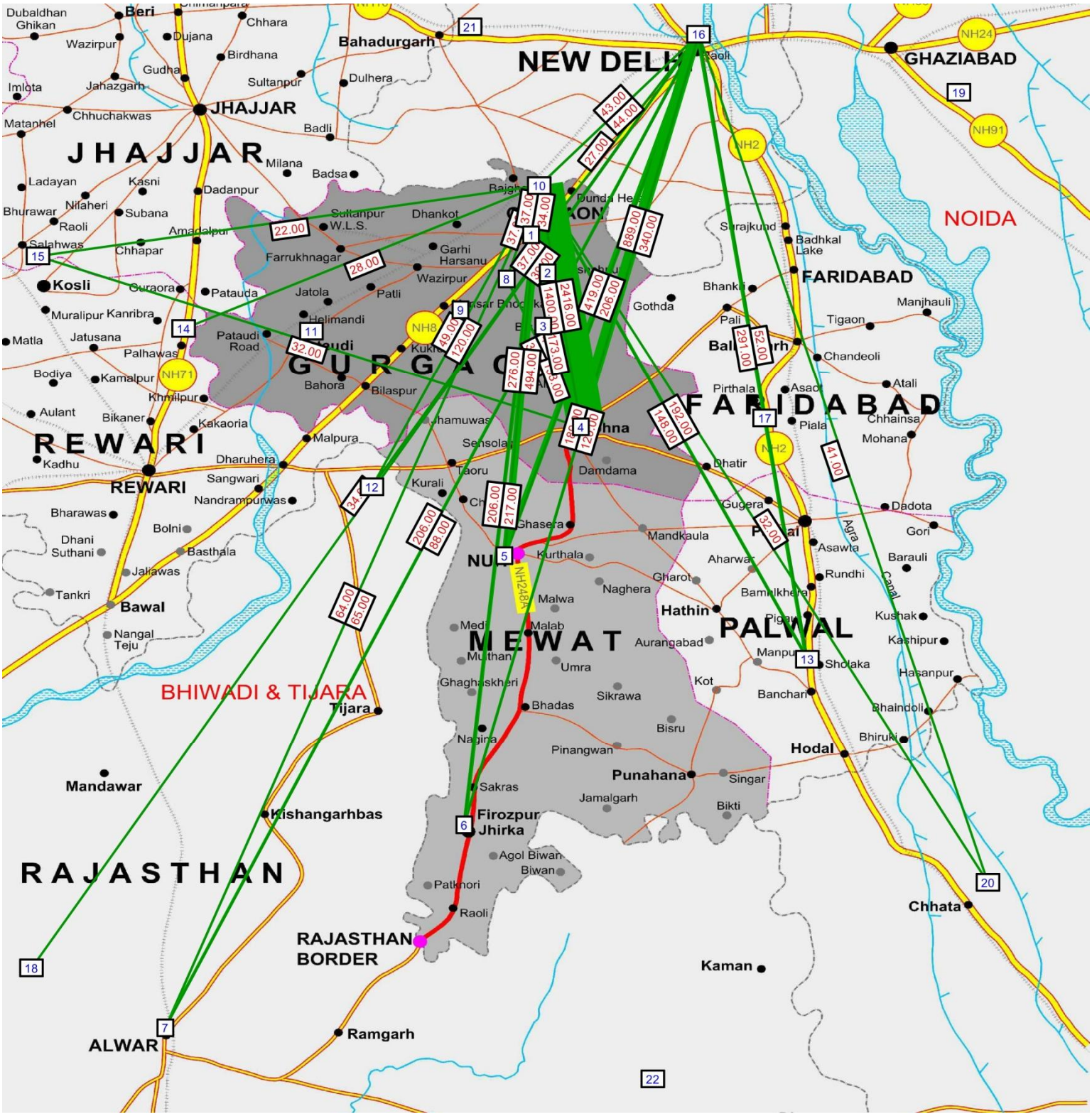


Figure 5-15 Desire Line Diagram for Passenger Traffic near G.D Goenka University, (@Km 21)

Near G.D Goenka University (@Km 21), Maximum Passenger traffic is observed between Gurgaon and Sohna and New Delhi. Few trips are also observed between Gurgaon and Nuh and New Delhi and Nuh. Other areas contributing to the passenger traffic at this location are Firozpur Jhirka, Old Gurgaon and few districts of Haryana.

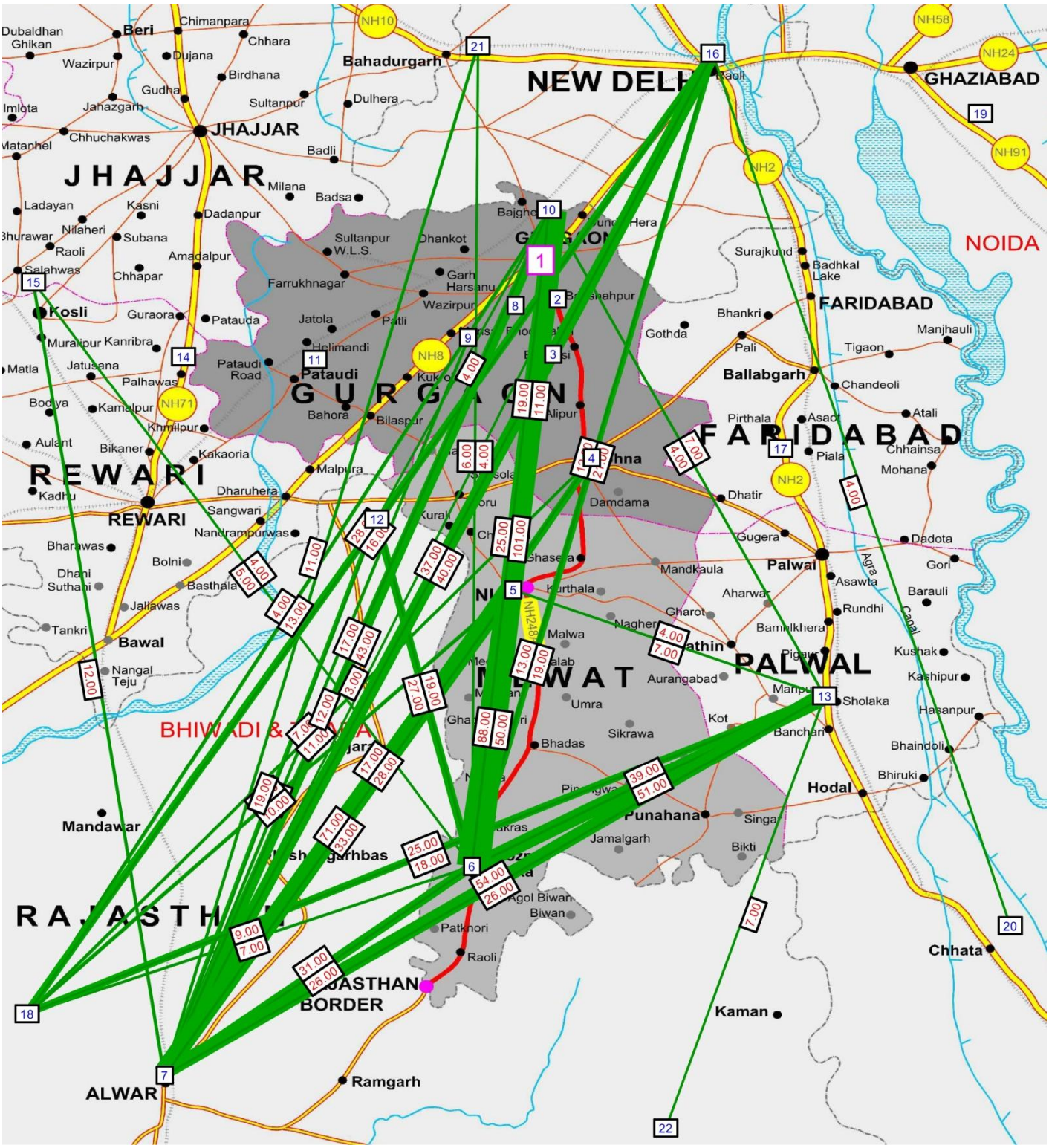


Figure 5-16 Desire Line Diagram for Passenger Traffic near Dhanwala, (@Km 77)

Dhanwala, (@Km 77), Maximum interaction is observed between Firozpur Jhirka and Nuh, Gurgaon and Firozpur Jhirka and between Nuh and Alwar. Substantial interaction observed between Palwal and Firozpur Jhirka and Gurgaon and Alwar. Other parts of Rajasthan also contribute in passenger traffic captured at this location.

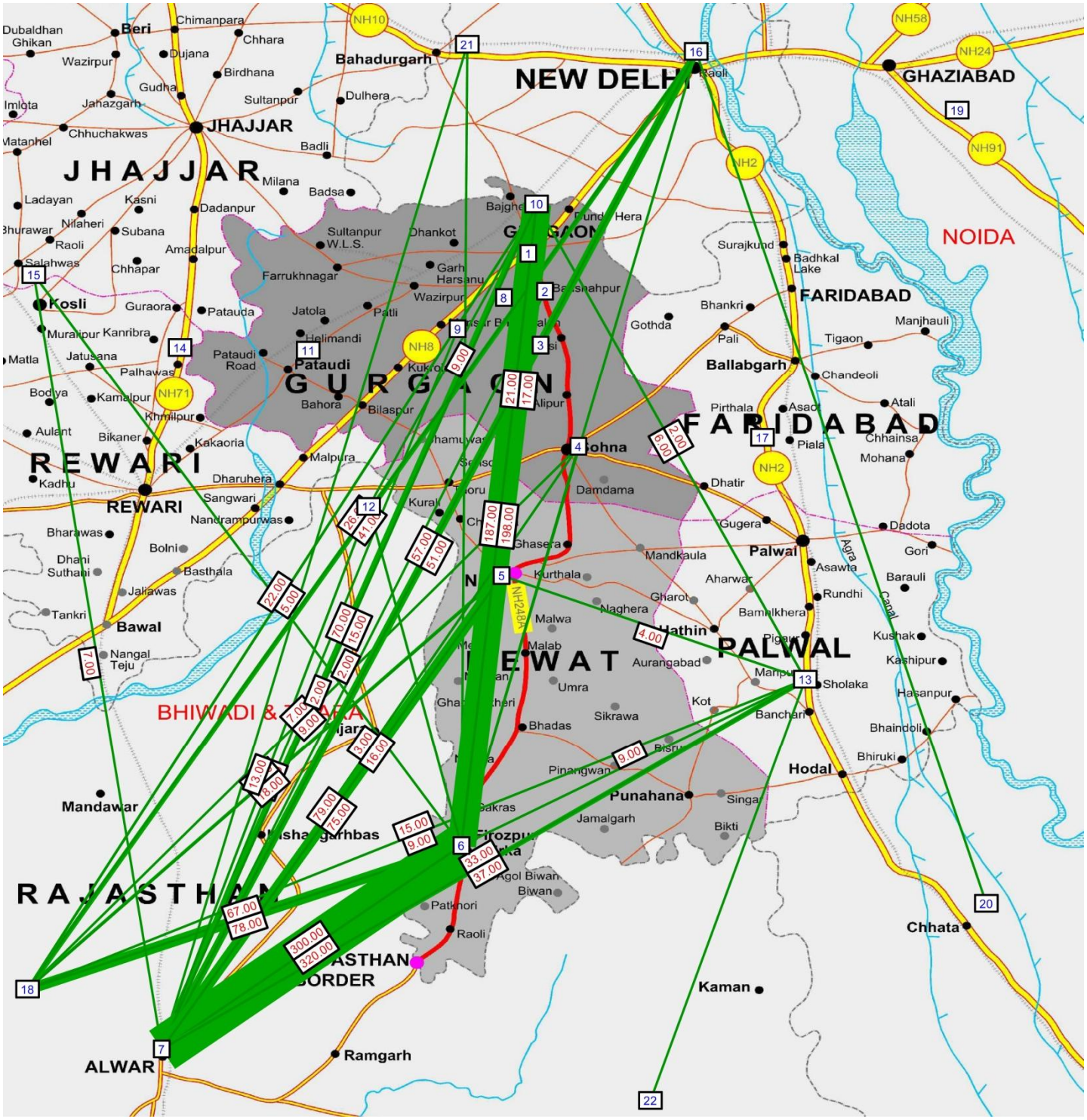


Figure 5-17 Desire Line Diagram for Passenger Traffic near Maholi, (@Km 84)

Maholi (@Km84), Maximum Passenger traffic is observed between Firozpur Jhirka & Alwar and Gurgaon & Firozpur Jhirka. Substantial amount of passenger traffic can be seen between New Delhi and Alwar, Nuh and Alwar and Firzpur Jhirka and other parts of Rajasthan.

5.6.2 Travel Pattern-Freight Vehicles

Similarly, travel pattern analysis of the freight vehicles captured at all the locations was analyzed to understand the origin and destination of the trips. Following table give the details of the pattern observed at different locations.

Table 5-16 : Travel Pattern-Freight Vehicles

	Zone No.	Zones	G.D Goenka University (@km21)	Dhanwala (@km 77)	Maholi (@km 84)
Along the Project Corridor	1	Rajiv Chowk, Subhash Chowk, Alipur	0.6%	-	-
	2	Badshapur	4.1%	0.02%	0.04%
	3	Bhundsi	5.6%	1.8%	0.4%
	4	Sohna	26.8%	10.1%	4.9%
	5	Nuh	3.%	7.7%	4.3%
	6	Firopur jhirka	4.2%	14.1%	12.4%
	7	Alwar	1.0%	20.2%	33.9%
Total traffic along Project Corridor			**45.45**	**54.02**	**56.04**
Regional Interaction	8	Old Gurgaon and Udyog Vihar	-	-	0.7%
	9	Manesar	-	0.06%	-
	10	New Gurgaon	34.7%	5.4%	3.5%
	11	Pataudi	0.04%	-	0.01%
	12	Dharuhera and Bilapsur	1.6%	0.6%	0.3%
	13	Ballabgarh & Palwal	3.6%	8.1%	2.7%
	14	Jhajjar/Rewari	0.7%	0.5%	0.6%
	15	Rest of Haryana	0.7%	3.8%	1.9%
	16	Delhi	8.1%	8.9%	14.5%
	17	Faridabad	-	1.8%	3.6%
	18	Rajasthan	0.4%	4.3%	5.6%
	19	U.P	0.4%	0.6%	0.8%
	20	Rest of UP	0.9%	2.3%	1.8%
	21	North India	0.0%	0.6%	0.2%
	22	Rest of India	3.1%	8.8%	7.3%

Key observations from the passenger trips observed at different locations are:

- 45-56% of trips are originating or destining along the project road.
- Share of trips generating from Delhi varies from 8% to 14%.
- Near G.D Goenka University (@km 21), High share of traffic is from Gurgaon district i.e. 34.7 % whereas other locations have share of only 3-4 % from the same zone.
- Ballabgarh, Palwal, Hodal and Dhaurahera and Bilaspur areas also contribute substantially in overall freight traffic with shares varying from 1% to 8%
- Share of other states varies from 4% to 9% at different locations

- Maximum share of 28% can be observed near G.D Goenka University (@km 21) from Sohna along the Project corridor followed by Bhondsi, Ferozepur Jhirka, Badshapur and Nuh with share of 3-5% each.
- Near Dhanwala (@Km 77) share of Firozpur Jhirka, Sohna, Nuh and Alwar is high whereas at Km 84, High share of Alwar and Firozpur Jhirka can be seen.

Freight matrices for all the surveyed locations are presented in Appendix 5-22 to 5-24. Location wise desire line diagram showing interaction between different zones in presented in Figure 5-17 to 5-19.

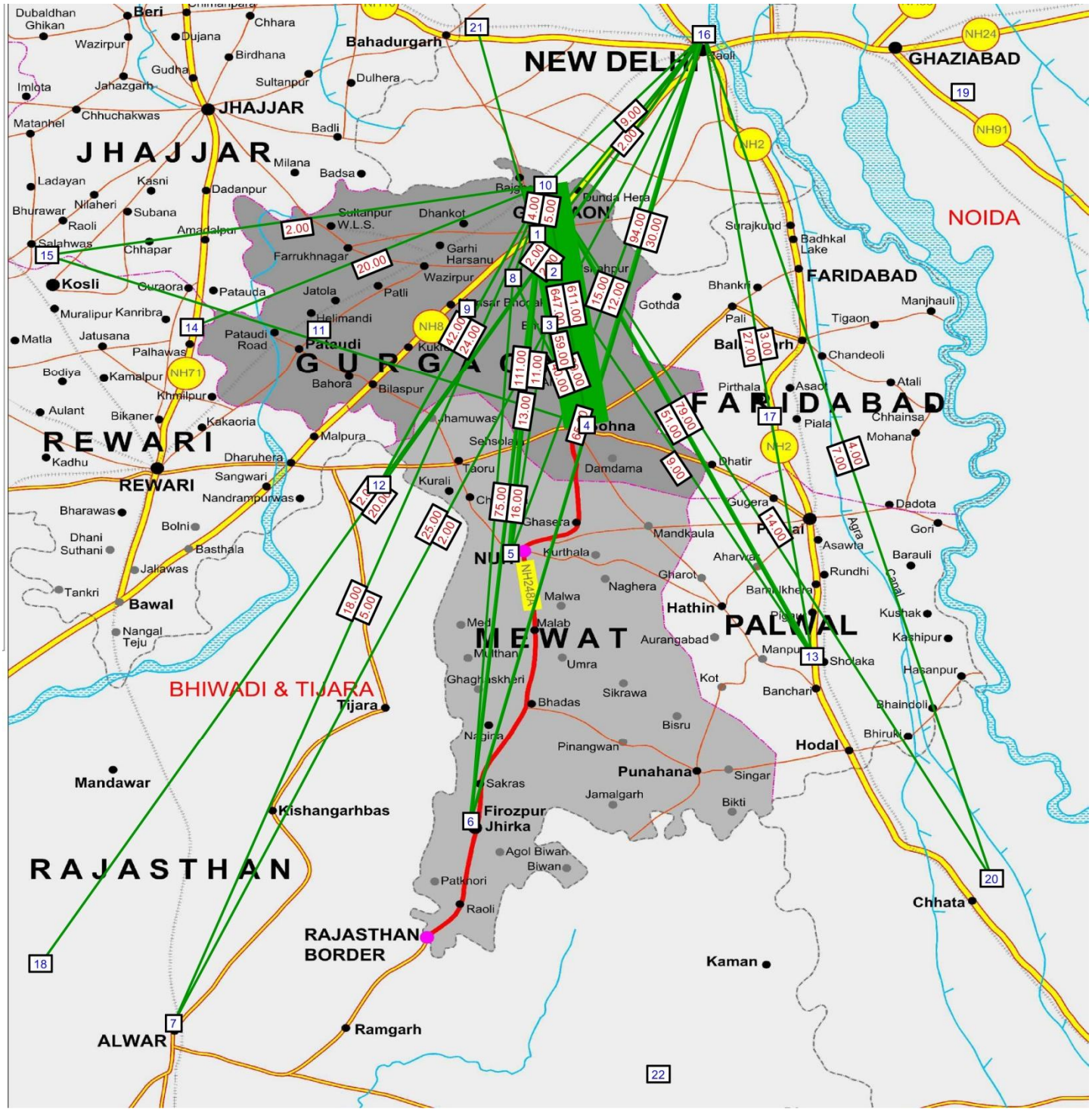


Figure 5-18 Desire Line Diagram for Freight Traffic near G.D Goenka University (@Km21)

G.D Goenka University (@Km 21), Maximum Freight traffic movement is observed between Gurgaon and Sohna. Some movement is observed between Gurgaon and Firozpur Jhirka and Gurgaon and Palwal. Few trips are observed between other locations such as Alwar, Old Gurgaon and Rajasthan.

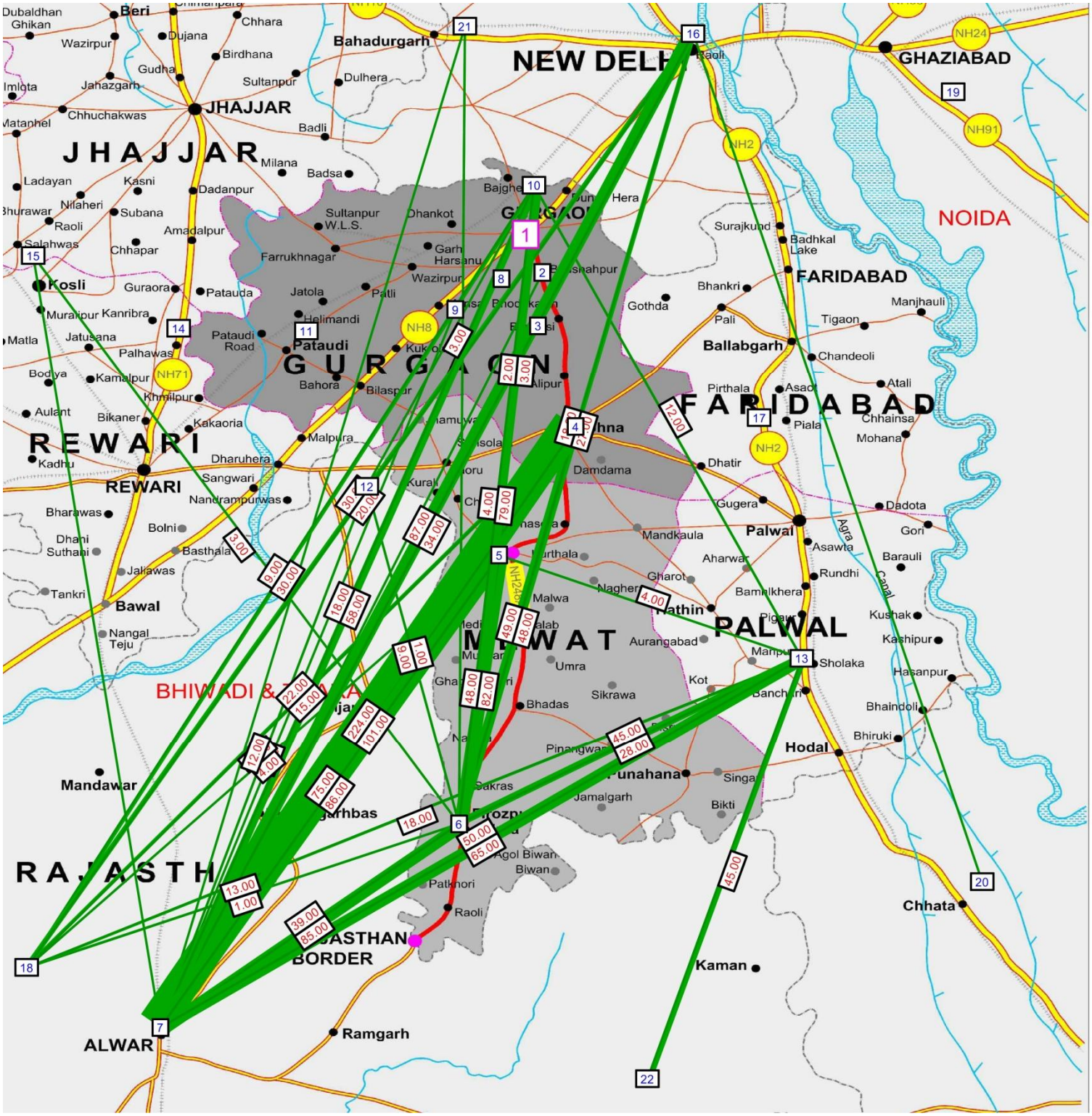


Figure 5-19 Desire Line Diagram for Freight Traffic near Dhanwala (@Km 77)

Dhanwala (@Km 77), Maximum Freight movement is observed between Sohna and Alwar , Nuh and Alwar and Nuh and Firozpur Jhirka. Other areas contributing to freight traffic at this location are Gurgaon, New Delhi, Palwal and Rajasthan.

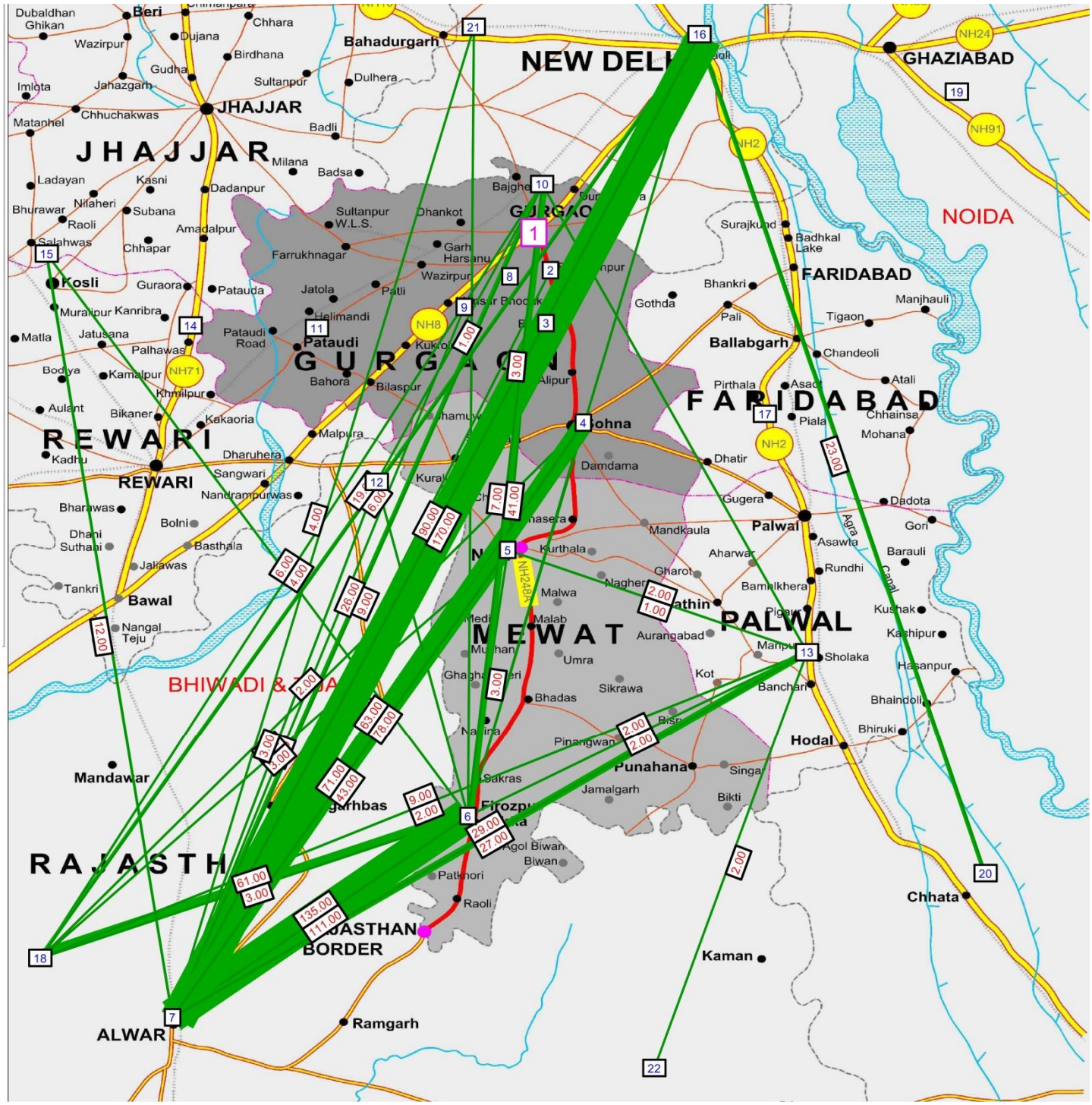


Figure 5-20 Desire Line Diagram for Freight Traffic near Maholi (@Km 84)

Maholi (@Km 84), Maximum Freight movement is observed between Firozpur Jhirka and Alwar followed by movement between New Delhi and Alwar. Substantial Freight movement is observed between Sohna and Alwar. Also, movement between Firozpur Jhirka and other parts of Rajasthan is observed at this location.

5.6.2.1 Commodity Survey Analysis

Different commodities recorded during the O-D survey were classified into 20 categories including empty as given in Table 5-17. Due consideration has been given to include all possible commodities moving along the project road.

Table 5-17 : Commodities Codes

Code	Commodity
1	Fruits & Vegetables
2	Agricultural products (Foodgrains)
3	Miscellaneous Food Items
4	Iron and Steel
5	Automobiles
6	Petroleum Products
7	Chemicals
8	Machinery Items
9	Textile
10	Cement
11	Construction Material (Sand, Bricks etc.)
12	Wood
13	Electronic Goods
14	Postal/Parcel
15	Plastic Goods
16	LPG Gas
17	Medical Products
18	Animal/Poultry
19	Miscellaneous Products
20	Empty

Commodity movement pattern shows considerable movement of Construction Materials, Iron and Steel, Textile, Fruits and Vegetables etc. along the project corridor. Location-wise distribution of various commodities is presented in Table 5-18.

Table 5-18 : Share of commodities at Different Survey Locations

S. No	Commodity	G.D Goenka University (@km21)	Dhanwala (@km77)	Maholi (@km84)
1	Fruits & Vegetables	1%	7%	3%
2	Agricultural products (Foodgrains)	-	1%	5%
3	Miscellaneous Food Items	6%	4%	7%
4	Iron and Steel	14%	4%	17%
5	Automobiles	3%	-	1%
6	Petroleum Products	1%	-	1%
7	Chemicals	-	-	1%
8	Machinery Items	2%	3%	1%
9	Textile	2%	5%	1%
10	Cement	1%	1%	1%
11	Construction Material (Sand, Bricks etc.)	16%	9%	3%
12	Wood	-	-	1%
13	Electronic Goods	-	-	-
14	Postal/Parcel	1%	-	-
15	Plastic Goods	-	4%	1%
16	LPG Gas	2%	-	-
17	Medical Products	-	-	-
18	Animal/Poultry	2%	1%	1%
19	Miscellaneous Products	4%	16%	8%
20	Empty	45%	43%	48%

- Share of empty vehicles at survey locations varies from 43%-48%.
- Building Materials, Iron and Steel and Other Miscellaneous products have major share among products transported in this corridor.
- From Gurgaon-Sohna near G.D Goenka University (@km 21), Building materials has share of 16% among commodities transported in this stretch because most of the construction activities are happening in this area. Firozpur-Nuh near Dhanwala (@km 77) has share of 9% for this commodity.
- Share of Iron and Steel is maximum near Maholi (@ km 84) with 17 % and near G.D Goenka University (@km 21) with share of 14%.
- In Firozpur-Nuh Corrdior near Dhanwala (@km 77), Textile has share of 5% among other commodities.

5.6.3 Lead Analysis

The survey data was analysed to assess the lead distribution for vehicles. The distribution observed for different vehicle types is mentioned in Table 5-19. Lead varies from 60kms to 104 kms for Car which suggests local to regional movement of this mode. There is a substantial difference in lead of

LCV vehicles. For location near G.D Goenka University (@km21), LCV lead observed at km21 is 28km but it was 241kms at km84; this shows that LCV's are used for local movement but at other locations they used to transport goods regionally. 2x-3x lead varies from 82km to 502km and 175km to 363 km respectively. This shows that these modes are used to transfer goods for intermediate to longer distances. But lead of MAV's suggested that these modes are primarily used for longer trip lengths only.

Table 5-19 : Location wise Lead Analysis

Location Name (Section)	Car	Bus	LCV	2-x	3-x	MAV
G.D Goenka University @Km21 (Ashram Chowk - Sohna)	60	106	28	82	175	366
Dhanwala @Km77 (Bhadas-Firozpur Jhirka)	104	134	-	502	410	404
Maholi @Km84 (Firozpur jhirka-Alwar)	71	119	241	321	363	406

5.6.4 Purpose wise analysis- Passenger Vehicles

Purpose wise analysis suggests that work and business trips accounts for more than 65% in areas near to urban settlements like near to G.D Goenka University (@km21). But for other locations, passenger trips are mainly performed for Social Purposes. As these locations are away from any urban influences, people perform journeys for social & medical reasons only.

Table 5-20 : Purpose-wise Analysis of Passenger Vehicles at Different Locations

Purpose	G.D Goenka University (@km21)	Dhanwala (@km77)	Maholi (@km84)
Work	63%	33%	34%
Business	2%	3%	1%
Education	5%	1%	2%
Shopping	1%	0%	1%
Religious/Tourism	2%	13%	11%
Social	21%	46%	44%
Medical	7%	5%	7%

5.6.5 Local Traffic

Local traffic around a toll plaza is eligible for toll concessions as per NHAI policy.

As per Circular of NHAI, No. NHAI/13013/19/02-03/CMD/CO/Concession Vol III dated 29th March, 2005 all the local residents, local transport operators, school buses and bus operators plying

within a given radius as specified in the circular are eligible for concession in user fee. Definition of Local Traffic as well as concession given to this traffic is detailed in the following section:

Local Traffic is that traffic which is originated or destined within 20 km radius of the proposed toll plaza. This traffic will get concession after the production of the proof of their residence and proof of their vehicle ownership. Concessional slabs suggested for passenger and commercial traffic are listed below.

Monthly passes to local residents for Car/jeep/Van:

- Local area monthly passes at the monthly rate of Rs. 150/- for the residents of villages/towns/cities falling within a radius of 10 km from the fee collection booths may be issued for their car/jeep/van on production of residence proof and ownership proof of the vehicle for which the pass is being issued.
- Local area monthly passes at the monthly rate of Rs. 300/- for the residents of villages/towns/cities falling within a radius of 10 km and up to 20 km from the fee collection booths may be issued for their car/jeep/van on production of residence proof and ownership proof of the vehicle for which the pass is being issued.

Monthly passes for Buses:

- Monthly Passes for the state transport buses may be given at the specified rate in favour of state government transport on the certification by the competent authority (not less than General Manager, State Government Road Transport) certifying the number of buses plying in the route per day. In case Private local operators, the same may be considered on production of their permit for the route operators and time table of the route operation duly certified by the District Transport Authority.

Monthly passes for School Buses:

- Monthly passes for the school buses, for school student crossing the toll plaza may be issued @ Rs. 1000/- after obtaining the written request of the principal of the school along with recognition of the school and registration of the buses.

Concessional fee for LCV/Trucks:

- Concessional fee shall be charged from the Local Transport Operators on production of proof for plying within 20 kms i.e. goods challan for origin and destination clearly specifying the return details of the vehicle. The fee for such transport will be Rs. 25/- for Trucks for each entry and Rs. 15/- for Light Commercial vehicles.

  Mode-wise Local Traffic estimated for the toll plaza at Km 13.00 of Gurgaon-Nuh-Rajsthan Border section of NH-248 is mentioned in the table below.

Mode	Total Vehicles	Local Vehicles	% of Local Vehicles
Passenger Vehicles			
Car	9442	6008	64%
Minibus	40	40	100%
Bus	495	129	26%
Freight Vehicles			
LCV	683	683	100%
Trucks	2198	176	8%

Inferences:

It is observed that 64% of cars and 100% of minibuses plying through the toll plaza location are local traffic. Around 26% of the buses passing through toll plaza location are local traffic. The rest is through traffic.

All the LCVs operated through toll plaza location are local traffic, carrying smaller commodities and serving surrounding towns and villages. Around 8% of the trucks are serving nearby towns and can be considered as local traffic. The majority of heavy freight movement is through in nature.

5.7 TURNING MOVEMENT COUNT ANALYSIS

Turning Movement counts are done at 11 locations on project corridor. The average daily traffic, Peak traffic and Peak hour factor of these locations are presented below:

Table 5-21 : ADT and Peak Hour Traffic Distribution

Sl. No.	Location & Chainage	Type of Intersection	Total Traffic Flow (PCU)	Peak Hour PCU	Peak Hour
1	Subhash Chowk (@1.9km)		2,30,525	17,140	08:00 - 09:00
2	Vatika Chowk (@5km)		1,36,261	8,453	08:00 - 09:00
3	Marutikunj (@9.7km)		49,368	3,410	08:00 - 09:00
4	KR Mangalam University (@19.4km)		28,538	1,822	08:00 - 09:00

Sl. No.	Location & Chainage	Type of Intersection	Total Traffic Flow (PCU)	Peak Hour PCU	Peak Hour
5	KMP Expressway (@30.8 km)		21,256	1,521	10:00 - 11:00
6	Salamba (@41.2 km)		20,251	1,738	11:00 - 12:00
7	Nuh (@42.6 km)		59,912	4,011	10:00 - 11:00
8	Akera Junction (@54.3 km)		30,475	2,011	07:00 - 08:00
9	Badhkhali (@63.7km)		26,791	1,524	10:00 - 11:00
10	Ambendkar Roundabout at Firozpur Jhirka (@80.06 km)		26,277	2,103	08:00 - 09:00

All the surveyed intersection lies either near to urban areas or near the settlements. So heavy traffic is observed on all the intersections with total flow varying from 20,000 PCU to 2,00,000 PCU and peak hour traffic from 1500 PCU to 17,000 PCU.

As per IRC 92-1985, "An interchange may be justifies when an at grade inter-section fails to handle the volume of traffic resulting in serious congestion and frequent choking of intersection. The situation may arise when the total traffic of all arms of the intersection is in excess of 10,000 PCU's per hour." Considering this; No intersection warrants for full interchange. As per SP 090-2010, "Vehicular Underpass/overpass shall be provided at intersection of Project highway with all N-H and S-H. Such grade separated facility shall also be provided across other categories of road carrying ADT of 5000 PCU or more." Considering this and also in discussion with local authorities; Cross road facilities such as VUP, Flyover or Viaduct have been decided for the intersection locations.

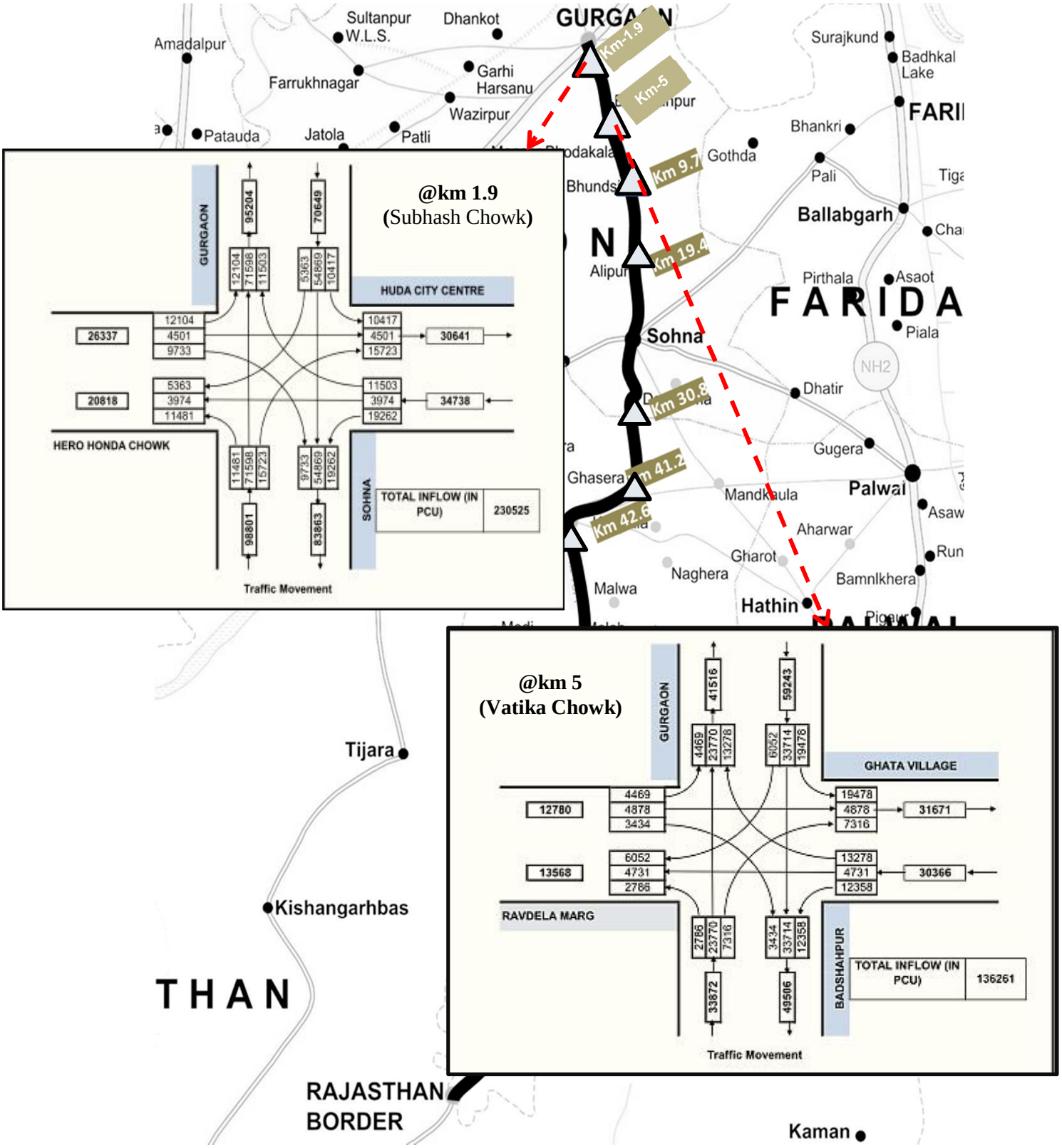
Based on the guidelines mentioned above, interventions required at different intersections along the project corridor are worked out. Existing situation and interventions required at all the intersections are presented in Table 5-22.

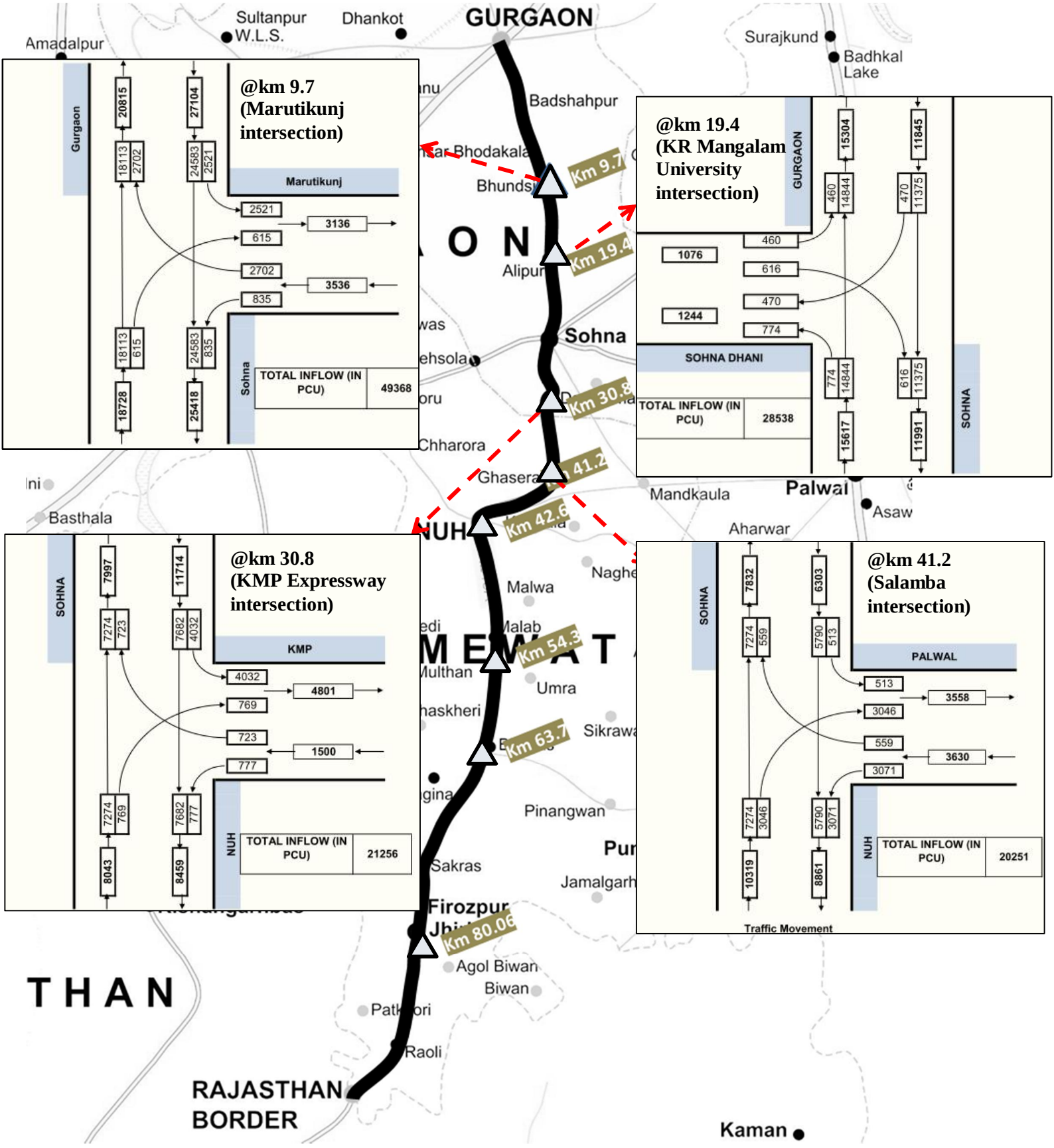
Table 5-22 : Existing Situation and Interventions for Intersections

Intersection	Existing Situation	Problems	Mitigation Measures
Subhash Chowk (@1.9km)	At grade with signalized junction	Queueing at the intersection during peak hour	Main Carriageway shall be grade separated by an

Intersection	Existing Situation	Problems	Mitigation Measures
			Underpass as the Cross road has already been elevated. Left and right turning local traffic shall be controlled by traffic signal.
Vatika Chowk (@5km)	At grade Junction	Queueing at the intersection during peak hour	Grade Separated Junction. Left and right turning local traffic shall be controlled by traffic signal.
Marutikunj (@9.7km)	At grade Junction with Marutikunj	Congestion during Peak Hour	Grade separated Junction
KR Mangalam University (@19.4km)	At grade Jucntion	Safety issue due to mixing of University bound traffic with high speed through traffic	Elevation of Project road with 20m VUP with slip roads.
KMP Expressway (@30.8 km)	Grade Separated Junction	-	-
Salamba (@41.2 km)	Major at grade junction	Traffic congestion	Grade separated Junction
Nuh (@42.6 km)	Major at grade junction	Traffic congestion during peak hour in commercial area of Nuh	Grade separated Junction
Akera Junction (@54.3 km)	At grade junction	Heavy traffic on all the arms.	Grade separated Junction
Badhkhali (@63.7km)	Major at grade junction	Traffic congestion in commercial area od Badhkali village	Grade separated Junction
Ambendkar Roundabout at Firozpur Jhirka (@80.06 km)	Major at grade junction with roundabaout	Heavy traffic congestion at junction due to Kheli Pahari stone quarry.	Grade separated Junction

Turning flow at each location is presented in Figure 5-21. The summarized data of mode wise traffic movement at all the locations is presented in Appendix 5-25 to Appendix 5-32**.**


Sultanpur W.L.S.
Dhankot
Amadalpur
Farrukhnagar
Garhi Harsanu
Wazirpur
Patauda
Jatola
Patli
Km-1.9
Km-5
Km 9.7
Km 19.4
Km 30.8
Km 41.2
Km 42.6
Surajkund
Badhkal Lake
Bhankri
Gothda
Pali
Ballabgarh
Pirthala
Asaot
Piala
Sohna
Dhatir
Gugera
Palwal
Mandkaula
Aharwar
Gharot
Naghera
Bamnlkhera
Hathin
Ghasera
Malwa
Tijara
Kishangarhbas
THAN
RAJASTHAN BORDER
Kaman
@km 1.9
(Subhash Chowk)
GURGAON
HUDA CITY CENTRE
HERO HONDA CHOWK
SOHNA
26337
20818
30641
34738
TOTAL INFLOW (IN PCU)
230525
Traffic Movement
@km 5
(Vatika Chowk)
GHATA VILLAGE
RAVDELA MARG
BADSHAHPUR
12780
13568
31671
30366
TOTAL INFLOW (IN PCU)
136261
Traffic Movement


GURGAON
Sultanpur W.L.S.
Dhankot
Amadalpur
Surajkund
Badhkal Lake
Badshahpur
Bhundsi
Alipur
Sohna
Chharora
Ghasera
Mandkaula
Palwal
Asaw
Aharwar
Basthala
Malwa
Multhan
Umra
Sikrawa
Pinangwan
Sakras
Jamalgarh
Firozpur Jhi
Agol Biwan
Biwan
Raoli
RAJASTHAN BORDER
Kaman
Km 9.7
Km 19.4
Km 30.8
Km 41.2
Km 42.6
Km 54.3
Km 63.7
Km 80.06
@km 9.7 (Marutikunj intersection)
Gurgaon
Marutikunj
Sohna
TOTAL INFLOW (IN PCU) 49368
@km 19.4 (KR Mangalam University intersection)
GURGAON
SOHNA DHANI
SOHNA
TOTAL INFLOW (IN PCU) 28538
@km 30.8 (KMP Expressway intersection)
SOHNA
KMP
NUH
TOTAL INFLOW (IN PCU) 21256
@km 41.2 (Salamba intersection)
SOHNA
PALWAL
NUH
TOTAL INFLOW (IN PCU) 20251
Traffic Movement

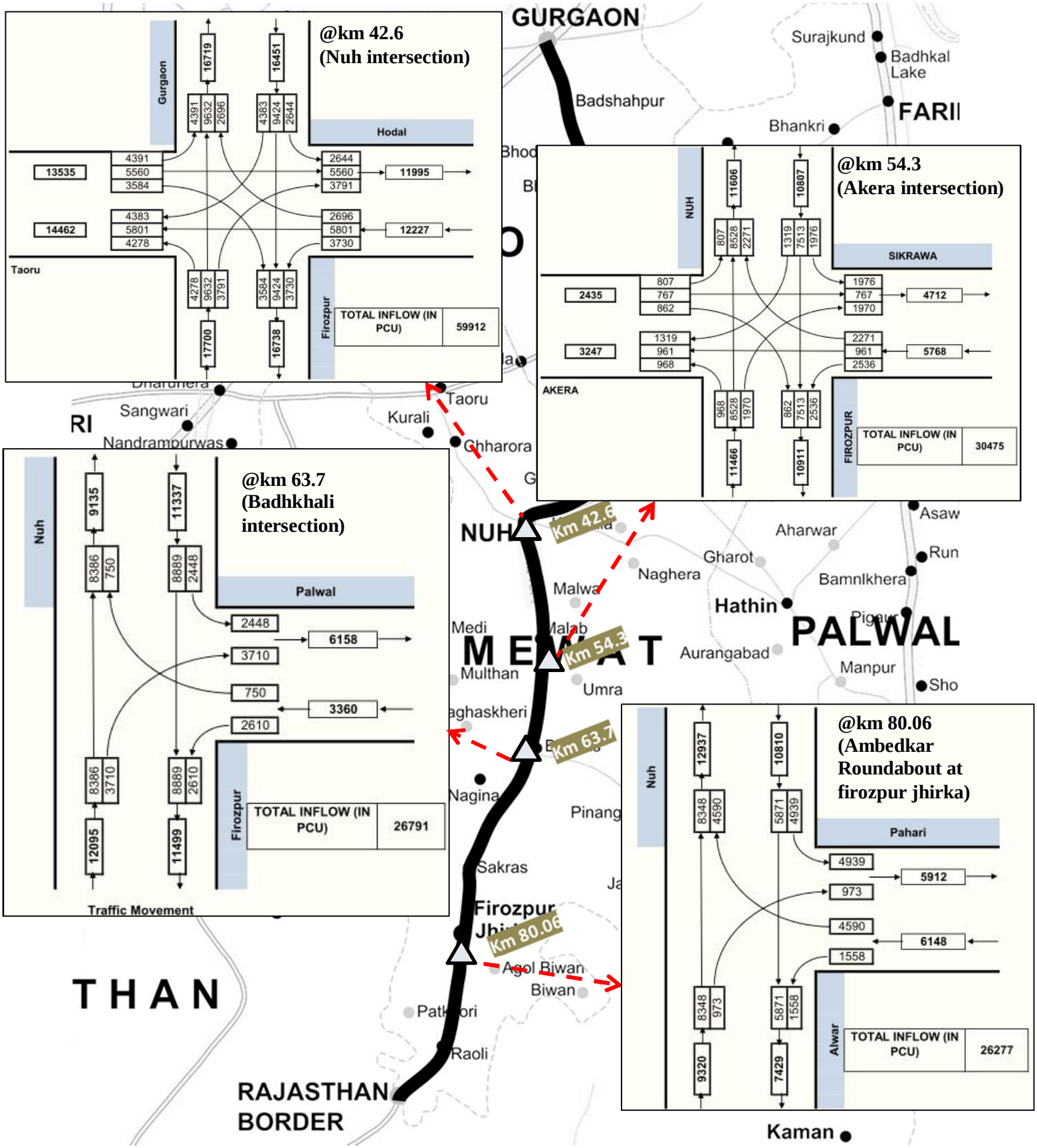


Figure 5-21 Turning Flow at Different Intersections

5.8 PROJECTED TRAFFIC & CAPACITY ANALYSIS

The future traffic demand assessment is made based on the past socio economic data for the influencing states, registered motor vehicle data and population census data. Traffic forecast are made for the horizon years which will form the basis for maintenance of project road and capacity augmentation for the project road.

Traffic forecast has been based on the transport demand elasticity approach, wherein a log-log relationship has been established between traffic and socio-economic indicators. Traffic growth rates by vehicle type for the project corridor have been determined. The projection for future traffic involves critical analysis of some of the key socio-economic indicators and the rate of change expected in the project influence area. They broadly include:

- Registered Motor Vehicles
- Net State Domestic Product (NSDP)
- Population and Urbanization
- Perspective Economic Growth.

5.8.1 Project influence area

The study of the socio-economic profiles of the project influence area (PIA) provides an overview of the factors likely to influence the pattern of economic development and hence the traffic flows and volumes on Gurgaon-Nuh section of NH 248A. The factors include population, Per-capita Income, NSDP and targeted growth rates of the economy. These factors help to generate basic inputs to estimate the future growth in transport demand, transport demand elasticity's and economic growth rates. From OD survey analysis, it is observed that the majority of vehicles are from Haryana state. Therefore, the data of Haryana State has been used in estimating the growth rates of goods and Passenger traffic.

5.8.2 Past trend in growth of registered motor vehicles

If the area is well defined and the general development pattern of influence area remains same, it can be assumed that traffic growth rate is approximately equal to the average growth rate of vehicle registration. There is a strong influence of number of vehicles in operation in Haryana.

The Compound Annual Growth Rate (%) of different vehicle types from 2001-13 is shown in Table 5-23.

Table 5-23 : Growth of Registered Vehicles in Haryana

Year	Two wheelers	Car/Jeep	Taxi	Bus	LMV Pass.	Trucks	LMV Goods	Tractor	Others
2005	1729236	402585	17294	11297	43239	166437	67991	394111	21477
2006	1881174	469109	16344	19986	45858	176046	74494	382581	21434
2007	2172669	551020	17738	22101	52620	200977	83921	405605	21646
2008	2463672	650265	13869	26906	63914	220470	90793	430365	13030
2009	2768197	730544	14791	29516	73134	230858	96558	473438	8185
2010	2975418	836293	15081	33520	83745	249991	102541	490828	4408
2011	3370426	968980	19978	35646	94770	275162	114384	487321	10336
2012	3755349	1110721	23793	39153	103995	292735	124897	516658	10809
2013	4146906	1265119	27946	42800	114465	307509	137511	545192	11490
Growth Factor									
Growth 2005-06	8.79%	16.52%	-5.49%	76.91%	6.06%	5.77%	9.56%	-2.93%	-0.20%
Growth 2006-07	15.50%	17.46%	8.53%	10.58%	14.75%	14.16%	12.65%	6.02%	0.99%
Growth 2007-08	13.39%	18.01%	-21.81%	21.74%	21.46%	9.70%	8.19%	6.10%	-39.80%
Growth 2008-09	12.36%	12.35%	6.65%	9.70%	14.43%	4.71%	6.35%	10.01%	-37.18%
Growth 2009-10	7.49%	14.48%	1.96%	13.57%	14.51%	8.29%	6.20%	3.67%	-46.15%
Growth 2010-11	13.28%	15.87%	32.47%	6.34%	13.16%	10.07%	11.55%	-0.71%	134.48
Growth 2011-12	11.42%	14.63%	19.10%	9.84%	9.73%	6.39%	9.19%	6.02%	4.58%
Growth 2012-13	10.43%	13.90%	17.45%	9.31%	10.07%	5.05%	10.10%	5.52%	6.30%
Average Growth	*11.6%*	*15.4%*	*7.4%*	*19.7%*	*13.0%*	*8.0%*	*9.2%*	*4.2%*	*2.9%*

5.8.3 Past Growth of Economy

Net State Domestic Product (NSDP) of a state is the prime economic indicator of the economic development and growth performance of the state. It captures the value of economic performance and earning from each sector of the economy, and their contribution to the economy. The NSDP also implies the outlook for framing supporting economic regulatory policies.

Growth of traffic on the project road also depends on existing development and future growth prospects of the connecting regions. As the traffic on the road is mostly contributed by the state of Haryana, the economic data of these two states are taken in the analysis. The economic data has been processed based on past trend and presented in Table 5-24.

Table 5-24 : Growth in NSDP, Population and PCI of Haryana State from 1991-14

Year	Population (000)	Growth (Annual)	*NSDP(Constant Prices 2004-2005)	*PCDP(Constant Prices 2004-2005)
1991	16464			
2001	21145	2.53%		
2011	25353	1.83%		
2005			862.22	37972
2006			940.11	40627
2007			1047.00	44423
2008			1128.96	47046
2009			1215.88	49780
2010			1367.80	55044
2011			1460.53	57797
2012			1585.23	61716
2013			1671.69	64052
2014			1783.07	67260

* Rupees in Billion

To assess the future trend of growth of the various socio-economic parameters the past trend of GDP, NSDP, Population & Per capita NSDP has been linearly extrapolated.

5.8.4 Perspective Growth Rate

Haryana State

Haryana is one of the most economically developed regions in South Asia, and its agricultural and manufacturing industries have experienced sustained growth since the 1970s. Since 2000, the state has emerged as the largest recipient of investment per capita in India.

It is bordered by Punjab and Himachal Pradesh to the North, and by Rajasthan to the West and South and by Uttar Pradesh and Delhi in the East. The river Yamuna defines its eastern border with Uttar Pradesh. Haryana surrounds the country's capital Delhi on three sides, forming the northern, western and southern borders of Delhi. Consequently, a large area of south Haryana is included in

the National Capital Region for purposes of planning for development. Important cities in Haryana are:

Gurgaon, has seen emergence of an active information technology industry in the recent years. With organizations like IBM, Hewitt Associates, Dell, Convergys, United Healthcare and NIIT set up back offices or contact centers in Gurgaon. The headquarters of DLF Limited, India's largest real estate company, in Gurgaon, Haryana.

Faridabad is a biggest industrial city of Haryana as well as North India.

Rohtak has the largest wholesale cloth market of Asia, known as shori market. As of 2012, Haryana State Industrial and Infrastructure Development Corporation (HSIIDC) have developed an Industrial Model Township (IMT). Near Gurgaon city, IMT Manesar has been developed.

Bahadurgarh is an important developing industrial town with glass, steel, tiles manufacturing and biscuits production.

Panipat has heavy industry, including a refinery operated by the Indian Oil Corporation and a National Thermal Power Corporation power plant. It is known for its woven *modhas* or round stools.

Hissar is another developing city.

Haryana has four main geographical features.

The Yamuna-Ghaggar plain forming the largest part of the state

The Shivalik Hills to the northeast

Semi-desert sandy plain to the southwest

The Aravalli Range in the south

The Yamuna flows along the state's eastern boundary.

Haryana's main seasonal river, the Ghaggar rises in the outer Himalayas, between the Yamuna and the Satluj and enters the state near Pinjore in the Panchkula district. Passing through Ambala and Sirsa, it reaches Bikaner in Rajasthan and runs for 460 km before disappearing into the deserts of Rajasthan. Important tributaries include the Chautang and Tangri.

The seasonal Markanda River is a stream, which in ancient times was known as the Aruna. It originates from the lower Shivalik Hills and enters Haryana west of Ambala. During monsoons, this stream swells into a raging torrent notorious for its devastating power. The surplus water is carried on to the Sanisa Lake where the Markanda joins the Saraswati and later the Ghaggar.

Three other rivulets in and around the Mewat hills, the Indori, Dohan and Kasavati all flow from East to West and once were tributaries of the Drishadwati/Saraswati rivers.

There are two agroclimatic zones in Haryana. The northwestern part is suitable for rice, wheat, vegetables and temperate fruits, and the southwestern part is suitable for high-quality agricultural produce, tropical fruits, exotic vegetables and herbal and medicinal plants. The cultivable area is 84% of the geographical area of the state. About 98% of cultivable area is under cultivation.

Agriculture and related industries have been the backbone of the local economy. Since 2001, the state has witnessed a massive influx of immigrants from across the nation, primarily from Bihar, Bengal, Uttrakhand, Rajasthan, Uttar Pradesh and Nepal.

Primarily an agrarian economy, Haryana is one of the largest contributors to the food grain pool of India. Cotton, sugarcane and oilseeds are the main commercial crops that have also led to the growth of a large number of agro-based industries. Despite the fact that Haryana is just 1.37 percent of the total geographical area of India and has less than 2 percent of the total population, the state has one of the highest per capita incomes in the country. Its compact size has been a significant reason for its development.

Haryana's major strength also lies in its industries. Cars, tractors, motorcycles, refrigerators, bicycles and sanitary ware are manufactured in the state.

From its inception Industry and Services Sectors registered higher growth rate than the Agriculture and Allied Sectors which resulted in the increased share of Industry and Services Sectors and decreased share of Agriculture and Allied Sector in the GSDP. The composition of GSDP shows that the share of Agriculture & Allied Sector is continuously declining whereas the share of Services Sector is continuously increasing.

Mega Food Park Project at Industrial Estate Barhi has been proposed over an area of about 75 acres, under the Mega Food Park Scheme (MFPS) of Ministry of Food Processing Industries (MOFPI), Govt. of India. The project site has been earmarked. Govt. of India will provide grant assistance of 50 crore for this project.

Haryana State is not known to have significant deposits of any major minerals and its mining operations are largely confined to the mining of minor minerals such as Stone, Boulder, Gravel, Sand, etc. which are largely used for the construction industry.

Infrastructure is a key driver of economic growth and it has the potential to fuel the economy. Inadequate and inefficient infrastructure can prevent the economy from realizing its full growth potential regardless of the progress on other fronts. Creation and maintenance of physical infrastructure facilities is also a pre-requisite to attract foreign investments. Physical infrastructure covering power, transportation, communication and storage besides facilitating economic growth has direct impact on quality of life.

There are numerous manufacturing companies in the region. These include Hindustan National Glass, Maruti Udyog Limited, Escorts Group, Hero MotoCorp, Alcatel, Sony, Whirlpool India, Bharti Telecom, Liberty Shoes and HMT. In addition there are more than 80,000 small-scale industrial units in the state which cumulatively bring in a substantial income for the state and its people. Yamunanagar district has a paper mill BILT.

In order to leverage investments along DFS (Dedicated Freight Corridor) from Delhi to Mumbai, the State Government is planning three major initiatives in collaboration with DIPP (Department of Industrial Policy and Promotion), Ministry of Commerce, Government of India i.e. (i) Integrated Multi Model Logistic Hub in Southern Haryana to cater to the entire NCR, (ii) Global City in Gurgaon District, and (iii) MRTS (Mass Rapid Transit System) connecting Gurgaon-

Manesar-Bawal. Further, notification for the Draft Development Plan of Manesar Bawal Investment Region (MBIR), to be developed initially over an area of 402 sq. km., has been issued. KMP (Kundli Manesar Palwal) Expressway which was pending for last few years will now be completed in a time bound manner.

The growth trend can be predicted with good accurately for short time. The changes in socio-economic scenario and other influencing factors cannot be predicted for long time horizon. The growth rates of traffic are calculated in 5 years interval.

The growth rates of traffic on the project road by different mode have been projected on the basis of the growth rate calculated based on econometric model prescribed by IRC. The linear projection of the NSDP as per the past trend and assessed future NSDP rate of growth of influencing states are presented in Table 5-25.

Table 5-25 : Perspective Growth rates of Haryana

Year	NSDP	PCI
2018-20	7.36%	5.94%
2021-25	6.59%	5.40%
2026-30	5.93%	4.92%
2031-35	5.41%	4.53%
> 2035	4.98%	4.21%

5.8.5 Transport Demand Elasticity

As stated earlier, the elasticity approach was used for determining growth rates of future traffic. Elasticity approach is based on the premise that vehicular growth rates are influenced by the area economies of the traffic originating and destining states/regions. Under this methodology, a quantitative relationship is established between time series vehicle registration data and socio-economic indicators. This is done by fitting *log-log* regression equations with vehicle registration data as the dependent variable and socio-economic indicators as the independent variable. Using the vehicular growth rates, projections of vehicular traffic have been made over the analysis period.

As the traffic contribution on the project corridor is mainly from Haryana, transport demand elasticities are developed with respect to socio economic indicators of Haryana state. The methodology involves fitting regression equation to the time series data. The NSDP is considered as independent variable for freight vehicles and per-capita income and population is considered as independent variable for passenger vehicles. The elasticity values are presented in Table 5-26.

Table 5-26 : Elasticity values Derived by Regression Analysis

Sl. No.	Vehicle Type	Economic / Demographic Variable	R2	Elasticity
1	Car	NSDP	0.996	1.47
		Population	0.999	6.86
		PCI	0.995	1.84
2	Taxi	NSDP	0.227	0.42
		Population	0.246	2.03

Sl. No.	Vehicle Type	Economic / Demographic Variable	R2	Elasticity
		PCI	0.224	0.52
3	Bus	NSDP	0.870	1.48
		Population	0.864	6.88
		PCI	0.869	1.86
4	LCV Pass	NSDP	0.989	1.32
		Population	0.989	6.17
		PCI	0.988	1.66
5	Two Wheeler	NSDP	0.992	1.09
		Population	0.997	5.10
		PCI	0.990	1.37
6	Trucks	NSDP	0.994	0.93
		PCI	0.993	1.17
7	LCV Goods	NSDP	0.989	1.00
		PCI	0.986	1.26
8	All Goods Combined	NSDP	0.994	0.95
		PCI	0.993	1.20
9	Tractors	NSDP	0.944	0.53
		Population	0.948	2.48
		PCI	0.942	0.66

The elasticity values of buses and LCV passenger with PCI are very high. Thses values are moderated based on the perspective growth trend and moderated elasticity used for these modes for calculation of growth rates. Elasticity values for trailers are used considering its national growth trend. The adopted values of elasticities are presented in Table 5-27.

Table 5-27 : Adopted Elasticity Values

Vehicle Type	Elasticity
Two Wheeler	1.37
Car/Jeep	1.84
Bus	0.80
Taxi	0.52
LCV Pass	1.20
Trucks	0.93
LCV Goods	1.00
Trailers	1.10
Tractors	0.53

5.8.6 Traffic Growth Rates

Based on the estimated elasticity values and forecast growth rate of economic variables, the future growth rates for each type of vehicle were computed using following model.

Tgr = PCI gr*100*E

Where,

Tgr = Traffic Growth Rate

PCI gr = Per Capita Income Growth Rate

E = Elasticity value

The above model is primarily used for passenger vehicles. Similarly, the model applied for estimating growth rate of goods vehicles is as follows:

Tgr = NSDP gr * 100*E

Where,

Tgr = Traffic Growth Rate

NSDP gr = growth rate of NSDP (in real terms)

E = Elasticity value

Projected Traffic Growth Rate: Considering the factors such as past performance of the economy, recent developments in economic liberalization measures, shift in between sectors, opportunities available in local and global markets etc., future economic growth scenario is formulated. The projected traffic has been calculated for the realistic, pessimistic and optimistic scenarios.

Any projection beyond 10-15 years will have little relevance. Therefore, traffic is projected up to the year 2035 in 5 years slab. No further projection is attempted. Hence, the entire period beyond 2030 has been kept as one slab. The traffic growth rates calculated are given below in Table 5-28.

Table 5-28 : Traffic Growth rate for the Project Road (Realistic)-Scenario-1

Year	2-Wheeler	Car/Jeep	Bus	Taxi	Auto Rick.	Truck	LCV Good	Tract.	Tract. & Trailer
2018-20	8.1%	10.9%	4.7%	3.1%	8.8%	6.8%	7.4%	3.9%	8.1%
2021-25	7.4%	9.9%	4.3%	2.8%	7.9%	6.2%	6.6%	3.5%	7.2%
2026-30	6.7%	9.05%	3.9%	2.6%	7.1%	5.5%	5.9%	3.1%	6.5%
2031-35	6.2%	8.3%	3.6%	2.4%	6.5%	5.0%	5.4%	2.8%	5.9%
> 2035	5.7%	7.7%	3.4 %	2.2%	5.9%	4.6%	4.9%	2.6%	5.5%

The growth rate has been developed for optimistic and pessimistic scenario. Growth rate for pessimistic scenario are considered as -10% as compared to realistic scenario (scenario-1). For optimistic scenario a +10% growth prospective as compared to realistic scenario has been considered. The growth rate in Scenario-2 and Scenario-3 is given in Table 5-32 and 5-32. The future traffic projections given in the following paras are based on scenario-1.

Table 5-29 : Traffic Growth rate for the Project Road (Pessimistic)-Scenario-2

Year	2-Wheeler	Car/Jeep	Bus	Taxi	Auto Rick.	Trucks	LCV Goods	Tract.	Tract. & Trailor
2018-20	7.3%	9.8%	4.3%	2.8%	7.9%	6.2%	6.6%	3.5%	7.3%
2021-25	6.6%	8.9%	3.8%	2.5%	7.1%	5.5%	5.9%	3.2%	6.5%
2026-30	6.0%	8.2%	3.5%	2.3%	6.4%	4.9%	5.3%	2.8%	5.8%
2031-35	5.5%	7.5%	3.3%	2.1%	5.8%	4.5%	4.8%	2.6%	5.3%
> 2035	5.2%	6.9%	3.03 %	1.9%	5.4%	4.2%	4.5%	2.8%	4.9%

Table 5- 30 : Traffic Growth rate for the Project Road (Optimistic)-Scenario-3

Year	2-Wheeler	Car/ Jeep	Bus	Taxi	Auto Rick.	Trucks	LCV Goods	Tract.	Tract. & Trailor
2018-20	8.9%	12. %	5.2%	3.4%	9.7%	7.5%	8.1%	4.3%	8.9%
2021-25	8.1%	11%	4.7%	3.1%	8.7%	6.7%	7.3%	3.8%	7.9%
2026-30	7.4%	10%	4.3%	2.8 %	7.8%	6.1%	6.5%	3.4%	7.2%
2031-35	6.8%	9.2 %	3.9%	2.6%	7.1%	5.5%	5.9%	3.2%	6.5%
> 2035	6.3%	8.5 %	3.7%	2.4%	6.6%	5.1%	5.5%	2.9%	6.0%

5.8.7 Traffic Forecast

Using the traffic growth rates described in previous section, traffic forecast considering all modes of traffic was done for horizon years. Refer Table 5-31 for overall realistic traffic forecast. Detailed mode wise traffic projections are shown in Appendix 5-33 to 5-38.

Table 5-31 : Projected Traffic – Realistic Scenario

Year	Rajiv Chowk-Ashram Chowk (6 lane)		Ashram Chowk-Sohna (4 lane)		Sohna-Nuh (4 lane)		Nuh-Badhkhali (2 lane)		Badhkhali-Firozpur Jhirka (2 lane)		Firozpur Jhirka-Rajasthan Border (2 lane)	
	Total Veh.	Total PCUs	Total Veh.	Total PCUs	Total Veh.	Total PCUs	Total Veh.	Total PCUs	Total Veh.	Total PCUs	Total Veh.	Total PCUs
2016	68923	68760	18761	23847	12579	18582	17349	23248	9975	15309	8838	10755
2017	75234	74945	20388	25778	13637	20039	18804	24962	10779	16446	9568	11597
2018	82156	81715	22167	27878	14789	21604	20388	26898	11652	17678	10360	12494
2019	89752	89140	24110	30162	16042	23298	22112	28995	12599	19008	11220	13464
2020	98087	97282	26234	32648	17406	25131	23988	31266	13627	20443	12155	14514
2021	106389	105379	28338	35093	18750	26920	25838	33485	14635	21837	13075	15539
2022	115429	114192	30620	37736	20202	28842	27838	35872	15722	23331	14068	16641
2023	125276	123785	33097	40592	21771	30910	30000	38441	16893	24933	15138	17825
2024	136002	134232	35785	43680	23468	33134	32337	41206	18155	26651	16293	19098
2025	147690	145611	38704	47020	25303	35526	34865	44182	19515	28493	17540	20467
2026	159276	156877	41584	50297	27104	37854	37349	47085	20846	30279	18762	21801
2027	171812	169063	44690	53818	29040	40344	40017	50190	22272	32183	20073	23226
2028	185376	182245	48039	57603	31119	43006	42886	53514	23800	34213	21479	24750
2029	200056	196507	51653	61673	33355	45854	45969	57073	25437	36378	22987	26380
2030	215945	211941	55553	66050	35758	48901	49283	60883	27192	38687	24605	28122
2031	231771	227300	59421	70372	38131	51888	52559	64625	28920	40943	26201	29832
2032	248801	243826	63573	74996	40668	55068	56061	68612	30762	43338	27904	31650
2033	267131	261609	68028	79944	43382	58455	59808	72860	32727	45881	29722	33587
2034	286860	280747	72811	85240	46285	62061	63816	77389	34823	48581	31662	35648
2035	308098	301347	77945	90910	49390	65903	68104	82218	37060	51449	33734	37842
> 2035	329324	321924	83059	96535	52471	69690	72360	86985	39271	54267	35787	40006

Highlighted number suggests the requirement of 6 laning in different years.

As per Circular no. NH-33044/37/2015/S&R(R), *when the traffic on the highway exceeds 10,000 PCU, the highway must be upgraded from 2 lane to 4 lane and when the traffic on the highway exceeds 25,000 PCU, the highway must be upgraded from 4 lane to 6 lane.*

- As per the traffic projections for different sections along the project corridor, immediate 4-laning is necessary.
- Six laning will be required for Ashram Chowk-Sohna in 2017, for Sohna-Nuh in 2020, for Nuh-Badhkhali in 2018, for Badhkali-Firozpur Jhirka in 2024 and for Firozpur Jhirka-Rajasthan Border in 2029.

5.9 TOLLABLE TRAFFIC

Since the Project corridor will be a developed as a toll road, it is very important to estimate the tollable traffic that will actually pay toll. Tollable traffic has been estimated by removing toll exempted vehicles such as two wheelers, autos and agricultural vehicles.

Toll plaza locations has been fixed at km 13 and 74+500 keeping in mind connecting state highways, parallel roads and other leakage points and the minimum required distance between consecutive toll plazas.

Tollable traffic estimated for the locations is presented in the following tables. Table 5-32 and Table 5-33 shows the projected tollable traffic at km 13 and km 74+500 respectively.

Table 5-32 : Tollable Traffic near Bhondsi Village (@km 13)

Years	Car	Taxi	M.Bus	Bus	M. LCV	LCV	Goods Auto	Trucks	MAV	HCM
2016	7248	896	111	511	770	702	67	1899	428	19
2017	8040	924	117	535	826	754	72	2029	462	20
2018	8919	952	122	560	887	810	77	2168	500	22
2019	9895	982	128	587	953	870	83	2317	540	24
2020	10976	1012	134	615	1023	934	89	2476	584	26
2021	12067	1041	140	641	1090	995	95	2629	626	27
2022	13266	1070	146	669	1162	1061	101	2791	672	29
2023	14585	1100	152	698	1239	1131	108	2962	721	32
2024	16034	1131	159	728	1321	1206	115	3145	773	34
2025	17628	1163	166	759	1408	1285	122	3338	829	36
2026	19224	1193	172	789	1492	1362	129	3523	883	39
2027	20964	1223	179	820	1580	1443	137	3718	941	41
2028	22863	1255	186	852	1674	1528	145	3923	1002	44
2029	24933	1287	193	886	1774	1619	154	4141	1067	47
2030	27190	1320	201	921	1879	1715	163	4370	1137	50
2031	29458	1351	208	954	1981	1808	172	4590	1205	53
2032	31915	1383	216	989	2088	1906	181	4822	1276	56
2033	34576	1416	223	1025	2201	2009	191	5065	1352	59
2034	37460	1449	231	1062	2320	2118	201	5321	1432	63
2035	40584	1483	240	1100	2446	2233	212	5589	1518	67
2036	43729	1516	248	1137	2568	2344	223	5849	1601	70

Table 5-33 : Tollable Traffic near Chak Rangala Village (@km 74+500)

Years	Car	Taxi	M.Bus	Bus	M. LCV	LCV	Goods Auto	Trucks	MAV	HCM
2016	1841	207	24	155	390	255	36	2570	286	2
2017	2043	214	25	163	419	274	38	2747	309	2
2018	2266	220	26	170	450	294	41	2935	334	2
2019	2514	227	27	179	483	315	44	3137	361	2
2020	2788	234	29	187	518	339	47	3352	390	2
2021	3066	241	30	195	552	361	50	3559	418	3
2022	3370	248	31	204	589	385	54	3778	449	3
2023	3705	255	33	212	628	410	57	4010	481	3
2024	4073	262	34	221	669	437	61	4257	516	3
2025	4478	269	36	231	713	466	65	4519	553	4
2026	4884	276	37	240	756	494	69	4769	589	4
2027	5326	283	38	250	801	523	73	5033	628	4
2028	5808	290	40	259	848	554	77	5311	669	4
2029	6334	298	42	270	899	587	82	5605	713	5
2030	6907	306	43	280	952	622	87	5915	759	5
2031	7483	313	45	290	1004	656	92	6214	804	5
2032	8108	320	46	301	1058	691	97	6527	852	5
2033	8784	328	48	312	1115	729	102	6857	903	6
2034	9516	335	50	323	1176	768	107	7203	956	6
2035	10310	343	52	335	1239	810	113	7566	1013	6
2036	11109	351	53	346	1301	850	119	7918	1069	7

5.10 CONCLUSION

- Project Road has 6 traffic homogeneous sections namely Rajiv Chowk - Ashram Chowk (0-4.9), Ashram Chowk - Sohna (4.9-23.3), Sohna - Nuh (23.3-42.63), Nuh - Bhadas (42.63-63.7), Bhadas - Firozpur Jhirka (63.7-80.060), Firozpur Jhirka - Rajsthan Border (80.060-93.960).
- Traffic volume along the corridor varies from 10,665 PCU to 73,753 PCU at different sections of the project road.
- Car and 2-Wheeler are the predominant passenger modes at all the sections of the project road. This is due to high urban development and presence of major cities along the corridor.
- As the stretch from Rajiv Chowk (0+000) km to Bhondsi (9+700 km) carries very high volume due to its urban character and the stretch is already 6-lane; this will be converted to elevated facility in future to ease the traffic movement.
- Traffic flow suggests the project corridor to be converted to 4-lane divided carriageway immediately.
- Traffic projections on this highway suggest that 6 laning would be necessary in the year 2017 for Ashram Chowk-Sohna which is currently a 4-lane facility. For Sohna-Nuh and Nuh-Badhkali section, 6-laning will be required in year 2020 and 2018 respectively.
- Travel pattern of passenger vehicles shows that around 44-64% of traffic is destined along the Project corridor and 10-30% of traffic is destined with in Gurgaon and Mewat district.
- Travel pattern of freight vehicles shows that around 45-56% of traffic is destined along the Project corridor and 34% of traffic is destined with in Gurgaon and Mewat district for location near G.D Goenka University (@21km). Whereas only 3-5% of traffic from Dhanwala (@Km 77) and Maholi (@Km 84) is destined in these districts.
- Cross road facilities such as VUP or grade separated facilities are required for all intersections as per SP: 090-2010. Other than these all major intersections to be developed as grade separated facility.
- Requirement of Bypass are observed at two locations viz Ghasera and Malab to ease out traffic movement and non-availability of ROW at these locations.

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CHAPTER 6: ENGINEERING SURVEYS AND INVESTIGATIONS

6.1 ROAD INVENTORY AND ROAD CONDITION

An inventory of the project road has been carried out with visual observations supplemented with measurements using tape at site. All existing details like terrain, land-use, surfacing type and width, shoulder surfacing type & width, subgrade, local soil type, curve details, intersection details, retaining structures details, location of water bodies, height of embankment or depth of cut, ROW, cross drainage structures, road side arboriculture, existing utility services, general drainage conditions etc., were recorded. The road inventory has been referenced to the existing kilometer posts established along the roadside. A detailed road inventory is presented in the ***Appendix-6.1.***



Fig. 6.1: Start of the Project Road at km 11+682 (existing) of NH-248A



Fig. 6.2: End of the Project Road at km 24+400(existing) of NH-248A

National Highway 248A starts at Shahpura in Rajasthan and ends in Gurgaon, Haryana. The project road section starts from PWD R.D. 2+400 at Rajiv Chowk, Gurgaon which is a 4 legged – grade separated junction at km. 32+650 of NH-8 and ends at PWD R.D. 95+985 of NH-248A at Rajasthan border. Hence the total actual existing length of the project road is 93.585 km. However as discussed in previous chapter, the report discusses regarding the Package-II of the project where the Package-II starts from PWD R.D. 11+682 at ends at PWD R.D. 24+400. Hence the total actual existing length of the project road is 12.718 km.

6.1.1 Terrain

The project road is passing all along through plain terrain only.

6.1.2 Land Use

Land use along the project highway comprises agricultural, commercial and residential land. In the built-up areas both residential and commercial buildings have developed. At some stretches religious structures just abutting the shoulder have been noticed. A detail of the land use pattern along the project road is given in Road Inventory, ***Appendix-6.1***. Besides, the list of religious sensitive structures located close to the existing road is presented in **Table 6.1**.

Table 6.1: List of Religious Sensitive Structures

Sl. No.	Existing Chainage	Type of structure	Side	Distance from carriageway (m)
1	12+945	Temple	Both Sides	10

6.1.3 Carriageway and Roadway width

Between PWD R.D. 11+682 and end of the project i.e PWD R.D 24+400, the existing NH-248A is of 2 x 2-lane configuration with median varying between 0.5m to 1.5m.

The existing roadway configuration of the project highway is tabulated in **Table 6.2A** below.

Table 6.2: Existing Roadway Configuration of Main Carriageway

Sl. No.	PWD R.D.		Length (km)	Existing Lane Configuration
	From	To		
1	11+682	24+400	12.718	2 x 2-lane
Total			**12.718**	

Roadside covered drain evident in the built up sections along the project highway. In rural areas, roadside drain is seldom noticed.

6.1.4 Surfacing Type

The entire project road stretch has bituminous surface type pavement.

6.1.5 Embankment Height

The average height of embankment varies from 0 to 0.5 m. However, higher embankment exists at approaches to the bridges. Condition of the embankment is fair. At seldom locations height of embankment is more than 3.0m.

6.1.6 Right of Way

As per the information gathered from revenue maps, the project road under Package-II has existing ROW varying mostly between 45-60m. Besides, at site, it is also noticed that the distance between the property lines on either side is sometimes more than the width marked in the revenue map. In other words, the available land is more than the ROW marked on the revenue map. For the purpose of this study and as per discussion with NHAI, the existing ROW adopted is the maximum between the available ROW at site and the ROW demarcated in the revenue map. Chainage-wise ROW as available from revenue map and the available land at site is presented in **Appendix 6.2.**

The summary of existing ROW is presented in **Table 6.3**.

Table 6.3: Summary of Existing ROW

Sl. No.	Existing ROW	Approx. Length (km)	Percent
1	<=30	0	0%
2	30-35	0	0%
3	35-40	0.78	6%
4	40-45	0.128	1%
5	45-60	11.81	93%
6	>60	0	0%
	Total	**12.718**	**100.00%**

6.1.7 Villages and Towns

The villages and towns through which the project road traverses are listed in **Table 6.4.**

Table 6.4: List of Built-up sections

Sl. No	Name of Built-up Area	Existing Chainage (Km)		Length (Km)
		From	To	
1	Bhondsi	12+700	14+600	1.90
2	University Area	21+900	22+900	1.0
3	Sohna	23+000	24+400	1.40

6.1.8 Side Drain

Roadside covered drain evident in the built up sections along the project highway. In rural areas, roadside drain is seldom noticed. The location and details of existing drains are tabulated below:

Table 6.5: Location and details of side drains

Sl. No	Existing Chainage		Length (m)	Side	Details
	From	To			
1	12+870	13+770	900	BS	RCC drain
2	23+470	24+400	930	BS	RCC drain

6.1.9 Horizontal Curves

The horizontal alignment of the project road is mostly straight and with flatter curves except in some odd locations, like in Malab village where geometry is substandard in a short stretch.

6.1.10 Road Junctions

There are 4 nos. of major and 10 minor junctions along the project highway. Most of the minor junctions lead to the nearby villages/settlement areas. Based on reconnaissance survey the details of intersections are tabulated in **Table 6.6** below:

Table 6.6: Details of Intersections

Sl. No.	Existing Chainage	Junction Type		LHS			RHS			Remarks
				Type	Width	Leads	Type	Width	Leads	
1	12+181	**T**	**Major**	BT	4.50	Maruti Kunj				
2	13+019	T	Minor				BT	6.90	Bhondsi	
3	14+150	**T**	**Major**	BT	5.30	Ritroj road				
4	16+305	T	Minor	BT	3.80	Mahendwara				
5	16+725	+	**Major**				BT	3.90	Ghamroj	
6	18+286	Y	Minor				BT	3.70	Alipur	
7	18+336	T	Minor	BT	5.00	Garhi Bazidpur				
8	19+800	Y	Minor				BT	5.70	Raiseena	
9	20+212	T	Minor	BT	3.80	Berka				
10	21+950	T	**Major**				BT	5.30	Mohamad pur Gurjar	
11	22+675	T	Minor	Gr.	3.00	Village				
12	24+010	Y	Minor				BT	5.50	Sohna	Maharaja Agrasen road
13	24+120	Y	Minor	BT	3.50	Berka				
14	24+370	T	Minor				BT	5.20	Sohna	

6.1.11 Road Signs

Informatory signs exist occasionally to guide the drivers along the highway from safety point of view. Conditions of these sign boards are generally fair to good. However adequacy of road signs shall be assessed based on required driver safety.

6.1.12 Pavement Condition Survey

Detailed field studies have been carried out to collect pavement/shoulder/drainage conditions and are presented in ***Appendix 6.3- Pavement Condition Survey.***

Pavement Condition

Pavement condition survey was done primarily by visual observations. Pavement rating has been carried out following the guidelines described in IRC: 82 and on the basis of extent and magnitude of the pavement distresses. The pavement rating criteria as followed is given in **Table: 6.7**.

Table 6.7: Pavement based distress rating for highways

Defects	Range of Distress		
Cracking (%)	>10	5-10	<5
Ravelling (%)	>10	1-10	<1
Potholes (%)	>1	0.1-1	<0.1
Shoving (%)	>1	0.1-1	<0.1
Patching (%)	>10	1-10	<1
Settlement and Depression (%)	>5	1-5	<1
Rut depth using 3m Straight edge	>10	5-10	<5
Rating	1	1.1-2	2.1-3
Condition	Poor	Fair	Good

Based on the extent of distress, each distress is rated on a scale of 3, where anything less than equal to 1 is equivalent to poor condition, rating between 1 and 2 reflects fair condition and between 2 and 3 it is good condition. Each of the rating for individual distress is aggregated by a weightage factor as per IRC: 82 and as presented in **Table 6.8**.

Table 6.8: Weightage for distress in rating calculation

Sl. No.	Parameter	Weightage (Multiplier)
1	Cracking	1.0
2	Raveling	0.75
3	Potholes	0.5
4	Shoving	1.0
5	Patching	0.75
6	Settlement	0.75
7	Rut depth	1.0

The final rating value is calculated by taking the average of weighted rating values of all the distresses. The condition of road pavement has been analysed using the above approach for each km and shown in the line chart in subsequent section of the report.

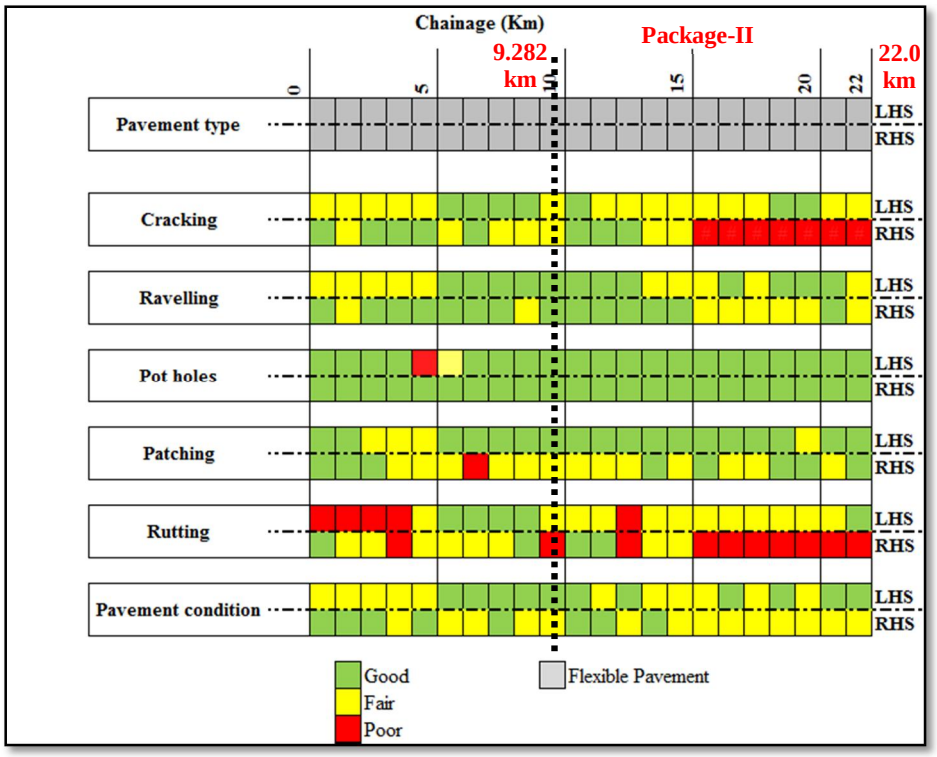


Fig.6.3: Linear representation for pavement condition, type and distress distribution

The riding quality of the pavement visually varies from good to fair. Following IRC: 21, 6 km length of left carriageway is found in good condition where rest of the 6.718 km length is in fair condition. For right carriageway 3 km length of the project road is found in good condition and rest of the length 9.781 km is found in fair condition. However, extensive cracking and rutting is observed in the most of the stretches in both carriageway which are in fair condition, this is depicted in **Fig. 6.3**. Mostly three types of cracks were observed namely, longitudinal cracks, transverse and alligator cracks.

6.2 AXLE LOAD SURVEY & ANALYSIS

6.2.1 General

The intensity of traffic loading and the corresponding damaging power of different categories of vehicles is an important parameter for the design of pavements. The main objective of the axle load survey is to determine a Vehicle Damaging Factor (VDF) of each commercial vehicle and their axle load spectrum/distribution and expected damage on pavement and extent of over loading.

6.2.2 Location

Axle load survey was conducted for duration of 48-hours (both direction) along with the volume count simultaneously at two locations viz. PWD R.D. 79+400 (before Firozepur Jhirka) and PWD R.D. 86+400 (after Firozepur Jhirka) to assess the axle load spectrum on the each traffic homogenous section of the project road and in turn to determine the Vehicle Damage Factor (VDF) for commercial vehicles. The survey was done using portable weigh pad. Axle load survey was conducted to cover both directional traffic and both for empty and loaded commercial vehicles i.e. Light Goods Vehicles (LGV), 2-axle trucks, 3-axle tracks and multi-axle trucks.

6.2.3 Vehicle Damaging Factor

The Vehicle Damaging factor (VDF) is an important indexing factor for characterizing the traffic loading on the road. The VDF can easily be computed from the axle load data by the following formula, provided sufficiently large and fairly distributed sample of vehicles are included in the axle load survey. The vehicle damage factor is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration to the number of standard axle load repetitions. It is defined as equivalent number of standard axle per commercial vehicle. The VDF varies with the vehicle axle configuration, axle loading, terrain, type of road and from region to region.

$$\mathbf{VDF} = \frac{\mathbf{Total\ EAL}}{\mathbf{Number\ of\ Vehicles\ Weighed}}$$

6.2.4 Load Equivalence Factors

For design purpose the variation in axle loads is usually handled through reducing the actual axle load to “Equivalent Axle Load (EAL)”. An equivalency is simply convenient means for indexing the wide spectrum of actual loads to one selected value. One of the most important and useful products of AASHO Road Test was the development of a relationship characterizing the relative damaging effect of varying axle load on pavements in terms of equivalent 8.2 Tonne (80KN) single axle load (1KN = 9.81 tonne). This relationship sometimes referred as “Fourth Power” rule, has subsequently been verified by studies reported by several agencies in different countries.

$$\mathbf{Single\ Axle\ Load\ with\ Single\ Wheet} = \left(\frac{\text{Axle Load in KN}}{65}\right)^4$$

$$\mathbf{Single\ Axle\ Load\ with\ Dual\ Wheels} = \left(\frac{\text{Axle Load in KN}}{80}\right)^4$$

$$\mathbf{Tandem\ Axle\ Load} = \left(\frac{\text{Axle Load in KN}}{148}\right)^4$$

$$\mathbf{Tridem\ Axle\ Load} = \left(\frac{\text{Axle Load in KN}}{224}\right)^4$$

The rule states that damaging power of an axle load increases roughly as fourth power with the weight of an axle. Any single axle load less than 8200 kg i.e. 80KN is some fractional EAL, whereas any greater single load is some multiple of EAL. In order to convert axle loads, from axle load surveys into EAL, these are usually grouped into the intervals of 10KN for Single Axle, 20KN for Tandem Axle and 30KN for Tridem Axle and the frequency of each vehicle intervals is determined (Cl. 4.4.5 of IRC:37-2012). Equivalencies factors are obtained for each category from "Fourth Power" rule. Product of frequency of axle load and load equivalency factors gives the EAL for that weight class of the sample.

$$Total\ EAL = \sum (No.\ of\ Vehicles\ in\ each\ weight\ class\ x\ Load\ equivalency\ factor\ of\ the\ class$$

Load equivalency factor used in the study are tabulated in **Table 6.9A** to **Table 6.9C**.These equivalency factors are based on "Fourth Power" rule as specified in Cl. 4.4 of IRC: 37.

Table 6.9A: Load Equivalency Factors for Single Axle

Sl. No.	Axle Load Category (KN)		Average Axle Load (KN)	Load Equivalency Factor	
	From	To		Single Axle with Single Wheel	Single Axle with Dual Wheels
1	0	10	5	3.50128E-05	1.52588E-05
2	10	20	15	0.003	0.001
3	20	30	25	0.022	0.010
4	30	40	35	0.084	0.037
5	40	50	45	0.230	0.100
6	50	60	55	0.513	0.223
7	60	70	65	1.000	0.436
8	70	80	75	1.773	0.772
9	80	90	85	2.924	1.274
10	90	100	95	4.563	1.989

Table 6.9B: Load Equivalency Factors for Tandem Axle

Sl. No.	Axle Load Category (KN)		Average Axle Load (KN)	Load Equivalency Factor
	From	To		
1	0	20	10	2.08427E-05
2	20	40	30	0.002
3	40	60	50	0.013
4	60	80	70	0.050
5	80	100	90	0.137

Sl. No.	Axle Load Category (KN)		Average Axle Load (KN)	Load Equivalency Factor
	From	To		
6	100	120	110	0.305
7	120	140	130	0.595
8	140	160	150	1.055
9	160	180	170	1.741
10	180	200	190	2.716

Table 6.9C: Load Equivalency Factors for Tridem Axle

Sl. No.	Axle Load Category (KN)		Average Axle Load (KN)	Load Equivalency Factor
	From	To		
1	0	30	15	2.01082E-05
2	30	60	45	0.002
3	60	90	75	0.013
4	90	120	105	0.048
5	120	150	135	0.132
6	150	180	165	0.294
7	180	210	195	0.574
8	210	240	225	1.018

6.2.5 Axle Load Spectrum Analysis

Axle load spectrum analysis was done location wise, direction wise and vehicle wise. Various parameters were arrived and the same are described below:

Vehicle Damage Factor (VDF)

The vehicle damage factor values were arrived for each vehicle type, location wise and direction wise. Distribution of the damaging effect i.e. VDF, caused by each vehicle category at different location and by their direction of travel is depicted in **Fig. 6.4** below.

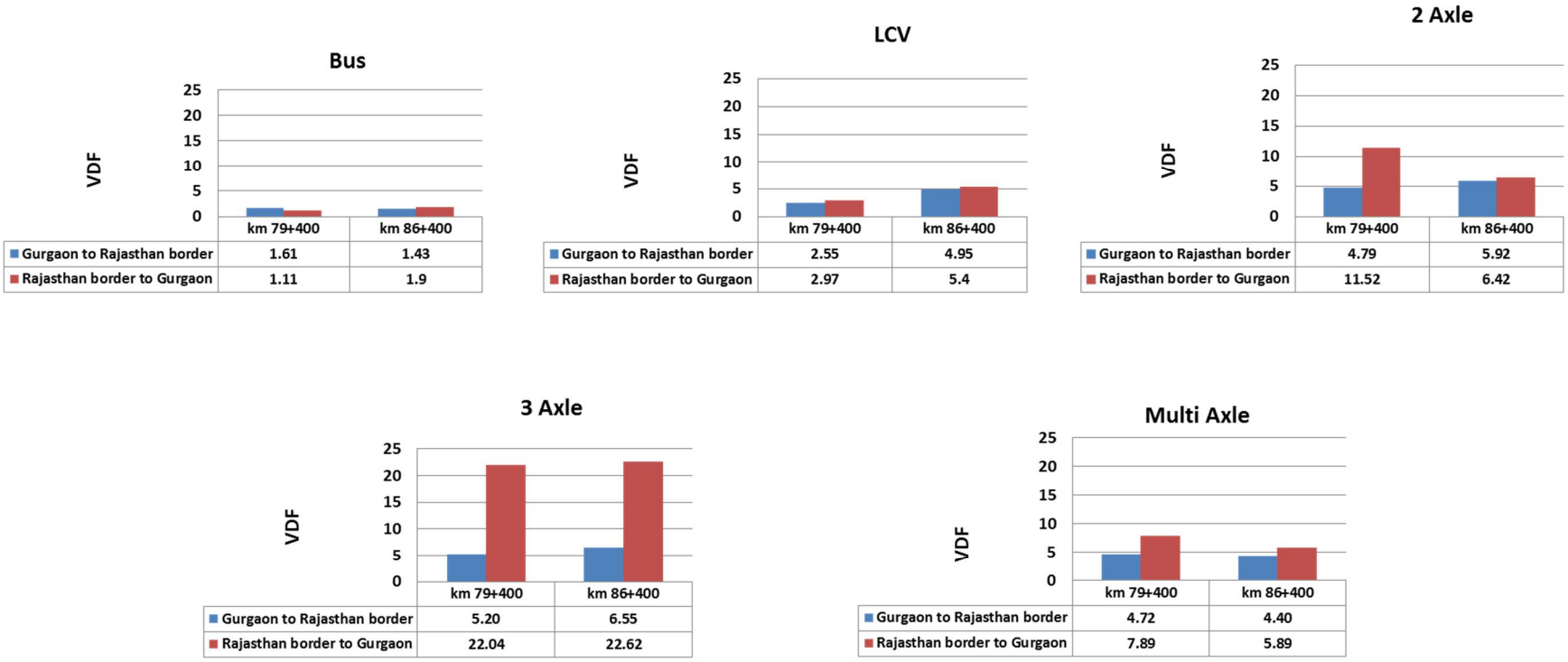


Fig.6.4: Comparison of Vehicle Damage Factors (VDF) by Vehicle Category, Location and Direction of Travel

Sample Size

The sample size of axle load survey is presented in **Table 6.10 A** to **Table 6.10B.**

Table 6.10A: Sample size of axle load survey at location R.D. 79+400

Type of Vehicle	Gurgaon to Rajasthan border			Rajasthan border to Gurgaon		
	Vehicles Sampled	Total Vehicle	Sample Size, %	Vehicles Sampled	Total Vehicle	Sample Size, %
LCV	12	115	10.4	12	125	9.6
2 Axle	57	178	32.0	37	195	19.0
Bus	14	72	19.4	6	74	8.1
3 Axle	131	1051	12.5	150	1000	15.0
Multi Axle	13	162	8.0	14	106	13.2
Total	**227**	**1578**	**14.4**	**219**	**1500**	**14.6**

Table 6.10B: Sample size of axle load survey at location R.D. 86+400

Type of Vehicle	Gurgaon to Rajasthan border			Rajasthan border to Gurgaon		
	Vehicles Sampled	Total Vehicle	Sample Size, %	Vehicles Sampled	Total Vehicle	Sample Size, %
LCV	12	115	10.4	11	111	9.9
2 Axle	25	116	21.6	40	83	48.2
Bus	8	72	11.1	11	80	13.8
3 Axle	155	413	37.5	177	366	48.4
Multi Axle	38	191	19.9	29	125	23.2
Total	**238**	**907**	**26.2**	**268**	**765**	**35.0**

Summary of Overloading

As per "Dimensions and Weights of Road Design Vehicles", IRC: 3 – 1983, maximum permissible gross weight and axle load by vehicle type is presented in **Table 6.10 C** below:

Table 6.10C: Permissible Axle Load

Sl. No.	Type of Vehicle	Permissible Gross weight			
		Front Axle	Rear Axle	Tandem	Total
1	***LCV***	6t (58.9KN)	6t (58.9KN)	-	12t (117.8KN)
2	***2 Axle***	6t (58.9KN)	10.2t (101.6KN)	-	16.2 (159.0KN)
3	***Bus***	6t (58.9KN)	10.2t (101.6KN)	-	16.2 (159.0KN)
4	***3 Axle***	6t (58.9KN)	-	18t (176.6KN)	24 (235.5KN)
5	***Multi Axle***	6t (58.9KN)	10.2t (101.6KN)	18t (176.6KN)	34.2 (335.6KN)

The percentage of vehicles exceeding their legal axle load or gross vehicle weight is presented in **Fig. 6.5**. The gross vehicle weight distribution at both the survey locations for each direction is presented in **Fig. 6.6**.

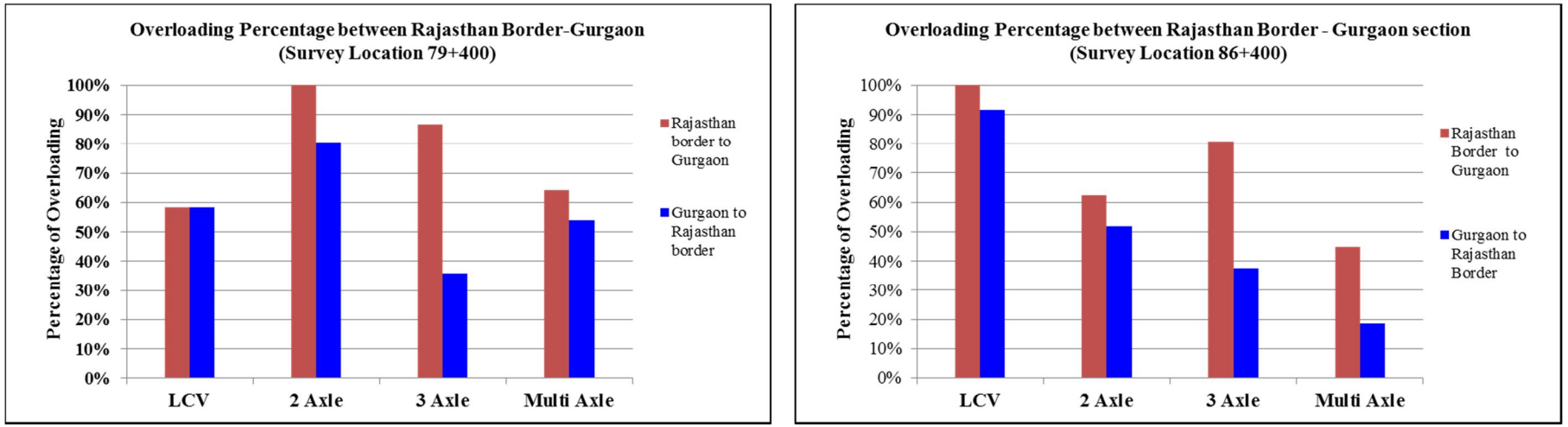


Fig. 6.5: Direction-wise distribution of Percentage of Different Vehicle Category exceeding Permissible Axle Load /GVW Limit (Overloading)

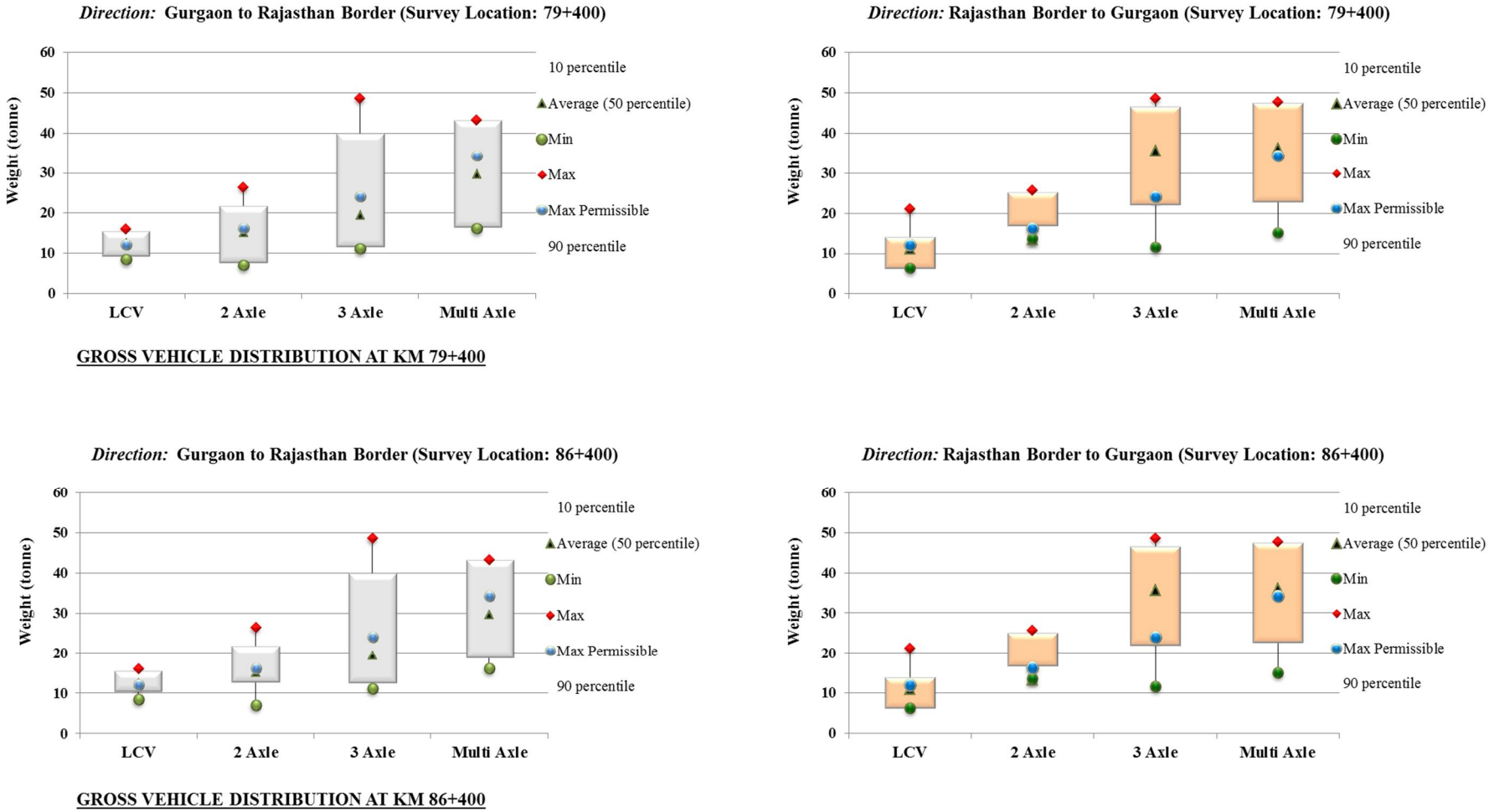


Fig. 6.6: Gross Vehicle Weight Distribution vs. Permissible Limit

From **Fig. 6.5** reveals that overloading is as high as 64%~ 100% (km 79+400) and 45%~100% (km 86+400) for 2-axle, 3-axle and multi-axle trucks plying from Rajasthan to Gurgaon border. In opposite direction overloading is found varying between 35%~ 83% (km 79+400) and 18%~92% (km 86+400). At 79+400 km, 64% of the multi-axle vehicles,87% 3 Axle vehicles and 100% 2 Axle vehicles plying between Rajasthan Border-Gurgaon section) are overloaded. As depicted in **Fig. 6.6**, VDF distribution of traffic travelling from Rajasthan border to Gurgaon has been estimated to be more than that in the opposite direction. The value of the estimated VDF has been used to estimate the design traffic loading for pavement design.

Hence the adopted VDF values are presented in **Table 6.11**.

Table 6.11: Adopted VDF Values

Vehicle Type	Stretch			
	km 0+000 to km 79+400 (*Survey Location: km 79+400)*		**km 79+400 to km 94+300 (** *Survey Location: km 86+400)*	
	Gurgaon to Rajasthan border	**Rajasthan border to Gurgaon**	**Gurgaon to Rajasthan Border**	**Rajasthan Border to Gurgaon**
Bus	1.61	1.11	1.43	1.90
LCV	2.55	2.97	4.95	5.40
2 Axle	4.79	11.52	5.92	6.42
3 Axle	5.20	22.04	6.55	22.62
M Axle	4.72	7.89	4.40	5.89

The axle load analyses for data collected at two locations are presented in **Annexure 6.1A** to **Annexure 6.1B.**

6.3 BENKELMAN BEAM DEFLECTION TECHNIQUE

The evaluation of structural strength of existing flexible pavement was carried out using a Benkelman Beam in accordance with the procedure given in IRC 81.

For measuring pavement deflection, the C.G.R.A procedure that is based on testing under static load was adopted. A standard truck having a rear axle weighing 8200kg fitted with dual tyre inflated to a pressure of 5.60 kg/sq.cm was used for loading the pavement. The beam was calibrated using metal plates of known thickness prior to testing. The dual wheels of the truck are cantered above the selected point.

Deflection surveys have been carried out as per the scheme given below:

- Main line surveys;
- Control section testing

The deflection tests for the main line have been carried out for the km 7 to km 16.6 along the road sections covered under the study. The control section testing has been carried out for each 100 m long homogeneous road segment based on the data derived from pavement condition surveys. The deflection measurements for such homogeneous section were at an interval of 100 m. Pavement temperature was recorded at every one hour during the testing period by inserting a

thermometer in a hole (approximately 5 cm deep and 10 mm diameter) drilled in the pavement and filled with glycerol. At any deviation of the pavement temperature during measurements from the standard temperature of 35o C, correction has been applied to the deflection measured in accordance with the procedure described in IRC: 81. Seasonal correction was carried out using the moisture correction factors given in Fig. 2 to Fig. 7 in IRC: 81. PI and moisture content of the subgrade were established from test pit excavations carried out simultaneously with the Benkelman Beam tests. The Benkelman Beam Deflection data are presented in **Table 6.12**, the graphical representation of the same is presented in **Fig. 6.8**. The detail analysis is presented in ***Annexure-6.2.***



Fig. 6.7: View of BBD Survey at PWD R.D. 14+400 (Chainage 12+000)

Table 6.12: Characteristic Deflection along the Project Road

Chainage*		Characteristic Deflection (mm), Dc	
From (km)	**To (km)**	**Left C/w**	**Right C/w**
9	10	0.99	0.44
10	11	0.78	0.51
11	12	1.31	0.63
12	13	0.39	0.70
13	14	0.35	0.69
14	15	0.55	0.38
15	16	0.45	0.51
16	17	0.43	0.23
17	18	0.49	0.23
18	19	0.46	0.52
19	20	0.46	0.99
20	21	0.51	0.38
21	22	0.14	0.62

Note:*0km = PWD RD 2+400 km

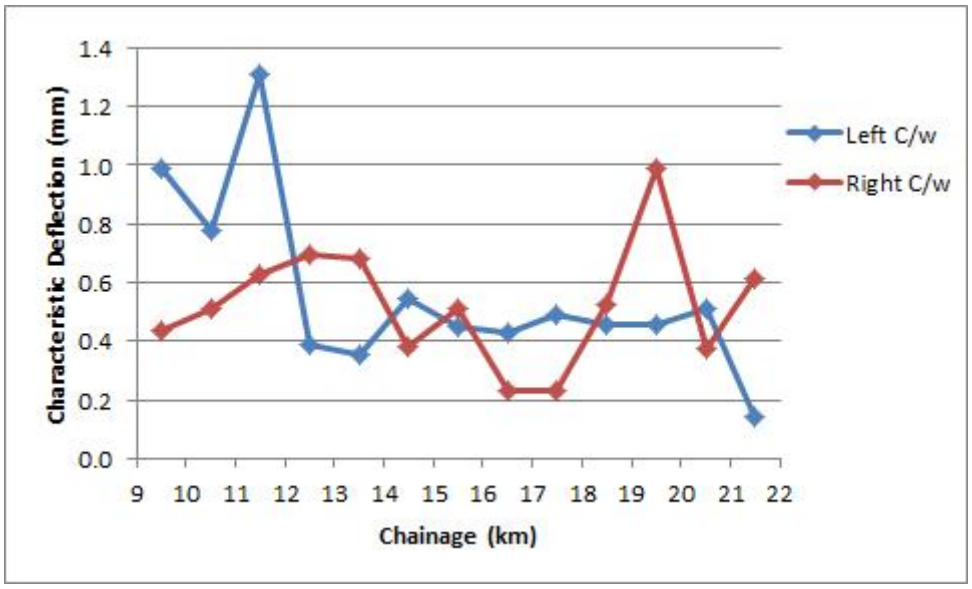


Fig. 6.8: Characteristic Deflection (mm) along the Project Road

6.4 TRIAL PITS

The investigations were carried out along the existing road using trial pits made as under:

Test Pit - 1.0m x 1.0m at every 2 Km or change of soil strata.

At small pit locations following information were collected:

- Pavement Composition
- Soil samples were collected for their Classification.



Fig. 6.9: Pit test at km 13+600 (RHS)

At Large pit locations following tests were conducted:

- Pavement Composition
- In-situ density test at sub-grade top by Core Cutter method

- Characterisation (grain size and Atterberg limits)
- Laboratory moisture-density characteristics
- Laboratory CBR (4-day soaked condition and swell)

6.4.1 Pavement Composition

For each test pit, the following information is recorded:

- Test pit reference (Identification number, location)
- Pavement composition (material type and thickness)
- Subgrade type (textural classification) and condition (dry, wet)

A broad variation in pavement thickness along the project road was observed. The wearing coat (Bituminous) varies from 95 mm to 270 mm. While granular course varies from 210 mm to 635 mm. The subgrade below the sub-base course was observed to be mostly of non-plastic nature. Pavement composition of the existing road is given in **Table 6.13**.

Table 6.13: Pavement Composition of the Existing Road

Chainage (km)	Side	Pavement thickness		
		Bituminous course (mm)	Granular course (mm)	Total (mm)
9+500	(RHS)	240	430	670
11+600	(LHS)	240	425	665
13+500	(RHS)	230	440	670
15+500	(LHS)	210	400	610
17+400	(RHS)	215	410	625
20+350	(LHS)	220	390	610

The above pavement crust is depicted in **Fig. 6.10** below.

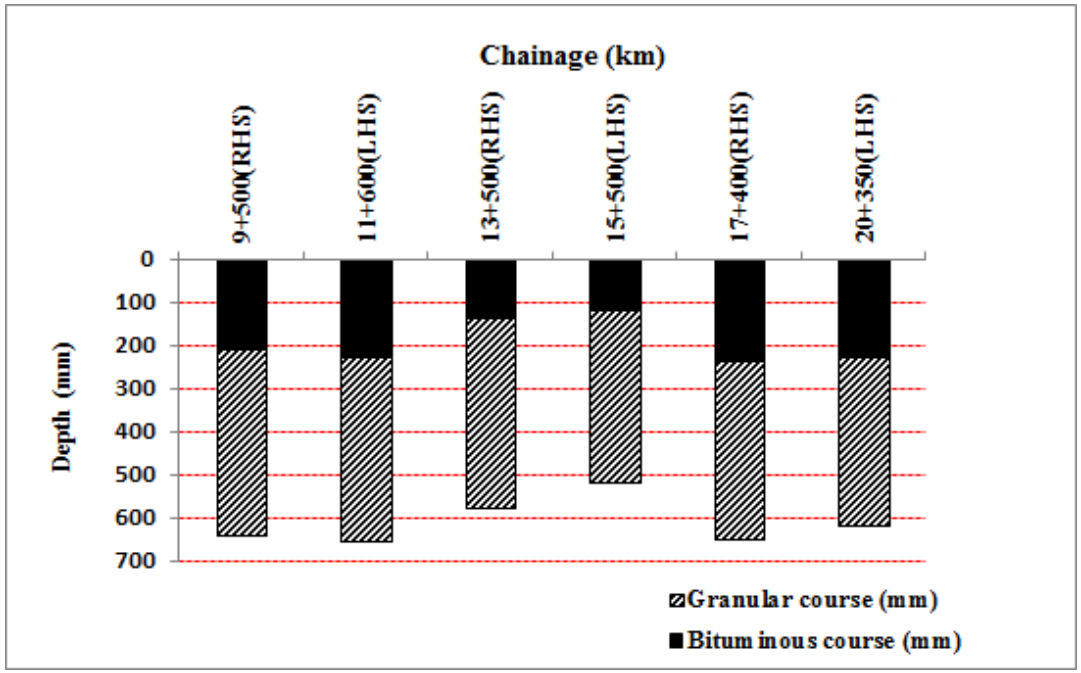


Fig. 6.10: Existing Pavement Composition Graph

Note: Chainages shown is considering Rajiv Chowk as Km. 0+000 (PWD R.D. 2+400)

6.4.2 Characterization of Subgrade

The details of all the tests carried out on subgrade for their physical, strength and stability Characteristics are given in **Table 6.14**.

Table 6.14: Different Tests carried out on Subgrade Soil

Sl. No.	Test Parameters	Method Reference
1	Field Density	IS:2720 (Part 28)
2	Water Content	IS:2720 (Part 2)
3	Grain Size Analysis	IS:2720 (Part 4)
4	Atterberg Limits	IS:2720 (Part 5)
5	MDD-OMC(Compaction)	IS:2720 (Part 8)
6	CBR	IS:2720 (Part 16)
7	Free Swell Index	IS:2720 (PART 40)

The laboratory test results consist of gradation, Atterberg limits, compaction characteristics (maximum dry unit weight and optimum moisture content relationship as per heavy compaction), CBR (soaked),free swelling etc. for the subgrade soils underneath the existing pavement. The test results of subgrade soils are summarised in **Table 6.15**. It is inferred that the average CBR of existing subgrade is 8%.

Table 6.15: Test Results of Existing Subgrade Soil

Location	% Passing through I.S. Sieve				% Sand content	Atterberg limit			Free swelling index (%)	Field moisture (%)	M.D.D. (gm/cc)	O.M.C (%)	CBR (%)
	4.75 mm	2.00 mm	425 mic.	75 mic		L.L	P.L.	P.I.					
0+150	100	97.36	88.4	38.8	61.2	21.9	N.P	N.P	0	7.37	1.975	10.6	9.89
2+500	100	97.23	87.82	50.42	49.58	22.6	N.P	N.P	0	6.71	1.945	11.2	9.68
5+100	100	95.81	85.61	43.26	56.74	22.2	N.P	N.P	0	7.4	1.99	10.3	10.13
9+500	100	96.14	85.43	47.56	52.44	22.8	N.P	N.P	0	6.09	1.965	10.6	9.46
15+500	100	98.14	89.95	53	47	23.25	N.P	N.P	0	7.23	2	10	10.21

6.5 MATERIAL INVESTIGATIONS

The sources for material; metal quarry material and sand quarry have been identified around the project area. The details of borrow soil and quarry material, location and distance from the project road are given in **Table 6.16**.

6.5.1 Borrow Area Soil

The borrow areas were identified in and around (not within ROW) the project road. The borrow area map is presented in the **Fig. 6.12**.The suitability of borrow material is established from laboratory testing.



Fig.6.11: Borrow area at 2.4 km distance from km 41+700 (RHS)

Table 6.16: Details of Borrow Soil Location and Distance from the Project Road

Sl. No.	Sample no.	Location/offset (km)#	Side
1	BA-1	3.6 km from Ch. 21+575	RHS
2	BA-2	3.0 km from Ch. 17+364	RHS
3	BA-3	6.9 km from Ch. 23+550	LHS

Equation Chainage applied is km 0+000 = PWD R.D. 2+400

The laboratory test results of borrow are samples is presented in ***Table 6.17*.**

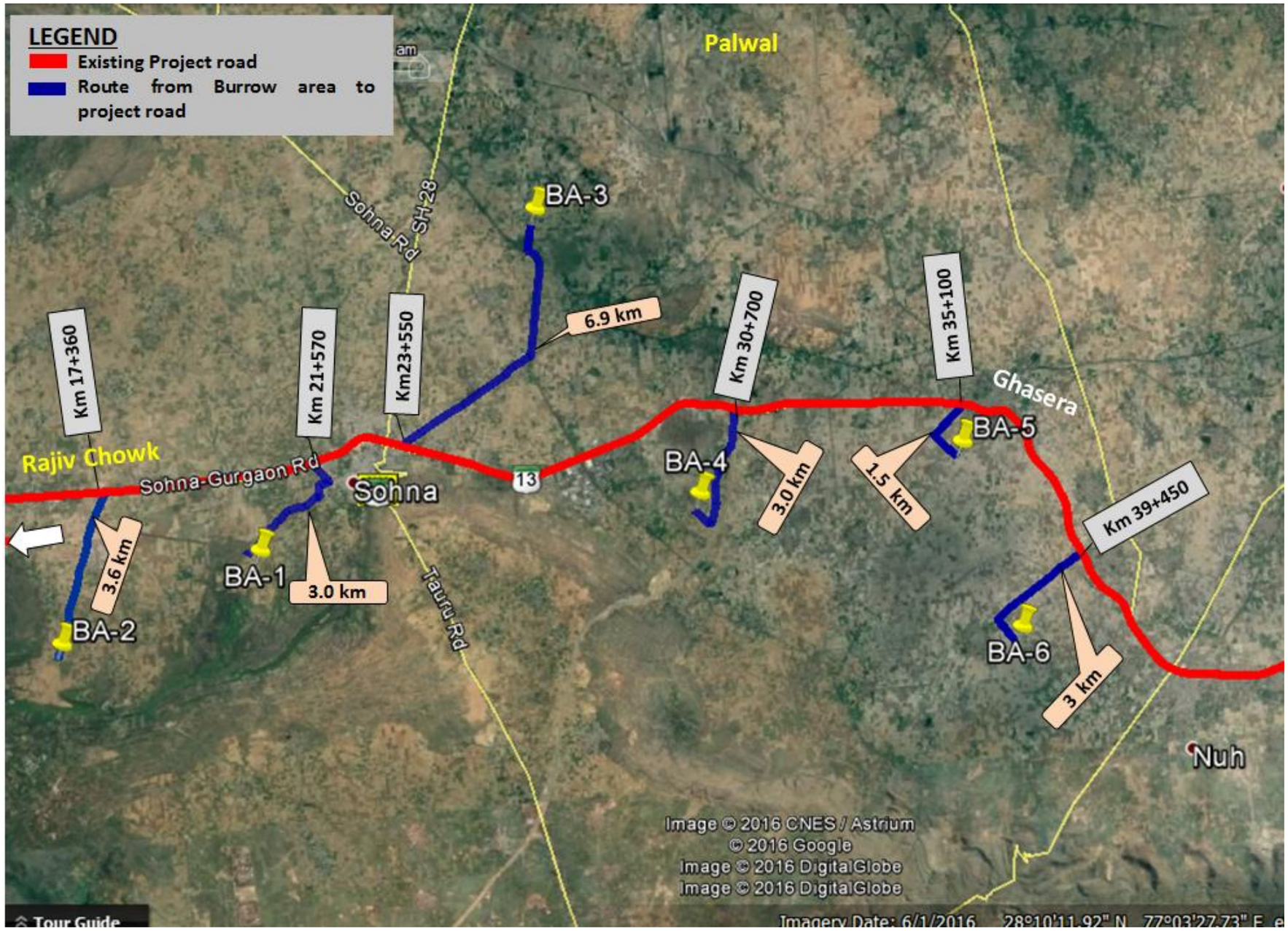


Fig. 6.12: Location of Borrow areas near from km 0+000 to km 16+600

(Equation Chainage applied is km 0+000 = PWD R.D. 2+400)

Table 6.17: Test Results of Borrow Area Soil

Chainage (km)	% passing through sieve				% Sand content	L.L.	P.L.	P.I.	Free swelling index (%)	Field moisture (%)	M.D.D. (gm/cc)	O.M.C. (%)	C.B.R.(%) in soaked condition
	4.75 mm	2.0 mm	425 mic	75 mic									
16+800	100	97.25	90.02	35.79	64.21	19.5	N.P.	N.P.	0	9.01	1.995	10.4	11.82
20+400	100	100	95.15	38.51	51.49	22.8	N.P.	N.P.	0	9.55	1.96	10.8	10.5

As 90 percentile of the borrow area samples has CBR value greater than 10%, hence for pavement design CBR value adopted is 10%.

6.5.2 Aggregates

Investigation of quarry area has been carried out to ascertain the potential source of aggregates which can be used for construction of different layers of pavement. The aggregates to be used for the project are from Raisina quarry. The test results of aggregates have been represented in **table 6.18**.

Table 6.18 Coarse aggregate test result

Source/ location	Type of material	Sieve size in mm										% Water Absorption	Specific Gravity	% Impact Value	L.A.V
		40	20	12.5	10	4.75	2.36	1.18	0.6	0.3	0.15				
Raisina Crusher	20mm	100.0	93.8	18.11	2.15							0.34	2.724	17.88	21.95
	10mm	100.0	92.4	17.3	3.1							0.81	2.672	19.56	25.36

Source/ location	Type of material	Sieve size in mm								Fine modulus	Specific Gravity	Silt content (%)	% Water Absorption
		12.5	10	4.75	2.36	1.18	0.6	0.3	0.15				
Raisina Crusher	Fine Dust	100.0	100.0	98.5	88.2	65.3	39.1	16.5	9.0	2.835	2.63	4.1	**1.7**

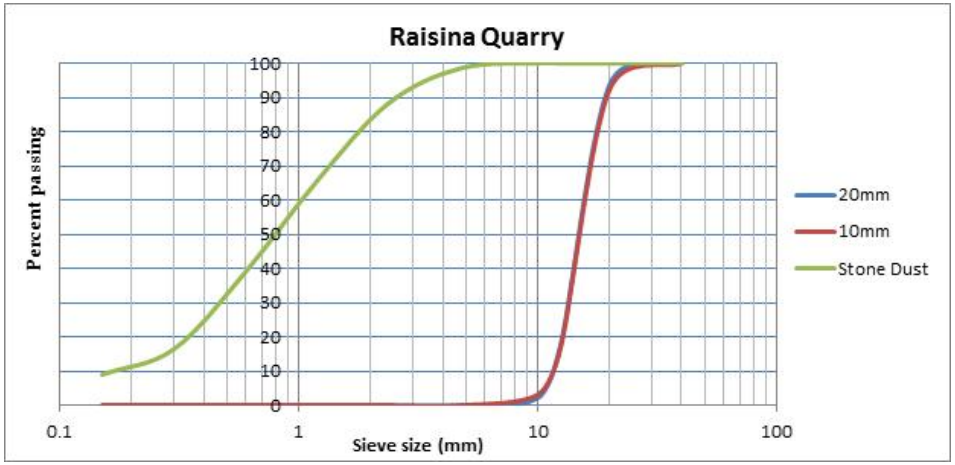


Fig.6.13: Sieve analysis of aggregates from Raisina quarry

6.6 INVENTORY AND CONDITION SURVEY OF CULVERTS

The detailed inventory and condition survey of the culverts is presented in ***Appendix- 6.5***.There are around 13 culverts in the existing alignment. The overall width of existing culverts is found to be minimum 20.0 m. The maximum numbers of culverts are found in fair condition and some of the culverts (2 nos.) are found to be buried or completely choked. Detailed development proposal of the each culverts are given in **Chapter 8.0: Development Proposal**. Details of existing culverts, type of culvert and their numbers are given in **Table 6.19A**.

Table 6.19A: Details of Culverts and Condition

Sl. No.	Existing Chainage	No.	Dia./Length (Clear span) – in m	Culvert Type (Slab / Pipe/Hume pipe)	Width(m)
1	13+130	1	4	Slab	30.1
2	13+468	1	1.5	Slab	20.5
3	14+736	1	1.5	Slab	20.5
4	16+500	1	1.5	Slab	20.5
5	17+168	1	5.07(Skew) 3.25(Straight)	Slab	22
6	18+250	1	1.3	Slab	20.5
7	18+357	1	1.2	Slab	20.5
8	19+521	1	3	RCC Box	23.5
9	20+313	1	3	Slab	23.5
10	21+570	1	1.2	Slab	20.5
11	22+585	1	1.3	Slab	20.5
12	22+868	1	1.3	Slab	20.5
13	23+768	1	1.5	Slab	36.5

Table 6.19B: Summary of culverts

Type of Structure	Number
RCC Slab	12
RCC Box	1
TOTAL	13



Fig. 6.14: Existing Slab Culvert at km 13+130

6.7 BRIDGES INVESTIGATIONS

Detailed inventory and condition survey of all bridges and culverts on the project road has been carried out.

6.7.1 Bridge Inventory

There are 2 Minor Bridges on the project road. In these bridges, substructure and foundation are made of reinforced cement concrete. The Inventory details of bridges have been presented in ***Appendix-6.4***. Their location, span arrangement and length and type of structure are listed below in **Table 6.20**. The bridges are in fair condition. Bank protection is not provided at all the locations of bridges. The wearing course at these bridges is in satisfactory condition. Detailed development proposal of the each bridge is given in **Chapter 8.0: Development Proposal**.

Table 6.20: Minor Bridges along the Project Road

Sl. No.	Existing Chainage	Structure (Major/Minor Bridge)	No.	Clear Span (m)	Length (m)
1	15+855	Minor Bridge	1	10.80	11.42
2	19+095	Minor Bridge	1	7.60	8.22

6.7.2 Condition Survey of Bridges

Condition survey of all bridges at this stage has been carried out by visual observation. During the initial inspection it was observed that most of the bridges are found in fair condition. In most of the bridges, Floor protection and railing works are satisfactory and found to be adequate. Vegetation growth has come up in almost all the bridge because of non-maintenance / non-clearance of channel near the structure.

The details of condition survey of bridges are presented in ***Appendix- 6.4***.

Table 6.21: Condition of Minor Bridges along the Project Road

Sl. No.	Existing Chainage	Structure Type	No of Spans	Clear Span (m)	Total Length (m)	C/W Width (m)	Total Width (m)	Condition
1	15+855	Minor	1	10.80	11.42	19.5	20.50	• Condition is fair • Slope pitching not evidenced
2	19+095	Minor	1	7.60	8.22	19.5	20.50	• Structure in fair condition



Fig. 6.15: Minor Bridge at km 15+855 (PWD R.D.)

6.8 RAILWAY OVER BRIDGE (ROB) AND LEVEL CROSSING

Currently there is no railway crossing in the entire project corridor. However, as confirmed by Dedicated Freight Corridor Corporation of India (DFCCIL), a railway alignment of Western Dedicated Freight Corridor has been proposed to cross the project road at PWD R.D. 28+870 at Sohna by a viaduct of 67.2 m long (2 x 33.6 m). The location map and other details as available from DFCCIL is presented in ***Annexure- 2.1***

6.9 SUBMERGENCE AREAS

Along the project road, there is no submergence area.

6.10 HYDROLOGICAL INVESTIGATION

6.10.1 Hydro meteorological sub-zone

There are 23 meteorological sub zones in India and the State of Haryana near Gurgaon Nuh is covered in sub zone 1(e), (as shown in Fig.6.16) mainly, The project road alignment lies in the hydro meteorological sub zone 1(e)).

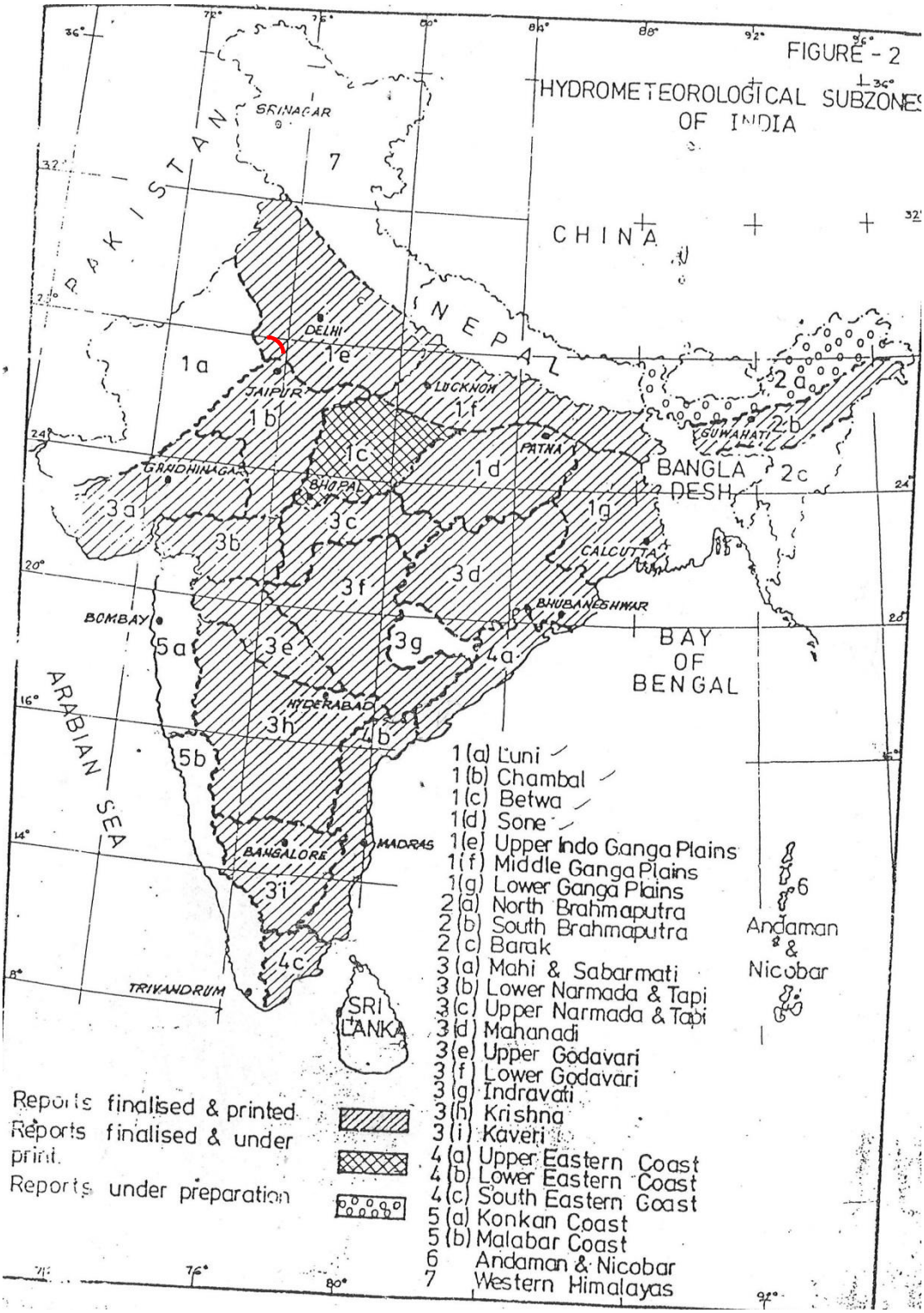


Fig.6.16: Meteorological sub zones of India

The sub-zone 1(e) experiences 75% to 80% of rainfall by southwest monsoon during the monsoon season from mid June to mid October.

6.10.2 Data collection and analysis

6.10.2.1 Requirements for Hydrological and Hydraulic Design

The hydrological study aims at estimating the peak discharge of the flood generated by the run-off of rainfall within the catchment area. The hydrological study requires:

- Knowledge of the characteristics of peak rainfall in the regions:
- Knowledge of the characteristics of the catchment areas:
- Topographic data about the stream, upstream and downstream:
- Survey of India topo sheets maps to a scale of 1:50,000 for identification of catchment area and its characteristics.
- Preparation of Detailed Project Report -Hydrology Report.

Topographic surveys have been done at all the major and minor stream crossings with a view to obtain the cross section of the rivers at the proposed road crossing and up to a reasonable distance on upstream and downstream. The High Flood Levels (HFL) have been obtained from existing flood marks or ascertained from enquiry with local knowledgeable persons. The characteristics of the catchment areas have been ascertained from Survey of India top sheets, to a scale of 1:50,000 from which, catchment area at the proposed bridge site, length of the stream and fall in elevation from originating point to the point of crossing, could be determined. Slope of the stream has been determined from the contours on the topo sheets.

6.10.2.2 Rainfall intensity: - Central Water Commission Data

The project road falls in zone 1(e) is-pluvial of 240mm/hr. (100 year return period, 24hr maximum rainfall) (Fig 6.17.) Therefore 100 yr.1 hr. rainfall = 0.34*240=81.6 mm/hr.(8.16 cm/hr.)

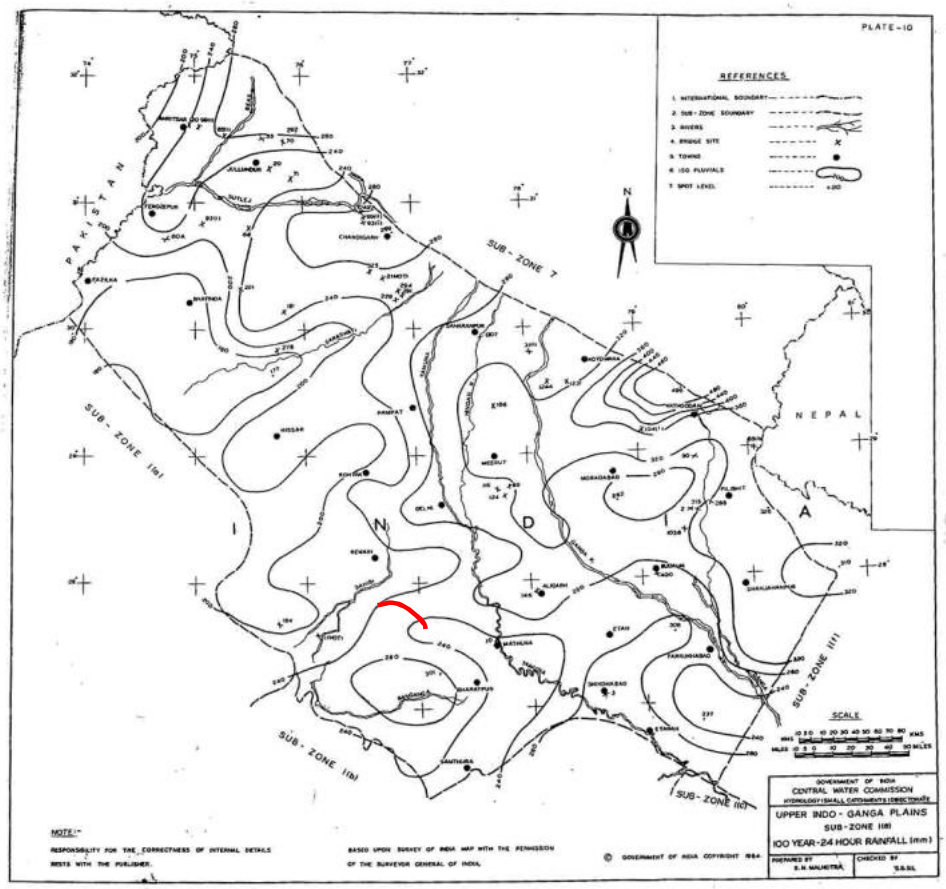


Fig. 6.17: IS pluvial of 100 year 1hr. rainfall with project road superimposed

6.10.3 Design basis and design parameters

6.10.3.1 Design Criteria

The Hydraulic design is carried out using the rational formula. The design is based on 100-year return period, one hour duration. Channel Hydraulics is derived using Manning's formula.

6.10.3.2 Estimation of Run-off

Calculation of Discharges

Discharges for the streams of bridges have been calculated with the :

i) Rational Formula

$Q = 0.028PfAIc$

Where Q = maximum runoff in m^3/sec

A = Area of catchments in hectares

Ic = Critical intensity of rainfall in cm/hr

P = Percentage Coefficient of runoff for catchments characteristics

f = Fraction depending upon size of catchment ("f" curve is given **Fig. 6.18**)

Maximum value of P is taken as per IRC SP-13, Para 4.9- Guidelines for the small bridges and culverts.

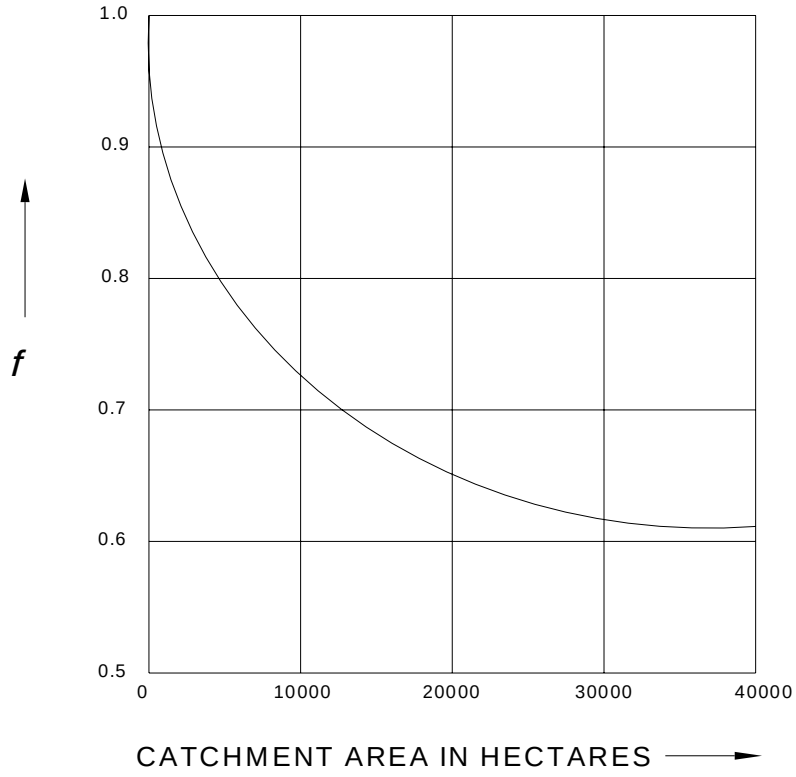


Fig. 6.18: 'f 'curve for catchment areas

Run-off Coefficient

The value of Run off Coefficient C, depends upon catchment characteristics such as property of soil, type of ground cover etc. The suggested value of C (Runoff coefficient are given in Table 6.22 below)

Table 6.22: Coefficient of Runoff

Sl. No.	Description of Surface	Coefficient of Run-off (P)
1	Steep bare rock and water tight pavement surface (concrete and bitumen)	0.90
2	Steep rock with some vegetative cover	0.80
3	Plateau areas with light vegetative cover	0.70
4	Bare stiff clayey soils (impervious soils)	0.60
5	Stiff clayey soils (impervious soils) with vegetative cover and uneven paved road surfaces	0.50

Sl. No.	Description of Surface	Coefficient of Run-off (P)
6	Loam lightly cultivated or covered and macadam or gravel roads	0.40
7	Loam largely cultivated or turfed	0.30
8	Sandy soil, light growth, parks, gardens, lawns, and meadows	0.20
9	Sandy soil covered with heavy bush or wooded/forested areas	0.10

(Reference IRC SP 42-Guidelines on Drainage, Para 10.5 Table 2)

The project road area is considered corresponding to P=0.3

Rainfall Intensity

Let F cm of rainfall during T hrs. in individual storm, then the mean intensity of rainfall

I = F/T cm/hr

Since the intensity of rainfall is not uniform throughout the whole duration of T hrs. the small interval T will be having higher rain fall intensity than the mean intensity I taken over the whole period of T hrs. Thus the mean intensity of the storm of the shorter duration can be higher than that of the prolonged one.

If i is the intensity of a shorter duration storm of t hrs. Then

i/I = T+1/t+1

or

I = F/T x (T+1/t+1)

One Hour Rainfall of Peak Runoff

Considering a time interval of one hour some where within the duration of the storm, then, one hour rainfall intensity

Io = F/T x (T+1/1+1)

= F/2 x (T+1/T)

Time of Concentration (tc)

Time taken by the runoff from the farthest point on the periphery of the catchment (called the critical point) to reach the site of bridge is called the concentration time.

$$tc = (0.87 \times L^3/H)^{0.385}$$

Where,

tc = time of concentration in hours

L = Distance from the critical point to the bridge site in km

H = the fall in level from the critical point to the bridge site in m

The Critical or Design Intensity of Rainfall

The critical intensity Ic is the maximum intensity of rainfall in a time interval equal to time of concentration tc

Thus, **Ic = F/T (T+1/tc+1)**

=Io (2/tc+1)

(Reference IRC SP-13-2004 Guidelines for the Design of small bridges and culverts para 4.7.6 eqn.4.10b).

ii) Discharge by Manning's Formula

$$Q = \text{Area} \times \text{Velocity} = \frac{A \times R^{2/3} \times S^{1/2}}{n}$$

Where, V – Velocity in meter/sec.

R – The hydraulic mean depth in meters (R=A/P)

S – Bed slope over a reasonably long reach

n – The rugosity coefficient

The value of n is given in **Table 6.23** (table 3 of IRC SP-13, Para-5.4-Guidelines for Designers small Bridges & Culverts).

Table 6.23: Rugosity Co-efficient, n

Surface	Perfect	Good	Fair	Bad
Natural Streams 1. Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.03	0.033
2. Same as 1, but some weeds and stones	0.03	0.033	0.035	0.04
3. Winding, some pools and shoals, clean	0.035	0.04	0.045	0.05
4. Same as3, lower stages, more ineffective slope and sections	0.04	0.045	0.05	0.055
5. Same as 3, some weeds and stones	0.033	0.035	0.04	0.045
6. Same as 4, stony sections	0.045	0.05	0.055	0.06
7. Sluggish river reaches, rather weedy or with very deep pools	0.05	0.06	0.07	0.08
8. Very weedy reaches	0.075	0.1	0.125	0.15

Cross sections of the streams have been taken of immediate upstream and downstream of the existing bridge locations on the basis of invert levels of the stream beds taken during the road survey.

The slope of the channel upstream of the bridges is rolling terrain to plain terrain and the cross section of streams varies with distance from bridge location.

6.10.3.3 Fixing Design Discharge

The Hydraulic design is carried out using the rational formula. The design is based on 100-year return period, one hour duration. Channel Hydraulics is derived using Manning's formula. Summary of catchment areas, design HFL etc. is given in **Table 6.24**.

Table 6.24: Summary of Catchment, Design discharge and H.F.L of bridges

(Design Chainage)	Bridge No	Catchment Area(Sq.km) A	H(m) (top level-bed level)	L(Km)	Tc(Time of concentration(hr)) tc=(.87L3/H).385	Ic(Critical intensity of rainfall) = (Io(2/(tc+1))mm/hr	Coeff. Of run off(P)	Q (Design Discharge) =0.028*C*IC*A*f	Depth	Width	Side slope (H:V)	Slope of Channel	A(m)	P(m)	R(m)	dw(Design depth(m))	V(m/sec)	Qc(Discharge carring capacity)(m)	Min Span(m)	FGL (Existing road level)(m)	Invert level(U/s,D/s)	Remarks	Proposed Span(m)
10+730	Culvert	0.42	75.00	1.12	0.205	17.926	0.4	**8.33**	2.00	4.00	RECT.	0.0670	3.000	5.500	0.545	0.75	2.879	**8.636**	4.00	226.0	224.8/Not available		1*4.0 Retain as per hydrology
11+068	Culvert	0.33	40.00	0.85	0.190	18.154	0.3	**5.03**	2.00	1.50	RECT.	0.0471	2.250	4.500	0.500	1.50	2.277	**5.123**	1.50	221.6	220.275/ 220.175		1*2 Retain as per hydrology
12+336	Culvert	0.40	60.00	1.20	0.242	17.393	0.3	**5.84**	2.00	1.50	RECT.	0.0500	2.475	4.800	0.516	1.65	2.396	**5.930**	1.50	220.96	220.2/ 219.48		1*2 Retain as per hydrology
13+455	Minor Bridge	2.93	90.00	2.88	0.569	12.117	0.4	**15.31**	2.00	6.00	2:1	0.0313	7.020	10.025	0.700	0.90	2.323	**16.308**	10.20	223.45			1*10.8 Retain as per hydrology
14+100	Culvert	0.43	50.00	1.40	0.310	16.488	0.3	**5.96**	2.00	1.50	RECT.	0.0357	2.850	5.300	0.538	1.90	2.082	**5.935**	1.50	216.2	214.72/ 214.5		1*2 Retain as per hydrology
14+700	Culvert	5.10	100.00	4.46	0.905	11.338	0.3	**24.29**	2.00	4.00	RECT.	0.0224	9.320	8.660	1.076	2.33	2.621	**24.427**	4.00	215.2	214.36/ 214.1		1*4 Retain as per hydrology
15+850	Culvert	5.46	108.00	4.46	0.879	11.497	0.3	**26.37**	2.00	4.00	RECT.	0.0242	9.600	8.800	1.091	2.40	2.749	**26.386**	4.00	214.5	211.95/ 211.85		1*4 Retain as per hydrology
15+957	Culvert	0.40	88.00	1.72	0.316	16.409	0.3	**5.51**	2.00	1.20	RECT.	0.0512	2.460	5.300	0.464	2.05	2.259	**5.558**	1.20	212.9	212.06/ 211.97		1*1.2 Retain as per hydrology

6.10.4 Longitudinal drains

The longitudinal drains are proposed to be provided on both side of the road so that the storm water/seepage water does not damage the pavements layers. These drains are proposed to be discharged into nearby culverts. *As for as possible the longitudinal drains are proposed to be lined so that it is cleaned easily, periodically.*

Adequate drainage is a primary requirement for maintaining the structural soundness and functional efficiency of a road. Inadequate surface drainage results in

(i) Weakening if pavement structural and sub grade through infiltration of water from the top

(ii) Erosion of shoulders, verges and embankment slopes by water running of the pavement

Continuous gradients of roads and intensity of rainfall require effective drainage system viz. longitudinal drains along roads and cross drainages (culverts).

Longitudinal drains are proposed to be provided on both carriageways in between main carriageway and service road. Strom water flows from the one side towards other sides across the carriageway.

6.10.4.1 Choice of cross-section of open drains

The choice of cross-section of open drain is generally limited to 3 types viz.

- Triangular
- Trapezoidal
- Rectangular

Triangular cross section has the disadvantage of lesser flow capacity. Trapezoidal cross section requires more width and suitable for rural sections. Rectangular sections are well suited for urban road side drains.

6.10.4.2 Rainfall intensity: - Central Water Commission Data

The project road falls in zone1(e) is-pluvial of 200 mm/hr. (50 year return period, 24hr maximum rainfall) (Fig 6.19) Therefore 50 yr. ,1 hr. rainfall = 0.34*200=68 mm/hr.(6.8 cm/hr.)

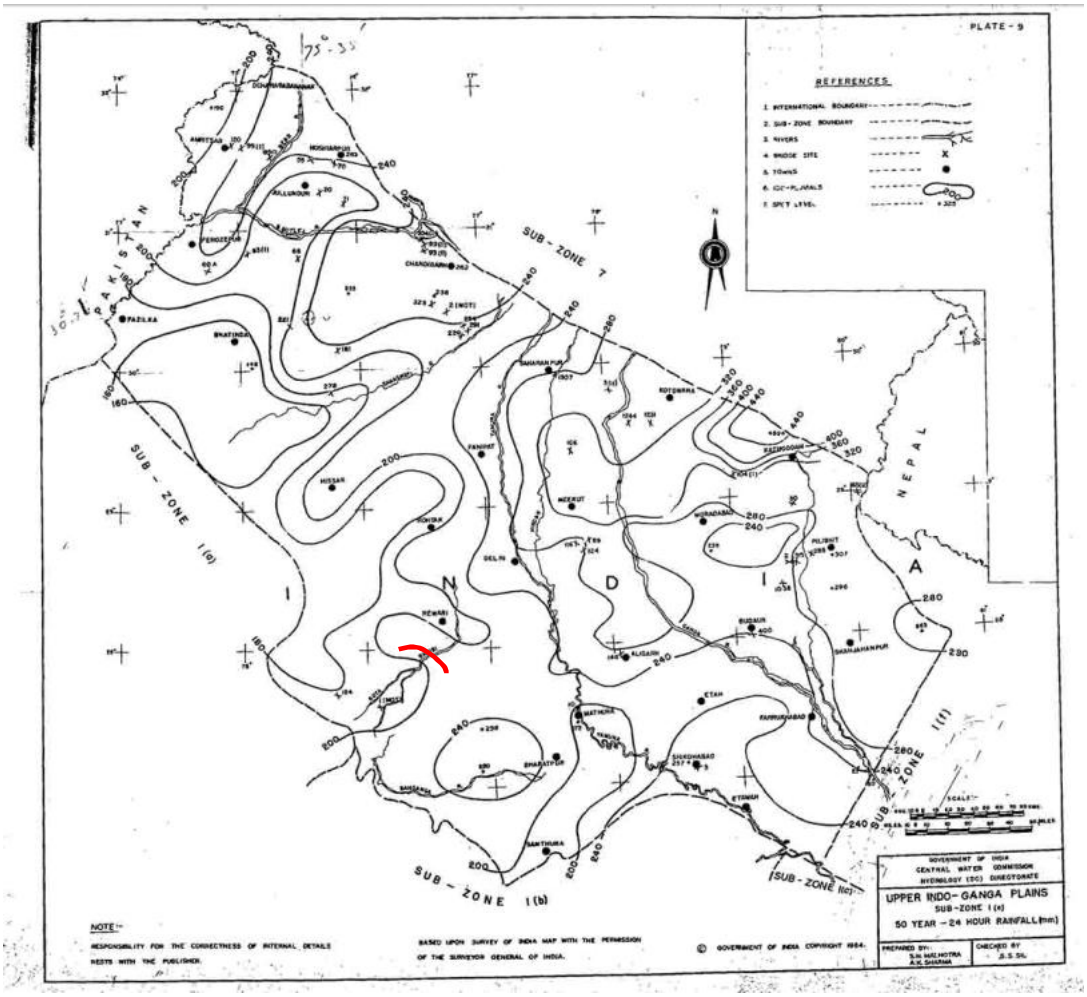


Fig. 6.19: IS pluvial of 50 year 1hr. rainfall with project road superimposed

6.10.4.3 TCS applicable to urban areas

The TCS used for calculation is given below:

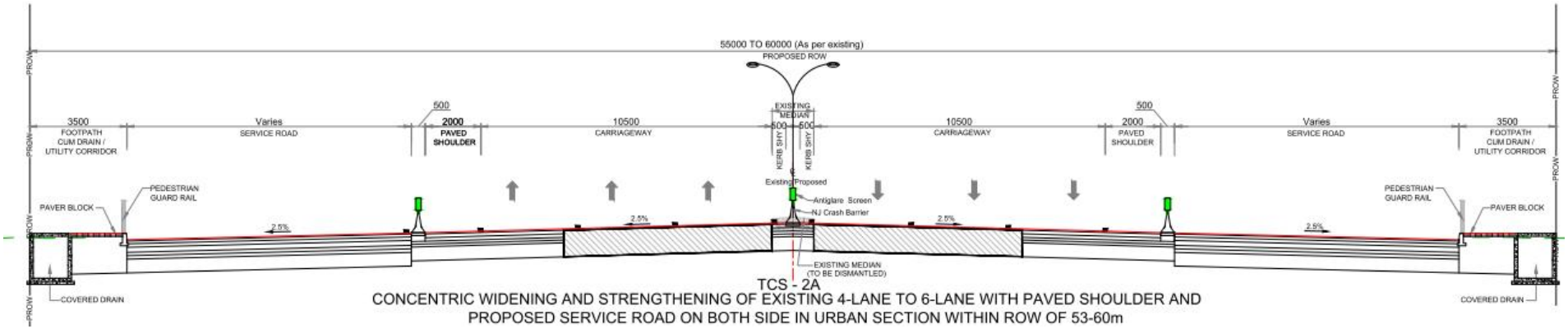


Fig. 6.20: Typical cross section

6.10.5 Rectangular lined drain

Empirical Formula

i. Coefficient of runoff

The drain is carrying runoff from the roadway width and the adjoining unimproved areas. The coefficients of runoff of the various surfaces are:

- Asphaltic concrete = 0.90
- Green areas largely culivated = 0.30
- Urban areas on roadside = (0.30+0.9)/2 =0.6

(i) Road side carriageway drain.

(ii) Pav. = $\frac{0.90 \times (0.75 + 0.5 + 10.5 + 2 + 1.25 + 10.5 + 2.5 + 2) \times L + .6(30) * L}{30..0\ L + 30.0\ L}$

$= \frac{(27.0+18.0) \times L}{60 * L} = 0.75$

Where L is the length of the road under consideration = 800 m distance from start of grade to cross drainage points. = (average distance in between culverts).

ii. Time of concentration

The storm duration chosen for design is equal to the time of concentration. Maximum discharge in drainage system occurs when the entire catchment is contributing to the flow. The time of concentration, tc is the time required for a given drop of water from the most remote part water shed to reach the point of exit.

Time of concentration for overland flow is determined from graph of time of concentration (Ref. Fig. 5, para 10.8 IRC_SP42), given below

For overland flow on adjoining area (Urban Area) tc = 6minutes

For flow in drain, tc = Distance/Velocity

=800/1 _ (Min. velocity = 1 m/sec).

= 800/1*60 minutes

=13.33 minutes

Total tc = 19.33 minutes

= 0.322 hrs

iii. Area

Area = 60 x 800/ 10000 hectares

= 4.80 hectares

iv. Rainfall Intensity _50 year return period

I =F/T*(T+1)/(tc+1)

=6.8/1*(1+1)/(0.322+1) *[50 year return, 1 hr. Rainfall Intensity=70mm/hr.)]*

= 10.29cm/hrs

Rainfall Intensity 25 year return

=10.29*2.22/2.56 (Conversion factor Ref. IRC –SP42)

= 8.92 cm/hr.

v. Discharge.

Discharge Q = 0.028 x P x A x ic

= 0.028 x 0. 75 x 4.80x 8.92 m^3/sec

= 0. 899 m^3/sec …….. equation (i)

Manning's Formula

The section of drain on carriageway is proposed to be rectangular with 1.5m base width. Let the effective depth of drain be d m

Wetted parameter P = 2 x d+1.5 m

Hydraulic Radius, R = A/P = 1.5*d/ 2d + 1.5 m

Discharge Q = Area x 1/n x R 2/3 x S 1/2 (Manning's formula)

Area = 1.5 x d

n = roughness coefficient = 0.016 for concrete bed and side / concrete

For a minimum bed slope of drain of one in thousand

Discharge,

Q = 1.25d x 1/0.016 x (1.5*d /(2d + 1.5))^.667 x (1 / 1000)^0.05= 0.899 m^3/ sec.

Table 6.25: Calculation of Effective depth

Q Des.	Bottom Width	Length	Slope	A	P	R	dw	V	No. of Cells	Discharge Capaciy
(m3/sec)	(m)	(m)		(sq.m.)	(m)	(m)	(m)	(m/s)		
0.899	1.25	800	0.001	1.0625	2.95	0.36	0.85	1.00	1	1.063

Solving the equation we get d = 0.85 m for v=1m/sec(self-cleansing velocity)

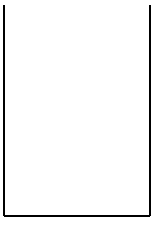
The discharge = Peak runoff calculated in equation (ii), therefore

d =0.85 cm

Adding 30 cm free board.

d (effective) = 85 + 30 =115 cm

Provide 1.25m*1.15 m clear.



Location:KM 79+400

Sl. No.	Axle Load (KN)			
	Gurgaon to Rajasthan border		Rajasthan border to Gurgaon	
	Front	Rear	Front	Rear
1	42.38	79.17	42.38	68.47
2	46.30	89.66	43.75	69.65
3	44.93	89.86	68.87	137.54
4	46.30	83.39	39.44	82.99
5	32.96	62.98	45.32	90.84
6	35.02	56.70	30.02	33.55
7	38.65	63.96	36.69	63.57
8	31.98	50.91	47.68	79.46
9	57.49	98.49	29.63	34.14
10	45.32	79.17	28.06	33.55
11	43.75	90.64	35.90	49.83
12	61.21	89.66	43.95	78.68

Class of Vehicle : LCV
Gurgaon to Rajasthan border (Location: KM 79+400)

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	4	16.67	16.67	0.0841	0.34	1.10
5	40	50	6	25.00	41.67	0.2297	1.38	4.50
6	50	60	3	12.50	54.17	0.5126	1.54	5.02
7	60	70	3	12.50	66.67	1.0000	3.00	9.80
8	70	80	2	8.33	75.00	1.7725	3.55	11.58
9	80	90	4	16.67	91.67	2.9243	11.70	38.20
10	90	100	2	8.33	100.00	4.5629	9.13	29.80
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			24	100.00			30.62	100.00

No. of Vehicles weighed = 12
No. of Axles weighed = 24
Total Damaging effect = 30.62
Axle Equivalency = 1.28
Vehicle Damage Factor = 2.55

Rajasthan border to Gurgaon

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	2	8.33	8.33	0.0219	0.04	0.12
4	30	40	7	29.17	37.50	0.0841	0.59	1.65
5	40	50	6	25.00	62.50	0.2297	1.38	3.87
6	50	60	0	0.00	62.50	0.5126	0.00	0.00
7	60	70	4	16.67	79.17	1.0000	4.00	11.22
8	70	80	2	8.33	87.50	1.7725	3.55	9.94
9	80	90	1	4.17	91.67	2.9243	2.92	8.20
10	90	100	1	4.17	95.83	4.5629	4.56	12.80
11	100	110	0	0.00	95.83	6.8093	0.00	0.00
12	110	120	0	0.00	95.83	9.7980	0.00	0.00
13	120	130	0	0.00	95.83	13.6769	0.00	0.00
14	130	140	1	4.17	100.00	18.6072	18.61	52.19
Total			24	100.00			35.65	100.00

No. of Vehicles weighed = 12
No. of Axles weighed = 24
Total Damaging effect = 35.65
Axle Equivalency = 1.49
Vehicle Damage Factor = 2.97

Both Directions

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	2	4.17	4.17	0.0219	0.04	0.07
4	30	40	11	22.92	27.08	0.0841	0.92	1.40
5	40	50	12	25.00	52.08	0.2297	2.76	4.16
6	50	60	3	6.25	58.33	0.5126	1.54	2.32
7	60	70	7	14.58	72.92	1.0000	7.00	10.56
8	70	80	4	8.33	81.25	1.7725	7.09	10.70
9	80	90	5	10.42	91.67	2.9243	14.62	22.06
10	90	100	3	6.25	97.92	4.5629	13.69	20.66
11	100	110	0	0.00	97.92	6.8093	0.00	0.00
12	110	120	0	0.00	97.92	9.7980	0.00	0.00
13	120	130	0	0.00	97.92	13.6769	0.00	0.00
14	130	140	1	2.08	100.00	18.6072	18.61	28.08
Total			48	97.92			66.27	71.92

No. of Vehicles weighed = 24
No. of Axles weighed = 48
Total Damaging effect = 66.27
Axle Equivalency = 1.38
Vehicle Damage Factor = 2.76

Location: KM 79+400

Sl. No.	Axle Load (KN)			
	Gurgaon to Rajasthan border		Rajasthan border to Gurgaon	
	Front	Rear	Front	Rear
1	56.21	83.97	64.16	147.74
2	48.66	91.23	63.77	137.93
3	48.85	94.76	63.96	137.54
4	56.31	132.14	60.43	128.51
5	38.75	34.92	56.11	119.29
6	51.21	103.01	64.35	134.00
7	48.07	83.78	60.63	138.81
8	41.01	35.90	63.47	131.26
9	52.39	117.23	55.92	128.12
10	56.11	119.29	64.35	141.85
11	52.58	92.80	59.06	135.18
12	60.43	133.81	64.35	154.80
13	69.45	171.28	74.75	161.08
14	75.34	170.11	75.14	141.85
15	40.52	63.96	66.12	157.16
16	74.75	161.08	55.72	110.46
17	44.73	75.34	75.93	153.82
18	53.66	88.88	55.52	110.66
19	46.89	72.01	69.45	171.28
20	36.69	31.59	73.18	176.78
21	48.66	84.07	75.93	167.36
22	52.58	83.09	55.13	110.66
23	55.72	110.46	75.34	170.11
24	49.34	91.92	78.68	173.05
25	46.30	80.15	75.14	135.18
26	44.83	38.65	55.52	98.30
27	71.22	121.84	74.95	151.27
28	76.32	153.43	78.68	173.24
29	44.64	68.47	75.34	127.73
30	56.31	95.16	75.34	134.79
31	57.68	122.43	55.13	110.66
32	38.65	52.39	63.37	126.94
33	56.70	110.56	51.60	82.60
34	72.01	121.84	65.33	133.61
35	44.73	79.07	47.28	95.55
36	42.58	63.77	63.67	134.00
37	40.81	35.81	68.87	157.55
38	48.66	72.20		
39	64.35	135.18		
40	48.66	75.34		
41	75.34	95.94		
42	40.91	35.81		
43	91.63	93.88		
44	76.32	90.64		
45	58.47	112.42		
46	81.03	113.99		
47	84.37	173.24		
48	40.61	35.90		
49	44.93	72.79		
50	42.67	37.67		
51	42.97	68.87		
52	38.26	35.22		
53	49.25	83.97		
54	40.91	35.90		
55	77.99	112.23		
56	75.93	153.82		
57	63.67	134.00		

Class of Vehicle : 2-Axle Truck (Location: KM 79+400)

Gurgaon to Rajasthan border
Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	4	7.02	7.02	0.0841	0.34	0.78
5	40	50	24	42.11	49.12	0.2297	5.51	12.86
6	50	60	13	22.81	71.93	0.5126	6.66	15.54
7	60	70	4	7.02	78.95	1.0000	4.00	9.33
8	70	80	9	15.79	94.74	1.7725	15.95	37.21
9	80	90	2	3.51	98.25	2.9243	5.85	13.64
10	90	100	1	1.75	100.00	4.5629	4.56	10.64
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			57	100.00			42.88	100.00

SINGLE AXLE (REAR WITH DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0012	0.00	0.00
3	20	30	0	0.00	0.00	0.0095	0.00	0.00
4	30	40	10	17.54	17.54	0.0366	0.37	0.16
5	40	50	0	0.00	17.54	0.1001	0.00	0.00
6	50	60	1	1.75	19.30	0.2234	0.22	0.10
7	60	70	4	7.02	26.32	0.4358	1.74	0.76
8	70	80	6	10.53	36.84	0.7725	4.63	2.02
9	80	90	7	12.28	49.12	1.2744	8.92	3.88
10	90	100	8	14.04	63.16	1.9885	15.91	6.92
11	100	110	1	1.75	64.91	2.9675	2.97	1.29
12	110	120	7	12.28	77.19	4.2700	29.89	13.00
13	120	130	3	5.26	82.46	5.9605	17.88	7.78
14	130	140	4	7.02	89.47	8.1091	32.44	14.11
15	140	150	0	0.00	89.47	10.7923	0.00	0.00
16	150	160	2	3.51	92.98	14.0918	28.18	12.26
17	160	170	1	1.75	94.74	18.0957	18.10	7.87
18	170	180	3	5.26	100.00	22.8977	68.69	29.87
19	180	190	0	0.00	100.00	28.5974	0.00	0.00
20	190	200	0	0.00	100.00	35.3003	0.00	0.00
21	200	210	0	0.00	100.00	43.1177	0.00	0.00
22	210	220	0	0.00	100.00	52.1668	0.00	0.00
23	220	230	0	0.00	100.00	62.5706	0.00	0.00
24	230	240	0	0.00	100.00	74.4580	0.00	0.00
25	240	250	0	0.00	100.00	87.9639	0.00	0.00
26	250	260	0	0.00	100.00	103.2288	0.00	0.00
27	260	270	0	0.00	100.00	120.3992	0.00	0.00
28	270	280	0	0.00	100.00	139.6275	0.00	0.00
TOTAL			57	100.00			229.95	100.00

No. of Vehicles weighed =	57
No. of Axles weighed =	114
Total Damaging effect =	272.82
Axle Equivalency =	2.39
Vehicle Damage Factor =	4.79

Rajasthan border to Gurgaon

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	1	2.70	2.70	0.2297	0.23	0.56
6	50	60	9	24.32	27.03	0.5126	4.61	11.22
7	60	70	15	40.54	67.57	1.0000	15.00	36.48
8	70	80	12	32.43	100.00	1.7725	21.27	51.74
9	80	90	0	0.00	100.00	2.9243	0.00	0.00
10	90	100	0	0.00	100.00	4.5629	0.00	0.00
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			37	100.00			41.11	100.00

Single Axle (REAR WITH DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0012	0.00	0.00
3	20	30	0	0.00	0.00	0.0095	0.00	0.00
4	30	40	0	0.00	0.00	0.0366	0.00	0.00
5	40	50	0	0.00	0.00	0.1001	0.00	0.00
6	50	60	0	0.00	0.00	0.2234	0.00	0.00
7	60	70	0	0.00	0.00	0.4358	0.00	0.00
8	70	80	0	0.00	0.00	0.7725	0.00	0.00
9	80	90	1	2.70	2.70	1.2744	1.27	0.33
10	90	100	2	5.41	8.11	1.9885	3.98	1.03
11	100	110	0	0.00	8.11	2.9675	0.00	0.00
12	110	120	5	13.51	21.62	4.2700	21.35	5.54
13	120	130	4	10.81	32.43	5.9605	23.84	6.19
14	130	140	10	27.03	59.46	8.1091	81.09	21.06
15	140	150	3	8.11	67.57	10.7923	32.38	8.41
16	150	160	5	13.51	81.08	14.0918	70.46	18.30
17	160	170	2	5.41	86.49	18.0957	36.19	9.40
18	170	180	5	13.51	100.00	22.8977	114.49	29.73
19	180	190	0	0.00	100.00	28.5974	0.00	0.00
20	190	200	0	0.00	100.00	35.3003	0.00	0.00
21	200	210	0	0.00	100.00	43.1177	0.00	0.00
22	210	220	0	0.00	100.00	52.1668	0.00	0.00
23	220	230	0	0.00	100.00	62.5706	0.00	0.00
24	230	240	0	0.00	100.00	74.4580	0.00	0.00
25	240	250	0	0.00	100.00	87.9639	0.00	0.00
26	250	260	0	0.00	100.00	103.2288	0.00	0.00
27	260	270	0	0.00	100.00	120.3992	0.00	0.00
28	270	280	0	0.00	100.00	139.6275	0.00	0.00
TOTAL			37	100.00			385.05	100.00

No. of Vehicles weighed = 37
No. of Axles weighed = 111
Total Damaging effect = 426.16
Axle Equivalency = 3.84
Vehicle Damage Factor = 11.52

Both Directions

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	4	4.26	4.26	0.0841	0.34	0.40
5	40	50	25	26.60	30.85	0.2297	5.74	6.84
6	50	60	22	23.40	54.26	0.5126	11.28	13.43
7	60	70	19	20.21	74.47	1.0000	19.00	22.62
8	70	80	21	22.34	96.81	1.7725	37.22	44.32
9	80	90	2	2.13	98.94	2.9243	5.85	6.96
10	90	100	1	1.06	100.00	4.5629	4.56	5.43
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			94	100.00			83.99	100.00

Single Axle (Rear with Dual wheels)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	10.00	10.64	10.64	0.0366	0.37	0.06
5	40	50	0.00	0.00	10.64	0.1001	0.00	0.00
6	50	60	1.00	1.06	11.70	0.2234	0.22	0.04
7	60	70	4.00	4.26	15.96	0.4358	1.74	0.28
8	70	80	6.00	6.38	22.34	0.7725	4.63	0.75
9	80	90	8.00	8.51	30.85	1.2744	10.20	1.66
10	90	100	10.00	10.64	41.49	1.9885	19.89	3.23
11	100	110	1.00	1.06	42.55	2.9675	2.97	0.48
12	110	120	12.00	12.77	55.32	4.2700	51.24	8.33
13	120	130	7.00	7.45	62.77	5.9605	41.72	6.78
14	130	140	14.00	14.89	77.66	8.1091	113.53	18.46
15	140	150	3.00	3.19	80.85	10.7923	32.38	5.26
16	150	160	7.00	7.45	88.30	14.0918	98.64	16.04
17	160	170	3.00	3.19	91.49	18.0957	54.29	8.83
18	170	180	8.00	8.51	100.00	22.8977	183.18	29.79
19	180	190	0.00	0.00	100.00	28.5974	0.00	0.00
20	190	200	0.00	0.00	100.00	35.3003	0.00	0.00
21	200	210	0.00	0.00	100.00	43.1177	0.00	0.00
22	210	220	0.00	0.00	100.00	52.1668	0.00	0.00
23	220	230	0.00	0.00	100.00	62.5706	0.00	0.00
24	230	240	0.00	0.00	100.00	74.4580	0.00	0.00
25	240	250	0.00	0.00	100.00	87.9639	0.00	0.00
26	250	260	0.00	0.00	100.00	103.2288	0.00	0.00
27	260	270	0.00	0.00	100.00	120.3992	0.00	0.00
28	270	280	0.00	0.00	100.00	139.6275	0.00	0.00
TOTAL			94	100.00			615.00	100.00

No. of Vehicles weighed =	94
No. of Axles weighed =	282
Total Damaging effect =	698.99
Axle Equivalency =	2.48
Vehicle Damage Factor =	7.44

Location: KM 79+400

Sl. No.	Axle Load (KN)			
	Gurgaon to Rajasthan border		Rajasthan border to Gurgaon	
	Front	Rear	Front	Rear
1	46.50	60.43	48.66	60.63
2	55.33	71.61	48.07	55.92
3	50.82	67.49	52.39	64.16
4	45.81	67.39	48.07	65.53
5	51.31	72.50	43.36	59.64
6	46.89	64.35	45.71	63.57
7	47.68	63.96		
8	46.50	62.98		
9	48.66	72.40		
10	51.60	72.01		
11	51.21	70.14		
12	48.66	68.38		
13	48.66	64.26		
14	48.85	63.96		

Class of Vehicle : Bus (Location : KM 79+400)
Gurgaon to Rajasthan border

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	9	32.14	32.14	0.2297	2.07	9.19
6	50	60	5	17.86	50.00	0.5126	2.56	11.40
7	60	70	9	32.14	82.14	1.0000	9.00	40.01
8	70	80	5	17.86	100.00	1.7725	8.86	39.40
9	80	90	0	0.00	100.00	2.9243	0.00	0.00
10	90	100	0	0.00	50.00	4.5629	0.00	0.00
Total			28	100.00			22.49	100.00

No. of Vehicles weighed = 14
No. of Axles weighed = 28
Total Damaging effect = 22.49
Axle Equivalency = 0.80
Vehicle Damage Factor = 1.61

Rajasthan border to Gurgaon

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	5	41.67	41.67	0.2297	1.15	17.18
6	50	60	3	25.00	66.67	0.5126	1.54	23.00
7	60	70	4	33.33	100.00	1.0000	4.00	59.82
8	70	80	0	0.00	100.00	1.7725	0.00	0.00
9	80	90	0	0.00	100.00	2.9243	0.00	0.00
10	90	100	0	0.00	100.00	4.5629	0.00	0.00
Total			12	100.00			6.69	100.00

No. of Vehicles weighed = 6
No. of Axles weighed = 12
Total Damaging effect = 6.69
Axle Equivalency = 0.56
Vehicle Damage Factor = 1.11

Both Directions

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	14	35.00	35.00	0.2297	3.22	11.02
6	50	60	8	20.00	55.00	0.5126	4.10	14.05
7	60	70	13	32.50	87.50	1.0000	13.00	44.55
8	70	80	5	12.50	100.00	1.7725	8.86	30.37
9	80	90	0	0.00	100.00	2.9243	0.00	0.00
10	90	100	0	0.00	100.00	4.5629	0.00	0.00
Total			40	100.00			29.18	100.00

No. of Vehicles weighed = 20
No. of Axles weighed = 40
Total Damaging effect = 29.18
Axle Equivalency = 0.73
Vehicle Damage Factor = 1.46

Location: KM 79+400

Sl. No.	Axle Load (KN)							
	Gurgaon to Rajasthan border				Rajasthan border to Gurgaon			
	Front	Rear1	Rear2	Tandem	Front	Rear1	Rear2	Tandem
1	49.64	103.59	98.69	202.28	90.84	161.08	159.51	320.59
2	42.18	38.75	36.00	74.75	62.98	121.84	114.38	236.22
3	48.66	92.02	86.92	178.93	82.99	167.55	164.22	331.77
4	41.10	35.90	35.12	71.02	83.97	185.02	177.17	362.19
5	43.75	40.71	37.08	77.79	74.95	167.95	163.24	331.19
6	51.21	97.61	92.61	190.22	79.46	178.44	173.34	351.79
7	42.48	38.06	35.51	73.58	71.22	158.43	153.62	312.06
8	47.28	80.05	82.60	162.65	75.24	181.29	177.27	358.56
9	41.50	38.55	35.51	74.07	68.47	167.95	161.08	329.03
10	47.28	42.18	35.51	77.70	71.61	167.95	173.15	341.09
11	42.58	38.36	38.65	77.01	79.36	167.95	181.09	349.04
12	50.52	92.02	84.17	176.19	84.17	167.95	190.12	358.07
13	41.79	38.16	34.92	73.08	72.40	192.86	186.19	379.06
14	43.46	39.73	36.69	76.42	87.90	188.94	182.37	371.31
15	48.66	111.64	104.38	216.02	71.02	166.97	158.73	325.69
16	51.60	99.96	94.76	194.73	75.24	177.27	173.74	351.00
17	41.01	35.71	33.75	69.45	72.40	178.15	173.24	351.39
18	42.38	38.65	36.10	74.75	79.07	181.09	177.07	358.16
19	45.32	42.18	38.26	80.44	75.54	178.25	173.24	351.49
20	41.79	38.65	36.00	74.65	71.81	175.21	172.46	347.67
21	44.34	36.00	34.14	70.14	52.58	104.18	99.67	203.85
22	42.18	36.89	34.83	71.71	82.60	170.11	167.16	337.27
23	44.05	40.81	36.00	76.81	55.13	98.30	90.45	188.74
24	41.99	39.14	35.81	74.95	51.21	98.49	95.55	194.04
25	43.36	40.81	37.47	78.28	62.98	122.04	119.29	241.33
26	41.50	37.08	34.14	71.22	61.02	90.64	87.70	178.35
27	41.01	35.90	33.16	69.06	86.72	181.29	176.09	357.38
28	45.32	41.30	39.04	80.34	78.97	174.03	169.12	343.15
29	42.58	38.46	35.90	74.36	53.56	90.64	87.90	178.54
30	42.18	38.65	33.75	72.40	62.98	110.66	108.30	218.96
31	40.81	39.44	36.00	75.44	82.60	181.29	177.17	358.46
32	42.67	39.04	34.04	73.08	57.49	106.54	113.21	219.74
33	62.98	102.42	99.67	202.09	82.99	173.24	179.13	352.38
34	42.77	38.75	35.90	74.65	41.99	38.65	35.90	74.56
35	41.89	37.18	33.94	71.12	53.56	106.14	100.45	206.60
36	47.58	91.92	86.92	178.84	90.84	184.62	181.09	365.72
37	42.58	37.18	33.16	70.34	90.06	183.84	178.93	362.77
38	62.98	82.80	80.05	162.85	82.60	173.24	169.71	342.96
39	41.01	37.67	34.92	72.59	57.68	110.46	102.61	213.07
40	42.18	38.75	35.90	74.65	53.76	106.34	101.44	207.78
41	49.83	98.79	95.55	194.34	82.99	181.09	177.95	359.05
42	48.85	83.97	80.25	164.22	53.56	109.28	106.34	215.62
43	43.85	40.91	36.00	76.91	82.60	181.09	176.78	357.87
44	43.75	94.76	81.03	175.80	79.85	185.80	181.19	366.99
45	52.58	83.09	80.05	163.14	82.60	188.94	185.11	374.06
46	42.18	97.51	93.57	191.08	63.37	122.04	119.09	241.13
47	41.01	36.00	31.98	67.98	41.40	37.87	34.14	72.01
48	44.73	39.44	36.00	75.44	41.79	37.47	35.90	73.38
49	41.40	38.75	35.12	73.87	88.68	184.62	181.09	365.72
50	42.97	110.85	114.97	225.83	82.60	173.05	170.11	343.15
51	51.60	104.18	98.79	202.97	78.68	161.28	153.62	314.90
52	41.89	38.46	33.75	72.20	55.72	110.66	103.40	214.05
53	43.36	39.44	36.98	76.42	79.85	173.24	172.46	345.70
54	42.67	38.75	33.84	72.59	51.21	102.61	92.80	195.42

55	42.38	37.87	34.04	71.91	78.68	181.29	188.74	370.03
56	51.21	102.42	98.69	201.11	56.31	102.81	101.44	204.24
57	48.66	91.82	88.49	180.31	79.07	174.03	169.12	343.15
58	41.99	38.95	35.12	74.07	91.23	190.90	185.80	376.70
59	40.91	36.49	33.16	69.65	63.37	121.84	114.58	236.42
60	44.54	40.91	36.49	77.40	56.31	108.69	102.22	210.92
61	42.18	37.96	34.63	72.59	78.68	180.90	176.87	357.77
62	41.40	37.77	35.41	73.18	61.61	114.38	112.62	227.00
63	42.58	37.96	35.12	73.08	80.64	177.36	175.60	352.96
64	56.31	108.69	102.22	210.92	76.13	168.14	165.00	333.15
65	41.50	37.87	35.81	73.67	82.99	181.29	179.92	361.20
66	78.68	102.42	98.39	200.81	82.99	188.55	181.39	369.94
67	42.87	35.90	35.02	70.93	82.99	181.29	178.93	360.22
68	43.46	39.34	36.20	75.54	56.31	102.22	94.57	196.79
69	48.85	83.78	80.15	163.93	82.60	181.09	177.17	358.26
70	42.48	38.16	35.61	73.77	63.57	125.96	123.80	249.76
71	43.85	41.01	37.67	78.68	82.60	177.95	173.24	351.20
72	42.97	36.69	37.77	74.46	51.60	82.60	75.93	158.53
73	49.25	102.71	106.24	208.95	55.72	90.45	87.70	178.15
74	45.32	40.52	37.96	78.48	51.60	82.60	78.87	161.47
75	41.79	38.26	36.20	74.46	82.60	177.95	173.05	351.00
76	44.34	39.14	38.36	77.50	95.55	188.74	185.80	374.55
77	95.16	139.01	153.62	292.63	63.37	122.23	118.11	240.35
78	42.97	38.16	36.10	74.26	82.60	161.08	157.55	318.63
79	45.42	40.32	38.26	78.58	55.13	110.26	102.61	212.88
80	47.58	85.94	83.39	169.32	41.40	38.06	33.75	71.81
81	42.18	39.04	36.49	75.54	78.68	161.47	157.55	319.02
82	47.28	42.18	39.44	81.62	90.84	193.65	183.84	377.49
83	44.93	40.42	38.26	78.68	55.33	79.07	75.93	155.00
84	63.37	112.23	106.34	218.57	82.99	192.47	200.91	393.38
85	46.89	40.81	38.36	79.17	91.63	181.09	176.78	357.87
86	43.95	39.04	36.20	75.24	56.11	84.76	80.83	165.59
87	42.67	39.44	38.95	78.38	51.60	82.99	75.93	158.92
88	41.79	38.75	36.20	74.95	62.98	114.58	108.50	223.08
89	78.68	161.47	157.55	319.02	79.85	181.09	206.79	387.89
90	52.58	90.84	89.66	180.50	82.99	161.08	180.70	341.78
91	42.38	36.10	37.87	73.97	94.76	188.74	185.80	374.55
92	50.82	95.55	93.88	189.43	79.07	174.03	168.93	342.96
93	79.85	181.09	206.79	387.89	51.60	106.14	100.65	206.79
94	94.76	188.74	185.80	374.55	55.33	110.66	106.14	216.80
95	82.99	192.47	200.91	393.38	54.15	108.30	105.36	213.66
96	79.07	174.03	168.93	342.96	55.72	70.83	68.08	138.91
97	48.85	95.35	97.12	192.47	57.49	102.81	114.19	217.00
98	50.62	101.44	98.98	200.42	82.99	184.82	179.13	363.95
99	52.58	110.26	109.09	219.35	90.84	192.86	188.74	381.61
100	45.52	40.61	38.85	79.46	51.21	63.57	55.52	119.09
101	82.99	161.08	180.70	341.78	79.26	173.24	162.26	335.50
102	48.56	102.61	105.46	208.07	79.07	161.47	169.32	330.79
103	79.26	173.24	162.26	335.50	82.99	181.29	175.99	357.28
104	44.73	39.93	41.69	81.62	82.99	174.03	169.71	343.74
105	42.97	36.00	37.67	73.67	78.68	110.46	102.61	213.07
106	82.99	179.13	192.28	371.41	55.62	102.61	95.26	197.87
107	44.93	38.75	35.22	73.97	41.40	38.65	34.14	72.79
108	48.66	92.02	88.88	180.90	43.75	41.79	47.28	89.07
109	48.85	84.07	86.72	170.79	76.91	173.24	166.97	340.21
110	55.52	105.85	102.22	208.07	55.13	106.34	103.40	209.74
111	42.18	37.08	37.67	74.75	82.99	190.71	184.82	375.53
112	46.70	39.93	35.90	75.83	62.98	114.58	110.26	224.85
113	43.36	38.75	35.22	73.97	76.91	168.93	161.47	330.40
114	42.38	37.08	33.57	70.65	53.17	102.22	95.94	198.16
115	44.73	38.65	35.22	73.87	84.66	185.11	180.70	365.81
116	43.85	40.81	37.47	78.28	84.56	161.08	153.62	314.70
117	78.68	182.66	179.13	361.79	79.07	188.55	181.09	369.64
118	76.91	168.93	161.47	330.40	82.80	181.09	178.74	359.83

119	48.66	36.30	40.81	77.11	82.99	182.66	192.86	375.53
120	52.58	105.56	102.81	208.36	82.60	161.47	179.23	340.70
121	46.99	42.58	36.10	78.68	79.07	173.05	169.52	342.57
122	48.17	91.82	86.92	178.74	55.72	94.76	86.52	181.29
123	82.99	192.47	189.73	382.20	81.03	184.62	180.31	364.93
124	50.23	100.65	96.82	197.48	79.17	180.90	175.01	355.91
125	48.95	91.82	86.92	178.74	86.52	192.67	188.55	381.22
126	82.99	190.71	184.82	375.53	55.52	82.60	77.89	160.49
127	82.99	182.66	192.86	375.53	51.21	102.81	98.49	201.30
128	47.58	37.47	38.26	75.73	62.98	168.93	165.40	334.32
129	46.89	37.08	36.40	73.48	79.07	180.70	185.80	366.50
130	49.64	100.65	102.81	203.46	55.72	110.26	102.61	212.88
131	56.51	91.23	86.92	178.15	62.98	125.96	121.15	247.11
132					78.87	179.92	175.99	355.91
133					82.99	192.47	189.73	382.20
134					66.90	184.62	179.92	364.54
135					74.95	168.93	165.20	334.13
136					82.80	185.02	180.31	365.32
137					78.68	182.66	179.13	361.79
138					55.52	88.68	80.83	169.52
139					52.88	103.10	98.98	202.09
140					56.70	126.16	119.58	245.74
141					48.66	102.61	98.69	201.30
142					58.27	134.20	122.04	256.24
143					51.60	68.87	65.33	134.20
144					56.31	114.58	110.46	225.04
145					57.68	95.55	92.02	187.57
146					49.64	68.87	63.57	132.44
147					74.95	173.24	168.93	342.17
148					55.72	82.60	79.07	161.67
149					55.72	86.72	79.85	166.57
150					41.59	37.87	34.34	72.20

Class of Vehicle : Three Axle Truck (Location : KM 79+400)
Gurgaon to Rajasthan border
Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	98	74.81	74.81	0.2297	22.51	31.15
6	50	60	15	11.45	86.26	0.5126	7.69	10.64
7	60	70	3	2.29	88.55	1.0000	3.00	4.15
8	70	80	7	5.34	93.89	1.7725	12.41	17.17
9	80	90	6	4.58	98.47	2.9243	17.55	24.27
10	90	100	2	1.53	100.00	4.5629	9.13	12.63
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			131	100.00			72.28	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0	0.00	0.00	0.0000	0.00	0.00
2	20	40	0	0.00	0.00	0.0017	0.00	0.00
3	40	60	0	0.00	0.00	0.0130	0.00	0.00
4	60	80	73	55.73	55.73	0.0500	3.65	0.60
5	80	100	4	3.05	58.78	0.1367	0.55	0.09
6	100	120	0	0.00	58.78	0.3052	0.00	0.00
7	120	140	0	0.00	58.78	0.5953	0.00	0.00
8	140	160	0	0.00	58.78	1.0552	0.00	0.00
9	160	180	14	10.69	69.47	1.7408	24.37	4.01
10	180	200	10	7.63	77.10	2.7162	27.16	4.47
11	200	220	15	11.45	88.55	4.0535	60.80	10.00
12	220	240	1	0.76	89.31	5.8326	5.83	0.96
13	240	260	0	0.00	89.31	8.1417	0.00	0.00
14	260	280	0	0.00	89.31	11.0766	0.00	0.00
15	280	300	1	0.76	90.08	14.7416	14.74	2.42
16	300	320	1	0.76	90.84	19.2486	19.25	3.16
17	320	340	2	1.53	92.37	24.7177	49.44	8.13
18	340	360	2	1.53	93.89	31.2770	62.55	10.28
19	360	380	5	3.82	97.71	39.0625	195.31	32.11
20	380	400	3	2.29	100.00	48.2183	144.65	23.78
21	400	420	0	0.00	100.00	58.8964	0.00	0.00
22	420	440	0	0.00	100.00	71.2569	0.00	0.00
23	440	460	0	0.00	100.00	85.4679	0.00	0.00
24	460	480	0	0.00	100.00	101.7055	0.00	0.00
25	480	500	0	0.00	100.00	120.1538	0.00	0.00
26	500	520	0	0.00	100.00	141.0048	0.00	0.00
27	520	540	0	0.00	100.00	164.4586	0.00	0.00
28	540	560	0	0.00	100.00	190.7234	0.00	0.00
TOTAL			131	100.00			608.32	100.00

No. of Vehicles weighed = 131
No. of Axles weighed = 393
Total Damaging effect = 680.60
Axle Equivalency = 1.73
Vehicle Damage Factor = 5.20

Rajasthan border to Gurgaon

Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	9	6.00	6.00	0.2297	2.07	0.81
6	50	60	43	28.67	34.67	0.5126	22.04	8.68
7	60	70	15	10.00	44.67	1.0000	15.00	5.91
8	70	80	37	24.67	69.33	1.7725	65.58	25.82
9	80	90	37	24.67	94.00	2.9243	108.20	42.61
10	90	100	9	6.00	100.00	4.5629	41.07	16.17
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			150	100.00			253.96	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0	0.00	0.00	0.0000	0.00	0.00
2	20	40	0	0.00	0.00	0.0017	0.00	0.00
3	40	60	0	0.00	0.00	0.0130	0.00	0.00
4	60	80	6	4.00	4.00	0.0500	0.30	0.01
5	80	100	1	0.67	4.67	0.1367	0.14	0.00
6	100	120	1	0.67	5.33	0.3052	0.31	0.01
7	120	140	3	2.00	7.33	0.5953	1.79	0.06
8	140	160	3	2.00	9.33	1.0552	3.17	0.10
9	160	180	9	6.00	15.33	1.7408	15.67	0.52
10	180	200	8	5.33	20.67	2.7162	21.73	0.72
11	200	220	21	14.00	34.67	4.0535	85.12	2.81
12	220	240	6	4.00	38.67	5.8326	35.00	1.16
13	240	260	7	4.67	43.33	8.1417	56.99	1.88
14	260	280	0	0.00	43.33	11.0766	0.00	0.00
15	280	300	0	0.00	43.33	14.7416	0.00	0.00
16	300	320	5	3.33	46.67	19.2486	96.24	3.18
17	320	340	12	8.00	54.67	24.7177	296.61	9.80
18	340	360	37	24.67	79.33	31.2770	1157.25	38.23
19	360	380	26	17.33	96.67	39.0625	1015.63	33.55
20	380	400	5	3.33	100.00	48.2183	241.09	7.96
21	400	420	0	0.00	100.00	58.8964	0.00	0.00
22	420	440	0	0.00	100.00	71.2569	0.00	0.00
23	440	460	0	0.00	100.00	85.4679	0.00	0.00
24	460	480	0	0.00	100.00	101.7055	0.00	0.00
25	480	500	0	0.00	100.00	120.1538	0.00	0.00
26	500	520	0	0.00	100.00	141.0048	0.00	0.00
27	520	540	0	0.00	100.00	164.4586	0.00	0.00
28	540	560	0	0.00	100.00	190.7234	0.00	0.00
TOTAL			150	100.00			3051.75	100.00

No. of Vehicles weighed = 150
No. of Axles weighed = 450
Total Damaging effect = 3305.71
Axle Equivalency = 7.35
Vehicle Damage Factor = 22.04

Both Directions

Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	107	38.08	38.08	0.2297	24.58	7.53
6	50	60	58	20.64	58.72	0.5126	29.73	9.11
7	60	70	18	6.41	65.12	1.0000	18.00	5.52
8	70	80	44	15.66	80.78	1.7725	77.99	23.91
9	80	90	43	15.30	96.09	2.9243	125.75	38.54
10	90	100	11	3.91	100.00	4.5629	50.19	15.38
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			281	100.00			326.24	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.0000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.0017	0.00	0.00
3	40	60	0.00	0.00	0.00	0.0130	0.00	0.00
4	60	80	79.00	28.11	28.11	0.0500	3.95	0.11
5	80	100	5.00	1.78	29.89	0.1367	0.68	0.02
6	100	120	1.00	0.36	30.25	0.3052	0.31	0.01
7	120	140	3.00	1.07	31.32	0.5953	1.79	0.05
8	140	160	3.00	1.07	32.38	1.0552	3.17	0.09
9	160	180	23.00	8.19	40.57	1.7408	40.04	1.10
10	180	200	18.00	6.41	46.98	2.7162	48.89	1.34
11	200	220	36.00	12.81	59.79	4.0535	145.93	4.01
12	220	240	7.00	2.49	62.28	5.8326	40.83	1.12
13	240	260	7.00	2.49	64.77	8.1417	56.99	1.57
14	260	280	0.00	0.00	64.77	11.0766	0.00	0.00
15	280	300	1.00	0.36	65.12	14.7416	14.74	0.41
16	300	320	6.00	2.14	67.26	19.2486	115.49	3.18
17	320	340	14.00	4.98	72.24	24.7177	346.05	9.52
18	340	360	39.00	13.88	86.12	31.2770	1219.80	33.55
19	360	380	31.00	11.03	97.15	39.0625	1210.94	33.31
20	380	400	8.00	2.85	100.00	48.2183	385.75	10.61
21	400	420	0.00	0.00	100.00	58.8964	0.00	0.00
22	420	440	0.00	0.00	100.00	71.2569	0.00	0.00
23	440	460	0.00	0.00	100.00	85.4679	0.00	0.00
24	460	480	0.00	0.00	100.00	101.7055	0.00	0.00
25	480	500	0.00	0.00	100.00	120.1538	0.00	0.00
26	500	520	0.00	0.00	100.00	141.0048	0.00	0.00
27	520	540	0.00	0.00	100.00	164.4586	0.00	0.00
28	540	560	0.00	0.00	100.00	190.7234	0.00	0.00
TOTAL			281	100.00			3635.34	100.00

No. of Vehicles weighed = 281
No. of Axles weighed = 843
Total Damaging effect = 3961.58
Axle Equivalency = 4.70
Vehicle Damage Factor = 14.10

Location :KM 79+400

Sl. No.	Axle load (KN)																								
	Gurgaon to Rajasthan border													Rajasthan border to Gurgaon											
									Engine		Trailer											Engine		Trailer		
	Axle Configuration	Front	Rear1	Rear2	Rear3	Rear4	Rear5	Front Single	Single	Tandem	Single	Tandem	Tridem	Axle Configuration	Front	Rear1	Rear2	Rear3	Rear4	Rear5	Front Single	Single	Tandem	Single	Tandem	Tridem
1	1-1-2	47.3	42.2	36.1	33.2	0.0	0.0	47.3	42.18	0.00	0	69.26	0	1-0-3	74.0	0.0	49.4	172.1	169.1	0.0	74.0	0.00	0.00	0.00	0.00	390.63
2	1-1-2	49.2	101.4	134.0	136.4	0.0	0.0	49.2	101.44	0.00	0	270.36	0	1-1-2	55.5	134.0	141.5	136.2	0.0	0.0	55.5	134.00	0.00	0.00	277.62	0.00
3	1-2-2	47.2	36.1	32.8	27.9	36.1	0.0	47.2	0.00	68.87	0	63.96	0	1-1-2	57.7	122.4	141.9	134.8	0.0	0.0	57.7	122.43	0.00	0.00	276.64	0.00
4	1-1-3	47.3	62.0	76.5	77.5	76.3	0.0	47.3	62.00	0.00	0	0.00	230.3	1-0-3	59.1	0.0	49.4	102.2	101.4	0.0	59.1	0.00	0.00	0.00	0.00	253.10
5	1-0-3	46.5	0.0	49.9	82.6	88.7	0.0	46.5	0.00	0.00	0	0.00	221.2	1-1-2	55.7	122.2	142.0	134.0	0.0	0.0	55.7	122.23	0.00	0.00	275.96	0.00
6	1-1-2	48.7	38.5	40.9	36.7	0.0	0.0	48.7	38.46	0.00	0	77.60	0	1-1-2	61.4	114.6	126.2	122.2	0.0	0.0	61.4	114.58	0.00	0.00	248.39	0.00
7	1-1-2	47.3	42.4	38.3	33.2	0.0	0.0	47.3	42.38	0.00	0	71.42	0	1-1-2	41.4	63.4	59.4	56.3	0.0	0.0	41.4	63.37	0.00	0.00	115.76	0.00
8	1-1-2	57.7	83.2	115.6	115.2	0.0	0.0	57.7	83.19	0.00	0	230.73	0	1-1-2	56.3	122.4	141.9	135.2	0.0	0.0	56.3	122.43	0.00	0.00	277.03	0.00
9	1-1-2	48.2	40.8	42.6	35.9	0.0	0.0	48.2	40.81	0.00	0	78.48	0	1-1-2	39.4	38.1	36.3	33.9	0.0	0.0	39.4	38.06	0.00	0.00	70.24	0.00
10	1-1-2	58.5	76.3	82.6	80.4	0.0	0.0	58.5	76.32	0.00	0	163.04	0	1-1-2	51.2	43.9	86.9	83.0	0.0	0.0	51.2	43.95	0.00	0.00	169.91	0.00
11	1-1-2	61.4	114.6	124.4	120.1	0.0	0.0	61.4	114.58	0.00	240	244.47	0	1-1-2	39.8	51.8	48.5	71.4	82.6	79.1	39.8	51.80	0.00	0.00	119.88	0.00
12	1-0-3	68.1	0.0	110.3	109.3	110.1	0.0	68.1	0.00	0.00	439	0.00	330	1-1-2	49.8	45.3	64.9	69.5	0.0	0.0	49.8	45.32	0.00	0.00	134.40	0.00
13	1-1-2	61.4	114.6	126.2	122.2	0.0	0.0	61.4	114.58	0.00	0	248.39	0	1-1-3	43.4	63.4	55.7	41.4	38.1	0.0	43.4	63.37	0.00	0.00	0.00	135.18
14														1-1-2	51.6	134.2	141.9	132.4	0.0	0.0	51.6	134.20	0.00	0.00	274.29	0.00
15																										
16																										
17																										

Class of Vehicle : Multi Axle Truck (Location : KM 79+400)
Gurgaon to Rajasthan border

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0219	0.00	0.00
4	30	40	0.00	0.00	0.00	0.0841	0.00	0.00
5	40	50	8.00	61.54	61.54	0.2297	1.84	31.34
6	50	60	2.00	15.38	76.92	0.5126	1.03	17.49
7	60	70	3.00	23.08	100.00	1.0000	3.00	51.17
8	70	80	0.00	0.00	100.00	1.7725	0.00	0.00
9	80	90	0.00	0.00	100.00	2.9243	0.00	0.00
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
Total			13	100.00			5.86	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	1.00	10.00	10.00	0.0366	0.04	0.26
5	40	50	3.00	30.00	40.00	0.1001	0.30	2.10
6	50	60	0.00	0.00	40.00	0.2234	0.00	0.00
7	60	70	1.00	10.00	50.00	0.4358	0.44	3.04
8	70	80	1.00	10.00	60.00	0.7725	0.77	5.39
9	80	90	1.00	10.00	70.00	1.2744	1.27	8.90
10	90	100	0.00	0.00	70.00	1.9885	0.00	0.00
11	100	110	1.00	10.00	80.00	2.9675	2.97	20.71
12	110	120	2.00	20.00	100.00	4.2700	8.54	59.61
13	120	130	0.00	0.00	100.00	5.9605	0.00	0.00
14	130	140	0.00	0.00	100.00	8.1091	0.00	0.00
15	140	150	0.00	0.00	100.00	10.7923	0.00	0.00
Total			10	100.00			14.33	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	6.00	54.55	54.55	0.050	0.30	0.85
5	80	100	0.00	0.00	54.55	0.137	0.00	0.00
6	100	120	0.00	0.00	54.55	0.305	0.00	0.00
7	120	140	0.00	0.00	54.55	0.595	0.00	0.00
8	140	160	0.00	0.00	54.55	1.055	0.00	0.00
9	160	180	1.00	9.09	63.64	1.741	1.74	4.94
10	180	200	0.00	0.00	63.64	2.716	0.00	0.00
11	200	220	0.00	0.00	63.64	4.054	0.00	0.00
12	220	240	1.00	9.09	72.73	5.833	5.83	16.55
13	240	260	2.00	18.18	90.91	8.142	16.28	46.22
14	260	280	1.00	9.09	100.00	11.077	11.08	31.44
15	280	300	0.00	0.00	100.00	14.742	0.00	0.00
16	300	320	0.00	0.00	100.00	19.249	0.00	0.00
17	320	340	0.00	0.00	100.00	24.718	0.00	0.00
18	340	360	0.00	0.00	100.00	31.277	0.00	0.00
19	360	380	0.00	0.00	100.00	39.063	0.00	0.00
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	440	460	0.00	0.00	100.00	85.468	0.00	0.00
24	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			11.00	100.00			35.23	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	0.00	0.00	0.00	0.048	0.00	0.00
5	120	150	0.00	0.00	0.00	0.132	0.00	0.00
6	150	180	0.00	0.00	0.00	0.294	0.00	0.00
7	180	210	0.00	0.00	0.00	0.574	0.00	0.00
8	210	240	2.00	66.67	66.67	1.018	2.04	34.24
9	240	270	0.00	0.00	66.67	1.679	0.00	0.00
10	270	300	0.00	0.00	66.67	2.621	0.00	0.00
11	300	330	1.00	33.33	100.00	3.911	3.91	65.76
12	330	360	0.00	0.00	100.00	5.627	0.00	0.00
13	360	390	0.00	0.00	100.00	7.855	0.00	0.00
14	390	420	0.00	0.00	100.00	10.686	0.00	0.00
15	420	450	0.00	0.00	100.00	14.222	0.00	0.00
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	100.00	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			3.00	100.00			5.95	100.00

No. of Vehicles weighed =	13
No. of Axles weighed =	54
Total Damaging effect =	61.37
Axle Equivalency =	1.14
Vehicle Damage Factor	4.72

Rajasthan border to Gurgaon

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0219	0.00	0.00
4	30	40	2.00	14.29	14.29	0.0841	0.17	2.33
5	40	50	3.00	21.43	35.71	0.2297	0.69	9.55
6	50	60	7.00	50.00	85.71	0.5126	3.59	49.71
7	60	70	1.00	7.14	92.86	1.0000	1.00	13.85
8	70	80	1.00	7.14	100.00	1.7725	1.77	24.56
9	80	90	0.00	0.00	100.00	2.9243	0.00	0.00
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
12	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
Total			14	100.00			7.22	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	1.00	10.00	10.00	0.0366	0.04	0.16
5	40	50	2.00	20.00	30.00	0.1001	0.20	0.85
6	50	60	1.00	10.00	40.00	0.2234	0.22	0.95
7	60	70	2.00	20.00	60.00	0.4358	0.87	3.71
8	70	80	0.00	0.00	60.00	0.7725	0.00	0.00
9	80	90	0.00	0.00	60.00	1.2744	0.00	0.00
10	90	100	0.00	0.00	60.00	1.9885	0.00	0.00
11	100	110	0.00	0.00	60.00	2.9675	0.00	0.00
12	110	120	1.00	10.00	70.00	4.2700	4.27	18.18
13	120	130	3.00	30.00	100.00	5.9605	17.88	76.15
Total			10.00	100.00			23.48	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	1.00	9.09	9.09	0.050	0.05	0.08
5	80	100	0.00	0.00	9.09	0.137	0.00	0.00
6	100	120	2.00	18.18	27.27	0.305	0.61	0.92
7	120	140	1.00	9.09	36.36	0.595	0.60	0.89
8	140	160	0.00	0.00	36.36	1.055	0.00	0.00
9	160	180	1.00	9.09	45.45	1.741	1.74	2.62
10	180	200	0.00	0.00	45.45	2.716	0.00	0.00
11	200	220	0.00	0.00	45.45	4.054	0.00	0.00
12	220	240	0.00	0.00	45.45	5.833	0.00	0.00
13	240	260	1.00	9.09	54.55	8.142	8.14	12.24
14	260	280	5.00	45.45	100.00	11.077	55.38	83.26
15	280	300	0.00	0.00	100.00	14.742	0.00	0.00
16	300	320	0.00	0.00	100.00	19.249	0.00	0.00
17	320	340	0.00	0.00	100.00	24.718	0.00	0.00
18	340	360	0.00	0.00	100.00	31.277	0.00	0.00
19	360	380	0.00	0.00	100.00	39.063	0.00	0.00
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	420	440	0.00	0.00	100.00	71.257	0.00	0.00
24	440	460	0.00	0.00	100.00	85.468	0.00	0.00
25	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			11.00	100.00			66.52	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	0.00	0.00	0.00	0.048	0.00	0.00
5	120	150	1.00	33.33	33.33	0.132	0.13	1.06
6	150	180	0.00	0.00	33.33	0.294	0.00	0.00
7	180	210	0.00	0.00	33.33	0.574	0.00	0.00
8	210	240	0.00	0.00	33.33	1.018	0.00	0.00
9	240	270	1.00	33.33	66.67	1.679	1.68	13.44
10	270	300	0.00	0.00	66.67	2.621	0.00	0.00
11	300	330	0.00	0.00	66.67	3.911	0.00	0.00
12	330	360	0.00	0.00	66.67	5.627	0.00	0.00
13	360	390	0.00	0.00	66.67	7.855	0.00	0.00
14	390	420	1.00	33.33	100.00	10.686	10.69	85.51
15	420	450	0.00	0.00	100.00	14.222	0.00	0.00
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	100.00	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			3.00	100.00			12.50	100.00

No. of Vehicles weighed =	14
No. of Axles weighed =	59
Total Damaging effect =	109.72
Axle Equivalency =	1.86
Vehicle Damage Factor =	7.84

BOTH DIRECTION

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0219	0.00	0.00
4	30	40	2.00	7.41	7.41	0.0841	0.17	1.29
5	40	50	11.00	40.74	48.15	0.2297	2.53	19.32
6	50	60	9.00	33.33	81.48	0.5126	4.61	35.27
7	60	70	4.00	14.81	96.30	1.0000	4.00	30.58
8	70	80	1.00	3.70	100.00	1.7725	1.77	13.55
9	80	90	0.00	0.00	100.00	2.9243	0.00	0.00
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
12	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
Total			27	100.00			13.08	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	2.00	9.09	9.09	0.0366	0.07	0.14
5	40	50	5.00	22.73	31.82	0.1001	0.50	0.93
6	50	60	1.00	4.55	36.36	0.2234	0.22	0.41
7	60	70	3.00	13.64	50.00	0.4358	1.31	2.42
8	70	80	1.00	4.55	54.55	0.7725	0.77	1.43
9	80	90	1.00	4.55	59.09	1.2744	1.27	2.36
10	90	100	0.00	0.00	59.09	1.9885	0.00	0.00
11	100	110	1.00	4.55	63.64	2.9675	2.97	5.49
12	110	120	3.00	13.64	77.27	4.2700	12.81	23.71
13	120	130	3.00	13.64	90.91	5.9605	17.88	33.10
14	130	140	2.00	9.09	100.00	8.1091	16.22	30.02
15	140	150	0.00	0.00	100.00	10.7923	0.00	0.00
16	150	160	0.00	0.00	100.00	14.0918	0.00	0.00
17	160	170	0.00	0.00	100.00	18.0957	0.00	0.00
Total			22.00	100.00			54.03	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	7.00	31.82	31.82	0.050	0.35	0.34
5	80	100	0.00	0.00	31.82	0.137	0.00	0.00
6	100	120	2.00	9.09	40.91	0.305	0.61	0.60
7	120	140	1.00	4.55	45.45	0.595	0.60	0.59
8	140	160	0.00	0.00	45.45	1.055	0.00	0.00
9	160	180	2.00	9.09	54.55	1.741	3.48	3.42
10	180	200	0.00	0.00	54.55	2.716	0.00	0.00
11	200	220	0.00	0.00	54.55	4.054	0.00	0.00
12	220	240	1.00	4.55	59.09	5.833	5.83	5.73
13	240	260	3.00	13.64	72.73	8.142	24.42	24.00
14	260	280	6.00	27.27	100.00	11.077	66.46	65.31
15	280	300	0.00	0.00	100.00	14.742	0.00	0.00
16	300	320	0.00	0.00	100.00	19.249	0.00	0.00
17	320	340	0.00	0.00	100.00	24.718	0.00	0.00
18	340	360	0.00	0.00	100.00	31.277	0.00	0.00
19	360	380	0.00	0.00	100.00	39.063	0.00	0.00
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	420	440	0.00	0.00	100.00	71.257	0.00	0.00
24	440	460	0.00	0.00	100.00	85.468	0.00	0.00
25	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			22.00	100.00			101.75	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	0.00	0.00	0.00	0.048	0.00	0.00
5	120	150	1.00	16.67	16.67	0.132	0.13	0.72
6	150	180	0.00	0.00	16.67	0.294	0.00	0.00
7	180	210	0.00	0.00	16.67	0.574	0.00	0.00
8	210	240	2.00	33.33	50.00	1.018	2.04	11.04
9	240	270	1.00	16.67	66.67	1.679	1.68	9.11
10	270	300	0.00	0.00	66.67	2.621	0.00	0.00
11	300	330	1.00	16.67	83.33	3.911	3.91	21.20
12	330	360	0.00	0.00	83.33	5.627	0.00	0.00
13	360	390	0.00	0.00	83.33	7.855	0.00	0.00
14	390	420	1.00	16.67	100.00	10.686	10.69	57.94
15	420	450	0.00	0.00	100.00	14.222	0.00	0.00
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	100.00	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			6.00	100.00			18.44	100.00

No. of Vehicles weighed =	24
No. of Axles weighed =	113.00
Total Damaging effect =	187.31
Axle Equivalency =	1.66
Vehicle Damage Factor =	7.80

VDF SUMMARY

(Location: KM 79+400)

Vehicle Type	Gurgaon to Rajasthan border	Rajasthan border to Gurgaon	Both Direction
BUS	1.61	1.11	1.46
LCV	2.55	2.97	2.76
2 Axle	4.79	11.52	7.44
3 Axle	5.20	22.04	14.19
Multi Axle	4.72	7.84	7.80

Location - KM 86+400

Sl. No.	Axle Load (KN)			
	Rajasthan Border to Gurgaon		Gurgaon to Rajasthan Border	
	Front	Rear	Front	Rear
1	31.98	97.51	38.06	57.29
2	42.67	94.57	54.54	88.88
3	62.29	145.97	42.38	83.68
4	44.15	68.96	57.49	99.87
5	55.33	74.36	58.47	106.34
6	49.25	75.14	43.56	110.46
7	34.92	67.69	62.29	87.11
8	35.71	67.30	41.89	87.90
9	55.17	115.95	53.58	97.71
10	37.87	83.39	62.29	106.73
11	47.68	82.60	49.25	94.76
12			55.17	95.75

Class of Vehicle : LCV (Location - KM 86+400)
Rajasthan Border to Gurgaon

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	4	18.18	18.18	0.0841	0.34	0.57
5	40	50	4	18.18	36.36	0.2297	0.92	1.55
6	50	60	2	9.09	45.45	0.5126	1.03	1.73
7	60	70	4	18.18	63.64	1.0000	4.00	6.74
8	70	80	2	9.09	72.73	1.7725	3.55	5.97
9	80	90	2	9.09	81.82	2.9243	5.85	9.85
10	90	100	2	9.09	90.91	4.5629	9.13	15.37
11	100	110	0	0.00	90.91	6.8093	0.00	0.00
12	110	120	1	4.55	95.45	9.7980	9.80	16.51
13	120	130	0	0.00	95.45	13.6769	0.00	0.00
14	130	140	0	0.00	95.45	18.6072	0.00	0.00
15	140	150	1	4.55	100.00	24.7639	24.76	41.72
Total			22	100.00			59.36	58.28

No. of Vehicles weighed = 11
No. of Axles weighed = 22
Total Damaging effect = 59.36
Axle Equivalency = 2.70
Vehicle Damage Factor = 5.40

Gurgaon to Rajasthan Border

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	1	4.17	4.17	0.0841	0.08	0.14
5	40	50	4	16.67	20.83	0.2297	0.92	1.55
6	50	60	6	25.00	45.83	0.5126	3.08	5.17
7	60	70	2	8.33	54.17	1.0000	2.00	3.36
8	70	80	0	0.00	54.17	1.7725	0.00	0.00
9	80	90	4	16.67	70.83	2.9243	11.70	19.68
10	90	100	4	16.67	87.50	4.5629	18.25	30.70
11	100	110	2	8.33	95.83	6.8093	13.62	22.91
12	110	120	1	4.17	100.00	9.7980	9.80	16.48
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
14	130	140	0	0.00	100.00	18.6072	0.00	0.00
Total			24	100.00			59.44	100.00

No. of Vehicles weighed = 12
No. of Axles weighed = 24
Total Damaging effect = 59.44
Axle Equivalency = 2.48
Vehicle Damage Factor = 4.95

Both Directions

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	5	10.87	10.87	0.0841	0.42	0.35
5	40	50	8	17.39	28.26	0.2297	1.84	1.55
6	50	60	8	17.39	45.65	0.5126	4.10	3.45
7	60	70	6	13.04	58.70	1.0000	6.00	5.05
8	70	80	2	4.35	63.04	1.7725	3.55	2.98
9	80	90	6	13.04	76.09	2.9243	17.55	14.77
10	90	100	6	13.04	89.13	4.5629	27.38	23.04
11	100	110	2	4.35	93.48	6.8093	13.62	11.46
12	110	120	2	4.35	97.83	9.7980	19.60	16.49
13	120	130	0	0.00	97.83	13.6769	0.00	0.00
14	130	140	0	0.00	97.83	18.6072	0.00	0.00
15	140	150	1	2.17	100.00	24.7639	24.76	20.84
Total			46	100.00			118.81	79.16

No. of Vehicles weighed =	23
No. of Axles weighed =	46
Total Damaging effect =	118.81
Axle Equivalency =	2.58
Vehicle Damage Factor =	5.17

Location - KM 86+400

Sl. No.	Axle Load (KN)			
	Rajasthan Border to Gurgaon		Gurgaon to Rajasthan Border	
	Front	Rear	Front	Rear
1	48.27	53.56	60.43	114.38
2	42.38	74.36	43.36	38.65
3	48.46	64.94	57.09	63.37
4	48.07	120.27	61.02	79.07
5	48.27	97.41	47.58	58.27
6	59.15	66.51	57.88	91.43
7	48.85	102.61	55.92	83.39
8	55.52	128.90	48.56	77.89
9	44.15	112.42	51.21	63.77
10	56.31	122.04	92.80	115.56
11	62.98	134.89	93.35	159.90
12	82.60	118.31	37.08	33.55
13	51.21	84.17	56.31	103.79
14	60.72	122.33	84.76	101.04
15	92.80	115.56	46.11	71.61
16	56.60	95.55	48.07	75.24
17	56.31	76.32	82.60	128.12
18	75.93	98.49	52.29	83.97
19	75.93	167.36	64.16	106.54
20	74.95	123.02	44.44	79.07
21	49.93	75.73	81.54	174.58
22	49.64	76.32	92.80	115.56
23	52.39	83.39	92.80	115.56
24	44.44	79.07	114.48	177.56
25	51.21	84.76	64.94	81.03
26	63.18	124.19		
27	64.94	125.76		
28	93.35	159.90		
29	81.54	174.58		
30	55.62	177.56		
31	53.17	167.16		
32	75.64	142.83		
33	51.99	75.14		
34	51.21	74.95		
35	69.85	122.04		
36	60.23	120.98		
37	51.60	102.81		
38	51.21	74.95		
39	69.85	122.04		
40	74.95	123.02		

Class of Vehicle : 2-Axle Truck
Rajasthan Border to Gurgaon
Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	10	25.00	25.00	0.2297	2.30	5.70
6	50	60	14	35.00	60.00	0.5126	7.18	17.80
7	60	70	7	17.50	77.50	1.0000	7.00	17.37
8	70	80	5	12.50	90.00	1.7725	8.86	21.99
9	80	90	2	5.00	95.00	2.9243	5.85	14.51
10	90	100	2	5.00	100.00	4.5629	9.13	22.64
11	100	110	0	0.00	100.00	6.8093	0.00	0.00
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			40	100.00			40.31	100.00

SINGLE AXLE (REAR WITH DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0012	0.00	0.00
3	20	30	0	0.00	0.00	0.0095	0.00	0.00
4	30	40	0	0.00	0.00	0.0366	0.00	0.00
5	40	50	0	0.00	0.00	0.1001	0.00	0.00
6	50	60	1	2.50	2.50	0.2234	0.22	0.10
7	60	70	2	5.00	7.50	0.4358	0.87	0.40
8	70	80	8	20.00	27.50	0.7725	6.18	2.86
9	80	90	3	7.50	35.00	1.2744	3.82	1.77
10	90	100	3	7.50	42.50	1.9885	5.97	2.76
11	100	110	2	5.00	47.50	2.9675	5.94	2.74
12	110	120	3	7.50	55.00	4.2700	12.81	5.92
13	120	130	11	27.50	82.50	5.9605	65.57	30.30
14	130	140	1	2.50	85.00	8.1091	8.11	3.75
15	140	150	1	2.50	87.50	10.7923	10.79	4.99
16	150	160	1	2.50	90.00	14.0918	14.09	6.51
17	160	170	2	5.00	95.00	18.0957	36.19	16.73
18	170	180	2	5.00	100.00	22.8977	45.80	21.17
19	180	190	0	0.00	100.00	28.5974	0.00	0.00
20	190	200	0	0.00	100.00	35.3003	0.00	0.00
21	200	210	0	0.00	100.00	43.1177	0.00	0.00
22	210	220	0	0.00	100.00	52.1668	0.00	0.00
23	220	230	0	0.00	100.00	62.5706	0.00	0.00
24	230	240	0	0.00	100.00	74.4580	0.00	0.00
25	240	250	0	0.00	100.00	87.9639	0.00	0.00
26	250	260	0	0.00	100.00	103.2288	0.00	0.00
27	260	270	0	0.00	100.00	120.3992	0.00	0.00
28	270	280	0	0.00	100.00	139.6275	0.00	0.00
TOTAL			40	100.00			216.35	100.00

No. of Vehicles weighed =	40
No. of Axles weighed =	80
Total Damaging effect =	256.67
Axle Equivalency =	3.21
Vehicle Damage Factor =	6.42

Gurgaon to Rajasthan Border (Location - KM 86+400)

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	1	4.00	4.00	0.0841	0.08	0.19
5	40	50	6	24.00	28.00	0.2297	1.38	3.04
6	50	60	6	24.00	52.00	0.5126	3.08	6.78
7	60	70	4	16.00	68.00	1.0000	4.00	8.82
8	70	80	0	0.00	68.00	1.7725	0.00	0.00
9	80	90	3	12.00	80.00	2.9243	8.77	19.34
10	90	100	4	16.00	96.00	4.5629	18.25	40.24
11	100	110	0	0.00	96.00	6.8093	0.00	0.00
12	110	120	1	4.00	100.00	9.7980	9.80	21.60
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			25	100.00			45.36	100.00

SINGLE AXLE (REAR WITH DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0012	0.00	0.00
3	20	30	0	0.00	0.00	0.0095	0.00	0.00
4	30	40	2	8.00	8.00	0.0366	0.07	0.07
5	40	50	0	0.00	8.00	0.1001	0.00	0.00
6	50	60	1	4.00	12.00	0.2234	0.22	0.22
7	60	70	2	8.00	20.00	0.4358	0.87	0.85
8	70	80	5	20.00	40.00	0.7725	3.86	3.76
9	80	90	3	12.00	52.00	1.2744	3.82	3.72
10	90	100	1	4.00	56.00	1.9885	1.99	1.94
11	100	110	3	12.00	68.00	2.9675	8.90	8.67
12	110	120	4	16.00	84.00	4.2700	17.08	16.64
13	120	130	1	4.00	88.00	5.9605	5.96	5.81
14	130	140	0	0.00	88.00	8.1091	0.00	0.00
15	140	150	0	0.00	88.00	10.7923	0.00	0.00
16	150	160	1	4.00	92.00	14.0918	14.09	13.72
17	160	170	0	0.00	92.00	18.0957	0.00	0.00
18	170	180	2	8.00	100.00	22.8977	45.80	44.60
19	180	190	0	0.00	100.00	28.5974	0.00	0.00
20	190	200	0	0.00	100.00	35.3003	0.00	0.00
21	200	210	0	0.00	100.00	43.1177	0.00	0.00
22	210	220	0	0.00	100.00	52.1668	0.00	0.00
23	220	230	0	0.00	100.00	62.5706	0.00	0.00
24	230	240	0	0.00	100.00	74.4580	0.00	0.00
25	240	250	0	0.00	100.00	87.9639	0.00	0.00
26	250	260	0	0.00	100.00	103.2288	0.00	0.00
27	260	270	0	0.00	100.00	120.3992	0.00	0.00
28	270	280	0	0.00	100.00	139.6275	0.00	0.00
TOTAL			25	100.00			102.67	100.00

No. of Vehicles weighed =	25
No. of Axles weighed =	75
Total Damaging effect =	148.03
Axle Equivalency =	1.97
Vehicle Damage Factor =	5.92

Both Directions
Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	1	1.54	1.54	0.0841	0.08	0.10
5	40	50	16	24.62	26.15	0.2297	3.68	4.29
6	50	60	20	30.77	56.92	0.5126	10.25	11.97
7	60	70	11	16.92	73.85	1.0000	11.00	12.84
8	70	80	5	7.69	81.54	1.7725	8.86	10.34
9	80	90	5	7.69	89.23	2.9243	14.62	17.07
10	90	100	6	9.23	98.46	4.5629	27.38	31.96
11	100	110	0	0.00	98.46	6.8093	0.00	0.00
12	110	120	1	1.54	100.00	9.7980	9.80	11.44
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			65	100.00			85.67	100.00

SINGLE AXLE (REAR WITH DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	2.00	3.08	3.08	0.0366	0.07	0.02
5	40	50	0.00	0.00	3.08	0.1001	0.00	0.00
6	50	60	2.00	3.08	6.15	0.2234	0.45	0.14
7	60	70	4.00	6.15	12.31	0.4358	1.74	0.55
8	70	80	13.00	20.00	32.31	0.7725	10.04	3.15
9	80	90	6.00	9.23	41.54	1.2744	7.65	2.40
10	90	100	4.00	6.15	47.69	1.9885	7.95	2.49
11	100	110	5.00	7.69	55.38	2.9675	14.84	4.65
12	110	120	7.00	10.77	66.15	4.2700	29.89	9.37
13	120	130	12.00	18.46	84.62	5.9605	71.53	22.42
14	130	140	1.00	1.54	86.15	8.1091	8.11	2.54
15	140	150	1.00	1.54	87.69	10.7923	10.79	3.38
16	150	160	2.00	3.08	90.77	14.0918	28.18	8.83
17	160	170	2.00	3.08	93.85	18.0957	36.19	11.34
18	170	180	4.00	6.15	100.00	22.8977	91.59	28.71
19	180	190	0.00	0.00	100.00	28.5974	0.00	0.00
20	190	200	0.00	0.00	100.00	35.3003	0.00	0.00
21	200	210	0.00	0.00	100.00	43.1177	0.00	0.00
22	210	220	0.00	0.00	100.00	52.1668	0.00	0.00
23	220	230	0.00	0.00	100.00	62.5706	0.00	0.00
24	230	240	0.00	0.00	100.00	74.4580	0.00	0.00
25	240	250	0.00	0.00	100.00	87.9639	0.00	0.00
26	250	260	0.00	0.00	100.00	103.2288	0.00	0.00
27	260	270	0.00	0.00	100.00	120.3992	0.00	0.00
28	270	280	0.00	0.00	100.00	139.6275	0.00	0.00
TOTAL			65	100.00			319.03	100.00

No. of Vehicles weighed =	65
No. of Axles weighed =	195
Total Damaging effect =	404.70
Axle Equivalency =	2.08
Vehicle Damage Factor =	6.23

Location - KM 86+400

Sl. No.	Axle Load (KN)			
	Rajasthan Border to Gurgaon		Gurgaon to Rajasthan Border	
	Front	Rear	Front	Rear
1	45.32	59.45	49.64	63.96
2	43.36	63.96	51.80	64.55
3	44.01	65.61	51.80	67.79
4	51.21	62.69	47.68	64.16
5	53.56	81.72	45.32	68.08
6	57.49	77.50	51.99	68.47
7	53.37	83.39	48.07	69.26
8	51.70	68.47	49.74	73.38
9	52.48	71.32		
10	48.66	65.24		
11	48.36	71.22		

Class of Vehicle : Bus
Rajasthan Border to Gurgaon (Location - KM 86+400)

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	5	22.73	22.73	0.2297	1.15	5.49
6	50	60	7	31.82	54.55	0.5126	3.59	17.17
7	60	70	5	22.73	77.27	1.0000	5.00	23.92
8	70	80	3	13.64	90.91	1.7725	5.32	25.44
9	80	90	2	9.09	100.00	2.9243	5.85	27.98
10	90	100	0	0.00	54.55	4.5629	0.00	0.00
Total			22	100.00			20.90	100.00

No. of Vehicles weighed = 11
No. of Axles weighed = 22
Total Damaging effect = 20.90
Axle Equivalency = 0.95
Vehicle Damage Factor = 1.90

Gurgaon to Rajasthan Border

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	5	31.25	31.25	0.2297	1.15	10.02
6	50	60	3	18.75	50.00	0.5126	1.54	13.42
7	60	70	7	43.75	93.75	1.0000	7.00	61.09
8	70	80	1	6.25	100.00	1.7725	1.77	15.47
9	80	90	0	0.00	100.00	2.9243	0.00	0.00
10	90	100	0	0.00	93.75	4.5629	0.00	0.00
Total			16	100.00			11.46	100.00

No. of Vehicles weighed = 8
No. of Axles weighed = 16
Total Damaging effect = 11.46
Axle Equivalency = 0.72
Vehicle Damage Factor = 1.43

Both Directions

Sl. No.	Axle Load Category (KN)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	0	0.00	0.00	0.0841	0.00	0.00
5	40	50	10	26.32	26.32	0.2297	2.30	7.10
6	50	60	10	26.32	52.63	0.5126	5.13	15.84
7	60	70	12	31.58	84.21	1.0000	12.00	37.08
8	70	80	4	10.53	94.74	1.7725	7.09	21.91
9	80	90	2	5.26	100.00	2.9243	5.85	18.07
10	90	100	0	0.00	100.00	4.5629	0.00	0.00
Total			38	100.00			32.36	100.00

No. of Vehicles weighed = 19
No. of Axles weighed = 38
Total Damaging effect = 32.36
Axle Equivalency = 0.85
Vehicle Damage Factor = 1.70

Location - KM 86+400

Sl. No.	Axle Load (KN)							
	Rajasthan Border to Gurgaon				Gurgaon to Rajasthan Border			
	Front	Rear1	Rear2	Tandem	Front	Rear1	Rear2	Tandem
1	86.72	176.97	181.29	358.26	41.40	36.10	33.94	70.04
2	78.87	183.25	188.94	372.19	42.58	38.06	40.32	78.38
3	80.83	175.40	176.97	352.38	41.40	38.06	36.79	74.85
4	80.83	180.90	184.04	364.93	47.28	55.52	58.47	113.99
5	82.60	192.47	206.40	398.87	59.06	88.49	91.33	179.82
6	68.87	202.48	208.76	411.24	41.40	38.06	38.36	76.42
7	41.40	35.90	35.51	71.42	41.40	38.06	38.85	76.91
8	82.60	198.55	194.63	393.18	55.52	108.11	112.42	220.53
9	70.04	177.17	179.92	357.08	41.40	37.87	39.53	77.40
10	52.19	115.17	119.88	235.05	47.68	46.89	44.73	91.63
11	72.20	173.44	167.95	341.39	44.15	40.02	39.83	79.85
12	68.47	173.24	171.97	345.21	41.79	43.75	40.91	84.66
13	64.94	83.58	85.86	169.44	43.36	42.58	40.61	83.19
14	82.60	193.45	194.63	388.08	41.40	38.06	36.79	74.85
15	47.68	91.23	88.88	180.11	82.60	192.47	206.40	398.87
16	71.22	157.35	163.73	321.08	39.93	38.65	40.71	79.36
17	68.87	168.34	169.81	338.15	41.79	44.54	41.69	86.23
18	75.73	144.99	142.93	287.92	41.40	38.85	36.69	75.54
19	48.27	90.64	94.08	184.72	40.81	38.85	39.63	78.48
20	67.10	153.62	157.25	310.88	41.40	38.65	37.08	75.73
21	69.85	177.17	175.80	352.96	68.47	173.24	171.97	345.21
22	64.06	148.43	149.50	297.93	59.25	45.32	44.05	89.37
23	80.05	154.80	158.43	313.23	63.77	107.32	109.09	216.41
24	63.77	176.97	181.39	358.36	88.88	202.28	206.89	409.18
25	88.88	202.28	206.89	409.18	41.59	38.06	36.69	74.75
26	72.01	133.22	134.79	268.01	42.18	38.26	36.49	74.75
27	72.79	106.34	105.46	211.80	41.79	38.06	35.71	73.77
28	42.58	53.96	55.43	109.38	46.50	40.81	41.99	82.80
29	82.99	193.55	194.92	388.48	41.99	38.06	35.12	73.18
30	71.61	166.57	170.60	337.17	42.58	37.87	35.71	73.58
31	85.35	163.04	163.24	326.28	42.58	36.49	38.85	75.34
32	42.97	38.65	35.61	74.26	53.56	122.63	124.19	246.82
33	93.39	192.86	191.39	384.26	82.99	193.55	194.92	388.48
34	86.92	167.95	173.24	341.19	63.37	116.74	114.58	231.32
35	62.00	78.87	73.77	152.64	58.66	106.54	108.11	214.64
36	73.18	83.39	77.50	160.88	48.07	48.07	38.16	86.23
37	90.64	193.26	198.55	391.81	54.54	101.83	96.73	198.55
38	46.11	47.28	45.32	92.61	55.92	98.79	100.26	199.04
39	85.35	169.71	164.42	334.13	41.79	38.26	39.44	77.70
40	71.61	148.92	144.21	293.12	61.41	92.80	92.61	185.41
41	80.05	177.56	181.09	358.65	53.46	72.79	76.32	149.11
42	100.94	178.44	174.23	352.67	100.94	178.44	176.19	354.63
43	102.22	200.32	212.39	412.71	59.06	90.06	91.63	181.68
44	68.28	177.27	172.46	349.73	42.08	38.26	39.83	78.09
45	71.32	158.33	150.88	309.21	46.50	50.42	51.60	102.02
46	43.36	70.44	73.77	144.21	63.77	176.97	181.39	358.36
47	55.92	94.57	91.82	186.39	55.13	70.04	82.01	152.06
48	46.89	124.10	117.52	241.62	42.18	55.43	54.54	109.97
49	82.60	219.94	194.04	413.98	47.97	85.74	83.78	169.52
50	42.38	38.65	36.10	74.75	46.11	90.06	90.64	180.70
51	80.05	177.17	75.34	252.51	48.07	67.89	69.85	137.73

Sl. No.	Axle Load (KN)							
	Rajasthan Border to Gurgaon				Gurgaon to Rajasthan Border			
	Front	Rear1	Rear2	Tandem	Front	Rear1	Rear2	Tandem
52	86.92	204.64	194.04	398.68	47.28	75.14	79.17	154.31
53	42.58	38.06	35.12	73.18	93.39	192.86	191.39	384.26
54	82.60	215.43	192.86	408.29	82.60	219.94	194.04	413.98
55	80.25	194.04	186.98	381.02	45.52	107.13	110.26	217.39
56	86.92	200.71	188.74	389.46	58.27	84.07	86.13	170.20
57	74.95	177.17	180.31	357.48	80.25	194.04	186.98	381.02
58	44.73	74.95	70.44	145.38	49.44	108.30	109.97	218.27
59	43.07	38.75	35.90	74.65	41.59	37.87	34.14	72.01
60	79.17	189.04	186.29	375.33	40.81	37.47	36.10	73.58
61	69.26	81.82	73.77	155.59	41.59	38.06	35.51	73.58
62	71.32	195.81	188.94	384.75	79.17	189.04	186.29	375.33
63	79.11	179.92	176.97	356.89	79.11	179.92	176.97	356.89
64	74.95	188.74	182.37	371.11	44.64	39.04	37.08	76.13
65	73.48	166.57	153.43	320.00	48.27	84.17	80.25	164.42
66	43.07	38.85	35.71	74.56	55.13	114.38	109.68	224.06
67	91.23	201.11	192.96	394.07	42.67	38.26	35.12	73.38
68	79.17	188.94	185.02	373.96	51.70	121.84	116.35	238.19
69	72.10	158.43	154.80	313.23	91.23	201.11	192.96	394.07
70	82.60	177.95	181.68	359.63	48.85	68.47	60.43	128.90
71	83.39	181.39	177.17	358.56	42.58	37.67	35.12	72.79
72	90.84	192.96	187.76	380.73	44.15	39.04	35.71	74.75
73	74.95	177.27	179.92	357.18	42.18	37.87	35.51	73.38
74	73.58	177.56	180.90	358.46	39.73	35.51	38.26	73.77
75	81.03	181.88	182.66	364.54	48.07	104.38	100.26	204.64
76	41.59	38.26	40.61	78.87	82.60	177.95	181.68	359.63
77	55.52	102.42	108.50	210.92	79.23	192.96	77.20	270.17
78	76.71	175.21	177.27	352.47	47.28	70.24	64.94	135.18
79	77.20	192.86	190.80	383.67	42.97	37.96	36.10	74.07
80	74.85	174.23	175.21	349.43	44.93	38.95	35.12	74.07
81	52.39	82.21	79.36	161.57	42.18	38.55	35.12	73.67
82	76.32	158.63	156.08	314.70	82.60	215.43	192.86	408.29
83	81.03	181.19	187.67	368.86	55.52	102.42	108.50	210.92
84	79.23	177.46	181.29	358.75	41.63	38.65	35.90	74.56
85	57.49	142.25	141.22	283.47	41.99	37.87	35.90	73.77
86	74.75	177.17	179.23	356.40	50.42	63.18	65.24	128.41
87	72.79	172.17	173.05	345.21	40.81	38.65	36.79	75.44
88	79.23	192.96	77.20	270.17	49.25	69.26	71.61	140.87
89	83.39	192.67	190.90	383.57	41.69	38.85	36.69	75.54
90	43.56	41.40	44.15	85.54	41.89	38.75	35.12	73.87
91	71.22	159.90	163.53	323.44	79.23	177.46	181.29	358.75
92	62.59	102.61	104.28	206.89	41.40	38.16	35.90	74.07
93	41.79	39.63	41.40	81.03	49.34	105.46	97.51	202.97
94	69.26	175.01	179.13	354.14	42.38	37.87	35.12	72.99
95	83.39	200.52	194.73	395.24	43.36	39.53	37.08	76.62
96	41.40	36.89	34.53	71.42	47.28	65.92	62.00	127.92
97	78.87	180.90	178.15	359.05	79.07	93.98	88.88	182.86
98	82.99	193.06	188.74	381.81	56.31	102.61	98.69	201.30
99	81.13	179.13	175.40	354.53	57.29	101.63	98.30	199.93
100	82.60	193.16	190.51	383.67	41.40	38.06	36.69	74.75
101	78.68	181.88	176.97	358.85	41.79	39.44	37.47	76.91
102	102.22	204.44	207.38	411.82	63.37	121.84	124.00	245.84
103	98.69	205.42	193.75	399.17	68.87	107.58	110.26	217.84

Sl. No.	Axle Load (KN)							
	Rajasthan Border to Gurgaon				Gurgaon to Rajasthan Border			
	Front	Rear1	Rear2	Tandem	Front	Rear1	Rear2	Tandem
104	56.31	100.26	98.69	198.95	56.31	115.17	37.08	152.25
105	89.66	161.47	158.33	319.81	41.40	38.06	110.46	148.52
106	52.39	69.26	66.22	135.48	52.39	74.95	72.79	147.74
107	90.64	154.80	144.60	299.40	53.37	76.71	70.83	147.54
108	80.05	169.32	158.43	327.75	41.40	38.65	36.79	75.44
109	71.12	149.01	142.44	291.46	49.25	75.34	59.06	134.40
110	82.99	177.17	179.23	356.40	51.60	62.98	87.70	150.68
111	103.59	203.66	193.75	397.40	45.32	90.84	93.88	184.72
112	86.13	185.02	177.27	362.28	70.14	90.84	36.10	126.94
113	34.92	158.43	153.43	311.86	42.58	37.87	35.90	73.77
114	98.79	221.31	198.36	419.67	41.40	38.65	72.79	111.44
115	75.73	181.09	177.76	358.85	51.60	75.34	114.38	189.73
116	84.17	192.77	188.84	381.61	57.68	117.92	36.49	154.41
117	60.63	215.43	188.74	404.17	41.40	37.87	42.58	80.44
118	72.40	167.36	164.61	331.97	54.35	114.38	77.89	192.28
119	82.99	177.17	174.13	351.30	55.52	82.60	94.76	177.36
120	42.97	38.46	35.90	74.36	56.70	95.16	91.04	186.19
121	83.97	190.12	181.98	372.09	41.40	37.08	34.92	72.01
122	75.54	178.25	174.42	352.67	42.58	38.26	100.65	138.91
123	95.45	158.43	151.86	310.29	65.92	105.75	108.69	214.45
124	69.45	110.46	105.16	215.62	54.54	101.83	96.73	198.55
125	71.61	154.21	147.84	302.05	55.92	98.79	100.26	199.04
126	80.15	177.17	169.32	346.49	41.79	38.26	39.44	77.70
127	68.47	178.15	170.50	348.65	61.41	92.80	92.61	185.41
128	48.66	110.26	105.95	216.21	42.18	38.55	35.12	73.67
129	88.88	181.09	204.44	385.53	39.65	38.06	34.92	72.99
130	39.93	38.02	39.73	77.75	41.59	36.69	33.55	70.24
131	53.76	123.21	117.72	240.93	41.63	38.65	35.90	74.56
132	57.78	128.31	133.81	262.12	41.40	38.06	110.46	148.52
133	37.96	36.57	33.51	70.08	52.39	74.95	72.79	147.74
134	61.80	70.99	78.87	149.86	53.37	76.71	70.83	147.54
135	57.68	115.17	110.26	225.43	48.07	67.89	69.85	137.73
136	56.31	132.04	129.69	261.73	47.28	75.14	79.17	154.31
137	68.87	114.19	110.17	224.35	42.58	83.09	79.85	162.94
138	60.74	120.27	126.94	247.21	79.07	161.47	159.71	321.18
139	69.06	108.11	98.49	206.60	41.40	38.65	37.08	75.73
140	74.75	118.11	116.35	234.46	41.40	43.36	41.89	85.25
141	68.87	123.80	120.07	243.88	52.09	61.61	69.55	131.16
142	66.90	121.84	114.38	236.22	41.01	42.58	38.75	81.32
143	71.02	124.19	117.13	241.33	90.64	154.80	144.60	299.40
144	75.93	127.92	104.57	232.50	39.44	37.67	38.36	76.03
145	43.56	86.52	82.99	169.52	43.65	38.65	36.79	75.44
146	79.07	161.08	157.55	318.63	43.07	33.94	36.49	70.44
147	56.31	66.90	63.37	130.28	71.22	122.63	126.94	249.57
148	79.07	161.47	159.71	321.18	46.30	38.26	37.87	76.13
149	55.33	66.32	62.20	128.51	80.05	169.32	158.43	327.75
150	86.92	168.93	168.14	337.07	51.21	110.75	104.18	214.94
151	67.30	102.22	100.65	202.87	51.99	131.06	62.98	194.04
152	56.31	88.88	87.01	175.89	48.66	94.76	88.09	182.86
153	52.19	102.22	98.69	200.91	47.38	40.22	38.06	78.28
154	62.98	126.35	123.02	249.37	45.32	38.26	34.92	73.18
155	57.68	115.17	110.26	225.43	90.64	154.80	144.60	299.40

Sl. No.	Axle Load (KN)							
	Rajasthan Border to Gurgaon				Gurgaon to Rajasthan Border			
	Front	Rear1	Rear2	Tandem	Front	Rear1	Rear2	Tandem
156	56.31	132.04	129.69	261.73				
157	68.87	114.19	110.17	224.35				
158	56.31	100.26	98.69	198.95				
159	89.66	161.47	158.33	319.81				
160	52.39	69.26	66.22	135.48				
161	90.64	154.80	144.60	299.40				
162	80.05	169.32	158.43	327.75				
163	52.09	61.61	69.55	131.16				
164	41.01	42.58	38.75	81.32				
165	38.65	35.71	38.95	74.65				
166	39.44	37.67	38.36	76.03				
167	43.65	38.65	36.79	75.44				
168	43.07	33.94	36.49	70.44				
169	71.22	122.63	126.94	249.57				
170	46.30	38.26	37.87	76.13				
171	40.81	38.06	35.71	73.77				
172	51.21	110.75	104.18	214.94				
173	51.99	131.06	62.98	194.04				
174	48.66	94.76	88.09	182.86				
175	47.38	40.22	38.06	78.28				
176	45.32	38.26	34.92	73.18				
177	71.22	122.63	126.94	249.57				
178	0.00	0.00	0.00	0.00				
179	0.00	0.00	0.00	0.00				
180	0.00	0.00	0.00	0.00				

Class of Vehicle : Three Axle Truck (Location - KM 86+400)
Rajasthan Border to Gurgaon
Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	5	2.82	2.82	0.0841	0.42	0.14
5	40	50	28	15.82	18.64	0.2297	6.43	2.10
6	50	60	22	12.43	31.07	0.5126	11.28	3.68
7	60	70	25	14.12	45.20	1.0000	25.00	8.16
8	70	80	44	24.86	70.06	1.7725	77.99	25.45
9	80	90	40	22.60	92.66	2.9243	116.97	38.18
10	90	100	9	5.08	97.74	4.5629	41.07	13.40
11	100	110	4	2.26	100.00	6.8093	27.24	8.89
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			177	100.00			306.40	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0	0.00	0.00	0.0000	0.00	0.00
2	20	40	0	0.00	0.00	0.0017	0.00	0.00
3	40	60	0	0.00	0.00	0.0130	0.00	0.00
4	60	80	19	10.73	10.73	0.0500	0.95	0.03
5	80	100	4	2.26	12.99	0.1367	0.55	0.01
6	100	120	1	0.56	13.56	0.3052	0.31	0.01
7	120	140	5	2.82	16.38	0.5953	2.98	0.08
8	140	160	5	2.82	19.21	1.0552	5.28	0.14
9	160	180	5	2.82	22.03	1.7408	8.70	0.24
10	180	200	7	3.95	25.99	2.7162	19.01	0.51
11	200	220	9	5.08	31.07	4.0535	36.48	0.99
12	220	240	8	4.52	35.59	5.8326	46.66	1.26
13	240	260	9	5.08	40.68	8.1417	73.27	1.98
14	260	280	5	2.82	43.50	11.0766	55.38	1.50
15	280	300	7	3.95	47.46	14.7416	103.19	2.79
16	300	320	11	6.21	53.67	19.2486	211.73	5.73
17	320	340	12	6.78	60.45	24.7177	296.61	8.02
18	340	360	32	18.08	78.53	31.2770	1000.86	27.07
19	360	380	9	5.08	83.62	39.0625	351.56	9.51
20	380	400	21	11.86	95.48	48.2183	1012.58	27.39
21	400	420	8	4.52	100.00	58.8964	471.17	12.74
22	420	440	0	0.00	100.00	71.2569	0.00	0.00
23	440	460	0	0.00	100.00	85.4679	0.00	0.00
24	460	480	0	0.00	100.00	101.7055	0.00	0.00
25	480	500	0	0.00	100.00	120.1538	0.00	0.00
26	500	520	0	0.00	100.00	141.0048	0.00	0.00
27	520	540	0	0.00	100.00	164.4586	0.00	0.00
28	540	560	0	0.00	100.00	190.7234	0.00	0.00
TOTAL			177	100.00			3697.29	100.00

No. of Vehicles weighed =	177
No. of Axles weighed =	531
Total Damaging effect =	4003.69
Axle Equivalency =	7.54
Vehicle Damage Factor =	22.62

Gurgaon to Rajasthan Border

Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	4	2.58	2.58	0.0841	0.34	0.31
5	40	50	88	56.77	59.35	0.2297	20.22	18.53
6	50	60	33	21.29	80.65	0.5126	16.92	15.51
7	60	70	9	5.81	86.45	1.0000	9.00	8.25
8	70	80	8	5.16	91.61	1.7725	14.18	13.00
9	80	90	8	5.16	96.77	2.9243	23.39	21.44
10	90	100	4	2.58	99.35	4.5629	18.25	16.73
11	100	110	1	0.65	100.00	6.8093	6.81	6.24
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			155	100.00			109.10	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0	0.00	0.00	0.0000	0.00	0.00
2	20	40	0	0.00	0.00	0.0017	0.00	0.00
3	40	60	0	0.00	0.00	0.0130	0.00	0.00
4	60	80	57	36.77	36.77	0.0500	2.85	0.31
5	80	100	10	6.45	43.23	0.1367	1.37	0.15
6	100	120	4	2.58	45.81	0.3052	1.22	0.13
7	120	140	10	6.45	52.26	0.5953	5.95	0.66
8	140	160	14	9.03	61.29	1.0552	14.77	1.63
9	160	180	6	3.87	65.16	1.7408	10.44	1.15
10	180	200	16	10.32	75.48	2.7162	43.46	4.79
11	200	220	11	7.10	82.58	4.0535	44.59	4.92
12	220	240	4	2.58	85.16	5.8326	23.33	2.57
13	240	260	3	1.94	87.10	8.1417	24.42	2.69
14	260	280	1	0.65	87.74	11.0766	11.08	1.22
15	280	300	2	1.29	89.03	14.7416	29.48	3.25
16	300	320	0	0.00	89.03	19.2486	0.00	0.00
17	320	340	2	1.29	90.32	24.7177	49.44	5.45
18	340	360	6	3.87	94.19	31.2770	187.66	20.69
19	360	380	1	0.65	94.84	39.0625	39.06	4.31
20	380	400	5	3.23	98.06	48.2183	241.09	26.58
21	400	420	3	1.94	100.00	58.8964	176.69	19.48
22	420	440	0	0.00	100.00	71.2569	0.00	0.00
23	440	460	0	0.00	100.00	85.4679	0.00	0.00
24	460	480	0	0.00	100.00	101.7055	0.00	0.00
25	480	500	0	0.00	100.00	120.1538	0.00	0.00
26	500	520	0	0.00	100.00	141.0048	0.00	0.00
27	520	540	0	0.00	100.00	164.4586	0.00	0.00
28	540	560	0	0.00	100.00	190.7234	0.00	0.00
TOTAL			155	100.00			906.91	100.00

No. of Vehicles weighed =	155
No. of Axles weighed =	465
Total Damaging effect =	1016.02
Axle Equivalency =	2.18
Vehicle Damage Factor =	6.55

Both Directions

Single Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0	0.00	0.00	0.0000	0.00	0.00
2	10	20	0	0.00	0.00	0.0028	0.00	0.00
3	20	30	0	0.00	0.00	0.0219	0.00	0.00
4	30	40	9	2.71	2.71	0.0841	0.76	0.18
5	40	50	116	34.94	37.65	0.2297	26.65	6.41
6	50	60	55	16.57	54.22	0.5126	28.19	6.79
7	60	70	34	10.24	64.46	1.0000	34.00	8.18
8	70	80	52	15.66	80.12	1.7725	92.17	22.18
9	80	90	48	14.46	94.58	2.9243	140.37	33.78
10	90	100	13	3.92	98.49	4.5629	59.32	14.28
11	100	110	5	1.51	100.00	6.8093	34.05	8.19
12	110	120	0	0.00	100.00	9.7980	0.00	0.00
13	120	130	0	0.00	100.00	13.6769	0.00	0.00
Total			332	100.00			415.50	100.00

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.0000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.0017	0.00	0.00
3	40	60	0.00	0.00	0.00	0.0130	0.00	0.00
4	60	80	76.00	22.89	22.89	0.0500	3.80	0.08
5	80	100	14.00	4.22	27.11	0.1367	1.91	0.04
6	100	120	5.00	1.51	28.61	0.3052	1.53	0.03
7	120	140	15.00	4.52	33.13	0.5953	8.93	0.19
8	140	160	19.00	5.72	38.86	1.0552	20.05	0.44
9	160	180	11.00	3.31	42.17	1.7408	19.15	0.42
10	180	200	23.00	6.93	49.10	2.7162	62.47	1.36
11	200	220	20.00	6.02	55.12	4.0535	81.07	1.76
12	220	240	12.00	3.61	58.73	5.8326	69.99	1.52
13	240	260	12.00	3.61	62.35	8.1417	97.70	2.12
14	260	280	6.00	1.81	64.16	11.0766	66.46	1.44
15	280	300	9.00	2.71	66.87	14.7416	132.67	2.88
16	300	320	11.00	3.31	70.18	19.2486	211.73	4.60
17	320	340	14.00	4.22	74.40	24.7177	346.05	7.52
18	340	360	38.00	11.45	85.84	31.2770	1188.53	25.81
19	360	380	10.00	3.01	88.86	39.0625	390.63	8.48
20	380	400	26.00	7.83	96.69	48.2183	1253.67	27.23
21	400	420	11.00	3.31	100.00	58.8964	647.86	14.07
22	420	440	0.00	0.00	100.00	71.2569	0.00	0.00
23	440	460	0.00	0.00	100.00	85.4679	0.00	0.00
24	460	480	0.00	0.00	100.00	101.7055	0.00	0.00
25	480	500	0.00	0.00	100.00	120.1538	0.00	0.00
26	500	520	0.00	0.00	100.00	141.0048	0.00	0.00
27	520	540	0.00	0.00	100.00	164.4586	0.00	0.00
28	540	560	0.00	0.00	100.00	190.7234	0.00	0.00
TOTAL			332	100.00			4604.21	100.00

No. of Vehicles weighed =	332
No. of Axles weighed =	996
Total Damaging effect =	5019.71
Axle Equivalency =	5.04
Vehicle Damage Factor =	15.12

Location - KM 86+400

Sl. No.	Axle Load (KN)																								
	Rajasthan Border to Gurgaon													Gurgaon to Rajasthan Border											
									Engine		Trailer												Engine		Trailer		
	Axle Configuration	Front	Rear1	Rear2	Rear3	Rear4	Rear5	Front Single	Single	Tandem	Single	Tandem	Tridem	Axle Configuration	Front	Rear1	Rear2	Rear3	Rear4	Rear5	Front Single	Single	Tandem	Single	Tandem	Tridem
1	1-1-2	77.7	65.1	181.1	184.8	0.0	0.0	77.7	65.14	0.00	0.00	365.91	0.00	1-2-3	41.9	41.9	41.8	39.5	38.8	36.7	41.9	0.00	83.68	0.00	0.00	115.07
2	1-1-3	54.0	85.5	90.8	84.2	100.5	0.0	54.0	85.54	0.00	0.00	0.00	275.46	1-0-3	69.5	0.0	104.8	102.9	104.4	0.0	69.5	0.00	0.00	0.00	0.00	312.06
3	1-0-3	56.3	0.0	46.7	110.3	104.2	0.0	56.3	0.00	0.00	0.00	0.00	261.14	1-1-2	46.7	41.4	73.0	76.3	0.0	0.0	46.7	41.40	0.00	0.00	149.31	0.00
4	1-1-2	74.2	66.5	101.8	106.5	0.0	0.0	74.2	66.51	0.00	0.00	208.36	0.00	1-1-3	31.5	30.6	33.7	41.4	40.0	0.0	31.5	30.61	0.00	0.00	0.00	115.17
5	1-1-3	44.5	41.1	37.2	37.3	33.2	0.0	44.5	41.10	0.00	0.00	0.00	107.62	1-1-3	36.1	41.6	41.4	36.5	34.5	0.0	36.1	41.59	0.00	0.00	0.00	112.42
6	1-0-3	55.9	0.0	30.0	108.3	115.2	0.0	55.9	0.00	0.00	0.00	0.00	253.49	1-2-2	61.4	111.2	114.8	122.0	119.9	0.0	61.4	0.00	226.02	0.00	241.91	0.00
7	1-1-2	41.8	34.3	36.3	37.9	0.0	0.0	41.8	34.34	0.00	0.00	74.16	0.00	1-0-3	41.8	0.0	24.5	36.7	34.3	0.0	41.8	0.00	0.00	0.00	0.00	95.55
8	1-0-3	71.2	0.0	30.4	173.0	175.6	0.0	71.2	0.00	0.00	0.00	0.00	379.06	1-0-3	41.8	0.0	35.5	33.6	35.7	0.0	41.8	0.00	0.00	0.00	0.00	104.77
9	1-1-2	55.3	44.1	114.2	112.4	0.0	0.0	55.3	44.15	0.00	0.00	226.61	0.00	1-0-3	82.2	0.0	100.7	105.2	118.7	0.0	82.2	0.00	0.00	0.00	0.00	324.51
10	1-0-3	54.0	0.0	35.8	122.0	121.2	0.0	54.0	0.00	0.00	0.00	0.00	279.00	1-1-2	63.0	110.7	114.8	110.5	0.0	0.0	63.0	110.66	0.00	0.00	225.24	0.00
11	1-1-2	49.4	75.9	106.3	110.3	0.0	0.0	49.4	75.93	0.00	0.00	216.60	0.00	1-0-3	38.8	0.0	41.4	31.8	34.3	0.0	38.8	0.00	0.00	0.00	0.00	107.52
12	1-1-2	32.0	28.4	39.5	37.9	0.0	0.0	32.0	28.45	0.00	0.00	77.40	0.00	1-0-3	45.4	0.0	42.4	30.0	35.9	0.0	45.4	0.00	0.00	0.00	0.00	108.30
13	1-0-3	56.3	0.0	44.1	104.6	106.9	0.0	56.3	0.00	0.00	0.00	0.00	255.65	1-1-3	43.0	41.4	39.4	38.8	36.1	0.0	43.0	41.40	0.00	0.00	0.00	114.38
14	1-1-3	61.4	111.2	75.5	122.0	119.9	0.0	61.4	111.25	0.00	0.00	0.00	317.45	1-1-2	38.7	36.7	33.7	31.2	0.0	0.0	38.7	36.69	0.00	0.00	64.94	0.00
15	1-0-3	69.3	0.0	44.1	154.0	152.4	0.0	69.3	0.00	0.00	0.00	0.00	350.61	1-1-3	29.5	32.3	44.1	35.8	24.2	0.0	29.5	32.27	0.00	0.00	0.00	104.18
16	1-2-3	55.6	62.6	68.1	109.3	100.7	104.7	55.6	0.00	130.67	0.00	0.00	314.61	1-0-3	51.4	0.0	24.1	37.5	36.8	0.0	51.4	0.00	0.00	0.00	0.00	98.39
17	1-1-2	63.4	110.3	116.7	120.3	0.0	0.0	63.4	110.26	0.00	0.00	237.01	0.00	1-0-3	49.2	0.0	69.5	123.2	126.2	0.0	49.2	0.00	0.00	0.00	0.00	318.83
18	1-1-2	41.8	35.7	81.4	83.0	0.0	0.0	41.8	35.71	0.00	0.00	164.42	0.00	1-1-2	48.9	53.9	109.5	106.1	0.0	0.0	48.9	53.86	0.00	0.00	215.62	0.00
19	1-1-2	39.6	36.7	39.6	37.7	0.0	0.0	39.6	36.69	0.00	0.00	77.30	0.00	1-0-3	51.2	0.0	42.6	102.2	97.5	0.0	51.2	0.00	0.00	0.00	0.00	242.31
20	1-1-2	51.2	43.9	114.0	108.5	0.0	0.0	51.2	43.85	0.00	0.00	222.49	0.00	1-1-3	44.1	38.7	36.1	31.8	39.3	0.0	44.1	38.65	0.00	0.00	0.00	107.22
21	1-1-2	66.2	74.8	110.3	102.4	0.0	0.0	66.2	74.75	0.00	0.00	212.68	0.00	1-1-2	45.3	41.0	36.1	31.7	0.0	0.0	45.3	41.01	0.00	0.00	67.79	0.00
22	1-1-2	51.6	53.8	50.0	55.5	0.0	0.0	51.6	53.76	0.00	0.00	105.56	0.00	1-1-2	77.7	65.1	181.1	184.8	0.0	0.0	77.7	65.14	0.00	0.00	365.91	0.00
23	1-0-3	61.2	0.0	41.8	114.2	108.4	0.0	61.2	0.00	0.00	0.00	0.00	264.38	1-0-3	48.9	0.0	33.2	80.2	83.1	0.0	48.9	0.00	0.00	0.00	0.00	196.49
24	1-1-2	43.8	73.4	69.3	68.3	0.0	0.0	43.8	73.38	0.00	0.00	137.54	0.00	1-1-3	48.9	43.4	42.4	39.0	35.5	0.0	48.9	43.36	0.00	0.00	0.00	116.94
25	1-1-2	55.7	114.4	110.1	113.0	0.0	0.0	55.7	114.38	0.00	0.00	223.08	0.00	1-1-2	66.2	74.8	110.3	102.4	0.0	0.0	66.2	74.75	0.00	0.00	212.68	0.00
26	1-1-2	63.0	110.7	114.8	110.5	0.0	0.0	63.0	110.66	0.00	0.00	225.24	0.00	1-1-2	63.4	110.3	116.7	120.3	0.0	0.0	63.4	110.26	0.00	0.00	237.01	0.00
27	1-1-2	48.5	61.4	43.9	41.8	0.0	0.0	48.5	61.41	0.00	0.00	85.74	0.00	1-1-3	62.2	125.1	40.0	38.7	47.7	0.0	62.2	125.08	0.00	0.00	0.00	126.35
28	1-1-3	57.9	110.7	50.4	93.2	94.8	0.0	57.9	110.66	0.00	0.00	0.00	238.38	1-2-3	43.4	40.7	41.1	35.9	35.0	36.7	43.4	0.00	81.82	0.00	0.00	107.62
29	1-1-3	49.2	106.4	24.9	154.2	147.9	0.0	49.2	106.44	0.00	0.00	0.00	327.07	1-1-3	41.4	43.4	39.4	38.8	36.8	0.0	41.4	43.36	0.00	0.00	0.00	115.07
30														1-0-3	57.5	0.0	92.9	97.1	92.8	0.0	57.5	0.00	0.00	0.00	0.00	282.82
31														1-0-3	60.2	0.0	88.5	88.5	93.5	0.0	60.2	0.00	0.00	0.00	0.00	270.46
32														1-0-3	45.3	0.0	122.2	134.0	131.8	0.0	45.3	0.00	0.00	0.00	0.00	388.08
33														1-0-3	88.9	0.0	83.1	88.7	91.3	0.0	88.9	0.00	0.00	0.00	0.00	263.10
34														1-1-2	56.6	92.8	85.0	82.6	0.0	0.0	56.6	92.80	0.00	0.00	167.55	0.00
35														1-1-2	55.5	91.7	108.7	111.0	0.0	0.0	55.5	91.72	0.00	0.00	219.74	0.00
36														1-2-3	41.1	42.8	44.3	38.9	36.7	38.3	41.1	0.00	87.11	0.00	0.00	113.89
37														1-0-3	69.3	0.0	142.2	154.0	152.4	0.0	69.3	0.00	0.00	0.00	0.00	448.71
38														1-0-3	45.4	0.0	42.4	49.6	55.5	0.0	45.4	0.00	0.00	0.00	0.00	147.54

MULTI AXLE SUMMARY

Class of Vehicle : Multi Axle Truck
Rajasthan Border to Gurgaon

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0219	0.00	0.00
4	30	40	2.00	6.90	6.90	0.0841	0.17	0.90
5	40	50	7.00	24.14	31.03	0.2297	1.61	8.58
6	50	60	11.00	37.93	68.97	0.5126	5.64	30.10
7	60	70	6.00	20.69	89.66	1.0000	6.00	32.03
8	70	80	3.00	10.34	100.00	1.7725	5.32	28.39
9	80	90	0.00	0.00	100.00	2.9243	0.00	0.00
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
12	110	120	0.00	0.00	100.00	9.7980	0.00	0.00
13	120	130	0.00	0.00	100.00	13.6769	0.00	0.00
14	130	140	0.00	0.00	100.00	18.6072	0.00	0.00
15	140	150	0.00	0.00	100.00	24.7639	0.00	0.00
Total			29.00	100.00			18.73	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	1.00	4.76	4.76	0.0095	0.01	0.03
4	30	40	3.00	14.29	19.05	0.0366	0.11	0.37
5	40	50	3.00	14.29	33.33	0.1001	0.30	1.01
6	50	60	1.00	4.76	38.10	0.2234	0.22	0.75
7	60	70	3.00	14.29	52.38	0.4358	1.31	4.38
8	70	80	3.00	14.29	66.67	0.7725	2.32	7.76
9	80	90	1.00	4.76	71.43	1.2744	1.27	4.27
10	90	100	0.00	0.00	71.43	1.9885	0.00	0.00
11	100	110	1.00	4.76	76.19	2.9675	2.97	9.94
12	110	120	5.00	23.81	100.00	4.2700	21.35	71.50
13	120	130	0.00	0.00	100.00	5.9605	0.00	0.00
14	130	140	0.00	0.00	100.00	8.1091	0.00	0.00
15	140	150	0.00	0.00	100.00	10.7923	0.00	0.00
16	150	160	0.00	0.00	100.00	14.0918	0.00	0.00
17	160	170	0.00	0.00	100.00	18.0957	0.00	0.00
18	170	180	0.00	0.00	100.00	22.8977	0.00	0.00
Total			21.00	100.00			29.86	100.00

MULTI AXLE SUMMARY

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	3.00	17.65	17.65	0.050	0.15	0.18
5	80	100	1.00	5.88	23.53	0.137	0.14	0.16
6	100	120	1.00	5.88	29.41	0.305	0.31	0.36
7	120	140	2.00	11.76	41.18	0.595	1.19	1.42
8	140	160	0.00	0.00	41.18	1.055	0.00	0.00
9	160	180	1.00	5.88	47.06	1.741	1.74	2.07
10	180	200	0.00	0.00	47.06	2.716	0.00	0.00
11	200	220	3.00	17.65	64.71	4.054	12.16	14.49
12	220	240	5.00	29.41	94.12	5.833	29.16	34.76
13	240	260	0.00	0.00	94.12	8.142	0.00	0.00
14	260	280	0.00	0.00	94.12	11.077	0.00	0.00
15	280	300	0.00	0.00	94.12	14.742	0.00	0.00
16	300	320	0.00	0.00	94.12	19.249	0.00	0.00
17	320	340	0.00	0.00	94.12	24.718	0.00	0.00
18	340	360	0.00	0.00	94.12	31.277	0.00	0.00
19	360	380	1.00	5.88	100.00	39.063	39.06	46.55
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	440	460	0.00	0.00	100.00	85.468	0.00	0.00
24	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			17.00	100.00			83.91	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	1.00	7.69	7.69	0.048	0.05	0.13
5	120	150	0.00	0.00	7.69	0.132	0.00	0.00
6	150	180	0.00	0.00	7.69	0.294	0.00	0.00
7	180	210	0.00	0.00	7.69	0.574	0.00	0.00
8	210	240	1.00	7.69	15.38	1.018	1.02	2.66
9	240	270	4.00	30.77	46.15	1.679	6.72	17.57
10	270	300	2.00	15.38	61.54	2.621	5.24	13.71
11	300	330	3.00	23.08	84.62	3.911	11.73	30.68
12	330	360	1.00	7.69	92.31	5.627	5.63	14.72
13	360	390	1.00	7.69	100.00	7.855	7.85	20.54
14	390	420	0.00	0.00	100.00	10.686	0.00	0.00
15	420	450	0.00	0.00	100.00	14.222	0.00	0.00
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	92.31	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			13.00	100.00			38.24	100.00

No. of Vehicles weighed =	29
No. of Axles weighed =	123
Total Damaging effect =	170.74
Axle Equivalency =	1.39
Vehicle Damage Factor =	5.89

MULTI AXLE SUMMARY

Gurgaon to Rajasthan Border

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	1.00	2.63	2.63	0.0219	0.02	0.10
4	30	40	4.00	10.53	13.16	0.0841	0.34	1.50
5	40	50	17.00	44.74	57.89	0.2297	3.91	17.40
6	50	60	5.00	13.16	71.05	0.5126	2.56	11.42
7	60	70	8.00	21.05	92.11	1.0000	8.00	35.64
8	70	80	1.00	2.63	94.74	1.7725	1.77	7.90
9	80	90	2.00	5.26	100.00	2.9243	5.85	26.05
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
12	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
Total			38.00	100.00			22.45	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	0.00	0.00	0.00	0.0095	0.00	0.00
4	30	40	4.00	22.22	22.22	0.0366	0.15	0.71
5	40	50	6.00	33.33	55.56	0.1001	0.60	2.91
6	50	60	1.00	5.56	61.11	0.2234	0.22	1.08
7	60	70	1.00	5.56	66.67	0.4358	0.44	2.11
8	70	80	1.00	5.56	72.22	0.7725	0.77	3.74
9	80	90	0.00	0.00	72.22	1.2744	0.00	0.00
10	90	100	2.00	11.11	83.33	1.9885	3.98	19.25
11	100	110	0.00	0.00	83.33	2.9675	0.00	0.00
12	110	120	2.00	11.11	94.44	4.2700	8.54	41.34
13	120	130	1.00	5.56	100.00	5.9605	5.96	28.86
Total			18.00	100.00			20.66	100.00

MULTI AXLE SUMMARY

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	2.00	13.33	13.33	0.050	0.10	0.12
5	80	100	3.00	20.00	33.33	0.137	0.41	0.51
6	100	120	0.00	0.00	33.33	0.305	0.00	0.00
7	120	140	0.00	0.00	33.33	0.595	0.00	0.00
8	140	160	1.00	6.67	40.00	1.055	1.06	1.32
9	160	180	1.00	6.67	46.67	1.741	1.74	2.17
10	180	200	0.00	0.00	46.67	2.716	0.00	0.00
11	200	220	3.00	20.00	66.67	4.054	12.16	15.17
12	220	240	3.00	20.00	86.67	5.833	17.50	21.83
13	240	260	1.00	6.67	93.33	8.142	8.14	10.16
14	260	280	0.00	0.00	93.33	11.077	0.00	0.00
15	280	300	0.00	0.00	93.33	14.742	0.00	0.00
16	300	320	0.00	0.00	93.33	19.249	0.00	0.00
17	320	340	0.00	0.00	93.33	24.718	0.00	0.00
18	340	360	0.00	0.00	93.33	31.277	0.00	0.00
19	360	380	1.00	6.67	100.00	39.063	39.06	48.73
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	420	440	0.00	0.00	100.00	71.257	0.00	0.00
24	440	460	0.00	0.00	100.00	85.468	0.00	0.00
25	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			15.00	100.00			80.17	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	15.00	55.56	55.56	0.048	0.72	1.65
5	120	150	2.00	7.41	62.96	0.132	0.26	0.60
6	150	180	0.00	0.00	62.96	0.294	0.00	0.00
7	180	210	1.00	3.70	66.67	0.574	0.57	1.31
8	210	240	0.00	0.00	66.67	1.018	0.00	0.00
9	240	270	2.00	7.41	74.07	1.679	3.36	7.64
10	270	300	2.00	7.41	81.48	2.621	5.24	11.92
11	300	330	3.00	11.11	92.59	3.911	11.73	26.68
12	330	360	0.00	0.00	92.59	5.627	0.00	0.00
13	360	390	1.00	3.70	96.30	7.855	7.85	17.86
14	390	420	0.00	0.00	96.30	10.686	0.00	0.00
15	420	450	1.00	3.70	100.00	14.222	14.22	32.34
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	100.00	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			27.00	100.00			43.97	100.00

No. of Vehicles weighed =	38
No. of Axles weighed =	167
Total Damaging effect =	167.24
Axle Equivalency =	1.00
Vehicle Damage Factor =	4.40

MULTI AXLE SUMMARY

BOTH DIRECTION

Single Axle (FRONT)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0028	0.00	0.00
3	20	30	1.00	1.49	1.49	0.0219	0.02	0.05
4	30	40	6.00	8.96	10.45	0.0841	0.50	1.22
5	40	50	24.00	35.82	46.27	0.2297	5.51	13.39
6	50	60	16.00	23.88	70.15	0.5126	8.20	19.92
7	60	70	14.00	20.90	91.04	1.0000	14.00	34.00
8	70	80	4.00	5.97	97.01	1.7725	7.09	17.22
9	80	90	2.00	2.99	100.00	2.9243	5.85	14.20
10	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
11	90	100	0.00	0.00	100.00	4.5629	0.00	0.00
12	100	110	0.00	0.00	100.00	6.8093	0.00	0.00
Total			67	100.00			41.18	100.00

Single Axle (DUAL WHEEL)

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	10	0.00	0.00	0.00	0.0000	0.00	0.00
2	10	20	0.00	0.00	0.00	0.0012	0.00	0.00
3	20	30	1.00	2.56	2.56	0.0095	0.01	0.02
4	30	40	7.00	17.95	20.51	0.0366	0.26	0.51
5	40	50	9.00	23.08	43.59	0.1001	0.90	1.78
6	50	60	2.00	5.13	48.72	0.2234	0.45	0.88
7	60	70	4.00	10.26	58.97	0.4358	1.74	3.45
8	70	80	4.00	10.26	69.23	0.7725	3.09	6.12
9	80	90	1.00	2.56	71.79	1.2744	1.27	2.52
10	90	100	2.00	5.13	76.92	1.9885	3.98	7.87
11	100	110	1.00	2.56	79.49	2.9675	2.97	5.87
12	110	120	7.00	17.95	97.44	4.2700	29.89	59.17
13	120	130	1.00	2.56	100.00	5.9605	5.96	11.80
14	130	140	0.00	0.00	100.00	8.1091	0.00	0.00
15	140	150	0.00	0.00	100.00	10.7923	0.00	0.00
16	150	160	0.00	0.00	100.00	14.0918	0.00	0.00
17	160	170	0.00	0.00	100.00	18.0957	0.00	0.00
Total			39.00	100.00			50.52	100.00

MULTI AXLE SUMMARY

Tandem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	20	0.00	0.00	0.00	0.000	0.00	0.00
2	20	40	0.00	0.00	0.00	0.002	0.00	0.00
3	40	60	0.00	0.00	0.00	0.013	0.00	0.00
4	60	80	5.00	15.63	15.63	0.050	0.25	0.15
5	80	100	4.00	12.50	28.13	0.137	0.55	0.33
6	100	120	1.00	3.13	31.25	0.305	0.31	0.19
7	120	140	2.00	6.25	37.50	0.595	1.19	0.73
8	140	160	1.00	3.13	40.63	1.055	1.06	0.64
9	160	180	2.00	6.25	46.88	1.741	3.48	2.12
10	180	200	0.00	0.00	46.88	2.716	0.00	0.00
11	200	220	6.00	18.75	65.63	4.054	24.32	14.82
12	220	240	8.00	25.00	90.63	5.833	46.66	28.44
13	240	260	1.00	3.13	93.75	8.142	8.14	4.96
14	260	280	0.00	0.00	93.75	11.077	0.00	0.00
15	280	300	0.00	0.00	93.75	14.742	0.00	0.00
16	300	320	0.00	0.00	93.75	19.249	0.00	0.00
17	320	340	0.00	0.00	93.75	24.718	0.00	0.00
18	340	360	0.00	0.00	93.75	31.277	0.00	0.00
19	360	380	2.00	6.25	100.00	39.063	78.13	47.61
20	380	400	0.00	0.00	100.00	48.218	0.00	0.00
21	400	420	0.00	0.00	100.00	58.896	0.00	0.00
22	420	440	0.00	0.00	100.00	71.257	0.00	0.00
23	420	440	0.00	0.00	100.00	71.257	0.00	0.00
24	440	460	0.00	0.00	100.00	85.468	0.00	0.00
25	460	480	0.00	0.00	100.00	101.706	0.00	0.00
TOTAL			32.00	100.00			164.08	100.00

Tridem Axle

Sl. No.	Axle Load Category (Tonnes)		Number of Single Axles	% of Each Category	Cumulative %	Equivalency Factors	Equivalent Standard Axles	% of Damaging Effect
1	0	30	0.00	0.00	0.00	0.000	0.00	0.00
2	30	60	0.00	0.00	0.00	0.002	0.00	0.00
3	60	90	0.00	0.00	0.00	0.013	0.00	0.00
4	90	120	16.00	40.00	40.00	0.048	0.77	0.94
5	120	150	2.00	5.00	45.00	0.132	0.26	0.32
6	150	180	0.00	0.00	45.00	0.294	0.00	0.00
7	180	210	1.00	2.50	47.50	0.574	0.57	0.70
8	210	240	1.00	2.50	50.00	1.018	1.02	1.24
9	240	270	6.00	15.00	65.00	1.679	10.08	12.26
10	270	300	4.00	10.00	75.00	2.621	10.48	12.75
11	300	330	6.00	15.00	90.00	3.911	23.46	28.54
12	330	360	1.00	2.50	92.50	5.627	5.63	6.84
13	360	390	2.00	5.00	97.50	7.855	15.71	19.11
14	390	420	0.00	0.00	97.50	10.686	0.00	0.00
15	420	450	1.00	2.50	100.00	14.222	14.22	17.30
16	450	480	0.00	0.00	100.00	18.570	0.00	0.00
17	480	510	0.00	0.00	100.00	23.847	0.00	0.00
18	510	540	0.00	0.00	100.00	30.175	0.00	0.00
19	540	570	0.00	0.00	100.00	37.686	0.00	0.00
20	570	600	0.00	0.00	100.00	46.519	0.00	0.00
21	600	630	0.00	0.00	100.00	56.821	0.00	0.00
22	630	660	0.00	0.00	100.00	68.746	0.00	0.00
23	660	690	0.00	0.00	100.00	82.456	0.00	0.00
24	690	720	0.00	0.00	100.00	98.122	0.00	0.00
25	720	750	0.00	0.00	100.00	115.920	0.00	0.00
TOTAL			40.00	100.00			82.21	100.00

No. of Vehicles weighed =	67
No. of Axles weighed =	290.00
Total Damaging effect =	337.99
Axle Equivalency =	1.17
Vehicle Damage Factor =	5.04

VDF SUMMARY (Location - KM 86+400)

Vehicle Type	VDF Values		
	Rajasthan Border to Gurgaon	Gurgaon to Rajasthan Border	Both Direction
BUS	1.90	1.43	1.70
LCV	5.40	4.95	5.17
2 Axle	6.42	5.92	6.23
3 Axle	22.62	6.55	15.12
M Axle	5.89	4.40	5.04

BBD SURVEY ON NH-248A (Direction : Gurgaon- Rajasthan Border)

Section	Location	Identification Of lanes	Dial Gauge Reading			Pavement Temperature	Ct	MC (%)	MCF	(Df-Do)	(Di-Do)	Df-Do	Final diff. reading	D after correction	D Mean	Std dev	Cha. D	Calculated BM (mm)	BC	DBM
			Do	Di	Df															
7to 8 km	7.000	4 LANES	0	0.222	0.279	43.6	-0.086	6.7	1.43	0.279	0.22	0.057	0.446	0.51	0.48	0.215	0.91	74.54	40	50
	7.100	4 LANES	0	0.193	0.247	43.6	-0.086	6.7	1.43	0.247	0.19	0.054	0.422	0.48						
	7.200	4 LANES	0	0.246	0.278	43.6	-0.086	6.7	1.43	0.278	0.25	0.032	0.250	0.23						
	7.300	4 LANES	0	0.293	0.351	43.6	-0.086	6.7	1.43	0.351	0.29	0.058	0.454	0.53						
	7.400	4 LANES	0	0.341	0.438	43.6	-0.086	6.7	1.43	0.438	0.34	0.097	0.759	0.96						
	7.500	4 LANES	0	0.189	0.216	43.6	-0.086	6.7	1.43	0.216	0.19	0.027	0.211	0.18						
8 to 9 km	8.000	4 LANES	0	0.216	0.248	43.6	-0.086	6.7	1.43	0.248	0.22	0.032	0.250	0.23	0.41	0.201	0.81	47.29	40	0
	8.100	4 LANES	0	0.256	0.312	43.6	-0.086	6.7	1.43	0.312	0.26	0.056	0.438	0.50						
	8.200	4 LANES	0	0.248	0.309	43.6	-0.086	6.7	1.43	0.309	0.25	0.061	0.477	0.56						
	8.300	4 LANES	0	0.290	0.353	43.6	-0.086	6.7	1.43	0.353	0.29	0.063	0.493	0.58						
	8.400	4 LANES	0	0.196	0.225	43.6	-0.086	6.7	1.43	0.225	0.20	0.029	0.227	0.20						
	8.500	4 LANES	0	0.201	0.246	43.6	-0.086	6.7	1.43	0.246	0.20	0.045	0.352	0.38						
9 to 10 km	9.000	2 LANES	0	0.204	0.287	45.2	-0.102	6.7	1.43	0.287	0.20	0.083	0.649	0.78	0.43	0.281	0.99	96.34	40	50
	9.100	2 LANES	0	0.160	0.186	45.2	-0.102	6.7	1.43	0.186	0.16	0.026	0.203	0.14						
	9.200	2 LANES	0	0.141	0.186	45.2	-0.102	6.7	1.43	0.186	0.14	0.045	0.352	0.36						
	9.300	2 LANES	0	0.129	0.157	45.2	-0.102	6.7	1.43	0.157	0.13	0.028	0.219	0.17						
	9.400	2 LANES	0	0.141	0.217	45.2	-0.102	6.7	1.43	0.217	0.14	0.076	0.594	0.70						
	9.500	2 LANES	0	0.226	0.275	45.2	-0.102	6.7	1.43	0.275	0.23	0.049	0.383	0.40						
10 to 11 km	10.000	2 LANES	0	0.216	0.230	45.2	-0.102	6.7	1.43	0.23	0.22	0.014	0.028	-0.11	0.08	0.351	0.78	42.35	40	0
	10.100	2 LANES	0	0.183	0.210	45.2	-0.102	6.7	1.43	0.21	0.18	0.027	0.211	0.16						
	10.200	2 LANES	0	0.209	0.251	45.2	-0.102	6.7	1.43	0.251	0.21	0.042	0.328	0.32						
	10.300	2 LANES	0	0.197	0.216	45.2	-0.102	6.7	1.43	0.216	0.20	0.019	0.038	-0.09						
	10.400	2 LANES	0	0.210	0.227	45.2	-0.102	6.7	1.43	0.227	0.21	0.017	0.034	-0.10						
	10.500	2 LANES	0	0.180	0.217	45.2	-0.102	6.7	1.43	0.217	0.18	0.037	0.289	0.27						
11 to 12 km	11.000	4 LANES	0	0.242	0.348	44.2	-0.092	6.7	1.43	0.348	0.24	0.106	0.829	1.05	0.50	0.405	1.31	147.01	40	65
	11.100	4 LANES	0	0.172	0.186	44.2	-0.092	6.7	1.43	0.186	0.17	0.014	0.028	-0.09						
	11.200	4 LANES	0	0.192	0.229	44.2	-0.092	6.7	1.43	0.229	0.19	0.037	0.289	0.28						
	11.300	4 LANES	0	0.154	0.216	44.2	-0.092	6.7	1.43	0.216	0.15	0.062	0.485	0.56						
	11.400	4 LANES	0	0.266	0.361	44.2	-0.092	6.7	1.43	0.361	0.27	0.095	0.743	0.93						
	11.500	4 LANES	0	0.201	0.238	44.2	-0.092	6.7	1.43	0.238	0.20	0.037	0.289	0.28						
12 to 13 km	12.000	4 LANES	0	0.183	0.215	44.2	-0.092	6.7	1.43	0.215	0.18	0.032	0.250	0.23	0.07	0.156	0.39	0	40	0
	12.100	4 LANES	0	0.209	0.223	44.2	-0.092	6.7	1.43	0.223	0.21	0.014	0.028	-0.09						
	12.200	4 LANES	0	0.196	0.221	44.2	-0.092	6.7	1.43	0.221	0.20	0.025	0.050	-0.06						
	12.300	4 LANES	0	0.205	0.216	44.2	-0.092	6.7	1.43	0.216	0.21	0.011	0.022	-0.10						
	12.400	4 LANES	0	0.263	0.293	44.2	-0.092	6.7	1.43	0.293	0.26	0.030	0.235	0.20						
	12.500	4 LANES	0	0.216	0.252	44.2	-0.092	6.7	1.43	0.252	0.22	0.036	0.282	0.27						
13 to 14 km	13.000	2 LANES	0	0.183	0.227	46.3	-0.113	6.7	1.43	0.227	0.18	0.044	0.344	0.33	0.23	0.062	0.35	0	40	0
	13.100	2 LANES	0	0.216	0.252	46.3	-0.113	6.7	1.43	0.252	0.22	0.036	0.282	0.24						
	13.200	2 LANES	0	0.202	0.240	46.3	-0.113	6.7	1.43	0.24	0.20	0.038	0.297	0.26						
	13.300	2 LANES	0	0.197	0.226	46.3	-0.113	6.7	1.43	0.226	0.20	0.029	0.227	0.16						
	13.400	2 LANES	0	0.218	0.248	46.3	-0.113	6.7	1.43	0.248	0.22	0.030	0.235	0.17						
	13.500	2 LANES	0	0.269	0.301	46.3	-0.113	6.7	1.43	0.301	0.27	0.032	0.250	0.20						
14 to 15 km	14.000	2 LANES	0	0.225	0.270	46.3	-0.113	6.7	1.43	0.27	0.23	0.045	0.352	0.34	0.28	0.135	0.55	16.86	40	0
	14.100	2 LANES	0	0.241	0.279	46.3	-0.113	6.7	1.43	0.279	0.24	0.038	0.297	0.26						
	14.200	2 LANES	0	0.205	0.238	46.3	-0.113	6.7	1.43	0.238	0.21	0.033	0.258	0.21						
	14.300	2 LANES	0	0.258	0.301	46.3	-0.113	6.7	1.43	0.301	0.26	0.043	0.336	0.32						
	14.400	2 LANES	0	0.262	0.299	46.3	-0.113	6.7	1.43	0.299	0.26	0.037	0.289	0.25						
	14.500	2 LANES	0	0.250	0.290	46.3	-0.113	6.7	1.43	0.29	0.25	0.040	0.313	0.29						
15 to 16 km	15.000	4 LANES	0	0.293	0.329	48.1	-0.131	6.7	1.43	0.329	0.29	0.036	0.282	0.22	0.10	0.173	0.45	5.62	40	0
	15.100	4 LANES	0	0.309	0.328	48.1	-0.131	6.7	1.43	0.328	0.31	0.019	0.038	-0.13						
	15.200	4 LANES	0	0.158	0.206	48.1	-0.131	6.7	1.43	0.206	0.16	0.048	0.375	0.35						
	15.300	4 LANES	0	0.163	0.191	48.1	-0.131	6.7	1.43	0.191	0.16	0.028	0.219	0.13						
	15.400	4 LANES	0	0.290	0.305	48.1	-0.131	6.7	1.43	0.305	0.29	0.015	0.030	-0.14						
	15.500	4 LANES	0	0.223	0.258	48.1	-0.131	6.7	1.43	0.258	0.22	0.035	0.274	0.20						
16 to 17 km	16.000	4 LANES	0	0.208	0.226	48.1	-0.131	6.7	1.43	0.226	0.21	0.018	0.036	-0.14	0.02	0.203	0.43	3.37	40	0
	16.100	4 LANES	0	0.180	0.203	48.1	-0.131	6.7	1.43	0.203	0.18	0.023	0.046	-0.12						
	16.200	4 LANES	0	0.162	0.194	48.1	-0.131	6.7	1.43	0.194	0.16	0.032	0.250	0.17						
	16.300	4 LANES	0	0.184	0.212	48.1	-0.131	6.7	1.43	0.212	0.18	0.028	0.219	0.13						
	16.400	4 LANES	0	0.153	0.189	48.1	-0.131	6.7	1.43	0.189	0.15	0.036	0.282	0.22						
	16.500	4 LANES	0	0.206	0.226	48.1	-0.131	6.7	1.43	0.226	0.21	0.020	0.040	-0.13						

BBD SURVEY ON NH-248A (Direction : Gurgaon- Rajasthan Border)																			
Section	**Location**	**Identification Of lanes**	**Dial Gauge Reading**			**Pavement Temperature**	**Ct**	**MC (%)**	**MCF**	**(Df-Do)**	**(Di-Do)**	**Df-Do**	**Final diff. reading**	**D after correction**	**D Mean**	**Std dev**	**Cha. D**	**Calculated BM (mm)**	**BC**	**DBM**
			Do	**Di**	**Df**															
17 to 18 km	17.000	4 LANES	0	0.290	0.349	46.3	-0.113	6.7	1.43	0.349	0.29	0.059	0.461	0.50	0.05	0.221	0.49	10.11	40	0
	17.100	4 LANES	0	0.229	0.262	46.3	-0.113	6.7	1.43	0.262	0.23	0.033	0.258	0.21						
	17.200	4 LANES	0	0.261	0.279	46.3	-0.113	6.7	1.43	0.279	0.26	0.018	0.036	-0.11						
	17.300	4 LANES	0	0.187	0.212	46.3	-0.113	6.7	1.43	0.212	0.19	0.025	0.050	-0.09						
	17.400	4 LANES	0	0.208	0.228	46.3	-0.113	6.7	1.43	0.228	0.21	0.020	0.040	-0.10						
	17.500	4 LANES	0	0.301	0.326	46.3	-0.113	6.7	1.43	0.326	0.30	0.025	0.050	-0.09						
18 to 19 km	18.000	4 LANES	0	0.210	0.259	46.3	-0.113	6.7	1.43	0.259	0.21	0.049	0.383	0.39	0.09	0.186	0.46	6.74	40	0
	18.100	4 LANES	0	0.209	0.219	46.3	-0.113	6.7	1.43	0.219	0.21	0.010	0.020	-0.13						
	18.200	4 LANES	0	0.268	0.296	46.3	-0.113	6.7	1.43	0.296	0.27	0.028	0.219	0.15						
	18.300	4 LANES	0	0.211	0.236	46.3	-0.113	6.7	1.43	0.236	0.21	0.025	0.050	-0.09						
	18.400	4 LANES	0	0.270	0.312	46.3	-0.113	6.7	1.43	0.312	0.27	0.042	0.328	0.31						
	18.500	4 LANES	0	0.240	0.258	46.3	-0.113	6.7	1.43	0.258	0.24	0.018	0.036	-0.11						
19 to 20 km	19.000	4 LANES	0	0.230	0.254	43.5	-0.085	6.7	1.43	0.254	0.23	0.024	0.048	-0.05	0.14	0.159	0.46	6.74	40	0
	19.100	4 LANES	0	0.149	0.183	43.5	-0.085	6.7	1.43	0.183	0.15	0.034	0.266	0.26						
	19.200	4 LANES	0	0.202	0.236	43.5	-0.085	6.7	1.43	0.236	0.20	0.034	0.266	0.26						
	19.300	4 LANES	0	0.372	0.402	43.5	-0.085	6.7	1.43	0.402	0.37	0.030	0.235	0.21						
	19.400	4 LANES	0	0.165	0.196	43.5	-0.085	6.7	1.43	0.196	0.17	0.031	0.242	0.23						
	19.500	4 LANES	0	0.208	0.229	43.5	-0.085	6.7	1.43	0.229	0.21	0.021	0.042	-0.06						
20to 21 km	20.000	4 LANES	0	0.218	0.227	43.5	-0.085	6.7	1.43	0.227	0.22	0.009	0.018	-0.10	0.16	0.174	0.51	12.36	40	0
	20.100	4 LANES	0	0.202	0.239	43.5	-0.085	6.7	1.43	0.239	0.20	0.037	0.289	0.29						
	20.200	4 LANES	0	0.197	0.240	43.5	-0.085	6.7	1.43	0.24	0.20	0.043	0.336	0.36						
	20.300	4 LANES	0	0.214	0.248	43.5	-0.085	6.7	1.43	0.248	0.21	0.034	0.266	0.26						
	20.400	4 LANES	0	0.183	0.205	43.5	-0.085	6.7	1.43	0.205	0.18	0.022	0.044	-0.06						
	20.500	4 LANES	0	0.169	0.200	43.5	-0.085	6.7	1.43	0.2	0.17	0.031	0.242	0.23						
21 to 22 km	21.000	4 LANES	0	0.254	0.269	42.1	-0.071	6.7	1.43	0.269	0.25	0.015	0.030	-0.06	-0.06	0.100	0.14	0	40	0
	21.100	4 LANES	0	0.261	0.278	42.1	-0.071	6.7	1.43	0.278	0.26	0.017	0.034	-0.05						
	21.200	4 LANES	0	0.289	0.299	42.1	-0.071	6.7	1.43	0.299	0.29	0.010	0.020	-0.07						
	21.300	4 LANES	0	0.303	0.321	42.1	-0.071	6.7	1.43	0.321	0.30	0.018	0.036	-0.05						
	21.400	4 LANES	0	0.231	0.254	42.1	-0.071	6.7	1.43	0.254	0.23	0.023	0.046	-0.04						
	21.500	4 LANES	0	0.188	0.199	42.1	-0.071	6.7	1.43	0.199	0.19	0.011	0.022	-0.07						

BBD SURVEY ON NH-248A (Direction : Rajasthan Border-Gurgaon)

Section	Location of test Point(Ch.)	Identification of lanes	Dial Gauge Reading			Pavement Temperature	Ct	MC (%)	MCF	(Df-Do)	(Di-Do)	Df-Do	Final diff. reading	D after correction	D Mean	Std dev	Characteristic Deflection (mm)	Calculated BM (mm)	BC (mm)	DBM (mm)
			Do	Di	Df															
7to 8 km	7.500	4 LANES	0	0.241	0.282	35.1	-0.001	6.7	1.43	0.282	0.24	0.041	0.321	0.46	0.29	0.182	0.65	96.09	50	50
	7.600	4 LANES	0	0.296	0.321	35.1	-0.001	6.7	1.43	0.321	0.30	0.025	0.050	0.07						
	7.700	4 LANES	0	0.233	0.258	35.1	-0.001	6.7	1.43	0.258	0.23	0.025	0.050	0.07						
	7.800	4 LANES	0	0.244	0.270	35.1	-0.001	6.7	1.43	0.27	0.24	0.026	0.203	0.29						
	7.900	4 LANES	0	0.198	0.227	35.1	-0.001	6.7	1.43	0.227	0.20	0.029	0.227	0.32						
	8.000	4 LANES	0	0.201	0.246	35.1	-0.001	6.7	1.43	0.246	0.20	0.045	0.352	0.50						
8 to 9 km	8.500	4 LANES	0	0.280	0.305	36.6	-0.016	6.7	1.43	0.305	0.28	0.025	0.050	0.05	0.15	0.154	0.46	23.14	50	0
	8.600	4 LANES	0	0.319	0.344	36.6	-0.016	6.7	1.43	0.344	0.32	0.025	0.050	0.05						
	8.700	4 LANES	0	0.214	0.254	36.6	-0.016	6.7	1.43	0.254	0.21	0.040	0.313	0.42						
	8.800	4 LANES	0	0.254	0.273	36.6	-0.016	6.7	1.43	0.273	0.25	0.019	0.038	0.03						
	8.900	4 LANES	0	0.216	0.249	36.6	-0.016	6.7	1.43	0.249	0.22	0.033	0.258	0.35						
	9.000	4 LANES	0	0.287	0.302	36.6	-0.016	6.7	1.43	0.302	0.29	0.015	0.030	0.02						
9 to 10 km	9.500	2 LANES	0	0.291	0.322	36.6	-0.016	6.7	1.43	0.322	0.29	0.031	0.242	0.32	0.17	0.131	0.44	15.43	50	0
	9.600	2 LANES	0	0.276	0.302	36.6	-0.016	6.7	1.43	0.302	0.28	0.026	0.203	0.27						
	9.700	2 LANES	0	0.256	0.272	36.6	-0.016	6.7	1.43	0.272	0.26	0.016	0.032	0.02						
	9.800	2 LANES	0	0.215	0.239	36.6	-0.016	6.7	1.43	0.239	0.22	0.024	0.048	0.05						
	9.900	2 LANES	0	0.246	0.278	36.6	-0.016	6.7	1.43	0.278	0.25	0.032	0.250	0.33						
	10.000	2 LANES	0	0.189	0.213	36.6	-0.016	6.7	1.43	0.213	0.19	0.024	0.048	0.05						
10 to 11 km	10.500	2 LANES	0	0.223	0.241	38.2	-0.032	6.7	1.43	0.241	0.22	0.018	0.036	0.01	0.14	0.186	0.51	42.43	50	0
	10.600	2 LANES	0	0.189	0.215	38.2	-0.032	6.7	1.43	0.215	0.19	0.026	0.203	0.24						
	10.700	2 LANES	0	0.211	0.238	38.2	-0.032	6.7	1.43	0.238	0.21	0.027	0.211	0.26						
	10.800	2 LANES	0	0.207	0.232	38.2	-0.032	6.7	1.43	0.232	0.21	0.025	0.050	0.03						
	10.900	2 LANES	0	0.236	0.259	38.2	-0.032	6.7	1.43	0.259	0.24	0.023	0.046	0.02						
	11.000	2 LANES	0	0.243	0.272	38.2	-0.032	6.7	1.43	0.272	0.24	0.029	0.227	0.28						
11 to 12 km	11.500	4 LANES	0	0.216	0.241	38.2	-0.032	6.7	1.43	0.241	0.22	0.025	0.050	0.03	0.21	0.210	0.63	88.51	50	50
	11.600	4 LANES	0	0.219	0.232	38.2	-0.032	6.7	1.43	0.232	0.22	0.013	0.026	-0.01						
	11.700	4 LANES	0	0.196	0.237	38.2	-0.032	6.7	1.43	0.237	0.20	0.041	0.321	0.41						
	11.800	4 LANES	0	0.210	0.263	38.2	-0.032	6.7	1.43	0.263	0.21	0.053	0.414	0.55						
	11.900	4 LANES	0	0.256	0.281	38.2	-0.032	6.7	1.43	0.281	0.26	0.025	0.050	0.03						
	12.000	4 LANES	0	0.183	0.209	38.2	-0.032	6.7	1.43	0.209	0.18	0.026	0.203	0.24						
12 to 13 km	13.000	4 LANES	0	0.236	0.268	37.2	-0.022	6.7	1.43	0.268	0.24	0.032	0.250	0.33	0.25	0.225	0.70	115.04	50	50
	13.500	4 LANES	0	0.256	0.302	37.2	-0.022	6.7	1.43	0.302	0.26	0.046	0.360	0.48						
	13.500	4 LANES	0	0.204	0.226	37.2	-0.022	6.7	1.43	0.226	0.20	0.022	0.044	0.03						
	13.600	4 LANES	0	0.123	0.129	37.2	-0.022	6.7	1.43	0.129	0.12	0.006	0.012	-0.01						
	13.600	4 LANES	0	0.215	0.248	37.2	-0.022	6.7	1.43	0.248	0.22	0.033	0.258	0.34						
	13.700	4 LANES	0	0.221	0.252	37.2	-0.022	6.7	1.43	0.252	0.22	0.031	0.242	0.32						
13 to 14 km	13.700	2 LANES	0	0.214	0.239	37.2	-0.022	6.7	1.43	0.239	0.21	0.025	0.050	0.04	0.28	0.203	0.69	111.25	50	50
	13.800	2 LANES	0	0.199	0.219	37.2	-0.022	6.7	1.43	0.219	0.20	0.020	0.040	0.03						
	13.800	2 LANES	0	0.243	0.272	37.2	-0.022	6.7	1.43	0.272	0.24	0.029	0.227	0.29						
	13.900	2 LANES	0	0.233	0.300	37.2	-0.022	6.7	1.43	0.3	0.23	0.067	0.524	0.72						
	13.900	2 LANES	0	0.291	0.322	37.2	-0.022	6.7	1.43	0.322	0.29	0.031	0.242	0.32						
	14.000	2 LANES	0	0.226	0.254	37.2	-0.022	6.7	1.43	0.254	0.23	0.028	0.219	0.28						
14 to 15 km	14.500	2 LANES	0	0.296	0.314	41.9	-0.069	6.7	1.43	0.314	0.30	0.018	0.036	-0.05	0.09	0.148	0.38	0	50	0
	14.600	2 LANES	0	0.263	0.289	41.9	-0.069	6.7	1.43	0.289	0.26	0.026	0.203	0.19						
	14.700	2 LANES	0	0.221	0.256	41.9	-0.069	6.7	1.43	0.256	0.22	0.035	0.274	0.29						
	14.800	2 LANES	0	0.248	0.274	41.9	-0.069	6.7	1.43	0.274	0.25	0.026	0.203	0.19						
	14.900	2 LANES	0	0.256	0.278	41.9	-0.069	6.7	1.43	0.278	0.26	0.022	0.044	-0.04						
	15.000	2 LANES	0	0.209	0.217	41.9	-0.069	6.7	1.43	0.217	0.21	0.008	0.016	-0.08						
15 to 16 km	15.500	4 LANES	0	0.252	0.284	41.9	-0.069	6.7	1.43	0.284	0.25	0.032	0.250	0.26	0.21	0.153	0.51	42.43	50	0
	15.600	4 LANES	0	0.243	0.282	41.9	-0.069	6.7	1.43	0.282	0.24	0.039	0.305	0.34						
	15.700	4 LANES	0	0.286	0.319	41.9	-0.069	6.7	1.43	0.319	0.29	0.033	0.258	0.27						
	15.800	4 LANES	0	0.320	0.351	41.9	-0.069	6.7	1.43	0.351	0.32	0.031	0.242	0.25						
	15.900	4 LANES	0	0.254	0.260	41.9	-0.069	6.7	1.43	0.26	0.25	0.006	0.012	-0.08						
	16.000	4 LANES	0	0.216	0.243	41.9	-0.069	6.7	1.43	0.243	0.22	0.027	0.211	0.20						
16 to 17 km	16.500	4 LANES	0	0.217	0.236	40.8	-0.058	6.7	1.43	0.236	0.22	0.019	0.038	-0.03	0.01	0.108	0.23	0	50	0
	16.600	4 LANES	0	0.179	0.200	40.8	-0.058	6.7	1.43	0.2	0.18	0.021	0.042	-0.02						
	16.700	4 LANES	0	0.298	0.320	40.8	-0.058	6.7	1.43	0.32	0.30	0.022	0.044	-0.02						
	16.800	4 LANES	0	0.260	0.283	40.8	-0.058	6.7	1.43	0.283	0.26	0.023	0.046	-0.02						
	16.900	4 LANES	0	0.253	0.271	40.8	-0.058	6.7	1.43	0.271	0.25	0.018	0.036	-0.03						
	17.000	4 LANES	0	0.276	0.302	40.8	-0.058	6.7	1.43	0.302	0.28	0.026	0.203	0.21						

BBD SURVEY ON NH-248A (Direction : Rajasthan Border-Gurgaon)																			
Section	Location of test Point(Ch.)	Identification of lanes	Dial Gauge Reading			Pavement Temperature	Ct	MC (%)	MCF	(Df-Do)	(Di-Do)	Df-Do	Final diff. reading	D after correction	D Mean	Std dev	Characteristic Deflection (mm)	Calculated BM (mm)	BC (mm)	DBM (mm)
			Do	Di	Df															
17 to 18 km	17.500	4 LANES	0	0.271	0.296	40.8	-0.058	6.7	1.43	0.296	0.27	0.025	0.050	-0.01	0.05	0.087	0.23	0	50	0
	17.600	4 LANES	0	0.263	0.289	40.8	-0.058	6.7	1.43	0.289	0.26	0.026	0.203	0.21						
	17.700	4 LANES	0	0.298	0.325	40.8	-0.058	6.7	1.43	0.325	0.30	0.027	0.211	0.22						
	17.800	4 LANES	0	0.227	0.244	40.8	-0.058	6.7	1.43	0.244	0.23	0.017	0.034	-0.03						
	17.900	4 LANES	0	0.258	0.279	40.8	-0.058	6.7	1.43	0.279	0.26	0.021	0.042	-0.02						
	18.000	4 LANES	0	0.222	0.241	40.8	-0.058	6.7	1.43	0.241	0.22	0.019	0.038	-0.03						
18 to 19 km	18.500	4 LANES	0	0.216	0.239	35.2	-0.002	6.7	1.43	0.239	0.22	0.023	0.046	0.06	0.17	0.176	0.52	46.28	50	0
	18.600	4 LANES	0	0.256	0.281	35.2	-0.002	6.7	1.43	0.281	0.26	0.025	0.050	0.07						
	18.700	4 LANES	0	0.224	0.249	35.2	-0.002	6.7	1.43	0.249	0.22	0.025	0.050	0.07						
	18.800	4 LANES	0	0.188	0.202	35.2	-0.002	6.7	1.43	0.202	0.19	0.014	0.028	0.04						
	18.900	4 LANES	0	0.209	0.248	35.2	-0.002	6.7	1.43	0.248	0.21	0.039	0.305	0.43						
	19.000	4 LANES	0	0.219	0.251	35.2	-0.002	6.7	1.43	0.251	0.22	0.032	0.250	0.35						
19 to 20 km	19.500	4 LANES	0	0.228	0.253	35.2	-0.002	6.7	1.43	0.253	0.23	0.025	0.050	0.07	0.46	0.264	0.99	190.86	50	85
	19.600	4 LANES	0	0.294	0.336	35.2	-0.002	6.7	1.43	0.336	0.29	0.042	0.328	0.47						
	19.700	4 LANES	0	0.217	0.248	35.2	-0.002	6.7	1.43	0.248	0.22	0.031	0.242	0.34						
	19.800	4 LANES	0	0.168	0.207	35.2	-0.002	6.7	1.43	0.207	0.17	0.039	0.305	0.43						
	19.900	4 LANES	0	0.249	0.333	35.2	-0.002	6.7	1.43	0.333	0.25	0.084	0.657	0.94						
	20.000	4 LANES	0	0.215	0.263	35.2	-0.002	6.7	1.43	0.263	0.22	0.048	0.375	0.53						
20to 21 km	20.500	4 LANES	0	0.281	0.302	33.7	0.013	6.7	1.43	0.302	0.28	0.021	0.042	0.08	0.13	0.123	0.38	0	50	0
	20.600	4 LANES	0	0.205	0.236	33.7	0.013	6.7	1.43	0.236	0.21	0.031	0.242	0.37						
	20.700	4 LANES	0	0.217	0.240	33.7	0.013	6.7	1.43	0.24	0.22	0.023	0.046	0.08						
	20.800	4 LANES	0	0.227	0.246	33.7	0.013	6.7	1.43	0.246	0.23	0.019	0.038	0.07						
	20.900	4 LANES	0	0.193	0.218	33.7	0.013	6.7	1.43	0.218	0.19	0.025	0.050	0.09						
	21.000	4 LANES	0	0.196	0.221	33.7	0.013	6.7	1.43	0.221	0.20	0.025	0.050	0.09						
21 to 22 km	21.500	4 LANES	0	0.163	0.184	33.7	0.013	6.7	1.43	0.184	0.16	0.021	0.042	0.08	0.26	0.176	0.62	84.72	50	50
	21.600	4 LANES	0	0.158	0.172	33.7	0.013	6.7	1.43	0.172	0.16	0.014	0.028	0.06						
	21.700	4 LANES	0	0.148	0.163	33.7	0.013	6.7	1.43	0.163	0.15	0.015	0.030	0.06						
	21.800	4 LANES	0	0.209	0.243	33.7	0.013	6.7	1.43	0.243	0.21	0.034	0.266	0.40						
	21.900	4 LANES	0	0.124	0.161	33.7	0.013	6.7	1.43	0.161	0.12	0.037	0.289	0.43						
	22.000	4 LANES	0	0.168	0.216	33.7	0.013	6.7	1.43	0.216	0.17	0.048	0.375	0.56						

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CHAPTER 7: DESIGN STANDARDS

7.1 GENERAL

The formulation of the design standards is required in order to avoid any inconsistency in design from one section to the other and provide desired level of service and safety. For this project it is proposed to follow Design Standards given in IRC codes, guidelines and special publications, and MORTH circulars as applicable to National Highways. Where the said standards are silent the following standards has been referenced and the one considered the best and most relevant adopted:

American Association of State Highway and Transport Officials (AASHTO) standards

British Standards

Any other National or International Standard as considered suitable

The standards have been framed based on 6-Laning Manual i.e. IRC: SP-87.

7.2 ITEMS DETAILED FOR DESIGN STANDARDS

The design standards of all the elements of a highway corridor can be grouped into the following categories as given in **Table 7.1.**

Table 7.1: Categorization of elements for design standards

Category	Design element
Design Capacity	Design service volume standards Design capacity standards
Geometric Design	Cross-sectional elements Sight distance Horizontal curves Vertical curves
Pavement Design	CBR, Traffic, Structural Strength
Grade Separators and Cross Drainage Structures	Underpasses Flyover / ROBs Bridges and Culverts
Intersections and Interchanges.	At grade intersections Grade separated intersections Acceleration and deceleration lanes
Slope protection	Side slopes Slope protection
Drainage system	Longitudinal, cross drainage
Safety Measures	Guard rails & safety barriers Traffic signals Road signage & pavement markings Footpaths and sidewalks

Category	Design element
Highway Landscaping	
Toll Plaza Complex	
Road Furniture	
Truck Lay bys, Truck Parking	
Bus Stops and Bus Bays	

7.3 CAPACITY STANDARDS

The main reference for the determination of standard capacities for roads in India is the Indian Road Congress code (IRC: 64). Table 7.2 summarizes the capacity standards and design service volumes for various categories of roads in flat terrain for the peak hour traffic in the range of 8-10% of design service level corresponding to a Level of Service (LoS) B with the curvature of the road being low (0-50 degrees per Km).

Table 7.2: Design service volumes & capacity standards for various road categories

Type	Design Service Volume
	PCU/day
2-Lane with paved shoulder	18000
4-Lane (dual carriageway)	40,000

7.4 GEOMETRIC DESIGN STANDARDS

7.4.1 Design Standards

Design Standards for major features have been extracted from IRC: SP: 87 standards conforming to design speeds 100 Kmph and 80 Kmph for plain terrain given in **Table 7.3.**

Table 7.3: Geometric Design Standards for the Project Corridor

Sl. No.	Description	Standards For 6-Lane
1.	Design speed *Rural Section* *Built-up Section*	 100kmph /(80Kmh)* 80kmph /(65Kmh)*
2.	Proposed ROW *Existing road section*	60m restricted to 50 m in some identified stretch
3.	Roadway *i. Lane width* *ii. Paved shoulder on outer side* *Width in Rural Section* *Width in Built-up Section* *iii. Earthen shoulder width on outer side in rural section* *iv. Cross slope in lanes and paved shoulders* *v. Cross slope in Cement Concrete Surfacing* *vi. Cross slope in earthen shoulders*	 3.5m 1.5m 2.0 m 2.0 m 2.5% 2.0% 3.0%

Sl. No.	Description	Standards For 6-Lane
4.	Edge strip kerb shyness *Median side (In Urban / Built-up Area)*	0.5m
5.	Side walk	2.0m
6.	Utility Corridor	2.0 m
7.	Sight distance *i. Desirable Minimum (100kmph/80kmph)* ii. *Safe Stopping Distance*	360m / 260m 180m / 130m
8.	Horizontal curvature *(for 100kmph/80kmph)* *i. Requiring no super elevation* *ii. Absolute minimum for 80 kmph*	1800m / 1100 m 400m / 255 m
9.	Maximum Super elevation	5 %
10.	Rate of change of super elevation	1 in 150
11.	Vertical Alignment Minimum distance between PVI	150 m
12.	Gradient: Ruling and Limiting	3.33% & 5.0%
13.	Minimum length of vertical curve	50 m
14.	Maximum grade change not requiring vertical curve	0.5%
15.	Vertical clearance to road bridge over road	5.0 m (in rural section) 5.5m (in urban section)
16.	Embankment slope In normal section In pitching proposed sections In high embankment (>3m)	 2H: 1V 1.5H: 1V 3.0H: 1V

( )* Absolute Minimum`

The project corridor is proposed to be improved as per the improvement proposals detailed in Chapter 8 and following the standards as specified here. The proposed centerline has been designed with an objective to maximize the usage of existing pavement, better traffic management during construction and better compaction of the widened embankment. Besides, all geometric improvement has been proposed considering the availability of ROW.

7.4.2 Vertical Profile

The Vertical Profile of the project corridor has been finalized on the basis of DTM data collected during the topographic survey. In addition to the standards and guidelines set in this chapter, there are other considerations to finalize the vertical profiles, which are presented below:

Minimum distance between two PVIs (Point of Vertical Intersection) is 150m

Minimum longitudinal gradient is 0.5%, for longitudinal drainage for Kerbed Pavements

Minimum length of a vertical curve is 50m.

Maximum gradient for Underpass approaches is 2.5 %.

Minimum K (rate of change of vertical curvature) value, corresponding to intermediate sight distance (ISD), has been considered as 135 for the summit curve and 45 for valley curve.

7.4.3 Typical Cross-sections

The proposed cross sections for Package-II are presented in **Chapter 8: Development Proposal.**

7.4.4 Super Elevation

Super Elevation has been designed on the basis of provisions of IRC-73. Type of surface (Flexible or Rigid Pavement) has been taken into consideration while computing the component of side friction for the development of super elevation values. Considering the movement of slow moving vehicles, maximum super elevation has been restricted to 5%.

7.4.5 Transition Curves

IRC geometric design standards for rural highways, IRC:73 suggests that the length of the transition curve should be the larger of the two values arrived at on the basis of the following criteria:

i) Rate of change of centrifugal acceleration and

ii) Rate of change of super elevation (not steeper than 1 in 150)

7.5 STANDARDS FOR PAVEMENT DESIGN

7.5.1 Flexible Pavement

Designs for new pavement and overlays has been dealt in accordance with Indian and international practice. The Preliminary Designs are carried out on the basis of sub-grade 4 day soaked CBR at 97% MDD. Flexible pavement for new carriageways has been designed in accordance with the guidelines of IRC: 37. Stage construction shall not be permitted. The structural coefficients of various layers has been suitably modified to suit the Indian conditions. The resulting pavement compositions from both the methods along with suggested future overlays have been compared based on their performance as reflected in life cycle cost analysis.

The new flexible pavement structure shall comprise of Bituminous Concrete (BC) wearing coarse on bituminous base course of Dense Bituminous Macadam (DBM) and Bituminous Course. Below the bituminous layers, a Granular flexible base with well-graded aggregates in the form of Wet Mix Macadam (WMM) base has been laid on top of GSB layer. Flexible pavement proposed on rigid based shall be a five layer structure comprising BC, DBM, Aggregate Interlayer, Cement Treated Base (CTB), Cement Treated Sub-base (CTSB) and subgrade. All these layers shall be constructed to the requirements of MORT&H specifications. The drainage layer, which is a part of the Granular Sub Base (GSB) layer, has been provided extending over the full width of formation to the embankment slope, which will also act as drainage layer both for surface and capillary water that would affect the structural performance of the pavement.

New rigid pavement, for the proposed 6-lane carriageway, as per requirement, has been proposed to be plain-jointed type. Plain-jointed pavement has been designed in accordance with the

method prescribed in IRC: 58, "Guidelines for the Design of Plain Jointed Rigid Pavements for Highways".

The initial design of overlays on the existing carriageway has been carried out in accordance with IRC: 81 using BBD deflections. The requirement of future overlays has been linked to the pavement condition as reflected by pavement roughness and the composition and timings has been based on economic analysis.

Paved shoulder is required to be integrated with that of the carriageway pavement. Thus requires the thickness of pavement structure to be the same thickness as that for the traffic lanes since the lower layer of the sub-base for the carriageway is extended to the full width of formation for the lateral drainage of any water percolating into the pavement.

7.6 GRADE SEPARATORS AND CROSS DRAINAGE STRUCTURES

7.6.1 Grade separators

In order to avoid incidence of major reconstruction work in the future which may result in traffic disturbances, the underpasses that carry pedestrian walkways, cart tracks, village, district and other roads, State and National highways, cross drainage, combined cross drainage cum road has been designed taking into account of the future long term developments in the vicinity of the Project Road. Design has been carried out as per MORTH circulars and relevant IRC codes.

7.6.2 Drainage structures

Drainage structures basically comprise of Major Bridges, Minor Bridges and Culverts. The standards / specifications for classifying these are given as:

Major Bridge

Bridges having an overall length more than 60 m.

Minor Bridge

Bridges having length varying between 6 to 60 meters are termed as minor bridges.

7.7 SLOPE PROTECTION

7.7.1 Side Slopes

As per IRC: SP-87. The foregoing slopes require an appreciable width of land. It is therefore felt that the side slopes of 1V:2H and 1V:3H are enough for embankments height up to 3m and higher than 3m respectively.

7.7.2 Slope Protection

While embankments less than 3m have been turfed, stone pitching is proposed for embankment having height more than 3 meters.

7.8 INTERSECTIONS AND INTERCHANGES

At grade intersections adversely influence the quality of highways in terms of speed, capacity and safety because of interruptions to the flow of traffic. Thus the basic requirement for the design of

intersections is not only to cater for safe movements for the drivers, but also to provide them full traffic information by way of signs, pavement markings and traffic signals. Further, simplicity and uniformity should be the guiding principles for intersection design to ensure the safe passage of manoeuvres and reduce conflict points, either by elimination of certain manoeuvres or separated in space, horizontally or vertically or time. Based upon these principles, at-grade intersections have been categorized as Minor/Canalized (with or without acceleration and deceleration lanes)/Staggered/Rotaries/Signalized intersections depending upon the following parameters.

- Traffic volume and number of lanes on the project road;
- Traffic volume and number of lanes on the cross road;
- Turning traffic volumes;
- Type and category of cross road;
- Site conditions / constraints; and
- Any local importance

7.8.1 At Grade Intersections

At-grade intersections have been designed according to IRC Special Publication 41 'Guidelines for the Design of At-grade Intersections in Rural and Urban Areas' and the MORTH Type Designs for Intersections on National Highways.

7.8.2 Grade Separated Intersections

IRC: 92 give guidelines for the design of interchanges and has been followed. However an interchange is a highly developed feature and may require the use of other international standards such as these given in the AASHTO's publication 'A Policy on Geometric Design of Highways and Streets'.

7.9 DRAINAGE SYSTEM

An effective surface and sub-surface drainage system of pavement structure has been designed as stipulated in IRC SP: 42. The drainage system has been planned and designed for the drainage of medians, toll plazas, wayside amenities, truck parking areas, bus-bays and other highway features ensuring that there has been no pooling of water at any time on the highway.

Table 7.4: Recommended slopes in various elements for proper surface drainage

Element	Recommended Slope
Lanes and paved shoulders with Bituminous Concrete Surfacing	2.5%
Lanes and paved shoulders with Cement Concrete Surfacing	2%
Cross slope in earthen shoulders	3.5%

7.10 SAFETY MEASURES

Safety measures are the most important aspects to be considered in Highway Projects in the present scenario. The elements these safety measures would take into consideration and their specifications are given as follows:

7.10.1 Pedestrian Guard Rails and Safety Barriers

The Safety Barrier shall conform to MORTH Circulars. Safety barriers have been located at sharp horizontal curves, high embankments, bridge approaches.

7.10.2 Highway Signs

The design and location of route marker signs for National Highways has been as per IRC: 2. IRC: 67 is also to be referred.

The design and placement of Highway kilometer stones, their dimensions, size, colour and arrangement of letters has been in accordance with IRC: 26, IRC: 8 and Ministry Circulars.

The design, location and materials to be used for road delineators have been as per IRC: 79.

Standards prescribed by MORTH have been followed for overhead signs.

7.10.3 Pavement Markings

Pavement markings have been as per IRC: 35. These markings has been applied to road centre lines, edge line, continuity line, stop lines, give-way lines, diagonal/chevron markings, zebra crossing and at parking areas by means of an approved self-propelled machine which has a satisfactory cut-off value capable of applying broken lines automatically.

7.10.4 Traffic Signals

The traffic signals, their configuration, size, location and other requirements have been constructed as per Clause 13 of IRC: 93. Construction requirements shall conform to IS: 7537-1974, unless otherwise stated in IRC: 93. Posts has been painted and protected as per Clause 3.7 of IS: 7537-1974.

7.11 HIGHWAY LANDSCAPING

IRC: SP: 21 "Manual on Landscaping" shall guide the plantation of rows of trees with staggered pitch on either side of the road. The choice of the trees shall also be made as per the same code. Local, indigenous species that grow in the project area microclimate has been planted. Indicative arrangements for plantation of trees have been in accordance with the MORTH Technical

Circular No. NHI-41 (34)/69 dated. A spacing of 10-15m c/c is recommended for spacing of trees parallel to the roads. Setback distance of trees needed in different situations has been as per the IRC: SP: 21 and the IRC: 66.

Shrubs in medians shall not normally exceed 1-1.5m in height and has been as per IRC: SP: 21. To ensure survival from herbivorous animals, shrubs/plants containing latex are recommended.

Construction of Cement Concrete (CC) (M-20) footpaths for pedestrians has been as per MORTH Specifications.

7.12 TOLL PLAZA COMPLEX

Toll plaza has been designed as per IRC:SP-87.

7.13 ROAD FURNITURE

Road furniture such as Traffic signs, Kilometer posts, Hectometer stones, and ROW pillar etc on the Project Highway provided as per IRC Codes shall meet requirements of MORTH Specifications. Where any item is not covered by it, then its specification shall conform to BIS /AASHTO / ASTM /British Standards in that order of precedence.

7.14 TRUCK LAY BYE

Approved drawing as per MORTH and IRC specification has been used.

7.15 BUS STOPS AND BUS BAYS

The layout, design and location of the bus stops have been as per IRC: 80. The bus stop layout shall provide safe entry and exit of buses from the project corridor and safe movement of passengers. The shelter structure has been structurally safe and functional so as to protect the waiting passengers adequately from sun, rain and wind. The covered structure has been of steel pipes and with fibreglass roof. The seating and plinth of the structure has been of coursed stone masonry.

7.16 DESIGN METHODOLOGY AND DESIGN STANDARD FOR STRUCTURES

The detailed inventory and condition survey of the existing structure has been conducted. Based on detailed survey the proposal for structural arrangement has been finalised. The tentative cost along with the proposal is being submitted to client for their review and approval.

The detailed methodology and standards to be adopted for detailed design are illustrated below:

Materials

Concrete Grade

Grade of concrete in various elements shall be kept as follows for moderate conditions of exposure;

- All RCC members - M35 for bridges with PSC spans and other major a bridges, M35/M30 for minor bridges, M30 for culverts
- All PCC members - M20 for bridges with PSC spans and major bridges, M15 for minor bridges and culverts

Reinforcement Steel

Only Thermo Mechanically Treated (TMT) bars conforming to IS: 1786-2008 shall be used as reinforcing steel.

Exposure Condition

Moderate exposure conditions will be considered while designing various components of all the structures.

Concrete Clear Covers:

For all reinforcement - As per relevant IRC code

For Pre-stress cable - As per relevant IRC code

Pre-stressing System

System (Post tensioning)	19C15 multi-pull strand system of "Freyssinet" or "ISMALCCL" or equivalent
Cables (Post tensioning)	19C15 cables with strands of 15.2mm nominal diameter
High Tensile Steel	For both post/pre tensioning
Strands	Nominal 15.2mm dia. 7 ply low relaxation strands conforming to class 2 of IS: 14268-95
Area	150 sq. mm per strand (nominal cross sectional area)
Ultimate load	279.19 KN per strand
Modulus of Elasticity	1.95x105MPa
Sheathing (Post tensioning)	90mm OD Bright metal corrugated flexible sheathing for 19C15 cables respectively
Friction Coefficient (Post tensioning)	0.25/radian
Wobble Coefficient (Post tensioning)	0.0046/m
Anchorage Slip (Post tensioning)	6mm average
Loss of force due to Relaxation	2.5% at 0.7 UTS after 1000 hrs. The final relaxation value for design shall be 3.0 times the 1000 hr. value

Stressing shall be carried out simultaneously from both ends. All the strands of a cable shall be stressed in one go. Provisions for 4% emergency cables will be provided. If they are not utilized during construction, they will be pulled out and cable ducts will be grouted and plugged suitably. Access to the super-structure shall be provided to enable maintenance, inspection and future pre-stressing operations.

Structural Steel

All structural steel, castings and forgings, fasteners (bolts, nuts, washers and rivets), welding consumables and wire ropes and cables shall conform to the provisions of IRC: 24.

Bearings

- Mild steel, high tensile steel, cast steel, steel forgings and stainless steel shall conform to the provisions contained in clause 925.1 of IRC: 83 (Part III).
- Reinforced elastomeric bearings shall be proposed for short span simply supported superstructures. Elastomeric bearings shall be designed as per IRC: 83 (Part II) and shall conform to Cl.2005 of MORTH's Specifications for Road & Bridge Works (5th Revision).
- RCC type solid slab superstructures of bridges shall be proposed to rest directly on pier/abutment caps with a tar paper in between.
- Pot fixed/Pot PTFE sliding bearings shall be proposed for long span simply supported superstructures. These bearings shall be designed and supplied by the approved manufacturers. The loads and forces on the bearings shall be calculated to enable the manufacturer to design these bearings and these shall conform to Cl. 2006 of MORTH's Specifications for Road & Bridge Works (5th Revision).

Expansion Joints

The following types of Expansion Joints shall be adopted;

- **Filler type expansion joints**

Filler type expansion joints shall be proposed for minor bridges with solid slab superstructures having span lengths not exceeding 10 metres. These types of joints shall conform to Cl. 2605 of MoRTH's Specifications for Road & Bridge Works (5th Revision).

- **Single Strip seal expansion joints**

Single Strip seal expansion joints shall be proposed for superstructures having movements up to 80mm (± 40mm). The strip seal type expansion joints shall conform to Cl. 2607 of MORTH's Specifications for Road and Bridge works (5th Revision).

Miscellaneous

- An asphaltic concrete wearing course shall be proposed over the deck slab. It shall consist of a coat of mastic asphalt 6mm thick with a prime coat over the deck before the wearing course is laid.
- Drainage spouts with gratings at the top shall be provided on the bridges to ensure proper drainage of surface water.
- An approach slab, 3.5m long and 300mm thick, resting on the bracket taken out from the dirt wall shall be provided on both sides of the bridge resting on the 150mm thick leveling course. The gap between the approach slab and dirt wall shall be filled with bituminous joint filler sealing compound.
- Weep holes shall be provided behind abutment and wing wall to avoid building up of hydrostatic pressure behind them. Weep holes shall be provided 150mm, above the low water level or bed level whichever is higher.

MORTH Specifications

The specifications for Road and Bridge Works of Ministry of Road Transport & Highways published by Indian Road Congress will be used for materials to be used for construction of bridges.

Loads and Load Combinations

Dead Loads

Following unit weights has been assumed in the design as per IRC Codes.

Pre-stressed Concrete	-	2.5 t/cu.m
Reinforced Concrete	-	2.4 t/cu.m
Plain Cement Concrete	-	2.4 t/cu.m
Structural steel	-	7.85 t/cu.m
Dry Density of Soil	-	2.07 t/cu.m
Saturated Density of Soil	-	2.2 t/cu.m

Superimposed Dead Loads

Wearing Coat : 65mm thick asphaltic concrete with total weight of 0.2 t/sq.m (including allowance for overlay)

Crash barriers : From design (i.e. 1.0 t/m per side)

Carriageway Live Load

Preliminary design of all the new cross drainage structures shall be done for the following loading;

Live Loads : One/Two lanes/Three lanes of IRC Class A (Whichever produces worst effect) or one lane of IRC Class 70R (wheeled/ tracked) + one lane of Class A.

The impact factor shall be as per IRC: 6 for the relevant load combinations.

Footpath Live Load: The loading shall be taken 400kg/m^2 according to IRC: 6.

Longitudinal Forces

The following effects shall be considered for calculating the longitudinal forces in the design

- Braking forces as per the provision of Cl. 211 of IRC: 6.
- Frictional resistance offered to the movement of free bearings due to change of temperature.
- Distribution of longitudinal forces due to horizontal deformation of bearings/frictional resistance shall be carried out as per Cl. 211.5 of IRC: 6 by assuming stiff supports.

Centrifugal Forces

Bridges on a horizontal curve shall be designed for centrifugal forces based on the following equation;

C = W*V^2/127R,

Where, C = Centrifugal force acting normal to the traffic

W = Carriageway live load

V = Design speed of the vehicles using the bridge in Km per hour

R = Radius of curvature in meters

The centrifugal force shall be considered to act at 1.2m above the formation level of the bridge in the transverse direction. No impact value on carriageway live load shall be considered for calculating the centrifugal force.

Water Current Forces

The effect of water current forces shall be calculated in accordance with clause number 210 of IRC: 6 on sub-structure and foundations.

Earth Pressure

Horizontal forces due to earth pressure shall be calculated as per the provision of Cl. 214 of IRC:6 assuming the following soil properties;

Type of soil assumed for backfilling	:	Gamma = 2.0 t/cu. m
Angle of Internal Friction	:	$\phi = 30°$
Angle of Wall Friction	:	$\delta = 20°$

Coefficient of Friction `μ' at base: tan (2/3ϕ), where ϕ is the angle of internal friction of substrata immediately under the foundation.

Live load surcharge shall be considered as equivalent to 1.2m height of earth fill in case of abutments and equivalent to 0.6m height of earth fill in case of return/wing walls.

Wind Forces

Structures shall be checked for wind effects as stipulated in the Cl. 209 of the IRC: 6.

Seismic Effect

The project road falls under seismic zone III. Horizontal seismic force shall be calculated using the following formula;

F_{eq} = Ah x (Dead Load + Appropriate Live Load)

Where,

Ah = horizontal seismic coefficient = (Z/2) x (Sa/g)/(R/I)

Z = Zone factor and is equal to 0.10 for seismic zone II

I = Important factor and is taken as 1.2 for important bridges

R = Response reduction factor

Sa/g = Average response acceleration coefficient depending upon fundamental period of vibration T

T = Fundamental period of the bridge in seconds in horizontal vibrations.

Combination shall be taken according to clause 219.4 of IRC: 6.

Temperature Range

The bridge structure/components i.e. bearings and expansion joints, shall be designed for a temperature variation of + 25°C considering extreme climate. The super-structures shall be designed for effects of distribution of temperature across the deck depth as per stipulations of BD 37/88; suitably modified for the surfacing thickness.

Differential Shrinkage Effects

A minimum reinforcement of 0.2% of cross sectional area in the longitudinal direction of the cast-in-situ slab shall be provided to cater for differential shrinkage stresses in superstructures with in-situ slab over pre-cast girders as per Cl. 605.2 of IRC: 22.

Construction Stage Loadings

A uniformly distributed load of 3.6 KN/m2 of the form area shall be taken into account of construction stage loadings in the design of superstructure elements, wherever applicable, as per Cl. 4.2.2.2.2 of IRC: 87.

Buoyancy

100% buoyancy shall be considered while checking stability of foundations. Pore pressure uplift limited to 15% shall be considered while checking stresses of the substructure elements.

In the design of abutments of river bridges, the effects of buoyancy shall be considered assuming the fill behind abutments has been removed by scour.

Load Combination

All members have been designed to safely sustain the most critical combination of various loads and forces that can coexist. Various load combinations as relevant with increase in permissible stresses considered in the design shall be as IRC: 6 and Cl. 706 of IRC: 78.

Codes to be adopted for design

Latest revision of the following latest codes have been used for the preliminary design of the structures

i. IRC: 5 - Standard Specifications & Code of Practice for Road bridges, Section I – General Features of Design (Seventh Revision)

ii. IRC:6 - Standard Specifications and Code of Practice for Road bridges, Section I – General Features of Design (Fifth Revision)

iii. IRC:7 - Recommended Practice for Numbering Bridges and Culverts (First Revision)

iv. IRC: 112 –Code of Practice for Concrete Road Bridges

v. IRC: 22 - Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Second Revision)

vi. IRC: 24 - Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method)Third Revision)

vii. IRC:45 - Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well

viii. IRC: 54 - Lateral and Vertical Clearances at Underpasses for Vehicular Traffic

ix. IRC: 78 - Standard Specifications and Code of Practice for Road Bridges, Section VII – Foundations & Substructure (Second Revision)

x. IRC: 83 (Part I) - Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearing, Part I: Metallic Bearing (First Revision)

xi. IRC:83 (Part III) - Standard Specifications and Code of Practice for Road bridges, Section IX – Bearings, Part III: POT, POT-CUM-PTFE, PIN and Metallic Guide Bearings

xii. IRC: 87 – Guidelines for the Design and Erection of False work or Road Bridges.

xiii. IRC:89 - Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision)

xiv. BD 37/88 - (British loading)

xv. BS 5400 - Part IX (For design of POT/POT-PTFE Bearings)

xvi. IRC: SP: 13-Guidelines for the Design of Small Bridges & Culverts (First Revision)

xvii. IRC: SP: 18 - Manual for Highway bridge Maintenance Inspection

xviii. IRC: SP: 35 - Guidelines for Inspection and Maintenance of Bridges

xix. IRC: SP: 40 - Guidelines on Techniques for strengthening and Rehabilitation of Bridges

xx. IRC:SP: 47 - Guidelines on Quality Systems for Road Bridges (Plain Reinforced, Pre-stressed and Composite Concrete

xxi. IRC: SP:87 – Manual of Specifications and Standards for 6 laning of highway through Public Private Partnership

7.17 HYDRAULIC AND HYDROLOGICAL INVESTIGATIONS

Following methods has been used for calculating discharge for bridges-

a) Empirical Formulae for peak run-off from catchment
b) Rational Formulae for peak run-off from catchment
c) Discharge by the Manning's Formulae

The flood discharge calculated from the above methods has been compared with each other and the highest of these values has been adopted as the design discharge Q, provided it does not exceed the next highest discharge by more than 50 per cent. In case the difference is more than 50 per cent then the design discharge has been restricted to the limit of 50 per cent. Culverts has been designed for a flood frequency of 20 years whereas bridges has been designed for a flood frequency of 50 years. Gumbels method and log Pearson Type III distribution methods has been used to calculate the design discharge for a return period of 20 years and 50 years.

Discharge for calculation of scour and design of protection works

Conventional method as stipulated in IRC: 78 has been used for calculating scour depth of piers and abutments. Laceys method has been used for calculating waterway requirements.

Calculation for scour depth and design of protection works has been carried out for a larger discharge in order to give adequate factor of safety. The percentage increase in discharge based on catchment area has been as follows-

a) 30% increase in discharge for catchment area up to 500 square kilometers
b) 25% to 20% for medium catchments of 500 to 5000 square kilometers
c) 20% to 10% for larger catchments of 5000 to 25000 square kilometers
d) 10% for larger catchments above 25000 kilometers

However there shall not be any increase in discharge for calculations of linear waterway requirements.

7.18 SUB-SOIL INVESTIGATION

Detailed sub-soil investigations shall be carried out at all proposed bridge locations in the subsequent stage. One borehole at abutment location shall be drilled for structures of length between 6m to 30m.Two boreholes i.e. one at abutment location and one at intermediate location between abutments shall be drilled for each bridge having a length between 30m to 60m. In case of bridges having overall length more than 60 metres one borehole shall be carried out at each abutment and pier location.

The sub-soil exploration and testing have been carried out through the sub-soil consultant empanelled by the MORTH. Sub-soil investigation shall be done as per IRC 78.

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CHAPTER 8: DEVELOPMENT PROPOSALS

8.1 GENERAL

This chapter is intended to give brief descriptions concerning the various improvement proposals for the up-gradation of the Gurgaon – Nuh – Rajasthan border section of NH-248A. However NHAI has decided to implement the project under following three construction packages:

Package	Existing Chainage / RD		Design Chainage		Length (km)	Remarks
	From	To	From	To		
I	2+400	11+682	0+000	9+282	9.282	Rajiv Chowk to Sohna
II	11+682	24+400	9+282	22+000	12.718	
III	24+400	95+984	22+000	93+484	71.484	Sohna –Rajasthan Border

In line with the above, this chapter discusses different improvement proposals for Package – II section of the project road. The project road section under Package-II starts from existing chainage km 11+682 and ends at km 24+400 of NH-248A. Therefore, the total actual existing length of project road is 12.718 km.

As discussed in **Chapter 5: Traffic Survey, Analysis and Forecast**, the current traffic between Rajiv Chowk (km 0+000) to Ashram/Vatika Chowk (km 4+900) is 68760 PCU and between Ashram / Vatika Chowk (km 4+900) to Sohna (km 23+300) it is 23847 PCU. Thus with the traffic projection, it is apparent that traffic would exceed 25000 PCU for km 4+900 to km 23+300 section of the project road in 2017-18. Therefore considering the current traffic and rapid urbanization of the project influence area, NHAI has decided for 6-laning of the Package-II section of the project road with 6-lane service road.

The improvement proposal, thus, is based on the findings from various engineering surveys and investigations carried out on the project road section, discussions with NHAI and as discussed in **Chapter 5: Traffic Survey, Analysis and Forecast and Chapter 6: Engineering Survey and Investigation.**

Improvement proposals for a highway essentially consist of two components, viz. Geometric and Structural. Geometric improvement deals with visible dimensions of roadway and is dictated by the traffic and economic considerations. Geometric design involves several design elements such as horizontal and vertical alignments, sight distance considerations, cross sectional elements, lateral and vertical clearances, intersection treatment, control of access, etc. The structural component deals with the pavement and embankment design aspects, i.e. the ability of the highway to adequately carry and support the vehicle / wheel loads over the design period.

The improvement proposals for the proposed widening to 6-lane with paved shoulder configuration system includes the provision for the following major items:

- Geometric Improvements
- Pavement
- Road Junctions
- Bridges and Cross-Drainage Structures
- Safety and Special Problems and
- Road Appurtenances

8.2 GEOMETRIC DESIGN PROPOSALS

The proposals for the improvement of the geometric elements of the existing National Highway include:

- Improvement to cross-sectional elements
- Alignment Design

8.2.1 Improvement to Cross-sectional Elements

Proposed Cross Sectional Elements

Lane Width

The width of a basic traffic lane is proposed to be 3.50 m. Thus, for 6-lane the carriageway widths will be 21.0 m. 0.5 m wide edge strip with a composition same as that of the adjacent pavement will be provided as compensation for kerb shyness on the median side.

Paved Shoulders

Full strength pavement for paved shoulder is proposed. Width of these shoulders will be 1.50m in rural sections and 2.0m in urban stretches.

Median

In general median width, excluding the kerb shyness, is of 4.0m in rural area and 1.5m in urban area. In urban stretch where land is limited, median in form of crash barrier of 0.5 m width has been proposed.

Service Road / Slip Road

Where Service road is provided, it will be of 9.25/10.25/10.75m carriageway width of different pavement composition based on the expected traffic. The width is dependent on the availability of land.

Footpath

Where footpath is proposed, minimum width of footpath will be of 3.5 m. It has been proposed at the outermost boundary of the proposed ROW.

Utility Corridor

Due to space constraint the utility corridor has been accommodated beneath the Footpath.

Side Slopes

For fill sections, the following side slopes are proposed:

Embankment height up to 3.0 m	-	2H:1V and Considering the Embankment material property
Embankment height from 3.0 m to 6.0 m	-	2.5H:1V and Considering the Embankment material property
Embankment height exceeding 6.0 m	-	To be designed as per material property and as per IRC: 75
Cutting sections	-	1H: 1V and with considering the material property of the cutting material.

Crossfall

In case of flexible pavement, the crossfall for the pavement and paved shoulders will be 2.5%. In rigid pavement crossfall of 2.0% has been considered. For earthen shoulders and median the corresponding value will be 3.0%.

Proposed ROW

In general minimum ROW has been proposed to be 49m. However in some stretches due to the constraints in land availability proposed ROW ranges between 35-49m.The maximum ROW of 60m has been proposed except toll plaza and FOB locations.

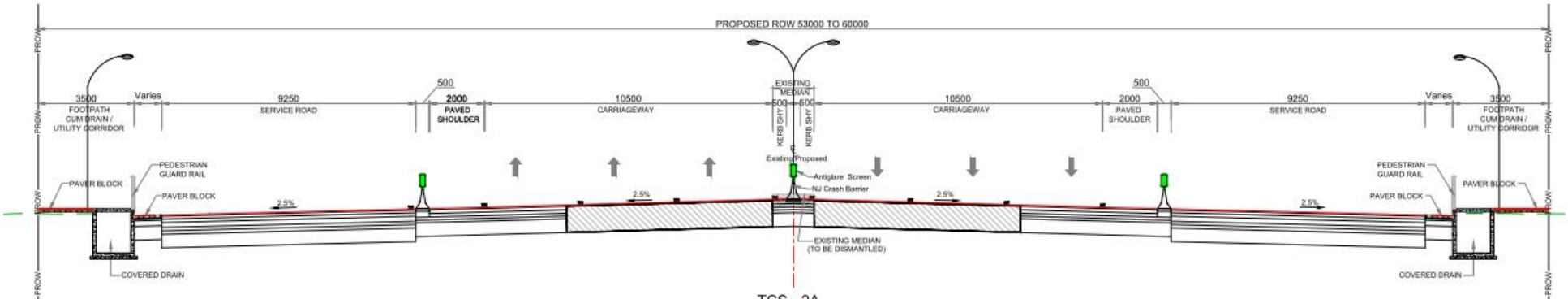
8.2.2 Typical Cross Section

The typical cross sections to be followed in the project stretch are detailed as below:

Sl. No.	TCS	Description
1	TCS-2A	Concentric widening and strengthening of existing 4-lane to 6-lane with paved shoulder and proposed service road on both side in urban section within ROW of 53-60m
2	TCS-2B	Concentric widening and strengthening of existing 4-lane to 6-lane with paved shoulder and proposed service road on both side in urban section within ROW of 53m
3	TCS-3A	Concentric widening and strengthening of existing 4lane to 6-lane with paved shoulder and proposed service road in rural section within ROW of 56m (as per existing) (proposed median 2.5m)
4	TCS-3B	Concentric widening and strengthening of existing 4lane to 6-lane with paved shoulder and proposed service road in rural section within ROW of 60m (proposed median 2.5m)

Sl. No.	TCS	Description
5	TCS-4B	Proposed 6-lane in viaduct with service road on both side in urban section within ROW of 49-60m(proposed median 2.5m)
6	TCS-5	Proposed 6lane without paved shoulder in elevated structure with service road in urban section within ROW of 35-58m (proposed median 2.5m)
7	TCS-5A	Proposed 6lane without paved shoulder in elevated structure with service road in urban section (proposed median 2.5m)
8	TCS-6A	Proposed 6lane flyover approach with service road on both side in urban section within ROW of 54m (proposed median 2.5m)
9	TCS-7	Proposed 6lane with paved shoulder in flyover approach with service / slip road on both side in urban section within ROW of 54-60m (proposed median 2.5m)
10	TCS-8	Proposed 6lane in flyover approach with service road on both side in urban section within ROW of 49m (proposed median 2.5m)
11	TCS-11A	Strengthening of existing 4-lane to 6-lane with service road on both sides in urban section within ROW of 60m
12	TCS-11B	Strengthening of existing 4-lane to 6-lane with service road on both sides in urban section within ROW of 58m to 59m

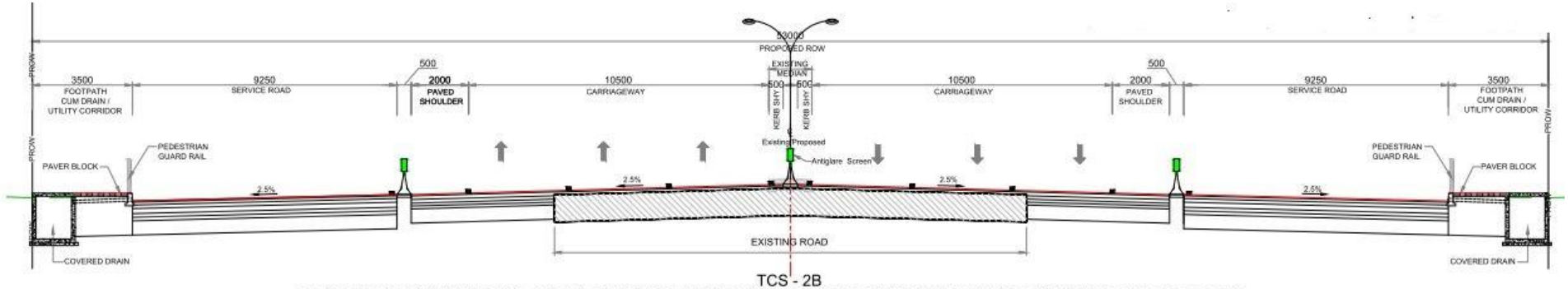
Figures 8.1 to 8.12 shows the typical cross sections to be followed on the project stretch.



TCS - 2A

CONCENTRIC WIDENING AND STRENGTHENING OF EXISTING 4-LANE TO 6-LANE WITH PAVED SHOULDER AND PROPOSED SERVICE ROAD ON BOTH SIDE IN URBAN SECTION WITH IN ROW OF 53-60m

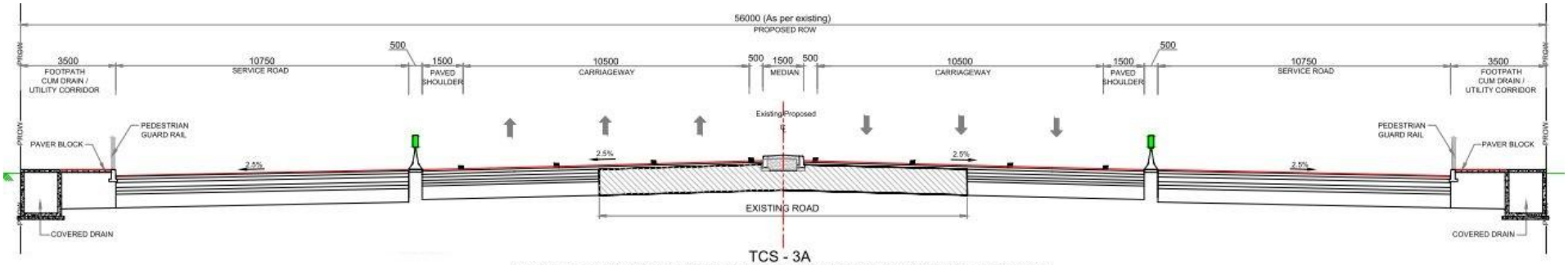
Figure 8.1



TCS - 2B

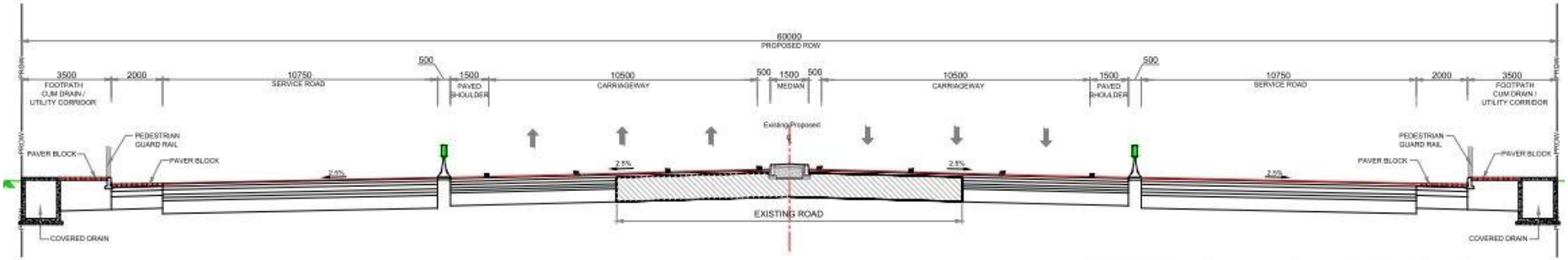
CONCENTRIC WIDENING AND STRENGTHENING OF EXISTING 4-LANE TO 6-LANE WITH PAVED SHOULDER AND PROPOSED SERVICE ROAD ON BOTH SIDE IN URBAN SECTION WITHIN ROW OF 53m

Figure 8.2



TCS - 3A
CONCENTRIC WIDENING AND STRENGTHENING OF EXISTING 4LANE TO 6-LANE WITH PAVED SHOULDER AND PROPOSED SERVICE ROAD IN RURAL SECTION WITHIN ROW OF 56m (As per existing)

Figure 8.3



TCS - 3B
CONCENTRIC WIDENING AND STRENGTHENING OF EXISTING 4LANE TO 6-LANE WITH PAVED SHOULDER AND PROPOSED SERVICE ROAD IN RURAL SECTION WITHIN ROW OF 60m

Figure 8.4

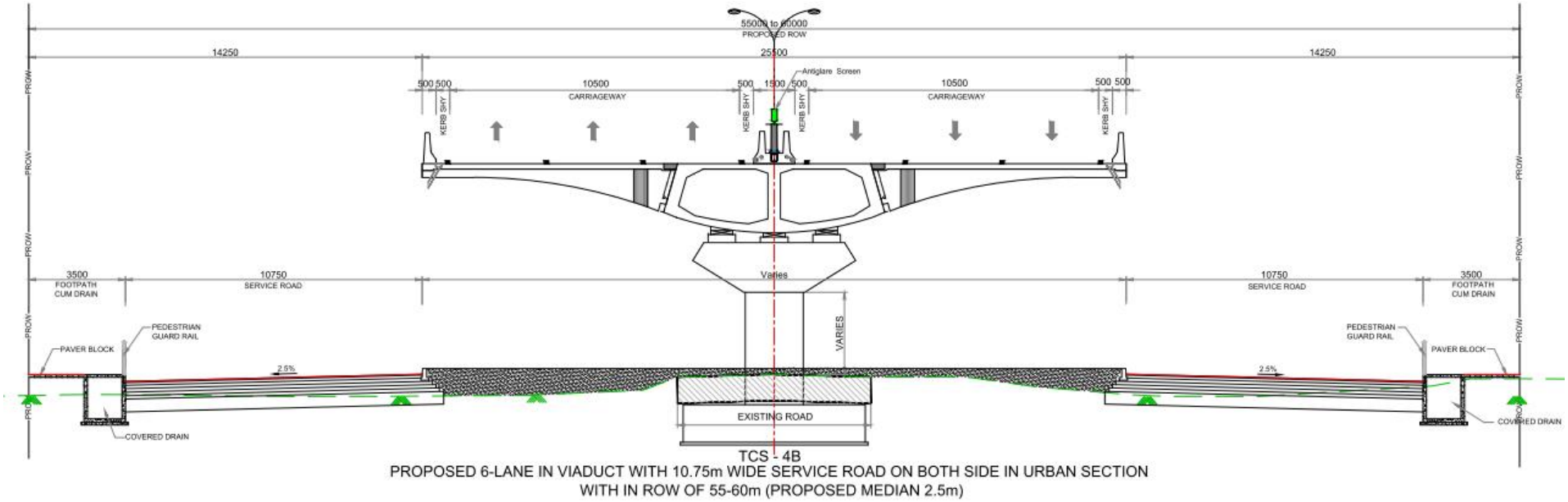
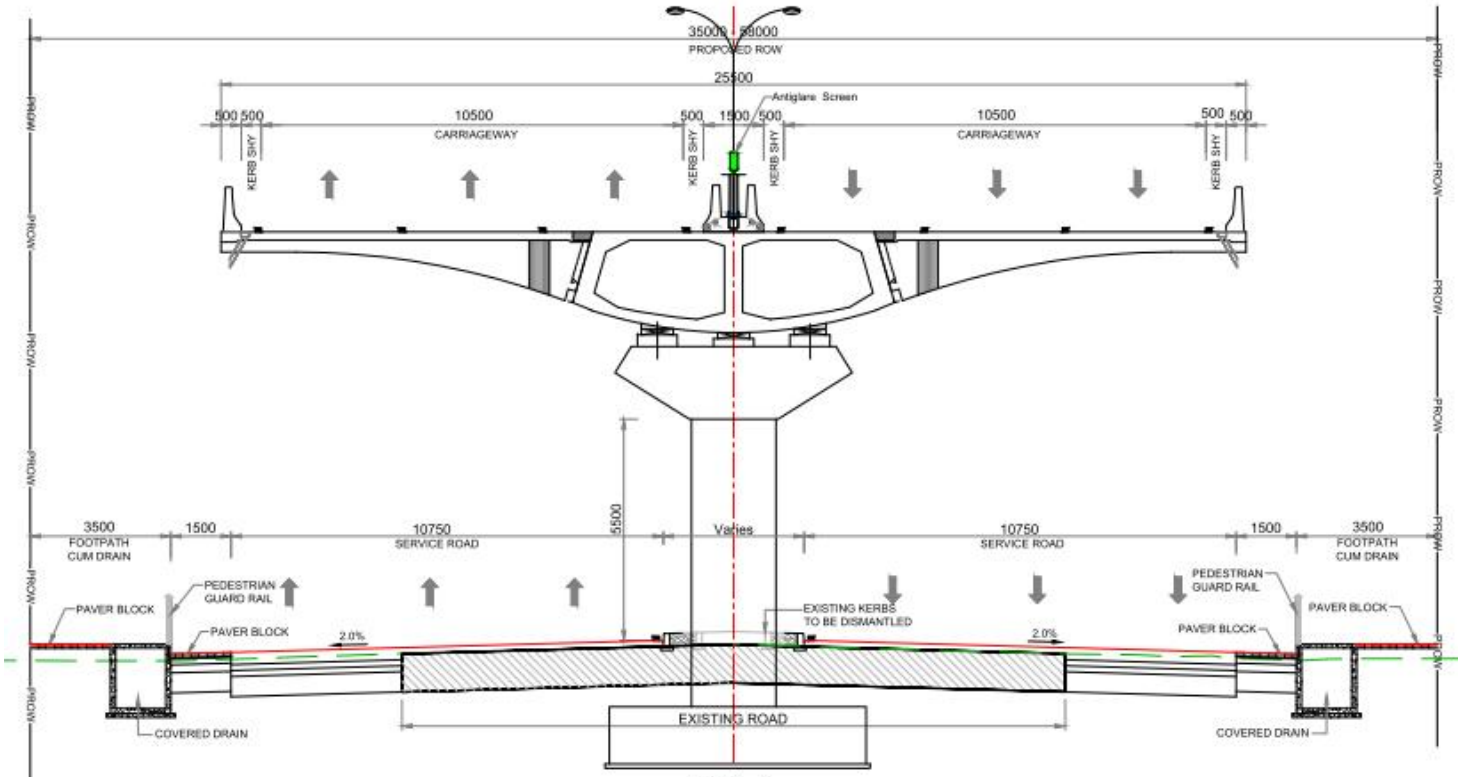

55000 to 60000
PROPOSED ROW
14250
25500
14250
Antiglare Screen
500 500
10500
CARRIAGEWAY
500
1500
500
10500
CARRIAGEWAY
500 500
KERB SHY
KERB SHY
KERB SHY
KERB SHY
ROW
3500
FOOTPATH
CUM DRAIN
10750
SERVICE ROAD
Varies
10750
SERVICE ROAD
3500
FOOTPATH
CUM DRAIN
PEDESTRIAN
GUARD RAIL
PAVER BLOCK
2.5%
VARIES
EXISTING ROAD
2.5%
PEDESTRIAN
GUARD RAIL
PAVER BLOCK
COVERED DRAIN
COVERED DRAIN
TCS - 4B
PROPOSED 6-LANE IN VIADUCT WITH 10.75m WIDE SERVICE ROAD ON BOTH SIDE IN URBAN SECTION
WITH IN ROW OF 55-60m (PROPOSED MEDIAN 2.5m)

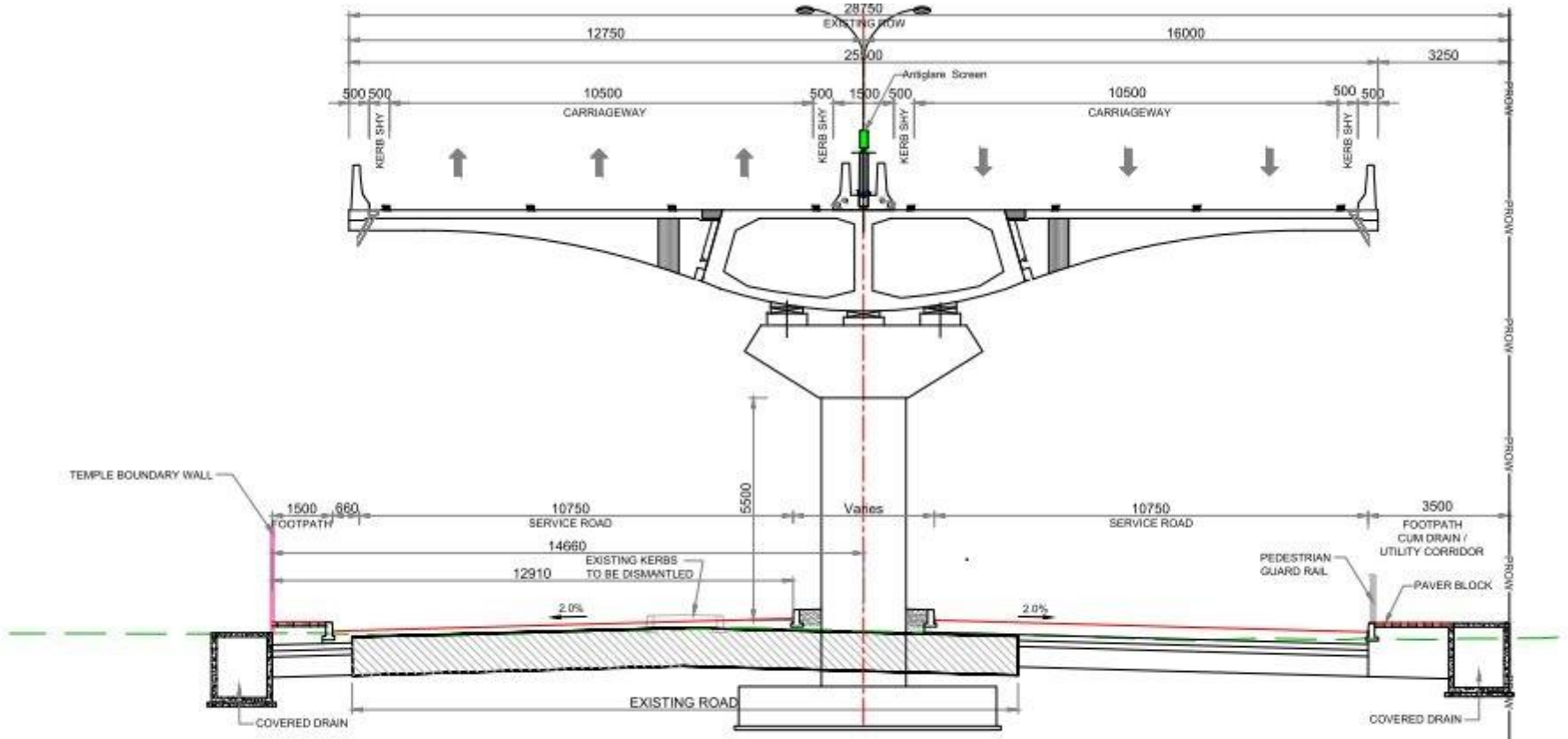
Figure 8.5



TCS - 5

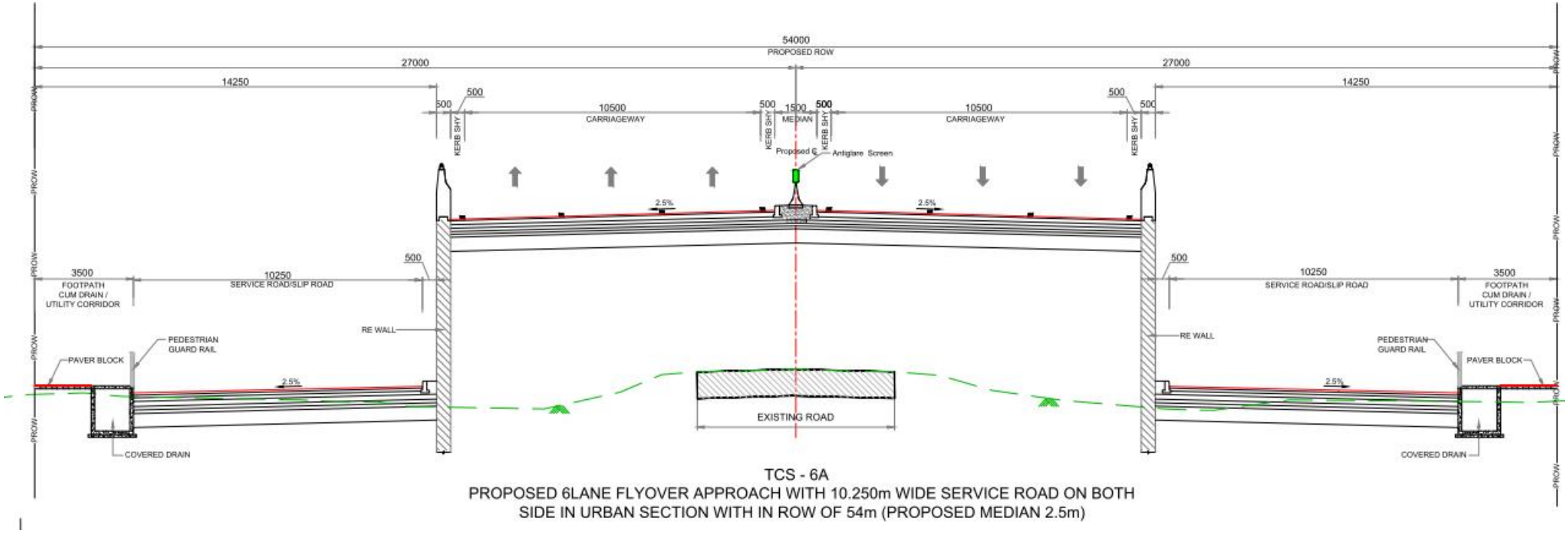
PROPOSED 6LANE WITHOUT PAVED SHOULDER IN ELEVATED STRUCTURE WITH 10.75m WIDE SERVICE ROAD IN URBAN SECTION WITH IN ROW OF 35-58m (PROPOSED MEDIAN 2.5m)

Figure 8.6



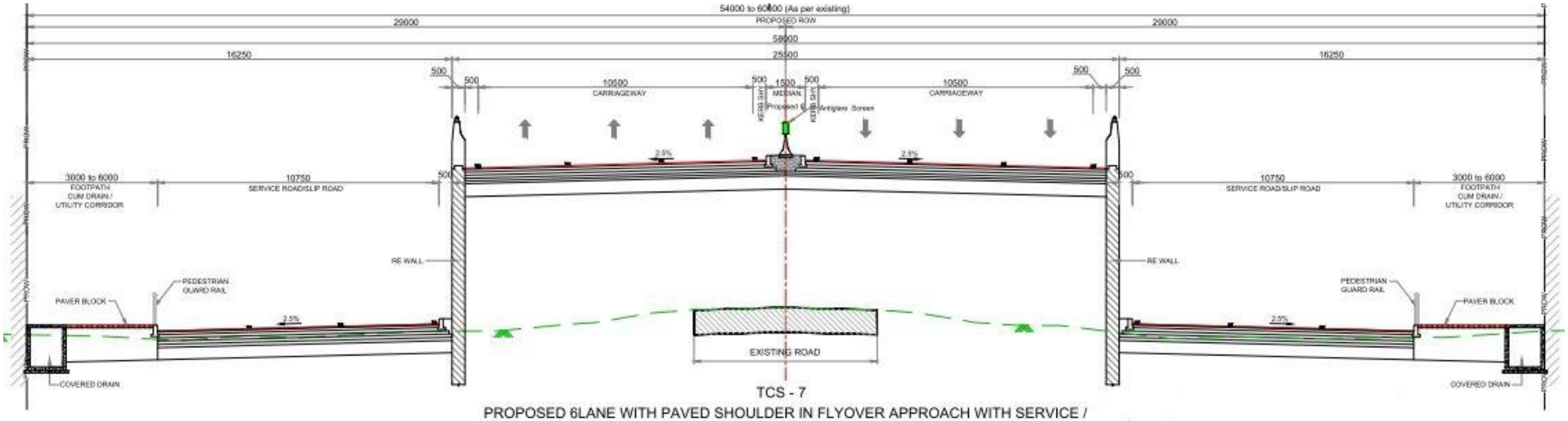
TCS - 5A
PROPOSED 6LANE WITHOUT PAVED SHOULDER IN ELEVATED
STRUCTURE WITH SERVICE ROAD IN URBAN SECTION
(PROPOSED MEDIAN 2.5m)

Figure 8.7



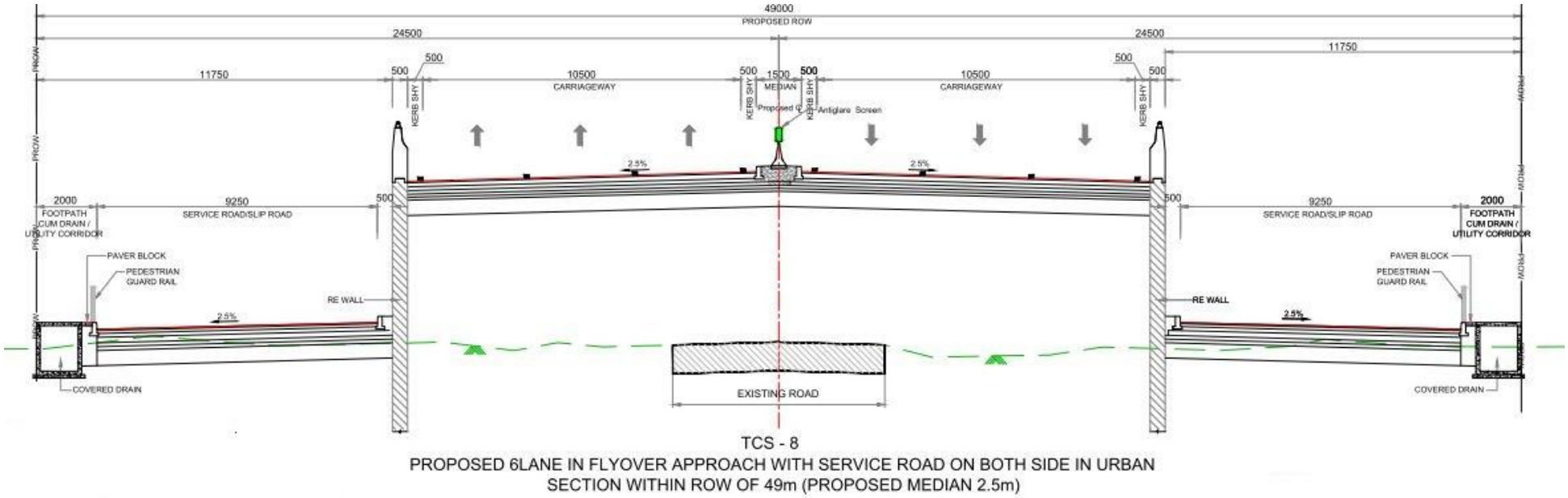
TCS - 6A
PROPOSED 6LANE FLYOVER APPROACH WITH 10.250m WIDE SERVICE ROAD ON BOTH SIDE IN URBAN SECTION WITH IN ROW OF 54m (PROPOSED MEDIAN 2.5m)

Figure 8.8



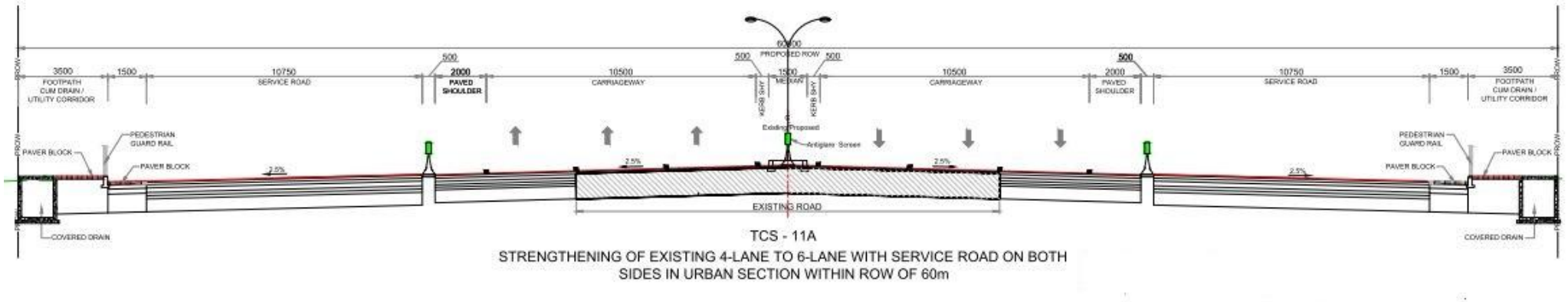
TCS - 7
PROPOSED 6LANE WITH PAVED SHOULDER IN FLYOVER APPROACH WITH SERVICE / SLIP ROAD ON BOTH SIDE IN URBAN SECTION WITHIN ROW OF 54m TO 60m
(PROPOSED MEDIAN 2.5m)

Figure 8.9



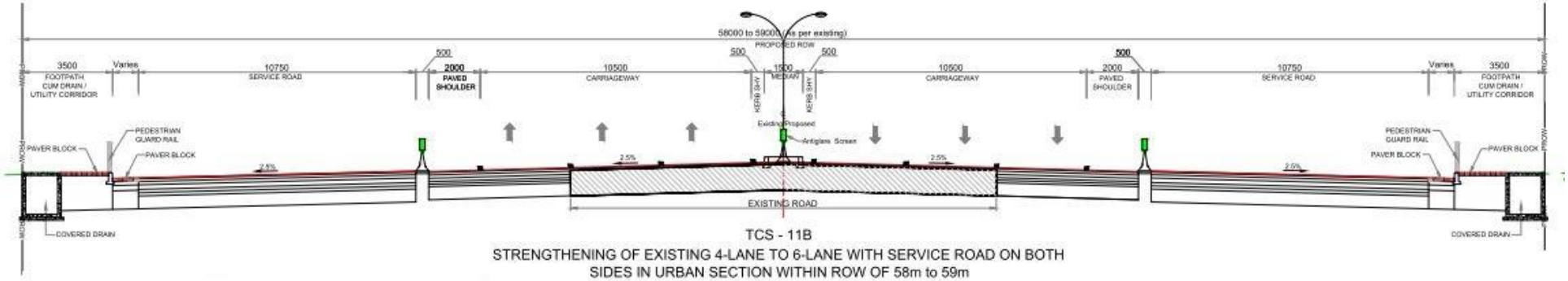
TCS - 8
PROPOSED 6LANE IN FLYOVER APPROACH WITH SERVICE ROAD ON BOTH SIDE IN URBAN SECTION WITHIN ROW OF 49m (PROPOSED MEDIAN 2.5m)

Figure 8.10



TCS - 11A
STRENGTHENING OF EXISTING 4-LANE TO 6-LANE WITH SERVICE ROAD ON BOTH SIDES IN URBAN SECTION WITHIN ROW OF 60m

Figure 8.11



TCS - 11B
STRENGTHENING OF EXISTING 4-LANE TO 6-LANE WITH SERVICE ROAD ON BOTH SIDES IN URBAN SECTION WITHIN ROW OF 58m to 59m

Figure 8.12

8.2.3 Widening Scheme

The existing project road section of NH 248A from existing km 11+682 to km 24+400 in the State of Haryana has multi-dimensional facets with respect to land use and road geometry and considering all these aspects the section-wise policy adopted for widening based on the initial investigations is given in **Table 8.1**.

Table 8.1: Widening Schedule

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Applicable Typical cross section (TCS)	Remark	Village Name
	From	To	From	To				
1	11+682	11+806	9+282	9+406	124	TCS-6A	Approach	
2	11+806	12+166	9+406	9+766	360	TCS-4B	Viaduct	
3	12+166	12+870	9+766	10+470	704	TCS-5	Elevated structure	Maruti Kunj Road crossing
4	12+870	12+970	10+470	10+570	100	TCS-5A	Elevated structure	Bhondsi
5	12+970	13+034	10+570	10+634	64	TCS-5	Elevated structure	Bhondsi
6	13+034	13+394	10+634	10+994	360	TCS-4B	Viaduct	Bhondsi
7	13+394	13+528	10+994	11+128	134	TCS-8	Approach	Bhondsi
8	13+528	14+680	11+128	12+280	1152	TCS-2B		
9	14+680	15+040	12+280	12+640	361	TCS-3A		
10	15+040	15+790	12+640	13+390	750	Toll plaza		
11	15+790	16+253	13+390	13+853	463	TCS-3A		
12	16+253	16+710	13+853	14+310	457	TCS-7	Approach	
13	16+710	16+740	14+310	14+340	30	VUP		Ghamroj village
14	16+740	17+254	14+340	14+854	514	TCS-7	Approach	
15	17+254	17+810	14+854	15+410	556	TCS-3A		
16	17+810	18+271	15+410	15+871	461	TCS-7	Approach	
17	18+271	18+346	15+871	15+946	75	1×30+ 1×15+ 1×30 m span	Flyover	Alipur Village
18	18+346	18+822	15+946	16+422	476	TCS-7	Approach	
19	18+822	20+033	16+422	17+633	1211	TCS-3B		
20	20+033	21+100	17+633	18+700	1067	TCS-11A		
21	21+100	21+460	18+700	19+060	360	TCS-11B		
22	21+460	21+611	19+060	19+211	151	TCS-7	Approach	

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Applicable Typical cross section (TCS)	Remark	Village Name
	From	To	From	To				
23	21+611	22+325	19+211	19+925	714	TCS-4B	Viaduct (30m span at km 19+550)	University Area
24	22+325	22+472	19+925	20+072	147	TCS-7	Approach	
25	22+472	24+400	20+072	22+000	1928	TCS-2A		
Total length(m)					**12718**			

Note:

All the given Design Chainages are with respect to the Right median edge (RME)

*Median width shown is inclusive of the shyness proposed on either side.

The widening scheme can be summarised as given below:

Summary of Widening Scheme

TCS	Description	Widening Side	Median Width* (m)	Total length (m)
TCS-2A	Concentric widening and strengthening of existing 4-lane to 6-lane with paved shoulder and proposed service road on both side in urban section within ROW of 53-60m	Concentric	1.5	1928
TCS-2B	Concentric widening and strengthening of existing 4-lane to 6-lane with paved shoulder and proposed service road on both side in urban section within ROW of 53m	Concentric	1.5	1152
TCS-3A	Concentric widening and strengthening of existing 4lane to 6-lane with paved shoulder and proposed service road in rural section within ROW of 56m (as per existing) (proposed median 2.5m)	Concentric	2.5	1379
TCS-3B	Concentric widening and strengthening of existing 4lane to 6-lane with paved shoulder and proposed service road in rural section within ROW of 60m (proposed median 2.5m)	Concentric	2.5	1211
TCS-4B	Proposed 6-lane in viaduct with service road on both side in urban section within ROW of 49-60m(proposed median 2.5m)	Concentric	2.5	1434
TCS-5	Proposed 6lane without paved shoulder in elevated structure with service road in urban section within ROW of 35-58m (proposed median 2.5m)	Concentric	2.5	768
TCS-5A	Proposed 6lane without paved shoulder in elevated structure with service road in urban section (proposed median 2.5m)	Concentric	2.5	100
TCS-6A	Proposed 6lane flyover approach with service road on both side in urban section within ROW of 54m (proposed	Concentric	2.5	124

TCS	Description	Widening Side	Median Width* (m)	Total length (m)
	median 2.5m)			
TCS-7	Proposed 6lane with paved shoulder in flyover approach with service / slip road on both side in urban section within ROW of 54-60m (proposed median 2.5m)	Concentric	2.5	2311
TCS-8	Proposed 6lane in flyover approach with service road on both side in urban section within ROW of 49m (proposed median 2.5m)	Concentric	2.5	134
TCS-11A	Strengthening of existing 4-lane to 6-lane with service road on both sides in urban section within ROW of 60m	Concentric	2.5	1067
TCS-11B	Strengthening of existing 4-lane to 6-lane with service road on both sides in urban section within ROW of 58m to 59m	Concentric	2.5	360
Toll Plaza (m)				750
Total length(m)				**12718**

The summary of TCS applicable sections is given below in Table 8.2:

Table 8.2: Summary of TCS Applicable sections

Sl. No.	TCS	TCS applicable sections				Length (m)	Total length (m)
		Existing Chainage		Design Chainage			
		From	To	From	To		
1	TCS-2A	22+472	23+100	20+072	20+700	628	1928
		23+100	24+100	20+700	21+700	1000	
		24+100	24+400	21+700	22+000	300	
2	TCS-2B	13+528	14+680	11+128	12+280	1152	1152
3	TCS-3A	14+680	15+040	12+280	12+640	360	1380
		15+790	16+253	13+390	13+853	463	
		17+254	17+810	14+854	15+410	556	
4	TCS-3B	18+822	20+033	16+422	17+633	1211	1211
5	TCS-4B	11+806	12+166	9+406	9+766	360	1434
		13+034	13+394	10+634	10+994	360	
		21+611	21+708	19+211	19+308	97	
		21+708	22+325	19+308	19+925	617	
6	TCS 5	12+166	12+190	9+766	9+790	24	768
		12+190	12+500	9+790	10+100	310	

Sl. No.	TCS	TCS applicable sections				Length (m)	Total length (m)
		Existing Chainage		Design Chainage			
		From	To	From	To		
		12+500	12+870	10+100	10+470	370	
		12+970	13+000	10+570	10+600	30	
		13+000	13+034	10+600	10+634	34	
7	TCS-5A	12+870	12+970	10+470	10+570	100	100
8	TCS-6A	11+682	11+806	9+282	9+406	124	124
9	TCS-7	16+253	16+500	13+853	14+100	247	2311
		16+500	17+254	14+100	14+854	754	
		17+810	17+880	15+410	15+480	70	
		17+880	18+024	15+480	15+624	144	
		18+024	18+586	15+624	16+186	562	
		18+586	18+822	16+186	16+422	236	
		21+460	21+505	19+060	19+105	45	
		21+505	21+611	19+105	19+211	106	
		22+325	22+390	19+925	19+990	65	
		22+390	22+472	19+990	20+072	82	
10	TCS-8	13+394	13+528	10+994	11+128	134	134
11	TCS-11A	20+033	21+100	17+633	18+700	1067	1067
12	TCS-11B	21+100	21+460	18+700	19+060	360	360

The details of proposed ROW for the Project Highway are given below:

Table 8.2A: Details of Proposed ROW

Existing Chainage		Design Chainage		Length (m)	Proposed ROW (m)	Remark
From	To	From	To			
11+682	12+190	9+282	9+790	508	54	
12+190	12+500	9+790	10+100	310	58	
12+500	13+000	10+100	10+600	500	56	
13+000	13+034	10+600	10+634	34	39	
13+034	13+394	10+634	10+994	360	55	
13+394	13+528	10+994	11+128	134	49	

Existing Chainage		Design Chainage		Length (m)	Proposed ROW (m)	Remark
From	To	From	To			
13+528	14+680	11+128	12+280	1152	53	
14+680	15+040	12+280	12+640	360	56	
15+040	15+243	12+640	12+843	203	Varying from 56 to 101m	Toll Plaza
15+243	15+556	12+843	13+156	313	197	
15+556	15+790	13+156	13+390	234	Varying from 56 to 104m	
15+790	16+253	13+390	13+853	463	56	
16+253	16+500	13+853	14+100	247	57	
16+500	17+335	14+100	14+935	835	54	
17+335	17+388	14+935	14+988	53	Vary from 54-71m	Truck Lay bye
17+388	17+488	14+988	15+088	100	71	
17+488	17+541	15+088	15+141	53	Vary from 71-56m	
17+541	17+810	15+141	15+410	269	56	
17+810	17+880	15+410	15+480	70	58	
17+880	18+024	15+480	15+624	144	60	
18+024	18+586	15+624	16+186	562	58	
18+586	21+087	16+186	18+687	2501	60	
21+087	21+113	18+687	18+713	26	71	Foot over bridge
21+113	21+505	18+713	19+105	392	59	
21+505	21+708	19+105	19+308	203	58	
21+708	22+390	19+308	19+990	682	60	
22+390	22+487	19+990	20+087	97	55	
22+487	22+513	20+087	20+113	26	70	Foot over bridge
22+513	24+100	20+113	21+700	1587	59	
24+100	24+400	21+700	22+000	300	60	

All the above schemes are general policy decisions; these will be dependent on the precise geometric configuration, realignment, re-sectioning, reconstruction, exact land widths available etc. which will be refined if required during the next stage.

8.2.4 Alignment Design

The entire geometric design has been based on the ground modelling by highway MX design software. The design of proposed alignment for 6-lane with paved shoulder has been carried out based on the widening scheme as discussed in the section 8.2.3 above.

Horizontal Alignment

Efforts have been made during design of horizontal alignment to accommodate the proposed highway within the available ROW, without compromising with the design standards as adopted and as discussed in Chapter 7: Design Standard. A minimum radius of 400m has been kept along with a good balance between additional land acquisition, structure and highway geometric. The super-elevation and the length of the transition curve have been finalised with maximum super-elevation of 5%.

Vertical Alignment

Vertical Alignment will be designed for minimum criteria of Intermediate Sight Distance (ISD). The existing road profile will be reviewed on the basis of cross-sections taken at regular intervals with the help of Digital Terrain Model (DTM).

8.3 PROPOSAL FOR SERVICE ROADS/SLIP ROAD

Considering the urban nature of the project road section in this package, 3-lane service road on both sides has been proposed. The stretches where service roads are proposed along with its carriageway width is summarized in Table 8.3 below:

Table 8.3: Details of Service Road/Slip Road

Existing Chainage		Design Chainage		Length (m)	Details of Service Road		
From	To	From	To		Total width (m)	Side	Type
11+682	11+806	9+282	9+406	124	10.25	Both sides	Service Road/ Slip Road
11+806	13+394	9+406	10+994	1588	10.75	Both sides	Service Road
13+394	13+528	10+994	11+128	134	9.25	Both sides	Service Road/ Slip Road
13+528	14+680	11+128	12+280	1152	9.25	Both sides	Service Road
14+680	15+040	12+280	12+640	360	10.75	Both sides	Service Road
15+790	17+254	13+390	14+854	1464	10.75	Both sides	Service Road/ Slip Road
17+254	17+810	14+854	15+410	556	10.75	Both sides	Service Road
17+810	18+822	15+410	16+422	1012	10.75	Both sides	Service Road/ Slip Road
18+822	21+460	16+422	19+060	2638	10.75	Both sides	Service Road
21+460	21+611	19+060	19+211	151	10.75	Both sides	Service Road/ Slip Road
21+611	22+325	19+211	19+925	714	10.75	Both sides	Service Road

Existing Chainage		Design Chainage		Length (m)	Details of Service Road		
From	To	From	To		Total width (m)	Side	Type
22+325	22+472	19+925	20+072	147	10.75	Both sides	Service Road/ Slip Road
22+472	23+100	20+072	20+700	628	10.25	Both sides	Service Road
23+100	24+400	20+700	22+000	1300	10.75	Both sides	Service Road

*Length of taper portion of entry and exit are not included.

8.4 HOMOGENEOUS SECTIONS FOR PAVEMENT DESIGN

8.4.1. Analysis of Unit Delineation by Cumulative Differences

A relative and straight forward and powerful analytical method for delineating statistically homogeneous units from pavement response measurements along a highway system is the cumulative difference approach. The method is fundamentally easy to visualize. This approach is adopted because it is readily adaptable to computerized solution and graphic analysis. This approach can be used for a wide variety of measured pavement response variables. In order to delineate a pavement length, an attempt is made to isolate each unique factor influencing potential pavement performance. Performance factors considered for delineating a pavement length follows:

- CBR
- Pavement Condition (Cracking and Rutting)
- Traffic
- Pavement Deflection

The project road has been divided into one homogeneous road sections on the basis of traffic generation and dispersal nodes located along the project road. The important dispersal/generation locations identified along the project road include:

- Gurgaon (PWD R.D. – 2+400 / Design km 0+000)
- Major Junction at Sohna (PWD R.D 25+662 / Design km 23+257)

8.4.2. Homogeneous section for pavement design of widening of existing lane and new construction

Considering the above mentioned traffic generation/ distribution points and analysis of traffic data as given in Chapter 5, it was inferred that the total project stretch can be divided into one homogeneous section as stated below from the traffic point of view.

Homogeneous Section	Description	Existing Length in Km
I	Km 9+282 to 22+000	12.718

The CBR and traffic volume parameters are considered in unit delineation of project corridor for the pavement design for widening portions and new construction. The selection parameters and sections are presented in **Figure 8.13** and **Fig. 8.14** separately for left and right carriageway and final sections adopted are given in **Table 8.4**.

Table 8.4: Homogeneous Sections for Pavement Design of Widening of Existing Lane

Design Chainage		Length (km)	Homogeneous Section
From	To		
GURGAON – SOHNA (LEFT CARRIAGEWAY)			
9+282	22+000	12.718	I
SOHNA – GURGAON (RIGHT CARRIAGEWAY)			
9+282	22+000	12.718	I

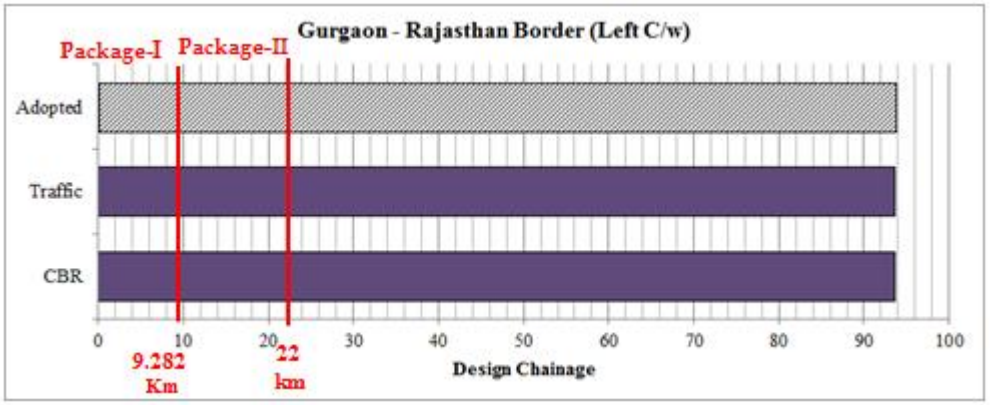


Figure 8.13: Homogeneous Sections for Pavement Design for Widening on Left Side

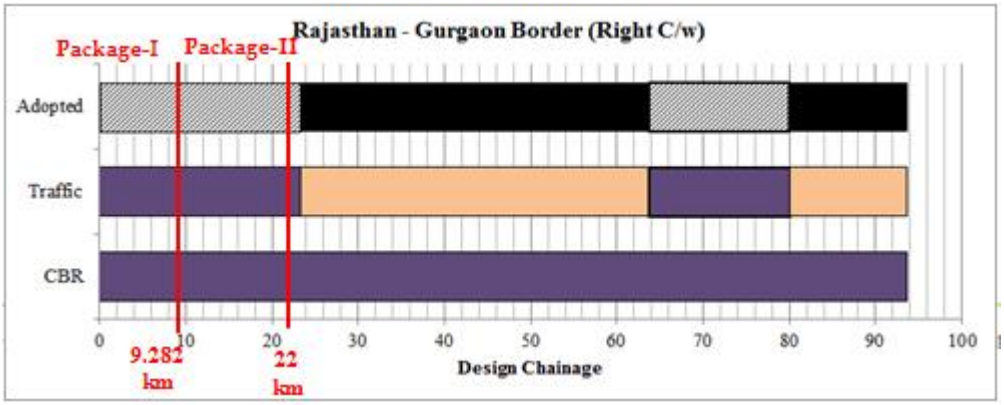


Figure 8.14: Homogeneous Sections for Pavement Design for Widening on Right Side

8.4.3. Homogeneous section for overlay and reconstruction of existing lane

The characteristic deflection, pavement condition and traffic volume is considered in unit delineation of project corridor for overlay design. The selection parameters and sections are presented in **Figure 8.15** and **Fig. 8.16** separately for left and right carriageway and final sections adopted are given in **Table 8.5**.

Table 8.5: Homogeneous Sections for Overlay of Existing Lane

Design Chainage		Length (km)	Section
From	To		
GURGAON – SOHNA (LEFT CARRIAGEWAY)			
9+282	11+128	1.846	I
11+128	22+000	10.872	II
SOHNA – GURGAON (RIGHT CARRIAGEWAY)			
9+282	19+000	9.718	I
19+000	19+112	0.112	II
19+112	22+000	2.888	III

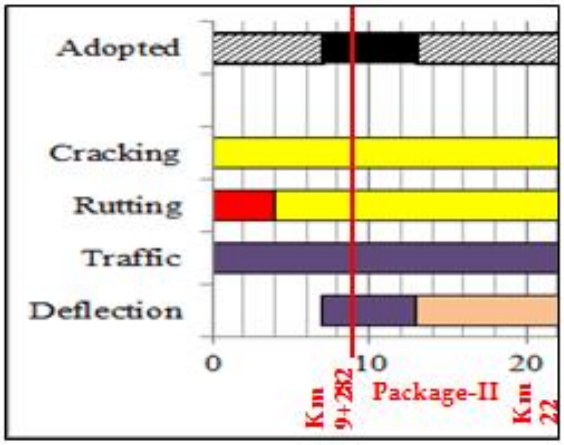


Figure 8.15: Homogeneous Sections for Pavement Design for Overlay / Reconstruction on Left Side

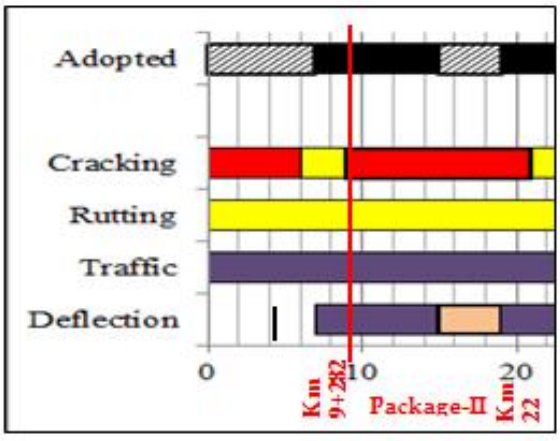


Figure 8.16: Homogeneous Sections for Pavement Design for Overlay / Reconstruction on Right Side

8.5 PAVEMENT OPTIONS

Pavement is the most significant component of a road and therefore its design strengths must be assured to support the projected traffic loading throughout the design period. The cost of pavement represents largest proportion of the total construction cost (i.e. about 40% for new roads and about 60% for rehabilitation projects).

The purpose of the pavement study is to make analysis of different pavement alternatives to provide a basis for selection of the most advantage solution, considering all costs occurring during the life of the pavement, viz., construction costs, maintenance costs and costs for the road users.

In pavement option study, the following would be studied in detail:

- New flexible pavement on the widening part and for full reconstruction stretches
- Flexible overlay over the existing pavement
- Flexible Pavement for partial reconstruction stretches of existing pavement.
- Flexible pavement with rigid base

The different pavement design methods for above pavement options shall be studied and applied, which are given in **Table 8.6**.

Table 8.6: Pavement Design Methods

Pavement Option	Option Type	Design Method
1	New Flexible Pavement	IRC: 37-2012
2	Flexible Overlay	IRC: 81-1997
3	New Rigid Pavement	IRC: 58-2015

8.5.1. Life cycle costing analysis of Pavement

The choice of the appropriate economically advantageous pavement type, flexible or rigid, is made by carrying out Life Cycle Cost (LCC) analysis which takes into account the initial investment cost and also the maintenance/rehabilitation cost over the design life of the pavement structure. Life cycle cost analysis can be defined as a procedure by which a pavement design alternative will be selected, which will provide a satisfactory level of service at the lowest cost over design life. The economic analysis methods used most commonly for this purpose include present worth, annualized cost, and rate of return. The analysis is most sensitive to the factors of inflation, discount rate, and analysis period.

In the subsequent paragraphs, an attempt has been made to study the long-term economic viability of pavement types using Present-Worth method of analysis. Thus, comparative cost of one kilometre each of flexible pavement and rigid pavement representing a uniform section has been worked out at current market rate, with respective maintenance strategy.

Cost of Construction per km:

The cost of construction of flexible and rigid pavement has been calculated for 1 km section of road. The cost has been given below in tables:

Flexible pavement

Material Type	Thickness (mm)	Width (m)	Length (m)	Qty (m^3)	Unit Rate/m^3	Cost per km
BC	50	26	1000	1300	8014	10,418,200
DBM	50	26	1000	1300	7210	9,373,000
AIL	100	26	1000	2600	2101	5,462,600
CTB	150	26	1000	3900	2992	11,668,800
CTSB	250	26	1000	6500	2746	17,849,000
Subgrade	500	26	1000	13000	293	3,809,000
Prime Coat		26	1000	26000	22	572,000
Tack Coat		26	1000	26000	11	286,000
					Total	**59,438,600**

Rigid pavement

Material Type	Thickness (mm)	Width (m)	Length (m)	Qty (m^3)	Unit Rate/m^3	Cost per km
Pavement Quality Concrete (M-40)	350	26	1000	9100	7587	69,041,700
Dry Lean Concrete (M-10)	150	26	1000	3900	3533	13,778,700
Granular Sub-base	150	26	1000	3900	2101	8,193,900
Subgrade	500	26	1000	13000	293	3,809,000
					Total	**94,823,300**

Maintenance Cost

It is assumed that as a functional overlay, one layer of 40 mm BC will be laid on 5^{th} and 10^{th} year after construction of road. The average yearly maintenance cost of Flexible pavement and Rigid pavement is assumed as 6lac/yr./km and 3lac/yr./km respectively. The cost of Functional overlay is given below:

Functional overlay

Material Type	Thickness	width	length	qty	Unit Rate	Cost
Bituminous Course	40	25	1000	1000	8014	8,014,000
Tack Coat		25	1000	25000	11	275,000
					Total	**8,289,000**

Life Cycle Cost Analysis

Period of analysis has been considered same as the design life of flexible pavement i.e. 15 years. The discount rate of 12% has been taken. Inflation rate of 5% has been considered for future rise in prices of materials.

The details of economic analysis based on net present worth method i.e. net present value of total of construction, maintenance cost, over the analysis period of 15 years are provided in Table given below for flexible and rigid pavement. The summary of Initial and Life Cycle Costs are given below:

Data Assumption:

Analysis Period = 15 Years

Discount Rate = 12%

Inflation Rate = 5% per Year

Table 8.7: Life cycle cost analysis

Years	Flexible Pavement			Rigid pavement		
	Construction cost (Cr.)	Maintenance cost (Cr.)	NPV	Construction cost(Cr.)	Maintenance cost (Cr.)	NPV
0	5.94	0	5.94	9.48	0	9.48
1		0.06	0.06		0.03	0.03
2		0.07	0.06		0.03	0.03
3		0.07	0.05		0.04	0.03
4		0.08	0.05		0.04	0.02
5		1.06	0.60		0.04	0.02
6		0.08	0.04		0.04	0.02
7		0.09	0.04		0.04	0.02
8		0.09	0.04		0.05	0.02
9		0.10	0.04		0.05	0.02
10		1.35	0.43		0.05	0.02
11		0.11	0.03		0.05	0.02
12		0.11	0.03		0.06	0.01
13		0.12	0.03		0.06	0.01
14		0.12	0.03		0.06	0.01
15		0.13	0.02		0.07	0.01
	Total NPV cost		7.48	**Total NPV cost**		9.77

Life Cycle cost of rigid pavement will be about 31% higher than flexible pavement after 15 years. From the above it can be concluded that flexible pavement can serve satisfactorily economical for 15 years with nominal maintenance.

8.5.2. IRC: 37-2012 Method of Flexible Pavement Design –Widening and for New construction

The basic objective of pavement design is to increase the fatigue life of pavement by restricting the tensile strain caused by traffic in the bituminous layer to 70 micro strains and also to construct rut resistant pavement by limiting the vertical subgrade strain to 200 micro strain during the design life. This is ensured following the guidelines laid down in IRC: 37-2012.

Design Life

For the design of pavement, the design life is defined in terms of the cumulative number of standard axles that can be carried before strengthening of the pavement is necessary.

It is recommended that pavements for National Highways should be designed for a life of 15 years in IRC: 37-2012. However, to enhance the financial viability of the project, pavement design in stages is not adopted satisfying the following minimum design requirements:

The thickness of sub-base and base layers is designed for a minimum design period of 15 years and the initial bituminous surfacing for a minimum design period of 15 years. Stage construction shall not be permitted for pavement design.

Vehicle Damage Factors

The vehicle damage factor is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration to the number of standard axle load repetitions. It is defined as equivalent number of standard axle per commercial vehicle. The VDF varies with the vehicle axle configuration, axle loading, terrain, type of road and direction of travel. The vehicle damage factors arrived and as presented Section 6.3 of Chapter 6: Engineering Survey and Investigation and adopted are presented in Table 8.8A.

Table 8.8A: Vehicle Damage Factors adopted for the Design

Vehicle Type	Gurgaon to Sohna (Left c/w)	Sohna to Gurgaon (Right C/w)
Bus	1.61	1.11
LCV	2.55	2.97
2 Axle	4.79	11.52
3 Axle	5.20	22.04
M Axle	4.72	7.89

Design Traffic

The design traffic is considered in terms of the cumulative number of standard axles to be carried during the design life of the road. This can be computed using the following equation:

$$N = \frac{365 * [(1+r)^n - 1] * A * D * F}{r}$$

Where,

N=the cumulative number of standard axles to be catered for in the design in terms of msa

A=Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day

D=Lane distribution factor

F=Vehicle damage factor

n=Design life in years

r=Annual growth rate of commercial vehicles

The traffic has been used from the projected traffic computed in Chapter 5.0.

For 4-lane section the directional distribution and lane distribution of traffic is assumed to be 0.5 and 0.75 respectively. While for 6-lane section the directional and lane distribution factor is assumed as 0.5 and 0.6 respectively.

The design traffic is then computed for design life location wise is presented in **Annexure 8.1**. The design traffic obtained for each homogeneous section is presented in Table 8.8B.

Table 8.8B: Design Traffic in Million Standard Axles

Homogeneous Section	Design Chainage		Length (km)	Design MSA		
				Gurgaon - Sohna (Left C/w)	Sohna – Gurgaon (Right C/w)	
	From	To		15 years	10 years	15 years
I	9+282	22+000	12.718	51	75	133

CBR Value

The 90 percentile CBR value of borrow earth to be used as subgrade material is considered as 10% (refer Table 6.17A of Chapter 6: Engineering Survey and Investigations). As per site condition the subgrade on the widened portion will be mostly laid on the existing ground. As the average CBR of the existing ground is found to be 8%, **the effective CBR of the subgrade considered in design is 9%.** Therefore during construction it is to be ensured that minimum 500mm thick existing ground is recompacted to achieve minimum CBR of 8%.

Pavement Materials

The general specification sections and characterization of material is presented in Table 8.9.

Table 8.9: Materials Specification and Characterisation

Sl. No.	Pavement Layers and Materials	Sections Details	Remarks
1	Embankment Construction	Section 305	Minimum Soaked CBR 8%
2	Subgrade	Section 305	Minimum Soaked CBR 10%
3	Granular Sub-base Upper Layer Lower Layer	Section 401	Minimum compacted thickness 100mm Grading I of Table 400-1 Grading I of Table 400-2
4	Base Course-WMM	Section 406	Thickness of single layer shall be 75mm-200mm
5	Cement Treated Base	Section 403	
6	Cement Treated Sub-base	Section 403	
7	Prime Coat	Section 502	
8	Tack Coat	Section 503	
9	Bituminous Macadam	Section 504	Thickness of single layer shall be 50mm-

Sl. No.	Pavement Layers and Materials	Sections Details	Remarks
			100mm
10	Dense Bituminous Macadam	Section 507	Thickness of single layer shall be 50mm-100mm
11	Bituminous Concrete	Section 512	Thickness of single layer shall be 50mm for Grade-1 and 30-40mm for Grade-2
12	Dry Lean concrete	Section 601	Thickness of single layer shall be 100 mm and 150 mm
13	Pavement Quality Concrete	Section 602	Minimum compacted thickness of 140mm

The project road being heavily loaded in one direction (Sohna to Gurgaon – right carriageway) and lightly loaded on the other (Gurgaon to Sohna – left carriageway), Consultant has designed the pavement based on direction of travel. Besides, flexible pavement with both WMM + GSB i.e. flexible base and cement treated based (CTB) and cement treated subbase (CTSB) i.e. rigid base have been explored for the heavily loaded right carriageway. Based on the cost the pavement option has been decided. The section below discusses on these two pavement options.

Flexible Pavement with WMM and GSB

The flexible pavement with flexible base has been designed as a three layered system consisting of typical component layers, namely subgrade, sub-base & base course (granular) and binder & surface course (bituminous).

As per IRC: 37-2012 VG 40 grade bitumen is recommended for bituminous course where traffic exceeds 30MSA. Although the left carriageway has traffic less than 30MSA the right carriageway has traffic much higher than 30MSA. Hence to keep uniformity of the viscosity grade of bitumen for the project, VG 40 grade is adopted in design of both the carriageways.

Using the IITPAVE software, the flexible pavement thicknesses required for pavement widening and new pavement of stretches have been designed and is given in **Table 8.10A**.The detailed analysis is given in ***Annexure 8.2.***

Existing ground to be checked for suitability and loosened recompacted to desired MDD and CBR.

Table 8.10A: Flexible Pavement Thickness with WMM + GSB for Widening of Existing Lane, New pavement and Reconstruction Stretches

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Pavement Thickness (mm)							
					Gurgaon - Sohna (LEFT C/W)				Sohna - Gurgaon (RIGHT C/W)			
	From	To			BC	DBM	WMM	GSB	BC	DBM	WMM	GSB
I	9+282	22+000	12.718	9%	40	95	250	200	50	125	250	200

Flexible Pavement with CTB and CTSB

The flexible pavement with rigid base has been designed as a five layered system consisting of five layers, namely subgrade, cement treated sub-base (CTSB), cement treated base course

(CTB), an aggregate interlayer (AIL) and bituminous layer (binder & surface course). This option is explored for the heavily loaded right carriageway only.

Using IITPAVE software and carrying out cumulative fatigue damage analysis for rigid base, the 5 layer system has been designed for widening on right side or reconstruction / new construction of right carriageway only. The same is presented in **Table 8.10B**.The detailed analysis has been presented in **Annexure 8.3**.

Table 8.10B: Flexible Pavement Thickness with CTB + CTSB for New Right carriageway and Reconstruction of existing right carriageway only

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Pavement Thickness (mm)				
					Sohna – Gurgaon (RIGHT C/W)				
	From	To			BC	DBM	Aggregate Interlayer (AIL)	CTB	CTSB
I	9+282	22+000	12.718	9%	50	50	100	150	250

In order to compare the cost of the above two pavement options for new / reconstruction of right carriageway, the cost of new 1km of flexible pavement on one carriageway + paved shoulder (width – 9m) with flexible base and rigid base have been analyzed. The rate of each pavement layer as considered in the analysis is presented in Table 8.11A and the comparison of the cost of the pavement options for each homogeneous section for right carriageway is presented in Table 8.11B.

Table 8.11A: Rate of different Pavement Layer

Item	Unit	Rate (Rs.)
BC	cum	8014
DBM	cum	7210
WMM	cum	2290
GSB	cum	2101
CTB	cum	2992
CTSB	cum	2746
Aggregate Interlayer	cum	2101

Table 8.11B: Comparative Analysis of Cost of 1km and 9m wide Flexible Pavement with flexible and rigid base

HS	Design Chainage		Length (km)	Cost (in Cr./km/carriageway)	
				Flexible Base (WMM+GSB)	Rigid Base (Aggregate Interlayer + CTB + CTSB)
	From	To			
I	9+282	22+000	12.718	2.07	1.90

Hence from the above it is evident that flexible pavement with rigid base is more economical. Hence Consultant proposes flexible pavement with rigid base for construction of new and reconstruction of right carriageway of the project road section. However where existing right carriageway has been proposed for overlay and is being widened to accommodate additional lane and paved shoulder, the same is proposed to be carried out using flexible base.

Hence based on the above the pavement thickness adopted for left and right carriageway are presented in **Table 8.12A** and **Table 8.12B** respectively below:

Table 8.12A: ADOPTED Flexible Pavement Thickness for Widening/New/Reconstruction of Left Carriageway (Gurgaon – Sohna)

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Design MSA (15 years)	Pavement Thickness (mm)			
						Gurgaon - Raj Border (LEFT C/W)			
	From	To				BC	DBM	WMM	GSB
I	9+282	22+000	12.718	9%	51	40	95	250	200

Table 8.12B: ADOPTED Flexible Pavement Thickness for Widening/New/Reconstruction of Right Carriageway (Sohna - Gurgaon)

HS	Design Chainage		Length (km)	Effective Subgrade CBR	Design MSA		Pavement Thickness (mm)								
							Raj Border - Gurgaon (RIGHT C/W)								
							Widening of Existing Right C/w with Overlay				New / Reconstruction of Right C/w				
	From	To			10 years	15 years	BC	DBM	WMM	GSB	BC	DBM	AIL	CTB	CTSB
I	9+282	22+000	12.718	9%	75	133	50	125	250	200	50	50	100	150	250

8.5.3. IRC: 81-1997 Method of Flexible Overlay – For Strengthening of Existing Pavement

The average characteristic deflection (Dc) values to be used for design purposes have been worked from BBD survey. The design traffic in terms of cumulative standard number of axle with respect to homogeneous traffic sections is already given in **Table 8.18**. The thicknesses are deduced from Figure 9 of IRC 81-1997 in terms of bituminous macadam construction. Since the materials specified in wearing course of widening portion are BC/DBM, the thicknesses obtained in terms of BM should be determined using equivalency factors:

1cm of Bituminous Macadam = 1.5cm of WBM/Wet Mix Macadam/BUSG

1cm of Bituminous Macadam = 0.7cm of DBM/BC

The overlay thickness calculated and proposed is presented in **Table 8.13**.

Table 8.13: Proposed Overlay Thicknesses on existing lane

Design Chainage		Characteristic Deflection		Design MSA		Equivalent BM Thickness as per IRC-81		Equivalent (DBM+BC) thickness (mm) as per IRC - 81		Proposed Overlay Thickness (mm)			
										Left C/w		Right C/w	
From	To	Left C/w	Right C/w	Left C/w	Right C/w	Left C/w	Right C/w	Left C/w	Right C/w	BC	DBM	BC	DBM
9+282	11+128	Reconstruction of pavement / flyover / viaduct											
11+128	12+000	1.31	0.63	51	133	147.01	88.51	102.907	62.0	40	65	50	50
12+000	12+641	0.39	0.7	51	133	0	115.04	0	80.5	40	0	50	50
12+641	13+390	Reconstruction of pavement / flyover / viaduct/toll plaza											
13+390	13+853	0.35	0.69	51	133	0	111.25	0	77.9	40	0	50	50
13+853	14+854	Reconstruction of pavement / flyover / viaduct											
14+854	15+000	0.55	0.38	51	133	16.86	0	11.802	0.0	40	0	50	0
15+000	15+410	0.45	0.51	51	133	5.62	42.43	3.934	29.7	40	0	50	0
15+410	16+422	Reconstruction of pavement / flyover / viaduct											
16+422	17+000	0.43	0.23	51	133	3.37	0	2.359	0.0	40	0	50	0
17+000	18+000	0.49	0.23	51	133	10.11	0	7.077	0.0	40	0	50	0
18+000	19+000	0.46	0.52	51	133	6.74	46.28	4.718	32.4	40	0	50	0
19+000	19+060	0.46	0.99	51	133	6.74	190.86	4.718	133.6	40	0	50	85
19+060	20+072	Reconstruction of pavement / flyover / viaduct											
20+072	21+000	0.51	0.38	51	133	12.36	0	8.652	0.0	40	0	50	0
21+000	22+000	0.14	0.62	51	133	24.68	84.72	17.276	59.3	40	0	50	50

8.5.4. IRC: 58-2012 Method of Rigid Pavement Design

Rigid pavement for new carriageway has been designed as per IRC: 58-2012 for Toll plaza location.

Wheel Load

A tyre pressure of 8 kg/cm^2 may be adopted for the design.

For important roads, such as Expressways, National Highways and other roads where there will be uninterrupted traffic flow and high volume of truck traffic, the suggested value of Load Safety Factor (LSF) is 1.2. For roads of lesser importance having lower proportion of truck traffic, LSF may be taken as 1.1. For residential and other streets that carry small number of commercial traffic, the LSF may be taken as 1.0.

It is recommended that the basic design of the slab be done with a 98th percentile axle load, and the design thereafter checked by for fatigue consumption for higher axle loads.

Design Period

Normally, cement concrete pavements have a life span of 30 years and should be designed for this period.

Design Traffic

Design traffic of 25 per cent of the total two- lane two-way commercial vehicles may be considered as a very conservative estimate for design against fatigue failure. In case of four-lane and multi-lane divided highways, 25 per cent of the total traffic in the direction of predominant traffic may be taken for design of pavement.

Temperature Differential

Temperature differential between the top and bottom of pavements causes the concrete slab to warp, giving rise to stresses. For this purpose, guidance may be had from **Table 8.14**.

Table 8.14: Recommended Temperature Differentials for Concrete

Zone	States	Temperatures Differentials, ^{0}C in Slabs of Thickness			
		15cm	20cm	25cm	30cm
I	Punjab, U.P., Uttaranchal, Gujarat, Rajasthan, Haryana and North M.P., excluding hilly regions.	12.5	13.1	14.3	15.8

Characteristics of Subgrade and Sub-Base

The strength of subgrade is expressed in terms of modulus of subgrade reaction k, which is defined as pressure per unit deflection of the foundation as determined by plate bearing tests. An approximate idea of k-value of a homogeneous soil subgrade may be obtained from its soaked CBR value-using **Table 8.15**.

Table 8.15: Approximate k-value corresponding to CBR Values for Homogeneous Soil Subgrade

Soaked CBR Value %	2	3	4	5	7	10	15	20	50	100
k-value (kg/cm^2/cm)	2.1	2.8	3.5	4.2	4.8	5.5	6.2	6.9	14.0	22.2

The approximate increase in k-values of subgrade due to different thicknesses of sub-bases made up of untreated granular, cement treated granular material and dry lean concrete (DLC) layers may be taken from **Tables 8.16** and **8.17**. Unconfined compressive strength of cement treated granular material should be a minimum of 2.1 MPa and compressive strength of DLC should be 7 MPa at 7 days.

Table 8.16: k-Values over Granular and Cement Treated Sub-bases

k-value (kg/cm^2/cm)	**Effective k (kg/cm^2/cm) over untreated granular layer sub-base of thickness in cm**			**Effective k (kg/cm^2/cm) over cement treated sub-base of thickness in cm**		
	15	**22.5**	**30**	**10**	**15**	**20**
2.8	3.9	4.4	5.3	7.6	10.8	14.1
5.6	6.3	7.5	8.8	12.7	17.3	22.5
8.4	9.2	10.2	11.9	-	-	-

Table 8.17: k-Values over Dry Lean Concrete Sub-base

k-value of Subgrade (kg/cm^2/cm)	2.1	2.8	4.2	4.8	5.5	6.2
Effective k over 100 mm DLC, (kg/cm^2/cm)	5.6	9.7	16.6	20.8	27.8	38.9
Effective k over 150 mm DLC, (kg/cm^2/cm)	9.7	13.8	20.8	27.7	41.7	-

Separation Layer between sub-base and pavement:

Foundation layer below concrete slabs should be smooth to reduce the inter layer friction. A separation membrane of minimum thickness of 125 micron polythene is recommended to reduce the friction (Ref. IRC: 15-2002) between concrete slabs and dry lean concrete sub-base (DLC).

Drainage Layer

In order to facilitate quick disposal of water that is likely to enter subgrade, a drainage layer of 150mm thick GSB has been considered as per IRC: 15-2002.

Characteristics of Concrete

Flexural strength of plain concrete as per IS: 456-1978 is given as

$$f_{cr} = 0.7x\sqrt{f_{ck}}$$

Where f_{cr} = flexural strength (modulus of rupture), N/mm^2

f_{ck} = Characteristic compressive cube strength concrete, N/mm^2

According to Croney and Croney,

f_{cr} = 0.49 x fck0.55 for gravel aggregates and

f_{cr} = 0.36 x fck0.7 for crushed aggregates

For M-40 concrete, fcr values from the above three equations are obtained as 44.27 (IS: 456), 37.26 (gravel) and 47.61 kg/cm2 (crushed rock) respectively. Hence a flexural strength of 45 kg/cm2 is recommended for M-40 concrete.

The recommended value of modulus of elasticity of pavement concrete is 3x105 kg/cm2. Pavement concrete is subjected to dynamic loading and the ratio of static and dynamic moduli on the same concrete is found as 0.8. The modulus value increases both with age and strength but the variation is small.

A Poisson's Ratio of 0.15 is considered.

The coefficient of thermal expansion of concrete (Alpha) of the same mix proportions varies with the type of aggregate. However, for design purpose, a value of (Alpha) = I0XI0-6 per 0C may be adopted in all cases.

The ratio between the flexural stress due to the load and the flexural strength of concrete is termed as the stress ratio (SR). If the SR is less than 0.45, the concrete is expected to sustain infinite number of repetitions. As the stress ratio increases, the number of load repetitions required to cause cracking decreases. The relation between fatigue life (N) and stress ratio is given as:

N= unlimited for SR< 0.45

$$N = \left[\frac{4.2577}{SR - 0.4325}\right]^{3.268} \quad \text{When } 0.45 \leq SR \leq 0.55$$

$$\text{Log } N = \left[\frac{0.9718 - SR}{0.0828}\right] \quad \text{for SR} > 0.55$$

The designed thickness obtained from IRC 58-2015 for rigid pavement sections is presented in **Table 8.18**. The design calculations are given in **Annexure 8.4**.

Table 8.18: Proposed Rigid Pavement Thickness for Main Carriageway

Material Type	Thickness (mm)	
	Left Carriageway	Right Carriageway
Pavement Quality Concrete (M-40)	300	350
Dry Lean Concrete (M-10)	150	150
Granular Sub-base	200	150
Subgrade	500	500

8.6 JUNCTIONS DESIGN

Road junction/intersection is a key element of highway design. The efficiency, safety, speed, cost of operation and capacity of road system depends very much on the intersection design. The choice between an at-grade and grade separated junctions at a particular site depends upon various factors such as traffic, economy, safety, aesthetic delay etc. Grade separated junctions generally are more expensive initially and are justified in certain situations. The main objective of intersection design is to reduce the severity of potential conflicts between motor vehicles, buses, trucks, bicycles, pedestrians and facilities while facilitating the convenience, ease, safety and comfort of people traversing the intersections. The design should be fitted closely to the natural transitional paths and operating characteristics of the users.

Design of a safe intersection depends on many factors as given below:

- Human factors
- Traffic considerations (mainly design hour turning movements, type of movement and vehicle speeds)
- Road and environmental considerations (sight distance, conflict area, geometric features)
- Economic factors.

Generally intersections can be classified in to three categories depending on the traffic conditions. These are

- Uncontrolled intersections at-grade;
- Intersections with Priority Control;
- Time separated / signalised intersection at-grade;
- Space separated intersections/Grade separated intersections

8.6.1. General Criterion for improvement proposal at junctions

- *A signalised intersection besides other warrants is justified if the major street has a traffic volume of 650 to 800 vehicles per hour (both directions) and Minor Street has 200 to 250 vehicles per hour in one direction only. The detailed warrants for signalised intersection are laid down as per IRC: 93-1985.*
- *The vehicular under/overpass structures will be provided at the intersection of the Project Highway with all the National Highways and State Highways. Such under/over passes will also be provided across other categories of roads carrying an average daily traffic of more than 5000 PCUs on the date of inviting bids.(As per Clause:2.13.2, IRC:SP:84-2009)*
- *An interchange, besides any overriding necessity, is justified when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour. The detailed warrants for interchanges are given in IRC: 92-1985.*

The turning movement surveys for estimation of peak hour traffic for the design of major intersection have been carried out. The details regarding composition and directional movement of traffic is furnished in **Chapter 5.** The data derived from surveys were analysed to identify requirements of suitable remedial measures, such as construction of underpasses, flyovers, interchanges, and grade-separated intersections along the project road alignment.

The geometric design of junctions has been done taking in to account the site conditions, turning movement characteristics, level of services, overall economy and operational safety.

8.6.2. Details of Junctions Improvement Proposal

Existing 4 major and 10 minor junctions are proposed to be improved as a part of upgradation project. Cross roads with paved carriageway are only considered for development of the junction. The junction improvement plan for junctions is listed in Table given below:

Table 8.19: Existing junction Improvement Proposal

Sl. No.	PWD RD	Design Chainage	Junction Type		LHS				RHS				Remarks
					Type	Width	Leads	Proposal	Type	Width	Leads	Proposal	
1	12+181	9+781	**T**	**Major**	BT	4.50	Maruti Kunj	**Flyover**					**Maruti Kunj road junction**
2	13+019	10+619	T	Minor					BT	2x14.5	Bhondsi	**Flyover**	Bhondsi
3	14+150	11+750	**T**	**Major**	BT	5.30	Ritroj road	**At grade**					**Proposed junction with Bhondsi-Silani permit line**
4	16+305	13+905	T	Minor	BT	3.80	Mahendwara	At-grade					
5	16+725	14+325	T	**Major**					BT	3.90	Ghamroj	**VUP**	
6	18+286	15+886	Y	Minor					BT	3.70	Alipur	**Flyover**	Staggered junction
7	18+336	15+936	T	Minor	BT	5.00	Garhi Bazidpur	**Flyover**					
8	19+800	17+400	Y	Minor					BT	5.70	Raiseena	At-grade	
9	20+212	17+812	T	Minor	BT	3.80	Berka	At-grade					
10	21+950	19+550	T	Major					BT	5.30	Mohamadpur Gurjar	**Flyover**	
11	22+675	20+275	T	Minor	Gr.	3.00	Village	At-grade					
12	24+010	21+610	Y	Minor					BT	5.50	Sohna	At-grade	Maharaja Agrasen road
13	24+120	21+720	Y	Minor	BT	3.50	Berka	At-grade					
14	24+370	21+970	T	Minor					BT	5.20	Sohna	At-grade	

8.7 DESIGN OF BRIDGES/ELEVATED STRUCTURES

8.7.1. Existing Bridges

There are no major bridge and 2 minor bridges on the project road. The existing bridges are on natural streams, nallahs and canals. All are slab bridges.

Following criteria are checked to assess the requirement/possibility of widening and reconstruction of the existing bridges:

- Overall width of the structure
- All existing bridges which are structurally distressed shall be reconstructed as new bridge
- All existing brick arch bridge if any shall be dismantled and replaced by a new bridge
- Based on inventory and condition survey of the existing bridges, following proposals have been prepared

8.7.2. Proposal of New Bridges

The development proposal of the widening of existing and new bridges have been prepared and tabulated in **Table 8.20**.

Span arrangement

In general, The proposed span arrangement for widening of existing bridges are kept same as existing where there is no signs of hydraulic inadequacy.

Proposed structures under the category of reconstruction due to poor condition or lesser carriageway are more or less with the same span as existing.

The new bridges which are proposed at submerged location are fixed with span arrangement based on preliminary hydraulic investigation. The detailed hydraulic calculation will be presented during detailed design.

The proposed span arrangement at these locations is given below.

Foundation

The type and depth of foundation will be established during detailed design as per the geo-technical report.

Carriageway width

The carriageway width of proposed structures is kept as per the cross-sections given in IRC manual specified for six lane.

Table 8.20: Development Scheme of Bridges

Details of Existing Structures								Development Proposal			
Sl. No.	**Existing Chainage**	**Design Chainage**	**No of Spans**	**Clear Span/ Dia (m)**	**Total width (m)**	**Superstructure Type**	**Condition**	**Proposal**	**Proposed span (Clear span)**	**Proposed Structure type**	**Total Width**
1	15+855	13+455	1	1 x 10.80	20.50	RCC Solid slab	• Overall Condition is Satisfactory • RCC wall type Substructure	Concentric widening of each side for MCW	1 x 10.8	RCC BOX	27.5 for Main Carriageway+ 2 x 15.25 m for Service Road Bridges (Service road bridge includes service road of 10.75m width,3.5m wide footpath, pedestrian guard rail and crash barrier)
2	19+095	16+695	1	1x7.6	20.50	RCC Solid slab	•Structure in fair condition	Concentric widening	1x7.6	RCC Box	27.5 for Main Carriageway+ 2 x 15.25 m for Service Road Bridges (Service road bridge includes service road of 10.75m width,3.5m wide footpath, pedestrian guard rail and crash barrier)

8.7.3. Proposal of Elevated Structure/ Flyover/ Vehicular Underpass (VUP)

The project road being passing through heavily built-up location at many locations, no. of Flyovers and viaduct has been proposed. As per the requirements of IRC the maximum height of the RE wall has been restricted to 5m.Viaduct has been proposed when height exceeds 5m.

The list of Elevated Structure/ Flyover/ VUPs is tabulated in **Table 8.21** below.

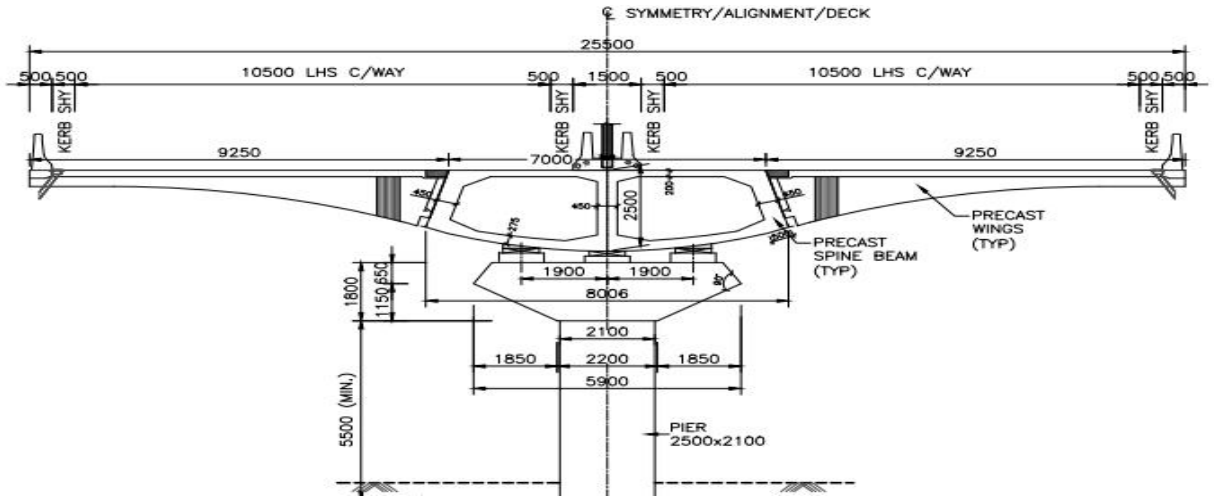


Fig: 8.17. Typical Cross section for 6-lane Elevated section

Table 8.21: Proposal for Elevated Structure/ Flyover/VUPs

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Span Arrangement	Proposed Structure	Total Width (m)	Vertical Clearance (m)	Remark
	From	To	From	To						
1	11+806	12+166	9+406	9+766	360	10x36.0m	Viaduct	25.5	As per Design Profile	Bhondsi
	12+181		9+781		30	1x30.0m	Elevated Structure	25.5	5.5	Bhondsi
	12+196	13+004	9+796	10+604	808	1x26.0+ 21x36.0+ 1x26.0m	Elevated Structure	25.5	5.5	Bhondsi
	13+019		10+619		30	1x30.0m	Elevated Structure	25.5	5.5	Bhondsi
	13+034	13+394	10+634	10+994	360	10x36.0m	Viaduct	25.5	As per Design Profile	Bhondsi
2	16+710	16+740	14+310	14+340	30	1x30.0m	VUP	25.5	5.5	Ghamroj Village
3	18+271	18+346	15+871	15+946	75	1x30.0+ 1x15.0+ 1x30.0m	Flyover	25.5	5.5 m	Alipur Villlage
4	21+611	21+935	19+211	19+535	324	9x36.0m	Viaduct	25.5	As per Design Profile	University area
	21+950		19+550		30	1x30.0m	Flyover	25.5	5.5 m	University area
	21+965	22+325	19+565	19+925	360	10x36.0m	Viaduct	25.5	As per Design Profile	University area

8.7.4. Proposal of Pedestrian facilities

Foot over bridges (FOB) has also been proposed where it is found necessary to facilitate safe pedestrian crossing. The FOB shall also facilitate crossing of the bike / cycle traffic. The proposed FOB are tabulated in **Table 8.22A.**

Table 8.22A: Proposal for Foot Over Bridge (FOB)

Sl. No.	Existing Chainage	Design Chainage	Type of Structure	Overall Length (m)	Clear width of FOB (m)	Vertical Clearance (m)	Remarks
1	21+100	18+700	Steel Structure with Ramps and elevators on both sides	71.0	5.0 (3m – Walkway + 2m-Bike lane)	5.5	Near under construction Residential Housing Society
2	22+500	20+100	Steel Structure with Ramps and elevators on both sides	65.0	5.0 (3m – Walkway + 2m-Bike lane)	5.5	Near GD Goenka University

Pedestrian facilities have been provided in accordance with IRC: 103-2012. Tactile paving on footpath has been proposed as per IRC: 103-2012. At every intersection it is proposed to provide kerb ramp to facilitate smooth transition from higher level to lower level. Kerb ramp is also proposed at the intersection of the footpath with the access to the private property.

Footpath shall be provided at locations given in Table 8.22B.

Table 8.22B: Footpath Location

Sl. No.	Design Chainage		Length (m)	Facilities	Width (m)	Side	Remarks
	From	To					
1	9+282	10+470	1188	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
2	10+470	10+570	100	Utility corridor-cum-Drain Cum Footpath	3.5 on RHS /1.5 m LHS	Both side	
3	10+570	10+994	424	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
4	10+994	11+128	134	Utility corridor-cum-Drain Cum Footpath	2.0	Both side	
5	11+128	12+640	1512	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
6	12+640	13+390	750	Utility corridor-cum-Drain Cum Footpath	2.0	Both side	Toll plaza
7	13+390	13+853	463	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	

Sl. No.	Design Chainage		Length (m)	Facilities	Width (m)	Side	Remarks
	From	To					
8	13+853	14+100	247	Utility corridor-cum-Drain Cum Footpath	4.5	Both side	
9	14+100	14+854	754	Utility corridor-cum-Drain Cum Footpath	3.0	Both side	
10	14+854	15+410	556	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
11	15+410	15+480	70	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
12	15+480	15+624	144	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
13	15+624	16+186	562	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
14	16+186	16+297	111	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
15	16+297	16+422	125	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
16	16+422	19+060	2638	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
17	19+060	19+105	45	Utility corridor-cum-Drain Cum Footpath	5.5	Both side	
18	19+105	19+211	106	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
19	19+211	19+925	714	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
20	19+925	19+990	65	Utility corridor-cum-Drain Cum Footpath	6.0	Both side	
21	19+990	20+700	710	Utility corridor-cum-Drain Cum Footpath	3.5	Both side	
22	20+700	21+700	1000	Utility corridor-cum-Drain Cum Footpath	5.0	Both side	
23	21+700	22+000	300	Utility corridor-cum-Drain Cum Footpath	5.5	Both side	

8.7.5. Improvement Proposal of Existing Culverts

There are total 13 culverts existing on the project road section. All existing culverts are either slab, box or pipe culverts having overall width equal or more than 12.0m. The summary of the proposal in presented in **Table 8.23** and the detailed development proposal is presented in **Table 8.24**.

Table 8.23: Summary of Development Proposal for Culverts

Proposal	No. of culvert	Remark
Retained	0	-
Reconstruction	5	Reconstruction as Box culvert
Widening	8	Box culvert
Total	13	

Table 8.24: Development Proposals for Culverts

Sl. No	PWD RD	Design Chainage	Existing			Development Proposed			
			Existing Structure	Total width (m)	Size(m) Span Arrangement (m)	(Retained / Widened / Reconstruction / New Construction)	Proposed Structure Type	Span Arrangement	Total Width (m)
1	13+130	10+730	Slab	30.1	1x4.0	Concentric Widening	Box	1x4.0m	55
2	14+268	11+868	Slab	20.5	1x1.5	Concentric Widening	Box	1x1.5m	53
3	14+736	12+336	Slab	20.5	1x1.5	Concentric Widening	Box	1x1.5m	56
4	16+500	14+100	Slab	20.5	1x1.5	Reconstruction	Box	1x1.5m	57
5	17+168	14+768	Slab	22	1x3.25	Reconstruction	Box	1x 3.5m	54
6	18+250	15+850	Slab	20.5	1x1.3	Reconstruction	Box	1x1.5m	58
7	18+357	15+957	RCC Box	20.5	1x1.2	Reconstruction	Box	1x1.5m	58
8	19+521	17+121	Slab	23.5	1x3.0	Concentric Widening	Box	1x3.0	60
9	20+313	17+913	Slab	23.5	1x3.0	Concentric Widening	Box	1x3.0	60
10	21+568	19+168	Slab	20.5	1x1.2	Reconstruction	Box	1x1.5m	58
11	22+585	20+185	Slab	20.5	1x1.3	Concentric Widening	Box	1x1.3	55
12	22+868	20+468	Slab	20.5	1x1.3	Concentric Widening	Box	1x1.3	55
13	23+768	21+368	Slab	36.5	1x1.5	Concentric Widening	Box	1x1.5	59

8.8 DRAINS

The location of RCC Cover drains are given in ***Table 8.25***:

Table 8.25: Location of RCC Cover Drain

Sl. No.	Existing Chainage		Design Chainage		Length (m)	Side	Remarks
	From	To	From	To			
1	11+682	24+400	9+282	22+000	12.718	Both	

8.9 RAINWATER HARVESTING SYSTEM

Rain water harvesting system shall be provided along the project highway at the following locations as per MOEF guidelines and IRC:SP:50-2013 and IRC:SP:42-2014..

Table 8.26: Location of Rain Water Harvesting

Sl. No.	Details such as Location/Interval/ Size	Remarks
1	At 500m interval staggered on both sides	
2	At 500 m interval beneath the elevated structure between the design chainage 9+796 to 10+994 (at Bhondsi). The location shall be decided in consultation with NHAI / IE.	
3	In rest area	

8.10 NOISE BARRIERS

Noise barriers to be installed both sides of elevated portion of Main Carriageway and also along the both sides of elevated portion service roads. Noise barriers shall comprise of 08 mm thick Polycarbonate sheet, GI pipe Structure, Aluminum Pressure pad profile, rubber gasket and other related accessories. Noise / sound barrier shall be provided on both sides of the main carriageway at following locations:

Table 8.27: Location of Noise / Sound Barrier

Sl. No.	Design Chainage		Length (m)	Side	Built up	Remarks
	From	To				
1	9+282	11+128	1846	Both	Bhondsi	Along both side of the elevated corridor including its approaches
2	19+112	20+021	909	Both	University	Along both side of the elevated corridor including its approaches
	Total		**2755**			

8.11 ANTIGLARE SCREEN

Anti-glare screen shall be provided in the median as shown in the TCS for enhancing road safety. Specifications of anti-glare screen shall be as per the following:

- Top of the Screen shall be atleast 1.8m above the finished road level
- Shall be able to block light at angles from 0° to 20°
- Shall be installed inclined to the median
- Spacing (D) and the angle of inclination (x) shall be decided on the basis of the curvature of the road following the equation and fig. given below:
  - Cut-off angle = 20°+Θ, as defined by National Cooperative Highway Research Program (NCHRP): 66, 1979
  - x = angle of inclination w.r.t. median centre line
  - Spacing of anti-glare screen (D) in meters = B x [cot (x) + cot(20°+Θ)],where
  - Θ = degree of curvature of road in degree = 1746 / R, where R = radius of median centerline in metres
  - B = width of the anti-glare screen in metres
- Shall be double sided along with retro-reflective marking along edges of both sides of the screen
- Shall be wear resistant, resistant against corrosion and UV radiation and can stand against most arduous traffic conditions
- Shall be acceptable at temperature between -10°C and +60°C
- The system structure shall be capable to withstand wind speed of 150 km/h
- Shall have no sharp edges and corners on which people can get hurt
- Easy to install
- Shall not discolor
- Aesthetically pleasing with green body to make the drive comfortable

8.12 CONCRETE BLOCK PAVING

Along the project highway CC block paving on either side shall be provided as per the typical cross-section.

8.13 ROAD FURNITURE AND OTHER FEATURES

8.13.1. Introduction

The road furniture, traffic safety features and other facilities included in the design are:

- Bus Bays

- Truck Lay byes
- Road Markings
- Traffic Signs
- Kilometre Stone Details
- 200m Stones and Boundary Stones
- Delineators and Object Markers
- Guard Post
- Crash Barrier
- Road Humps and Rumble Strips

8.13.2. Bus Bays and Bus Shelters

Bus Bays are proposed as per the recommendations of IRC: 80-1981. The typical bus bay consists of deceleration and acceleration lanes of 45m length with stopping lane of 5.0 m wide, 15m long in rural areas and 10m long in urban areas. A raised footpath of 2.0m wide is proposed for the safety of waiting passengers. In urban areas, where the frequency of buses stopping is more, the length of the stopping lane has been increased to 30m to accommodate two buses stopping at the same time. Adequate arrangements have also been made to drain off surface water. The nearby village/town sections where bus laybye with bus shelters on both sides of the 4-lane road are proposed are presented in **Table 8.28**.

Table 8.28: Locations of Bus Bays with Bus Shelter

Sl. No.	Existing Chainage	Design Chainage	Proposal	Near Builtup	Side
1	12+900	10+500	Bus Shelter Only	Bhondsi	Both
2	16+600	14+200	Bus Shelter Only	Ghamroj	Both
3	18+200	15+800	Bus Shelter Only	Alipur	Both

8.13.3. Truck Lay Byes

Local consultations were held at the places of petty repair shops, restaurants/dhaba etc. and subjective opinion of the drivers regarding necessity of truck lay bye is gathered. It consists of deceleration and acceleration lane of length 45.0m with central parking area of 150.0m length and 7.0m wide with 1.2m wide raised Kerb Island separating carriageway and Laybye. Sufficient working area and space for roadside establishments such as repair shops, vulcanising shops, service centre, spare parts shops, telephone booth and light refreshments with first aid facilities can be provided. One truck lay-byes on both sides have been proposed and its location is presented in **Table 8.29**.

Table 8.29: Locations of Truck Laybyes

Sl. No.	Existing Chainage	Design Chainage	Side	Straight Length (m)
1	17+438	15+038	Both side	100

8.13.4. Rest areas(Wayside Amenities)

Wayside amenities shall be provided at location given in Table 8.30, with minimum facilities as per para 12.6 of IRC: SP: 87. In approximately 2 Hectares of land, the following minimum facilities shall be provided:

Cafeteria/Restaurant for seating 50 persons; Toilets (separate for ladies and gents) (WC - 5 nos.; Urinals - 10 nos.); Dormitory with 20 beds; drinking water facility; parking for 100 trucks and 50 cars in addition to STD/ISD Telephone Facility, Shops and First Aid facilities.

Table 8.30: Location of Rest Areas

Sl. No.	Rest Areas to be constructed at Locations		Area to be developed in (Ha)	Side (LHS/RHS/ Both Sides)
	Existing Chainage	Design Chainage		
1.	16+150	13+750	2×2 Ha	Both sides

8.13.5. Road Markings

Road markings perform the important function of guiding and controlling traffic on a highway. The markings serve as psychological barriers and signify the delineation of traffic paths and their lateral clearance from traffic hazards for safe movement of traffic. Road markings are therefore essential to ensure smooth and orderly flow of traffic and to promote road safety. The Code of Practice for Road Markings, IRC: 35 has been used in the study as the design basis.

The location and type of marking lines, material and colour is followed using IRC: 35-"Code of Practice for Road Markings".

The road markings were carefully planned on carriageways, intersections and bridge locations.

8.13.6. Cautionary, Mandatory and Informatory Signs

Cautionary, mandatory and informatory signs have been provided depending on the situation and function they perform in accordance with the IRC: 67 guidelines for Road Signs.

8.13.7. Kilometre Stone Details

The details of kilometre stones are in accordance with IRC: 8 guidelines. Kilometre stones are located on the left-hand side of the road as one proceeds from the station from which the Kilometre count starts. On divided roads with a central median, kilometre stones would be provided at the left on both sides of the road i.e., independently for each direction of travel. Kilometre stones shall be fixed at right angles to the centre line of the carriageway.

8.13.8. 200m Stones and Boundary Stones

The details of 200m stones and boundary stones conform to IRC: 26 and IRC: 25. 200m stones are located on the same side of the road as the kilometre stones. The inscription on the stones shall be the numerals 2, 4, 6 and 8 marked in an ascending order in the direction of increasing kilometerage away from the starting station. The numerals shall be 80mm high. The colour of the numerals shall be black on a white background. Boundary stones shall be located on either side of the road opposite every 200m stone and kilometre stone. In addition these shall be fixed at all angular points of the boundary. Where the boundary is on a curve or the land is of significant value and likely to be encroached upon, the boundary stones, as required, shall be installed at closer intervals.

8.13.9. Delineators and Object Markers

Roadway delineators are intended to mark the edges of the roadway so as to guide drivers on the alignment ahead. Object markers are used to indicate hazards and obstructions within the vehicle flow path, for example, channelling islands close to the intersections.

Delineators and object markers are provided as per the details given in the drawings and are provided in accordance with the provisions of IRC: 79. They are basically driving aids and should not be regarded as substitutes for warning signs, road markings or barriers. Delineators are provided for all curves of radius less than 600m. They are not provided at locations where Chevron sign boards are provided.

8.13.10. Guard Post

Guard posts are proposed on embankments of height more than 1.0m, bridge approaches and horizontal curves of radius greater than 161m. The spacing of guard post shall be 2.0m c/c in these areas. Typical Guard post consists of precast (M20) post of size 200mm x 200mm and a height of 600mm above ground level. They are encased in M15 cement concrete for a depth of 450mm below ground level. Guard posts are painted with alternate black and white reflective paint of 150mm wide bands.

8.13.11. Crash Barrier

Metal Beam Crash Barrier is proposed at locations where the embankment height is more than 3.0m, at horizontal curves of radius less than 161m and also at major bridge approaches. Metal beam rail shall be W-profile corrugated sheet steel beams complying with the following mechanical properties.

i. Tensile strength, Min = 483 MPA

ii. Elongation in 2 inches, Min = 12%

iii. Yield, Min = 345 MPA

The beam elements shall have nominal width of 483mm. Post consists of formed channel of size 150 x 75 x 5, 785mm long and space consists of formed channel of size 150 x 75 x 5, 330 mm

long. All members of the system should be hot dipped galvanised to have a minimum counting of 550g/sqm, each face in compliance to relevant MOST Specification (Cl. 810). The spacing of posts should be 2.0m c/c. Crash barrier system absorbs impact of vehicle and laterally restrains a vehicle from veering off. This ensures minimum damage to the vehicle and passengers.

8.13.12.Road Humps and Rumble Strips

The Road Humps are formed by providing a rounded hump of 3.7m width (17m radius) and 0.10m height for the preferred advisory crossing speed of 25kmph for general traffic as per the IRC: 99–1988 guidelines. The basic material for construction is bituminous concrete formed to required shape. Road humps are located at T-intersections (and cross road intersections) on minor roads or perpendicular arms about 25m away from the inner edge of the carriageway. Proper signs boards and markings are provided to advise the drivers in advance of the situation. Road humps are extended across carriageway up to the edge of paved shoulder.

Rumble Strips are formed by a sequence of transverse strips laid across a carriageway. Maximum permitted height of 15mm provided no vertical face exceeds 6mm. These rumble device produce audible and vibratory effects to alert drivers to take greater care and do not normally reduce traffic speeds in themselves. The typical design details of rumble strips proposed are transverse strips of Bituminous Concrete 500mm wide and overall thickness 15mm laid across a carriageway up to the end of paved shoulder. There will be 6 such transverse strips spaced at 2.0m c/c. Rumble strips are proposed in advance of :

i) Sharp curves with radius less than 161m.

ii) Transition zones (speed limit zones).

iii) Village/urban approaches

Proper sign boards and marking are proposed to advise the drivers in advance of the situation.

8.13.13.Toll plaza

Location of toll plazas has been proposed based on the traffic dispersal pattern at the respective homogenous sections, road geometry and vertical profile of the road and the surrounding area.

Also while fixing the toll plazas for this project, the proposed Toll Plaza locations for the preceding and succeeding packages were considered.

The location of the toll plazas is based on the following:

- Distance between the toll plazas
- Distance from nearest major settlements and municipal limits
- Maximum capture of tollable traffic to increase financial viability
- Avoidance of bridges and culverts
- Avoidance of junctions
- Avoidance of sharp curves

The locations for the toll plaza for the different section are given in Table 8.31:

Table 8.31: Location and Section of Toll Plaza

Sl. No.	Existing Chainage (Km)	Design Chainage (Km)	Length(m)	Section for toll plaza	No. of lanes
1	15+400	13+000	Tapering length-203m Straight length of Toll plaza- 313m Tapering length-234m	From km 9+282 to km 22+000	24 (12 lanes in each direction)

8.13.13.1. Toll Plaza Design

A width of 3.2m between two upstand kerbs of tollbooth islands is considered optimum in order to channel vehicles and to ensure they stop close enough to the toll collector. Provision of different toll lanes width reduces the flexibility, and hence should have not been proposed.

One extra lane 4.5m width should be provided in each direction, in addition to toll lanes, for non-tollable/exempt vehicles and oversized (extra wide) vehicles, which cannot pass through regular toll lanes.

Number of Toll Lanes

The minimum toll lanes required with semi-automatic toll system for the projected peak hour traffic of 15 years is as presented below in Table 8.32.The tollable traffic data has already been presented in Table 5.32 of Chapter-5: Traffic survey and analysis.

Table 8.32: Required Toll Lanes

Toll Plaza	20 yrs tollable traffic using semi-automatic toll	20 yrs tollable traffic using e-tolling*	20 Years Tollable Vehicle in each direction (nos.)	Peak Hour factor (%)	Peak Hour Traffic in each direction(nos.)		Semi-automatic Toll Lane @ 240 vph (nos.) in each direction	Dedicated Toll Lane for e-tolling in each direction @1200 vph
					Semi-automatic	Automatic		
1	19907	12284	32191	6.4%	1274	786	6	3

Assumption*: 50% of car traffic will use e-tolling in its 20 yrs. design life

As per analysis of tollable traffic, 2×10 (including 1 extra lane for oversized vehicles in each direction) no of lanes required for toll plaza. However as per NHAI guidelines vide circular no. 11014/11/2016-HR-1(Policy Matter 10.1.16/2017) dated 12.06.2017,the number of lanes at any toll plaza would, however, be not less than four times the number of lanes for which the highway has been designed. So considering the guideline the proposed no of lanes shall be 24(12 in each direction).

Land width for Toll Plaza

Land width for the toll plaza is to be acquired to permit the provision of toll lanes for projected peak hour traffic of 20 years subjected to a minimum number of 20 toll lanes and including all other building and structures to be accommodated at the Toll plaza location.

General Layout

A flared entry and exit approach to the toll plaza should be laid out for the safe transition of vehicles from the highway to toll plazas and vice versa. Various flare angles can be used however a flare angle of 1:10 is considered to be most appropriate for National Highways where the average approach speed of vehicles is in the order of 61 – 90 km/hr. The total width at the toll plaza axis is a direct function of the number of toll lanes required in the system.

8.13.14. Road Safety Audit

Road Safety audit has the greatest potential for improving safety and is most cost–effective when it is applied to a road or traffic design before the project is built. It can be conducted on any design proposal that involves changes to the ways road users will interact, either with each other or with their physical environment. It is a formal process using a defined procedure.

As per the requirements of *TOR*, Road Safety Audit (RSA) has been carried out for project road and sufficient measures has been taken for improving detailed engineering design with respect to the road safety audit. The details of audit taken are described in Check list below:

Checklist: Feasibility Stage Audit

Sl. No.	Contents	Item	Yes/No	Comment
1.	Aspects to be checked	A. Safety and operational implications of proposed alignment and junction strategy with particular references to expected road users and vehicle types likely to use the road.	Yes	The design of the proposed alignment takes care of the principal factors affecting safety and operational implications as per relevant IRC Codes.
		B. Width options considered for various sections.	Yes	As provisioned in IRC Codes.
		C. Departures from standards and action taken.	Yes	Followed relevant IRC Codes.
		D. Provision of pedestrians, cyclists and intermediate transport.	Yes	3.5 m wide footpath in urban section has been provided.
		E. Safety implications of the scheme beyond its physical limits i.e. how the scheme fits into its environs and road hierarchy.	Yes	Geometric design takes care of the safety issues of the environs. Besides provision of crash barriers, railings, lighting in the urban sections also contribute to the safety scheme. In stretches with narrow median (<4.5m) antiglare screen has been proposed to be installed on the median center atop the NJ type crash barrier.
2.	A1: General	Departures from Standards	Yes	Followed relevant IRC codes except for TCS at locations of land constraints
		Cross-sectional variation	Yes	No abrupt variation to cause concern for safety.
		Drainage	Yes	Road grades and cross fails are adequate for satisfactory drainage. Provision of proper drainage system along the road has been made.
		Climatic conditions	Yes	Design has taken care of temperature and rainfall.
		Landscaping	NA	To be taken care of at execution stage ensuring the same does not obstruct visibility.
		Services apparatus	Yes	Design is adequate in dealing with overhead services.
		Lay-byes	Yes	Bus lay-byes, truck lay-byes at identified locations have been provided.
		Footpaths	Yes	Provided for the entire project stretch.
		Pedestrian Crossings	Yes	Provided at identified locations by FOBs Also the elevated corridor will facilitate easy access to pedestrian traffic.

Sl. No.	Contents	Item	Yes/No	Comment
		Access (minimize number of private accesses)	Yes	Service road on the both side has been proposed for the entire project corridor.
		Emergency vehicles	NA	Not applicable at Design Stage.
		Public Transport		
		Future Widening	Yes	
		Staging of Contracts	NA	
		Adjacent development	Yes	Access to major adjacent developments has been considered in design.
3.	A2: Local Alignment	Visibility	Yes	Horizontal and vertical alignments satisfy visibility criteria at all locations. Design is based on ISD.
		New/Existing road interface	Yes	Sufficient transition zone has been proposed. All cross roads were properly designed with main road.
		Safety Aids on steep hills.	NA	
4.	A3: Junctions	Minimise potential conflicts	Yes	Many major junctions have been grade separated by Flyover/Overpass.
		Layout	Yes	Followed IRC standards.
		Visibility	Yes	Horizontal and vertical alignments are consistent with visibility. Standards are appropriate for speed. Free sight line has been maintained.
5.	A4: Non-motorized road users provision	Adjacent land	Yes	Safe access to adjacent land has been designed.
		Pedestrians	Yes	Flyover has been proposed at suitable locations in urban sections. Besides in urban stretches, 3.5m wide footpath and FOB have been proposed.
		Cyclists & Non-motorised vehicles	Yes	Proposed service road shall cater to this traffic.
6.	A5: Signs and lighting	Lighting	Yes	Provisions have been made.
		Signs / Markings	Yes	Provisions have been made.
7.	C6: Construction and Operation	Build ability	Yes	
		Operational	NA	
		Network Management	No	Would be taken care in the subsequent stage.

DESIGN TRAFFIC IN MILLION STANDARD AXLE

Gurgaon -Rajasthan Border

Survey location: 3KM

Base Year/ Traffic Count Year: August 2016

VEHICULAR TRAFFIC PROJECTION IN AADT , BOTH DIRECTION

YEAR		Bus		LCV		2-axle		3-axle		Multi Axle	
		AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %
BASE YEAR	2016	700	0.05	1032	0.07	823	0.07	1026	0.07	588	0.08
Construction Period	2017	735	0.05	1105	0.07	881	0.07	1098	0.07	635	0.08
	2018	772	0.05	1182	0.07	942	0.07	1174	0.07	686	0.08
1	2019	810	0.05	1265	0.07	1008	0.07	1257	0.07	741	0.08
2	2020	851	0.05	1353	0.07	1079	0.07	1345	0.07	800	0.08
3	2021	893	0.04	1448	0.07	1154	0.06	1439	0.06	864	0.07
4	2022	929	0.04	1549	0.07	1223	0.06	1525	0.06	925	0.07
5	2023	966	0.04	1658	0.07	1297	0.06	1616	0.06	990	0.07
6	2024	1005	0.04	1774	0.07	1375	0.06	1713	0.06	1059	0.07
7	2025	1045	0.04	1898	0.07	1457	0.06	1816	0.06	1133	0.07
8	2026	1087	0.04	2031	0.06	1545	0.06	1925	0.06	1212	0.07
9	2027	1130	0.04	2153	0.06	1637	0.06	2041	0.06	1297	0.07
10	2028	1176	0.04	2282	0.06	1735	0.06	2163	0.06	1388	0.07
11	2029	1223	0.04	2419	0.06	1840	0.06	2293	0.06	1485	0.07
12	2030	1272	0.04	2564	0.06	1950	0.06	2431	0.06	1589	0.07
13	2031	1322	0.04	2718	0.05	2067	0.05	2576	0.05	1700	0.06
14	2032	1375	0.04	2854	0.05	2170	0.05	2705	0.05	1802	0.06
15	2033	1430	0.04	2996	0.05	2279	0.05	2840	0.05	1911	0.06
16	2034	1488	0.04	3146	0.05	2393	0.05	2982	0.05	2025	0.06
17	2035	1547	0.04	3304	0.05	2512	0.05	3132	0.05	2147	0.06
18	2036	1609	0.03	3469	0.05	2638	0.05	3288	0.05	2276	0.05
19	2037	1657	0.03	3642	0.05	2770	0.05	3453	0.05	2389	0.05
20	2038	1707	0.03	3824	0.05	2908	0.05	3625	0.05	2509	0.05
21	2039	1758	0.03	4016	0.05	3054	0.05	3806	0.05	2634	0.05
22	2040	1811	0.03	4216	0.05	3207	0.05	3997	0.05	2766	0.05
23	2041	1865	0.03	4427	0.05	3367	0.05	4197	0.05	2904	0.05
24	2042	1921	0.03	4649	0.05	3535	0.05	4406	0.05	3049	0.05
25	2043	1979	0.03	4881	0.05	3712	0.05	4627	0.05	3202	0.05
26	2044	2038	0.03	5125	0.05	3898	0.05	4858	0.05	3362	0.05
27	2045	2099	0.03	5381	0.05	4092	0.05	5101	0.05	3530	0.05
28	2046	2162	0.03	5650	0.05	4297	0.05	5356	0.05	3707	0.05
29	2047	2227	0.03	5933	0.05	4512	0.05	5624	0.05	3892	0.05
30	2048	2294	0.03	6229	0.05	4738	0.05	5905	0.05	4087	0.05

Cumulative Both Direction Traffic in Million

Year	BUS	LGV	2-Axle	3-Axle	M-Axle
8 years	2.769	4.736	3.700	4.612	2.820
10 years	3.611	6.355	4.931	6.147	3.800
15 years	6.028	11.301	8.693	10.835	6.898
20 years	8.951	17.647	13.519	16.850	11.039
30 years	12.029	28.745	22.020	27.448	17.981

CUMULATIVE NUMBER OF STANDARD AXLES TO BE CATERED FOR DESIGN IN TERMS OF MSA PER LANE IN EACH DIRECTION

Directional Distribution		0.5
Lane Distribution (D)		0.6
VDF Values (F)	Bus	1.61
	LCV	2.55
	2-Axle	4.79
	3-Axle	5.20
	M-Axle	4.72

The Cumulative number of Standard Axles (N)

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times D \times F$$

A= Initial traffic in the year of completion of construction

n= Design life in years

r = Annual growth Rate of Commercial Vechile

Year	BUS	LGV	2-Axle	3-Axle	M-Axle	TOTAL	
8 years	1.335	3.623	5.317	7.195	3.992	**21**	**msa**
10 years	1.740	4.862	7.086	9.589	5.380	**29**	**msa**
15 years	2.906	8.645	12.492	16.903	9.767	**51**	**msa**
20 years	4.314	13.500	19.426	26.287	15.631	**79**	**msa**

DESIGN TRAFFIC IN MILLION STANDARD AXLE

Rajasthan - Gurgaon Border

3KM

Base Year/ Traffic Count Year: August 2016

VEHICULAR TRAFFIC PROJECTION IN AADT , BOTH DIRECTION

YEAR		Bus		LCV		2-axle		3-axle		Multi Axle	
		AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %
BASE YEAR	2016	700	0.05	1032	0.07	823	0.07	1026	0.07	588	0.08
Construction Period	2017	735	0.05	1105	0.07	881	0.07	1098	0.07	635	0.08
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5	2023	966	0.04	1658	0.07	1297	0.06	1616	0.06	990	0.07
6	2024	1005	0.04	1774	0.07	1375	0.06	1713	0.06	1059	0.07
7	2025	1045	0.04	1898	0.07	1457	0.06	1816	0.06	1133	0.07
8	2026	1087	0.04	2031	0.06	1545	0.06	1925	0.06	1212	0.07
9	2027	1130	0.04	2153	0.06	1637	0.06	2041	0.06	1297	0.07
10	2028	1176	0.04	2282	0.06	1735	0.06	2163	0.06	1388	0.07
11	2029	1223	0.04	2419	0.06	1840	0.06	2293	0.06	1485	0.07
12	2030	1272	0.04	2564	0.06	1950	0.06	2431	0.06	1589	0.07
13	2031	1322	0.04	2718	0.05	2067	0.05	2576	0.05	1700	0.06
14	2032	1375	0.04	2854	0.05	2170	0.05	2705	0.05	1802	0.06
15	2033	1430	0.04	2996	0.05	2279	0.05	2840	0.05	1911	0.06
16	2034	1488	0.04	3146	0.05	2393	0.05	2982	0.05	2025	0.06
17	2035	1547	0.04	3304	0.05	2512	0.05	3132	0.05	2147	0.06
18	2036	1609	0.03	3469	0.05	2638	0.05	3288	0.05	2276	0.05
19	2037	1657	0.03	3642	0.05	2770	0.05	3453	0.05	2389	0.05
20	2038	1707	0.03	3824	0.05	2908	0.05	3625	0.05	2509	0.05
21	2039	1758	0.03	4016	0.05	3054	0.05	3806	0.05	2634	0.05
22	2040	1811	0.03	4216	0.05	3207	0.05	3997	0.05	2766	0.05
23	2041	1865	0.03	4427	0.05	3367	0.05	4197	0.05	2904	0.05
24	2042	1921	0.03	4649	0.05	3535	0.05	4406	0.05	3049	0.05
25	2043	1979	0.03	4881	0.05	3712	0.05	4627	0.05	3202	0.05
26	2044	2038	0.03	5125	0.05	3898	0.05	4858	0.05	3362	0.05
27	2045	2099	0.03	5381	0.05	4092	0.05	5101	0.05	3530	0.05
28	2046	2162	0.03	5650	0.05	4297	0.05	5356	0.05	3707	0.05
29	2047	2227	0.03	5933	0.05	4512	0.05	5624	0.05	3892	0.05
30	2048	2294	0.03	6229	0.05	4738	0.05	5905	0.05	4087	0.05

Cumulative Both Direction Traffic in Million

Year	BUS	LGV	2-Axle	3-Axle	M-Axle
8 years	2.769	4.736	3.700	4.612	2.820
10 years	3.611	6.355	4.931	6.147	3.800
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20 years	8.951	17.647	13.519	16.850	11.039
30 years	12.029	28.745	22.020	27.448	17.981

CUMULATIVE NUMBER OF STANDARD AXLES TO BE CATERED FOR DESIGN IN TERMS OF MSA PER LANE IN EACH DIRECTION

Directional Distribution		0.5
Lane Distribution (D)		0.6
VDF Values (F)	Bus	1.11
	LCV	2.97
	2-Axle	11.52
	3-Axle	22.04
	M-Axle	9.21

The Cumulative number of Standard Axles (N)

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times D \times F$$

A= Initial traffic in the year of completion of construction

n= Design life in years

r = Annual growth Rate of Commercial Vechile

Year	BUS	LGV	2-Axle	3-Axle	M-Axle	TOTAL	
8 years	0.926	4.221	12.786	30.493	7.790	**56**	**msa**
10 years	1.207	5.664	17.039	40.638	10.498	**75**	**msa**
15 years	2.015	10.072	30.037	71.636	19.058	**133**	**msa**
20 years	2.993	15.728	46.712	111.405	30.499	**207**	**msa**

Direction: Gurgaon to Rajasthan Border (Homogeneous section -I)

INPUT DATA

Effective CBR :	9	%	
h :	450	mm	Thickness of Granular Layers
$\mu_{bituminous}$:	0.5	above 35 degree	
$\mu_{bituminous}$:	0.35	below 35 degree	
$\mu_{granular}$:	0.35	upto 35 degree	
Design MSA (bituminous)=	51		
Design MSA (granular)=	51		
Realiability =	90		

Assumed Thickness (mm)	
BC	40
DBM	95
GB	250
GSB	200

Subgrade: As per IRC: 37-2012, the elastic modulus of subgrade is estimated as given below

E_{SG} = $10 * CBR^{0.64}$ for CBR upto 5%

=

E_{SG} = $17.6 * CBR^{0.64}$ for CBR > 5%

= **72** Mpa

Elastic modulus of Granular Layer:

E_{Gr} = $E_{SG} * 0.2 * h^{0.45}$ where

= **224** Mpa E_{SG} = The Modulus of Elasticity of subgrade

Failure Criteria

The fatigue cracking at the bottom of the BT layer and rutting on the top of subgrade are considered as failures which govern the design (as given in Annexure 1 of IRC: 37-2012)

Fatigue Life of Pavement:

The fatigue life in terms of MSA is worked out using the following equations.

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

$$N_F = 2.21 * 10^{\wedge -04} * \left[\frac{1}{e_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 80% reliability =

VG 30 used

e_t = 1.97E-04

M_R = 3000

To avoid frequent maintenance, a reliability level of 90 per cent is recommended for highways having a design traffic exceeding 30 msa.

$$N_F = 2.021 * 10^{\wedge -04} * \left[\frac{1}{e_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 90% reliability = 0.000202 **OK**

VG 40 used

with 13% bitumen content (by vol)

e_t = 1.97E-04

M_R = 3000

N_f = No. of cumulative standard axle to produce **20% cracked surface area**

ε_t = Maximum Tensile strain at the bottom of the bituminous layer,

M_R = resilient modulus of the bituminous layer.

Rutting Life of Pavement:

The equations for rutting for 80 per cent and 90 per cent reliability respectively are given (46, 54) as Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

N= 4.1656E-08 * $[1/\varepsilon v]^{4.5337}$ at 80% reliability =

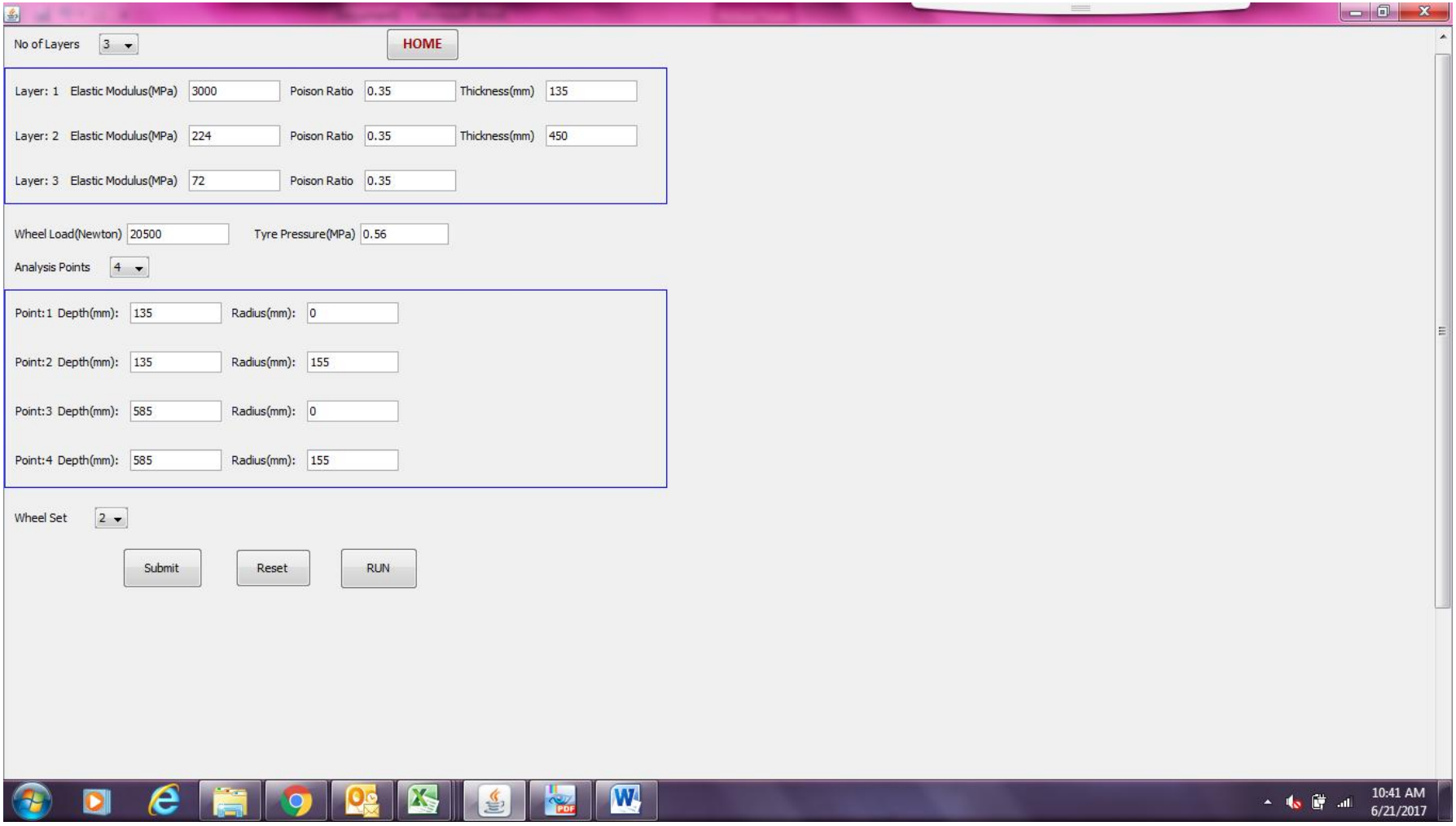
N= 1.41E-08 * $[1/\varepsilon v]^{4.5337}$ at 90% reliability = **OK**

ε_v = 3.16E-04

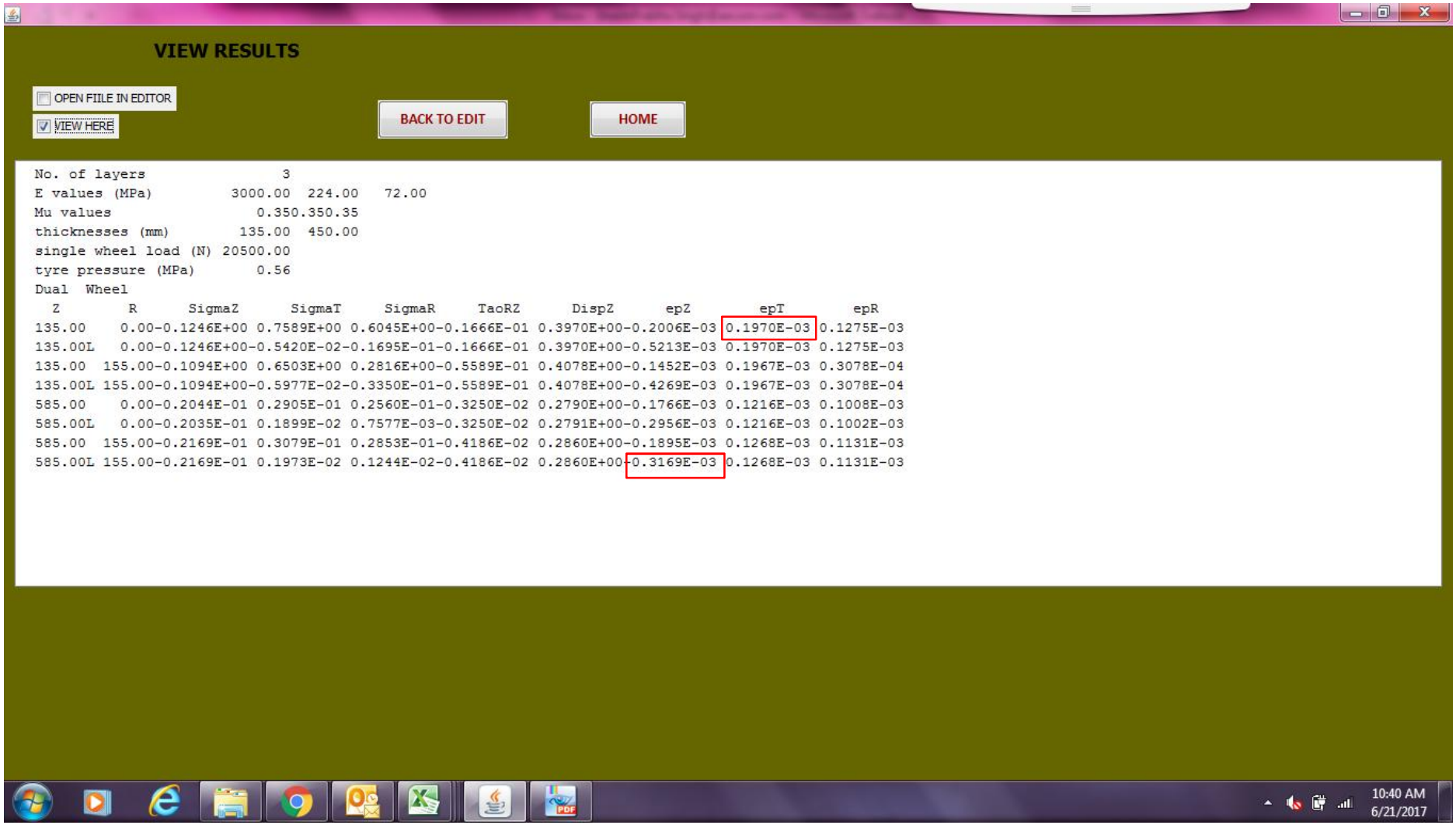
N = No. of cumulative standard axle to produce a rutting of 20 mm

ε_v = Vertical subgrade strain

IITPAVE OUTPUT for Homogeneous section-I
(Direction: Gurgaon – Rajasthan Border)



IITPAVE OUTPUT for Homogeneous section-I
(Direction: Gurgaon – Rajasthan Border)



Direction: Rajasthan Border to Gurgaon (Homogeneous section -I)

INPUT DATA

Effective CBR :	9	%	
h :	450	mm	Thickness of Granular Layers
$\mu_{bituminous}$:	0.5	above 35 degree	
$\mu_{bituminous}$:	0.35	below 35 degree	
$\mu_{granular}$:	0.35	upto 35 degree	
Design MSA (bituminous)=	133		
Design MSA (granular)=	133		
Realiability =	90		

Assumed Thickness (mm)	
BC	50
DBM	125
WMM	250
GSB	200

Subgrade: As per IRC: 37-2012, the elastic modulus of subgrade is estimated as given below

E_{SG} = $10 * CBR^{0.64}$ for CBR upto 5%

=

E_{SG} = $17.6 * CBR^{0.64}$ for CBR > 5%

= 72 Mpa

Elastic modulus of Granular Layer:

E_{Gr} = $E_{SG} * 0.2 * h^{0.45}$ where

= 224 Mpa E_{SG} = The Modulus of Elasticity of subgrade

Failure Criteria

The fatigue cracking at the bottom of the BT layer and rutting on the top of subgrade are considered as failures which govern the design (as given in Annexure 1 of IRC: 37-2012)

Fatigue Life of Pavement:

The fatigue life in terms of MSA is worked out using the following equations.

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

$$N_F = 2.21 * 10^{-04} * \left[\frac{1}{\varepsilon_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 80% reliability =

VG 30 used

ε_t = 1.55E-04

M_R = 3000

To avoid frequent maintenance, a reliability level of 90 per cent is recommended for highways having a design traffic exceeding 30 msa.

$$N_F = 2.021 * 10^{-04} * \left[\frac{1}{\varepsilon_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 90% reliability = 1.58E-04 OK

VG 40 used

with 13% bitumen content (by vol)

ε_t = 1.55E-04

M_R = 3000

N_f = No. of cumulative standard axle to produce 20% cracked surface area

ε_t = Maximum Tensile strain at the bottom of the bituminous layer,

M_R = resilient modulus of the bituminous layer.

Rutting Life of Pavement:

The equations for rutting for 80 per cent and 90 per cent reliability respectively are given (46, 54) as

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

N= 4.17E-08 * $[1/\varepsilon v]^{4.5337}$ at 80% reliability =

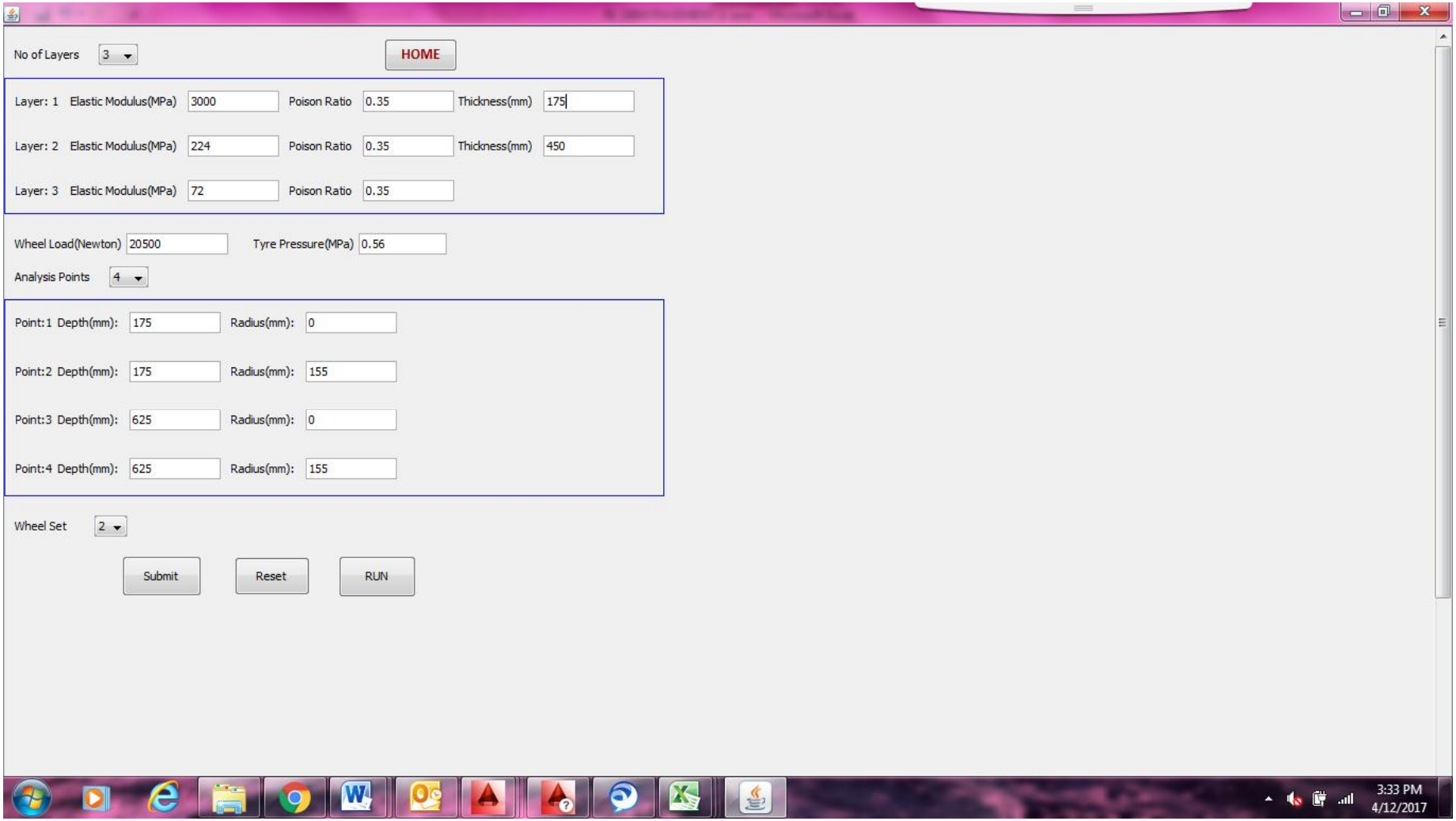
N= 1.41E-08 * $[1/\varepsilon v]^{4.5337}$ at 90% reliability = 3.00E-04 OK

ε_v = 2.57E-04

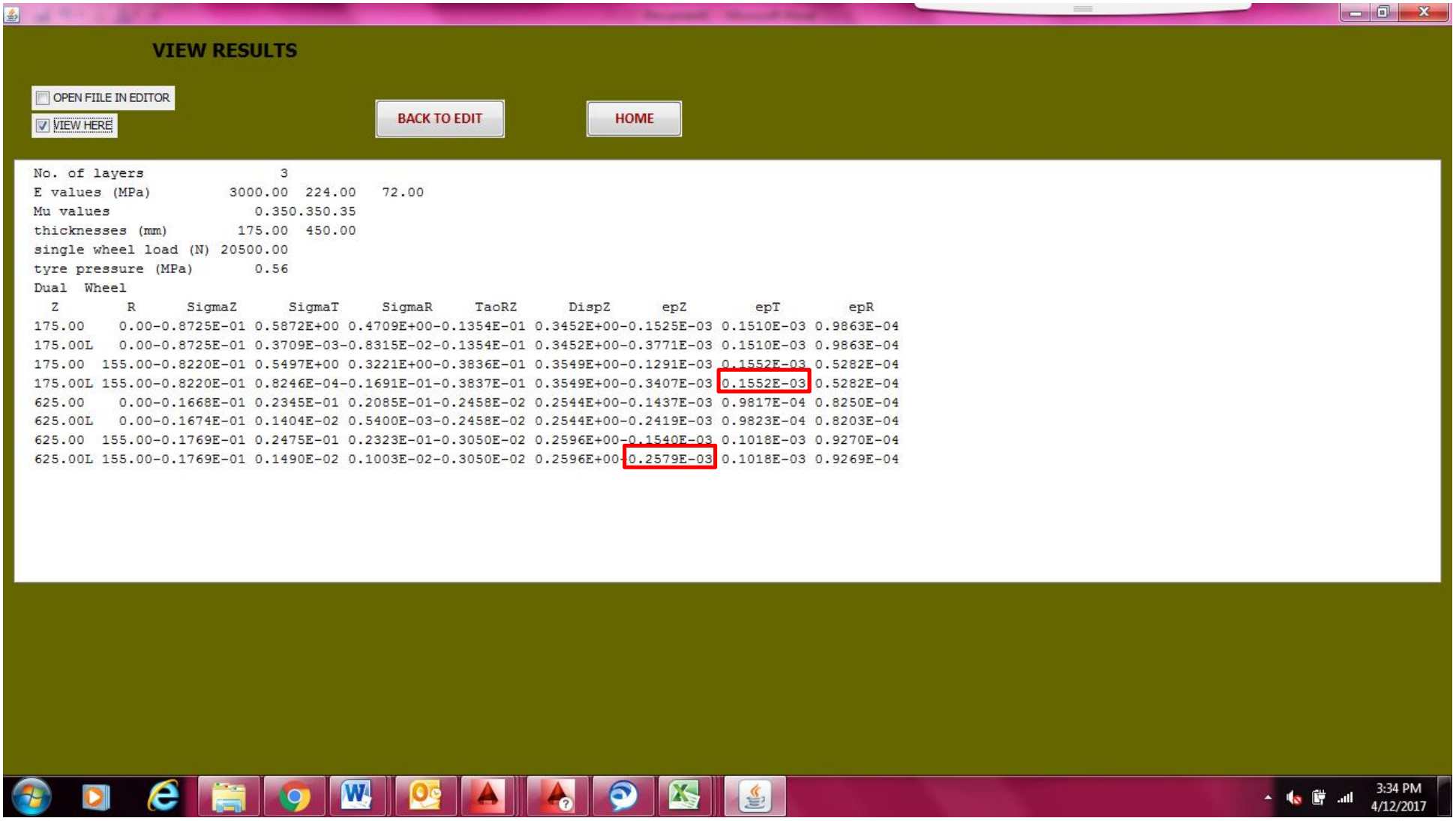
N = No. of cumulative standard axle to produce a rutting of 20 mm

ε_v = Vertical subgrade strain

IITPAVE OUTPUT for Homogeneous section-I
(Direction: Rajasthan Border –Gurgaon)



IITPAVE OUTPUT for Homogeneous section- I
(Direction: Rajasthan Border – Gurgaon)



Direction: Rajasthan Border to Gurgaon (Homogeneous section -I)

INPUT DATA

Effective CBR :	9	%	
h :	400	mm	Thickness of Granular Layers
$\mu_{bituminous}$:	0.5	above 35 degree	
$\mu_{bituminous}$:	0.35	below 35 degree	
$\mu_{granular}$:	0.35	upto 35 degree	
µctb=	0.25		
µctsb=	0.25		
Design MSA (bituminous)=	133		
Design MSA (Cemented Base)=	133		
Realiability =	90		

Assumed Thickness (mm)

BC	50
DBM	50
Agrregate layer	100
CTB	150
CT Subbase	250

Subgrade: As per IRC: 37-2012, the elastic modulus of subgrade is estimated as given below

E_{SG} = $10 * CBR^{0.64}$ for CBR upto 5%

=

E_{SG} = $17.6 * CBR^{0.64}$ for CBR > 5% µsg= 0.4

= **72** Mpa

Egra= 450 Mpa

Elastic modulus of Cemented Layer:

E_{CTB} = 5000 Mpa

E_{CTSB} = 600 Mpa

Failure Criteria

The fatigue cracking at the bottom of the BT layer and rutting on the top of subgrade are considered as failures which govern the design (as given in Annexure 1 of IRC: 37-2012)

Failure of BT layer:

The fatigue life in terms of MSA is worked out using the following equations.

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

Permissible strain from eq.

$$N_F = 2.21 * 10^{-04} * \left[\frac{1}{\varepsilon_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 80% reliability =

VG 30 used

Calculated strain e_t = 1.29E-04

M_R = 3000

To avoid frequent maintenance, a reliability level of 90 per cent is recommended for highways having a design traffic exceeding 30 msa.

Permissible strain from eq.

$$N_F = 2.021 * 10^{-04} * \left[\frac{1}{\varepsilon_t}\right]^{3.89} * \left[\frac{1}{M_R}\right]^{0.854}$$

at 90% reliability = 1.58E-04 OK

VG 40 used

with 13% bitumen content (by vol)

Calculated strain e_t = 1.29E-04

M_R = 3000

N_f = No. of cumulative standard axle to produce **20% cracked surface area**

ε_t = Maximum Tensile strain at the bottom of the bituminous layer,

M_R = resilient modulus of the bituminous layer.

Fatigue Life of CTB Pavement:

The fatigue life in terms of MSA is worked out using the following equations.

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

Permissible strain from eq.

$$N = RF * \left[\frac{11300/E^{0.0804} + 191}{\varepsilon_t}\right]^{12}$$

= 1.24E+03 OK

e_t = 4.84E-05

M_R = 5000 RF= 1

Rutting Life of Pavement(strain on subgrade):

The equations for rutting for 80 per cent and 90 per cent reliability respectively are given (46, 54) as

Fatigue lives of a bituminous mixture at a reliability level of 80 per cent and 90 per cent (46, 54) respectively are given as:

N= 4.17E-08 * $[1/\varepsilon v]^{4.5337}$ at 80% reliability =

N= 1.41E-08 * $[1/\varepsilon v]^{4.5337}$ at 90% reliability = 3.80E-04 OK

ε_v = 1.75E-04

N = No. of cumulative standard axle to produce a rutting of 20 mm

ε_v = Vertical subgrade strain

Bituminous Pavements with Cemented Base and Cemented Subbase with Crack Relief Interlayer of Aggregate

Direction: Rajasthan Border to Gurgaon (Homogeneous section -I)

INPUT DATA

CBR :	9	%
h :	500	mm
$\mu_{bituminous}$:		above 35 degree
$\mu_{bituminous}$:	0.35	below 35 degree
$\mu_{aggregate\ layer}$:	0.35	upto 35 degree
μ_{CTB} :	0.25	
μ_{CTSB} :	0.25	
Design period =	15	years
MSA =	133	
Realiability =	90	
Grade of Bitumen =	VG 40	
M_R Bituminous layer =	3000	MPa
M_R Aggregate layer =	450	MPa
M_R (Cementatious Base layer) =	1.4	MPa
M_R (Sub Base layer) =	600	MPa

Temperature = 35

Road Type = National Highway

Reliability Factor = 1

Assumed Pavement Thickness (mm)

BC	50
DBM	50
Aggregate inter La	100
CTB	150
cem. GSB	250

Subgrade: As per IRC: 37-2012, the elastic modulus of subgrade is estimated as given below

E_{SG} = $10 * CBR^{0.64}$ for CBR upto 5%

= Mpa

E_{SG} = $17.6 * CBR^{0.64}$

= **72** Mpa for CBR > 5%

Fatigue Damage analysis

Single Axle Load				Tandem Axle Load				Tridem Axle Load			
From	**To**	**No of Single Axle**	**% of Axle**	**From**	**To**	**No of Tandem**	**% of Axle**	**From**	**To**	**No of Single Axle**	**% of Axle**
185	195	0	0%	390	410	1	1%	585	615	0	0%
175	185	1	0%	370	390	16	10%	555	585	0	0%
165	175	5	2%	350	370	37	23%	525	555	0	0%
155	165	3	1%	330	350	23	14%	495	525	0	0%
145	155	4	1%	310	330	8	5%	465	495	0	0%
135	145	8	3%	290	310	0	0%	435	465	0	0%
125	135	11	4%	270	290	5	3%	405	435	0	0%
115	125	4	1%	250	270	1	1%	375	405	1	25%
105	115	5	2%	230	250	9	6%	345	375	0	0%
95	105	3	1%	210	230	16	10%	315	345	0	0%
85	95	13	5%	190	210	14	9%	285	315	0	0%
< 85		228	80%	170	190	6	4%	255	285	0	0%
				0.00	170.00	25	16%	<255		3	75%
Total		285.00	100%			161.00	1.00			4.00	

Cumulative no. of repetation of Axle during design period (C) = $365*A*[(1+r)^n - 1]/r$

A = Initial no of axles per day in the year when the road is operational

r= annual rate of growth of traffic (5%) = 0.05

n= design period in years = 15 years

∴ C = 21.9 Single axle
∴ C = 8.9 Tandem Axle
∴ C = 6.9 Tridem Axle

Single Axle

Axle Load (kN)	Expected Repetations (Ni)	Stress (Mpa) from IITP	Stress Ratio	Nfi	Fatigue Life consumed (Ni/Nfi)	wheel load(N)
190.00	0	0.61	0.436	3.17E+06	0.00	47500
180.00	76,763	0.58	0.414	5.76E+06	0.01	45000
170.00	383,817	0.56	0.400	8.58E+06	0.04	42500
160.00	230,290	0.53	0.379	1.56E+07	0.01	40000
150.00	307,054	0.5	0.357	2.84E+07	0.01	37500
140.00	614,107	0.47	0.336	5.16E+07	0.01	35000
130.00	844,398	0.44	0.314	9.38E+07	0.01	32500
120.00	307,054	0.4	0.286	2.08E+08	0.00	30000
110.00	383,817	0.37	0.264	3.79E+08	0.00	27500
100.00	230,290	0.34	0.243	6.89E+08	0.00	25000
90.00	997,925	0.31	0.221	1.25E+09	0.00	22500
85.00	17,502,063	0.29	0.207	1.87E+09	0.01	21250
				S	0.12	

Tandem Axle

Axle Load (kN)	Expected Repetations	Stress (Mpa) from IIT pave	Stress Ratio	Nfi	Fatigue Life consumed	wheel load(N)
400	55,071	0.64	0.457	1.74E+06	0.03	50000
380	881,140	0.61	0.436	3.17E+06	0.28	47500
360	2,037,635	0.58	0.414	5.76E+06	0.35	45000
340	1,266,638	0.56	0.400	8.58E+06	0.15	42500
320	440,570	0.53	0.379	1.56E+07	0.03	40000
300	-	0.5	0.357	2.84E+07	0.00	37500
280	275,356	0.47	0.336	5.16E+07	0.01	35000
260	55,071	0.44	0.314	9.38E+07	0.00	32500
240	495,641	0.4	0.286	2.08E+08	0.00	30000
220	881,140	0.37	0.264	3.79E+08	0.00	27500
200	770,997	0.34	0.243	6.89E+08	0.00	25000
180	330,427	0.31	0.221	1.25E+09	0.00	22500
170	1,376,781	0.29	0.207	1.87E+09	0.00	21250
				S	0.85	

Tridem Axle

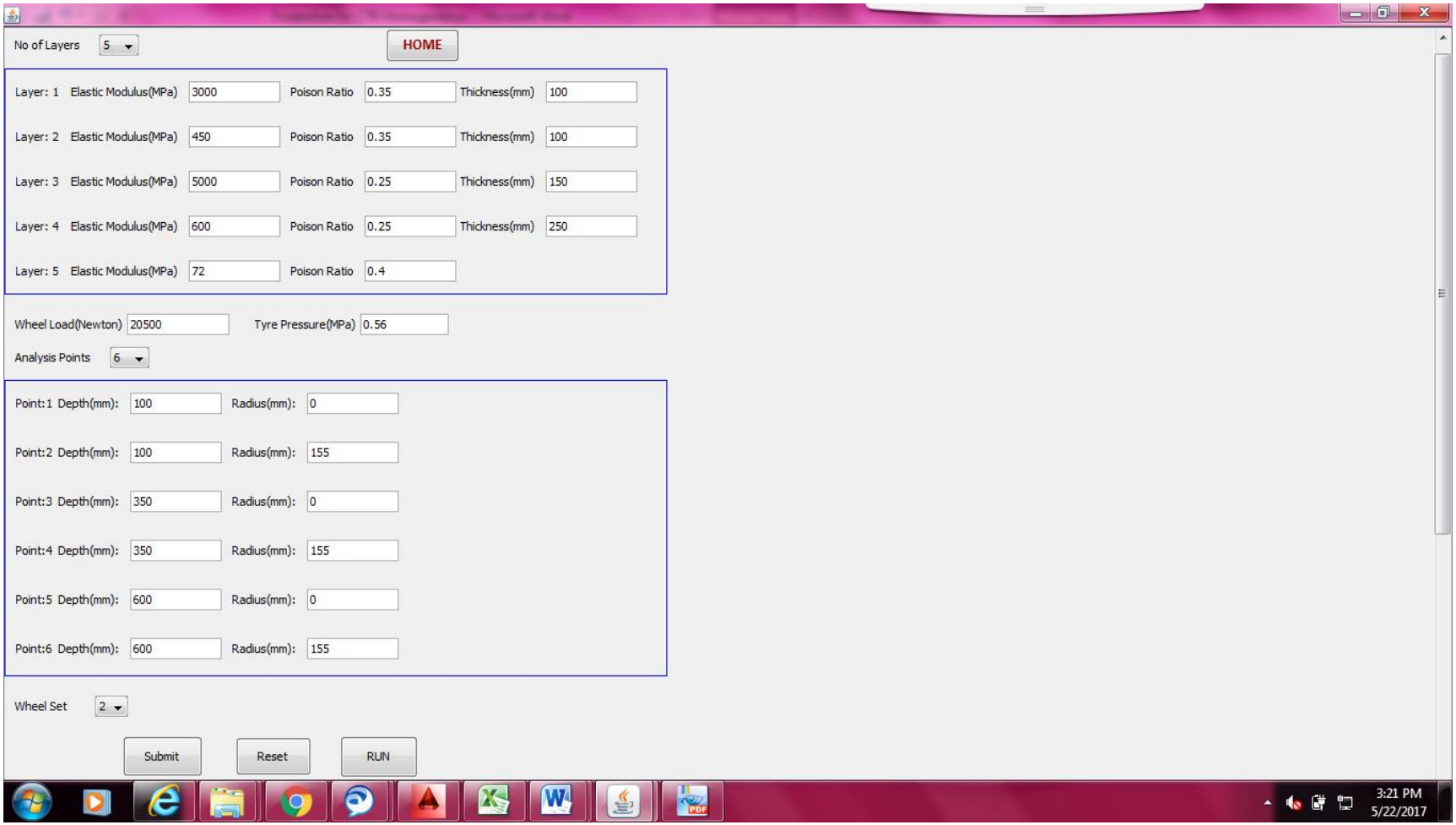
Axle Load (kN)	Expected Repetations	Stress (Mpa) from IIT	Stress Ratio	Nfi	Fatigue Life consumed (Ni/Nfi)	wheel load(N)
600	0	0.64	0.457	1.74E+06	0.00	50000
570	0	0.61	0.436	3.17E+06	0.00	47500
540	0	0.58	0.414	5.76E+06	0.00	45000
510	0	0.56	0.400	8.58E+06	0.00	42500
480	0	0.53	0.379	1.56E+07	0.00	40000
450	0	0.5	0.357	2.84E+07	0.00	37500
420	0	0.47	0.336	5.16E+07	0.00	35000
390	1724436	0.44	0.314	9.38E+07	0.02	32500
360	0	0.4	0.286	2.08E+08	0.00	30000
330	0	0.37	0.264	3.79E+08	0.00	27500
300	0	0.34	0.243	6.89E+08	0.00	25000
270	0	0.31	0.221	1.25E+09	0.00	22500
255	5173308	0.29	0.207	1.87E+09	0.00	21250
				S	0.02	

Total Fatigue Damage(Ni/Nfi) = 0.99

OK

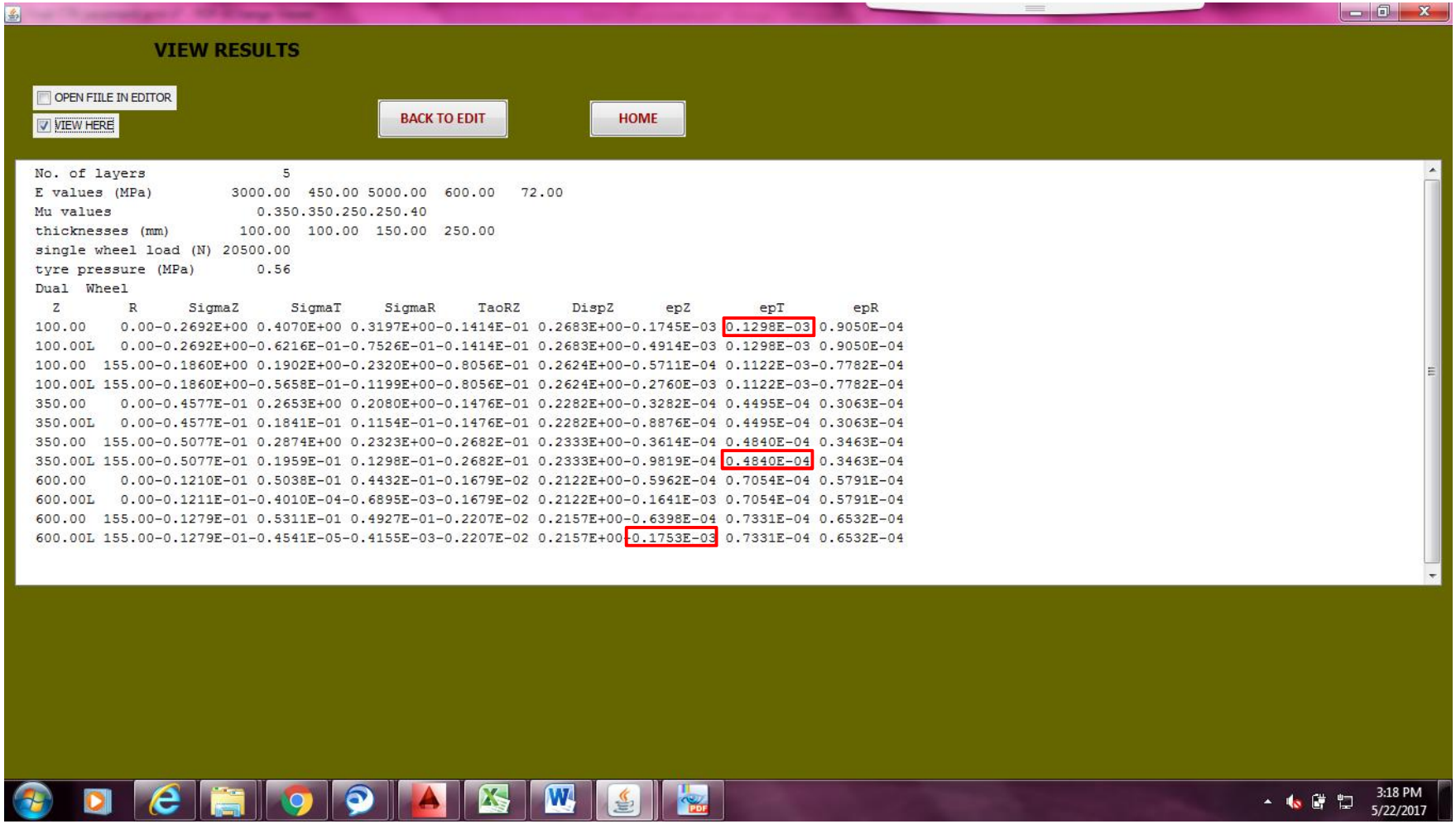
IITPAVE OUTPUT for Homogeneous section- I

Direction: Rajasthan Border-Gurgaon



IITPAVE OUTPUT for Homogeneous section - I

Direction: Rajasthan Border-Gurgaon



Design of Slab Thickness for Pavement

(with and without doweled transverse joints. Beta value will be 0.66 for doweled joint and 0.90 for without dowels case)

Type of pavement considered	
Carriageway	6-lane divided
Shoulders :- Tied concrete shoulders ? (yes/no)	no
Transverse joint spacing (m)	4.5
Lane width (m)	4.5
Transverse Joints have dowel bars? (yes/no)	yes
Design Traffic Estimation	
Design Period (years)	30
Total Two-way Commercial Traffic (cvpd) in the year of completion of construction	5042
Av. Annual rate of growth of commercial traffic (expressed as decimal)	
Cumulative No of Commercial vehicles during design period (two-way), A	137386462
Average No of axles per commercial vehicle, B	2.8
Cumulative No of Commercial Axles during design period (two-way), C = A*B	384682093
Proportion of traffic in predominant direction (For 2-lane 2-way highways use a value of 1.0), D	0.50
Lateral Placement factor (0.25 for 2-lane 2-way. For multilane highways the value is 0.25 X D), E	0.125
Factor for selection of traffic for BUC analysis (for six-hour period during day), F	0.2
Factor for selection of traffic for TDC analysis (for six-hour period during night), G	0.3
Design axle repetitions for BUC analysis (for 6 hour day time traffic), H = B*E*F	9617052
Proportion of vehicles with spacing between front and the first rear axle less than the spacing of transverse joints, I	0.55
Design axle repetitions for TDC analysis (for 6-hour night time traffic), J = B*E*G*I	7934068
Proportion of Front single (steering) Axles, K1	0.486
Proportion of Rear single Axles,K2	0.155
Proportion of tandem Axles, K3	0.352
Proportion of Tridem Axles, K4 = (1-K1-K2-K3)	0.007

Pavement Structural Details	
Modulus of subgrade reaction of subgrade, MPa/m	50.33
Thickness of Granular Subbase, mm	150
Thickness of Dry Lean Concrete subbase, mm	150
Effective modulus of subgrade reaction of foundation, MPa/m	284.67
Unit weight of Concrete, kN/m^3	24
28-day Flexural strength of cement concrete, MPa	4.5
Max. day-time Temperature Differential in slab, ^{0}C (for bottom-up cracking)	16.8
Night-time Temperature Differential in slab, ^{0}C (for top-down cracking) = day-time diff/2 + 5	13.4
Trial Thickness of Concrete Slab, m	0.35
Load Transfer Efficiency Factor for TDC analysis, Beta = 0.66 for dowel Joints, 0.90 for joints without dowels	0.66
Elastic Modulus of Concrete, Ec (MPa)	30000
Poisson's Ratio of Concrete, Mu	0.2
Radius of relative stiffness, m	0.79138
Design Axle Load Repetitions for Fatigue Analysis	
For Bottom-up Cracking Analysis	
Front single (steering) Axles = H * K1	4669229
Rear single Axles = H * K2	1493262
Tandem Axles = H * K3	3387699
Tridem Axles = H * K4	66862
For Top-Down Cracking Analysis	
Front single (steering) Axles = J * K1	3852114
Rear single Axles = J * K2	1231941
Tandem Axles = J * K3	2794851
Tridem Axles = J * K4	55162

Axle Load Spectrum Data

Fatigue Damage Analysis

Bottom-up Cracking Fatigue Analysis for Day-time (6 hour) traffic and Positive Temperature Differential

Top-Down Cracking Fatigue Analysis for Night-time (6 hour) traffic and Negative Temperature Differential

Rear Single Axle			Rear Tandem Axle			Rear Tridem Axle			Rear Single Axles					Rear Tandem Axles					Rear Single Axles					Rear Tandem Axles (Stess computed for 50% of axle load)					Rear Tridem Axles (Stress computed for 33% of axle load)				
Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)	Expected Repetitions (ni)	Flex Stress MPa	Stress Ratio (SR)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
185-195	190	0.00	380 - 400	390	0.62	530-560	545	0.00	0	2.296	0.510	480926	0.000	21042	1.9549	0.395	infinite	0.000	0	2.019	0.408	infinite	0.000	17359	2.0362	0.411	infinite	0.000	0	1.9897	0.402	infinite	0.000
175-185	180	0.35	360 - 380	370	9.94	500-530	515	0.00	5240	2.220	0.493	1065414	0.005	336666	1.8944	0.383	infinite	0.000	4323	1.984	0.401	infinite	0.000	277749	2.0013	0.404	infinite	0.000	0	1.9548	0.395	infinite	0.000
165-175	170	1.75	340 - 360	350	22.98	470-500	485	0.00	26198	2.145	0.433	infinite	0.000	778539	1.8339	0.370	infinite	0.000	21613	1.949	0.394	infinite	0.000	642295	1.9665	0.397	infinite	0.000	0	1.9199	0.388	infinite	0.000
155-165	160	1.05	320 - 340	330	14.29	440-470	455	0.00	15719	2.069	0.418	infinite	0.000	483957	1.7734	0.358	infinite	0.000	12968	1.914	0.387	infinite	0.000	399264	1.9316	0.390	infinite	0.000	0	1.8851	0.381	infinite	0.000
145-155	150	1.40	300 - 320	310	4.97	410-440	425	0.00	20958	1.994	0.403	infinite	0.000	168333	1.7129	0.346	infinite	0.000	17290	1.879	0.380	infinite	0.000	138875	1.8967	0.383	infinite	0.000	0	1.8502	0.374	infinite	0.000
135-145	140	2.81	280 - 300	290	0.00	380-410	395	25.00	41916	1.918	0.388	infinite	0.000	0	1.6524	0.334	infinite	0.000	34581	1.844	0.373	infinite	0.000	0	1.8618	0.376	infinite	0.000	13790	1.8153	0.367	infinite	0.000
125-135	130	3.86	260 - 280	270	3.11	350-380	365	0.00	57635	1.843	0.372	infinite	0.000	105208	1.5919	0.322	infinite	0.000	47549	1.809	0.366	infinite	0.000	86797	1.8269	0.369	infinite	0.000	0	1.7804	0.360	infinite	0.000
115-125	120	1.40	240 - 260	250	0.62	320-350	335	0.00	20958	1.767	0.357	infinite	0.000	21042	1.5314	0.309	infinite	0.000	17290	1.775	0.359	infinite	0.000	17359	1.792	0.362	infinite	0.000	0	1.7455	0.353	infinite	0.000
105-115	110	1.75	220 - 240	230	5.59	290-320	305	0.00	26198	1.692	0.342	infinite	0.000	189374	1.4709	0.297	infinite	0.000	21613	1.740	0.351	infinite	0.000	156234	1.7572	0.355	infinite	0.000	0	1.7107	0.346	infinite	0.000
95-105	100	1.05	200 - 220	210	9.94	260-290	275	0.00	15719	1.616	0.326	infinite	0.000	336666	1.4104	0.285	infinite	0.000	12968	1.705	0.344	infinite	0.000	277749	1.7223	0.348	infinite	0.000	0	1.6758	0.339	infinite	0.000
85-95	90	4.56	180 - 200	190	8.70	230-260	245	0.00	68114	1.540	0.311	infinite	0.000	294582	1.3499	0.273	infinite	0.000	56194	1.670	0.337	infinite	0.000	243031	1.6874	0.341	infinite	0.000	0	1.6409	0.331	infinite	0.000
< 85	80	80.00	< 180	170	19.25	< 230	215	75.00	1194610	1.465	0.296	infinite	0.000	652290	1.2894	0.260	infinite	0.000	985553	1.635	0.330	infinite	0.000	538139	1.6525	0.334	infinite	0.000	41371	1.606	0.324	infinite	0.000
		100.00			100.00			100.00	1493262	Fat Dam from Sing. Axles =			0.005	3387699	Fat Dam from Tand Axles =			0.000	1231941	Fat Dam from Sing. Axles =			0.000	2794851	Fat Dam from Tand Axles =			0.000	55162	Fat Dam from Tridem Axles =			0.000
Front Single Axles and Rear Tridem axles not considered for bottom-up analysis									Total Bottom-up Fatigue Damage due to single and tandem axle loads =					0.005	+	0.000	=	0.005	Total Top-Down Fatigue Damage =					0.000	+	0.000	+	0.000	=	0.000				
									Sum of CFD for BUC & TDC= 0.00										DESIGN IS SAFE SINCE SUM OF CFD FOR BUC AND TDC< OR EQ.1														

Design for Bonded Pavement Option

Subgrade CBR (%)=				8	Trial Slab thickness (m) over DLC, h1	0.35	Poisson's Ratio of DLC, μ2	0.2	Total Flexural Stiffness Provided =	127.42	+	44.02	=	171.44			
Granular Subabse Thickness (mm) =				250	Provide DLC thickness (m), h2	0.15	Depth to Neutral axis, m (See Fig.6)	0.22	which is more than the Flexural Stiffness of the Design Slab =					69.05			
Effective k-value from Tables 2 and 3 (MPa/m) =				72.0	Elastic Modulus of Pavement Concrete (MPa), E1	30000	Flex Stiffness of design Slab	69.05	Hence, Provide a Slab of thickness (m)	0.35	over DLC of thickness (m)			0.15			
For k of	72.0	MPa/m	and for		Elastic Modulus of DLC (MPa), E2	13600	Flex Stiffness of Partial Slab Provided	127.42	Slab thickness (h1) over DLC layer may be obtained by iteratively changing h1 and matching the design stiffness with the combined stiffness provided								
Doweled Joint	and	Tied Concrete Shoulders,	Slab Thickness (m) =	0.3	Poisson's Ratio of Paving Concrete, μ1	0.15	Flex Stiffness of DLC	44.02									

DESIGN TRAFFIC IN MILLION STANDARD AXLE

Base Year/ Traffic Count Year: August 2016

VEHICULAR TRAFFIC PROJECTION IN AADT , BOTH DIRECTION

YEAR		Bus		LGV		2-axle		3-axle		MAV	
		AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %	AADT	Growth Rate %
BASE YEAR	2016	700	0.05	1032	0.07	823	0.07	1026	0.07	588	0.08
Construction Period	2017	735	0.05	1105	0.07	881	0.07	1098	0.07	635	0.08
	2018	772	0.05	1182	0.07	942	0.07	1174	0.07	686	0.08
1	2019	810	0.05	1265	0.07	1008	0.07	1257	0.07	741	0.08
2	2020	851	0.05	1353	0.07	1079	0.07	1345	0.07	800	0.08
3	2021	893	0.04	1448	0.07	1154	0.06	1439	0.06	864	0.07
4	2022	929	0.04	1549	0.07	1223	0.06	1525	0.06	925	0.07
5	2023	966	0.04	1658	0.07	1297	0.06	1616	0.06	990	0.07
6	2024	1005	0.04	1774	0.07	1375	0.06	1713	0.06	1059	0.07
7	2025	1045	0.04	1898	0.07	1457	0.06	1816	0.06	1133	0.07
8	2026	1087	0.04	2031	0.06	1545	0.06	1925	0.06	1212	0.07
9	2027	1130	0.04	2153	0.06	1637	0.06	2041	0.06	1297	0.07
10	2028	1176	0.04	2282	0.06	1735	0.06	2163	0.06	1388	0.07
11	2029	1223	0.04	2419	0.06	1840	0.06	2293	0.06	1485	0.07
12	2030	1272	0.04	2564	0.06	1950	0.06	2431	0.06	1589	0.07
13	2031	1322	0.04	2718	0.05	2067	0.05	2576	0.05	1700	0.06
14	2032	1375	0.04	2854	0.05	2170	0.05	2705	0.05	1802	0.06
15	2033	1430	0.04	2996	0.05	2279	0.05	2840	0.05	1911	0.06
16	2034	1488	0.04	3146	0.05	2393	0.05	2982	0.05	2025	0.06
17	2035	1547	0.04	3304	0.05	2512	0.05	3132	0.05	2147	0.06
18	2036	1609	0.03	3469	0.05	2638	0.05	3288	0.05	2276	0.05
19	2037	1657	0.03	3642	0.05	2770	0.05	3453	0.05	2389	0.05
20	2038	1707	0.03	3824	0.05	2908	0.05	3625	0.05	2509	0.05
21	2039	1758	0.03	4016	0.05	3054	0.05	3806	0.05	2634	0.05
22	2040	1811	0.03	4216	0.05	3207	0.05	3997	0.05	2766	0.05
23	2041	1865	0.03	4427	0.05	3367	0.05	4197	0.05	2904	0.05
24	2042	1921	0.03	4649	0.05	3535	0.05	4406	0.05	3049	0.05
25	2043	1979	0.03	4881	0.05	3712	0.05	4627	0.05	3202	0.05
26	2044	2038	0.03	5125	0.05	3898	0.05	4858	0.05	3362	0.05
27	2045	2099	0.03	5381	0.05	4092	0.05	5101	0.05	3530	0.05
28	2046	2162	0.03	5650	0.05	4297	0.05	5356	0.05	3707	0.05
29	2047	2227	0.03	5933	0.05	4512	0.05	5624	0.05	3892	0.05
30	2048	2294	0.03	6229	0.05	4738	0.05	5905	0.05	4087	0.05

Cumulative Both Direction Traffic in Million

Year	BUS	LGV	2-Axle	3-Axle	M-Axle
10 years	3.611	6.355	4.931	6.147	3.800
15 years	6.028	11.301	8.693	10.835	6.898
20 years	8.951	17.647	13.519	16.850	11.039
25 years	12.358	25.746	19.678	24.528	16.352
30 years	16.308	36.082	27.539	34.326	23.132

CUMULATIVE NUMBER OF STANDARD AXLES TO BE CATERED FOR DESIGN IN TERMS OF MSA PER LANE IN EACH DIRECTION

Directional Distribution		0.5
Lane Distrubation (D)		0.6
VDF Values (F)	Bus	1.61
	LGV	2.97
	2-Axle	11.52
	3-Axle	22.04
	MAV	7.89

The Cumulative number of Standard Axles (N)

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times D \times F$$

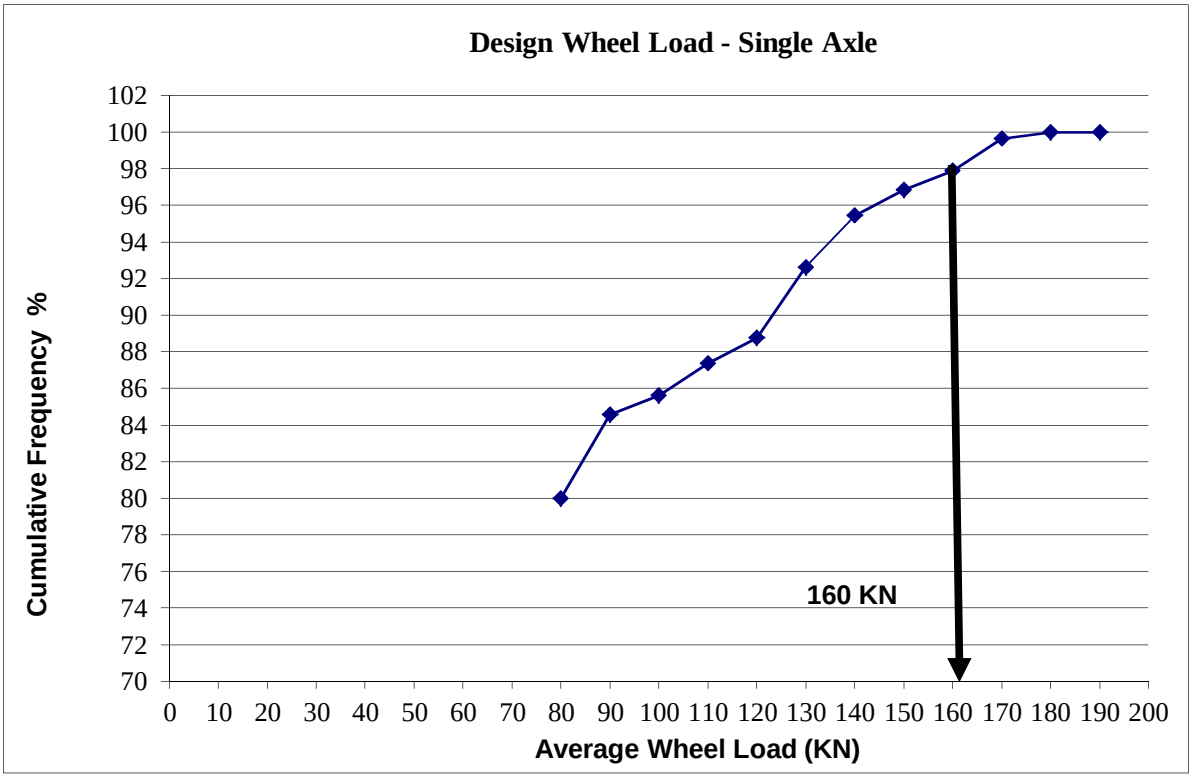
A= Initial traffic in the year of completion of construction

n= Design life in years

r = Annual growth Rate of Commercial Vehicle

Year	BUS	LGV	2-Axle	3-Axle	MAV	Total (msa)
10 years	1.744	5.664	17.039	40.638	8.994	**74**
15 years	2.912	10.072	30.037	71.636	16.327	**131**
20 years	4.323	15.728	46.712	111.405	26.129	**204**
25 years	5.969	22.946	67.994	162.162	38.705	**298**
30 years	7.877	32.158	95.157	226.942	54.754	**417**

Load Group (kN)	Mid-Point of Load Group (kN)	Frequency (%)	Cumulative
< 85	80	80.00	80.00
85-95	90	4.56	84.56
95-105	100	1.05	85.61
105-115	110	1.75	87.37
115-125	120	1.40	88.77
125-135	130	3.86	92.63
135-145	140	2.81	95.44
145-155	150	1.40	96.84
155-165	160	1.05	97.89
165-175	170	1.75	99.65
175-185	180	0.35	100.00
185-195	190	0.00	100.00
		100.00	



DESIGN OF DOWEL BAR		
Design wheel Load (Dual Wheel)	KN	160.00
Percentage of Wheel load to transferred by Dowel bar	%	50
Width of Joint (z)	cm	2
Diameter of Dowel bar (b)	cm	3.2
Characteristic compresive strength of concrete (M40) Grade (f_{ck})	Kg/cm^2	400
Allowable Bearing Stress on Concrete (F_b) = (10.16-b)*f_{ck}/9.525	Kg/cm^2	292.28
Spacing between Dowel bar, (s) =	cm	18
Distance of the first Dowel bar from the Pavement Edge	cm	15
Radius of Relative Stiffness, (l) $= \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$	cm	25.026
Number of dowel bars participating in load transfer when load is just over the dowel bar close to the edge of the slab, (n) = 1+ l /spacing		2
Total Load transferred by Dowel bar system		1.281 Pt
Load carried by the Outer dowel bar, (P_t)	Kg	49.971
Check for Bearing Stress		
Moment of Inertia of Dowel bar, (I) = $\pi b^4/64$	cm^4	5.147
Modulus of Dowel/Concrete interaction (Dowel Support), (K)	Mpa / m	41500
Modulus of the Elasticity of the Dowel bar, (E)	Kg/cm^2	2.0E+06
Relative stiffness of dowel bar embedded in concrete, (β) = $\sqrt[4]{Kb/4EI}$		0.238
Bearing Stress between the concrete and dowel bar (σ_{max}) = $\frac{KP_t}{4\beta^3 EI}(2+\beta Z)$	Kg/cm^2	9
Since Bearing Stres is less than the Allowable Bearing stress, Safe		

DESIGN OF TIE BARS		
Design Parameters		
Slab Thick ness	cm	35
Coefficient of friction between pavement and the Sub-base/base, (f)		1.5
Lane Width, (b)	m	4.5
Density of Concrete	kg/m3	2400
Weight of Slab, (W)	kg/m^2	840
Allowable Tensile Stress in plain bars (as per IRC:21-2000), (S)	kg/cm^2	1250
Allowable Tensile Stress in Deformed bars (as per IRC:21-2000), (S)	kg/cm^2	2000
Allowable Bond Stress in plain tie bars, (B)	kg/cm^2	17.5
Allowable Bond Stress in Deformed tie bars, (B)	kg/cm^2	24.6
Diameter of Tie bar	cm	1.2
Cross Sectional area of tie bar, (A)	cm^2	1.131
Perimetre of Tie bar, (P)	cm	3.770
(A) Spacing and length of the plain bar		
Area of Steel bar per metre width of join to resist the frictional force at slab bottom, (As) = bfW/ S	cm^2/m	4.536
Spacing of Tie bars c/c, = A/As	cm	24
Length of Tie bar, (L) = 2xSxA / BxP	cm	42.86
Increase length by 10 cm for loss of bond due to painting and another 5 cm for tolerance in placement, Therefore the length is	cm	58.00
(A) Spacing and length of the Deformed Tie bar		
Area of Steel bar per metre width of join to resist the frictional force at slab bottom, (As) = bfW/ S	cm^2/m	2.835
Spacing of Tie bars c/c, = A/As	cm	39
Length of Tie bar, (L) = 2xSxA / BxP	cm	48.78
Increase length by 10 cm for loss of bond due to painting and another 5 cm for tolerance in placement, Therefore the length is	cm	64.00

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CHAPTER-9: ENVIRONMENTAL SCREENING AND PRELIMINARY ENVIRONMENTAL ASSESSMENT

9.1 INTRODUCTION

The project road starts from Gurgaon city in the state of Haryana and ends at Haryana – Rajasthan border. The road section passes through 2 districts of Haryana, viz. Gurgaon and Mewat. Gurgaon also known as Gurugram, is located in Gurgaon district in the state of Haryana and is situated in the south eastern part of the state, and northern part of the country. Once a small dusty agricultural village, Gurgaon has now emerged to become the city with the third highest per capita income in India. Mewat is also a historical region in Haryana and it is located at southern edge of Haryana. It is semi-arid and its economy is mainly rain-fed agriculture. Nuh is the district-headquarter of Mewat.

The Gurgaon – Rajasthan border section of the project highway starts from PWD R.D. 2+400 at Rajiv Chowk, Gurgaon which is a 4 legged – grade separated junction at km. 32/650 of NH-8 and ends at PWD R.D. 95+985 of NH-248A at Rajasthan border. Hence the total actual existing length of the project road is 93.585 km. The index map depicting the project road is presented in **Fig 9.1**.

The main features and findings as discussed below are for the entire project corridor starting from Gurgaon at km 2+400 and ending at Rajasthan border at km 95+985 and not for any individual construction package.

9.2 ROAD AND ENVIRONMENT

Road projects are meant for improving the quality of life for people and developing the country's economy. For all positive impacts of the road projects, there may be also some significant detrimental impacts on communities in the project area and natural environment. There may be impact on properties of people, their livelihood and other social components. Similarly there can be direct or indirect impact on flora, fauna, water resources, land use etc. To account for all these issues, environmental and social impact assessments are utmost necessary. These concerns for environmental and social issues in road projects have also become a part of legal requirements and requirements for obtaining financial support. Environmental considerations are, therefore, of prime importance in road projects. Project Location Map is presented in **Fig. 9.1**.

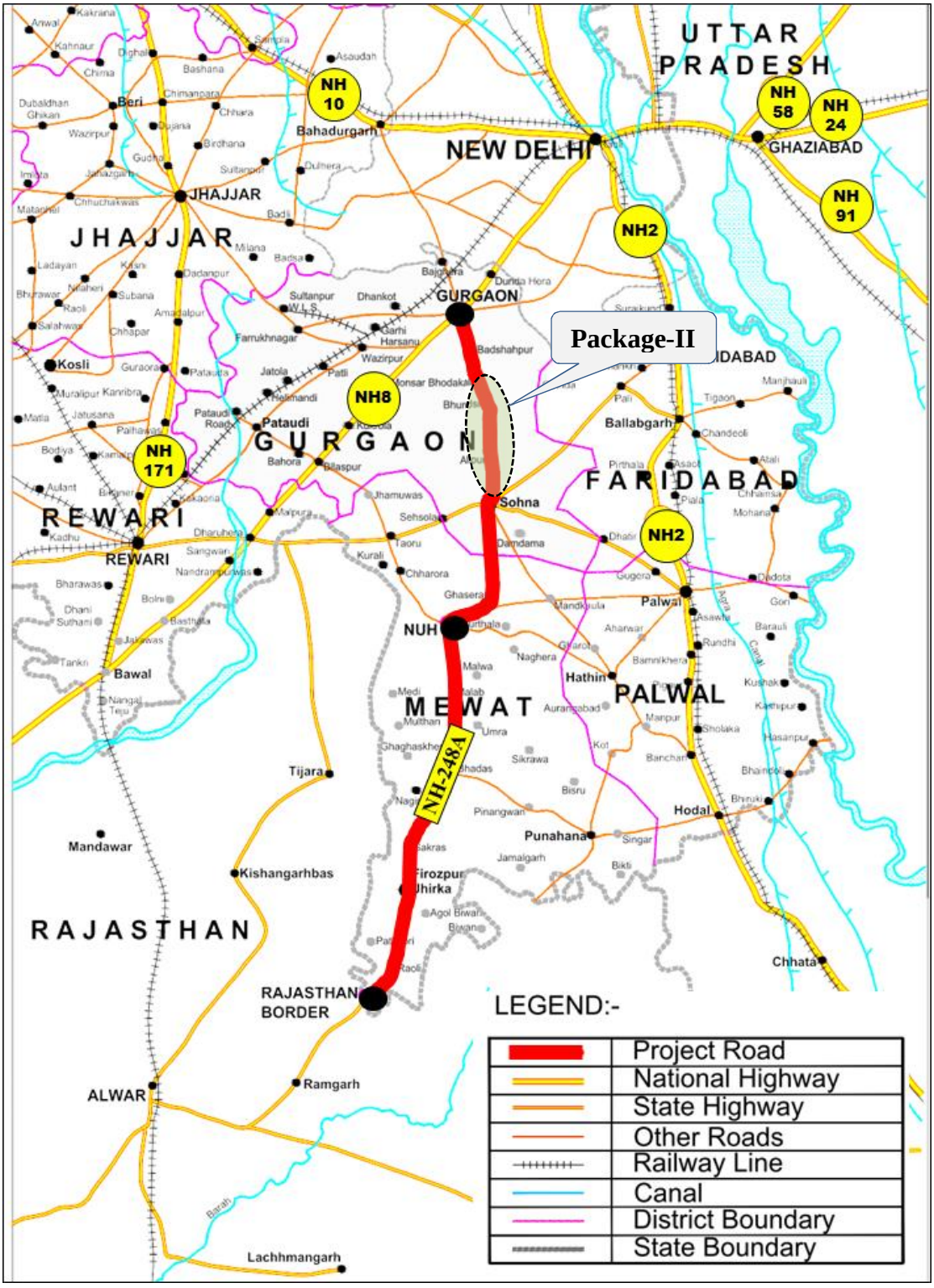


Fig. 9.1: Project Location Map

9.3 SCOPE OF PRESENT REPORT

Environmental assessment is a detailed process, which starts from the conception of the project and continues till the operation phases. The steps for environmental assessment are, therefore, different in different phases. The first step for environmental assessment is known as screening and scoping. The present study is Environmental Screening study which is preliminary study of Environmental Impact Assessment and is being conducted to identify the environmental ***implications*** of the project, preliminary identification of potential environmental impacts and for providing recommendations for integrating environmental measures into design. This study is a part of Detailed Project Report of the project in accordance with the Terms of Reference.

9.4 ENVIRONMENTAL POLICIES AND LEGISLATION

Table-9.1 presents Environmental regulations and legislations relevant to this project, along with their competent authority for implementation.

Table 9.1: Summary of Relevant Environmental Legislations

Act/Rule/Notification	Year	Objectives	Responsible Agency
The Environment (Protection) Act The Environment (Protection) Rules	1986 1986	To protect and improve the overall environment To regulate industrial setups. NOC required for establishing and operating crusher/ hot mix plants and project requiring Environmental Clearance.	Ministry of Environment and Forests (MoEF); GoI; Department of Forest, Govt. of Rajasthan (GoO); Central Pollution Control Board (CPCB);
Environment Impact Assessment Notification and amendments made thereafter.	2006 2009	To provide Environmental Clearance to new development activities following environmental impact assessment	MoEF; GoI; CPCB;
Indian Forest Act Forest (Conservation) Act Forest (Conservation) Rules	1927 1980 1981	To consolidate the laws related to forest, the transit of forest produce and the duty leviable on timber and other forest produce. Conservation of Forests, Judicious use of forestland for non-forestry purposes; and to replenish the loss of forest cover by Compensatory Afforestation on degraded forestland and non-forest land.	MoEF; Department of Forest, GoR
Wild Life (Protection) Act The Wild Life (Protection) Amendment Act	1972 2002	To protect wildlife in general and National Parks and Sanctuaries in particular. To protect wild animals, birds and plants with a view to ensure the ecological and environmental security of the country	Chief Conservator of Wildlife, Wildlife Wing, Forest Department, GoR National/State Board for Wildlife
National Forest Policy National Forest Policy (Revised)	1952 1988	To maintain ecological stability through preservation and restoration of biological diversity	Forest Department, GoI and GoR
The Water (Prevention and Control of Pollution) Act	1974	To control water pollution by controlling discharge of pollutants as per prescribed standards.	CPCB; RSPCB

Act/Rule/Notification	Year	Objectives	Responsible Agency
The Air (Prevention and Control of Pollution) Act	1981	To control air pollution by controlling emission of air pollutants as per prescribed standards	CPCB; RSPCB & Transport Department; GoR
Noise Pollution (Regulation and Control) Rules The Noise Pollution (Regulation and Control) Amendment Rules	2000 2006	To regulate and control noise producing and generating sources with the objective of maintaining the ambient air quality standards in respect of noise.	CPCB; RSPCB & Transport Department; GoR.
The Motor Vehicle Act Central Motor Vehicle Rules	1988 1989	To consolidate and amend the laws related to motor vehicles. Licensing of driving of motor vehicles, registration of motor vehicles, with emphasis on road safety standards and pollution control measures, standards for transportation of hazardous and explosive materials. To check vehicular air and noise pollution	Motor Vehicle Department
The Ancient Monuments and Archaeological Sites and Remain Act	1958	To provide for the preservation of ancient and historical monuments and archeological sites and remains of national importance and protection sculptures, carvings and other like objects.	Archaeological Department, GoI; Indian Heritage Society and Indian National Trust for Art and Culture Heritage (INTACH)

The highway projects have also been classified into two categories- Category A and Category B based on the following conditions:

Category 'A': New National Highways and expansion of existing National Highway greater than 100 Km, involving additional RoW or land acquisition greater than 40 m in Existing alignment and 60 m in re-alignment and by-passes. Involving and passing through more than one state.

Category B: State Highways expansion projects in hilly terrain (above 1000 m AMSL) and or ecologically sensitive areas.

Project is a National Highways and Category 'A' Project. This project is less than 100 km and according to 22rd Aug, 2013 MOEF & CC notification project does not required environmental clearance from Ministry of Environment, Forest and Climate Change.

Moreover any project or activity specified in Category B will be treated as Category A if located in whole or in part with in 10 km from the boundary of:

i. Protected areas notified under the Wild Life (Protection) Act, 1972,

ii. Critically Polluted areas as notified by Central Pollution Control Board from time to time,

iii. Eco sensitive areas as notified under section 3 of Environment Protection Act, 1986 such as Mahabaleshwar, Panchangi, Matheran, Pachmarhi, Dahanu, Doon Valley and project does not fall in any above notified Eco sensitive areas.

iv. Inter State boundaries and international boundaries.

9.4.1 Use of Fly Ash

According to the notification on 27th August, 2003 and notification on 3rd November 2009 of MoEF, and its amendment 25rd May, 2015 it is mandatory to use fly ash with in radius of 500 kilometers of thermal power plant to undertake construction or approve design for construction of roads embankments in contravention of the guidelines/ specification issued by the Indian Road Congress (IRC) as contained in IRC specification No. SP: 56 of 2001. In this project we can use fly ash from Faridabad thermal power station and another from Panipat thermal power station.

9.5 METHODOLOGY

The screening process mainly consists of following types of activities:

1. Study of Background information on project and related policy and legal issues
2. Collection of data from secondary sources
3. Reconnaissance survey of the project impact zone
4. Analysis of data and Screening exercise
5. Preliminary identification of Environmental impacts and mitigation

9.6 SCOPE OF DETAILED EIA STUDY

a) Study of Background Information

Study of Project Documents: First task is to study the project documents to have the understanding of the project objectives, its main components, its boundary etc. Unless the project is well understood, its different impacts on environment and social issues cannot be properly identified.

Study of Laws and regulations: Laws and regulations enacted by Government of India and State of Haryana relevant to road construction and environment were studied.

Study of Guidelines, Standards etc.: Ministry of Environment and Forests and Climate Change (MoEF&CC) and Indian Road Congress (IRC) have published different useful documents, which were studied for screening exercise.

b) Collection of Data from Secondary Sources

After having the background information about the project and its environmental aspects from legal and policy points, the next step involves collection of data from secondary sources. The data was collected on land use pattern, physiography, soil & geology, meteorology, forests, demography and related other environmental aspects. The relevant topo-sheets for the project were also collected from Survey of India.

c) Reconnaissance Survey of the Project Impact Zone

A team of environment and social experts carried out reconnaissance survey of the project road. As per reconnaissance survey a land width is available all along the project road. This can accommodate the expansion of road to 2 lane.

Sensitive environmental components along the corridor of impact were recorded. These are, road side trees, public utilities, community resources, etc. Informal public consultations with local people along the road side were also conducted to record their opinion about the project.

d) Analysis of Data and Screening Exercise

The data collected through the above steps were compiled to develop the environmental scenario of the project area and the sensitive components within that. The full road length was put under screening to identify the sensitive zones. For convenience, the roads are divided into 1 km sections and sensitive environmental issues under each section are identified. The identification of environmental sensitive features in project area would help in further detailed study and preparation of Environmental Impact Assessment report and Environmental Management Plan for the project at later phase.

e) Preliminary Identification of Environmental Impacts and Mitigation

Road construction related impacts occur at three stages of the project viz. Planning and Design, Construction and Operation stage. The broad impacts on physical, ecological and social environment were identified based on the screening data and suggestive mitigation measures shall be provided.

9.6.1 Geology and Soil

The soils mainly found along the project road in are mostly Silty Sand, Poorly graded, Sand silt mixture.

9.6.2 Land Use Pattern

The roadside environment is variable from urban developments to rural agricultural areas, semi-rural open areas with occasional roadside dwellings and small business scattered throughout the route. There is major development at some locations along the road in Gurgaon urban area. Major part of project road passes through rural open area. **Fig. 9.2.**

For the purpose of this roadside assessment, the land use types are identified as follows:

Built up	Gurgaon, sohna, Nuh, firozpur jirka, Malab etc. are some Major Built up in the Section.
Rural	A rural environment with isolated individual houses, schools, businesses alongside to the roadway.
Agriculture	Mainly cultivated land, with or without isolated thatched farmsteads.
Forest	Raipur Reserve Forest (Design Chainage-25+200 to 25+965) falls in this Section.



Fig. 9.2: Land Use Pattern

9.6.3 Water Resources

Drainage: Road side drainage is noticed in the urban section of the road. Conditions of the drains were described in engineering chapter 6 of survey Investigation.

Surface Water: There are three numbers of Major Canals crossing the project corridor. Water qualities along the project are predicted after environmental monitoring.

Ground Water: Ground water is an important source of drinking water. Water qualities along the project are predicted after environmental monitoring.

9.6.4 Climate

The climate of the state varies from sub-tropical, semi-arid to sub-humid, continental and monsoonal. Summers are very hot (up to a high of 47 degree Celsius)and winters are very cold (1˚ Celsius). The months of May and June are the hottest and the coldest months are December and January.

Rainfall recorded in the region is low and erratic in most parts excepting some areas of the Karnal and Ambala districts. Siwalik Hills region receives highest rainfall and the Aravalli Hills region records the least rainfall. Monsoon season normally spans from July to September and it sometimes causes local flooding. Winter rains are usually received between December and February. Maximum rainfall is recorded from Ambala area, being 47.16 inches (119.78cm) per annum, but it is sporadic in other areas. The average annual rainfall recorded from the state is about 650 mm and varies from less than 300 mm in southwester parts to over 1000 mm in the Siwalik Hills region. The three main climatic regions of the state are - hot arid region, hot semi-arid region and hot sub-humid region.

The mean rainfall (mm) recorded in hot arid region ranges from 300 mm-500 mm, whereas 500 mm - 750 mm in the hot semi-arid region and 750 mm - 1050 mm in the hot sub humid region of

the state. The mean temperatures recorded in the three regions are 27˚C, 26˚C, and 24˚C, respectively.

9.6.5 Flora and Fauna

Flora and Road side Plantation

The flora of study area is rich owing to climatic condition. Diversification of flora species is evident. There are varieties of plant species present in along the project road. Common varieties of trees found in roadside areas are Kikar, Neem, and Eucalyptus. Few trees are required to be cut due to this expansion. Exact number of trees to be shall be assessed after finalization of the alignment. And tree counting by forest department.

Fauna

Different species of fauna are present in the study area. The major fauna present are Frogs, and toads. Livestock reared in these districts are Cows. Common birds like Pigeon, Bulbul and sparrow, etc. were seen along the project road.

No endangered flora and fauna species are located along the project road corridor.

National Park/ Wildlife Sanctuary

There is no Wild life Sanctuary/National park falling within 10 km distance from the project road.

9.6.6 Religious Structures / Historical/Archaeological Sites

9.6.6.1 Religious Structures

The impact on religious structures is generally considered as an area of concern due to its association with the religious sentiments of the people. There are 11 numbers of religious properties likely to be affected due to project, which includes Temples, Mosques and Mazars etc.

9.6.6.2 Historical/Archaeological Sites

There is no historical or archaeological site listed under Archeological Survey of India along the project road.

9.6.7 Roadside Plantation

Tree cutting is a critical environmental issue but the cutting of roadside trees is inevitable during the widening process. A homogenous number of trees are present throughout the length of the project road at both the sides. The widening will have to be done judiciously so that maximum trees are saved. Road side Plantation in **Fig. 9.3.**



Fig. 9.3: Road Side Plantation

9.6.8 Bypass

Two bypasses have been proposed i.e. Ghasera bypass and Malab bypass. However, there is no bypass in the road section under package –II.

9.7 ENVIRONMENTAL IMPACT

During Widening to 6 lane road some Environment feature will be affected in below:

Sl. No.	*Environmental Impact*	*Affected Nos.*
1	*No. of trees to be felled (Nos.)*	*12700*
2	*Hand pumps (No.)*	*32*
3	*Bore wells (No.)*	*13*
4	*Water Tank (No.)*	*28*
5	*Ponds (No.)*	*9*
6	*Impact on Religious structures (No.)*	*11*
7	*Impact on Community structures (No.)*	*1*

Mitigation Measures

The proposed project cause potential adverse Environmental impacts which are less adverse in Nature and few of them are reversible and mitigation measures can be designated more readily for the identified impacts.

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CHAPTER-10: INITIAL SOCIAL ASSESSMENT AND PRELIMINARY LAND ACQUISITION

10.1 GENERAL

The initial social assessment study is meant to determine the magnitude of actual and potential impact on the population, properties and land due to improvement of proposed road with the objective to ensure the social considerations be given adequate weightage in the selection and design of proposed highway improvements. Basic idea is to minimize adverse social impacts with best possible engineering solutions at the optimal cost.

The main objective of this chapter is to delineate the major social impact issues, identify the potential hotspots and determine the magnitude of actual and potential impacts on people, properties and land. It also ensures the adequate weightage of social considerations in the selection and design of proposed road. It also recommends the cost-effective measures for minimizing the adverse social impacts.

The main features and findings as discussed below are for the entire project corridor starting from Gurgaon at km 2+400 and ending at Rajasthan border at km 95+985 and **not for any individual construction package**.

10.2 SCOPE AND OBJECTIVES

The Social Assessment process generally begins with screening at the time of project identification where steps are taken from the beginning and plans/ designs/ alignments are finalized in such a way that to the extent possible adverse impacts are avoided at the designing stage itself and make these roads people friendly. These steps are:

- Avoiding the adverse social impact at the designing stage especially while finalising the alignments.
- Mitigating the adverse impacts at designing stage and construction/ operation phase.
- Compensating the affected people/common properties and rehabilitation and resettlement measures.

The overall objective of conducting Social Screening is to provide input of social concerns to be dovetailed in project road design and to avoid or minimize the adverse social impacts with the best possible engineering solutions at the most optimal cost with complete co-ordination between the engineering, environmental and social teams during the design process.

In brief, keeping in mind the scope and objectives of the study, the following main tasks has been considered for accomplishment:

- To highlight the need for a proposed road project;
- To describe the proposed road project and alternatives;

- To evaluate the potential impacts of proposed road project options on the valued ecosystem components within the project study area;
- To consult the local people, officials and experts on options and impacts in order to establish institutional capacity;
- To encourage the public participation during consultation;
- To select the preferred project option and suggest mitigation plan.

10.3 METHODOLOGY

Social assessment need clear defination of the Corridor of Impact (CoI) and the Right of Way (ROW) for establishing the extent of social impact. To achieve the target which needs comprehensive data involves the following methodology:

- Establishing the width that may include carriageway, shoulder and safety zone, etc. Determining the CoI at this stage is important for undertaking social assessment surveys within the defined area. For this project the CoI has been determined to 45.0 mtrs on existing road and 60.0 on bypass and so the social assessment was made within the COI.
- 100% survey was conducted to asses the type and extent of loss on properties, enumeration of structures/ properties within the corridor of impact together with their area, type of construction, uses and its location (in terms of distance).
- Relevant baseline data on socio-economic and cultural conditions were collected from various available secondary sources, like Census Handbooks and District Gazetteers, Haryana Governments' official websites maintained by the NIC, etc., to understand the socio-economic context of the proposed project and for providing necessary inputs for social analysis of the project.

Thus, both primary and secondary data are required for establishing the extent of impact, which has been collected by administering the questionnaire for collecting information on structures, properties, land and type of ownership and social groups etc. with the help of enumerators/ investigators and by collecting secondary data from different govt. and non-govt. sources.

The data collected and recorded by the enumerators on questionnaires has been compiled on computers through MS-Excel (MS-Office Version 2010).

The tabulated data has been summarized in tables and analyzed so that social situation prevailing in the area is visualized and potential social issues are estimated. The analysis will prove the feasibility of the project and will help in suggesting various socially viable alignment options for engineering design and also come out with the mitigation measures to make the project socio-economically acceptable.

10.4 THE SOCIO BACKGROUND AND DEMOGRAPHIC PROFILE

The proposed project is traversing through the Gurgaon and Mewat districts in the state of Haryana and socio-economic profile of the PAPs have been briefed below:

- ***Number of Household and PAPs along the project road***

The properties likely to be affected by the proposed road are primarily screened at this stage by using structured questionnaire. These properties may include houses, shops, offices, religious establishments, markets, community halls or any other structure. It has been attempted to get the details of various structures that are located within the proposed COI of the project road.

According to the primary survey there are about **220 PAHs** comprising **1439 project**-affected persons (PAPs) likely to be affected directly or indirectly by the project within the corridor of impact in project. Of the total number of PAPs, 52.33% are male and 47.67% are females. The details of number of affected households and PAPs are summarized in the **Table 10.1** and **Table 10.2** respectively.

Table 10.1 Number of affected households along the Project Road

Sl. No.	Ownership Status	No. of Affected Households	Total %
1.	Owner (Titleholder/ Encroachers/ Squatters)	220	100.0
Total		**220**	**100.00**

Source: Social Survey, July 2016

At this stage of study, only those households are included in the surveys, who are losing their structures only. The analysis of the survey shows that all the affected 220 households comprise of about 1439 PAPs, who are likely to be affected directly or indirectly by the project within the corridor of impact. This figure does not include the affected persons of those households who were not available for survey and the family members of the wage earners. At few locations people were even reluctant in giving the details of their families.

Out of the total number of PAPs, 52.33% are males and 47.67% are females. The details of number of PAPs enumerated have been mentioned in **Table 10.2.**

Table 10.2 Number of PAPs along the Project Road

Sl. No.	Category	No. of PAPs	Total %
1	Male	753	52.33
2	Female	686	47.67
Total		**1439**	**100.00**

Source: Social Survey, July 2016

- ***Religious Category of PAHs***

Social customs and tradition play a major role in determining the socio-economic development as well as occupational pattern in the influence area, keeping this in mind an initial analysis has been conducted taking into account the religious profile of the PAPs within the corridor of impact. In the project road majority of the PAHs belong to Hindu religion, i.e. 59.55% followed by Muslim population 37.73% and 0.91% of Sikh population. However 1.81% of households did not respond or not present at the time of survey. This trend shows that Hindu and Muslim communities dominate the project road, which is also reflected in the type of religious structures

along the project road, where the worship places located on the project road are temples belongs to Hindu communities mosques & mazars belongs to Muslim communities. Table 10.3 delineates the religious cluster of the affected Households.

Table 10.3: Religious Categories of PAHs along the Project Road

Sl. No.	Religious Group	No. of Households	Total %
1.	Hindu	131	59.55
2.	Muslim	83	37.73
3.	Sikh	2	0.91
4.	NA/NR	4	1.81
Total		**220**	**100.00**

Source: Social Survey, July 2016

- ***Type of Family***

The project influence area is dominated by Joint families with 60.91% of the total affected households, in comparison to nuclear family, which is 35.45%, when analyzed, considering the proposed project within COI. **Table 10.4** shall be referred for details.

Table 10.4: Type of family of PAHs along the Project Road

Sl. No.	Type of Family	No. of Households	Total %
1.	Joint	134	60.91
2.	Nuclear	78	35.45
3.	Extended	4	1.82
4.	NA/NR	4	1.82
Total		**220**	**100.00**

Source: Social Survey, July 2016

- ***Vulnerable Groups along the Road***

The Social Impact Assessment identifies the vulnerable population in order to minimize the adverse impact and provide adequate mitigation measures. An assessment was made to bring out the vulnerable PAPs (SC, ST, Below Poverty Line families, Women-headed Households and households headed by physically handicapped persons). Their distribution on the stretch in terms of absolute numbers and percentage are given below.

The data reveals that out of 220 affected households, 21 households are vulnerable households are coming within the COI. Out of 21 households, 12 are Schedule Caste, and 8 households are BPL. The survey shows there is no any households belong to ST category. It shall be noted here that the number of BPL mentioned in the below table does not include those who fall under SC and ST category to avoid the repetition of data. Refer **Table 10.5** for the details of vulnerable groups:

Table 10.5: Vulnerable Groups along the Project Road

Sl. No.	Vulnerable Category	No. of Households	Total %
1.	SC	13	5.91
2.	ST	0	0.00
3.	BPL (Excluding SC, ST)	8	3.64
4.	PH	0	0.00
Total Vulnerable Category		**21**	**9.55**
Non Vulnerable Category		**199**	**90.45**
Total Household		**241**	**100.00**

Source: Social Survey, July 2016

10.5 POTENTIAL SOCIAL IMPACT EVALUATION WITHIN THE CORRIDOR OF IMPACT

The Social Assessment at an early stage of social survey aims to identify congested areas, potential impacts on the community, settlement and on land with the intension to provide the basic information to the Engineering Design team to integrate it with technical design. This assessment was made only on the defined corridor of impact.

10.5.1 Properties Likely to be affected

The properties likely to be affected by the proposed road improvement of the road in this project are about **279** structures. These structures are generally residential structures, commercial structures (i.e. Shops, Dhaba, Khokha, Petrol Pump) temples, small religious shrines, mosque and other type of squatters etc.

The estimated numbers of properties have been analyzed under different categories, such as private, religious, public/govt. etc. These divisions have been made according to their use and occupancy. Out of the total number of properties that are likely to be affected, 220 are private properties (properties that are owned by individuals and do not have govt. or community ownership) **Table 10.6**.

Table 10.6: Impact on Structures in Project Road Sections

Sl. No.	Type of Properties	No. of Structures	Total %
1.	Private	220	78.85
2.	Religious	11	3.94
3.	Government	47	16.85
4.	Community	1	0.36
Total		**279**	**100.00**

Source: Social Survey, July 2016

- ***Private Properties to be affected***

The total number of private properties likely to be affected is estimated to be 220 in project road. Further, these private properties have been examined into different categories. Of these private

properties, 158 commercial properties followed by 57 are residential properties and 5 are Res-cum-commercial properties.

- ***Religious Properties Likely to be affected along the Road***

The impact on religious structures is generally considered as an area of concern due to its association with the religious sentiments of the people. There are 11 number of religious properties likely to be affected due to project, which includes Temples, Mosques and Mazars etc.

- ***Community properties Likely to be affected along the Road***

The survey revealed that there is 1 community property that is likely to be affected due to proposed project road. The community property includes 1 Toilet.

- ***Government Properties likely to be affected***

The survey data shows that there are 47 government properties that are likely to be affected in proposed project road. The Government properties include *Bus Stop, School, Government Office Building, Police Chawki, Govt. Boundary Wall etc.*

- ***Type of Construction of the Private Structures***

As per the analysis of social screening survey, maximum number of the private property which are likely to be impacted within the corridor of impact in proposed road, are Temporary structures 80 (36.36%) followed by permanent structures 78 (35.46%) and semi-permanent 62 (28.18%).

10.5.2 Preliminary Land Acquisition

As per PWD requirement, the construction of the proposed road is to be done within 45.0 mtrs on existing road and 60.0 mtrs on bypass. The social assessment of the project road was done within defined corridor, so that if required, the impact on properties, population and other assets can be considered with ease. Hence, the calculation of land acquisition was done considering lane configuration within 45.0 mtrs on existing road and 60.0 mtrs on bypass.

The analyzed keeping in mind the large scale of displacement of people along the proposed road at different locations and accordingly the land requirement was also examined and was calculated for the 45.0 mtrs on existing road and 60.0 mtrs on bypass. Moreover, calculation of land acquisition for roadside amenities will be estimated and incorporated. The preliminary requirement of Land Acquisition for the project road is **105 Hectares**.

10.6 REHABILITATION OPTION

The social survey also included the in formations from the private structure owners regarding their rehabilitation option. Out of total 220 private structures owners' mostly (179) opted for adequate compensation at market rate and few structure owners (41) opted for Employment during construction.

10.7 DETAILED ENTITLEMENT MATRIX

As per the provisions mentioned in the broad entitlement framework of RFCTLARR Act-2013, the detailed entitlement matrix is worked out for providing compensation to the entitled families and properties. The detailed entitlement matrix prepared for this project will be given in the separate volume, 'Social Impact Assessment Report'.

10.8 STAKEHOLDERS CONSULTATION AND PEOPLES PERCEPTION

The process of information propagation about the project is one of the major tools to ensure and initiate the participation of the stakeholders. This also helps in collecting relevant information, feedback from various stakeholders for the social requirements of the project. Several group consultations was held at different locations with the affected people to apprise them about the development of the project and document their views, feedback and concern about the project so that their outlook can be incorporated in the engineering design. Besides, meetings were also held with the panchayat members of several villages in the course of social survey. Relevant data was taken from them which included demographic features, available resources, land rates and other important features.





Public consultation is a continuous process and has been carried out at all stages throughout the project road. However, in order to document the issues raised by the potential PAPs, public consultations at this stage were conducted at different locations. A large number of potentially affected persons (PAPs) expressed their views about the proposed project. In order to carry out the consultation along the project corridor the people/ stakeholders denied having interaction with the consultant's team separately at few locations. Thus the consultation conducted was in groups.

As the project will be implemented *through government departments and the process of resettlement and rehabilitation needs humane approach as well as closeness to the people and community service orientation, it was necessary to find out the capacity of the existing NGOs and CBOs to involve them in rehabilitation and resettlement work. Several NGOs were identified and examined on the basis of their past work performance, areas of work experience and its organizational set-up etc., However, the capacity assessment of the concerned NGOs in detail could not be carried out at this stage. Capacity assessment of the concerned NGOs in detail will be carried out in the later stage for preparing the Resettlement Action Plan (RAP).*

The detailed analysis and finding of public consultation will be given in the separate volume, '**Social Impact Assessment Report'**.

10.9 ESTIMATED R&R BUDGET

The budget estimation at this stage has premeditated keeping in mind alignment considerations, which was considered by PWD. This exercise at feasibility stage is aim to weigh up technical, social and economic implication of the project.

The resettlement cost estimate for the project proposed, includes compensation for private land determined in accordance with RFCTLARR Act and by adopting the multiplying factor.

The compensation for structure at replacement cost without depreciation, resettlement and rehabilitation assistances in accordance with the RFCTLARR Act and in accordance with the provisions of the EM. The total resettlement cost for the project in different heads of budget items are listed below:

Private Land: The compensation for private land has been calculated as an average of replacement cost of land in rural, semi-urban and urban area adjoining the road corridor. The replacement cost was gathered during census survey in discussion with local community. For budgetary purpose, the replacement cost for land has been taken as Rs. 5,45,69,063/- per Hecrate, being the average rate for private land from the DLC records. The multiplying factor as per RTFCTLARR Act is 1.0 and 2.0 based on the distance from the nearest urban centre and for budgeting purpose, the highest of the multiplying factor of 2.0 has been taken and along with the 100% solatium. Thus the land cost has been taken as Rs. 5,45,69,063/- per Hecrate including the multiplying factor and the solatium.

Structure: The compensation of affected structures is based on the rates of various types as described in Basic Schedule Rates (BSR), PWD, Govt. of Haryana, 2014 for building works, material and labour. For budgetary purpose, the replacement cost for structure without depreciation has been taken as Rs. 8,411 per sq.m. for permanent structure, Rs. 5,514 per sq.m. for semi-permanent structure and Rs. 2,052 per sq.m. of temporary structure. Replacement cost for compound wall/ boundary wall of stone masonry has been taken as Rs.1,354 per running meter. If there is delay in project implementation, the valuation committee will determine the replacement cost at the BSR's updated rate.

10.9.1 Total R & R Cost

The R&R budget for the project road is estimated to be around **Rs. 650.96** crore which includes cost of land, replacement cost of religious and community structures and R&R Assistance for the affected people. The tentative budget is given in **Table 10.7.**

Table 10.7: Total R & R Cost

Item	Input Unit	Rate	Gurgaon-Nuh Road	
			Quantity	Amount
Compensation				
Land Cost (Multiplying Factor 1.0	Ha.	5,45,69,063	105	**5,729,751,615**

Item	Input Unit	Rate	Gurgaon-Nuh Road	
			Quantity	Amount
to 2.0 and Solatium 100%)				
Permanent Structures (non-titleholders)	Sq.m	8,411	11724.00	98610564
Semi-permanent Structures (non-titleholders)	Sq.m	5,514	7941.00	43786674
Temporary Structures (non-titleholders)	Sq.m	2,052	1824.90	3744695
R&R Assistance				
Housing and House Site grant to impacted Residential Structures	One Time	120000	57	6840000
Subsistence allowance for Residential/ Commercial Structures	One Time	18000	220	3960000
Shifting allowance Residential/ Commercial Structures	One Time	10000	220	2200000
Rehabilitation Grant for reconstruction of impacted commercial Structures	One Time	20000	163	3260000
Vulnerable Household assistance	One Time	25000	21	525000
Training for Vulnerable household	One Time	5000	21	105000
Community Assets				
Places of worship	Unit	500000	11	5500000
Part of School	Unit	350000	5	1750000
Bus Stand	Unit	150000	9	1350000
Boundary Wall	Unit	100000	16	1600000
Petrol Pump etc.	Unit	100000	8	800000
Toilet	Unit	50000	1	50000
Govt / Trust Buildings	Unit	300000	9	2700000
Administrative Cost				
NGO Recruitment	LS	10000000	-	10000000
External Monitor	LS	1000000	-	1000000
Disclosure Expenses	LS	50000	-	50000
Training for PIU and PMU Staff	LS	200000	-	200000
Subtotal (Based on Data)				**5,917,783,548**
10% Contingency				591778354.8
TOTAL Subtotal + 10% Contingency				**6,509,561,903**
Total INR in Crores				**650.96**

10.10 CONCLUSION

In brief, the portrayal of assessment of social impact was nothing but an effort to depict the existing social scenario along the proposed road and perceived impacts on population due to implementation of the project with an intention to minimize the resettlement. A proper attention is required to take account of social consideration in the project planning and implementation as per policy of the Government of India, applicable resettlement policy and local needs of the people.

In finalizing the alternative options, the mitigation plan of social report and views expressed by the local community during consultation, especially the threat of displacement and negative impact on their business opportunities and livelihood has been taken into consideration.

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CHAPTER-11: COST ESTIMATE

11.1 GENERAL

The project cost estimates have been prepared based on various items of works required for the development of project road.

In general, the work is to be executed as per the IRC and MORTH as applicable for 6-lane and Technical Specifications contained in "Specifications Road and Bridge Works" (Fifth Revision – 2013).

11.2 ESTIMATION OF QUANTITIES

The quantities of major items of works have been worked out based on following:

- **Site Clearance:** The area considered for Site Clearance is the area within the proposed Right of Way excluding the existing carriageway area.

- **Earth Works**: This item provides for roadway excavation, earthwork in embankment, sub-grade and shoulders, medians, islands including disposal of surplus earth and unsuitable material. In this stage, the construction of embankment height has been taken as per site condition. Sub-grade soil having a CBR ≥ 8 % will be taken from borrows area. It is also to be ensured that during construction the existing 500m thick embankment / existing ground below the subgrade is recompacted to MDD and have CBR value ≥ 8 %.

- The pavement quantities like GSB, WMM & Bituminous items etc. have been worked out based on the geometrics and cross sections, pavement design done based on traffic and laboratory investigations. The total earthwork in cut-and-fill has been determined from average embankment height noted during road inventory survey**.**

- **Culverts:** The estimation of quantities for culverts is based on site condition & detailed inventory. The detailed recommendations are given in proposed development scheme chapter.

- **Bridges and Structures:** The estimates of quantities for bridges and other structures have been worked out based on condition of structures. The detailed recommendations are given in Chapter 8**.** In this stage the cost for structures has been worked out based on Rate per square meter basis.

- **Drainage and Protection Works:** Quantities for the surface, subsurface and roadside drains, drainage chutes in cement concrete and stone pitching at outfalls/escapes are as per actual including pre cast drain at edge of RE wall.

- **Traffic Signs and Markings:** Proper traffic signs were selected at required locations along the project corridor and special signs at tollgates were designed. The quantity of traffic signs and markings are calculated based on the detail drawings for the highway and junction to ensure safety in the proposed highway facility.

- **Truck lay-byes & Bus bays and Passenger Shelters:** Truck lay-byes shall in general be located near Toll Plaza, interstate borders and place of conventional stops of the truck operators etc. In this item, the estimates of quantities are based on the standard layout given in IRC: SP: 87 as applicable.

  Bus bays and Passenger shelters shall be allowed to stop for dropping and picking up passengers at bus bays location. In this item, the estimates of quantities are based on the standard layout given in IRC: SP: 87 as applicable.

- **Junctions Improvement and Toll Plaza:** This item includes quantities of kerbs, railings, median etc. at the location of junctions. The cost for junctions includes the cost for at grade junctions, which need improvement along the project roads.

  The estimates of quantities for toll plaza have been worked out based on design of rigid pavement. The cost for the toll plaza includes cost of construction of tollbooths, electrical works, high mast lighting, and toll administrative building with all other features as desired Standards.

- **Maintenance of Existing Roads:** The provision under this sub-head has been made to include reinforced cement concrete pipe duct, 300 mm dia in single row, across the road on interval of 0.5 km & 2 km in Built-up and rural section respectively. This also includes carrying out routine maintenance along the right of way based on present condition surveys and other pavement investigations data. Lump Sum amounts for traffic diversion during construction and planting of trees by the road side (Avenue trees) and flowering plants and shrubs in central verge and Maintenance of flowering plants and shrubs in central verge has been provided.

11.3 RATE ANALYSIS

Analysis of rates has been carried out using Haryana PWD Schedule of Rate, July 2014. As PWD SOR 2014 does not have the finished rates of the roadwork items, hence all rates have been analyzed adopting the following principles:

- Market rates have been adopted for the following basic materials:
  - Aggregates
  - Steel
  - Cement
  - Bitumen
- Cartage rate has been adopted from PWD SOR 2014.
- Premium on the same is yet to be notified by Govt. of Haryana,
- Considering the current market scenario, no escalation has been applied on the cartages.
- Machinery rate has been adopted from the MORTH Data Book with necessary escalation as per NHAI Circular No. 11041/218/2007-Admn dated 08.12.2010.

11.4 LAND ACQUISITION COST

Land Acquisition cost has been estimated based on the Schedule-3A prepared for the project. The collector rate for different villages in Gurugram district have been adopted to estimate the LA cost. The cost presented below is for section km 0+340 to km 22+000 of NH248A.

Table 11.1: Summary of Land Acquisition cost

Name of Village	Additional land required (in Ha.)	Private Land to be acquired (in Ha.)	Nature of Land	Collector rate (in Rs.)	Rate per Ha. (in Cr.)	LA Factor*	Cost (in Cr.)	Total cost after LA factor (in Cr.)
Fajilpur Jharsa	1.08751	0.89438	Commercial	20400 per Sq. Yard	24.40	2	21.82	43.64
Jharsa	1.05218	0.03793		32300per Sq. Yard	38.63	2	1.47	2.93
Islampur	0.14007	0.14007				2	5.41	10.82
Tikri	0.36064	0.33197				2	12.82	25.65
Bhondsi	0.46340	0.39896	Agricultural	11687500 per Acre	2.89	4	1.15	4.61
	8.13200	8.13200	Non Agricultural	6800 per Sq. Yard	8.13	2	66.14	132.27
Ghamroj	4.78000	2.98668	Agricultural	9070000 per Acre	2.24	4	6.69	26.78
	3.58000	4.96000	Non Agricultural	5800 per Sq. Yard	6.94	2	34.41	68.81
Alipur	0.61000	0.61000	Agricultural	9976500 per Acre	2.47	4	1.50	6.02
	0.00680	0.00680	Non Agricultural	5400 per Sq. Yard	6.46	2	0.04	0.09
Dunela	0.02200	0.02200	Agricultural	13604300 per Acre	3.36	4	0.07	0.30
	0.06400	0.06400	Non Agricultural	5400 Sq. Yard	6.46	2	0.41	0.83
Sohna	0.18075	0.17842	Agricultural	13604300 per Acre	3.36	4	0.60	2.40
	1.06000	1.06000	Non Agricultural	6100 Sq. Yard	7.30	2	7.73	15.47
Total Land Acquisition Cost							**160.28**	**340.60**

* 4times for agricultural land; 2times for non-agricultural land

11.5 UTILITY SHIFTING COST

Owing to the proposed upgradation, no. of utilities will be affected and would require shifting of the same .The list of identified utilities are given below:

Table 11.2: Details of affected utilities

Sl. No.	Utilities	Concerned stakeholders
1	Electric poles and street lights	DHBVN, Gurgaon DHBVN, Nuh

Sl. No.	Utilities	Concerned stakeholders
2	3 No. of 220KV lines,4 nos. of 66 KV line	HVPNL ,Gurgaon
3	Water pipeline, Sewer line	Public Health Engineering Circle, Gurgaon & Nuh
4	Water pipeline, Sewer line, Recycle line	HUDA Gurgaon
5	HT line	PGCIL

All the stakeholders have been notified for shifting of the affected utilities and accordingly joint site visit have been completed. Pending the receipt of the cost for utility shifting from the respective stakeholders a lump sum cost of Rs.135 Cr. has been considered at this stage for the section from Km 0+340 to 22+000 of NH248A .

11.6 PRELIMINARY PROJECT COST

The project cost on above items has been worked out for the year 2017-18 based on development proposal of the project corridor. The abstract of the estimate is presented below:

Table 11.3: Abstract Cost Estimate by Items

Sl. No.	Bill No	Description	Amount Package-II
1	Bill No 1	Site clearance and dismantling	4,599,947
			0.09%
2	Bill No 2	Earth work	414,436,015
			8.49%
3	Bill No 3	Granular sub-base and base courses	433,440,282
			8.88%
4	Bill No 4	Bituminous courses	435,520,026
			8.92%
5	Bill No 5	Cross drainage works	48,208,000
			0.99%
6	Bill No 6	Bridge's, underpass, flyover & rob etc.	2,406,263,721
			49.29%
7	Bill No 7	Drainage and protective works	610,505,620
			12.51%
8	Bill No 8	Traffic signs, markings and road appurtences	172,453,329
			3.53%
9	Bill No 9	Miscellaneous items	112,385,630
			2.30%
10	Bill No 10	Electrical works	34,323,000
			0.70%
11	Bill No 11	Toll plaza	150,000,000
			3.07%
12	Bill No 12	Traffic management including traffic diversion and safety during construction	59,366,580
			1.22%
Total Cost			4,881,502,150
Total Cost (in Cr.)			**488.15**

The total project cost for the project road section from km 9+282 to km 22+000 is given below:

Table 11.4: Total Project cost

Estimated Project Cost	
Particulars	**Amount (in Cr.)**
1) Base Civil Construction Cost	488.15
2) Escalation @ 5% upto Bid Due Date	-
3) Civil Construction Cost on Bid Date (1+2)	488.15
4) Contingencies @ 1% of Civil Construction Cost as mentioned in (3) above	4.88
5) Total EPC Cost (3+4)	493.03
6) IC/Pre-Operative Expenses @ 1% of Total EPC Cost mentioned in (5) above	4.93
7) O&M during Development Period	-
8) Total Cost (5+6+7)	**497.96**
9) Financing Expenses	3.88
10) Project Cost without IDC (8+9)	**501.85**
11) Interest During Construction (IDC) @ 10.10% p.a.	22.33
12) Estimated Project Cost as on Bid Date (10+11)	**524.17**
Cost of Preconstruction Activities (Rs. in Crores)	
Land Acquisition	340.60
Utility Shifting (Electrical Overhead & Underground, Water supply, Sewarage) Lump sum	135.0
Total Capital Cost (Rs. in Crores)	**1689.01**

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CHAPTER-12: FINANCIAL ANALYSIS

12.1 BACKGROUND

The main objective of financial analysis is to assess the likely returns to the investors under realistic conditions/assumptions. In the present studies the financial viability of the project is assessed, assuming minimum Equity IRR to be >=15%, on the basis of project's financial internal rate of return on investments, which is estimated on the basis of cash flow analysis.

The analysis attempts to ascertain the extent to which the investment can be recovered through toll revenue and the gap, if any, be provided though grant. This covers aspects like financing through debt and equity, loan repayment, debt servicing, taxation, depreciation, etc. The viability of the project is evaluated on the basis of Equity IRR. The Equity IRR is estimated on the basis of cash flow analysis, where both costs and revenues have been indexed to take account of inflation.

12.2 HOMOGENEOUS SECTIONS

The Project Road has been kept as one homogeneous link. The details of Homogeneous Link/Section adopted for tolling are presented below.

Table 12.1: Details of Toll Homogeneous Sections

Homogenous section	From km to km	Length (km)	Remarks
HS-1	00+340 - 22+000	21.660	Rajiv Chowk to Sohna

12.3 TRAFFIC COUNT

Traffic figures for revenue calculations are taken from Traffic study, presented in chapter 5 in this report. Table 12.2 below presents the traffic for revenue figures at proposed toll plaza locations.

Table 12.2: Traffic Count Data (AADT)

Traffic Homogenous Section #	Car	Mini Bus	Std Bus	LCV	2A	3A	MAV	Over size	Tolled PCUs
HS-01	8144	111	510	1539	727	1172	447	0	19,428

The traffic (AADT) at toll plaza is projected to analyse the concession period based on the traffic capacity parameters. Highway capacity for 4 Lane is considered as 60,000 PCUs. Table 12.3 presents the traffic projection.

Table 12.3: Traffic Projection (PCUs)

Year	Total Traffic in PCUs	Composition/ Remarks
Year 2016-17	**23847**	**Base Year**
Year 2017-18	25039	Year 1
Year 2018-19	26291	Year 2

Year	Total Traffic in PCUs	Composition/ Remarks
Year 2019-20	27606	Year 3
Year 2020-21	28986	Year 4
Year 2021-22	30435	Year 5
Year 2022-23	31957	Year 6
Year 2023-24	33555	Year 7
Year 2024-25	35233	Year 8
Year 2025-26	36995	Year 9
Year 2026-27	38844	Year 10
Year 2027-28	40786	Year 11
Year 2028-29	42826	Year 12
Year 2029-30	44967	Year 13
Year 2030-31	47215	Year 14
Year 2031-32	49576	Year 15
Year 2032-33	52055	Year 16
Year 2033-34	54658	Year 17
Year 2034-35	57391	Year 18
Year 2035-36	60260	Year 19
Year 2036-37	63273	Year 20
Year 2037-38	66437	Year 21
Year 2038-39	69759	Year 22
Year 2039-40	73247	Year 23
Year 2040-41	76909	Year 24
Year 2041-42	80754	Year 25
Year 2042-43	84792	Year 26
Year 2043-44	89032	Year 27
Year 2044-45	93483	Year 28
Year 2045-46	98,157	Year 29
Year 2046-47	103,065	Year 30

Capacity of 6 lane highway at (LOS-C) is 1.20 Lac PCUs. The traffic projection indicated that traffic is within limit in next 30 years, considering growth rate at 5% CAGR. Hence a concession period of 30 years has been adopted.

12.4 COST OF THE PROJECT

The costing for the project is done as per the details covered in this report.

Civil Construction Cost = Rs 1132.14 Crores (Rs 52.27 Crores/Km)

12.5 PHASING OF THE CAPITAL COST

The total cost for the proposed project road has been computed based on the 2017-18 prices. The annual phasing of capital cost is made as per the work schedule. Construction cost is phased over

a 2.5 years construction period from mid of 2018-19 to end of 2020-21 as 20%, 40 and 40% respectively.

12.6 COST ESCALATION

The base costs have been escalated at a rate of 5% per annum to obtain the actual costs in the year of expenditure. This is in line with long-term inflation rates of major materials utilized for construction.

12.7 LANDED PROJECT COST

The total landed costs for the proposed road at the end of the construction period has been estimated by adding the capitalized interest during construction (IDC). The total landed cost at the time of commissioning (start of 2020-21) is thus estimated is given in Table 12.4.

Table 12.4: Total Landed Cost including IDC

Sl. No.	Particulars	Amount (Rs in Cr.)
A	**Concessionaire Cost**	
1	Civil Construction Cost base year (2017-18)	1132.14
	Escalation for one year (Civil Cost in 2018-19)	**1188.75**
2	Physical Contingencies Charges (1% Civil Construction Cost)	11.89
3	**Estimated Project Cost (EPC), base year**	**1200.63**
4	IC & Preoperative Expenses (1% of EPC)	12.01
5	Interest During Construction, IDC	57.5
6	Finance Charges (1.0% of Debt)	9.08
7	Escalation @ 5.0% per annum (on TPC)	83.30
8	Viability Gap Funding VGF	0.0
9	**Concessionaire Cost of Project after Grant**	**1362.54**

12.8 TOLL RATES

Toll rates have been taken as per the toll notification of National Highway fee (determination of rates and collection) rules 2008 and the amendment thereto. There are seven structures (proposed) applicable for special tolling as detailed below.

T	**Major Structures having length of above 60 meters**	
	PACKAGE - 1	
1.	**Structure-1** a- Civil construction cost (in Rs. Cr)	OVERPASS 9.19 crores

	b- Base year assessing the said cost c- Length of structure in m d- Tollplaza e-Design Chainage	2017 75m Toll Plaza-I 1+905
2.	**Structure-2** a- Civil construction cost (in Rs. Cr) b- Base year assessing the said cost c- Length of structure in m d- Tollplaza e- Design Chainage	FLYOVER 458.61 crores 2017 4750m Toll Plaza-I 2+842 TO 7+592
	PACKAGE - 2	
3.	**Structure-3** a- Civil construction cost (in Rs. Cr) b- Base year assessing the said cost c- Length of structure in m d- Tollplaza e- Design Chainage	FLYOVER 153.36 crores 2017 1588m Toll Plaza-I 9+406 to 10+994
4.	**Structure-4** a- Civil construction cost (in Rs. Cr) b- Base year assessing the said cost c- Length of structure in m d- Tollplaza e- Design Chainage	FLYOVER 7.7 crores 2017 75m Toll Plaza-I 15+871 to 15+946
5.	**Structure-5** a- Civil construction cost (in Rs. Cr) b- Base year assessing the said cost c- Length of structure in m d- Tollplaza e- Design Chainage	FLYOVER 68.9 crores 2017 714m Toll Plaza-I 19+211 to 19+925
U	**Bypass costing Rs. 10 crore or more**	
1.	**Bypass-1** a- Civil construction cost (in Rs. Cr) b- Base year assessing the said cost c- Length of Bypass in km's d- Toll plaza e- Design Chainage	NIL

The toll rate applicable at toll plaza in 2017-18 for illustration only, is presented in table 12.5 below.

Table 12.5: Toll rates applicable for project road in 2017-18

Year	Car	Mini-Bus/ LCV	Bus / 2A Truck	3 Axle Truck	4-6 Axle Truck	>=7 Axle
2007-08	0.65	1.05	2.20	2.40	3.45	4.20
Toll Plaza 1 in 2017-18	105	170	355	385	555	675

12.9 TOLL REVENUE

The toll revenue is the product of the forecast traffic expected to use the road and the appropriate toll fee for the vehicle category. A toll indexing pattern @ 5% per year has been adopted and

rounded off to nearest one Rupee. Toll revenues have been calculated for each of toll fee structure proposed above is given below in **Table 12.6.**

Table 12.6: Expected Toll revenue earning from each toll plaza Revenue (Rs in Crores)

Sr. No.	Concession Year	Revenue	Remarks
0	2017	Base	
1.	2018	Construction	2.5 Years as Construction Period
2.	2019		
3.	2020		
4.	2021	104	
5.	2022	115	
6.	2023	127	
7.	2024	140	
8.	2025	154	
9.	2026	170	
10.	2027	188	
11.	2028	207	
12.	2029	228	
13.	2030	251	
14.	2031	278	
15.	2032	305	

Sr. No.	Concession Year	Revenue	Remarks
16.	2033	336	
17.	2034	371	
18.	2035	410	
19.	2036	451	
20.	2037	497	
21.	2038	548	
22.	2039	606	
23.	2040	666	
24.	2041	735	
25.	2042	810	
26.	2043	895	
27.	2044	984	
28.	2045	1,085	
29.	2046	1,197	
30.	2047	1,323	

12.10 OPERATION AND MAINTENANCE PERIOD EXPENSES

Routine maintenance costs comprise of maintenance of the pavement, collection of litter, traffic management (policing), accident repairs and all ancillary works including beautification.

The periodic maintenance costs include cost of overlay, repair/renovation of road furniture, drains, buildings etc. The periodic maintenance includes periodic renewals at every 5 years.

Routine maintenance/ Periodic maintenance costs have been considered as per the MORT&H guidelines 2011-12 prices. The details of the maintenance costs and administration charges (base year 2011-12) are given below in **Table 12.7**.

Table 12.7: Routine & Periodic Maintenance (MORT&H Guidelines)

Sr. No	Description		Rate	Unit
1	Insurance Expenses	=	0.15%	of the TPC
2	Routine Maintenance cost & Light (2011-12)	=	4.75	Lac/km/year (4L)
3	Periodic maintenance Cost (2011-12)	=	35	Lac/km /5thyear (4L)
4	Toll administration and other costs (2011-12)	=	1.6	Crores/Toll Plaza/year (4L)

Sr. No	Description		Rate	Unit
5	Other Office Expenses (2011-12)	=	2.5	Crores/year

Note: Above Rates are for 4 Lane projects, for 6 lane 1.5 times shall be applicable

12.11 RESULTS AND ANALYSIS

Based on the project structure traffic study and toll rate analysis, financial feasibility analysis has been carried out as per the methodology outlined in earlier sections. The minimum Equity IRR (Return on Equity) considered for the project is 15%. As per current scenario, existing traffic is low. Financial indicators are presented in **Table 12.8** below.

Table 12.8: Financial Indicators

S. No.	Particulars	Results (At 15% Equity IRR)	Results (At Maximum Permissible VGF of 10% of TPC as per clause 25.2.2 of DCA)
1.	Equity IRR	15.0%	12.6%
2.	Expected VGF (in %)	29%	10%
3.	Expected VGF (Rs. in Crore)	389	135
4.	Total Project Cost (Rs. in Crore)	1,340	1,355
5.	NPV of the Equity @ 12% discount rate (Rs. in Crore)	238	50

12.12 RECOMENDATIONS

From the above table it can be concluded that the project is financially **Not Viable** on BOT (Toll) basis with 10% Grant permissible for as per clause 25.2.2 of DCA and 30 years Concession Period. Hence the project is recommended to be taken up on HAM or EPC mode.

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CHAPTER 13: CONCLUSION AND RECOMMENDATIONS

13.1 CONCLUSION

The Feasibility study carried out by the Consultant has revealed the following:

a) The project road section starts from PWD R.D. 2+400 at Rajiv Chowk, Gurgaon which is a 4 legged – grade separated junction at km. 32+650 of NH-8 and ends at PWD R.D. 95+957 of NH-248A i.e. at Rajasthan Border.Based on various interactions with NHAI, it was decided to divide the project road into three distinct construction packages, viz.

   i) Package-I : PWD RD 2+400 to 11+682 and

   ii) Package-II : PWD RD 11+682 to 24+400

   iii) Package-III: PWD RD 24+400 to 95+957

b) The project road section for Package-II starts from existing chainage 11+682 and ends at existing chainage 24+400 (i.e. Sohna) of NH-248A. Therefore, the total existing length of project road is 12.718 km.

c) The current traffic between Rajiv Chowk (km 0+000) to Ashram/Vatika Chowk (km 4+900) is 68760 PCU and between Ashram / Vatika Chowk (km 4+900) to Sohna (km 23+300) it is 23847 PCU. Thus with the traffic projection, it is apparent that traffic would exceed 25000 PCU for km 4+900 to km 23+300 section of the project road in 2017-18. Therefore considering the current traffic and rapid urbanization of the project influence area, NHAI has decided to upgrade the road section under Package-II as 6 lane with paved shoulder configuration.

d) Between PWD R.D. 11+682 and end of the project i.e PWD R.D 24+400, the existing NH-248A is of 2 x 2-lane configuration with median varying between 0.5m to 1.5m.

e) Modewise analysis of traffic captured in the homogeneous section in this Package-I shows a distribution of 93%and 7% between passenger and Freight vehicles. In Passenger vehicles, Cars have the maximum share in overall traffic with 61% share (45,096 vehicles) followed by 2-W with 23% (16,968). Auto Rickshaws also have a substantial share of 7% in overall traffic. Share of Buses and LCV Passenger vehicles (used to ferry passenger) is 1.7% and 1.2% respectively. This shows that public vehicles are not sufficient in number.

f) Consultant has proposed Flyover cum Viaduct structures at km 9+781, km 10+619, km 15+909 and km 19+550. Based on the discussion with NHAI, Consultant has proposed one VUP at km 14+325.

g) Consultant has recommended a Toll plaza (total no. of lanes-24) at km 13+000.

h) From the Financial analysis, it can be concluded that the project is financially **Not Viable** on BOT (Toll) basis with 10% Grant permissible for as per clause 25.2.2 of DCA and 30 years Concession Period. Hence the project is recommended to be taken up on **Hybrid Annuity or EPC mode.**

13.2 RECOMMENDATIONS

Since the project is financially **Not Viable** on BOT (Toll) basis with 10% Grant permissible for as per clause 25.2.2 of DCA and 30 years Concession Period. Hence the project is recommended to be taken up on **Hybrid Annuity or EPC mode**.