

using connectors. The connectors were developed in a manner that they produce the actual pattern of route selection for accessing major roads. The routes chosen by drivers across the network take account of estimated travel times and travel costs, like Toll charges. In addition, other factors might influence a driver’s route choice decision, such as safety, comfort, and reliability. The Average Daily Traffic (ADT) for each of the links is adopted from the traffic counts conducted during April-June 2016.

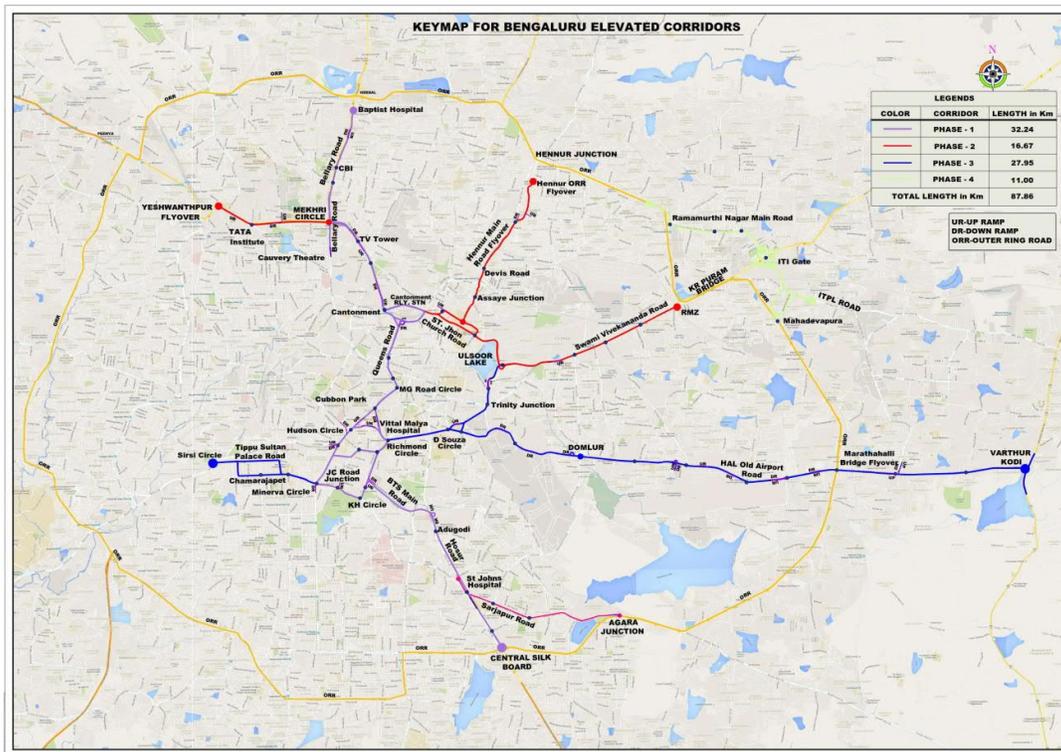


Figure 4-2: Proposed Elevated Corridors - BI Scenario

4.4.1 Demand Data

The demand data that is used in transport models is derived from OD (Origin Destination) Matrices as discussed in detail in Chapter 4, which is supplied to the model in the form of matrices. The process followed for matrix building includes a number of stages like OD data analysis, matrix compilation & maximization etc. The surveys those were undertaken to develop these matrices included:

1. Roadside Interview Survey (OD)
2. Manual Classified Traffic Volume Count (TVC)

Both, roadside interview & traffic volume count surveys included data for all major roads constituting the Primary network both at outer cordon points beyond the city as



well as in the city core area. Main vehicle types considered for modelling purpose includes:

- Two wheelers
- Auto rickshaws
- Cars (including taxis)
- Buses
- Light Commercial Vehicles (Mini LCVs, 4-Tyre & 6-Tyre)
- 2-Axle Trucks
- 3-Axle Trucks
- Multi Axle Vehicles (MAVs)
- Tractor-trailers

4.4.2 Development of O-D matrices

Location wise OD matrices were obtained for all the survey locations, following the above mentioned vehicular classification. The location wise matrices were then clubbed to obtain one combined OD matrix. In the estimation of the combined O-D matrix, the following procedure has been considered:

- If an O-D element (or O-D pair) can be observed at only one location, then the value of the O-D element from that location matrix is considered in the combined estimate.
- If an O-D matrix element can be observed at more than one location and are on the same path, then the maximum of that element in the location matrices has been considered for combined matrix.
- If an OD matrix element observed at more than one location, the OD pair of which has a parallel route than the sum of that element has been considered for the combined matrix.

Based on the expanded OD data, mode-wise share of different vehicle type is given in Table 4-4.

Table 4-4: Matrix Total by Mode (ADT, PCUs)

Modes	Expanded OD Matrix Total
TW	6,93,897
Auto Rickshaws	4,11,448
Cars	8,63,284
Buses	1,70,431
Goods (LCV + Trucks)	8,01,512
TOTAL	29,40,572

4.5 TRAFFIC ASSIGNMENT

Traffic assignment technique models the route choice behavior between a pair of origin & destination. If the decision is to be made based on a number of alternatives, then the

choice is determined on the basis of travel time & travel cost on each route. These are function of the road condition & also traffic congestion along a particular route.

#### 4.5.1 Assignment Approach

The assignment procedure adopted for the highway model is based on an Time Equilibrium Assignment model with multiple demand segments (cars, TW, buses & freight vehicles). The assignment is controlled to continue for as much iteration as are required to achieve a satisfactory level of convergence. In the case of VISUM model the process was continued until full convergence was achieved.

The methodology used for assignment of Private trips in this study is known as Equilibrium assignment. The Equilibrium assignment distributes the demand according to Wardrop's first principle – Equilibrium procedure only terminates when all routes of any OD pair are in the balanced state in terms of travel time, the procedure provides realistic results. The computation time required by the equilibrium assignment depends on the volume/capacity ratio in the network. Because new routes are found in every iteration step for a strongly saturated network, more computation time is required in this case.

In this method the impedance of the links is determined from the current travel time. The current travel time in links calculated using the capacity restraint function BPR with a, b and c values.

$$t_{cur} = t_0 * (1 + a. sat^b)$$

Where

- Sat - Volume/capacity ratio  $sat = q/q_{max} * C$
- $t_{cur}$  - Current travel time on a network object in loaded network
- $t_0$  - Travel time on a network object with free flow time
- q - Current volume
- $q_{max}$  - Capacity

#### 4.5.2 Generalized Cost Estimation

Generalized Cost (GC) goes as input into the traffic assignment model discussed above. The GC then becomes a critical parameter for defining the route choice between respective OD pairs.

Generalized cost consists of the monetary and non-monetary costs of a Journey. Monetary or "out-of-pocket" costs might include a fare on a public transport journey, or the costs of fuel, wear and tear and any parking charge, toll or congestion charge on a personal mode journey. Non-monetary costs refer to the time spent undertaking the



journey. Time is converted to a money value using a value of time figure, which usually varies according to the traveler’s income and the purpose of the trip.

The Generalized Cost is equivalent to the price of the good in supply and demand theory. Demand for journeys can be related to the generalized cost of those journeys using the price elasticity of demand. Supply is equivalent to capacity (and for roads, road quality) on the network. The cost of travel (C-generalized cost) between the zones has been estimated based on existing toll charges on highways and bridges.

For the purpose of present study, travel time and toll cost (wherever applicable) have been considered for estimating GC for each road link.

Skims of travel time are taken from the assignments. Generalised cost matrix is estimated for all modes and purposes. The expanded OD matrices were assigned to the network in VISUM on the basis of optimization of Travel Time & Toll cost, wherein the function for generalized cost can be described as below:

$$GC = TT + TC$$

Where,

TT = Travel Time

TC = Toll Cost

For the purpose of present study, travel time and toll cost (wherever applicable) have been considered for estimating GC for each road link. Adopted toll rates for the proposed elevated corridors are mentioned in Table 4-5 below:

Table 4-5: Adopted Toll Rates for Elevated Corridors

Mode	Toll Rate/ Km (INR)
Car	4.80
Bus	12.97
TW	1.62

#### 4.5.3 Model Calibration & Validation

Matrix calibration for the base year model has been done on the basis of screen line cross-traffic flow on the links using the 'T-flow Fuzzy' method. 'T-flow Fuzzy' updates a given O-D matrix in such a way that the modelled result of the assignment flows aims to closely match the observed traffic volume values on the given links.

The base traffic flow demand data obtained from the OD surveys data was segregated into the following basic matrix categories: Two Wheeler, Auto Rickshaw, Car, Bus, LCV, 2-Axle Truck, 3 Axle truck and MAV's. The OD matrices were then expanded with reference to the traffic volume count observed at the survey locations. These expanded OD matrices were given as an input to VISUM for running the calibration procedure. Mode-wise calibration procedure has been adopted in this study.

The matrices were calibrated to the observed link flows. Figure 4-3 shows the overview of the procedure which has been followed to produce the origin-destination matrix. The demand estimation in VISUM was checked by comparing the assigned flows against the observed flows for screen line cross traffic flow on the links. This was done by calculating the quality of fit using the GEH statistic. The GEH statistic is a common comparative measure in the context of transport modelling. The formula of the GEH statistic is as follows:

$$GEH = \sqrt{\frac{(O-M)^2}{0.5 * (O+M)}}$$

Where, O = Observed Flow  
M = Modelled Flow

The GEH is a measure that includes both the absolute and the relative difference between the traffic flow measured (i.e. Observed) and the flow simulated by the model. The quality of fit is considered acceptable if the GEH statistic is less than 5 in 85% of cases.

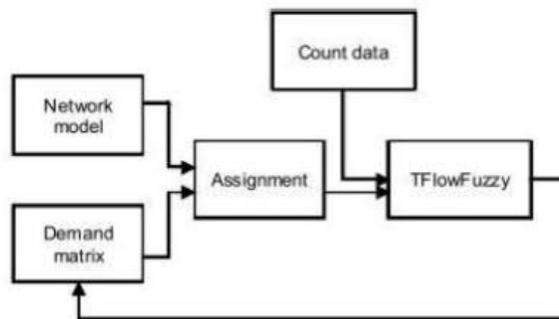


Figure 4-3: Estimation flow for Matrix Calibration

4.5.4 Base Year Traffic model Validation

Validation of the traffic model becomes essential to determine whether the model replicates the ground count or not. In order to validate the model, the 2016 vehicular trip matrices of all the modes were assigned on to the base year highway network.

Base year assignment for all the modes is presented in Figure 4-4.

Model validation was undertaken by comparing observed data collected from the surveys for the project with their equivalent synthesized results as produced by the transport model. Comparisons were made of traffic volumes. The assignment has been validated at all the identified screen-line locations with cross-traffic volume. The comparison of observed average daily traffic volumes in terms of PCUs on the links from survey to the synthesized modelled average daily traffic volumes in PCU are summarized in Table 4-6 for all Traffic Volume count locations chosen for field survey. The results show a reasonably good match between observed and synthesized traffic volumes. Based on the results of validation, traffic model was considered sufficiently robust for application for the study. Figure 4-4 presents the traffic assignment on the Study Area network for the base year.

Table 4-6: Observed and synthesized traffic volume

S. No.	Corridor	Observed ADT	Modelled ADT	Difference in Volume	% Change	GEH
1	Hebbal	198,588	198,312	276	0.1%	0.6
2	Kasturba road	89,576	89,500	76	0.1%	0.3
3	Silk board flyover	187,951	186,819	1132	0.6%	2.6
4	ITC colony – KR Puram	127,246	126,681	565	0.4%	1.6
5	Jayamahar Road	81,918	80,453	1465	1.8%	5.1
6	CPRI Road	94,869	93,458	1411	1.5%	4.6
7	Rangudanhalli	66,905	65,238	1667	2.5%	6.5
8	Hal Stop	108,999	108,500	499	0.5%	1.5
9	Sirsi	164,250	162,347	1903	1.2%	4.7
10	Jakkasandra	127,858	126,547	1311	1.0%	3.7

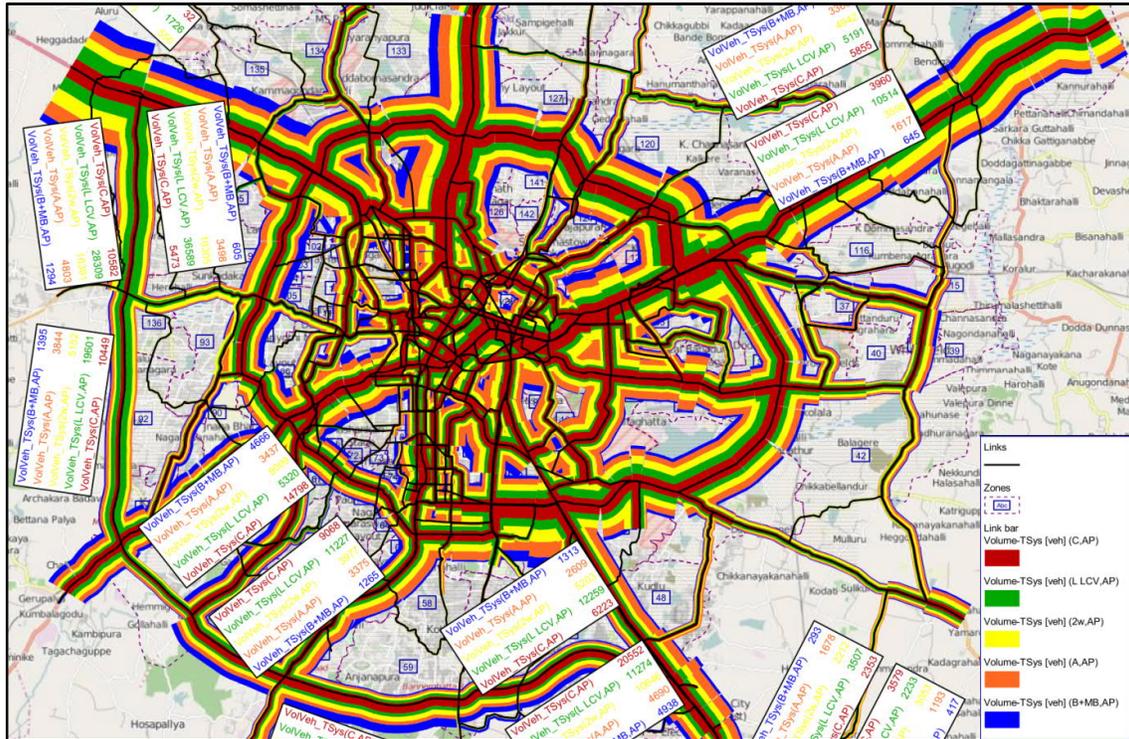


Figure 4-4: Traffic Assignment BAU Scenario - 2016

4.5.5 Divertible Traffic Estimation

As discussed above, Traffic Assignment Model was used to model traffic flows on the study area network. Same model will now be used to estimate potential divertible traffic likely to use the proposed elevated corridors due to reduction in travel time, increase speed along with payment of toll charge. Considering the proposed alignment of elevated corridors and enhanced parameters such as increased speed, capacity and entry-exit locations, the model was first run for estimation of divertible traffic for the base year. Since the network of proposed elevated corridors was coded for restriction of use by commercial vehicles, no trucks have been assigned on the proposed corridors.

The estimated traffic diversion in the base year as per the results of traffic assignment model is presented in Table 4-7.

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Table 4-7: Divertible Traffic (PCUs) on Proposed Elevated Corridors for the Base Year (2016)

Sl.No	Corridor Section	BAU Scenario (Traffic, PCUs)					Divertible Traffic BI Scenario With Elevated Corridors (PCUs)				Residual Traffic (PCUs)					Traffic Reduction (%)
		TW	Autos	Bus	Cars	Total	TW	Bus	Car	Total	TW	Autos	Bus	Car	Total	
North-South Corridor																
I	JAYAMAHAL ROAD	27982	13598	6050	37225	84855	56296	7217	63855	127368	15303	5430	5419	22644	48796	42%
II	QUEENS ROAD	18645	9712	2809	25005	56171	31408	5971	40812	78191	8642	6530	2294	9415	26881	52%
III	KASTURBA ROAD	30051	15641	12447	52001	110140	37300	6282	43460	87042	3010	8628	1568	5632	18838	83%
IV	RICHMOND ROAD-ST. JOSEPH JN.	17752	7033	4214	19943	48942	42230	4436	46250	92916	2825	7157	366	3427	13775	72%
V	ST. JOSEPH JN. - SIDDAIAH ROAD	16430	7748	6998	20260	51436	47749	7844	48255	103848	7299	6474	2437	9475	25685	50%
VI	SIDDAIAH ROAD - WILSON GARDEN	9894	3334	2743	12152	28123	47413	10184	48593	106190	3434	2511	452	4047	10444	63%
VII	HOSUR ROAD - SARJAPUR JUNCTION	25503	12248	9933	24891	72575	47907	8910	51706	108523	11072	6074	5223	10331	32700	55%
VIII	SARJAPUR JN. - ORR	11991	6297	1969	14437	34694	38333	7977	41454	87764	2122	6849	423	3118	12512	64%
East West- I Corridor																
I	YASHWANTHPUR - IISC	33421	13130	9010	36837	92398	28884	4428	24824	58136	10561	10666	4560	14428	40215	56%
II	TUMKUR ROAD: IISC - MEKHRI CIRCLE	41543	17783	16469	45686	121481	41585	6526	47216	95327	7240	5132	2157	8875	23404	81%
III	MILLERS ROAD - ST. JOHNS CHURCH	17303	9240	5332	32199	64074	39709	8986	56609	105304	2463	7937	954	7618	18972	70%

CH-4: Traffic Demand Forecast

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SI.No	Corridor Section	BAU Scenario (Traffic, PCUs)					Divertible Traffic BI Scenario With Elevated Corridors (PCUs)				Residual Traffic (PCUs)					Traffic Reduction (%)
		TW	Autos	Bus	Cars	Total	TW	Bus	Car	Total	TW	Autos	Bus	Car	Total	
	ROAD															
IV	KENSINGTON ROAD - MURPHY ROAD	24414	13570	8397	37635	84016	41164	6489	47495	95148	2030	5587	989	6026	14632	83%
V	OLD MADRAS ROAD - KR PURAM JUNCTION	63503	21550	14485	83626	183164	37569	8000	38751	84320	6918	6865	975	10066	24824	86%
VI	KR PURAM JUNCTION - BHATTARAHALLI	55293	19437	10394	40530	125654	31247	6593	23389	61229	2734	8280	838	2176	14028	89%
East West- II Corridor																
I	DEEPANJALI NAGAR - SULTAN ROAD	32884	13871	14489	45633	106877	25483	5757	20550	51790	8522	10343	2794	9238	30897	71%
II	KR MARKET - RICHMOND CIRCLE	17752	7033	4214	19943	48942	15223	5463	13280	33966	4206	4018	3681	5905	17810	64%
III	CHAMRAJAPETE - KH CIRCLE	8673	2852	1783	11861	25169	15002	3005	16122	34129	1788	4678	150	1427	8043	68%
IV	RICHMOND ROAD - HAL AIRPORT ROAD	26185	12335	3448	35361	77329	51332	6229	48537	106098	5941	3376	3043	5318	17678	77%
V	HAL AIRPORT ROAD - DOMLUR FLYOVER	26185	12335	3448	35361	77329	48117	6742	48893	103752	11624	8220	1224	8856	29924	61%
VI	OLD AIRPORT ROAD - MARATHAHALLI (ORR)	34367	12470	6984	41752	95573	34936	5607	32457	73000	5729	9627	770	7121	23247	76%

CH-4: Traffic Demand Forecast

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Sl.No	Corridor Section	BAU Scenario (Traffic, PCUs)					Divertible Traffic BI Scenario With Elevated Corridors (PCUs)				Residual Traffic (PCUs)					Traffic Reduction (%)
		TW	Autos	Bus	Cars	Total	TW	Bus	Car	Total	TW	Autos	Bus	Car	Total	
VII	VARTHUR ROAD	19210	7157	3546	18988	48901	28430	3133	19423	50986	1382	3341	92	977	5792	88%
Connecting Corridor - I																
	SARJAPUR ROAD	13676	8806	1428	17695	41605	21667	2278	22802	46747	1810	3893	170	2327	8200	80%
Connecting Corridor - II																
	D'SOUZA CIRCLE - BHASKARAN ROAD	48739	18138	9428	54675	130980	41729	8075	37415	87219	1881	3137	234	2539	7791	94%

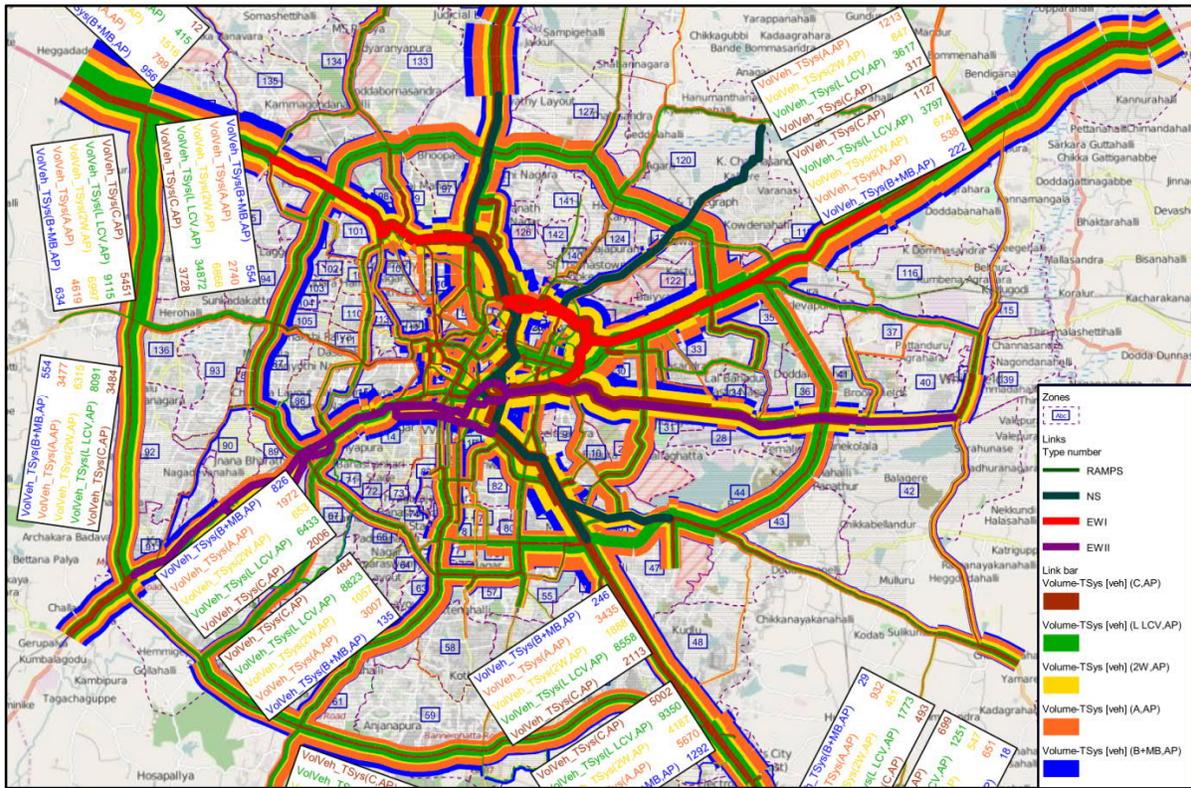


Figure 4-5: Traffic Assignment Business Induced (BI) Scenario – 2016

4.5.6 Conclusions

As evident from table above, traffic diversion will happen not only from the network where the elevated corridors have been proposed but also from surrounding network due to reduction distance, travel time and enhanced speed.

As per the model outputs, following conclusions can be drawn out:

- Maximum traffic i.e. 1,27,368 on the North South elevated corridor will be in the section on Jayamahal Road.
- On the East West-I corridor the maximum traffic will around 1,05,304 PCUs in the section between Millers Road - St. Johns Church Road.
- In the East West II corridor, maximum traffic will be in the range of 1,06,098 PCUs in the Richmond Road - Hal Airport Road.
- Out of all Connecting Corridors, CC-II will attract maximum traffic in the range of 87,219PCUs.
- A total of 46,747 PCUs of traffic will be diverted to CC-I corridor and 22,457 PCUs to CC-III Corridor in the base year.

#### 4.6 TRAFFIC FORECAST

Traffic growth rates have been estimated for the traffic flowing on the primary network within the city of Bangalore. The overall traffic growth rates have been estimated considering the growth rate used for passenger trip forecast as per the recommendations of Comprehensive Traffic and Transportation Plan (CTTP) for Bangalore, 2025 and the DPR for Bangalore Metro Phase I and II. The growth also considers the impact of Metro expansion in the city of Bangalore.

##### 4.6.1 Growth of Registered Vehicles

In order to analyze the vehicle growth in the city of Bangalore, the vehicle registration data of the city has been collected. The annual growth rates and Compound Average Growth Rate (%) of different vehicle types is presented in Table 4-8.

Table 4-8: Growth of Registered vehicles in Bangalore (In Lakhs)

Year	TW	Cars	Autos	Buses	Trucks	Taxi Cab	Tractors / Trailers	Others	Total Vehicles
1980	1.12	0.36	0.10	0.05	0.08	0.00	0.04	0.01	1.75
1985	2.16	0.60	0.10	0.05	0.12	0.00	0.01	0.02	3.07
1990	4.59	0.91	0.17	0.05	0.19	0.00	0.04	0.04	5.98
1995	6.49	1.26	0.37	0.11	0.29	0.02	0.06	0.10	8.71
2000	10.67	2.14	0.61	0.21	0.42	0.04	0.12	0.17	14.38
2001	11.62	2.36	0.64	0.23	0.48	0.05	0.13	0.16	15.66
2002	12.92	2.61	0.68	0.25	0.53	0.05	0.15	0.20	17.39
2003	14.19	2.87	0.72	0.28	0.59	0.07	0.16	0.24	19.12
2004	15.86	3.36	0.74	0.34	0.68	0.10	0.20	0.28	21.57
2005	18.11	3.87	0.80	0.37	0.85	0.13	0.23	0.31	24.67
2006	20.74	4.54	0.91	0.39	0.92	0.16	0.29	0.46	28.41
2007	22.32	5.27	0.95	0.48	1.10	0.18	0.31	0.45	31.07
2008	22.64	5.53	0.96	0.49	1.19	0.19	0.32	0.54	31.85
2009	26.08	6.46	1.06	0.42	1.29	0.21	0.32	0.69	36.53
2010	25.47	7.24	0.93	0.73	1.38	0.20	0.13	0.78	36.86
2015	41.11	11.59	1.59	0.88	0.96	0.99	0.16	0.43	59.49
CAGR	10.75%	10.32%	8.10%	8.33%	7.27%	14.06%	5.10%	11.29%	10.51%

Source: Comprehensive Traffic and Transportation Plan for Bangalore, 2025; RTA Karnataka.



4.6.2 Traffic Growth Rates

For the purpose of forecasting traffic growth rates, growth rate of population and passenger trips in the city of Bangalore has been considered. For this purpose the CTTT for Bangalore, 2025 along with the DPR for upcoming Phase II of Bangalore Metro have been studied and referred.

As per the CTTT the population of the city has grown at a Compound Annual Growth Rate (CAGR) of 3%. The employment growth estimates a CAGR of 4% till 2025. Considering this as the base for calculation, the DPR of Bangalore Metro Phase II is considered for the trip estimates for the future year as per projected metro ridership. The vehicle registration data for the city of Bangalore further reflects an overall CAGR of 6% till 2025.

Table 4-9 presents the CAGR for population, employment and registered vehicles for city of Bangalore.

Table 4-9: Growth trends in the city of Bangalore

Year	Population	Employment	Registered vehicles
2001	5,676,058	1,851,000	1,566,000
2011	7,000,749	2,426,000	3,686,000
2021	8,500,481	3,125,000	5,539,000
2025	12,300,000	5,050,000	6,357,000
CAGR	3%	4%	6%

Source: CTTT for Bangalore, 2025; DPR for Bangalore Metro.

The DPR of Bangalore Metro Phase II suggests a modal share of 16% for the metro and an average annual growth rate of 3% for entire passenger trips. Considering this the base year passenger trips as obtained from the overall O-D analysis have been projected at an annual rate of 3% for the horizon year 2035 and also for cardinal years with 5 year interval.

Of the total projected passenger trips, 16 % share of metro has been excluded for the year 2020, while beyond 2030, a shift of 20% of total passenger trips are assumed to be diverted to metro. Remaining non-metro trips have been further distributed by mode using the modal composition as observed in the base year for the purpose of obtaining mode wise horizon and cardinal year vehicular matrices. Substantial shift of bus passengers to metro trips is considered as per the DPR.

The modal share composition adopted for the project for the city of Bangalore is described in Table 4.10.



Table 4-10: Modal Share Composition for Horizon Year 2035

Modes	% Share
TW	25
Car	32
Auto	15
Bus	8
Metro	20

The mode wise passenger trips as projected for Bangalore city are presented in Table 4.11.

Table 4-11: Projected Passenger Trips by Mode

Year	TW	Car	Auto	Bus	Total	Metro trips	Non-Metro Trips
2016	701076	1274684	807300	5098738	7881,799		
2020	789068	1434669	908623	5738674	8871,034	1419,365	7451,668
2025	914746	1663174	1053344	6652696	10283,959	1645,434	8638,526
2030	1060441	1928075	1221114	7712298	11921927	2384,385	9537,542
2035	1229342	2235167	1415606	8940667	13820781	3455,195	10365,586

The growth rate for passenger trips was further applied on mode wise trip matrices for obtaining horizon and cardinal year passenger trip matrices by mode. Cardinal years include matrices for year 2020, 2025 and 2030 at 5-year intervals.

The mode wise passenger trip matrices were then converted back into vehicular matrices using the base year occupancy and further into PCUs matrices for the purpose of traffic assignment. The horizon year matrices are then assigned in the highway network using the base year assignment model considering the planned transport infrastructure upgradation.

The model will then result in project link volumes on the proposed elevated corridors considering the growth, future congested speeds and toll rates. Following section describes the traffic forecast under various highway network and demand scenarios.

4.6.3 Horizon year Network

The future traffic assignment procedure considers subsequent development phases which are expected to be incorporated to the existing primary network in the city of Bangalore. Proposed links and highways are thus incorporated into the future network scenarios to bring out the real picture of expected traffic flows in the upcoming days. The proposed new links that are incorporated into the base year network include:



1. Proposed Airport Expressway – expected to be functional by 2020.
2. Proposed extension of the NICE Ring Road – expected to be completed by 2020.

Figure 4-6 presents the horizon year network from 2020 and beyond.

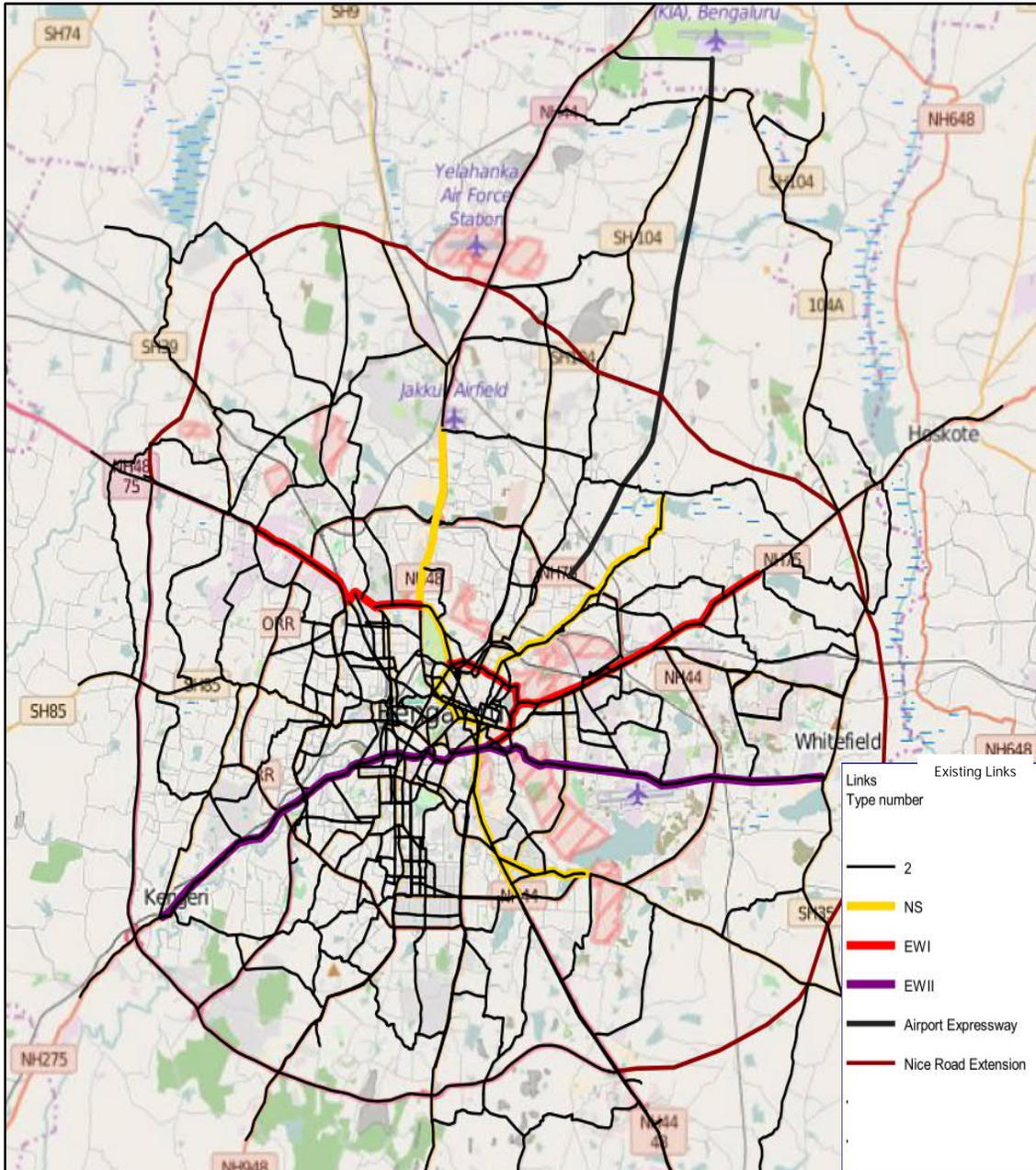


Figure 4-6: Horizon Year Road Network



4.6.4 Project Phasing

The proposed elevated corridors will be constructed in phases and not altogether. As and when each phase is constructed it will be made open to traffic and toll will be charged only for the length that is operational. It is proposed that North South (NS) Corridor along with Connecting Corridor 1 (CC-1) will be taken up for construction in the first phase followed by East West- 1 along with Connecting Corridors 2 & 3 (CC 2 & 3) and East West-2 corridors in subsequent phases 2 & 3. For the purpose of analysis the construction period of 3 years for each corridor has been considered.

The project phasing will further be used to estimate traffic diversion with respect to completion of each elevated corridor during the horizon period subject to their respective time of opening for operations, which will then be used to estimate toll-able traffic forecast both for horizon and cardinal years. Error! Reference source not found. Presents the Project Phasing and completion schedule.

Table 4-12: Project Phasing, Completion & Operation Schedule

Phase	Years	2019	2020	2021	2022	2023	2024
	Corridors						
I	NS + CC-1 (% Completion)	30	40	30			
II	EW-1 + CC-2+ CC-3 (% Completion)		30	40	30		
III	EW-2 (% Completion)			30	40	30	

As evident from above table, the NS & CC 1 Corridors will be operational in the year 2021, EW-1, CC-2 & CC-3 will be open in year 2023 and EW-2 will be open for commercial operations in the year 2025.

Phasing of proposed elevated corridors is presented in Volume IX- Drawings.

4.6.5 Toll-able Traffic Forecast

The projected vehicular matrices have been assigned on the horizon year network as discussed above to estimate link wise vehicular volume for estimating toll-able traffic for each phase till the horizon year study.

For the purpose of present study vehicular modes such as Cars, TW and Buses have been considered to be tolled and same will only be allowed to ply on the proposed



elevated corridor. Remaining traffic will use the existing network at grade for movement.

Toll-able traffic estimates have been made till the year 2037.

Projected tollable traffic for the proposed elevated corridors is presented in Table 4-13.



Table 4-13: Projected Toll able Traffic – Business Induced (BI) Scenario (Vehicles)

Corridors	Sections	Section Length (in KM)	Without Corridors : BAU Scenario			Phase I Completed			Phase I Tolling Begins			Phase II Tolling Begins			Phase III Tolling Begins			Projected Traffic Volume - Phase III									
			2016			2020			2021			2022			2023			2030			2035			2037			
			Base Year Assigned Traffic (Vehicles)			Vehicles			Vehicles			Vehicles			Vehicles			Vehicles			Vehicles			Vehicles			
			TW	Autos	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars
NS																											
I	JAYAMAHAL ROAD	2.6	37,309	9,066	2,750	37,225	78473	129	43,225	80043	132	44,090	105481	117	49,276	102067	131	52,961	101593	233	56,650	102845	135	49,780	107000	141	51,791
II	QUEENS ROAD	3.13	24,860	6,475	1,277	25,005	1,00,945	215	62,803	1,02,964	219	64,059	59,067	141	39,583	59,347	140	35,896	58,503	195	38,452	56,084	142	38,619	58,350	148	40,179
III	KASTURBA ROAD	2	40,068	10,428	5,658	52,001	105661	207	61,119	107775	211	62,341	62,732	131	38,042	65,525	160	37,505	62,955	219	38,688	62,572	158	38,664	65,100	164	40,226
IV	RICHMOND ROAD - ST. JOSEPH JN.	1.8	23,669	4,689	1,915	19,943	65,447	165	37,819	66,756	168	38,575	79,865	120	39,836	86,640	122	34,750	85,213	121	35,823	77,949	120	41,273	81,098	125	42,940
V	ST. JOSEPH JN. - SIDDAIAH ROAD	1.8	21,907	5,166	3,181	20,260	60409	165	36,188	61618	168	36,912	92,855	153	46,330	84,401	210	40,252	81,965	292	42,197	79,997	224	42,998	83,229	233	44,735
VI	SIDDAIAH ROAD - WILSON GARDEN	1.6	13,192	2,223	1,247	12,152	103236	262	58,187	105301	268	59,351	93,225	153	46,330	85,777	245	43,389	85,109	347	43,685	85,587	243	42,307	89,044	253	44,016
VII	HOSUR ROAD - SARJAPUR JUNCTION	2.3	34,004	8,166	4,515	24,891	127725	275	69,999	130280	281	71,399	113571	229	53,948	1,00,419	221	49,621	99,701	295	50,863	95,988	245	50,061	99,866	254	52,083
VIII	SARJAPUR JN. - ORR	1.2	15,988	4,198	895	14,437	90,105	215	41,247	91,907	219	42,072	82,257	174	31,764	73,111	172	32,380	74,095	232	33,657	75,944	193	31,270	79,012	201	32,533
EW -1																											
I	YASHWANTHPUR - IISC	1.5	44,561	8,754	4,095	36,837	0	0	0	0	0	0	62,635	91	27,371	59,049	94	25,074	59,256	144	24,630	61,600	111	23,889	64,089	115	24,854
II	TUMKUR ROAD: IISC - MEKHRI CIRCLE	2.5	55,391	11,855	7,486	45,686	0	0	0	0	0	0	82857	103	42,504	83,477	150	46,357	85,272	253	47,418	85,523	154	41,336	88,978	160	43,006
III	MILLERS ROAD - ST. JOHNS CHURCH ROAD	1.6	23,071	6,160	2,424	32,199	0	0	0	0	0	0	70,636	155	39,700	72,153	120	41,049	71,680	209	43,263	74,105	133	40,740	77,099	139	42,386
IV	KENSINGTON ROAD - MURPHY ROAD	2	32,552	9,047	3,817	37,635	0	0	0	0	0	0	77,577	90	41,411	86,232	173	42,713	82,940	156	40,764	80,325	112	37,857	83,570	117	39,386
V	OLD MADRAS ROAD - KR PURAM JUNCTION	3.64	84,671	14,367	6,584	83,626	0	0	0	0	0	0	100435	187	44,746	90,416	189	42,671	76,563	247	36,746	85,743	210	38,969	89,207	219	40,543
VI	KR PURAM JUNCTION - BHATTARAHALLI	13.6	73,724	12,958	4,725	40,530	0	0	0	0	0	0	80,352	170	29,336	70,895	138	24,659	67,876	187	24,403	69,427	170	23,402	72,232	177	24,347
EW-II																											
I	DEEPANJALI NAGAR - SULTAN ROAD	3	43,845	9,247	6,586	45,633	0	0	0	0	0	0	0	0	0	46,068	25	20,758	47,989	35	24,173	47,657	32	25,099	49,583	33	26,113
II	KR MARKET - RICHMOND CIRCLE	6.27	23,669	4,689	1,915	19,943	0	0	0	0	0	0	0	0	0	32,287	116	12,320	33,220	156	11,982	33,717	128	12,418	35,080	133	12,920
III	CHAMRAJAPETE - KH CIRCLE		11,564	1,902	810	11,861	0	0	0	0	0	0	0	0	0	34,728	52	16,189	34,277	75	17,100	31,224	33	16,784	32,485	35	17,462
IV	RICHMOND ROAD - HAL AIRPORT ROAD	2.5	34,913	8,224	1,567	35,361	0	0	0	0	0	0	0	0	0	1,01,001	185	38,430	97,253	253	40,469	92,160	217	43,696	95,883	226	45,461
V	HAL AIRPORT ROAD - DOMLUR FLYOVER	3.5	34,913	8,224	1,567	35,361	0	0	0	0	0	0	0	0	0	88,223	143	39,596	87,084	198	40,451	78,708	156	42,709	81,888	162	44,434
VI	OLD AIRPORT ROAD - MARATHAHALLI	6.5	45,823	8,313	3,175	41,752	0	0	0	0	0	0	0	0	0	78,069	117	38,000	76,864	171	36,561	71,241	138	38,160	74,119	144	39,702



Corridors	Sections	Section Length (in KM)	Projected Traffic Volume - Phase III																											
			Without Corridors : BAU Scenario				Phase I Completed			Phase I Tolling Begins			Phase II Tolling Begins			Phase III Tolling Begins			(All Corridors Operational)											
			2016				2020			2021			2022			2023			2030			2035			2037					
			Base Year Assigned Traffic (Vehicles)				Vehicles			Vehicles			Vehicles			Vehicles			Vehicles			Vehicles			Vehicles					
			TW	Autos	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars	TW	Buses	Cars			
	(ORR)																													
VII	VARTHUR ROAD	5.2	25,613	4,771	1,612	18,988	0	0	0	0	0	0	0	0	0	61,668	47	20,661	60,819	63	21,782	55,661	48	20,862	57,910	50	21,705			
CC-I	SARJAPUR ROAD	4.48	18,235	5,871	649	17,695	89,048	72	34,849	90,829	73	35,546	64,459	63	24,923	55,887	60	21,770	54,731	76	22,855	54,897	55	20,464	57,115	57	21,291			
CC-II	D'SOUZA CIRCLE - BHASKARAN ROAD	2.8	64,985	12,092	4,285	54,675	0	0	0	0	0	0	72,357	135	33,199	81,507	133	33,629	77,007	183	33,472	78,845	154	33,121	82,031	160	34,459			

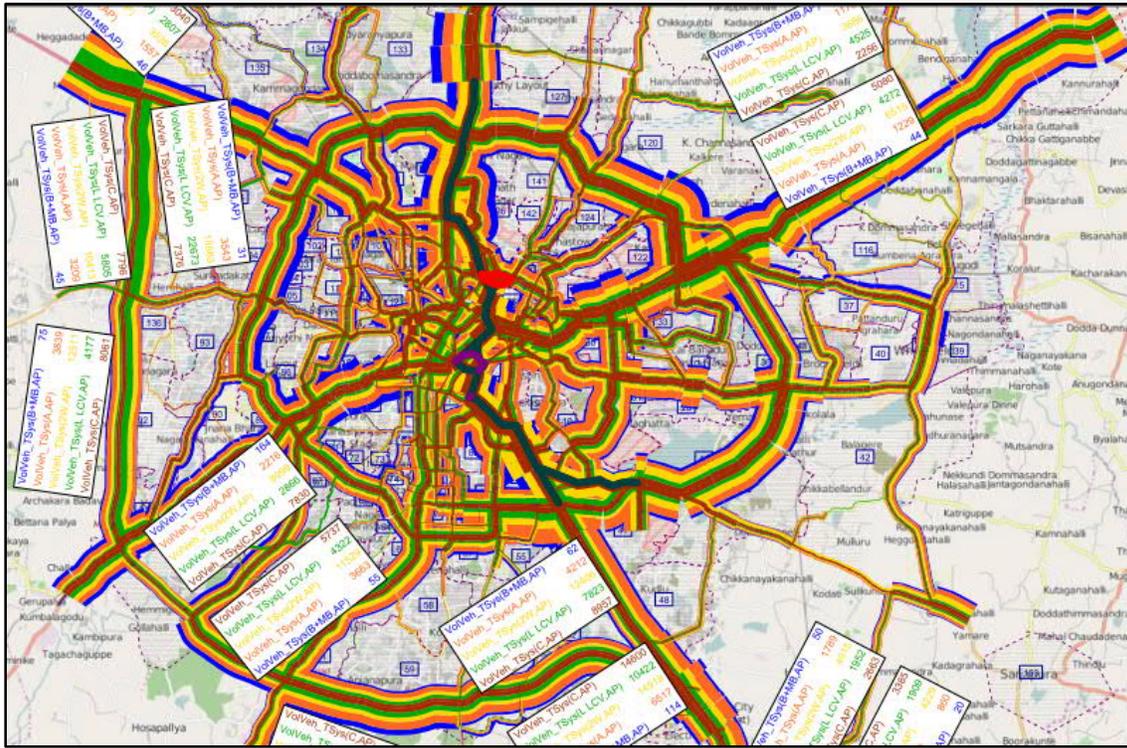


Figure 4-7: Projected Traffic Assignment, Phase I - 2021

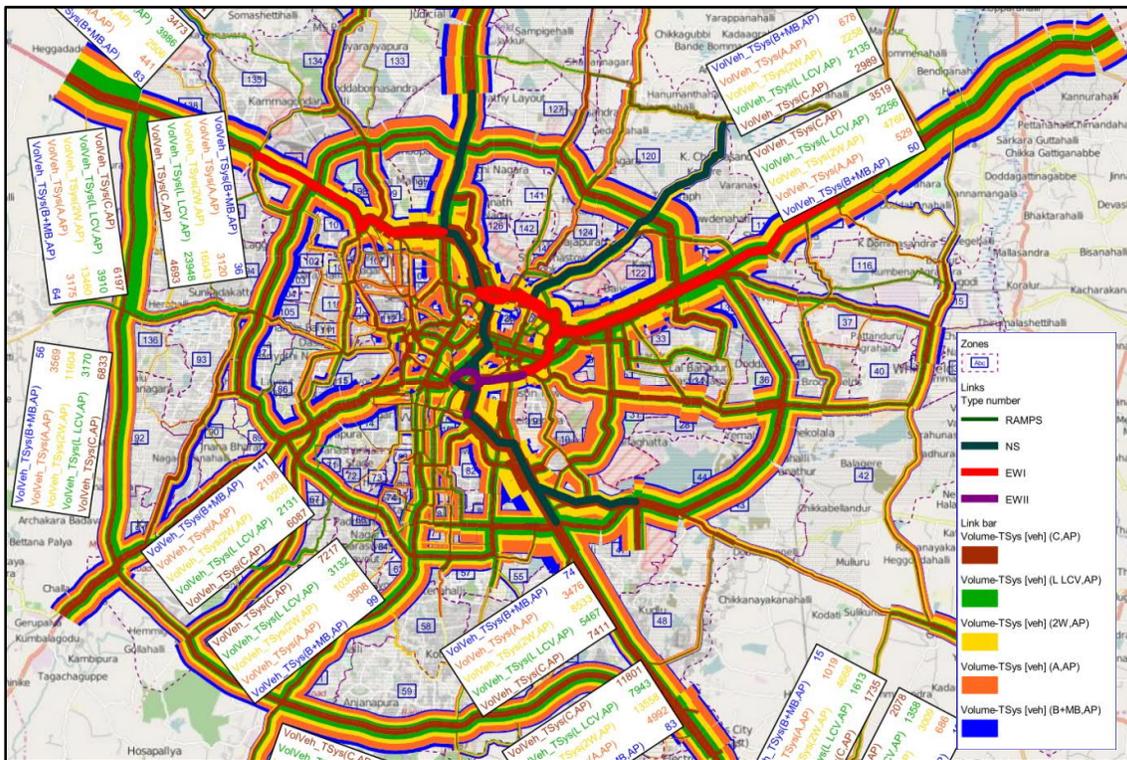


Figure 4-8: Projected Traffic Assignment, Phase II - 2023

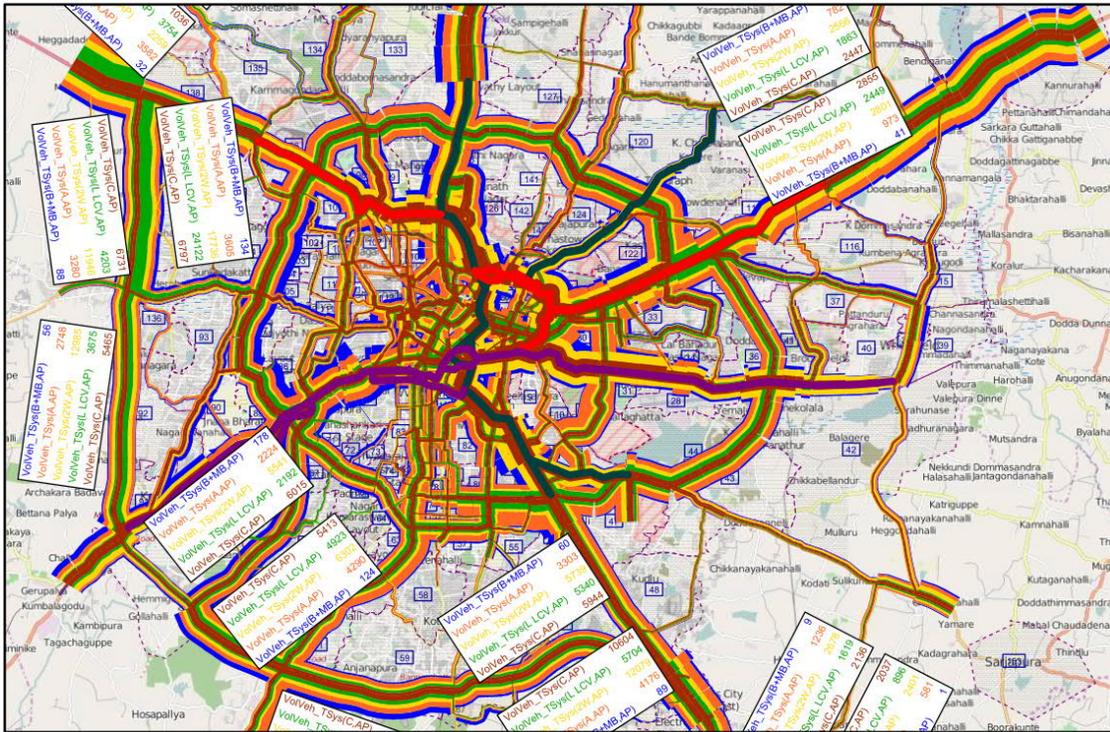


Figure 4-9: Projected Traffic Assignment, Phase III – 2025

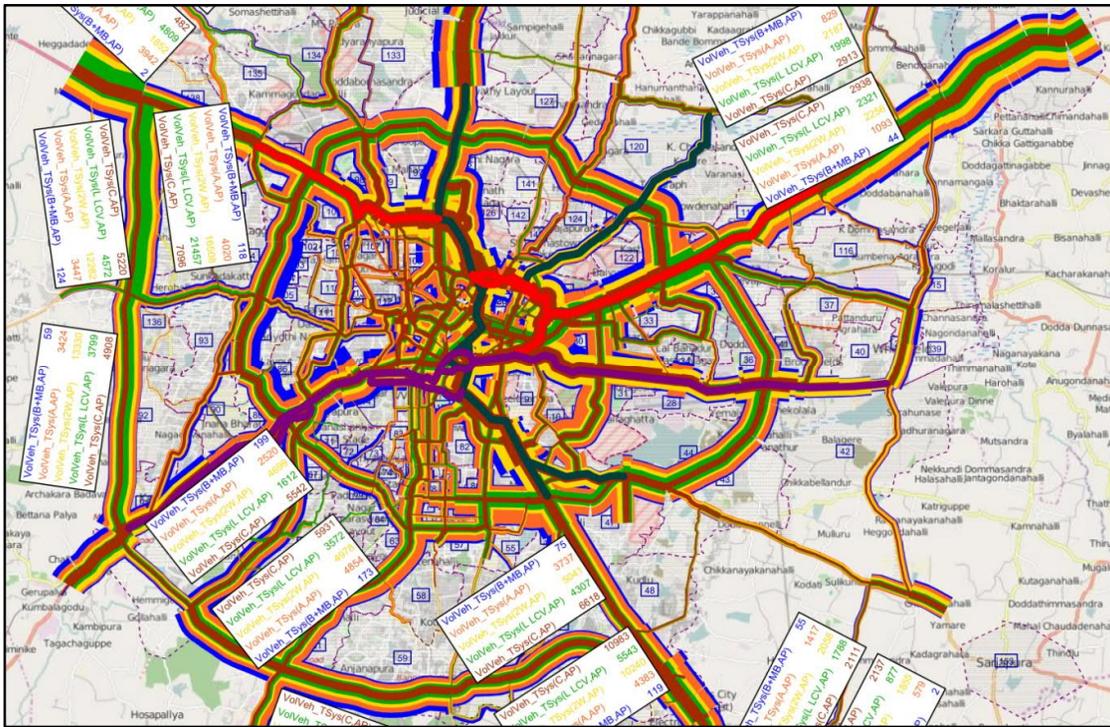


Figure 4-10: Projected Traffic Assignment 2030

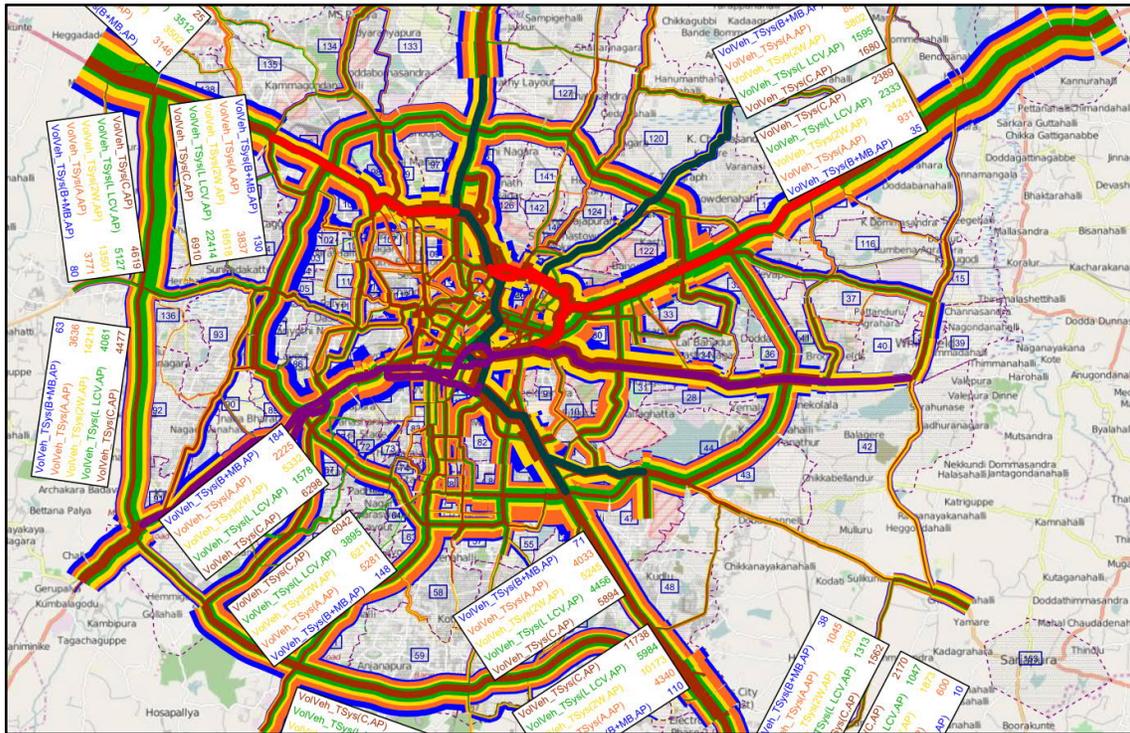


Figure 4-11: Projected Traffic Assignment 2037

#### 4.7 RECOMMENDATIONS

Once the toll-able traffic forecast is made, it is prudent to understand the capacity limitations of proposed transport infrastructure. The estimated traffic is analysed with respect to capacity of the proposed corridors and analysis is made to understand the timeline by which the proposed corridors will no longer be in a position to offer desired Level of Service and the traffic volume exceeds the capacity. The section briefly describes the capacity augmentation requirements of the proposed corridors.

##### 4.7.1 Capacity Augmentation Requirements

In order to plan for future network it is important to understand that when the present infrastructure will reach the design capacity. Therefore it is important to understand when these facilities require capacity augmentation and what impact it will have on other facilities, if not upgraded. The ground scenario of Bangalore in the base year 2016 shows clearly that capacity augmentation is a must for almost all major corridors in the city area. Especially in the core areas of central and southern Bangalore, capacity of the urban network has already been eaten up with roads having a V/C ratio of greater than 1.5.

With the growing trends of city population, and vehicular growth rates, capacity augmentation of the primary road network is a must for the city of Bangalore. The proposal of elevated corridors in the city of Bangalore having a stretch of 88 Km in a



whole may immediately address the capacity issue of the urban network in Bangalore which results in congestion, lesser journey speeds and higher vehicle operating costs in the city. The proposed corridors will provide higher capacities, greater travel speeds to the citizen of Bangalore, in turn addressing the ground problem to reduce congestion on the roads.

On the contrary, it is to be noted that the improved capacities and infrastructure facilities will attract more traffic to traverse on the elevated corridors. Not only these corridors will have diverted traffic from the ground, which used to traverse at grade in the existing scenario, these corridors will attract induced traffic from other zones to eat up the capacity.

With growing urbanization trends of Bangalore in terms of growth in population and traffic numbers in the city, the enhanced capacity of these proposed elevated corridors will soon be utilized fully within the horizon year 2023, when capacity of most of the elevated sections (around 70%) will be exhausted. Traffic assignments on the proposed corridors in all three suggested scenarios for the horizon years clearly indicate the same. Some of the proposed elevated sections are found to be exhausted in the base year situation only if the corridors are assumed to function from the base year only.

In Phases I, II and III section loads along the proposed elevated corridors show a steady increase in traffic volume from 2016 to 2023 where most part of the corridors have exceeded their maximum design capacity and shall be bound to congestion, decreased journey speeds and longer travel times.

The situation needs to be addressed with a holistic approach. The growing trends of urbanization are bound to have drastic impact on the traffic numbers on roads. The main goal is to reduce the number of private vehicles like two wheelers and cars on the road and provide the urban population better means to commute via public transit. With growing population trends and travel demand in the city of Bangalore, it is definitely advisable to bring forth a comprehensive mass transit system planning to shift more people to public transport than using private vehicles.

Table 4-14 presents the capacity augmentation requirements of proposed elevated corridors.

Table 4-14: Capacity Augmentation Requirements for Proposed Elevated Corridors

Corridor	Section	Capacity as per IRC in PCU	Capacity analysis		
			2023	2030	2037
			Total traffic in PCU	Total traffic in PCU	Total traffic in PCU
<b>NORTH-SOUTH</b>					
I	JAYAMAHAL ROAD	120000	129800	133358	132351
II	QUEENS ROAD	120000	80715	82758	84266
III	KASTURBA ROAD	120000	87002	86385	89412
IV	RICHMOND ROAD- ST. JOSEPH JN.	120000	99999	101250	104039
V	ST. JOSEPH JN. - SIDDAIAH ROAD	120000	104015	104313	107670
VI	SIDDAIAH ROAD - WILSON GARDEN	120000	108262	108281	111356
VII	HOSUR ROAD - SARJAPUR JUNCTION	120000	125422	126287	127543
X	SARJAPUR JN. - ORR	120000	87591	89739	92235
<b>EAST-WEST I</b>					
I	YASHWANTHPUR - IISC	120000	69567	69388	73174
II	TUMKUR ROAD: IISC - MEKHRI CIRCLE	120000	109294	111929	110092
III	MILLERS ROAD - ST. JOHNS CHURCH ROAD	120000	95427	97483	100515
IV	KENSINGTON ROAD - MURPHY ROAD	120000	107768	103313	102321
V	OLD MADRAS ROAD - KR PURAM JUNCTION	120000	110899	94711	107930
VI	KR PURAM JUNCTION - BHATTARAHALLI	120000	78134	75721	78911
<b>EAST-WEST II</b>					
I	DEEPANJALI NAGAR - SULTAN ROAD	60000	55365	60242	63373
II	KR MARKET - RICHMOND CIRCLE	30000	36790	37241	39523
III	CHAMRAJAPETE - KH CIRCLE	30000	42349	42973	41902
IV	RICHMOND ROAD - HAL AIRPORT ROAD	60000	114588	113966	117871
V	HAL AIRPORT ROAD - DOMLUR FLYOVER	60000	106077	106200	106207
VI	OLD AIRPORT ROAD - MARATHAHALLI (ORR)	60000	96810	94585	95608
VII	VARTHUR ROAD	60000	67016	67534	65247
CONNECTOR I	SARJAPUR ROAD	60000	63816	64070	64252
CONNECTOR II	D'SOUZA CIRCLE - BHASKARAN ROAD	60000	95051	91630	96335

#### 4.8 CONCLUSIONS

From the tabulated section loads for proposed elevated corridors for horizon year, certain inferences can be drawn forward:

- Maximum traffic volume was observed on the Section I – Jayamahar Road along the NS corridor accounting for 1,33,358 PCUs of traffic followed by Section - VII Hosur Road - Sarjapur Junction accounting 1,25,422 PCUs of traffic thereby exceeding the capacity in 2023.
- For EW II corridor, Section IV – Richmond Road - Hal Airport Road section accounts for 1,14,588 PCUs of traffic followed by Section-V Hal Airport Road - Domlur Flyover accounts for 1,06,077 thereby exceeding the capacity in the base year, i.e. 2023.
- CC-II D'souza Circle - Bhaskaran Road section accounts for 95,051 PCUs of traffic thereby exceeding the capacity in the base year, i.e. 2023.
- Section II and Section VII (Hosur Road – Sarjapur Junction section) of NS corridor is expected to exceed the 6-lane capacity by 2023.
- The capacity of the EW II corridor sections being 60,000 PCUs, Section IV and V of EW II corridor is expected to exceed the capacity by 2023.
- Major share traffic being diverted to elevated corridors are two wheelers, followed by private cars and commercial cabs.
- The CC-I i.e. Sarjapur road section is expected to have a maximum volume of 64,252 PCUs in the year 2037.
- CC-II i.e. Bhaskaran Road-Dsouza circle section is expected to have a maximum volume of 96,335 PCUs in 2037.

#### 4.9 RECOMMENDATIONS

From the tabulated section loads for proposed elevated corridors for horizon year, certain inferences can be drawn forward:

The above table clearly reflects that after completion of Phase III of the project, the proposed infrastructure will be able to sustain uncongested traffic flow beyond 2023, with a few critical elevated sections where the capacity will be utilized completely. Some of the capacity augmentation requirements to be included in design of proposed elevated corridors include the following:

- It is recommended Section III of the NS corridor being the common section of NS and EW-I corridors should be developed for 8 lane carriageway configuration.
- Considerations can be undertaken in the design to provide for additional lanes in the future in the affected sections of the corridors.
- Section IV and V of the EW-II corridor is expected a traffic volume which definitely requires 6-Lane divided carriageway configuration for uncongested traffic flow.
- CC-II is recommended to be developed for 6 lane carriageway configuration.



- A comprehensive mass transit network well integrated along the corridors can be a way out to decrease the volume of traffic on the roads.

#### 4.10 NEED FOR INTEGRATED MASS TRANSIT NETWORK

The very Objective of the elevated corridors in Bangalore will only be achieved if the proposal is integrated with development of Peripheral Ring Road (PRR) to avoid the through traffic from entering the City Core central area, development of Mass transit system including new Metro and Mono rail feeder corridors. The existing MRT System of Bangalore city can be strategically expanded using Metro rail and Mono rail combinations to connect all the arterial and sub arterial roads with the potential Production and Attraction zones to meet the growing travel demand of the city. Policy level interventions are required to integrate the upcoming metro corridors / Mono rail corridors with the proposed elevated corridors so as to provide last mile connectivity and generate substantial shift of passengers from private to public modes. Access to MRTS is needed to be optimized in both central as well as peripheral areas of the city of Bangalore to maximize its utility. Promoting public transit and strengthening mass transit network in the city can be a holistic way forward to solve the growing congestion impacts on the streets of Bangalore and improve the degrading quality of urban life as a whole.

CHAPTER – 5  
DESIGN PROPOSALS



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## CHAPTER 5 : DESIGN PROPOSALS

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### 5.1 INTRODUCTION

This chapter deals with various Design aspects of the project which includes following main sections:

- Design standards
- Geometric design
- Pavement Design
- Structural design

### 5.2 DESIGN STANDARDS

#### 5.2.1 Highway Design Standards:

Geometric design of the elevated road and existing road at ground level shall be as per IRC: 86, IRC: 92 and IRC: SP: 90 as well as other related codes taking into account the urban conditions. Uniformity of design standards will be maintained for the project corridor. Deficiencies in the existing geometry will be rectified to meet the minimum standards.

##### 5.2.1.1 Design Speed

As far as possible the design speed shall be 80/65 kmph and minimum speed shall be 50/ 40 kmph for elevated corridor. However, ramps and loop ramps shall be for 30 kmph. Unless otherwise there is site constrain from social and environmental point of view, generally the design speeds shall be maintained.

##### 5.2.1.2 Road Land Width

As per the IRC 86, a minimum Right of Way of 50m for Arterial roads and 30m for sub-Arterial roads should be available. However most of the Bengaluru urban roads do not have recommended right of way. On the other side, the traffic is growing exponential on these roads. Hence to have smooth flow of traffic, within available RoW or with minimum land acquisition elevated corridors are proposed. As far as possible consultant will try to accommodate the elevated corridor within the available land corresponds to each corridor. At few locations like short length narrow sections, curves, ramp/interchange locations, considering social/environmental aspects additional land requirement would be proposed. The client would acquire the additional land wherever required. The land to be acquired shall be indicated separately for each corridor after the finalization of alignment report, cross section and junction design.



5.2.1.3 Roadway Width

The standard lane width of the Project corridors shall be 3.5 m, the shyness shall be 500/250 mm for elevated corridor. For at grade road, due to construction of piers for elevated structure width of existing road will get reduced. Since land is a constraint and in urban conditions speeds will be less, hence lane width of 3.0 m and shyness of 250 mm is followed. This is in reference to the newly improved roads by BBMP under “Tender Sure” and other schemes, where the lane width is been standardized to 3.0 m. Overall roadway width for different cross sections are worked out separately and presented at the end of this chapter.

5.2.1.4 Shoulder Width

Width of shoulders on the outer side (left side of respective carriageway) shall be as given in Table.

Table 5-1: Dimensions of Shoulder

Type of Section	Width of Shoulder (m)		
	Paved	Earthen	Total
Built Up Area	2.0	-	2.0
Approaches to grade separated structures	2.0	-	2.0
Approaches of Bridges	1.5	2.0	3.5

The elevated corridors are provided with paved shoulders of 1.5 m, which will substantially increase the capacity and also provide emergency space for breakdown vehicles.

For at grade roads, the shoulders are provided depending upon the available roadway widths after accommodating footpaths.

5.2.1.5 Median:

As per IRC SP 84:2014, width of shoulder in urban areas is 1.5m excluding shyness. However due to constraints it is proposed to have 0.61m median (New Jersey Crash barrier) on proposed elevated corridors. At grade road median width will be guided by the width of pier of elevated structure. Mostly the width of pier including safety jacketing is 2m. At portal frame proposed locations as far as possible existing median width will be maintained.



5.2.1.6 Sight Distance and Radius

The minimum radii of horizontal curves for 4% super elevation are given below

Table 5-2: Desirable distance of Sight Distance (in-m)

Desirable	Minimum
265 m	150 m

Table 5-3: Speed, Horizontal Curvature and Sight Distance for Ramp Design

Particulars	Design Values for Major Highway Design Speed of				For Loop Ramps	
	80 km/hr		100 km/hr		Minimum	Desirable
	Minimum	Desirable	Minimum	Desirable		
Ramp Design Speed (km/hr)	40	50	50	65	30	40
Radius of Curvature (m)	60	90	90	155	30	60
Stopping sign distance (m)	45	60	60	90	25	45

- Note:
1. The major highway design speeds of 80 km/hr. is appropriate for highways in Urban areas.
  2. The radius of curvature values have been worked out for a maximum superelevation of 7 per cent

The radius of horizontal curves shall not be less than the desirable minimum values given in above table except for sections where site constraints are available. At those locations lesser radius will be provided.

5.2.1.7 Gradients

The ruling and limiting gradients are given in below table. Ruling gradients shall be adopted as far as possible. Limiting Gradient shall be adopted in difficult situations and for short lengths.

Nature of Terrain	Ruling Gradient	Limiting Gradient
Plain and Rolling	2.5%	3.5%*

At sections where there is acute land problem in case of providing the entry & exit ramps from the elevated structure then the limiting gradient have to be increased.

IRC 92 mentions gradients in the range of 4 - 6%, depending upon the site constraints the gradients in the range of 4 – 6% are used. Due to land constraints at few locations ramps length have to be reduced, hence steeper gradients provided but in no case are more than 6%.

5.2.1.8 Intersections

As part of consultancy agreement consultant need to improve at grade existing facilities. At grade intersections adversely influence the quality of roads in terms of

speed, capacity and safety because of interruptions to the flow of traffic. Thus the basic requirements for the design of intersections are 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. Intersections will be designed in line with IRC SP 41 but limiting improvements within available RoW.

#### 5.2.1.9 Utility Corridor

As a part of at-grade road improvement proposal, utility corridors will be proposed at ground level on either side along the proposed elevated corridors route. As far as possible 2 m wide strip of land at the extreme edge of ROW shall be kept for accommodating utilities, both over as well as underground. However no land will be proposed for acquisition. Provisions contained in IRC: 98 shall be followed as the project corridors fall in built up area. Utility Ducts in the form of 600mm diameter NP-4 Pipe across the Project corridor at a spacing of 500m shall be provided for crossing of Underground utilities. The provision of Utility corridor will be subjected to Land availability.

#### 5.2.1.10 Traffic Control Devices and Safety Measures

Traffic Control Devices, Road safety devices and Road side furniture shall comprise of road signs, road markings, object markers, hazard markers, studs, delineators, attenuators, safety barriers, pedestrian guard rails, boundary stones, km stones etc. Guidelines given in IRC: 25, IRC: 26, IRC: 35, IRC: 67, IRC: 79, IRC: 103 and section 800 of MORTH Specifications shall be used for providing these items unless otherwise specified.

#### 5.2.1.11 Bus-Stops

The Bus stops (at ground level) will be redesigned, wherever the bus stops are disturbed due to construction of elevated corridor or if the existing roads are being widened. The bus stop structure shall be structurally safe, aesthetically pleasing and functional so as to protect the waiting passengers from sun, rain and wind. Adequate drainage arrangement shall be provided at bus stops and bus bays.

Further, the roads leading to entry/exit of the elevated corridors are to be improved by providing proper bus bays/stops to ensure undue congestion due to entry/exit ramps.

Standard bus shelter plans that are being developed by BBMP is recommended.

#### 5.2.1.12 Toll Plaza

The project is envisaged as a toll free road and hence no toll plazas are designed. In case, the Govt. proposes for toll collection as part of revenue mobilization or to have

kind of restriction of personal vehicles, tolling by way of ERP "Electronic road pricing can be adopted", necessary infrastructure for ERP can be provided as its needed.

#### 5.2.1.13 Lighting System

Since the project corridors are traversing through the urban area Lighting shall be provided on elevated structure and lighting shall also be provided in soffit of the deck of elevated structure so that required illumination is available for existing ground level traffic. IS: 1944 (Part I and II) 1970 shall be followed in regard to lighting installations and also IRC:SP:90 shall be followed.

#### 5.2.1.14 Pedestrian Facilities

The proposed elevated corridors are meant for only motorized vehicles. Hence pedestrian facilities shall be retained/provided at ground level. Pedestrians are vulnerable to being involved in accidents. Therefore, adequate consideration shall be given to their safety through provision of facilities.

#### 5.2.1.15 Footpaths (sidewalks)

The width of sidewalks depends upon the expected pedestrian flow and shall be fixed subject to land availability, but shall not be less than 1.8m.

#### 5.2.1.16 Pedestrian crossings

Facility for crossing the carriageway by the pedestrians shall be provided through pedestrian underpass. At-grade pedestrian crossings shall be controlled. Controlled form of crossing shall be achieved through provision of Zebra Crossings, whether at signalized intersection or pedestrian actuated signal.

#### 5.2.1.17 Pavement Design

Designs for new pavement and overlays shall be produced in accordance with IRC codes. Generally, the recommendation for rehabilitating the existing pavement depends upon the functional condition, structural condition of the pavement, Subgrade type, Subgrade strength and characteristics. Once the improvement proposals are finalised the flexible pavement composition shall be designed as per IRC: 37 and concrete pavement shall be designed as per IRC 58 and white topping as per IRC SP 76.

#### 5.2.1.18 Summary of Proposed Cross-section

Lane width, shyness, median width and overall width of each cross section proposed are derived from IRC:SP:90 and IRC: 86. They are presented below for ready reference and approval.



Elevated Road:

- The lane width shall be 3.5 m
- The shyness shall be 0.5 m
- The median width shall be 0.610m in case of New Jersey Crash barrier.
- The total width of 6 lane flyover will be 24.61m
- The total width of 4 lane flyover will be 17.61m
- The total width of 4 lane with PS flyover will be 19.61m
- The total width of 3 lane flyover will be 12.5 m
- The total width of 2 lane flyover/Loop will be 9.0 m
- The width of Ramp will be 5.5 m

At Grade Road:

- The lane width shall be 3.0 m
- The shyness shall be 0.25 m

Combination of 2/3/4/5/6 lanes are to be planned depending upon the traffic flow, exit/entry points, accordingly the space standards will be adopted in the planning.

While finalizing the above cross section widths, provision of shoulder is dispensed, this is the deviation from the IRC codes.

Table 5-4: Geometric Design Standards for Project Corridors

S No.	Design Specification	Unit	Proposed Design Standards	Remarks
1	Design Speed	km/hr	50-80	IRC-86 & IRC:SP:90
	Design Speed for Ramps min.	km/hr	30-40	IRC-92
	Design Speed for loop min.	km/hr	30-40	IRC-92
2	PROW	m	Proposed elevated structure width plus a minimum of 1m on either for working space	
3	Carriageway Width	m	Lane width is 3.5 – Elevated Road Lane width is 3.0 – At grade Road	IRC-86
4	Width of Service road (min)	m	5.5/7.0	IRC:SP:84
5	Median Width in Urban Areas / with New Jersey barrier	m	1.5 / 0.610	IRC:SP:84

## Final Feasibility Report

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S No.	Design Specification	Unit	Proposed Design Standards	Remarks
6	Kerb Shyness	m	0.5/0.25	IRC:SP:84
7	Width of Parapet / Crash Barrier	m	0.5	IRC:SP:84
8	Width of Footpath-cum-drain	m	Minimum 1.8	IRC-103
9	Longitudinal Gradient			
	a) Max.	%	3.5%-4.0% for elevated road 4.0% - 6.0% for ramps	IRC:SP:90
	b) Min.	%	0.3 0.3	IRC:SP:90
10	Cross Fall	%	2.0/2.5 1.7/2.0	IRC:SP:90
11	Super-elevation (Maximum)	%	4.0 4.0	IRC:SP:90
12	Minimum Radius of Curvature	m	100-265	IRC-86
13	Safe Stopping Sight Distance	m	80-120	IRC:SP:90
14	Minimum VC Length	m	40-50	IRC-86
15.	Speed change lanes	m		
	Acceleration lane	m	250 (desirable)/180 (min.)*	IRC-92
	Deceleration lane	m	120 (desirable)/90 (min.)*	IRC-92
16.	Weaving length	m	300 (desirable)/200 (min.)*	IRC-92
17.	Lateral clearance	m	Min. 1.0	IRC:SP:90
18.	Vertical clearance	m	5.5/6.525/8.1	IRC:SP:90
* Depending upon the availability of the land.				

### 5.3 STRUCTURE DESIGN STANDARD:

Design standards will be clearly identified and enumerated for evolving a comprehensive design philosophy, which will cover all aspects of design for various parts of the elevated corridor viz. superstructure, substructure, foundations, protection works and repair and rehabilitation works of existing structures (if any being amalgamated with proposed corridor). The design philosophy will be primarily based on relevant IRC codes of practice (prescribed for design, execution, maintenance and safety during construction and service), IRC specifications, latest guidelines and circulars of NHAI/MORTH/KRDCL and relevant stipulations from Bureau of Indian Standards (BIS) Codes. For aspects not covered by IRC and BIS Standards, relevant recommendations of the International Standards (viz. EUROCODES, AASHTO-LRFD) and judicious Sound Engineering Practices will be followed. For the elevated structure passing across the Railway/Metro Lines, relevant Standards/instructions laid down by Ministry of Railways/BMRCL will be kept into consideration before finalizing the structure arrangement and its type.

The requirement of shape, size, type and configuration of the elevated corridor at any location will be decided by collecting sufficient relevant data and information and analyzing it with respect to volume, intensity and type of traffic, loadings, climatic conditions and geotechnical investigations, space restraints limitations because of underground and overhead utilities services and available geometries, traffic regulation during construction etc. All this data will be collected and then studies and investigations will be properly and adequately done for deciding the various parameters for planning, layout, design and construction and maintenance etc.

In the process of developing the design and structural drawings, Consultant shall make use of the data gathered and collected from the existing sources and the information obtained directly at the site. On the basis of the detailed site investigations, topographic surveys, core drilling and subsurface investigation, hydrological study (in any) and geometric alignment design, Consultant shall prepare the final design and drawings of various structure modules conforming to the site requirements.

#### 5.3.1 Durability Requirement

- Required bridge design life will be 100 years
- Structures will be designed for normal exposure conditions with adequate concrete cover to exposed surfaces.
- However for certain replaceable components the life time will be less. The design life of the temporary structures and support systems will be defined such that the structural stability is not compromised until all permanent works are completed.

## 5.3.2 Standards and Code of Practices

For planning and design the structures of elevated following codes of practices and specifications will be followed: -

Table 5-5: Code of Practices for Structures

IRC:5-2015	Standard Specifications and Code of Practice for Road Bridges Section: I - General Features of Design (5th Revision)
IRC:6 – 2014	Standard Specifications and Code of Practice for Road Bridges Section: II - Load and Stresses (Revised Edition)
IRC:22-2015	Standard Specifications and Code of Practice for Road Bridges Section - VI Composite Construction (Limit State Design) - (3rd Revision)
IRC:24 – 2010	Standard Specifications and Code of Practice for Road Bridges Section - V Steel Road Bridges (Limit State Design) - (3rd Revision)
IRC:78 -2014	Standard Specifications and Code of Practice for Road Bridges Section: VII – Foundations and Substructures (Revised Edition)
IRC:83 - 2015 (Part I)	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Rocker & Roller Bearings) – (2nd Revision)
IRC:83 - 2011 (Part II)	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Elastomeric Bearings)
IRC:83 - 2002 (Part III)	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (Spherical and Cylindrical Bearings)
IRC:83 - 2014 (Part IV)	Standard Specifications and Code of Practice for Road Bridges Section: IX – Bearings (POT, POT-cum-PTFE, Pin and Metallic Guide Bearings)
IRC:87 - 2011	Design and Erection of Formwork, False-work and Temporary Structures (1st Revision)
IRC:89 – 1997	Guidelines for design and construction of river training and control works for road bridges
IRC: SP:13 - 2004	Guidelines for the Design of Small Bridges and Culverts
IRC: SP:50 - 2013	Guidelines for Urban Drainage (1st Revision)
IRC: SP:56 - 2000	Guidelines for Steel Pedestrian Bridges
IRC: SP:64 – 2005	Guidelines for Analysis and Design of Cast in Place Voided Slab Superstructure
IRC: SP:66 – 2005	Guidelines for Design of Continuous Bridges
IRC: SP:69 - 2005	Guidelines and Specifications for Expansion Joints
IRC:SP:84-2014	Manual of Specifications & Standards for four Laning of Highways



	through Public Private Partnership
IRC:SP:90-2010	Manual for Grade Separators and Elevated Structures
IRG:SP:99-2013	Manual of Specifications and Standards for Expressways
IRC:SP:102-2014	Guidelines for Design and Construction of Reinforced Soil Walls
IRC:SP:104-2015	Guidelines for Fabrication and Erection of Steel Bridges

Other Design Codes and Standards to be followed as and when required:

- ASHTO-LRFD Bridge Design Specifications 6rd Edition 2012.
- AASHTO - Guide Specifications for Design and Construction of Segmental Concrete Bridges (1999)
- MORTH - Specifications for Road & Bridge Works (5th Revision)
- EUROCODE - European Standards (EC0 to EC8)
- Recommendations for Stay Cable Design, Testing and Installation, (PTI), Phoenix, Arizona, 2001
- FIB Bulletin 30, "Acceptance of Stay Cable Systems using Prestressing Steels", Lausanne, 2005.
- Any Specific Requirement of the Project as per TOR from KRDCL

Reference shall also be made to other Standard Engineering Practices as and when required. All calculations and drawings shall be made in metric (SI) system.

Each design discipline report will contain a comprehensive list of design codes and standards which should be used in the design calculations.

**5.3.3 Structural Analysis and Design**

Structures shall be designed according to requirements of IRC code of practice for modeling, loadings, load combinations and stress limits and shall be analyzed using grillage or FE models. Analysis will be carried out using internationally recognized structural software viz. STAAD-Pro, ADAPT-ABI, MIDAS-CIVIL etc. For substructure and foundation design, spread sheet calculations will be carried out.

Ultimate Limit State (ULS) and Serviceability Limit State (SLS) load combinations should be analyzed for shear, axial force and bending moments based on the expected foundation conditions and the requirements of latest IRC codes.

**5.3.4 The structural behaviour in the ULS shall be analysed with regard to:**

- Safety against structural failure;
- Deformation and rotation capacity against local mechanisms;
- Static equilibrium of the whole structure;

5.3.5 The structural behaviour in the SLS shall be analysed with regard to:

- Stress limitations;
- Crack widths;
- Water resistance;
- Deflections;

The global design analyses performed to determine the global force effects for the elevated structures will be based on linear elastic models, using the appropriate material properties. Local analysis in the Serviceability Limit State shall be based on elastic behavior.

5.3.6 Assumptions for Structural Analysis

- Plane sections remain plane, material is orthotropic and shear deformations are negligible.
- Stress and strain compatibility will be satisfied throughout the analysis and check
- Un-cracked sectional properties will be used for analysis.

5.3.7 Design Loadings

5.3.7.1 Dead Load (DL)

Dead Load is defined as the self-weight of the structure. For design purpose, self-weight of reinforced concrete and pre-stressed concrete will be taken as 25kN/m<sup>3</sup>. Similarly weight of the structural steel will be taken as 78.5 kN/m<sup>3</sup>.

5.3.7.2 Super Imposed Dead Load (SIDL):

SIDL is defined as self-weight of non-structural component such as surfacing and other utilities carried by the bridge / structure.

Following permanent elements loads will be considered in the category of SIDL:

- For design purposes weight of the asphaltic wearing course shall be considered as 2.2 kN/m<sup>2</sup> (with future overlay)
- Concrete crash barrier with a weight of 8.0kN/m will be considered for both unsupported longitudinal edges of the deck
- The weight of known utilities carried on the elevated structure shall be taken into consideration. As future utilities are unknown then an allowance of 1 kN/m per carriageway shall be considered for this purpose

5.3.7.3 Design Vehicular Loading (IRC Class Loading)

All proposed elevated structures with single or dividing carriageway will be designed for governing effect of IRC loadings (Class 70R and Class A) with appropriate lane reduction factor as specified in IRC: 6-2014. The above loads will be increased by appropriate impact factors as per provision of Cl: 208 of IRC: 6-2014.

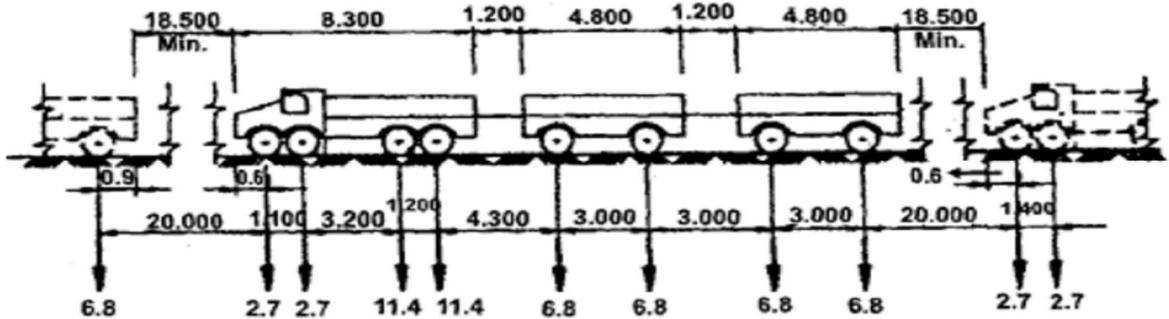
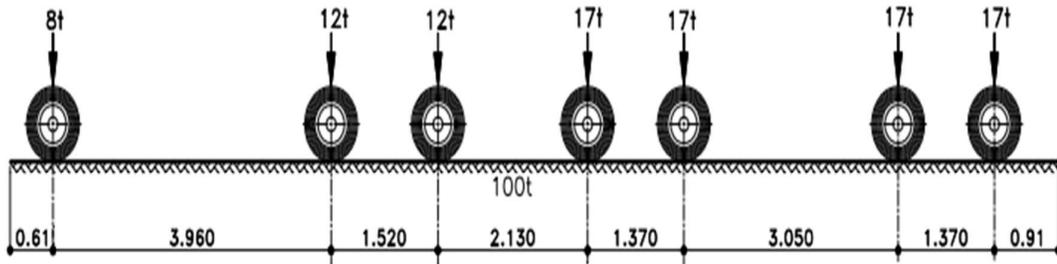


Figure 5-1: Class A Train of Vehicles

Class-A trains are spaced every 20m whereas 70R are spaced every 30m between axles for wheeled vehicles, and every 30 m from tail to nose for tracked vehicles.

5.3.7.4 For Local Live Load Analysis (LL)

Load cases of single axle of 20t and a bogie of 40 t (two axles spaced at 1220 mm) are to be considered for the local analysis of the deck. Transverse spacing of the wheels of the axle or the bogie, and wheel impact shall be as per the following sketch:



CLASS 70R (WHEELED) - LONGITUDINAL POSITION

Figure 5-2: Class 70R Train of Vehicles

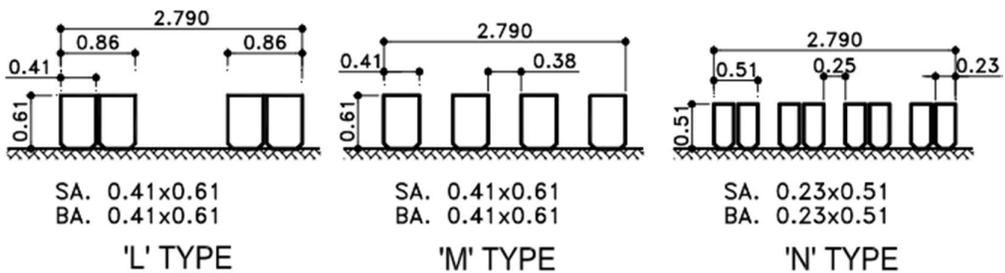


Figure 5-3: Traverse Spacing of the Wheels

Effect of Vehicle Impact for longitudinal and transverse analysis (IM)

Vertical impact for Class A loading shall be as per figure given below:

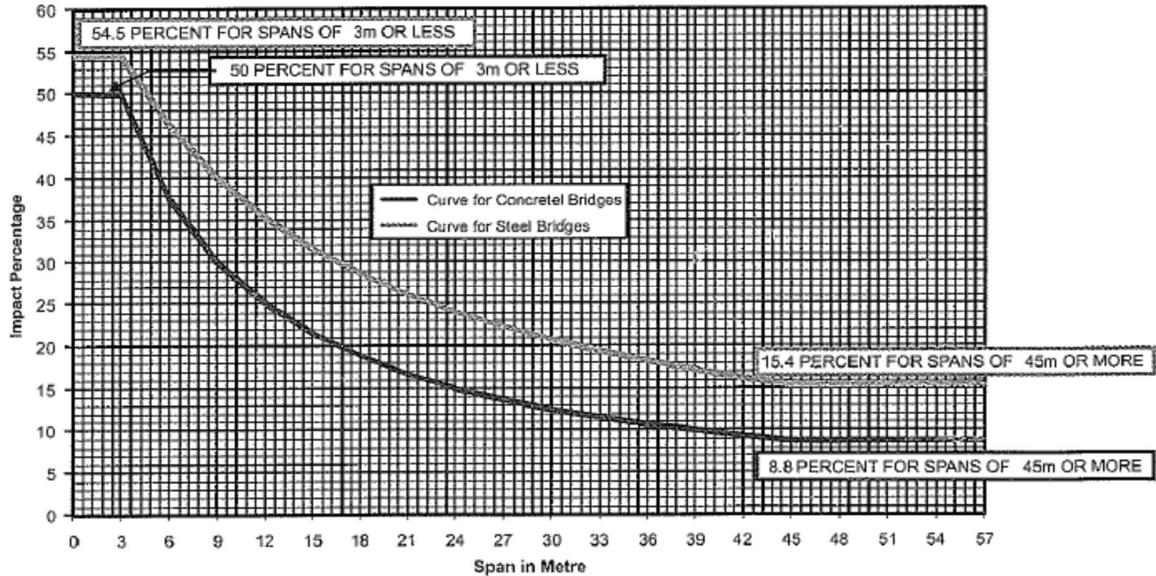


Figure 5-4: Vehicle Impact percentage for IRC Class A

Class 70 R – wheeled vehicles, impact shall be taken equal to 25 % for spans less than 12m, and in accordance with above figure for spans in excess of 12 m.

For Class 70 R – tracked vehicles, impact shall be taken equal to 25 % for spans upto 5 m, linearly reducing to 10% for spans of 9m. 10% for spans up to 40 m and in accordance with above figure for spans in excess of 40 m.

As per Cl. 4.(II) of IRC: SP: 66-2005, impact factor for the continuous bridge of unequal spans, the least effective span will be considered for determining the Impact Factor.

5.3.7.5 Longitudinal force of Live Load due to Braking (BR):

For the first two loaded lanes, braking force will be considered 20% of the vertical load of the first train load without reduction plus 10% for the succeeding trains. From the third loaded lane and succeeding lanes, only 5% of the vertical load of each lane shall be considered for all additional lanes.

Total braking force will be computed based on the number of design lanes in the same direction. Braking forces will not be increased for impact allowance and assumed to act horizontally at a height of 1.2m above the roadway surface and distributed equally on all bearings

### 5.3.7.6 Centrifugal forces (CF)

Bridges on a horizontal curve will be designed for centrifugal forces based on the following equation-

$$C = \frac{WV^2}{127R}$$

Where C = centrifugal force acting normal to the traffic

W = live load

V = the design speed of the vehicles using the bridge in km per hour

R = the radius of curvature in meters

The centrifugal force will be considered to act at 1.20m above the formation level of the elevated structure in the transverse direction. No impact value on carriageway live load has been considered for calculating the centrifugal force.

### 5.3.7.7 Vehicular Collision Load:

Effect of Vehicular collision load shall be in accordance with clause 222 of IRC: 6-2014.

Structures which are within 4.5 m away from carriageway shall be considered for collision loads. Collision load shall be taken as an accidental load. These loads shall be as per table 11 of IRC: 6-2014.

### 5.3.7.8 Accidental load on Crash Barriers

Loads coming from crash barriers of P-1 category (Refer IRC: 6-2014), will be considered for the transverse analysis of the superstructure. The transverse bending moment transmitted by the base of the barrier is equal to 15kN/m.

### 5.3.7.9 Wind loads

Wind load on structure shall be considered as per clause 209 of IRC: 6-2014.

A lateral wind force against moving live loads shall be considered as acting at 1.5m above the roadway and shall be assumed equal to 300 kg/m.

### 5.3.7.10 Seismic Loading

As per the seismic map given in IRC: 6-2014, the project corridors lie in Zone-II. Therefore all structures will be designed for basic seismic condition of Zone-II. Seismic force shall be calculated in accordance with the IRC: 6-2014.

$$F_{eq} = A_h (\text{Dead Load} + \text{Appropriate Live Load})$$

Where,

$$A_h = \text{horizontal seismic coefficient} = \left(\frac{Z}{2}\right) \times (I) \times \left(\frac{S_a}{g}\right)$$

Z = Zone factor shall be taken from IRC: 6 – 2014

I = Importance factor shall be taken from IRC: 6 – 2014.

R = Response reduction factor shall be taken from IRC: 6 – 2014

T = Fundamental period of the bridge in seconds in horizontal vibrations

$\frac{S_a}{g}$  = Average response acceleration coefficient depending upon fundamental period of vibration

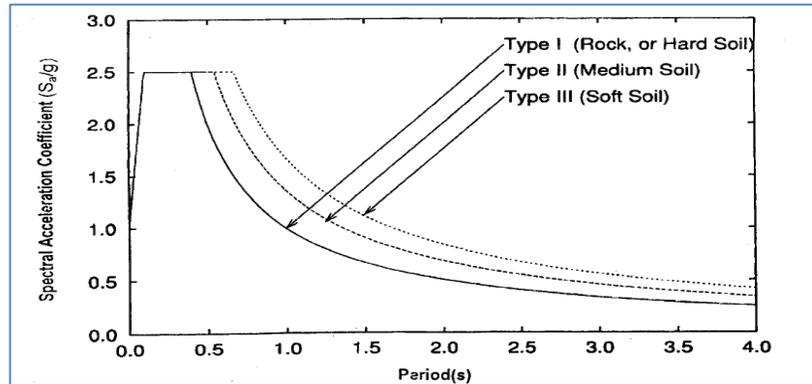


Figure 5-5: Response Spectra

### 5.3.7.10.1 Design response spectra

In accordance with provision of Cl. 219.4 of IRC:6-2014, the following seismic combinations will be considered for the seismic design loading on the structure:

$$EQ = EQ_x + 0.3 EQ_y$$

$$EQ = EQ_y + 0.3 EQ_x$$

Vertical seismic forces shall not be considered as the bridge is located in zone-II of Seismic Map of India.

The seismic force (modal mass) due to live load shall not be considered when acting in the direction of traffic, but shall be considered in the direction perpendicular to traffic. Parts of the structure embedded in soil shall not be considered to produce any seismic forces. Only 20% of Live Load on the deck will be considered in transverse seismic case.

Seismic effect on the structure will be determined by multi modal-dynamic analysis of the structure. Dynamic analysis is performed under three stages. The first being modal analysis, which includes determinations of natural frequencies, mode shapes and hence the participation factors and the spatial distribution of the masses for each mode. The second stage is the calculation of the spatial distribution of the effective

earth quake forces based on the concept of Response Spectrum. And in the third step, the evaluation of earthquake forces in different components of the structure.

### 5.3.8 Bearing Replacement

The superstructure deck, substructure and bearings shall be designed and detailed to permit future bearing replacement of each and every bearing and jacking points shall be clearly shown on the drawings.

- No reduction in traffic loading shall be considered during bearing replacement.
- A maximum jacking movement of 10mm shall be assumed for bearing replacement.

### 5.3.9 Settlement (SE)

If required, differential settlement shall be considered as a long term effect developing gradually and its effect shall be considered as being modified by concrete creep, however the maximum reduction due to creep shall be limited to 40%.

### 5.3.10 Earth Pressure

- Abutments, wing walls and retaining walls shall be designed for active pressures  $K_a$ .
- Walls that do not deflect will be designed for at rest pressure with  $k_0 = 0.5$
- Where live load is present behind retaining structures a live load surcharge equivalent to a minimum of 1.2 meter of soil shall be considered.
- An appropriate drainage system shall be provided behind all retaining structures.
- In case of structures with integral abutments, two different patterns for lateral earth pressure acting on abutments will be considered. One will be active earth pressure case for longitudinal temperature fall condition and other will be earth pressure at rest case for longitudinal temperature rise condition.
- Density of cohesion less backfill material shall be taken as 20kN/m<sup>3</sup>
- Backfill parameters proposed to be taken for the backfill material behind abutments and other earth retaining wall are:

$$\phi \geq 30^\circ, \delta = 20^\circ, \gamma_d = 20\text{kN/m}^3, \gamma_{\text{sub}} = 10\text{kN/m}^3$$

### 5.3.11 Creep and shrinkage effects (CR & SH)

Following engineering calculations of time dependent effects on concrete shall be considered as given below

- For shrinkage calculations purposes, the average humidity ratio shall be taken at 75%;

- Creep calculations will be done for 100 years horizon;

Time dependent effects of creep and shrinkage for precast and in-situ portion of the structure shall be computed using ACI-209 model.

A range of  $\pm 20\%$  shall be considered on the creep factor for both pre-cast and in-situ design

### 5.3.12 Thermal Effect (Cl.215 of IRC: 6-2014)

There are two temperature effects that cause forces in a continuous bridge viz. temperature gradient in the girder and a uniform temperature range applied to the entire structure

#### 5.3.12.1 Uniform temperature (TU)

Minimum and maximum air shade temperatures in the project corridor are equal to  $+0^{\circ}\text{C}$  &  $45.0^{\circ}\text{C}$  respectively. Therefore the mean of maximum and minimum air shade temperature is equal to  $22.5^{\circ}\text{C}$ .

As the bridge location has a difference between maximum and minimum shade temperature greater than  $20^{\circ}\text{C}$ ; the bridge temperature to be assumed when the structure is effectively restrained as per the table shown in IRC-6 § 215.2, is equal to mean of maximum and minimum air shade temperature  $+10^{\circ}\text{C}$  whichever is critical, which corresponds in this case to  $22.5^{\circ}\text{C}$  or  $32.5^{\circ}\text{C}$ .

Then, lowering of temperature will be in the range of  $32.5 - 0 = 32.5^{\circ}\text{C}$  and temperature increase equal to  $45.0 - 22.5 = 22.5^{\circ}\text{C}$ . Uniform temperature variation is considered as a long term loading. The elastic modulus for uniform temperature effects will be taken as 0.5 times the instantaneous elastic modulus.

#### 5.3.12.2 Temperature Gradient (TG)

Positive and reverse temperature differences have to be considered as a short term effect for the superstructures of main bridge only. The non-linear thermic diagram defined in IRC 6-2015 §215.3 will be used

Construction loads and construction load combinations shall be considered as per provision of AASHRO LRFD Section 5.14.2.3.2

Construction agency will be responsible for ensuring that his proposed handling, erection methods and sequences of construction do not overstress the permanent works.

Stability during Erection: § 5.14.2.4.4 of AASHTO-LRFD Specifications

During all stages of erection longitudinal and transverse stability of the incomplete structure shall be ensured and a minimum stability factor of 1.5 under the worst combinations of dead loads, construction loads, loads from erection equipment and wind load shall be required.

- A construction live load (CLL) of 50 kg/m<sup>2</sup> shall be considered during cantilever erection.
- Weight of the lifting frame (CE) will be taken as per manufacturer’s data for different segment sizes
- An impact (IE) of 10 % shall be considered for the moving construction loads

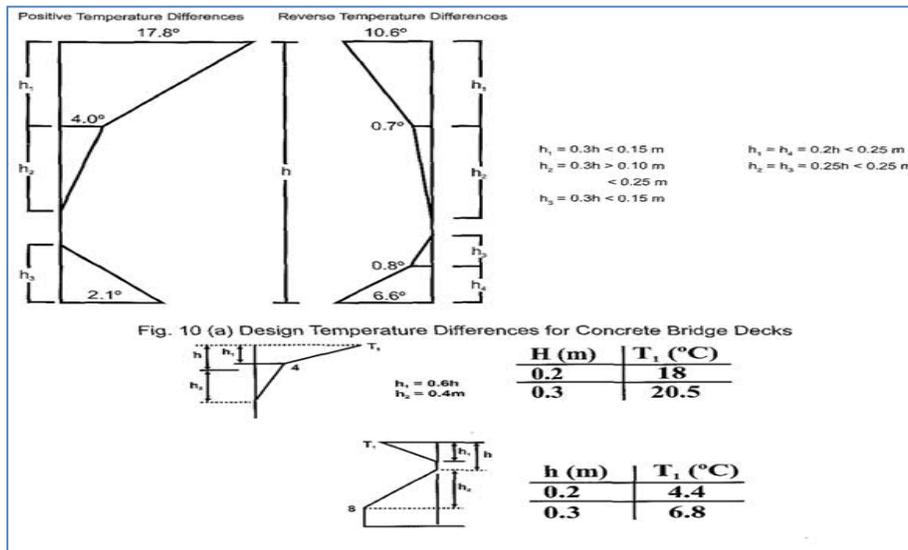


Figure 5-6: Temperature Difference across Steel and Composite Section

### 5.3.13 Combination of Loads for Design

Annexure-B to Cl.202.3 of IRC:6-2014

For Limit State Design Approach, load combination as shown in Annex B shall be adopted.

#### 5.3.13.1 Combination of Loads for under Ultimate Limit State

- For checking the equilibrium of the structure, under ULS Basic Combination, the partial safety factor for loads shown in Column No. 2 or 3 under Table 3.1 shall be adopted.
- For checking the structural strength of the structure, under ULS Basic Combination, the partial safety factor for loads shown in Column No. 2 under Table 3.2 shall be adopted.

- Under ULS Accidental Combination, for checking the equilibrium of the structure, the partial safety factor for loads shown in Column No. 4 or 5 under Table 3.1 and for checking the structural strength, the partial safety factor for loads shown in Column No. 3 under Table 3.2 shall be adopted.
- Under ULS Seismic Combination, for checking the equilibrium of the structure, the partial safety factor for loads shown in Column No. 6 or 7 under Table 3.1 and for checking the structural strength, the partial safety factor for loads shown in Column No. 4 under Table 3.2 shall be adopted.

### 5.3.13.2 Combination of Loads for under Serviceability Limit State

The serviceability limit state check shall be carried out in order to have control on stress, deflection, vibration, crack width, settlement and to estimate shrinkage and creep effects. It shall be ensured that the design value obtained by using the appropriate combination shall be less than the limiting value of serviceability criterion as per the relevant code. The rare combination of loads shall be used for checking the stress limit. The frequent combination of loads shall be used for checking the deflection, vibration and crack width. The quasi-permanent combination of loads shall be used for checking the settlement, shrinkage creep effects and the permanent stress in concrete.

- Under SLS Rare Combination, for checking the stress limits, the partial safety factor for loads shown in Column No. 2 under Table 3.3 shall be adopted.
- Under SLS Frequent Combination, for checking the deflection, vibration and crack width in pre-stressed concrete structures, partial safety factor for loads shown in column no. 3 under Table 3.3 shall be adopted.
- Under SLS Quasi-Permanent Combination, for checking the crack width in RCC structures, settlement, creep effects and to estimate the permanent stress in the structure, partial safety factor for loads shown in Column No. 4 under Table 3.3 shall be adopted.

The permissible stresses for pre-stressing and reinforcement shall be considered as per Chapter 12 of IRC:112-2011.

- Allowable compressive stresses in concrete under rare combination of loads shall be limited to  $0.48f_{ck}$ .
- Allowable compressive stresses in concrete under quasi permanent combination of loads shall be limited to  $0.36f_{ck}$ .
- Allowable stresses in reinforcement for reinforced concrete structures under rare and quasi permanent combination of loads shall be limited to 300MPa without fatigue check
- Crack width calculations shall be done as per Cl. 12.3.4 of IRC:112-2011. The crack width shall be limited to 0.3 mm for RC members & pre-stressed with unbounded tendons under quasi-permanent load combination and 0.2 mm for

pre-stressed members with bonded tendons under frequent load combination as per Table 12.1 of IRC: 112-2011.

### 5.3.14 Material Specifications

#### 5.3.14.1 Concrete

The specified compressive strength ( $f_{ck}$ ) of concrete at 28 days (based on tests of cube of size 150x150x150 mm made and tested in accordance with provision of IS:516). Equivalent cylindrical strength of the concrete will be considered as 80% of its cube strength.

Minimum concrete strength requirements for various components of structure are:

RCC Superstructure	-	M35
Substructure		M30
Pile Foundations	-	M30
Open Foundations	-	M30
RCC Crash Barriers	-	M40
RCC Approach Slab	-	M40
PCC for Leveling Course	-	M15

Instantaneous Young modulus for normal weight concrete is calculated using the following equation:

$$E_c = 5000\sqrt{f_{ck}}$$

Long time elasticity modulus shall be taken equal to half the instantaneous modulus.

- Poisson's ratio is taken as  $\nu = 0.2$  for un-cracked components;
- Poisson's ratio is neglected for components expected to be subject to cracking.

Shear modulus of concrete,  $G$ , is calculated using the following equation:

$$G = \frac{E_c}{2(1 + \nu)}$$

Coefficient of thermal expansion and contraction for normal concrete is taken as  $1.08 \times 10^{-5}/^{\circ}\text{C}$ .

Density of the pre-stressed concrete is taken equal to  $\rho_c = 25 \text{ kN/m}^3$

Density of the reinforced concrete is taken equal to  $\rho_c = 25 \text{ kN/m}^3$

Density of the plain concrete is taken equal to  $\rho_c = 22 \text{ kN/m}^3$



5.3.14.2 Steel reinforcement

Deformed bars of Grade Designation Fe-500 conforming to IS: 1786 is proposed to be used. Yield strength of steel reinforcement is considered equal to 500 MPa and Young modulus of elasticity equal to 200000 MPa

The following diameters of reinforcement can be used [in mm]: 8, 10, 12, 16, 20, 25, 28, 32, 36 & 40 with a maximum length for a single rebar of 12 m.

5.3.14.3 Structural Steel

Structural Steel in all structural steel work shall be conform to IS:2062-2011. Grade of the steel will be chosen from Table-1 & 2 of IS:2062-2011.

Provision of surface protective coating as per coating system-4 under Table-D2 of Annex-D of IRC:24-2010 will be proposed against protection of the structural steel. To ensure the 100 year life of the steel, no part of the structural steel will be left uncoated and proposed coating will be done at every 18 years.

5.3.15 Minimum Clear Concrete Cover

The following minimum concrete cover shall be provided:

Location		Minimum Cover mm
1	Cast-in-situ Concrete exposed to weather	40
2	Concrete of all substructure elements in contact with earth	75
3	Concrete of all substructure elements exposed to weather	50
4	Superstructure cast-in-place concrete exposed to weather	40
5	Concrete of foundation in contact with earth	75

5.3.16 Vertical and Lateral Clearances

Vertical clearance over road above finished road level of lower road	5.5m
Vertical clearance of underpass for pedestrians,	3.5m
Vertical clearance of underpass for cattle	4.5m
Vertical clearance for railway traction over rails	6.525m
Vertical clearance for railway freight corridor (to be confirmed)	8.1m*
Vertical clearance for power telecommunication lines	6.0m
Electric power lines up to 650v	6.5m
Lateral clearance at railway traction	As specified in Railway Code
* For present situation, vertical clearance of 6.525 is adopted	

### 5.3.17 Miscellaneous

#### 5.3.17.1 Crash Barriers

New Jersey type concrete barriers shall be used as vehicular parapets on the structures.

Barriers with circular top rails will be preferred to full height solid barrier as this allow across view for vehicle rider. On the outer face some fine ribbing or other carved finishing accepted to client will be done.

#### 5.3.17.2 Expansion Joints

Expansion joints will be provided at the all EJ support locations. It is proposed to provide modular strip or finger joints to cater large movements at the expansion joints. These joints will be designed according to Cl. 5.3 of IRC:SP:69-2005 and procured from the MORTH's approved manufacturers.

#### 5.3.17.3 Wearing Coat

Asphaltic concrete wearing coat, 50-65 mm thick as per MOORTH standards, will be provided.

#### 5.3.17.4 Approach Slab

Reinforced concrete approach slabs in M30 grade concrete at either end of the bridge, will be proposed, with one end supported on the reinforced concrete bracket projecting out from the dirt wall and the other end resting over the soil, in accordance with the guidelines issued by MOSRT & H. A leveling course, 150 mm thick, in M 15 grade concrete will be provided under the approach slab.

## 5.4 GEOMETRIC DESIGN:

### 5.4.1 INTRODUCTION

Geometric design has been carried out based on the design standards presented in Inception Report. However at few locations where due to site constraints design has been carried out with reduced speeds. At these locations safety measures like provision of signs and markings have been proposed to alert drivers. Regarding route/alignment of Project Corridors has been discussed in detail in Stage 2: Alignment report which was submitted in the month of September'2016. Further, geometric design has been fine-tuned based on updated topographic data, site constraints and to minimize the land acquisition. Corridor wise detail discussion has been carried out in following sections.

### 5.4.2 NORTH-SOUTH CORRIDOR-1 (NS-1):

CONNECTING HEBBAL ON NH-44 (NH-7) TO SILK BOARD ON NH-44 (NH-7).

Initially, the elevated corridor was started from Mekhri circle as BDA had proposed a elevated road 'six laning from Hebbal to Basaveshwara circle', however, after the tender was cancelled, Govt. has asked to consider elevated corridor from Hebbal. Based on the traffic studies and delays at esteem mall, consultants have recommended the elevated corridor must be integrated with the existing airport expressway at esteem mall, accordingly the plans are prepared. However, BMRCL has revealed that their station from two corridors from Gorguntapalya and KR puram and airport connectivity will interfere the elevated corridor alignment and also BDA has already fast-tracked the construction of two additional loops to Hebbal flyover. ( 2 lane loop from Airport to City at 2<sup>nd</sup> level and another 2 lane loop from KR puam to Airpor at 2<sup>nd</sup> level)

After several discussions and deliberations, it was agreed that Hebbal flyover is a complex issue and need to have road as well as metro connectivity here and a detailed study to find out how to integrate metro, elevated corridor, BDA loops is required. The Govt. has authorized BMRCL to prepare the study and present it. Till such time the KRDCL was asked to do the following

1. The elevated corridor shall start from Baptist Hospital
2. Airport to city: integrate the 2 lane airport to city loop of BDA and provide 1 lane up ramp at Baptist Hospital for the local traffic originating at Hebbal junction
3. City to Airport: Down 1 lane at Baptist Hospital for the local traffic leading to Hebbal junction and provision of extending 2 lanes to to the airport side once BMRCL study is done.

Hence, The revised corridor starts from Baptist Hospital and ends at Silk Board flyover via. - Jayamahal main road – Cantonment RUB jn.- Millars road – Netaji road jn.- Cantonment rly. Station road - Queen’s Road - Indian Express Junction - Infantry Road Junction - Minsk Square – MG road jn. –Kasturba Road - Tiffanys circle - Hudson Circle – Kaliga rao rd jn. – Subbaiah circle – Lang ford rd. jn. – Shantinagar bus stand – BTS road - Adugodi main road – St. John’s hospital jn. – Silk board jn.

Total Length of the Main Corridor: 24.32 km

Length of One way loops: 4.66 km

Number of lanes: 6 lanes

Number of ramps: 15 nos.

From Baptist hospital to Mekhri circle 3+3 lanes is the configuration, at Mekhri circle, 2+2 lanes are taken left towards Jayamahal road and 2+2 lanes are extended straight towards Kaveri Junction.

From Mekhri circle to Condonement its 3+3 lanes as additional traffic from Yeshwanthpura will also be connected.

A 3 lane one-way elevated loop is proposed around cantonment station to provide a seamless connectivity and movement for traffic coming from KR Puram, Mekhri circle and leading to city (via Queens road)

Further an interchange is provided at corner of Queens road for ingress/egress of buses and vehicles. This interchange will help to give access to Cantonment, proposed Metro station at bamboo Bazar.

From Queens road till Siddalingaiah circle (earlier known as tiffany’s junction) it’s a 3+3 lane in a Double decker to save all the trees along and to not impact buildings

From Siddalingaiah circle, the elevated corridor forms a oneway loop moving towards Richmond circle via vittal malya road, integrate with Richmond road, move on KH road and take left at BTS road next to Shanthinagar TTMC.

From Shanthinagar TTMC to Silk Board is a 2+2 lane moving on BTS road, Bosch campus, NDRI land and on Hosur road.

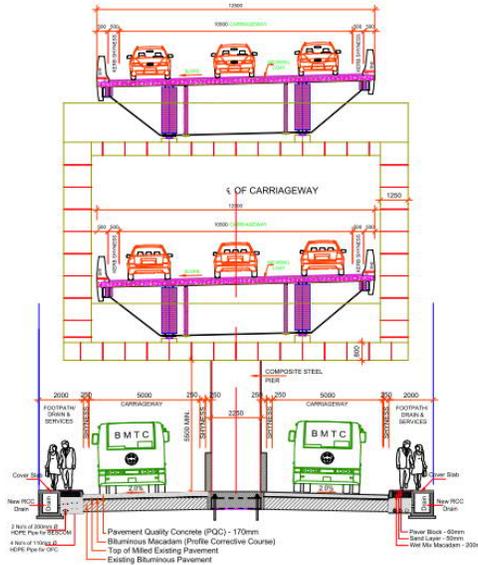
A CBD elevated one-way loop is proposed from Richmond circle, KH road, Lalbagh road, JC road, Hudson circle and back to Richmond circle. This elevated loop will function as hub and spoke wherein the loop will take traffic from Silk board, Mysore road, cantonment, Varthur kodi and disperse the traffic smoothly. The loop will provide much relief to the traffic below as all the through traffic gets elevated the road space below will be used only by local traffic. Further, the traffic movement at grade will become two way on these roads which will improve the access substantially.

The CBD loop is a 4 lane one way loop.

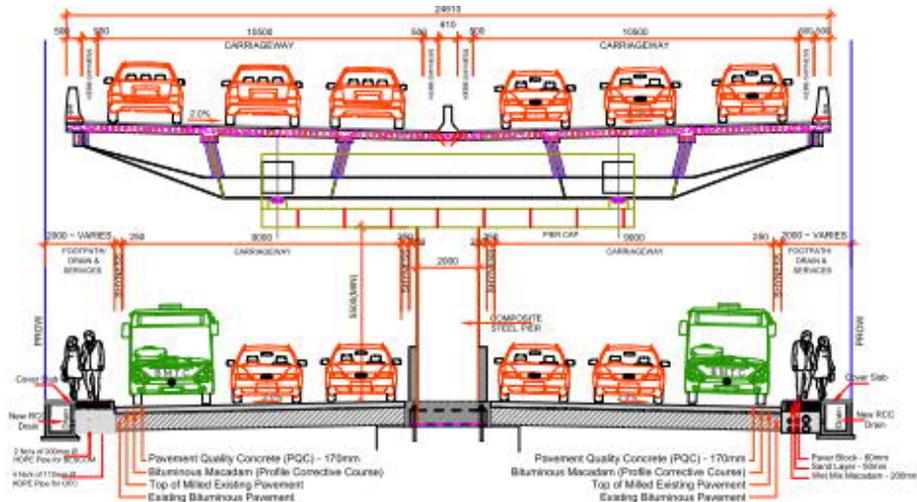
Further an interchange is provided at Shanthinagar TTMC for ingress/egress of buses to the bus stand.

Another interchange is provided at Augogodi on Hosur Road using NDRI/NIAMP land

5.4.3 Typical cross sections and their schedule proposed along North South Corridor



Proposed Typical Cross Section  
NS-TCS-05



Proposed Typical Cross Section  
NS-TCS-07

Figure 5-7: Indicative Typical Cross-sections along North South Corridor

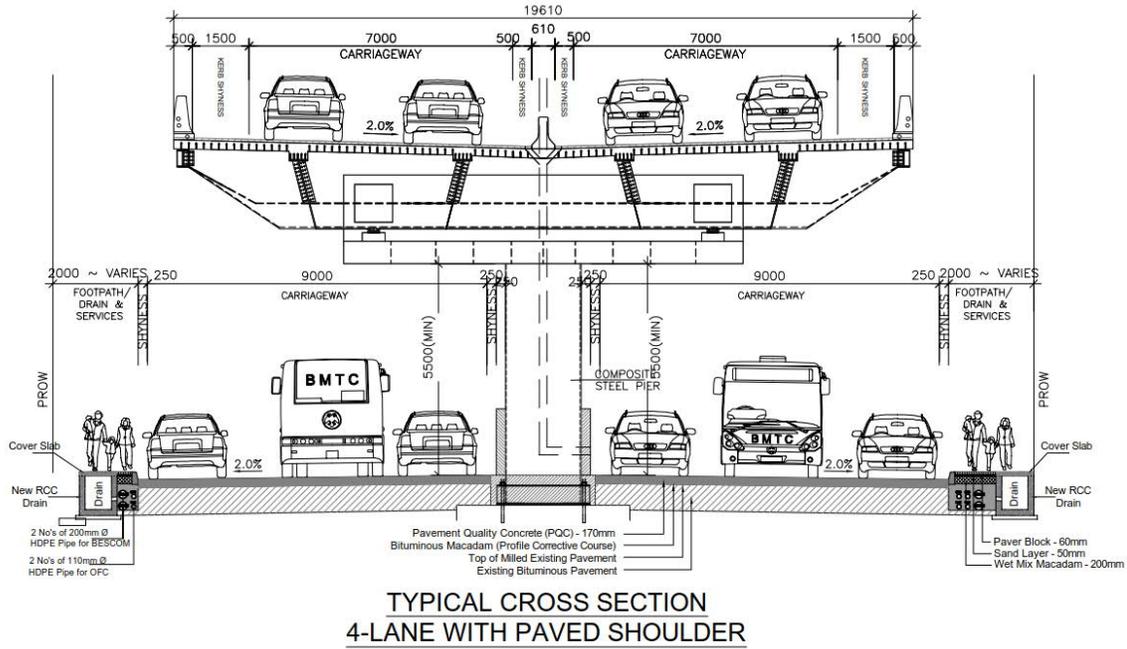


Figure 5-8: Indicative Typical Cross-sections 4-lane with Paved Shoulder North South Corridor

Table 5-6: Typical Cross Section schedules along North South Corridor

Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
0+000	2+300	2300	2 lane		
2+300	5+000	2700	6 lane		
0+000	0+300	300	Makeri Circle RHS Loop	Follow Existing	
0+300	0+600	300	3+3 Lane	6 Lane (3L + 3L) Service Road (2L+2L)	
0+600	0+900	300	3+3 Lane LHS Ramp	6 Lane (3L + 3L) Service Road (2L+2L)	
0+900	1+200	300	3+3 Lane RHS Ramp	6 Lane (3L + 3L) Service Road (2L+2L)	

Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
1+200	2+180	980	3+3 Lane	6 Lane (3L + 3L) Service Road (2L+2L)	
2+180	2+400	220	4+4 Lane RHS Ramp	6 Lane (3L + 3L) Service Road (2L+2L)	
2+400	2+650	250	3+3 Lane LHS Ramp	6 Lane (3L + 3L) Service Road (2L+2L)	
2+650	3+100	450	3 Lane Carriageway	Follow Existing	
3+100	3+800	700	3 Lane	4 Lanes (2L + 2L)	
3+800	4+500	700	3 Lane	Follow Existing	
4+500	4+780	280	3 Lane	2 Lane	
4+780	5+000	220	3+3 lane Varying Level Diff	2 Lane	
5+000	5+800	800	3+3 lane	2 Lane	
5+800	6+340	540	3+3 lane	6 Lane (3L + 3L)	
6+340	6+800	460	3+3 lane	4 Lanes (2L + 2L)	
6+800	7+040	240	3+3 lane Varying Level Diff	4 Lanes (2L + 2L)	
7+040	7+850	810	4 Lane	6 Lane (3L + 3L)	
7+850	8+150	300	2 Lane + 3 Lane Varying Level Diff	6 Lane (3L + 3L)	
8+150	8+600	450	2 Lane	2 Lane	
8+600	9+100	500	3 Lane	4 Lanes (2L + 2L)	
9+100	9+380	280	3 Lane	4 Lanes (2L + 2L)	
9+380	9+750	370	3 Lane LHS Ramp	4 Lanes (2L + 2L) Service LHS (2L)	
9+750	10+280	530	4 Lane with PS	Follow Existing	



Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
10+280	10+600	320	4 + 2 Lane RHS Ramp	Follow Existing	
10+600	11+480	880	4 Lane with PS	Follow Existing	
11+480	11+600	120	4 lane with PS + 2 Lane	6 Lane (3L + 3L)	
11+600	11+820	220	4 lane with PS + 2 Lane	6 Lane (3L + 3L)	
11+820	13+500	1680	4 Lane with PS	6 Lane (3L + 3L)	
13+500	13+800	300	4 Lane + 2 Lane Varying Level Diff	6 Lane (3L + 3L)	
13+800	14+020	220	2+2 Lane Split Carriageway	Follow Existing	
14+020	14+400	380	6 Lane Middle UP/Down Ramp	Service Road (2L + 2L)	
14+400	15+150	750	4 Lane	6 Lane (3L + 3L)	
15+150	15+550	400	2+2 Lane Split Carriageway	Follow Existing	
From South to North					
18+150	19+900	1750	5 Lane	4 Lanes (2L + 2L)	
0+000	0+400	400	3 lane	4 Lanes (2L + 2L)	
0+400	0+850	450	3 lane	2 Lanes	
0+850	1+400	550	5 lane	4 Lanes (2L + 2L)	

\*plus addition length of 4.66 km is planned as one ways and loops.

\*Details of TCS are shown in Plan of Drawing Volume IX.

#### 5.4.4 Horizontal alignment

Horizontal alignment design has been carried out using Mx road software on topographic survey data (base plan). Generally design standards mentioned in previous section have been followed, except at few locations where site constraints



compelled to deviate from standards. The minimum radius adopted is 40m at one location.

From the revised start point i.e before Hebbal flyover approach, the alignment is traversing along the existing road centerline.

Table 5-7: Details of the Corridor Horizontal Alignment

Section	From km	To km	Lane configuration	Land usage	Pier location	Description
From before Baptist Hospital to Mekri circle	0.0	5.0	3 lane divided		Centre of the ex. road	The exact start point of this corridor is from Baptist Hospital.
From Mekhri circle to Cantonment (Jayamahal road, Overlap length with EW1)	0.0	2.5	6 lane divided Also part length double decker (+1 level) and 3-lane (+2 level)	LHS – Airforce / Akashwani / Private / Religious RHS - Palace	On the RHS edge of ex. road	After the interchange at start point (Mekhri circle), proposed center line (PCL) alignment shifted from existing centerline and traverses towards RHS. This shift is proposed to utilize already acquired Palace land. Shift of alignment also necessary to accommodate 6-lane MCW cross section and two ramps on either side of MCW. By shifting alignment, acquisition of air force land



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						for the ramp coming from Hebbal is avoided.
Cantonment RUB junction to Queen’s road (Overlap length with EW1)	2.5	4.8	3 – lane one way	LHS –Private / Palace RHS – Railways / Religious / Private	Centre of the ex. road	This section of the corridor is highly complicated due to various existing roads meeting. Moreover EW1 corridor is also merging / diverging in this section itself. Considering above and land availability for the construction of 6-lane carriageway it is proposed to provide one way traffic movement. At Cantonment RUB junction traffic coming from Silk board / KR Puram will get diverted in two ways one towards Mekhri circle and other towards KR Puram by crossing existing railway line.

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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						At Queens road two ramps (entry/exit) provided for the convenience of railway passengers. EW1 corridor alignment is merging km 3.8. A minor elevated junction is proposed at this location for smooth merging /diverging of traffic towards EW1 corridor. Care has been taken while proposing the alignment along the Cantonment road to avoid conflict with railway track on RHS.
Queen's road junction to Tiffany's circle	4.8	7.0	6-lane double decker (+1 level) and 3-lane (+2 level)	LHS –Private / Govt. (stadium etc.) RHS –Religious / Govt. (park etc.) / Private	Centre of the ex. road	This section of the corridor traverses through narrow RoW. Hence to reduce impact on adjacent properties it is proposed to have double decker structure. At



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						<p>this junction LHS carriage way will be traversing on +1 level and RHS carriage way will be on +2 level. Though there is sufficient RoW in between Minsk square and MG road junction, but available length is not sufficient to negotiate from +2 level at Minsk square to +1 level and again to achieve +2 level at MG road junction. Just before Tiffanys jn. RHS carriage way will descend from +2 level to +1 level</p> <p>At km 5.7, this corridor alignment is crossing underground Metro</p>
Tiffany's circle to Kaligarao road junction	7.0	8.1	2/3-lane divided	LHS – Stadium / BBMP RHS – Park / Religious /private	Centre of the ex. road	This section of the corridor is traversing through Cubbon park, Hudson circle



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						and BBMP office. At Tiffanys jn. itself LHS carriageway got split into two way. One way leads to Hudson circle and other towards Richmod circle. At Town hall jn. LHS carriageway alignment takes left turn towards Kalinga rao road. At km 7.85 EW2 corridor RHS carriage way will cross at + level
Kalingarao road jn. to Subbaiah circle	8.1	8.6	2-lane one way	LHS – Govt. / Private RHS – Private/Religious	Portal arrangement	In this section LHS carriageway alignment traverses through Kalingarao road and meets EW2 alignment at subbaiah circle.
Subbaiah circle to Langford jn.	8.6	9.1	3-lane one way	LHS – Private RHS – Private	Centre of the ex. road	In this section LHS carriageway alignment traverses through Lal Bagh main road and

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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						meets EW2 alignment at Langford jn.. It is proposed to integrate existing Richmod circle flyover with project alignment. For this it is proposed to dismantle existing Richmod circle flyover ramp approaches and merge project alignment to it.
Lang ford jn. to Shantinagar bus stand (overlap with EW2 corridor)	9.1	9.8	3-lane one way	LHS – Private RHS – Private	Centre of the ex. road	In this section LHS carriageway alignment traverses through Double (KH) road and EW2 corridor overlaps
Shantinagar bus stand to Kengal Hanumanthaiah circle to Lalbagh main gate to Lalbagh Minerva circle (overlap with EW2 corridor)	18.2	19.9,	3-lane one way	LHS – Private / Religious / park RHS – Private / Religious	Centre of the ex. road	In this section RHS alignment traverses through KH road -Hosur main road- Lalbagh fort rd.- Jayachamaraja wodeyar rd and EW2 corridor overlaps



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
Lalbagh Minerva circle to JC rd. junction	0.1	0.4	3-lane one way	LHS – Private RHS – Private	Centre of the ex. road	In this section RHS alignment traverses through Jayachamaraja wodeyar rd
JC rd. junction to Kalingarao road junction ( overlap with EW2 corridor)	19.1	18.7, 0.8 – 1.3	3-lane one way	LHS – Private RHS – Private / Archeological	Centre of the ex. road	In this section RHS alignment traverses through Jayachamaraja wodeyar rd and EW2 corridor overlaps. EW2 corridor, RHS is getting bifurcated at km 18.7 in two ways, one way leads to Hudson circle and other towards Langford road jn
Shanti nagar bus stand to Adugodi main rd.	9.8 / 18.2	11.5	6-lane divided	LHS – Private / Govt. / encroachment RHS – Private / Govt. / religious / encroachment	Centre of the ex. road (upto km 10.2) and Portal arrangement there after	In this section alignment is traversing along the drain. After km 10.2 portal frame arrangement is proposed with portal piers on either side of service roads beside drain
Adugodi main rd. to Slik board jn.	11.5	15.56	6-lane divided	LHS – Private RHS – Private	Centre of the ex. Road, bt.km 13.7-km 13.9	In this section alignment traverse through



Section	From km	To km	Lane configuration	Land usage	Pier location	Description
					and km 14.4-14.7 Portal frame, bt. Km 13.9-km 14.4 and km 15.2-15.56 split carriageway	congested area of Adugodi main road. At Adugodi junction entry/exit ramps provided. At km 13.9 CC1 corridor's LHS carriage way is crossing at +2 level and merges with RHS of this corridor. Between 13.9 - 14.4 alignment get splits to accommodate entry/exit ramps. At end again alignment get splits and merges with existing silk board flyover. Since there is a proposal from BMRCL to integrate existing flyover, no major improvement proposed.

5.4.5 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model.

Table 5-8: Details of the Corridor Vertical Alignment

Section	From km	To km	Description
From Baptist Hospital to Mekhri Circle			
From Mekhri circle to Cantonment (Jayamahal road)	0.0	2.5	In this section, profile is designed at +1 level. (+1 level means, a minimum clearance of 5.5 m below the pier cap. Adding, height of pier cap and superstructure, the difference between at grade road and top of elevated road is 11.0m. this will enable minimum clearance of 5.5m +3.0 m from at grade road below the soffit of the elevated corridor, so that in the +3.0 m additional clearance can be utilized to accommodate existing and future skywalk/FOB's)
Cantonment RUB junction to Queen's road (Overlap length with EW1)	2.5	4.8	In this section profile is designed at +1 level. At Cantonment RUB junction traffic coming from Silk board / KR Puram will get diverted in two ways one towards Mekhri circle at +1 level and other towards KR Puram by crossing existing railway line at +2 level. Care has been taken while crossing Netaji road underpass and RUB at km 3.8. minimum clearance of 6.542m is maintained from rail top level. Further since carriageway deck is overhanging minimum clearance from rail top level has been maintained.
Queen's road junction to Tiffanys circle	4.8	7.0	In this section due to limited EROW double decker structure is proposed. Hence LHS carriageway will be on +1 level and RHS carriage way will be on +2 level.
Tiffanys circle to Kaligarao road junction	7.0	8.1	In this section profile is designed at +1 level
Kalingarao road jn. to Subbaiah circle	8.1	8.6	
Subbaiah circle to Langford jn.	8.6	9.1	Profile of previous section is continued and then matched with the Richmond circle flyover viaduct portion. RE wall approaches are proposed to dismantle.
Lang ford jn. to Shantinagar bus stand	9.1	9.8	Profile of Richmond circle flyover is followed upto viaduct portion of KH road ramp. RE wall approaches of flyover are proposed to dismantle
Shantinagar bus stand to Kengal Hanumanthaiah circle to Lalbagh main gate to Lalbagh Minerva circle	18.2	19.9,	In this section profile is designed at +1 level
Lalbagh Minerva circle to	0.1	0.4	In this section profile is designed at +1 level

Section	From km	To km	Description
JC rd. junctio			
JC rd. junction to Kalingarao road junction	19.1	18.7, 0.8 – 1.3	In this section profile is designed at +1 level
Shanti nagar bus stand to Adugodi main rd.	9.8 / 18.2	11.5	In this section profile is designed at +1 level. While traversing along the drain alignment crosses 3 bridges. Care has been taken to maintain vertical clearance from these bridge
Adugodi main rd. to Slik board jn.	11.5	15.56	In this section CC1 corridor alignment cross at +2 level. Care has been taken to maintain minimum vertical clearance from the Overpass at km 14.6

5.4.6 Major junctions along project corridor and improvement proposals

At Mekhri circle an interchange is proposed and there is no change in traffic movement at grade level. This interchange will integrate with the BDA elevated corridor and East west corridor-1 (EW-1). BDA elevated corridor MCW coming from Hebbal is traversing at +2 level. Keeping this in mind traffic movements from all legs of junction are as given below:

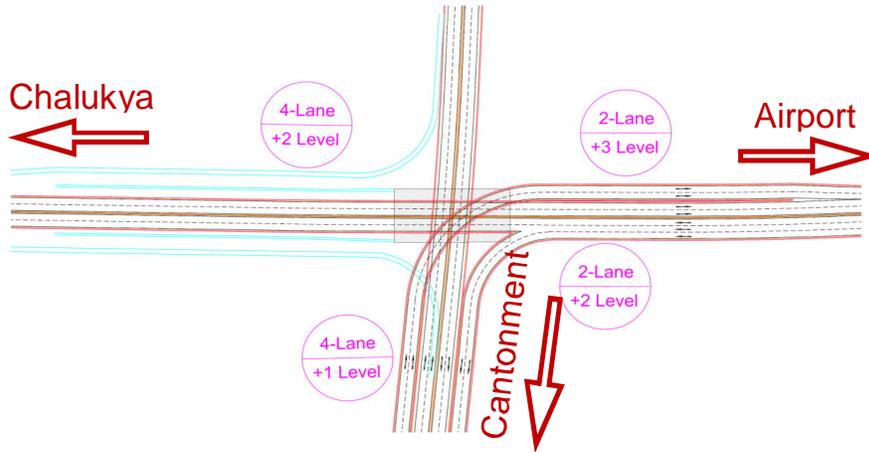


Figure 5-9: Loops at Mekhri Circle

Traffic from Cantonment:

Moving towards Gorguntapalya will travel at +1 level on MCW.

Moving towards Hebbal/Airport will traverse using left elevated ramp by crossing existing road and BDA elevated corridor at almost +1.5 level. After crossing, alignment of this ramp traverses using service road of existing underpass and merges with BDA elevated corridor at +2 level towards Hebbal direction.



Moving towards Chalukya will have to get down from elevated corridor using the down ramp at ch: 1.200.

Traffic from Gorguntapalya:

Moving towards Cantoment will travel at +1 level on MCW.

Moving towards Hebbal/Airport will traverse using left elevated ramp at +1 level.

Moving towards Chalukya will have to get down from elevated corridor using the down ramp at ch: 22.500.

Traffic from Hebbal:

Moving towards Chalukya will travel on BDA elevated corridor at +2 level.

Moving towards Cantonment will travel on left ramp at +1 level.

Moving towards Yeshwantapur will travel on loop ramp from +2 level to GL.

Traffic coming from Chalukya:

Moving towards Hebbal/airport will travel on BDA elevated corridor at +2 level.

Moving towards Cantonment will have to use existing at grade slip road.

Moving towards Yeshwantapur will have to use existing at grade slip road.

#### 5.4.7 Ramps

Ramps are crucial part of this project as they are the connection between elevated corridor and at grade road. Provision of as many as ramps will give the access to many commuters who wish to travel on elevated corridor. More ramps more the traffic on elevated corridor. However, frequent provision of ramps will also cause some inconvenience to elevated corridor traffic, it requires acceleration and deceleration lanes and requires more land. Most of this corridor traverses through narrow roads where provision of ramps will need to acquire huge multi story buildings. Hence ramps are provided at essential locations depending on land availability. Following table shows total number of ramps provided along this corridor.

Table 5-9: Details of entry/exit ramps along North South Corridor

Project Corridor	LHS Ramps		RHS Ramps		Total Ramps	
	Up	Down	Up	Down	Up	Down



NS (6-lane)	4	4	4	5	8	9
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5.4.8 At grade improvement proposals

As per the terms of reference along with the proposal of elevated corridor at grade road improvement has to be proposed. Moreover due (during) to construction of elevated corridor and by shifting of any underground utilities which are obstruction for construction of elevated corridor existing road would be damaged and restoration of same is unavoidable. Construction of piers is proposed by utilizing the median space. But a few locations existing median width is as low as 0.5m and generally 1.5m. Proposed pier width including jacketing requiring minimum of 2.5m. Hence due to less width of existing median, construction of piers for elevated corridor will encroach on to existing carriage way. Due to this after construction of elevated corridor at grade road carriageway will get reduced. To retain traffic lanes of existing carriageway on each side, widening of carriageway has been done by maintaining minimum width of the footpath cum drain (1.8m). Further since the speeds of city traffic is less compare to rural roads, width of each lane is proposed to be 3m. Lane width of 3m has already been followed on few city roads.

Further it is tried to provide footpath cum drain of minimum width 1.8m throughout. Entry / Exit curves of all existing junctions are smoothed within available land. Signs and markings have been provided. Street lighting has been proposed throughout the corridors.

5.5 EAST – WEST CORRIDOR-1(EW-1): CONNECTING NH48 (NH-4) AT RMZ ON OLD MADRAS ROAD AND YESHWANTHPURA FLYOVER ON TUMKUR ROAD

Initially the elevated corridor was proposed to start from Bhattarahalli, however, from Bhattarahalli to KR puram, the road jurisdiction is with NHAI and they have informed that a proposal to make this stretch signal free is in consideration and hence KRDCL can drop improvement of this stretch. Further, KR Puram cable stayed bridge cant be widened due to structural complexity, and additional lanes cant be provided through new bridge on either side due to presence of railway station on one side and metro coming on other side.

Hence, the project corridor starts at RMZ on Old Madras Road (after Benniganahalli RUB), and ends at Yeshwanthpura Flyover via. - Suranjandas Road Junction - 80 Feet Road junction - 100 feet Indiranagar road Junction - D Bhaskaran Road Junction - Kensington Road Junction (Philips buildings) – Ulsoor lake - St. John’s Road – Millars road - Jayamahal Main Road – Mekri circle - CV raman road

Further, since KR puram bridge is a bottle neck and needs a solution, a proposal of connecting ORR from Ramamurthynagar underpass to ORR at B narayanpura is proposed. This is a kind of making the ORR straight from Ramamurthynagar



underpass to ORR at B narayanpura. The idea behind this link is the traffic from Hebbal on ORR moving to Whitefield and Marathhalli will be diverted through this link making substantial relief at tin factory junction and below the KR puram bridge.

Once this traffic is diverted the tin factory junction and below the KR puram bridge will be left with only traffic from/to city which will save huge amount of travel time.

Further, a cloverleaf interchange is proposed at start of KR puram bridge (on Hosakote side) where the new link crossed NH-4 for interchanging the traffic directions)

This is called as Additional corridor as it was not part of original corridors given to study.

Total Length along main corridor: 26.94 km

Length of One way loops: 2.36 km

Number of lanes: 4 / 6 lanes

Number of ramps: 21 nos.

This corridor will have a overlap with N-S corridor between cantonment station and Mekhri circle. From Mekhri circle to Yeshwanthpura bus stand, the corridor will be a 2+2 lanes ending with integrating with Yeshwanthpura flyover.

5.5.1 Typical cross sections and their schedule proposed along the project corridor

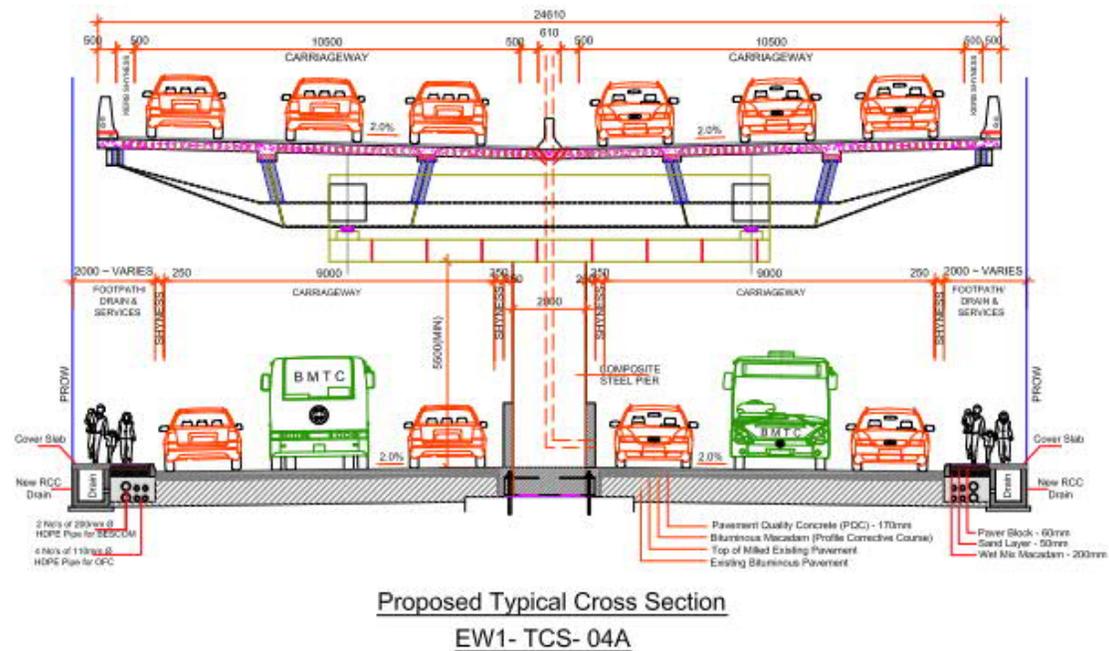
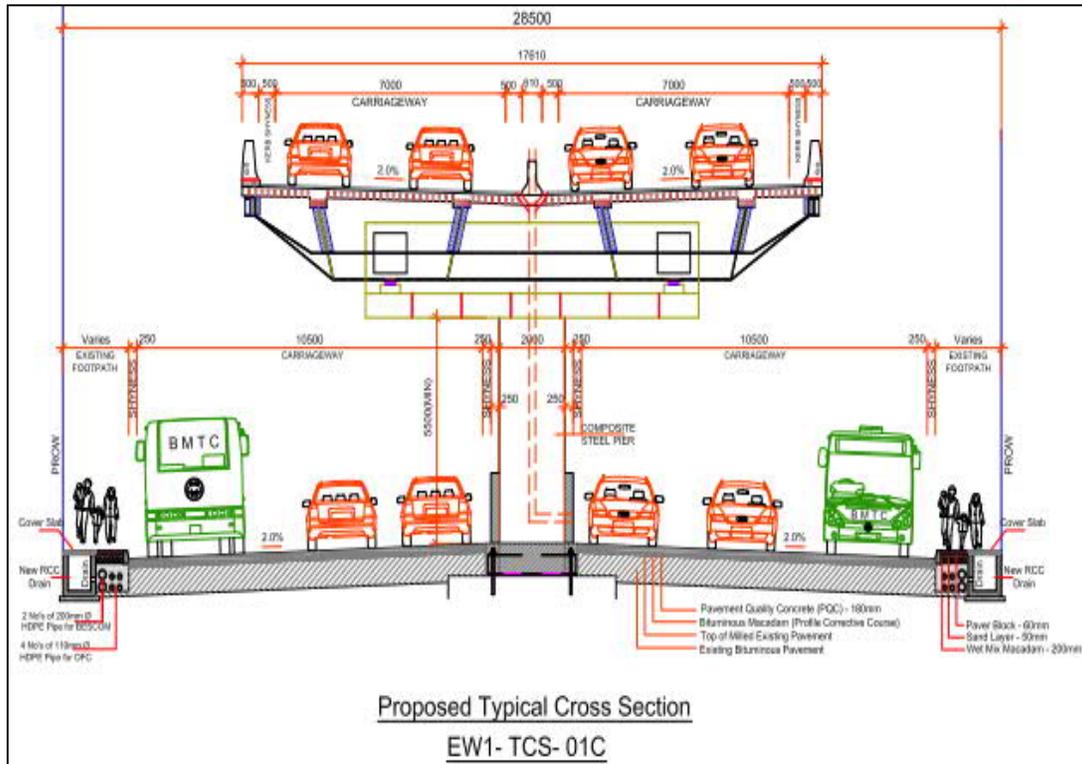


Figure 5-10: Indicative Typical Cross-section along East West Corridor

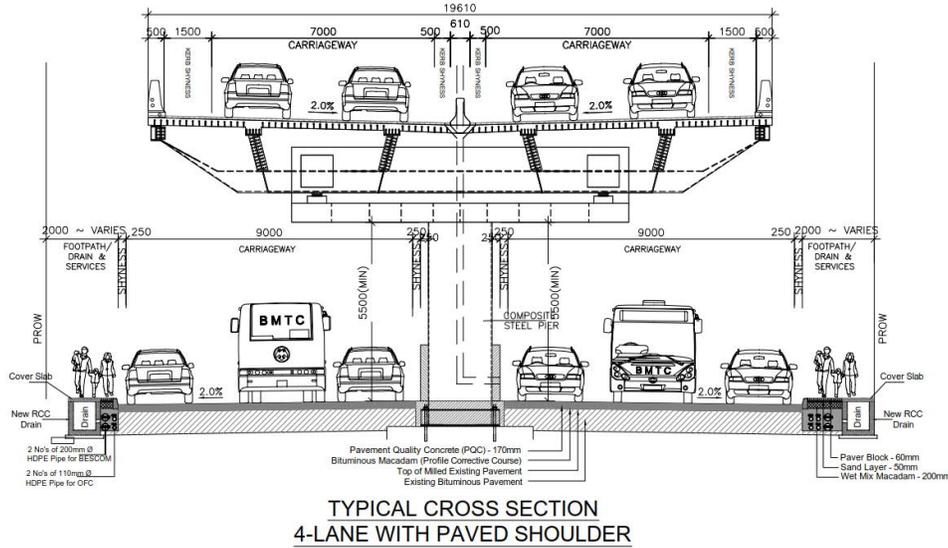


Figure 5-11: Indicative Typical Cross-section along East West Corridor

Table 5-10: Typical Cross Section schedules along East West Corridor-1

Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
0+000	0+400	400	4-Lane Ramp	6 Lanes (3L + 3L) + Service Road (2L + 2L)	
0+400	1+350	950	4-Lane	6 Lanes (3L + 3L) + Service Road (2L + 2L)	
1+350	2+460	1110	4-Lane	6 Lanes (3L + 3L)	
2+460	2+750	290	4-Lane	4 Lanes (2L + 2L)	
2+750	4+600	1850	EW1 & Additional Road Interchange and merging with Existing Flyover		
4+600	6+760	2160	No-Improvements		
6+760	7+230	470	4-Lane with paved shoulder with Ramp	4 Lanes (2L + 2L)	
7+230	8+650	1420	4-Lane with Paved Shoulder	6 Lanes (3L + 3L)	

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Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
8+650	9+680	1030	4-Lane with paved shpolder+2 Level	6 Lanes (3L + 3L)	
9+680	9+800	120	4-Lane with paved shoulder	6 Lanes (3L + 3L)	
9+800	10+050	250	4-Lane with paved shoulder LHS Ramp	6 Lanes (3L + 3L)	
10+050	10+700	650	4-Lane with paved shoulder	6 Lanes (3L + 3L)	
10+700	10+990	290	4-Lane with paved shoulder RHS Ramp	6 Lanes (3L + 3L)	
10+990	11+190	200	4-Lane with paved shoulder	6 Lanes (3L + 3L)	
11+190	11+600	410	Ulsoor Interchange crossing 1st level to 2nd Level		
11+600	12+080	480	4-Lane with paved shoulder	Tank Location	
12+080	12+400	320	4-Lane with paved shoulder	6 Lanes (3L + 3L)	
12+400	13+550	1150	4-Lane	4 Lanes (2L + 2L)	
13+550	13+800	250	4-Lane with paved shoulder	6 Lanes (3L + 3L)	
13+800	17+650	3850	Merging with NS Corridor		
17+650	18+100	450	4-Lane with Paved shoulder	6 Lanes (3L + 3L)	
18+100	18+650	550	4-Lane LHS+RHS Ramp	4 Lanes (2L + 2L) + Service Road (2L + 2L)	
18+650	19+820	1170	4-Lane	4 Lanes (2L + 2L)	
19+820	20+200	380	4-Lane LHS+RHS Ramp	4 Lanes (2L + 2L)	
20+200	20+500	300	4-Lane +2 Level	4 Lanes (2L + 2L)	
20+500	21+150	650	4-Lane +2 Level	No At-Grade Carriageway	
21+150	22+050	900	4-Lane	4 Lanes (2L + 2L) + Service Road (2L + 2L)	



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Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
22+050	22+460	410	4-Lane LHS+RHS Ramp	4 Lanes (2L + 2L) + Service Road (2L + 2L)	
22+460	22+650	190	4-Lane	4 Lanes (2L + 2L) + Service Road (2L + 2L)	
22+650	22+920	270	4-Lane	4 Lanes (2L + 2L) + Service Road (2L + 2L)	
22+920	23+100	180	4-Lane	4 Lanes (2L + 2L) + Service Road (2L + 2L)	
23+100	23+700	600	4-Lane	4 Lanes (2L + 2L) + Service Road (2L + 2L)	

\*Details of TCS are shown in Plan of Drawing Volume IX

**Table 5-11: Typical Cross Section schedules along East West-2 Corridor  
(Rammurthyagar Loop)**

Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
0+000	0+400	400	3 Lane Carriageway	4 Lanes (2L + 2L)	
0+400	1+600	1200	3 Lane Carriageway	Follow Existing	
1+600	2+130	530	3 Lane Carriageway	Follow Existing	
2+130	2+770	640	4 Lane	No At-Grade	
2+770	3+030	260	3 Lane + 2 Lane	Follow Existing	
3+030	5+600	2570	4 Lane	4 Lanes (2L + 2L)	
5+600	6+550	950	2+2 Lane Split Carriageway	Follow Existing	

\*Details of TCS are shown in Plan of Drawing Volume IX

### 5.5.2 Horizontal alignment

Generally design standards mentioned in previous section have been followed, except at few locations where site constraints compelled to deviate from standards. Minimum radius of curve provided is 60m at one location.

This Corridor starts on NH4 at RMZ. At grade NH4 traffic will reach elevated corridor at +1 level through entry/exit ramps located at center of the existing NH. Thereafter corridor alignment follows the existing road center line. Widening of existing NH is proposed due to reduction in width of carriageway due to construction of ramps. Widening of existing NH is proposed on either side of proposed ramps.

**Table 5-12: Details of the Corridor Horizontal Alignment**

Section	From km	To km	Lane configuration	Land usage	Pier location	Description
Gopalan mall / RMZ to Ulsoor lake	6.75	11.2	4-lane with paved shoulder divided	LHS - Private / Govt. yard RHS -	Centre of the ex. road	Entry / exit ramps provided in front of RMZ for the movement of traffic GL to +1 level. Ramps are provided in the middle of the existing



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
				Private /Military		road and existing at grade road is widened on either side of ramps for movement of at grade traffic and local traffic. Thereafter alignment is traversing along the middle of the at grade existing road/median. At km 8.95 alignment crosses existing metro staircase and at km 9.375 it crosses elevated metro line. Thereafter alignment negotiates narrow section between Indiranagar double road and Swamy Vivekananda rd. on LHS grave yard and on RHS temple / Eidga exists.
Ulsoor lake to St. John's road jn.	11.2	12.4	4-lane with paved shoulder divided	LHS Private Lake RHS Private Lake	Centre of the ex. road	At Kensington rd jn. CC2 is meeting this corridor. To have uninterrupted traffic flow an Interchange is proposed. After the Interchange alignment traverses through along the Ulsoor lake. There after alignment continuous on to Kensington rd up to St John's road jn.
St John's road to Coles park junction	12.4	13.5	3 / 4 - lane one way	LHS Private RHS Private	Centre of the ex. road	At km 12.4 alignment is proposed to split in two ways, LHS carriageway is proposed to continue along St John's road and RHS carriageway will take right turn and continue along Promenade rd. and at the end it will take left turn and traverse through Coles park and merges back with LHS carriageway. On Prmenade rd. km 13.0 CC3 corridor is meeting this corridor.
Coles park jn.	13.5	13.85	4-lane	LHS	Centre of the	This small section of the

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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
to Netaji road jn.			with paved shoulder divided	Private RHS Private	ex. road	corridor is highly congested and requires huge acquisition of properties.
Netaji rd. jn. to Cantonment rly. stn. RUB jn. (overlap with NS)	13.85	14.9	3 – lane one way	LHS –Private / Govt. / Religious RHS – Railways / Private	Centre of the ex. road	At the start of this section NS corridor is meeting. A small jn. at +1 level is proposed at this point. Due to meeting of two corridors lane width requirement is more. Due to lack of right of way for the construction of 8-lane carriageway it is proposed to provide one way traffic movement. At Queens road two ramps (entry/exit) provided for the convenience of railway passengers. At Cantonment RUB junction traffic coming from Silk board / KR Puram will get diverted in two ways one towards Mekhri circle and other towards KR Puram by crossing existing railway line. A minor elevated junction is proposed at this location for smooth merging /diverging of traffic from both the corridors. Care has been taken while proposing the alignment along the Cantonment road to avoid conflict with railway track on RHS.
Cantonment rly. stn. RUB jn. to Mekhri circle (Jayamahal road, Overlap length with EW1)	14.9	17.65	6 – lane divided	LHS – Palace RHS – Airforce / Akashwani / Private / Religious	On the RHS edge of ex. road	After the Cantonment RUB jn. proposed center line (PCL) alignment shifted from existing centerline and traverses towards RHS. This shift is proposed to utilize already acquired Palace land. Shift of alignment also necessary to accommodate 8-lane MCW cross section and



Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						two ramps on either side of MCW. By shifting alignment, acquisition of air force land for the ramp coming from Hebbal is avoided.
Mekhri circle to New BEL rd.	17.65	18.85	4 – lane divided	LHS – Private / Govt. RHS – Airforce	Centre of the ex. road	After the Mekhri circle jn. alignment traverses center of the existing road.
New BEL rd. to Yeshwantapur Flyover	18.85	20.5	4-lane divided	LHS – Govt. / Private RHS – CPRI /IISC	Centre of the ex. road	In this section align traverses through center of the existing road except at Sankey underpass. At Sankey underpass alignment is marginally shifted towards RHS to avoid impact on underpass. Care has been taken to maintain minimum clearance from the top of underpass.

**Additional Loop from Ramamurthy Nagara Bridge on ORR to Mahadevapura Flyover on ORR**

This additional loop is provided for connectivity between Ramamurthy Nagara Bridge on ORR to Mahadevapura Flyover on ORR, this is sort of straightening the ORR. At present, the traffic at KR Puram bridge is in chaos, the volume of traffic at this junction is many folds higher than the capacity it can handle. Added to it, merging and diverging of traffic before the bridge and the bottleneck below the bridge. Further, proposed metro corridor connecting baiyappanahalli and white field passes through RHS of the bridge, this will further worsen the traffic movements, during and after construction. Since, any improvements at this location is not possible as bridge can't be widened as it's a cable stayed bridge, also, no new bridge can be added, as on RHS, metro is coming and on LHS, there exists railway station.

The solution here is manifold, but important are 1) increase capacity by adding many lanes, 2) reduce the conflicts by introducing multi level ramps and 3) reduce traffic. Since first and second is not feasible, after careful study of the area, it was proposed, why not reduce the traffic itself?. So, it was proposed to connect the ORR from east to west bypassing the KR puram bridge via Ramamurthy nagar main road. This will reduce about 50% of the traffic entering KR puram bridge area and will give big relief to passengers.

The plan of connectivity is shown in drawings and a brief description is given below Table 5-13.

Table 5-13: Details of the Corridor Horizontal Alignment

ITPL to Mahadeva pura main rd.	0.0	0.500	4-lane divided	LHS Private RHS Private	Centre of the ex. Road	This section of the corridor is proposed to divert traffic coming from white field/ITPL/Kundanahalli gate towards ORR at Dodda Banasawadi underpass. As the Metro line is proposed to traverse at center of the existing road, entry /exit ramps are provided outside of the existing road. Further service road is proposed outside the ramps on either side.
Mahadeva pura main rd. to ORR	0.500	1.300	2-lane one way	LHS Private RHS Private	Centre of the ex. Road	At start of this section alignment is bifurcated in two ways. LHS alignment takes left turn on to Mahadevapura main road and at ORR crossing integrated with flyover.
ORR to ITPL road cross	1.3	2.1	2-lane one way	LHS Private RHS Private	Centre of the ex. Road	At ORR, corridor LHS Carriageway traffic is merged with ORR LHS CW at +1 level. Traffic coming from Marathhalli is proposed to cross RHS CW of ORR and merges with project corridor.
ITPL road cross to Interchange start point	2.1	2.6	4- lane divided	LHS Private RHS Private	Realignment	At start point of this section, LHS CW is proposed to merge with RHS corridor. Thereafter both carriage ways of project corridor will traverse together.
Interchange start point to Interchange end point	2.6	3.4	4/8-lane divided	LHS Private RHS Private	Realignment / center of the ex. road	This section of the corridor is proposed as elevated cloverleaf. This proposal is essential due to huge traffic coming from ITPL/ORR and old Madras road traffic intersects at this point.
Interchang	3.4	6.5	4/8-	LHS	Center of ex.	This section of the corridor is



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<p>e end point to Dodda Banaswad i underpass</p>			<p>lane divided</p>	<p>Private RHS - Private</p>	<p>road /split carriageway</p>	<p>traversing though highly congested area. Due to Metro proposal, proper arrangement was not possible without huge acquisition and high rise structures to cross existing Cable stayed bridge and flyovers connecting ORR at Tin factory. Hence it is proposed to divert ITPL and Marathalli side ORR traffic via ITI and Ramamurthy nagar. After ITI, existing RoW through Ramamurthy nagar is about 12m. Hence acquisition of properties is required. Just before RoB at ORR junction, alignment is proposed to split in two ways. Care has been taken to cross Dodda Banaswadi underpass by maintaining minimum vertical clearance of 5.5m. After crossing underpass LHS down ramp will follow middle of the existing underpass ramp and after the existing ramp project corridor ramp will merge with ORR. RHS ramp is proposed to start adjacent to existing underpass RT wall.</p>
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### 5.5.3 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model in below Table 5-14.

Table 5-14: Details of the Corridor Vertical Alignment

Section	From km	To km	Description
Gopalan mall / RMZ to Ulsoor lake	6.75	11.2	After traversing through existing RUB, it is again proposed to start the elevated section, hence profile designed from GL to reach +1 Level. At km 8.95 profile is designed in such way that it crosses existing metro station staircase at about +1.5 level and thereafter profile continue to rise up +2 level gradually to cross Metro line at km 9.375. After crossing Metro line profile is designed for decreasing gradient from +2 level to +1 level.
Ulsoor lake to St. John's road jn.	11.2	12.4	At Ulsoor lake jn. Interchange proposed. After crossing the Interchange, alignment traverses through Ulsoor lake. To minimize the impact on Ulsoor lake special structure like Cable stayed bridge with minimum supports proposed. Due to this profile of the Cable stayed bridge will be higher than +1 level and accordingly profile designed.
St John's road to Coles park junction	12.4	13.5	In this section profile is designed at +1 level with 5.5m minimum clearance from existing road. At the end of this section to reduce tree cutting profile is proposed rise from +1 level to 1.5 level.
Coles park jn. to Netaji road jn.	13.5	13.85	After the coles park profile will continue to rise upto +2 level till Netaji rd. underpass.
Netaji rd. jn. to Cantonment rly. stn. RUB jn. (overlap with NS)	13.85	14.9	After crossing underpass profile will be descend to +1 level and continue upto Cantonment RUB.
Cantonment rly. stn. RUB jn. to Mekhri circle (Jayamahal road, Overlap length with EW1)	14.9	17.65	Profile will rise from +1 level to +2 level at the crossing of RUB. After crossing the RUB profile is designed to be at +1 level and is continued upto Mekhri circle Interchange.
Mekhri circle to New BEL rd.	17.65	18.85	Profile will rise from +1 level to +2 level at the crossing of RUB. After crossing the RUB profile is designed to be at +1 level and is continued upto Mekhri circle Interchange. After the Interchange profile is continued at +1 level upto New BEL rd.
New BEL rd. to Yeshwantapur Flyover	18.85	20.5	In this section profile is proposed to rise from +1 level to +1.5 level to reduce the impact on tree tunnel.
ITPL to Mahadevapura	0.0	0.500	Traffic coming from ITPL is proposed to enter on to

Section	From km	To km	Description
main rd.			the project corridor through entry/exit ramps. Profile is designed from GL to +1 level.
Mahadevapura main rd. to ORR	0.500	1.300	At the start of this section traffic bifurcated in two directions. LHS alignment takes from left turn and proceeds at +1 level.
ORR to ITPL road cross	1.3	2.1	At ORR, corridor alignment merges with Mahadevapur flyover at +1 level. Traffic coming from LHS of ORR is proposed cross the RHS carriage way of ORR at +2 level and proceeds towards ITPL road.
ITPL road cross to Interchange start point	2.1	2.6	At ITPL road, corridor crosses proposed Metro line at + 2level and proceeds further and will cross rly line and further meets Interchange at +1 level.
Interchange start point to Interchange end point	2.6	3.4	At the Interchange corridor profile crosses EW1 corridor at +2 level. After the Interchange corridor profile will come down to +1 level and will continue till the end of corridor.
Interchange end point to Dodda Banaswadi underpass	3.4	6.5	At the end of corridor profile will cross RoB and dodda Banaswadi underpass at +1 level. Care has been taken in design of profile before merging ORR.

5.5.4 Major junctions along project corridor and improvement proposals

- At ITI, two major roads carrying huge traffic are crossing. Hence for smooth traffic movement Cloverleaf Interchange proposed. Traffic from KR puram to Yeshwantapur is proposed to travel on +1 level and traffic from ITPL/ORR to Ramamurthy nagar will traverse on +2 level. Other traffic movements from all legs of junction are as given below:

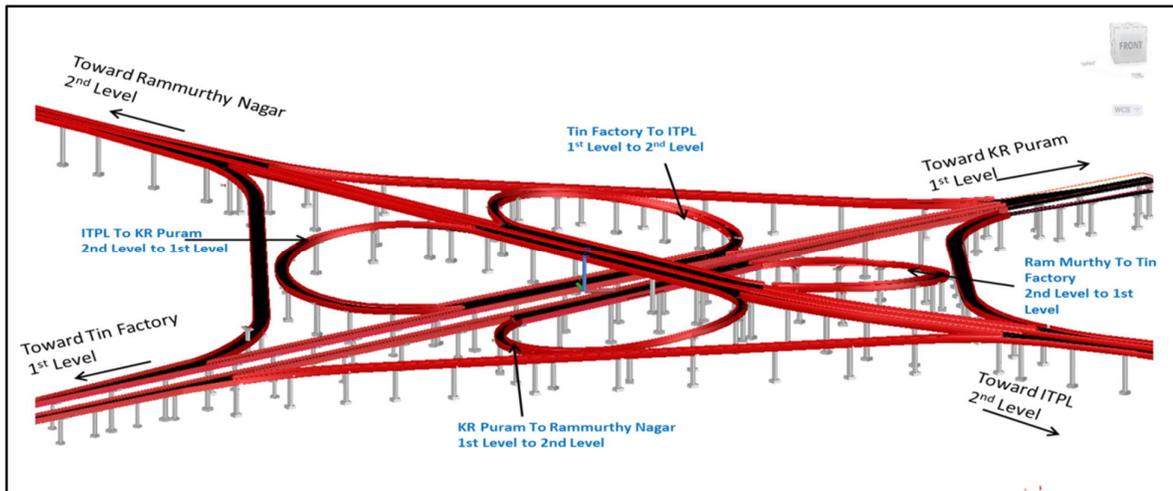


Figure 5-12: Interchange at ITI



Traffic coming from KP Puram:

Moving towards Ulsoor will travel on MCW at +1 level

Moving towards ITPL/ORR will use Southeast left slip ramp at +1 level

Moving towards Ramamurthy nagar will use Southwest loop and joins at +2 level

Traffic coming from Yeshwantapur:

Moving towards KP puram will travel on MCW at +1 level

Moving towards Ramamurthy nagar will use Northwest left slip ramp at +1 level

Moving towards ITPL/ORR will use Northeast loop and joins at +2 level

Traffic coming from ITPL/ORR:

Moving towards Ramamurthy nagar will travel on MCW at +2 level

Moving towards Yeshwantapur will travel use Southwest slip ramp at +1 level

Moving towards KR Puram will use Northwest loop and joins at +1 level

Traffic coming from Ramamurthynagar:

Moving towards ITPL/ORR will travel on MCW at +2 level

Moving towards Yeshwantapur will use Southwest loop ramp and joins at +1 level

Moving towards KR Puram will use Northeast slip ramp at +1 level

2. At Ulsoor, EW-1 and CC2 are meeting and forming major junction at +1 level. Hence an trumpet type Interchange is proposed. At +1 level traffic from KR Puram to MG road is proposed travel. Other traffic movements from all legs of junction are as in Figure:5-13.

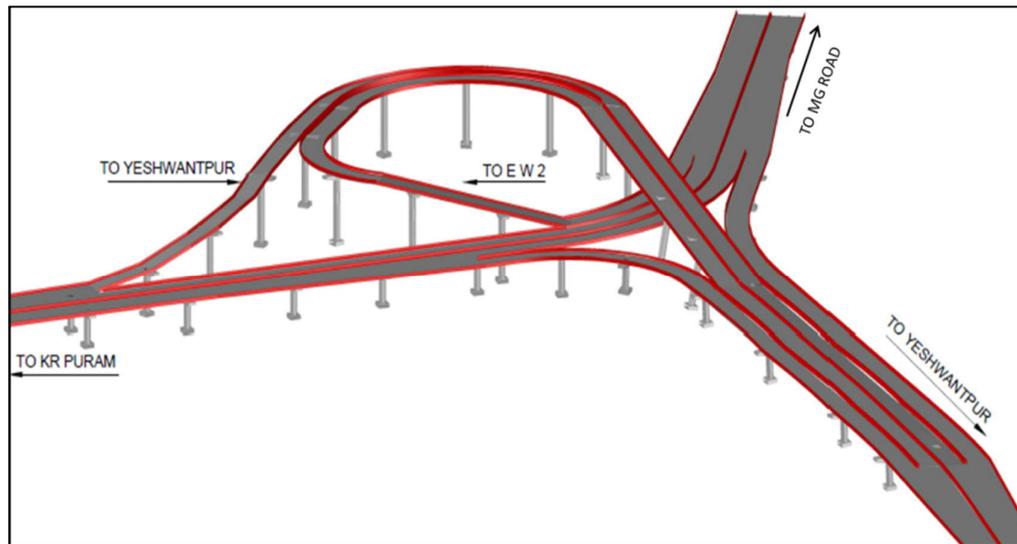


Figure 5-13: Interchange at Ulsoor Lake

Traffic coming from KP Puram:

Moving towards Yeshwantapur will travel on left ramp and will proceed at +2 level

Moving towards MG road will use MCW at +1 level

Traffic coming from Yeshwantapur:

Moving towards KP puram will travel on MCW at +1 level

Moving towards MG road will use loop ramp (+1 level will reach +2 level at the junction and through loop will reach +1 level)

Traffic coming from MG road:

Moving towards KR Puram will travel on MCW at +1 level

Which wants to go towards Yeshwantapur will travel left ramp +1 level

### 5.5.5 Ramps

Ramps are crucial part of this project as they are the connection between elevated corridor and at grade road. Provision of as many as ramps will give the access to many commuters who wish to travel on elevated corridor. More ramps more the traffic on elevated corridor. However frequent provision of ramps will also cause some inconvenience to elevated corridor traffic, it requires acceleration and deceleration lanes and requires more land. Most of this corridor traverses through narrow roads



where provision ramps will need to acquire huge multi story buildings. Hence ramps are provided at essential locations depending on land availability. Following table shows total number of ramps provided along this corridor.

Table 5-15: Details of entry/exit ramps along East West Corridor-1

Project Corridor	LHS Ramps		RHS Ramps		Total Ramps	
	Up	Down	Up	Down	Up	Down
EW-1 (6-lane/4-lane)	2	5	5	2	7	7

5.6 EAST – WEST CORRIDOR-2 (EW-2): CONNECTING SH-35 AT VARTHUR KODI AND SIRSI CIRCLE ON MYSORE ROAD

The corridor takes off at Varthur kodi junction on SH-35 – ends at Sirsi circle road via. Kundala halli gate junction – Marathahalli underpass (ORR) - Suranjandas Road Junction - Old Airport road – Wind tunnel road junction - Domlur Junction - Trinity Church Junction - D’Souza circle - General K S Thimayya Road - Vellara Junction - Richmond Circle - K.H.Road - Lalbagh Main Road – Minerva junction - Chamarajpet 5th Main Road - 9th Cross Road - 1st Main Road Junction - Alur Venkata Rao Road

Total Length : 23.30 km

Length of One way loops: 5.36 km

Number of lanes: 4/6 lanes

Number of ramps: 30 nos.

This is a straight corridor all the way from Varthur Kodi to Richmond Road, based on the traffic study it was found that this corridor is an ideal corridor to have an integrated structure carrying mass transportation and road traffic. This matter was discussed with BMRCL and after many deliberations, it was agreed consider having a common structure carrying rail and road at multi levels. The matter is under discussions and BMRCL will have to get back on the modality. However, pending the decision, the road corridor is proposed as of now.

5.6.1 Typical cross sections and their schedule proposed along East West-2 corridor

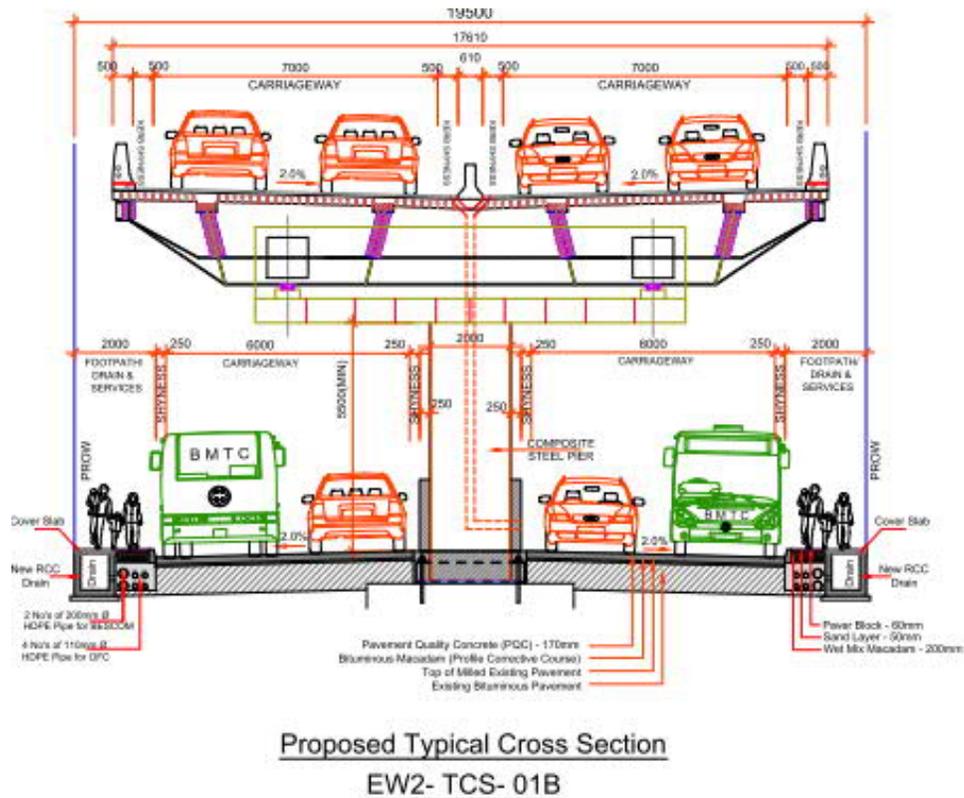


Figure 5-14: Indicative Typical Cross-sections along East West-2 Corridor

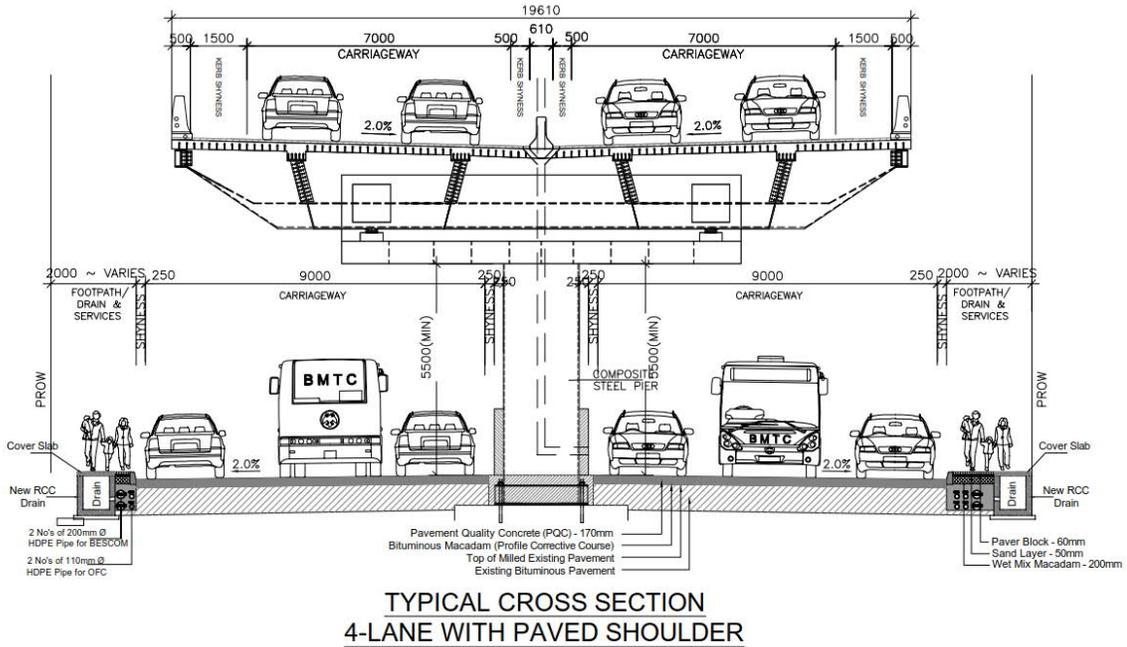


Figure 5-15: Indicative Typical Cross-sections 4-Lane with Paved Shoulder along East West-2 Corridor

Table 5-16: Typical Cross Section schedules along East West-2 Corridor

CHAINAGE		Total Length	Proposed Lane Configuration		Remarks
FROM	TO		Elevated Corridor	At-Grade Road	
0+000	0+350	350	4-Lane Ramp	Service Road (2L+2L)	
0+350	4+350	4000	4-Lane	4 Lanes (2L + 2L)	
4+350	5+030	680	4-Lane with Paved shoulder	Follow Existing RoB	
5+030	5+300	270	4-Lane with Paved shoulder	4 Lanes (2L + 2L)	
5+300	5+700	400	4-Lane with Paved shoulder	4 Lanes (2L + 2L)	
5+700	5+900	200	4-Lane LHS+RHS Ramps	4 Lanes (2L + 2L) Service Road LHS (2L)	
5+900	6+600	700	4-Lane	4 Lanes (2L + 2L)	

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CHAINAGE		Total Length	Proposed Lane Configuration		Remarks
FROM	TO		Elevated Corridor	At-Grade Road	
6+600	7+000	400	4-Lane LHS+RHS Ramps	4 Lanes (2L + 2L) Service Road (2L+2L)	
7+000	7+900	900	4-Lane	4 Lanes (2L + 2L)	
7+900	8+150	250	4-Lane LHS Ramps	4 Lanes (2L + 2L) Service Road LHS (2L)	
8+150	11+500	3350	4-Lane	4 Lanes (2L + 2L)	
11+500	12+100	600	4-Lane +2 Level	4 Lanes (2L + 2L)	
12+100	13+500	1400	4-Lane	4 Lanes (2L + 2L)	
13+500	13+840	340	4-Lane LHS Ramps	4 Lanes (2L + 2L)	
13+840	15+200	1360	4-Lane	4 Lanes (2L + 2L)	
15+200	15+550	350	2-Lane	4 Lanes (2L + 2L)	
15+550	17+050	1500	4-Lane	4 Lanes (2L + 2L)	
17+050	17+500	450	2-Lane	4 Lanes (2L + 2L)	
17+500	19+900	2400	Merging with NS Corridor		
19+900	22+580	2680	3-Lane	2 Lane (1L + 1L) 2 Lane (Loop)	
22+580	24+870	2290	4-Lane	4 Lanes (2L + 2L)	
24+870	25+170	300	4-Lane LHS+RHS Ramps	4 Lanes (2L + 2L) Service Road (2L+2L)	
25+170	25+400	230	4-Lane Split Carriageway	No At-Grade	
25+400	25+550	150	4-Lane	No At-Grade	
25+550	25+890	340	4-Lane Ramp	No At-Grade	
Total Length		25890			

\*Details of TCS are shown in Plan of Drawing Volume IX

Cross Section Schedule for East West Corridor 02 Loop – 01

CHAINAGE		Total Length	Proposed Lane Configuration		Remarks
FROM	TO		Elevated Corridor	At-Grade Road	
17+500	17+900	400	Merging with NS		
17+900	18+600	700	2 lane	3 Lanes	
18+600	19+100	500	2 lane	4 Lanes (2L + 2L)	
19+100	21+600	2500	2 lane	2 Lanes	
Total Length		4100			

\*Details of TCS are shown in Plan of Drawing Volume IX

Cross Section Schedule for East West Corridor 02 Loop – 02

CHAINAGE		Total Length	Proposed Lane Configuration		Remarks
FROM	TO		Elevated Corridor	At-Grade Road	
0+000	1+400	1400	Merging with NS Corridor		
1+400	1+900	500	2 lane +2 Level	Follow Existing	
1+800	2+200	400	2 lane LHS Ramp	3 Lanes	
2+200	2+400	200	2 lane	4 Lanes (2L + 2L)	
Total Length		2500			

\*Details of TCS are shown in Plan of Drawing Volume IX

## 5.6.2 Horizontal alignment

Generally design standards mentioned in previous section have been followed, except at few locations where site constraints compelled to deviate from standards. Minimum radius provided at two locations is 30m.

Table 5-17: Details of the Corridor Horizontal Alignment

Section	From km	To km	Lane configuration	Land usage	Pier location	Description
From Vathur kodi to Marthahalli jn. (ORR)	0.0	5.2	4 – lane divided	LHS – Private RHS -Private	Centre of the ex. road	Alignment starts with entry/exit ramps on White field road. Ramps are provided in the



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						middle of the existing road and existing at grade road is widened on either side of ramps for movement of at grade traffic and local traffic. Thereafter alignment is traversing along the middle of the at grade existing road/median. At km 4.4, alignment is traversing through median of existing RoB approach and obligatory span of 60m provided to cross viaduct.
Marthahalli jn. (ORR) to km 15.2 (Palm grove rd. jn.)	5.2	15.2	4 – lane divided	LHS –Private / HAL RHS –Private / HAL	Centre of the ex. road	In this section alignment traverses at the center of the existing road/median. It passes through HAL area crossing major junctions like Doddanakundi rd., Kariyamma Agrahara rd., Suranjandas rd., Wind tunnel rd., Lower Agaram rd. etc. At all these junctions obligatory spans



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						as per at grade road demand provided. At Domalur alignment is crossing existing flyover.
Km 15.2 (Palm grove rd. jn.) to Desouza Circle	15.2	15.5	3-lane oneway	LHS –Private / RHS – Private	Centre of the ex. road	At start of this junction connecting corridor 2 is merging. To avoid multilevel structure to connect EW2 & CC2 it is proposed to have one way movement. LHS traffic will continue to move straight and RHS traffic will get deviate towards left side on to Gen KS Thimmaiah rd. and take right turn on to Richmond rd. where CC2 RHS traffic also merges and then takes left turn to join EW2.
Desouza circle to Richmond circle	15.5	17.05	4-lane divided	LHS – Private / RHS – Private	Centre of the ex. road	This section of the corridor is traversing through commercial area with minimum existing RoW. At km 16.7 alignment is merging with

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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						Richmond circle flyover. RE wall portion of the approach is proposed to be dismantled and alignment is merged with viaduct portion of flyover.
Richmond circle to Langford rd. jn.	17.05	17.5	3-lane one way	LHS - Private RHS - Private	Centre of the ex. road	In this section traffic from NS corridor is merging with RHS traffic which is leading to Varthur. It is also proposed to merge at grade traffic from Majestic/local through ramp to enable this traffic to go towards south/east/west direction.
Langford jn. to Shantinagar bus stand (overlap with NS corridor)	17.5	18.2	3-lane one way	LHS - Private RHS - Private	Centre of the ex. road	In this section LHS carriageway alignment traverses through Double (KH) road
Shantinagar bus stand to Kengal Hanumanthiah circle to Lalbagh main gate to Lalbagh Minerva circle (overlap with NS corridor)	18.2	19.9	3-lane one way	LHS - Private / Religious / RHS - Private / Religious	Centre of the ex. road	In this section RHS alignment traverses through KH road -Hosur main road- Lalbagh fort rd.- Jayachamaraja wodeyar rd
Lalbagh Minerva circle	19.9	22.55	3-lane one	LHS - Private	Centre of the ex. road	In this section LHS alignment



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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
to jn. of 9 <sup>th</sup> cross rd. ( Alur venkata rao rd.) and 1 <sup>st</sup> main rd.			way	RHS Private -		traverses through Lal Bagh fort rd., 5 <sup>th</sup> Main rd. and 9 <sup>th</sup> cross rd of Chamarajpet rd.. One way will end at jn. of Alur venkata rao rd. and 9 <sup>th</sup> cross rd.
Jn. of 9 <sup>th</sup> cross rd. (Alur venkata rao rd.) and 1 <sup>st</sup> main rd. to JC rd. junction	19.1	21.6 (22.55 )	3-lane one way	LHS Private / Archeological RHS Private -	Portal arrangement	At km 19.1, JC road jn. RHS alignment merges with NS RHS alignment. This section traverses very narrow Arumugam Mudaliar road, Tippu sultan rd., Alur venkata rao rd.
Jn. of 9 <sup>th</sup> cross rd. (Alur venkata rao rd.)	22.55	25.890	4-lane divided	LHS Private RHS - Private	Centre of the ex. road (upto km 24.85) and split carriageway	In this section alignment is traversing along the existing median. At km 24.85 it is proposed to split the elevated carriageway to provide entry/exit ramps at the middle of the existing road. Due to this widening of existing road on either side of ramps has been proposed for the

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Section	From km	To km	Lane configuration	Land usage	Pier location	Description
						purpose of at grade traffic/ local traffic.

## 5.6.3 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model.

Table 5-18: Details of the Corridor Vertical Alignment

Section	From km	To km	Description
From Vathur kodi to Marthahalli jn. (ORR)	0.0	5.2	In this section profile is designed at +1 level. However to maintain 5.5m clearance at existing RoB elevated corridor has to be raised to +2 level.
Marthahalli jn. (ORR) to km 15.2 (Palm grove rd. jn.)	5.2	15.2	In this section profile is designed at +1 level. At Marthahalli Underpass care has taken to maintain minimum clearance. To cross Domalur Interchange, elevated corridor profile is designed at +2 level.
Km 15.2 (Palm grove rd. jn.) to Desouza Circle	15.2	15.5	In this section profile is designed at +1 level
Desouza circle to Richmond circle	15.5	17.05	
Richmond circle to Langford rd. jn.	17.05	17.5	Profile of previous section is continued and then matched with the Richmond circle flyover viaduct portion. RE wall approaches are proposed to dismantle.
Langford jn. to Shantinagar bus stand (overlap with NS corridor)	17.5	18.2	Profile of Richmond circle flyover is followed upto viaduct portion of KH road ramp. RE wall approaches of flyover are proposed to dismantle
Shantinagar bus stand to Kengal Hanumanthaiah circle to Lalbagh main gate to Lalbagh Minerva circle (overlap with NS corridor)	18.2	19.9	In this section profile is designed at +1 level
Lalbagh Minerva circle to jn. of 9 <sup>th</sup> cross rd. (Alur venkata rao rd.) and 1 <sup>st</sup> main rd.	19.9	22.55	
Jn. of 9 <sup>th</sup> cross rd. (Alur venkata rao rd.) and 1 <sup>st</sup> main rd. to JC rd. junction	19.1	21.6 (22.55)	

Section	From km	To km	Description
Jn. of 9 <sup>th</sup> cross rd. (Alur venkata rao rd.).	22.55	25.890	

5.6.4 Major junctions along project corridor and improvement proposals

At start point (Varthur kodi) multilevel flyover is proposed. At grade level a rotary has been provided for the convenience of traffic movement from three directions. For this purpose stream will have to be covered. Elevated corridor MCW starts on White field road with up /down ramps and takes right turn towards Marthahalli at +1 level. Other traffic movements from all legs of junction are as given below:

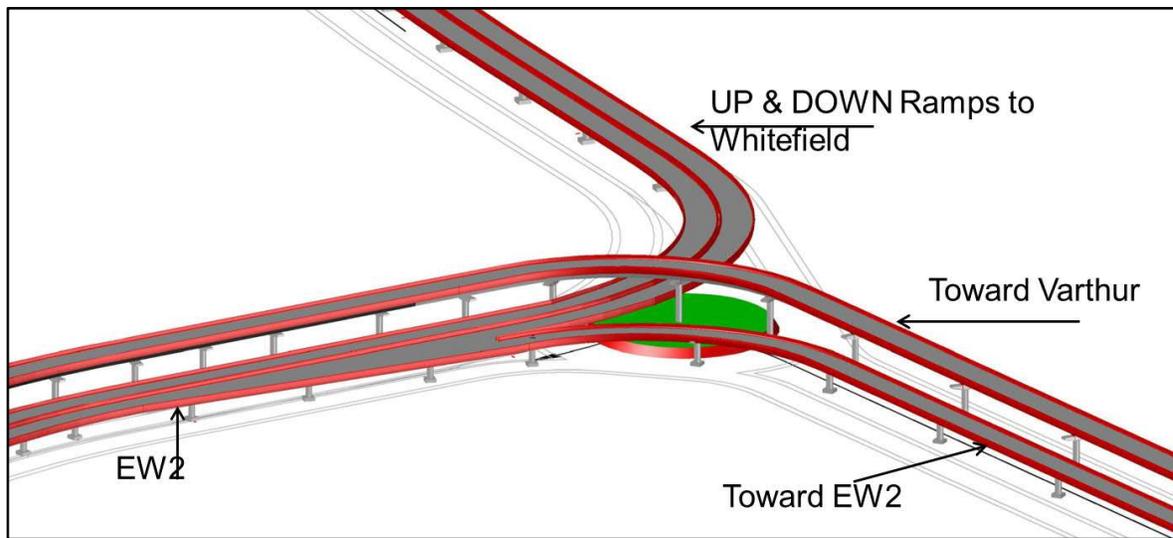


Figure 5-16: Interchange at Varthur Kodi

Traffic coming from White field:

Moving towards Marthahalli will travel on MCW from GL to +1 level through up / down ramps

Moving towards Varthur will use at grade slip road

Traffic coming from Varthur:

Moving towards Marthahalli will travel from GL to +1 level through ramp

Moving towards White field will use at grade road

Traffic coming from Marthahalli:

Moving towards White Field will travel RHS carriageway of MCW



Moving towards Varthur will travel on ramp which takes right turn from +1 level to +2 level while crossing the MCW and reaches GL

5.6.5 Ramps

Ramps are crucial part of this project as they are the connection between elevated corridor and at grade road. Provision of as many as ramps will give the access to many commuters who wish to travel on elevated corridor. More ramps more the traffic on elevated corridor. However frequent provision of ramps will also cause some inconvenience to elevated corridor traffic, it requires acceleration and deceleration lanes and requires more land. Most of this corridor traverses through narrow roads where provision ramps will need to acquire huge multi story buildings. Hence ramps are provided at essential locations depending on land availability. Following table shows total number of ramps provided along this corridor.

Table 5-19: Details of entry/exit ramps along East West Corridor-2

Project Corridor	LHS Ramps		RHS Ramps		Total Ramps	
	Up	Down	Up	Down	Up	Down
EW-2 (4-lane)	4	2	2	5	6	7

5.7 Connecting Corridor-1 (CC-1):

This corridor creates connectivity between North-South corridor and Sarjapura road, corridor starts at Sarjapur bridge at Aagara and traverses via Jakkasandra - Madiwala Market Junction - Koramangala 100 Feet Road Junction.

Total Length: 4.45 km

Number of lanes: 4 lanes

Number of ramps: 2 nos.

5.7.1 Typical cross sections and their schedule proposed along the project corridor

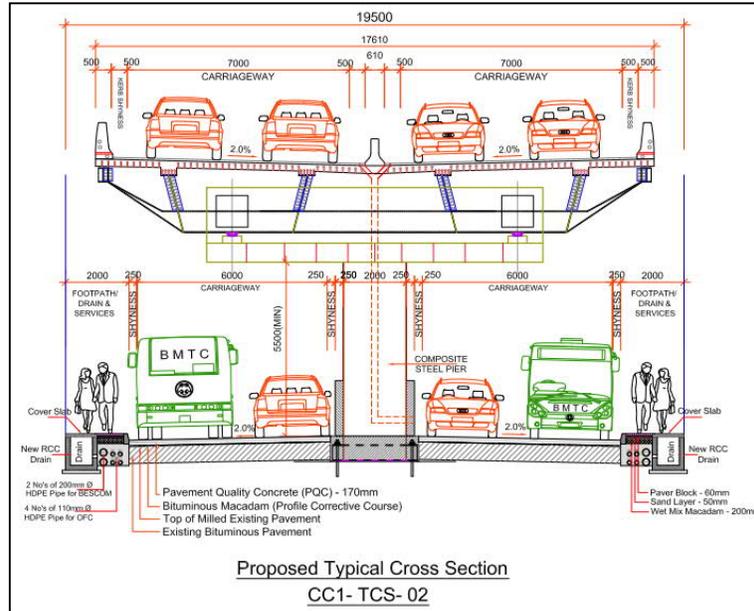


Figure 5-17: Indicative Typical Cross-sections along Connecting Corridor-1

Table 5-20: Typical Cross Section schedules along Connecting Corridor-1

CHAINAGE		Total Length	Proposed Lane Configuration		Remarks
FROM	TO		Elevated Corridor	At-Grade Road	
0+000	0+440	0+440	2+2 Lane Split Carriageway	Follow Existing	
0+440	1+500	1+060	4 Lane	4 Lanes (2L + 2L)	
1+500	3+700	2+200	4 Lane	Divided Carriageway LHS 2L + RHS 3L	
3+700	4+475	0+775	2 Lane +2 Level Crossing NS Corridor	Follow Existing	

\*Details of TCS are shown in Plan of Drawing Volume IX

5.7.2 Horizontal alignment

Horizontal alignment design has been carried out using Mx road software on topographic survey data (base plan). Generally design standards mentioned in previous section have been followed, except at few locations where site constraints compelled to deviate from standards.

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Table 5-21: Details of the Corridor Horizontal Alignment

Section	From km	To km	Lane configuration	Land usage	Pier location	Description
Sarjapur flyover to St John's Hospital bus stop	0.0	4.475	4 – lane divided	LHS – Private / lake RHS - Private	Centre of the ex. road	This corridor is proposed to provide access to Sarjapur which is one of the very fast growing areas in Bengaluru. Take off point of this corridor is from the Sarjapur flyover. Left carriage way merges flyover at central span and RHS carriageway takes off from RHS side of flyover. RHS carriageway crosses the ORR to merge with LHS carriageway. After merging alignment traverses in the center of the existing road. At the meeting point with NS, LHS carriageway is proposed to cross the NS corridor and merges. Care has been taken to avoid acquisition of Temple on RHS of flyover and not to encroach into Agara lake.

5.7.3 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model.

Table 5-22: Details of the Corridor Vertical Alignment

Section	From km	To km	Description
Sarjapur flyover to St John's Hospital Bus stop	0.0	4.475	At takeoff point alignment profile is at +1 level. At end point LHS carriageway crosses NS corridor at +2 level and merges with NS at +1 level.

5.7.4 Ramps

There are no ramps proposed in this section.

5.8 Connecting Corridor-2 (CC-2):

This corridor creates connectivity between East-West Corridor-1 and East-West Corridor-2, corridor starts from D'souza circle on Richmond road Junction and ends at Ulsoor Lake via General KS Thimayya Road - Trinity Junction & Ulsoor Lake Junction (connecting East West Corridor-1)

Total Length : 2.78 km

Number of lanes: 4 lanes

Number of ramps: 4 nos

5.8.1 Typical cross sections and their schedule proposed along the project corridor

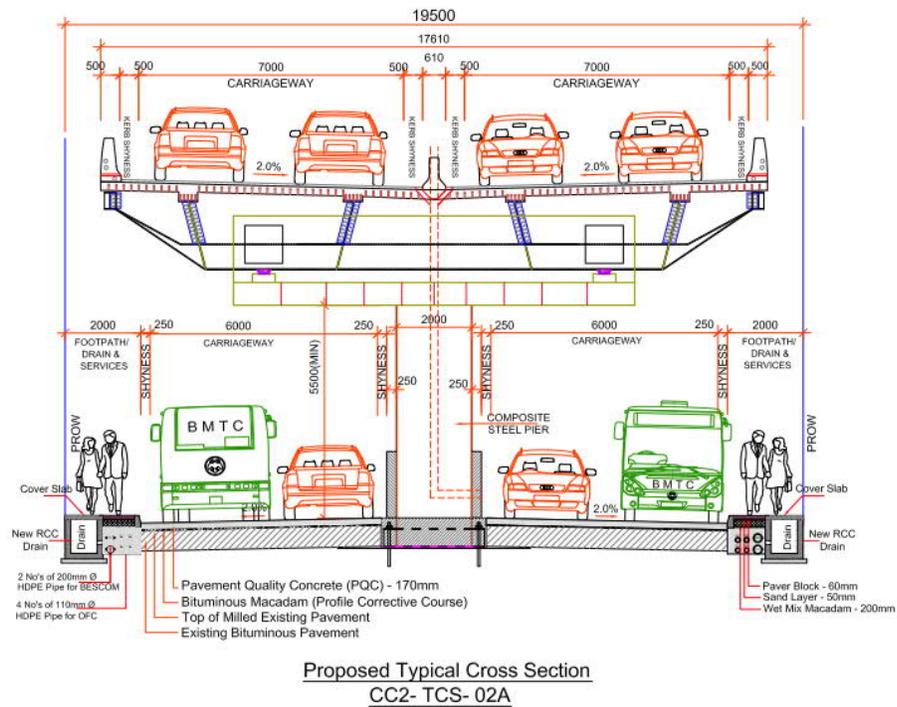


Figure 5-18: Indicative Typical Cross-sections along Connecting Corridor-2



Table 5-23: Typical Cross Section schedules along Connecting Corridor-2

Chainage		Total Length	Proposed Lane Configuration		Remarks
From	To		Elevated Corridor	At-Grade Road	
0+000	0+500	0+500	3 Lane Carriageway	Follow Existing	
0+500	1+040	0+540	4 Lane	4 Lanes (2L + 2L)	
1+040	1+450	0+410	4 Lane +2 Level	4 Lanes (2L + 2L)	
1+450	1+700	0+250	4 Lane	4 Lanes (2L + 2L)	
1+700	1+950	0+250	4 Lane LHS+RHS Ramps	4 Lanes (2L + 2L)	
1+950	2+500	0+550	4 Lane	4 Lanes (2L + 2L)	

\*Details of TCS are shown in Plan of Drawing Volume IX

5.8.2 Horizontal alignment

Horizontal alignment design has been carried out using Mx road software on topographic survey data (base plan). Generally design standards mentioned in previous section have been followed, except at few locations where site constraints compelled to deviate from standards. Minimum radius adopted is 30m at one location.

Table 5-24: Details of the Corridor Horizontal Alignment

Section	From km	To km	Lane configuration	Land usage	Pier location	Description
Desouza circle to Ulsoor lake	0.0	2.78	4 – lane divided	LHS – Private /Lake RHS - Private	Centre of the ex. road	This corridor is proposed to provide connection between EW1 and EW2. At start point one way loop provided to integrate with EW2 corridor. Alignment follows existing road center line. At km 1.275 Trinity circle corridor will cross Metro line. At end point Trumpet Interchange is proposed to integrate with EW1 corridor.

5.8.3 Vertical alignment

Vertical alignment design has been carried out using Mx road software on existing profile generated from digital terrain model.



Table 5-25: Details of the Corridor Vertical Alignment

Section	From km	To km	Description
Desouza circle to Ulsoor lake	0.0	2.78	At takeoff point alignment profile is at +1 level. At km 1.275 this corridor crosses Metro line at +2 level. At end point corridor profile is at +1 level.

5.8.4 Ramps

Following table shows total number of ramps provided along this corridor.

Table 5-26: Table shows details of entry/exit ramps

Project Corridor	LHS Ramps		RHS Ramps		Total Ramps	
	Up	Down	Up	Down	Up	Down
CC-2 (4-lane)	1	1	1	1	2	2

5.9 Bus Stops

The corridor is proposed to have a dedicated bus lane on it. Several discussions have been made with bus transport departments to understand how the bus routes are operated and bus occupancies, trips, etc., it was found that around 40 lakh trips are generated by BMTC buses on a daily basis. This is almost 40% of the total trips generated in the city. There are over 6500 buses as of now operating, the speeds of buses have drastically comedown making less no. of trips per day and the speed is falling year on year due to road congestions.

The dedicated lane on elevated corridor will provide much needed to space for bus travel. The BMTC will work on route optimization and what kind of buses to tun on elevated corridor as there will be a seamless connectivity through elevated corridors to Hebbal, silkboard, Shanthinagar TTMC, Majestic, Yeshwanthapura TTMC. Bus passengers traveling from say, Hebbal to Koramangala/city center/silkboard need to change many buses and spend huge time but take bus on elevated corridor to reach the destinations within a fraction of time. At cantonment interchange and Shanthinagar TTMC, provision of lifts/escalators/stairs are also provided for quick access by passengers.

Further, it was also agreed in the high-level meeting that roads leading to entry/exit ramps are to be improved and bus stops/bays are to be provided to make sure no undue congestion happens on these roads. Otherwise these will become a potential congestion points. In this regard, the Govt. has authorized KRDCL to prepare plans

including land acquisitions and execution can be made either through BBMP or through additional grants as required.

## 5.9 PAVEMENT DESIGN

### 5.9.1 Pavement Evaluation Summary

The existing pavement surface condition survey reveals that around 13% of the pavement surface is affected by distress in all the project roads except for connecting corridor 3 where 38 % of the pavement is affected by distresses. Around 87 % pavement surface of project roads is in fair condition. The characteristic deflection values obtained from BBD survey varies from 0.90 to 1.19 and average deflection value for the corridor is 1.03 mm.

All the roads comprise flexible pavement at present, Existing bituminous layer varies in thickness ranging 185 mm to 260mm in North South Corridor, 190 mm to 280 mm in East West 01 Corridor, 180 mm to 290 mm in East West 02 corridor, 190 mm to 270 mm in connecting corridor 01, 280 mm to 320 mm in connecting corridor 02, and 220 mm to 260 mm in connecting corridor 03. The average bituminous layers' thickness varies around 240 mm. This clearly indicates the significant BT thickness occurred as a result of repeated overlays.

### 5.9.2 Pavement Proposals

Pavements which bear the loads of commercial vehicles, are the costly component of the road. Pavement design, construction and maintenance call for a high degree of skill and expertise. Good performance and economy are the key attributes of a pavement. There are broadly two types of pavements viz, flexible pavement and the rigid pavement.

The project corridors are arterial roads of Bangalore city, Pavement evaluation clearly indicates functional and structural adequacy of existing pavement indicating and all types of pavement options can be proposed for the at grade improvements of these arterial roads where elevated corridor is proposed to decongest and to achieve free flow of traffic in the city.

Pavement design can be made with different types of Pavement options viz,

1. Flexible Pavement / Flexible Overlay
2. Rigid Pavement
3. White Topping
4. Inter locking Paver Blocks

Concrete overlay over the existing bitumen roads (known as White Topping technology) can provide long lasting road network in India. It is a major rehabilitation technology for improving old pavements with a strong, long life, and low maintenance structure. This technology has been developed over the last two decades, especially in USA, to improve the highways, runways, light duty roads and streets. It is very cost effective, fast and easy to construct. In India, Mumbai city has taken a big lead in this direction. Many other cities like Bengaluru, Pune, Nagpur, Indore, Chennai have also been adopting white topping technology for city roads.

As explained in the previous paragraphs White-topping on existing bituminous pavements provides many additional benefits as compared to conventional bituminous overlay alternative. Some of the benefits are:

- Long life, low maintenance, low life-cycle cost, improved safety and environmental benefits.
- Bituminous overlays exhibit a more rapid loss of serviceability as compared to concrete white-topping at some critical locations. The lives of successive bituminous overlays become progressively shorter after the first overlay.
- Deformation like rutting and cracking predominant in case of bituminous pavements is normally absent with concrete surfaces of white-topping. This is particularly true in a hot climate like India.
- Conventional White-topping improves structural capacity of existing bituminous pavement, if built on a strong base course, and it impedes structural distresses.
- White-topping requires much less maintenance and as such involves much less frequent lane closures of road, as compared to bituminous surfaces.
- White-topping is quite cost-effective to tackle annual budget constraints and high traffic levels. It is, therefore, quite relevant to Indian conditions.
- White-topping can uniformly fill ruts in the wheel path of bituminous pavements more effectively because concrete is far more stiff and consistent at high temperature than bituminous mixes. Broadly, for similar reasons, the occurrence of cracks is also relatively much less in case of white-topping.
- Concrete is relatively light in colour and hence concrete surface is more reflective to light, absorb less heat and reduce the urban heat island effect. Improved reflection of lights from vehicles enhances safety, lowers energy requirement of external lighting, lower contribution to heat in environment.
- Fuel consumption on concrete roads has been found to be less than the bituminous roads.
- Thus proving the white topping is the most feasible and suitable pavement option for the at grade improvement of project roads.

### 5.9.3 White Topping

White topping is defined as a Portland Cement Concrete (PCC) overlay constructed on the top of an existing bituminous pavement. Whitetopping is thus PCC resurfacing (overlay) as a rehabilitation or structural strengthening alternative on bituminous pavement.

White Topping Thickness Design Criteria

The design principle adopted for Conventional Whitetopping is similar to those of normal concrete pavements as provided in IRC:58 “Guidelines for the Design of Plain jointed Rigid Pavements for Highways” and IRC:15 “Standard Specifications and Code of Practice for Construction of Concrete Roads”. design of TWT and UTWT is as per IRC: SP: 76-2015. Determination of modified / effective / support modulus of Subgrade reaction (k). The correlation between CBR and ‘k’ value for the Subgrade as given in SP: 76-2015 be used for the design.

Modified “k” value on the top of Bituminous pavement can be determined using the charts given in IRC: SP: 76-2015: “Tentative Guidelines for Conventional, Thin and Ultra-Thin White topping”. Two charts are given for correlation based on the existing bituminous pavement is atop of granular base or cement treated base.

Alternative method is by using Benkelman Beam Deflection Test and is a Graphical method. In this “k” value can be determined based on characteristic deflection of BBD test as per IRC: 81.

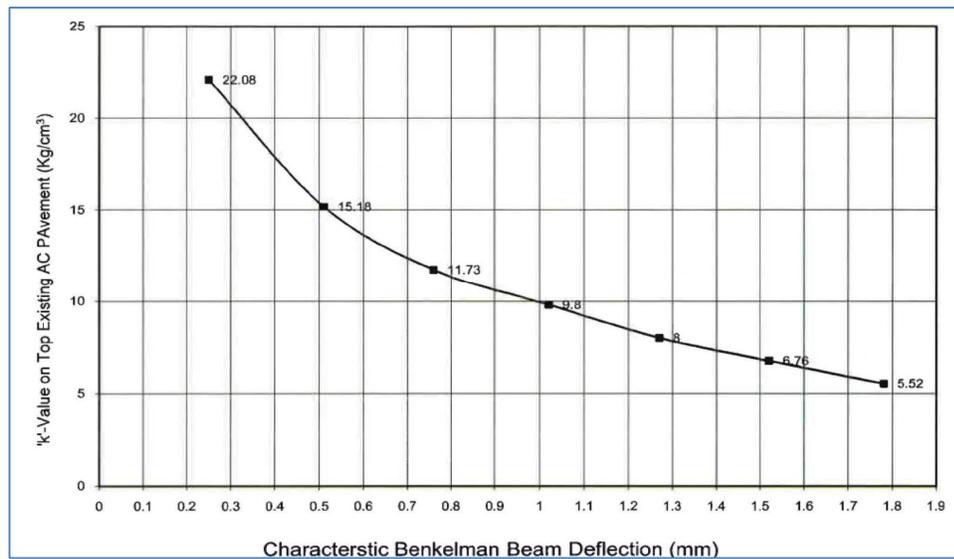


Figure 5-19: Graph showing relationship between BBD & Modulus of Subgrade reaction

Surface Preparation

For Conventional White-topping, no special efforts are made to encourage bonding between the overlay and the underlying bituminous surface; however, some steps for surface preparations may be required to address existing restorations in the existing



surface of the bituminous pavements or to correct surface profile. Three methods of surface preparation and overlying are normally used for White-topping.

Direct placement: The concrete overlay is placed directly on the existing hot bituminous surface after sweeping. Any ruts in the existing pavement are filled with concrete, resulting in a thicker concrete pavement in the rutted areas.

Milling: The existing bituminous surface is milled to obtain a uniform surface. Milling can be used to remove surface distortion like cracks in the top portion and adjust cross slopes. The removal of thickness should be between 25 to 50mm. Milling can also be selectively used with direct placement to treat the isolated stretch suffering from distortion in the project road. Milling is not mandatory.

Placemen of Leveling course: Sometimes a leveling course of bituminous mix is used to produce a uniform surface for paving. A leveling course typically consists of minimum 50mm if Bituminous Macadam (BM). Exact quantity will depend upon the undulations. When the distortion/rutting depth exceeds more than 50mm, the option of milling as an economical alternative may be evaluated.

5.9.3.1 Design of White-topping as per IRC SP: 76 – 2015.

The White Topping is designed based on the “Guidelines for Thin and Conventional White Topping, IRC: SP 76 - 2015” for the project road stretches considering the design life of 20 years. Using the below inputs, the design thickness is worked out and summarized. The sample white topping design and recommended white topping details is given below.

Commercial traffic prevailing in the Project stretches are studied by conducting Traffic volume count and Turning volume count at various location and AADT is arrived. Considering 2 years of construction period base year traffic is calculated and considered for pavement design. Traffic growth rate of 7.5 % is considered for a design period of 20years in accordance with the guidelines. The white topping thickness is designed with maximum length of the panel as1.2m. the sample design calculations for connecting corridor 02 of the project is tabulated below Table 5-31 to 5-36.

Table 5-27: Design Parameters

Design Parameters		
i)	Design Life, years	20
ii)	Traffic Growth Rate. R	0.075
iii)	Commercial Traffic, cvpd	2631
iv)	Grade of Concrete, M40	40



Design Parameters		
v)	Cumulative Repetitions in 20 years	51586136
vi)	Design traffic (25% of (v)), cvpd	10396534

Table 5-28: Percentages for Axle Loads for the Design of TWT

Axle load Class, Tons	% of Axle Loads	Axle load Class, Tons	% of Axle Loads
15-17	0.00		0.000
13-15	2.24	26-30	0.000
11-13	4.27	22-26	0.095
9-11	5.97	18-22	0.171
7-9	16.90	14-18	0.152
less than 8	69.94	less than 14	0.266
	99.32		0.68

Table 5-29: Expected Repetitions for Axle Loads

Single Axle Load		Tandem Axle loads	
Axle load Class, Tons	% of Axle Loads	Axle load Class, Tons	% of Axle Loads
16	0	28	0
14	232372	24	9871
12	444015	20	17768
10	621107	16	15794
8	1756513	less than 16	27640
less than 8	7271454		
	10325460		71074

Table 5-30: Design Data

Trial Thickness, cm	17
Subgrade Modulus, Kg/cm <sup>3</sup> . k	10.22
Design Period, years	20
Modulus of Rupture, Kg/cm <sup>3</sup>	45
Load Safety Factor	1
Length of Square Slab, cm	120
Modulus of Elasticity of concrete	300000
Poisson's ratio	0.15
Radius of relative Stiffness, cm l <sub>c</sub>	59.21

Table 5-31: Fatigue Life Consumed for Single Axle Load

Axle Loads, Tonnes	Load Stress, Kg/cm <sup>2</sup>	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed	Maximum load stresses, kg/cm <sup>2</sup>
16	25.6	0.57	0	94100	0.00	25.59
14	22.4	0.50	232372	762000	0.305	
12	19.2	0.43	444015	infinity	-	
10	16.0	0.36	621107	infinity	-	
8	12.8	0.29	1756513	infinity	-	
less than 8			7271454	infinity	-	
					0.30	

Table 5-32: Fatigue Life Consumed for Tandem Axle Load



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Axle Loads, Tonnes	Load Stress, Kg/cm <sup>2</sup>	Stress Ratio	Expected Repetition	Fatigue Life, N	Fatigue Life Consumed
28	29.8	0.67	0	4410	0.00
24	25.5	0.57	9871	71200	0.139
20	21.3	0.47	17768	5200000	0.000
16	17.01	0.38	15794	infinity	0.000
less than 16		0.00	27640	infinity	0.000
					0.14
The cumulative life consumed both by single and tandem axle is			0.44		
If the panel size is less than 1.30 m, then two axles of a tandem axle vehicle will not fall on the same panel simultaneously, hence, stresses should only be considered for single axle. The possibility of wheels of two adjacent vehicles Simultaneously placed on one panel is also excluded.					
The cumulative life consumed both by single and tandem axle is		0.30	Thickness provided is Safe Against Fatigue Failure		

$\sigma_T = 1.933-241000(\alpha \Delta T) + 1.267(L/l_e)$	
$\Delta T$	-0.15°C/cm x Thickness of white topping overlay
$\Delta T, \text{oC}$	-2.55
$\alpha$	0.00001
Length of Square Slab, cm	120
Radius of relative Stiffness, cm $l_c$	59.21
$\sigma_T, \text{Kg/Cm}^2$	10.646
Maximum load stresses, kg/cm <sup>2</sup>	25.59
Total flexural stresses due to load and curling=Maximum load stresses+ Curling stresses, Kg/cm <sup>2</sup>	36.24

Slab is Safe against Stress, Hence Design is Safe

In the same lines the pavement design is made for the rest of the project roads.

## 5.9.3.2 Recommendations for White-topping

The White Topping design for the project roads is done based on the guidelines given in IRC: SP: 76-2015. Recommended design white topping thickness with characteristic deflection is given below in Table 5.37.

Table 5-33: Road wise Summary of White Topping Design Thickness for Elevated Corridor (at grade Improvements)

Link No	Sections	Design Traffic, CVPD	White Topping Thickness, cm
Connecting Corridor - I			
1	SARJAPUR ROAD	2073	17
Connecting Corridor - II			
1	D'SOUZA CIRCLE - BHASKARAN ROAD	2631	17
East West Corridor - 01			
1	JALAHALLI - YASHWANTHPUR	14874	18
2	YASHWANTHPUR - IISC	2992	17
3	TUMKUR ROAD: IISC - MEKHRI CIRCLE	3426	17
4	MILLERS ROAD - ST. JOHNS CHURCH ROAD	1944	17
5	KENSINGTON ROAD - MURPHY ROAD	6036	17
6	OLD MADRAS ROAD - KR PURAM JUNCTION	6577	17
7	KR PURAM JUNCTION - BHATTARAHALLI	6701	18
East West Corridor - 02			
1	DEEPANJALI NAGAR - SULTAN ROAD	6119	17
2	KR MARKET - RICHMOND CIRCLE	7796	17
3	CHAMRAJAPETE - KH CIRCLE	8773	17
4	RICHMOND ROAD - HAL AIRPORT ROAD	5827	17
5	HAL AIRPORT ROAD - DOMLUR FLYOVER	4001	17
6	OLD AIRPORT ROAD - MARATHAHALLI (ORR)	5071	17
7	VARTHUR ROAD	2223	17



Link No	Sections	Design Traffic, CVPD	White Topping Thickness, cm
North South Corridor			
1	JAYAMAHAL ROAD	3168	17
2	QUEENS ROAD	3792	17
3	KASTURBA ROAD	1795	17
4	KASTURBA ROAD - KH ROAD	5275	17
5	KH ROAD to SHANTHINAGAR TTMC	7470	17
6	HOSUR ROAD - SARJAPUR JUNCTION	2838	17
7	SARJAPUR JN. - ORR	8477	17

Note: For locations where existing pavement is disturbed or having inadequate pavement structure, reconstruction is recommended. The recommended pavement composition for those locations is indicated below.

Table 5-34: Details of Design Thickness

Details	Thickness
White Topping (PQC), mm	As per Table 3.47
Bituminous Macadam (BM), mm	75 mm
Wet Mix Macadam (WMM), mm	250 mm
Granular Sub Base (GSB), mm	200 mm

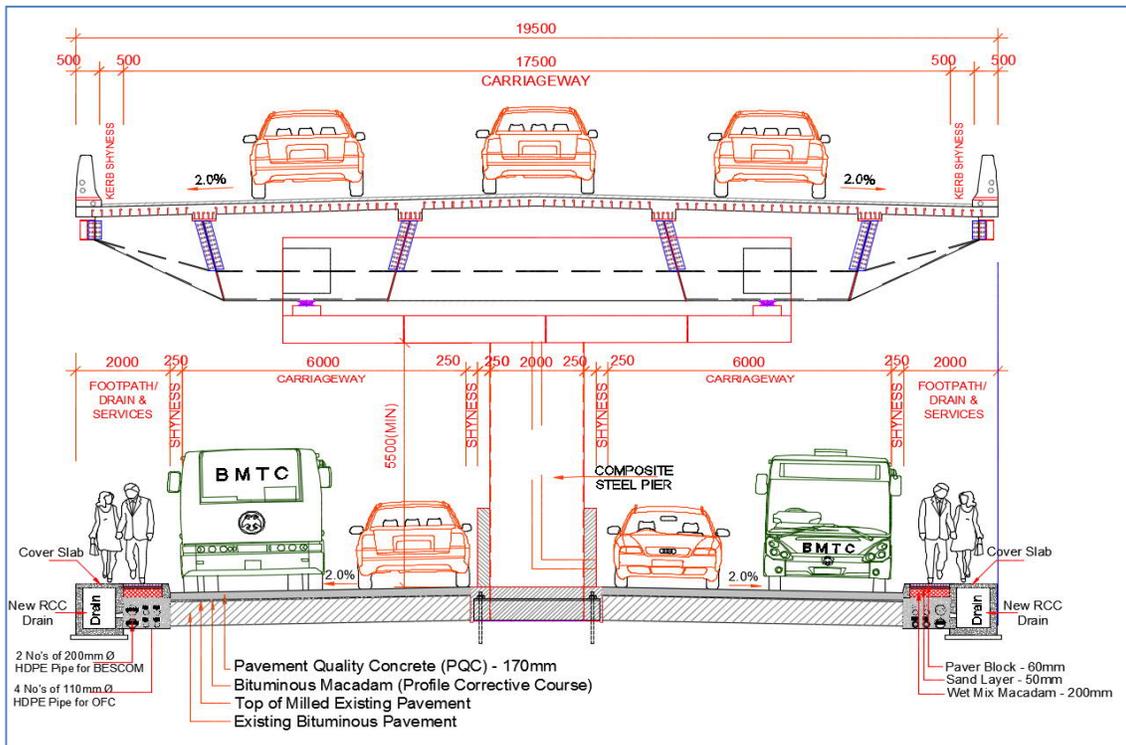
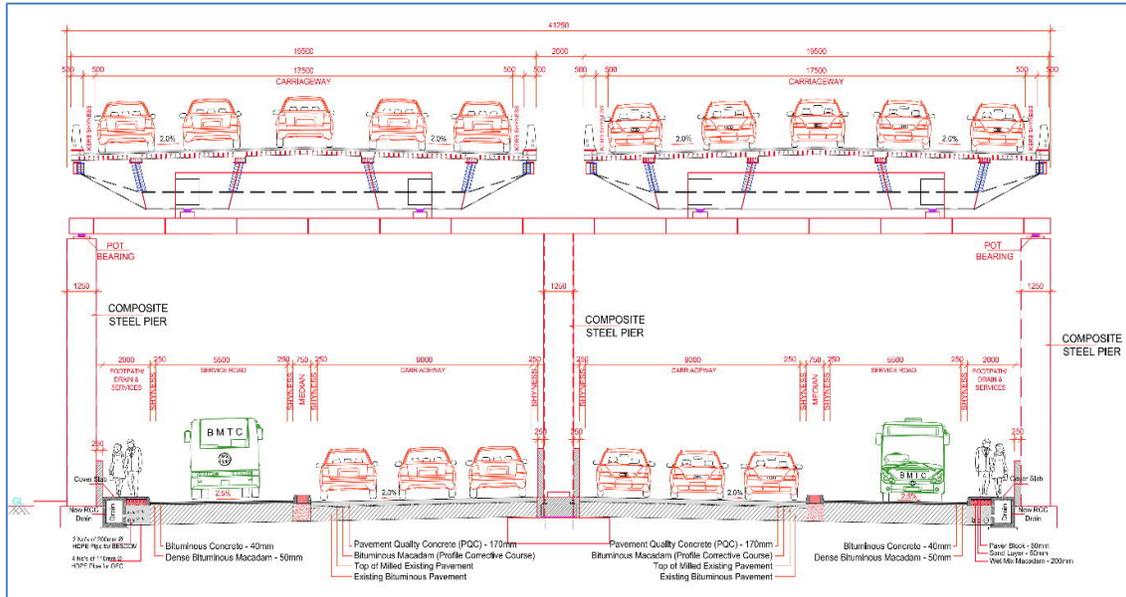
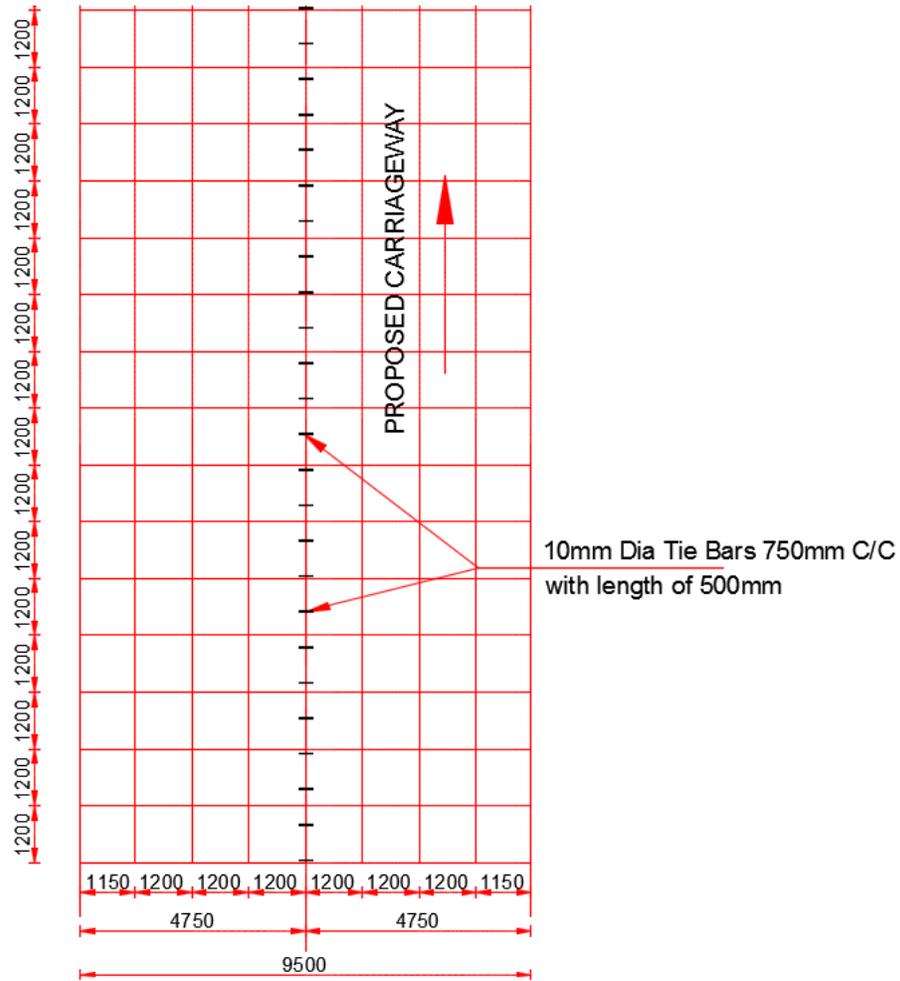


Figure 5-20: Typical Cross-section for At Grade Six Lane with Service Road

Figure 5-21: Typical Cross-section of At Grade Four-lane Carriageway



PLAN OF CC PAVEMENT FOR  
9.5M CARRIAGEWAY

Figure 5-22: Typical Panel Details for White-topping

## 5.10 STRUCTURAL DESIGN

### 5.10.1 Choice of Structural Material:

The choice of bridging material; steel and concrete, is a major decision to be taken for long elevated corridor for bridge engineers. Since the cost depends on the circumstances prevailing at that time, the information is always imprecise. It is the changes in this factors of this kind has been that involving box girder, plate girders etc. Selection of type of structural material and arrangement are governed by many factors such as availability of material, space for construction, Duration of project, construction technology, Cost of project, feasibility of construction and social and environmental impact etc.

However, only four factors pertinent to bridges need concern us:

- I. Relative economy,
- II. Speed of erection,
- III. Aesthetic considerations, and
- IV. Corrosion / maintenance.

### 5.10.2 Comparison: Concrete & Steel

Some of the basic differences are listed below pertaining to use of steel and concrete for bridges;

#### CONCRETE;

- Material is easily Available in India for Mega Elevated Project
- Post-tensioned box girders are efficient structures for medium to long span bridges (30m to 150m).
- Post-tensioned box girders can be constructed either in-situ or by the use of match cast precast segments.
- In-situ construction using ground supported false work has a relatively long construction cycle time and requires good foundations for the false-work to avoid cracking of the immature concrete during the staged construction process.
- The elevation view of Close Box type superstructure is nice and deck is thinner as a proportion to its span
- Very high torsion rigidity of superstructure in curved alignment of elevated corridor
- Future widening of the deck is difficult.
- Relatively economical from maintenance point of view.
- All utilities can be passed through inside the box section of the deck.
- Higher Cost for setting up the Pre-casting Yard.



- Less disturbance to the existing traffic during erection of the precast superstructure using launching gantries
- More experience in this type of precast construction in recent years
- Production of the concrete segments in a protective environment where stringent quality controls can be provided
- High concrete strengths can be achieved in precast fabrication resulting in a durable structure with minimizing life cycle maintenance costs.
- Accelerated construction schedule since pre-casting can occur in parallel with construction of the Foundation.
- Competitive price: the cost of special equipment will not be significant given the size of the project.
- Aesthetic value: visual continuity between substructure and superstructure, good proportions (span length/height), smooth lines.

#### STEEL;

- Supply of the material will depend on the production of high quality steel in the nearby area
- Steel bridges usually offer a competitive alternative to concrete structures for the range of the pre-stressed beam and post - tensioned concrete structures.
- The main disadvantage of steel structures, particularly when they are exposed to severe environmental conditions, is the need for a continual maintenance program.
- If a steel structure is not well maintained corrosion can quickly become a serious problem.
- Another concern is the limited local experience with steel bridges compared to concrete within the construction industry in India.
- Steel structures have a limited aesthetic appeal due to their lack of the more streamlined appearance available with formed concrete.
- However with suitable architectural treatment the appearance of steel structures can be enhanced.
- Steel structures are highly flexible with respect to future expansion.
- They can be constructed in a speedy manner and require a minimal amount of false work for superstructure construction.
- Steel girders and boxes can be fabricated to match the roadway alignment and curvature.
- The initial cost of steel structures is comparable to the most economical concrete structure types however the continual maintenance and inspection requirements of a steel bridge over its useful life adds to the total long term cost of the bridge.
- Therefore, steel structures are best suited for curved structures where economy, speed of construction, future expansion and flexibility are of importance

- Weight of girders is much less, and needs lower capacity trailers for transportation, and lighter cranes for handling and erection.
- Can be advantageous for construction on narrow roads, where large trailers and cranes cannot be deployed.

An exercise was performed for comparing the type of structure to be adopted and has been tabulated. The arrangement was with a continuity of 4 spans for both type of structure. The total length has been considered for 1.0 km. the exercise was performed for both 6 lane carriageway. It is observed that concrete structure is 20% cheaper than that of steel structure but the no. of foundations and the size makes it unfeasible in the urban area whereas steel structure due to its light weight, larger span length and lesser footprint area on the ground makes feasible in the urban area.

A comparative statement has been presented in below table.

Table 5-35: Comparative Statement Steel & Concrete Structure

Parameters			PC Box Girder Bridge	Steel Box Girder Bridge
Criteria	Span Length		40 m	40 m
	Bridge Effective Width		24.61 m	24.61 m
Landscape	Aesthetic view		Good	Good
Environmental Impact	Natural Environment	No. of Pier	25	25
	Regarding vibration problem		Good	Good
	Noise	No. of Expansion Joint	6	6
Structural Performance	Usage Record		Many	Moderate
	Durability	Durability of Bridge Deck	PC Slab	Composite Slab
Constructability	Impact on existing road		More Impact	Less Impact
	No. of Pile Nos.		More	Less
	Quality Control	Difficulty level of Quality Control	Slightly difficult	Easy
Maintenance	Painting		No paint	Paint
	Periodic Maintenance	Number of Expansion Joint	6	6

Parameters			PC Box Girder Bridge	Steel Box Girder Bridge
		Pier with bearings	1	0.6
Construction period			36 months	22 months
Cost	Ratio	Construction cost	1	1.2
		Maintenance Cost	1	1.5
		Life cycle cos	1	1.21
Evaluation				Recommended

### 5.10.3 Structural Arrangement

Steel bridges with advantage of the latest automated fabrication and construction techniques are able to provide economic solutions to the demands of safety, rapid construction, aesthetics, shallow construction depth, minimal maintenance and flexibility in future use. Steel also scores well on all the sustainability measures, and offers a broad range of benefits addressing the economic, environmental, and social priorities

The high strength-to-weight ratio of steel minimises the structural weight of superstructures and thus minimises the substructure costs. Minimum self-weight is also an important factor in the cost of transporting and handling components. Use of steel facilitates shallow construction depths.

Steel is the most recycled construction material and choosing it for a bridge represents a sustainable management of natural resources. When a steel bridge reaches the end of its useful life, the girders can be cut into manageable sizes to facilitate demolition, and returned to steelworks for recycling. Some 99% of structural steel either finds its way back into the steelmaking process where it is used to create new steel products or is reused. Alternatively, component parts of steel bridges can be reused in other structures; entire bridges have been relocated and bridges can be designed with ease of future relocation in mind.

Steel has broad architectural possibilities. Steel bridges can be made to look light or reassuringly solid, and can be sculptured to any shape or form. The high surface quality of steel creates clean sharp lines and allows attention to detail. Modern fabrication methods can easily provide curvature in plan and elevation. The painting of steelwork introduces colour and contrast, and repainting can change or refresh the appearance of the bridge. Steel being versatile and effective material for bridge construction, able to carry loads in tension, compression and shear. There

are basically two types of superstructure configurations under consideration viz. Plate girder system and Box girder system.

#### 5.10.3.1 Superstructure:

Box girder has been proposed for superstructure. Box girder configuration that is now more commonly used employs 'open topped' trapezoidal girders. These girders have a steel bottom flange, inclined steel webs and a narrow steel flange on top of each web. The closed cell is formed by the reinforced concrete deck slab. With this configuration, material access during construction can be minimised by the use of permanent formwork (or precast slabs) and for maintenance the cells are larger than those for rectangular steel boxes, thus reducing the difficulties of access.

The selection, or otherwise, of a steel box girder always needs a consideration of the relative advantages and disadvantages of box girder elements compared to the more traditional 'I' girder elements.

Advantages, compared to 'I' girders:

- High torsional stiffness and strength, giving greater suitability for horizontally curved bridges, greater aerodynamic stability and reduced susceptibility to lateral buckling of flanges (in lateral-torsional or distortional buckling modes)
- Reduced need for support points
- Improved durability and reduced maintenance of protective coatings (less exposed surface, fewer edges, avoidance of exposed horizontal surfaces, no exposed bracing and stiffeners).
- The clean lines of a closed box girder are also often considered give an excellent appearance, particularly for footbridges where the visual impact is considered to be important.

#### 5.10.3.2 Substructure & Foundation:

Substructure comprises of steel pier cap and composite steel pier resting on pile foundation. Inverted T Beam pier cap has been proposed to reduce the height of the structure. Pier cap comprises of steel plate with internal diaphragms connected to resist buckling. Composite pier has been proposed with concrete filled steel pier. This system reduces the size of pier considerably as it is a governing factor in urban area. Also the reduced time taken for erecting of pier and pier cap makes the proposal feasible. The foundation has been proposed considering Geotech investigation results. Pile foundation has been recommended as per the investigation results. Also as the proposed elevated corridor traverse through urban road pile foundation is preferred

over open foundation to minimize the hindrances to existing traffic and road caused during construction.

#### 5.10.4 Elevated Structural Configuration

The project corridor comprises of various spans and width of structures. The proposed corridors are for urban area with many cross roads of various widths and require different obligatory spans with faster mode of construction. The total deck width of elevated road varies from 9.0m to 24.61m. The corridor involves interchanges, multi-level decks, crossing existing structures, ramps etc. The configuration of deck slab is detailed as below,

Table 5-36: Deck Slab Configuration

SL No.	No. of Lanes	CB (m)	SH (m)	CW (m)	SH (m)	CB (m)	Median (m)	SH (m)	CW (m)	SH (m)	CB (m)	Total Width
1.	Two Lane	0.5	0.5	7.0	0.5	0.5	-	-	-	-	-	9.0
2.	Three Lane	0.5	0.5	10.5	0.5	0.5	-	-	-	-	-	12.5
3.	Four Lane	0.5	0.5	7.0	0.5	-	0.61	0.5	7.0	0.5	0.5	17.61
4.	Four Lane with Paved Shoulder	0.5	0.5	8.0	0.5	-	0.61	0.5	8.0	0.5	0.5	19.61
5.	Six Lane	0.5	0.5	10.5	0.5	-	0.61	0.5	10.5	0.5	0.5	24.61

CB; Crash barrier, SH; Kerb Shyness, CW; Carriageway

The structural configuration comprises of various arrangements with single and divided decks, Single and portal piers, pile foundations etc. The arrangement of substructure depends on the availability of space at grade. As the corridor is in urban area care has been taken to provide best suitable configuration such that minimum hindrances to the at grade traffic. Each location is studied in detail with respect to detail topographic survey and site condition before providing the pier locations and structural systems. Details Schedule of structural Proposal is presented in tables below. The Details of each cross section has been presented in Volume-III-Drawings

##### 5.10.4.1 North South Corridor:

##### 5.10.4.1.1 Main Corridor:

Table 5-37: North South Structural Typical Cross Section

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
1	0+000	2+300	2-Lane	Single Pier (2 Nos) Level 2	
2	2+300	5+000	6Lanes	Single Pier	
3	0+000	0+220	6Lanes (3L + 3L)	Single Pier	
4	0+220	0+495	6Lanes (3L + 3L)	3 Pier Portal	Merging
5	0+495	0+615	8Lanes (6L + 2L)	3 Pier Portal	Merging
6	0+615	0+815	8Lanes (6L + 2L)	3 Pier Portal +Ramp 1 Side	One Side Ramp
7	0+815	0+895	8Lanes (6L + 2L)	3 Pier Portal	Merging
8	0+895	1+175	8Lanes (6L + 2L)	3 Pier Portal +Ramp 1 Side	One Side Ramp
9	1+175	1+600	6-Lanes	3 Pier Portal	
10	1+600	2+000	8Lanes (4L + 4L ) DD	2 Pier Portal	Double Decker
11	2+000	2+370	10Lanes (8L DD + 2L)	2 Pier Portal	Double Decker with Ramp
12	2+450	2+450	8Lanes (6L + 2L)	3 Pier Portal	Merging
13	2+530	2+530	8Lanes (6L + 2L)	3 Pier Portal +Ramp 1 Side	One Side Ramp
14	2+530	2+650	8Lanes (6L + 2L)	2 Pier Portal +Ramp 1 Side	One Side Ramp

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
15	2+650	2+800	3 Lanes	Single Pier	Towards millers Road(Centerline Eccentric)
16	2+800	2+840	5 Lanes ((3L + 2L))	2 Pier Portal	
17	2+840	3+405	3-Lanes	Single Pier	
18	3+405	3+725	3-Lanes	Single Pier	6 Pile Group
19	3+725	3+875	6Lanes (3L + 3L )	2 Pier Portal	
20	3+875	4+035	3-Lanes	Single Pier	6 Pile Group
21	4+035	4+235	3-Lanes	Single Pier	
22	4+235	4+315	5Lanes(3L+2L)	2 Pier Portal	Merging
23	4+315	4+515	3Lanes	Single Pier	
24	4+515	4+540	3Lanes	2 Pier Portal	
25	4+540	4+740	3-Lanes	2 Pier Portal	
26	4+740	4+900	6Lanes (3L + 3L )	Single Pier (2 Nos) Level 2	One side Lvl 1 & Second side Lvl 2
27	4+900	5+050	6Lanes (3L + 3L )	3 Pier Portal	Double Decker
28	5+050	6+255	6Lanes (3L + 3L )	Single Pier	Double Decker

## Final Feasibility Report

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
29	6+255	6+375	6Lanes (3L + 3L )	2 Pier Portal	Double Decker
30	6+375	6+735	6Lanes (3L + 3L )	Single Pier	Double Decker
31	6+735	6+855	6Lanes (3L + 3L )	3 Pier Portal	Double Decker
32	6+855	7+195	6Lanes (3L + 3L )	Single Pier (2 Nos) Level 2	One side Lvl 1 & Second side Lvl 2
33	7+195	8+075	4Lanes	Single Pier	
34	8+075	8+510	2Lanes	2 Pier Portal	2 Pile Group
35	8+510	8+590	2Lanes	Single Pier	
36	8+590	9+120	3Lanes	Single Pier	
37	9+120	9+280	3Lanes	Single Pier	
38	9+280	9+720	5Lanes (3L+ 2L)	Single Pier + Ramp 1 Side	One Side Ramp
39	9+720	9+875	5Lanes (3L+ 2L)	3 Pier Portal	
40	9+875	10+27 5	4Lanes PS	Single Pier	Nala
41	10+27 5	10+71 5	6Lanes (4L + 2L )	2 Pier Portal +Ramp 1 Side	Nala(One side ramp)
42	10+71 5	11+49 5	4Lanes PS	Portal Pier (2 Nos)	Nala

## Final Feasibility Report

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
43	11+49 5	11+81 5	6Lanes (4L PS+ 2L )	Single Pier +Ramp Single Pier	One Side Ramp
44	11+81 5	13+45 5	4Lanes PS	Single Pier	
45	13+45 5	13+70 5	6Lanes (4L PS+ 2L )	Single Pier +Ramp Single Pier	One Side Ramp
46	13+70 5	14+03 0	4Lanes (2L +2L)+2Lane	Cantilever Pier Both side+Single pier higher level	Split CW on Individual Pier
47	14+03 0	14+07 0	8Lanes (4LPS +4L PS)	3 Pier Portal	
48	14+07 0	14+38 5	8Lanes (2L+2L+2L+2L)	Cantilever Pier +Two Single Pier Ramps+Seperated Single pier	Split CW on Individual Pier + Ramp both side
49	14+38 5	14+74 5	4Lanes (2L +2L)	3 Pier Portal	
50	14+74 5	15+14 5	4Lanes PS	Single Pier	
51	15+14 5	15+18 5	4Lanes (2L +2L)	3 Pier Portal	
52	15+18 5	15+56 0	4Lanes (2L +2L)	Cantilever Pier Both side	Split CW on Individual Pier
From South to North					
1	18+25 5	18+71 0	3 Lane	Single Pier	From Shantinagar bus station to Minerva circle (Overlap with EW2) Chainages shown are for EW2
2	18+71 0	18+76 0	5 Lane (3L + 2L)	2 Pier Portal + Ramp Single Pier	
3	18+76 0	18+80 0	5 Lane (3L + 2L)	2 Pier Portal	
4	18+80 0	19+90 0	3 Lane	Single Pier	



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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
From Minerva Circle to Hudson Circle (Overlap with EW2)					
5	0+000	0+400	2 Lane	Single Pier	From Minerva Circle to Hudson Circle (Overlap with EW2)
6	0+400	0+775	4 Lane	Single Pier	
7	0+775	0+855	6Lanes ((4L+ 2L))	2 Pier Portal	
8	0+855	1+415	4 Lane	Single Pier	

5.10.4.1.2 Loops:

Table 5-38: North South Structural Typical Cross Section of Loops

Sl No.	Length	Lane Configuration	Proposed Pier Configuration	Remark
1	80	2 Lane	Single Pier	U turn at Cantonment
2	550	5 Lane	Single Pier	Loop from Queens Road to Jaymahal Rd
3	360	3 Lane	Single Pier	Loop from Queens Road to Jaymahal Rd
4	220	3 Lane	Single Pier	Loop from St Johns Road to Jaymahal Rd (Opp to Cantonment Rly Stn)
5	520	5 Lanes(3L+2L)	Single Pier	Loops
6	80	2 Lane	Single Pier	Ramps at CSI Hospital (On Cantonment Rly Stn Rd)
7	120	2 Lane	Single Pier	Ramps at CSI Hospital (On Cantonment Rly Stn Rd)
8	160	2 Lane	Single Pier	Ramp Towards Mejastic
9	240	2 Lane	Single Pier	Ramps at Adugoddi LHS
10	280	2 Lane	Single Pier	Ramps at Adugoddi RHS
11		2 Lane	Single Pier	Ramps Towards Lal bagh Rd

## 5.10.4.2 East West Corridor 1:

## 5.10.4.2.1 Main Corridor:

Table 5-39: East West-1 Structural Typical Cross Section

Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
1	0+000	0+305	4 Lanes	RE wall	Approach
2	0+305	2+825	4 Lanes	Single pier	
3	2+825	3+035	4 Lanes	2 Pier Portal	
4	3+035	3+075	4 Lanes	3 Pier Portal	
5	3+075	3+180	4 Lanes	Single pier	
6	3+180	3+580	8Lanes (4L + 2L + 2L)	Single pier + Ramp 2 Side	Both Side Ramp
7	3+580	3+725	8Lanes (4L + 2L + 2L)	3 Pier Portal	Merging
8	6+750	7+060	4 Lanes PS	RE wall	Approach
9	7+060	8+680	4 Lanes PS	Single Pier	
10	8+680	9+790	4 Lanes PS	Single Pier	Crossing Metro
11	9+790	10+150	6 Lanes (4L PS+ 2L)	Single pier + Ramp 1 Side	One Side Ramp
12	10+150	10+715	4 Lanes PS	Single Pier	
13	10+715	11+135	6 Lanes (4L PS+ 2L)	Single pier + Ramp 1 Side	One Side Ramp
14	11+135	11+185	8 Lanes ((2L + 2L) + ((2L + 2L))	3 Pier Portal	Merging
20	11+185	11+435			Interchange
21	11+435	11+715	8Lanes (4L + 2L + 2L)	Single pier + Ramp 2 Side	Both Side Ramp & No approach
22	11+715	11+795	4Lanes	Single Pier	
23	11+795	12+300	4 Lanes PS	2 Pier Portal	
24	12+300	12+500	4 Lanes PS	Single Pier	
25	12+370	12+400	4 Lanes PS	2 Pier Portal	Merging
26	12+400	12+460	4 Lanes	Single Pier	
27	12+460	12+500	4 Lanes	2 Pier Portal	Merging
28	12+500	13+415	4 Lanes	Single Pier	

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
29	13+415	13+455	4 Lanes	2 Pier Portal	
30	13+455	13+495	4 Lanes	Single Pier	
31	13+495	13+535	4 Lanes PS	2 Pier Portal	Merging
32	13+535	13+780	4 Lanes PS	Single Pier	
33	13+780	13+795	4 Lanes (2L + 2L)	2 Pier Portal	Merging
34	13+795	13+875	3Lane	Cantilever Pier	
35	13+875	17+675			Overlap with NS
36	17+675	17+960	4 Lanes PS	Single Pier	
37	17+960	18+640	8Lanes (2L+4L PS+ 2L)	Single pier + Ramp 2 Side	Both Side Ramp
38	18+640	19+435	4 Lanes PS	Single Pier	
39	19+435	19+515	4 Lanes PS	2 Pier Portal	
40	19+515	19+715	4 Lanes PS	Single Pier	
41	19+715	19+795	4 Lanes PS	2 Pier Portal	
42	19+795	20+320	8Lanes (2L+ 4L PS + 2L)	Single pier + Ramp 2 Side	Both Side Ramp
43	20+320	20+480	4 Lanes PS	Single Pier	
44	20+480	20+520	4 Lanes PS	2 Pier Portal	
45	20+520	20+970	4 Lanes PS	Single Pier	
46	20+970	21+070	4 Lanes PS	(1 x 100 ) Bowstring bridge	

Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
47	21+070	21+915	4 Lanes PS	Single Pier	
48	21+915	22+475	8Lanes(2L+4L PS+2L)	Single pier + Ramp 2 Side	Both Side Ramp
49	22+475	23+195	4 Lanes PS	Single Pier	
50	23+195	23+945	4 Lanes PS	Single Pier	
51	23+945	27+945	4 Lanes (2L + 2L)	Single Pier	Both Side Ramp

## 5.10.4.2.2 Loops:

Table 5-40: East West-1 Structural Typical Cross Section of Loops

Sl No.	From	To	Proposed Lane Configuration	Proposed Pier Configuration	Remark
Pomarade Road					
1	12+37 0	12+450	3 Lanes	2 Pier Portal	Merging
2	12+45 0	13+610	3 Lanes	Single Pier	
3	13+61 0	13+650	3 Lanes	2 Pier Portal	Merging
4	13+65 0	13+720	3 Lanes	Single Pier	
5	13+72 0	13+760	3 Lanes	2 Pier Portal	Merging
Whitefield to Rammurthy Nagar					
1	0+000	0+140	3 Lane		Approach
2	0+140	0+870	3 Lane	Single Pier	RHS
3	0+140	2+150	3 Lane	Single Pier	LHS

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Sl No.	From	To	Proposed Lane Configuration	Proposed Pier Configuration	Remark
4	2+150	2+470	4 Lane	Single Pier	
5	2+470	2+630	4 Lane	3 Pier Portal	
6	2+630	2+780	4 Lane	Single Pier	
7	2+780	3+010	10 Lane ((2L + 3L)) + ((3L + 2L))	3 Pier Portal	Merging
8	3+010	3+255	4 Lane	Single Pier	
9	3+255	3+295	10 Lane ((2L + 3L)) + ((3L + 2L))	3 Pier Portal	Merging
10	3+295	5+575	4 Lane	Single Pier	
11	5+575	5+835	4 Lanes (2L + 2L)	Single Pier on Both Sides	RHS Ramp
12	5+575	6+395	4 Lanes (2L + 2L)	Single Pier on Both Sides	LHS Ramp
INTERCHANGES					
KR Puram					
1	3000	2 Lane	Single Pier	Loops	
Ulsoor Lake					
2	640	2 Lane	Single Pier	Loops	
3	280	4 Lane	Single Pier		

## 5.10.4.3 East West Corridor 2:

## 5.10.4.3.1 Main Corridor:

Table 5-41: East West-2 Structural Typical Cross Section

Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
1	0+000	0+340	4Lanes	Approach both sides	Approach
2	0+340	3+780	4Lane PS	Single Pier	
3	3+780	3+820	6Lanes(4L PS + 2L)	2 Pier Portal	
4	3+820	4+820	4Lane PS	Single Pier	
5	4+820	4+880	4 Lane PS	2 Pier Portal	
6	4+880	5+730	4 Lane PS	Single Pier	
7	5+730	5+930	8Lanes (4L PS + 2L +2L)	Single Pier + Ramp both Side	Merging
8	5+930	5+970	8Lanes (4L PS +4L PS)	2 Pier Portal	
9	5+970	6+570	4 Lane PS	Single Pier	Split CW on Common Pier
10	6+570	6+990	8Lanes (4L PS + 2L +2L)	Single Pier + Ramp both Side	Split CW on Individual Pier
11	6+990	7+030	8Lanes (4L PS + 4L PS)	2 Pier Portal	Split CW on Individual Pier
12	7+030	7+920	4 Lane PS	Single Pier	Split CW on Individual Pier
13	7+920	8+170	6L (4L PS + 2L)	Single Pier +Ramp 1 Side	No Improvement
14	8+170	8+200	6L (4L PS + 2L)	2 Pier Portal	Approach
15	8+200	13+500	4 Lane PS	Single Pier	
16	13+500	13+540	6L (4L PS + 2L)	2 Pier Portal	Crossing Metro
17	13+540	13+820	6L (4L PS + 2L)	Single Pier +Ramp 1 Side	One Side Ramp
18	13+820	14+780	4 Lane PS	Single Pier	5m difference
19	14+780	14+820	4 Lane PS	2 Pier Portal	One Side Ramp
20	14+820	15+180	4 Lane PS	Single Pier	Merging
21	15+180	15+210	4 Lane PS	2 Pier Portal	Interchange
22	15+210	15+240	2 Lane	Single Pier	Both Side Ramp & No approach
23	15+240	15+445	3 Lane	2 Pier Portal	
24	15+445	15+555	4 Lane (2 L + 2L)	2 Pier Portal	

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Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
25	15+555	16+995	4 Lane PS	Single Pier	
26	16+995	17+040	4 Lane(2L +2L)	2 Pier Portal	Merging
27	17+040	17+060	2 Lane	Cantilever Pier	
28	17+060	17+550			Existing Flyover
29	17+550	19+900			Overlap with NS Corridor
36	19+900	19+960	4 Lane (2 L + 2L)	2 Pier Portal + Ramp 1 Side	
37	19+960	22+550	2 Lane	Single Pier	
38	22+550	22+580	4 Lane (2L + 2L)	2 Pier Portal	Merging
39	22+580	24+865	4 Lane PS	Single Pier	
40	24+865	25+025	8 Lane ( 2L + 4L PS+ 2L)	Single Pier + 2 Side Ramp Cantilever Pier	Merging
41	25+025	25+410	2 Lane	Single Pier Both Side	
42	25+410	25+730	2 Lane	Single Pier	Overlap with NS
43	25+730	26+465	2 Lane	Approach Both sides	

## 5.10.4.3.2 Loops:

Table 5-42: East West-2 Structural Typical Cross Section of Loops

Sl No.	From	To	Proposed Lane Configuration	Proposed Pier Configuration	Remark
1	17+560	17+960			Overlap with NS Corridor
2	17+960	18+630	2 Lane	2 Pier Portal	From Subbaiah Circle to JC Road
3	18+630	19+110			Overlap with NS Corridor
4	19+110	21+680	2 Lane	2 Pier Portal	From Sirsi Circle to JC Road
5	1+415	1+455	2 Lane	2 Pier Portal	From Hudson Circle to Richmond Circle via Raja Rammohan Roy Rd
6	1+455	1+615	2 Lane	2 Pier Portal	
7	1+615	1+775	2 Lane	2 Pier Portal	
8	1+775	2+375	2 Lane	Single Pier	
9	2+375	2+500	2 Lane	2 Pier Portal	
10	2+500	2+720	2 Lane	Single Pier	

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Sl No.	From	To	Proposed Lane Configuration	Proposed Pier Configuration	Remark
11	2+720	2+770	2 Lane	2 Pier Portal	

## 5.10.4.4 Connecting Corridor 1:

Table 5-43: Connecting Corridor-1 Structural Typical Cross Section

Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
1	0+000	0+400	4Lanes (2L + 2L)	Cantilever Pier Both side	Split CW on Individual Pier
2	0+400	4+000	4Lanes	Single Pier	
3	4+000	4+475	2 Lanes	Single Pier	2nd Level

## 5.10.4.5 Connecting Corridor 2:

Table 5-44: Connecting Corridor-2 Structural Typical Cross Section

Sl. No	CHINAGES		Proposed Lanes Configuration	Proposed Pier Configuration	Remark
	FROM	TO			
1	0+000	0+555	3 Lane	2 Pier Portal	Split CW LHS
2	0+000	0+290	3 Lane	2 Pier Portal	Split CW RHS
2	0+555	1+695	4Lanes	Single Pier	2 <sup>nd</sup> Level
3	1+695	2+075	8Lanes (4L + 2L +2L)	Single Pier + Ramp 2 Side	Two Side Ramp
4	2+075	2+470	4Lanes	Single Pier	1 <sup>st</sup> Level



### 5.10.5 Structural Analysis/ Design Methodology

Structural Analysis shall be clearly identified and explained for evolving a comprehensive design methodology, which covers all aspects of design for various parts of the bridges/ structures (viz. superstructure, substructure, foundations & bearings).

A design methodology has been presented in Vol II of Main report.

CHAPTER – 6  
ENVIRONMENTAL ASPECTS



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## CHAPTER 6 : ENVIRONMENTAL ASPECTS

### 6.1 INTRODUCTION

Bengaluru's vehicle population has been growing day by day and there has been an uncontrolled and exponential growth in number of vehicles. This out growing numbers of vehicles are choking the city roads with frequent traffic jams and have made traffic police helpless. This increase in number of vehicles is adding to the problems of congestion, accidents, noise pollution and air pollution apart from spending more than 240 hours of time stuck in traffic every year ultimately resulting in loss of productivity, reduced quality of life, and increase in costs for services and goods.

As the widening of Bengaluru city roads is not possible due to narrow and highly developed roads, we are only left with the option of going vertical by going for elevated corridor which would counter the traffic woes of the city in the form of traffic congestion and may provide solution for many of the traffic related problems. The project envisages separating the cross-city traffic and the neighborhood traffic, with an aim to decongest the core city areas and provide easy access to different parts of the city and the suburban towns near to Bangalore city.

The project is planned based on two traffic directions of the city i.e North-South and East-West, with interconnecting and loop elevated corridors. In this context, Government of Karnataka has planned for elevated corridors to ensure safe, fast and congestion free connectivity to different parts of city by three main corridors (North-South and East-west (1&2)) and three connecting corridors. Details of elevated corridors is as shown in below *Table 6-1*.

**Table 6-1: Details of the Proposed Elevated Corridors**

SI No.	Name of the Corridor	Corridor Length (Km)	One way loop(Km)	Total Length (Km)
<b>Phase I</b>				
1	NS-1: North-South Corridor-1 connecting Hebbal to Central Silk Board (i.e., NH-7 towards Bellary to NH-7 towards Hosur)	15.22	12.57	27.79
2	CC-1: Connecting Corridor-1 Connecting East-West Corridor-2 at St. John's Hospital Junction to Agara on Outer Ring Road	4	0.45	4.45
<b>Phase II</b>				
3	EW-1: East-West Corridor-1 connecting K.R. Puram to Gorguntepalya (i.e., NH-4 towards Old Madras and NH-4 towards Tumkur Road)	5.85	3.70	9.55
4	CC-2: Connecting Corridor-2 Connecting East-West Corridor-1 at Ulsoor to East-West Corridor-2 at D'souza circle.	2.80	-	2.80
5	CC-3: Connecting Corridor-3 Connecting East-West Corridor-1 at Wheeler's road jn.to Hennur Flyover at Outer Ring Road	4.20	-	4.20
<b>Phase III</b>				
6	EW-2: East-West Corridor-2 connecting Varthur Kodi to Jnanabharathi (Old Airport Road, SH-35 to Mysore Road, SH-17)	23.30	5.360	28.660
<b>Phase IV</b>				
7	EW-1 Additional Corridor from Rammurthy Nagar (Ring road) to ITPL Stretch	11	-	11
<b>Total Length</b>		<b>87.86</b>	<b>21.82</b>	<b>87.86</b>



The alignment of the proposed elevated corridors improvement proposal is for two/four/six/ten lanes depending on the requirement and the availability of the space. The width of the elevated corridors may vary from 18 m to 62 m.

## **6.2 Environmental Impact Assessment (EIA)**

The main objective of the Environmental Impact Assessment is to identify the impact of the elevated corridor project on environment, and to ensure these environmental factors are considered in decision making. The assessment helps to alleviate the impacts either by avoiding the development proposals or by proposing mitigation and management measures.

The Environmental Impact Assessment Report is prepared in order to achieve the following objectives:

- Understanding the requirements of elevated corridor project.
- Review information about the general environmental settings along the project corridor as baseline data;
- Review the applicability of National and State framework and relevant guidelines and policies to the project implementation.
- Identify significant potential impacts of the project and characteristic of the impacts, magnitude, distribution, project affected group, and their duration to ensure that environmental considerations are given adequate importance in the selection and design of proposed improvements.
- Identifying Valued Environmental Components (VECs) and to formulate a screening criteria to help in the analysis of alternatives.
- Develop a broad frame work of mitigation measures and environmental management plan addressing identified impacts.

## **6.3 Applicability of Environmental Impact Assessment Notification to the project**

As per the EIA Notification, prior Environmental Clearance (EC) is required for certain types of projects. All developmental projects can be categorized under Category 'A' and Category 'B', subject to certain considerations listed in the Schedule.

Elevated corridors do not have a mention in the list of projects qualifying for environmental clearance as per EIA Notification and its amendment. Though, certain stretches of alignment of elevated corridor forms a part National Highways (NH 4 & NH 7) and State Highways, elevated corridors cannot be classified as NH or SH looking at their functional and locational roles.

As the elevated corridors are proposed for decongesting Bengaluru city roads projects can be classified under transportation sector, and considering these elevated corridors as a part of national and state highways which do have mention in the schedule of Notification, the total length of the main elevated corridor is 102.04 km, but it involves additional right of way or land acquisition less than 40 m along the existing alignments. The proposed six elevated corridors having a length of 102.04 km is to decongest the internal city roads and to give access controlled connectivity to the arterial roads which are connecting important neighbouring towns and cities. The elevated corridors are not continuous in nature to be considered as one project, but it constitutes of 6 different corridors connecting different parts of the city, hence the total length of all six corridors need not be considered as length to be qualified for environmental clearance.



The elevated corridor will be supported by pier structures from the median and all possible efforts will be made to limit width of the corridor within the available Right of Way (ROW). Hence, additional right of way or total width of acquisition along the proposed alignments does not exceed 40 m. In fact, one of the main objectives is, to minimise the land acquisition except for junction improvements and at entry and exit points to link proposed elevated corridors with the existing roads beneath (at grade). Hence considering both length and width of the project corridor do not qualify for environmental clearance.

However, an elevated corridors project is being considered under Townships and Area Development Projects (Item 8(b) of the Notification as per the NGT judgement in case of steel flyover project from Basaveshwara Circle to Hebbal, Bangalore (**Application Nos. 243 & 245 of 2016 (SZ)** for environmental clearance under Area Development projects and Townships, Category 8 (b) of EIA Notification, 2006 and subsequent amendments.

Proposed elevated corridor project has total built-up area of approximately 21,89,000 sqm and as it exceeds 3,00,000 sq. mtrs. qualifying under Schedule 8(b) of EIA Notification,.

The elevated corridor project is significantly different from building and construction projects in terms of project requirements, construction activities, environmental impacts and mitigation measures. The excerpts from EIA Notification for Highways and Area Development projects and Townships are given in the following table for reference.

Project or Activity	Category with threshold limit		Condition if any
	A	B	
<b>8</b>	<b>Building / Construction projects / Area Development projects and Townships</b>		
8(b)	Townships and Area Development projects	$\geq 1,50,000$ sq. mtrs and $< 3,00,000$ sq. mtrs built up area or covering an area $\geq 50$ ha and $< 150$ ha  $\geq 3,00,000$ sq. mtrs of built up area or covering an area $\geq 150$ ha <sup>1</sup>	Note - General Condition shall not apply".

#### 6.4 Clearances required for the project corridors

After reviewing various applicable acts and statutes mentioned above, it is understood that following clearances or permissions are required. A summary of clearances required for the project is shown in **Table 6-3**.

**Table-6-2: List of Clearances required for the Project**

Sl. No.	Subject	Relevant Act	Authority Granting Clearance/ In charge	When required
1	Environmental Clearance	EIA Notification, 2006 (including amendments) issued under Environment Protection Act, 1986	SEAC, MoEF, GoI	Before Construction
2	Consent / NOC for sub-projects	Air (Prevention and Control of Pollution) Act,	KSPCB, Karnataka	Before Construction

<sup>1</sup> Amendment made through Notifications dated 9th December 2016; 13th March 2018; & 3rd April 2018.



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Sl. No.	Subject	Relevant Act	Authority Granting Clearance/ In charge	When required
		1974 Water (Prevention and control of Pollution) Act, 1981		
3	Permission for cutting of trees and transportation	Karnataka Tree Preservation Act, 1976 & Forest Conservation Act, 1980	State Forest Department, MoEF, Govt. of India	Before Construction
4	Permission for construction of elevated corridor within prohibited area of protected Monuments and Heritage structures of Bangalore.	The Ancient Monuments and Archaeological Sites and Remains Act 1958 and subsequent amendments. listed in Revised Master Plan	National Monument Authority, GOI.	Before Construction
5	No Objection Certificate (NOC) for Crushers, Batching Plants, Wet Mix Macadam plants, Hot mix plants	Air (Prevention and Control of Pollution) Act, 1981 and Noise Pollution (Regulation and Control) Rules, 2000	KSPCB, Karnataka	During Construction
6	Storage, handling and transport of hazardous materials	Hazardous Waste (Management and Handling) Rules, 1989 and Manufacturing, Storage and Import of Hazardous Chemicals Rules, 1989	KSPCB, Karnataka	During Construction
7	Traffic Management and Regulation during operation	Local Traffic Police instructions/Regulations	Traffic Police Department	During Construction
8	Installation of Generators	Air (Prevention and Control of Pollution) Act, 1974	KSPCB	Before Installation
9	License for storing Diesel/Fuel	Petroleum Rules, 2002 (Amended in the year 2011) of the Petroleum Act, 1934.	Commissioner of Explosives	During Construction
10	Location/ layout of workers camp, equipment and storage yards	Environment Protection Act, 1986 The Building and Other Constructions Workers' (Regulation of employment & Conditions of Service) Act, 1996. International Labour Organisation (ILO)	KSPCB, District Health Officer	During Construction

Sl. No.	Subject	Relevant Act	Authority Granting Clearance/ In charge	When required
11	Employing Labour/ workers	The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996	District Labor Commissioner	Before Construction
11	Permission for withdrawal of groundwater for construction	Environment (Protection) Act, 1986	Central Ground Water Board, Ahmedabad	During Construction
12	Rehabilitation & Resettlement of Displaced families	KIADB Act with compensation at par with RFCTLARRA 2013.	GoI	Before start of construction
13	Construction within the regulated area of Archaeological Monuments	The Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act 2010	National Monuments Authority, GoI	Before start of construction

## 6.5 Baseline Environment

Information on baseline environment was collected from secondary source of data for the macro environmental parameters like climate, physiography (topography and geomorphology), biological and socio-economic environment of the project influence area, The micro-environmental details within the proposed Right of Way have been collected from primary sources of data during reconnaissance survey, extrapolation of environmental features on the proposed design, tree enumeration, etc.

Field visits have been carried out to identify environmentally sensitive locations such as air sensitive, noise sensitive, nearby water bodies and dense tree corridors along the proposed corridors, documenting them on base maps and google earth images to confirm locations of environmental conflict. Environmental monitoring of air, noise, water, soil and meteorological parameters will be undertaken as per the State Environmental Impact Assessment Authority (SEIAA) recommended Terms of References (TOR) through an approved laboratory.

## 6.6 Potential Environmental Impacts

The proposed elevated corridor project aims to ease the traffic nuisance being faced by Bengaluru dwellers and contributes towards better infrastructure and improved connectivity. Improved access to job locations, education, health facilities, market centers, tourist places and other essential services for the public of the city and dependent rural areas in the region; reduced sufferings during monsoons and adverse climatic conditions; improved public safety and security; productive use of time which influences and improves the income patterns; improves the quality of life and human dignity; opens up opportunities for social interaction; etc. All these factors improve economic and social welfare of communities in the vicinity and the state as a whole.

For all the positive impacts, road improvement projects could also generate some adverse impacts on environment. The direct environmental impacts are usually due to activities that are directly related to construction and rehabilitation activities, while indirect environmental impacts are usually related to



the operation of improved roads. Such indirect environmental impacts include cumulative impacts due to improved access to certain geographic areas.

Impacts of the elevated corridor project can be appropriately discussed under following heads.

- I. Impacts during Pre-construction Phase.
- II. Impacts during Construction Phase.
- III. Impacts during Operation Phase.

The proposed elevated corridor project will cause following significant impacts during pre-construction and construction phases.

- It is estimated that approximately 98 acres of land to be acquired along the alignment of the proposed six corridors. Most of the land acquired is for ramps, junction improvements, grade separators which are integral parts of the proposed project.
- Approximately 4,34,500 cum of debris would be generated from the excavations for piles and pile cap out of which 75% of the debris suiting to the requirements of soil fillings shall be utilized for ramp construction and 25 % of unserviceable materials shall have to be disposed in borrow pits or abandoned quarries in an environmentally sustainable manner.
- There are altogether 10 water bodies in the vicinity of project however, project alignment passes close to only three lakes that is Ulsoor lake, Varthur Lake and Agara Lake. Stringent mitigation measures will be taken up to avoid and reduce the impact of construction activities.
- Waste water generated at construction camps and labour camps will be treated to the standards prescribed by CPCB to water pollution in the vicinity of the project associated construction camps and labour camps.
- City traffic will get disrupted during the construction phase of the project due to traffic diversions which will be handled by effective traffic management and diversion plans.
- Generation of dust by the project activities like site preparatory earthworks; demolition of existing structures; foundation excavation works; erection and use of heavy equipment & machinery; loading, transporting and unloading soil and construction materials and material handling; traffic diversion; etc. is the main air quality issue associated with construction of the proposed elevated corridor. In addition to dust, it is also expected that project activities could release air pollutants like SO<sub>2</sub>, NO<sub>x</sub>, CO, Lead, Benzene and Volatile Organic Compounds (VOC). Proper dust and emission mitigation measures are proposed in the EMP to handle the dust during various phases of project implementation to prevent adverse impact on air sensitive receptors.
- The air pollutants emission is likely to come down to a greater extent by the operating vehicles on elevated corridor with extensive savings on consumption of fuel because of the signal free uninterrupted traffic movements.
- Project corridor alignment has more than 60 air and noise sensitive receptors such as schools, colleges, hostels, hospitals, libraries including 30 km stretch of communities (built-up sections). Dust mitigation by regular sprinkling of water and noise mitigation measures such as provision of barricades during construction and noise barriers will be made at all the identified air and noise sensitive receptors to reduce the impact during construction and operation stages.



- 3716 trees may get impacted by the project which seems to be the most significant to Bangalore city. The sincere efforts shall be made to save trees and avoid tree cutting at all the stages of the project implementation by just pruning the branches wherever possible. Attempt shall also be made to translocate at least 20 % of the trees being impacted to nearby identified locations. In addition at-grade median plantation will be taken up all along the proposed alignment and vertical gardens will be proposed on the piers of elevated corridor. In addition to above for every tree impacted it shall be compensated at the rate of ten trees as per the direction of Forest Department.
- There are two notified archaeological structures along the North - South corridor. Tipu Sultan's Summer Palace being a protected monument as per the Ancient Monuments and Archaeological Sites and Remains (Amendment & Validation) Act, 2010(prohibited area), is within a distance of 100 metres from the proposed East West Corridor - 2. Another notified structure Old Dungeon Fort & Gates is at a distance of 330 m from the proposed North - South corridor, beyond regulated area (200 meters further beyond prohibited area as per the latest circular). Required permission / NOC will be obtained from Archaeological Survey of India before construction of elevated corridor.
- The project would impact on the livelihood, public services, health and safety of community and labourers temporarily during construction of the project. Inconveniences caused by utility shifting, excavations, unplanned stacking of excavated earth and traffic diversions in the vicinity of project corridors will be handled suitably as per the Statutory provisions.

The impacts of the project on the environment during operational phase are summarized as below **Table 6-3**.

Apart from adverse impacts, construction of elevated corridor in a city like Bengaluru will also yield tangible benefits such as better accessibility, less atmospheric air pollution, less travel time, comfort and improved quality of life. The impact on the economic growth of the city, improved quality of life, reduced air pollution and its impact on health and wellbeing of city dwellers which are difficult to quantify. The project is expected to generate employment in the secondary and tertiary sector during construction and operation phases respectively. The proposed corridor will be safer, efficient and faster compared to the present roads. Proposed elevated corridors are aimed to provide quick access and reduce traffic congestion on the main roads in the city. Ease of traffic movement on the elevated corridors and reduction of vehicles on at grade roads will help in reduction of fuel consumption in the city and corresponding reduction in gaseous emissions and improves the air quality in the city. Any reduction in traffic and traffic congestion will also contribute for reduction in the noise levels.

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**Table-6-3: Environmental Impact Matrix for the Proposed Elevated Road Project**

Environmental Attributes  Different components of project implementation	Physical Environment						Biological Environment		Social Environment			Cultural Environment
	Air Quality	Surface & Ground water quality	Noise	Soil	Hydrology & Natural Drainage	Topography	Destruction of Habitat		Public Health & Safety	Land use	Public well-being	Temples and Archaeological monuments
							Flora	Fauna				
<b>I. Pre-construction Phase</b>												
Land acquisition	-	-	-	-	-	-	-	-	-	.ve/p	-ve/p	-ve/p
Demolition of physical properties	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	-ve/t	-ve/t	-ve/t	-	-	-ve/t	<b>.ve/p</b>	-ve p	<b>-ve p</b>
Cutting of Trees	<b>-ve/p</b>	<b>-ve/p</b>	-ve/p	<b>-ve/p</b>	<b>-ve/p</b>	-	<b>-ve/p</b>	<b>-ve/p</b>	<b>-ve/p</b>	<b>-ve/p</b>	<b>-ve/p</b>	-
Utility shifting	-ve/t	-	-ve/t	-ve/t	-ve/t	-ve/t	-ve/t	-	-ve/t	-ve/p	-ve/t	-
<b>II. Construction Phase</b>												
Clearing, Grubbing	-ve/t	-ve/t	-ve/t	-ve/p	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/p</b>	<b>-ve/t</b>	-ve/t	-ve/t	-ve/t	-
Borrowing & Quarrying	-ve/p	-ve p	-ve p	-ve/p	<b>-ve/p</b>	<b>-ve/p</b>	<b>-ve/p</b>	-ve/p	-ve/t	<b>-ve/p</b>	-	-
Pile Foundation	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	<b>-ve/t</b>	-ve/p	-ve/t	-	-	-ve/t	-	-ve/t	-
Casting and casting yards	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	-ve/t	-ve/t	-ve/t	-ve/t	-	-ve/t	-ve/t	-ve/t	-
Material Transport & Storage	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	-	-	-ve/t	-ve/t	-	-
Traffic Diversion	<b>-ve/t</b>	-	<b>-ve/t</b>	-ve/t	-	-	-ve/t	-ve/t	-ve/t	<b>-ve/t</b>	-ve/t	-
Labour/Construction Camp Activities	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	<b>-ve/t</b>	-ve/t	-
Batching Plant & Hot Mix Plant	<b>-ve p</b>	<b>-ve/t</b>	<b>-ve/t</b>	<b>-ve/t</b>	-ve/t	<b>-ve/t</b>	-ve/p	-	<b>-ve/t</b>	-ve/p	<b>-ve/t</b>	-
Use of Construction Equipment	<b>.ve/t</b>	-	<b>.ve/t</b>	-ve/t	-ve/t	-	-ve/t	-	-ve/t	-	-ve/t	-
Pavement works	<b>-ve/t</b>	-ve/p	<b>-ve/t</b>	-	<b>-ve/p</b>	-	-ve/t	-	.ve/t	-	-	-
<b>II. Operational Phase</b>												
Tree Plantation	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>	<b>.ve/p</b>
Vehicular Movement	<b>-ve/p</b>	-	<b>-ve/p</b>	-	-	-	.ve/p	.ve/p	<b>.ve/p</b>	-	<b>.ve/p</b>	<b>.ve/p</b>

Note: t – Temporary; p- Permanent; Impacts indicated in bold letters are significant impacts.

The impacts indicated above are indicative and represent the impact without mitigation measures.



## 6.7 Matrix Representation

The potential impacts during construction and operation phases are presented in the form of a matrix in **Table 6-5**. The table of matrix indicates the significance of the impact of different project activities both during construction and operation phases of the project. The quantification of these impacts is done using numerical scores from 0 to 5 as per the following criteria.

**Table-6-4: Score to Quantity the Impacts**

Sl. No.	Impact Indicators	Severity criteria	Impact Score
1	-	No impact	0
2	-ve t	Slight/ Short-term Impact	1
3	-ve t	Occasional reversible Impact	2
4	-ve p	Irreversible/ Long-term Impact	3
5	-ve p	Permanent damage	4

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Scores for various environmental parameters and project activities (Pre-construction and Construction phase) are presented in **Table 6-6**.

**Table-6-5: Cumulative Impact Score for the proposed elevated corridor project**

Environmental Attributes  Different activities of project implementation	Physical Environment						Biological Environment		Social Environment			Cultural Environment
	Air Quality	Surface & Ground water quality	Noise	Soil	Hydrology & Natural Drainage	Topography	Destruction of Habitat		Public Health & Safety	Land use	Public well-being	Temples and Archaeological monuments
							Flora	Fauna				
<b>I. Pre-construction Phase</b>												
Land acquisition	0	0	0	0	0	0	0	0	0	4	4	3
Demolition of physical properties	2	1	2	1	1	1	0	0	1	4	3	4
Cutting of Trees	4	4	3	4	4	0	4	4	4	4	4	0
Utility shifting	1	0	1	1	1	1	1	0	1	3	1	0
<b>II. Construction Phase</b>												
Clearing, Grubbing	1	1	1	3	2	2	4	2	1	1	1	0
Borrowing & Quarrying	3	3	3	3	4	4	4	3	1	4	0	0
Pile Foundation	2	1	2	2	3	1	0	0	1	0	1	0
Casting and casting yards	2	1	2	1	1	1	1	0	1	1	1	0
Material Transport & Storage	2	2	2	2	2	2	0	0	1	1	0	0
Traffic Diversion	2	0	2	1	0	0	1	1	1	2	1	0
Labour/Construction Camp Activities	2	2	2	2	1	2	2	1	2	2	1	0
Batching Plant & Hot Mix Plant	3	2	2	2	1	2	3	0	2	3	2	0
Use of Construction Equipment	2	0	2	1	1	0	1	0	1	0	1	0
Pavement works	2	3	2	0	4	0	1	0	1	0	0	0
<b>Total Cumulative Score</b>	<b>28</b>	<b>20</b>	<b>26</b>	<b>23</b>	<b>25</b>	<b>16</b>	<b>22</b>	<b>11</b>	<b>18</b>	<b>29</b>	<b>20</b>	<b>7</b>

## 6.8 Determining the sensitiveness of Project Corridor

For analysis of sensitiveness of the project corridor, twelve categories of commonly and frequently occurring environmental attributes present in impact zone, such as inhabitants resided within 50 m from the corridor; trees being cut and pruned within the corridor of impact and buffer zone respectively; impact of noise on noise sensitive receptors like schools, education institutions & hospitals; sensitive religious and community establishments; commercial establishments along the corridor; water bodies adjacent to project corridor; narrow and congested locations which are prone to increased air and noise pollution; impact on the common utilities like electrical lines, water pipelines, optical fibres, manholes; impact from project associated construction establishments such as borrow areas, quarries, batching plants, hot mix plants, construction camps, crushers, etc., are considered.

The total negative impact of various project activities (15 major activities) on an environmental parameter is represented as a cumulative impact score and the cumulative scores of various environmental parameters (12 Nos.) are given as total cumulative score. Any particular parameter having an individual score greater than 10 or more implies serious effects due to the project and calls for suitable mitigation measures. Implementation of mitigation measures in the form of Environmental Management plan will bring down the impact score of the project and reduces the sensitiveness of the project.

## 6.9 Environmental Management and Monitoring Plan

Environmental Management Plan (EMP) deals with the implementation procedure of the guidelines and mitigation measures recommended to avoid, minimize and mitigate foreseen environmental impacts of the project. It also includes management measures suggested for enhancement of the environmental quality along the proposed roads.

For each negative impact of the project, the mitigation measure, its timeframe for implementation and overseeing / supervision responsibilities are discussed. To ensure that the EMP is implemented, Environmental monitoring plan is also prepared for some of the performance indicators indicating locations of monitoring, frequency of monitoring, responsibility of monitoring,

## 6.10 Institutional Arrangements, Capacity Building and Training Programme

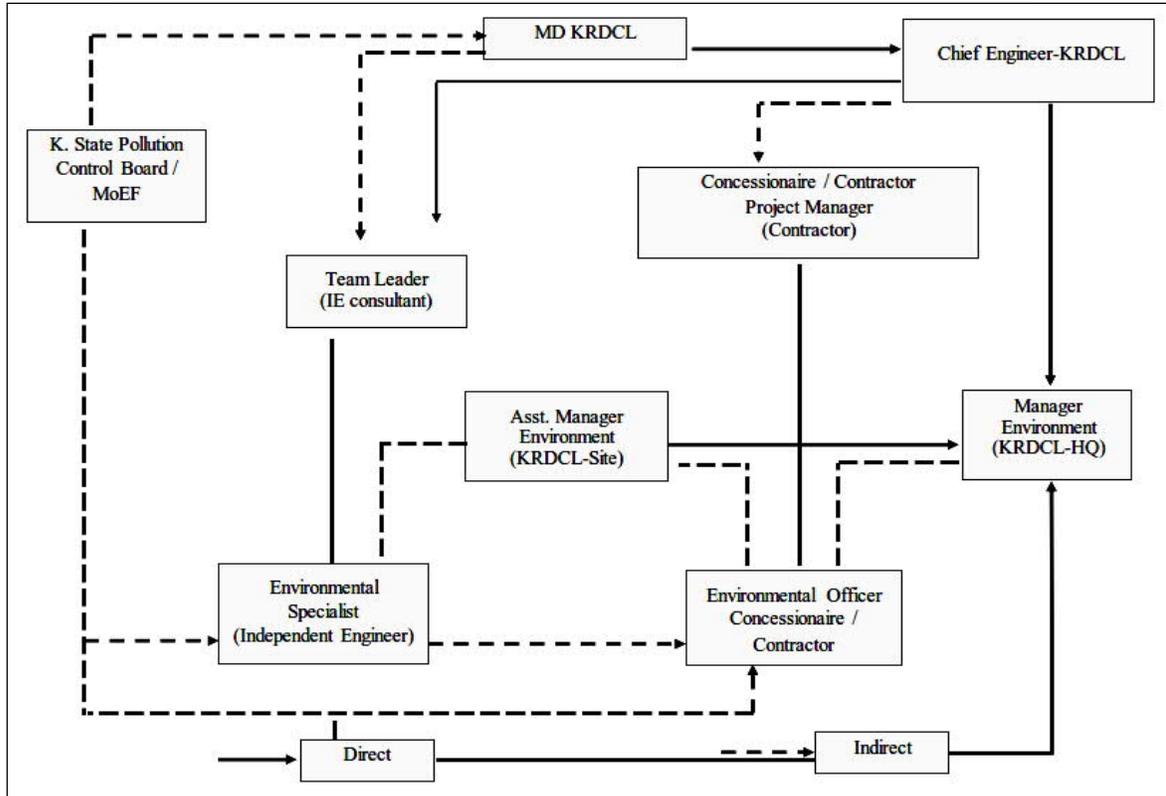
Project Implementation Unit (PIU) is responsible for implementing the project to ensure and achieve certain level of quality in the project, and make sure that the statutory requirements are not violated. The Managing Director heads KRDCL will be responsible for the successful implementation of the Project. The Chief Engineer is the head of Project Implementation Unit (PIU) of KRDCL set up for the implementation of the project. CE is assisted by Executive Engineers to look after all the technical issues of the project implementation and Manager (Environment) to look after Environmental issues of the project. It is proposed to constitute sub unit, Environmental Management Plan Implementation Unit (EMPIU), which functions under PIU.

The Manager (Environment) and Social expert of KRDCL will look after the environmental and social issues during the project preparation, implementation and operation with the assistance of the Environmental Specialist of Project Design and Environmental Officer (EO) of the CSC in the respective phases of implementation.

During the operation phase monitoring will be carried out by PIU or the concessionaire depending on the contract modalities with the help of environmental monitoring agencies approved by the State or Central Pollution Control Board.

Relationship among Environmental Specialist of Construction Supervision Consultancy (CSC), Karnataka Road Development Corporation Limited (KRDCCL) and Contractor/Concessionaire with respect to supervision and monitoring of EMP is depicted in the following Figure 6-1.

**Figure 6-1: Relationship among Environmental Specialist of CSC, KRDCCL and**



**6.11 Environmental Budgetary Provisions**

The budgetary provision for the implementing EMP of the elevated corridor project has been made. The cost for EMP implementation is estimated to be Rs. 120 Crores.

**6.12 Conclusion**

The proposed elevated corridor project will have both negative and positive impacts on the environment. Significant adverse impact will be on avenue trees along the proposed corridor alignment. It is estimated that approximately 3716 trees are to be cut and around 601 are to be trimmed. The other significant adverse impacts from the proposed project will be deterioration of air quality from construction activities and its impact on air sensitive receptors; increase in noise levels and its impact on noise sensitive receptors like schools, colleges, hospitals due to construction equipment and activities, disturbances to city traffic due to traffic diversions; land use changes by land acquisition to accommodate the traffic lanes along the corridor, at ramps and proposed grade separators; impact on nearby water during construction; transportation and disposal of unserviceable debris generated from excavations and structure demolition and impact on the livelihood, public

services, health and safety of community in the vicinity and labourers during construction of the project. Most of identified adverse impacts of the project are temporary in nature and can be mitigated through specific engineering solutions incorporated into the project design; construction methodology during project implementation and the remedial measures as per EMP.

Proposed project will have advantages like the connectivity to major arterial roads like Bellary road, Hosur road, Hoskote road, Tumkur road, Mysore road, Sarjapura road; help segregating the fast moving long distance traffic without interrupting the slow moving neighbourhood traffic; elevated roads will decongest most of the major junctions and make way for traffic movement without hindrance thus emitting less air pollutants and facilitate pedestrians to use at grade roads more safely.

Further, with the current phenomenal growing rate of vehicle population and the absence of adequate public transport system, which is ultimately leading to traffic chaos, Bengaluru city surely needs a comprehensive, integrated and sustainable transportation infrastructure which gives a boost to productivity, improved quality of life.

CHAPTER – 7  
SOCIAL IMPACT AND RAP



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## CHAPTER 7 : SOCIAL IMPACT AND RAP

### 7.1 OBJECTIVES OF SOCIAL IMPACT ASSESSMENT

A social impact assessment (SIA) is a proactive and anticipatory tool used to help understand the potential impacts that a proposed project may have on a community. Social Impact Assessment (SIA) alerts the planners as to the likely benefits and costs of a proposed project, which may be social and/or economic. The knowledge of these likely impacts in advance can help decision-makers in deciding whether the project should proceed, or proceed with some changes, or dropped completely. The most useful outcome of a SIA is to develop mitigation plans to overcome the potential negative impacts on individuals and communities.

### 7.2 BASIC TENETS OF R&R PLANNING

- Avoid, if not, minimise the adverse impacts to the local population, through exploring alternatives.
- Where ever IR is unavoidable and inevitable, ensure that those affected by the project are compensated fully and fairly for assets lost and help them in their resettlement process

People facing involuntary displacement should be involved in planning and implementing resettlement programmes and provide them with range of options to choose appropriate and sustainable alternate activity and enhance acceptability

### 7.3 PROJECT DESCRIPTION

Elevated corridors traverse through urban area connecting North-South-East-West of Bangalore.

#### 7.3.1 Administrative Profile

The project roads traverses through 36 wards of BBMP, the details are given in Table 7-1.

Table 7-1: Administrative Profile

SI No	District	Corridor	Ward No
1	Bangalore Urban	NS	99
2			79
3			78
4			77
5			76
6			70
7			67
8			68
9			66
10			65

SI No	District	Corridor	Ward No	
11			39	
12			92	
13			41	
14			78	
15			82	
16			62	
17			91	
18			89	
19			97	
20			EW1	63
21				1
22				3
23				78
24				42
25		53		
26		EW2	96	
27			98	
28			51	
29			82	
30			62	
31			91	
32		CC1	38	
33		CC2	41	
34		CC3	74	
35			76	
36			72	

### 7.3.2 Project Area Profile

According to the 2011 census of India, the total population of Karnataka was 61,095,297 of which 30,966,657 (50.7%) were male and 30,128,640 (49.3%) were female, or 1000 males for every 973 females. This represents a 15.60% increase over the population in 2001. The population density was 319 per km and 38.67% of the people lived in urban areas. The literacy rate was 75.36% with 82.47% of males and 68.08% of females being literate.

Bangalore district with a total population of 96, 21,551 is the most populous district in the State. The total area of Bangalore district is 2196 sq. km. and it is the smallest district in the state in terms of area. The district has the highest a density of 4,381 and it ranks 1st in the State. Bangalore district accounts for 15.8 percent of the total population of the State and stands at 1st place in the State. Bangalore has the highest decadal growth rate of 47.2 percent in the State. Bangalore is the most urbanized district with 90.9 percent of its population residing in urban areas. It has the highest institutional and houseless population. The district has the lowest Sex ratio of 916 in the State. The district with a Sex ratio of 944 among the child population in the age-group 0-6 holds the 24th rank in the State. The proportion of child population (0-6 age-group) is 10.9 percent in the district and

holds the rank of 16th in the State. The district has a second highest literacy rate of 87.7 in the State. The male literacy rate in the district is 91.0 percent and the female literacy rate is 84.0 percent. Bangalore ranks at second place in terms of female literacy rate. The Scheduled Caste population contributes 12.5 percent and the Scheduled Tribe population contributes 2.0 percent to the total population of the district. The district has registered a work participation of 44.1 percent and stands at 21st place in the State. The work participation rates for Male and Female population in the district are 62.0 and 24.6 respectively, the female work participation rate being lowest in the state. Among the total workers in the district 90.9 percent are Main workers and 9.1 percent are Marginal workers. Major work force of 92.9 percent is Other Workers. Only 4.6 percent are engaged in Agricultural sector i.e., Cultivators (2.3 percent) and Agricultural Labourers (2.3 percent) and 2.6 percent of the total workers are engaged in Household Industry. About 55.9 percent of the total population in the district is non-workers. The list of project affected wards are given below in Table 7-2.

Table 7-2: List of Project Affected Wards

SI. No.	WARD NUMBER	WARD NAME
North – South Corridor		
1	35	Aramane Nagara
2	34	Gangenahalli
3	46	Jayachamarajendra Nagara
4	63	Jayamahala
5	78	Pulikeshinagar
6	93	Vasanth Nagar
7	111	Shantala nagar
8	110	Sampangiram nagar
9	117	Shanthi Nagar
10	118	Sudham Nagara
11	145	Hombegowda nagar
12	146	Lakkasandra
13	147	Adugodi
14	151	Koramangala
15	152	Suddagunte Palya
16	172	Madivala
17	173	Jakkasandra
18	114	Agaram
19	174	HSR Layout
1	50	Benniganahalli
2	57	C V Raman Nagar
3	79	Sarvagna Nagar
4	58	New Tippasandara
5	80	Hoysala Nagar
6	90	Halsoor
7	78	Pulikeshinagar
8	91	Bharathi Nagar

SI. No.	WARD NUMBER	WARD NAME
9	92	Shivaji Nagar
10	63	Jayamahala
11	35	Aramane Nagara
12	45	Malleswaram
13	60	Sagarapuram
14	59	Maruthi Seva Nagar
15	49	Lingarajapura
16	24	HBR Layout
17	29	Kacharkanahalli
1	149	Varthuru
2	84	Hagadur
3	85	Dodda Nekkundi
4	150	Bellanduru
5	86	Marathahalli
6	87	HAL Airport
7	113	Konena Agrahara
8	88	Jeevanbhima Nagar
9	112	Domlur
10	114	Agaram
11	111	Shantala Nagar
12	117	Shanthi Nagar
13	118	Sudham Nagara
14	143	Vishveshwara Puram
15	119	Dharmaraya Swamy Temple
16	140	Chamrajapet
17	142	Sunkenahalli
18	136	Jagajivanaramnagar
19	141	Azad Nagar
20	157	Gali Anjenaya Temple ward
21	134	Bapuji Nagar
22	133	Hampi Nagar
23	158	Deepanjali Nagar
24	111	Shantala Nagar
25	114	Agaram
26	90	Halsoor

East - West Corridor: 1

SI. No.	WARD NUMBER	WARD NAME
1	50	Benniganahalli
2	57	C V Raman Nagar
3	79	Sarvagna Nagar
4	58	New Tippasandara

SI. No.	WARD NUMBER	WARD NAME
5	80	Hoysala Nagar
6	90	Halsoor
7	78	Pulikeshinagar
8	91	Bharathi Nagar
9	92	Shivaji Nagar
10	63	Jayamahala
11	35	Aramane Nagara
12	45	Malleswaram
13	60	Sagayarapuram
14	59	Maruthi Seva Nagar
15	49	Lingarajapura
16	24	HBR Layout
17	29	Kacharkanahalli

East - West Corridor: 2		
SI. No.	WARD NUMBER	WARD NAME
1	149	Varthuru
2	84	Hagadur
3	85	Dodda Nekkundi
4	150	Bellanduru
5	86	Marathahalli
6	87	HAL Airport
7	113	Konena Agrahara
8	88	Jeevanbhima Nagar
9	112	Domlur
10	114	Agaram
11	111	Shantala Nagar
12	117	Shanthi Nagar
13	118	Sudham Nagara
14	143	Vishveshwara Puram
15	119	Dharmaraya Swamy Temple
16	140	Chamrajapet
17	142	Sunkenahalli
18	136	Jagajivanaramnagar
19	141	Azad Nagar
20	157	Gali Anjenaya Temple ward
21	134	Bapuji Nagar
22	133	Hampi Nagar
23	158	Deepanjali Nagar
24	111	Shantala Nagar
25	114	Agaram
26	90	Halsoor

### 7.3.3 Methodology

The key tasks carried out for the preparation of Social screening report are summarized below

- Collection of Secondary data: The ward maps are collected from BBMP and other concerned offices. Secondary data pertaining socio economic features of project corridors are gathered from various agencies including Census of India and other published information.
- Land acquisition and R&R procedures: Land acquisition for the Project will be carried out according to the Karnataka Industrial Area Development Board Act with compensation in par with the Right of Fair Compensation and Transparency in Land Acquisition and Resettlement and Rehabilitation Act 2013
- Social Screening Survey: In order to understand the impact of the project and identify the social sensitive locations, screening surveys are conducted all along the project stretches. Summary of findings are presented in this report and snap shots of the site screening survey is given in plate -1.
- Information Dissemination, Public Participation and Focus Group Discussions; Stakeholder consultations are an integral part of the Social Impact Assessment. Consultations will be carried out with a wide range of stakeholders including affected communities, government agencies, local bodies, NGOs/CBOs etc in the next level of the study. At this stage opinion from public are gathered through FGDs.



Figure 7-1: Snap shots of site activities

### 7.3.4 Additional Land requirements

The project will entail private land acquisition from private individual, as the collection of land records are being collected from the respective agencies the estimate at this stage is

tentative. Section wise details are summarized in below Table 7-3 and detail corridor wise shown in Table 7-4.

Table 7-3: Additional Land Requirement

Corridor Name	Total LA (Sqm)
NS (6-lane) incl CC-1	37956.78
EW-1 (4-lane) incl CC-2 & 3	316520.36
EW-2 (4-lane)	42536.66
Land Acquisition in Sqm	397013.81

Table 7-4: Additional Land Requirement

Corridor Name	Pvt Land		Defence Land		Central Govt Land		State Govt Land		Total Land		Remarks
	Sqm	Acre - Gunta	Sqm	Acre - Gunta	Sqm	Acre - Gunta	Sqm	Acre - Gunta	Sqm	Acre - Gunta	
CC-1	478.07	0-05					850.89	0-08	1328.96	0-13	
CC-2	2778.55	0-27					6897.26	1-28	9675.81	2-15	
CC-3	14194.91	3-20					20162.57	4-39	34357.48	8-19	
EW-1	44226.45	10-37			197225.48	48-30	31035.14	7-26	272487.08	67-13	
EW-2	29435.07	7-11	5339.58	1-13	7044.94	1-29	717.07	0-07	42536.66	10-20	
NS-1	22230.44	5-20	4313.75	1-03	4300.14	1-02	5783.50	1-17	36627.83	9-02	
Total	113343.49	28-06	9653.33	2-16	208570.57	51-21	65446.42	16-05	397013.81	98-02	

### 7.3.5 Impact on Buildings

Consultant conducted social screening survey along all the project corridors and identified social impact especially impact on buildings/ structures. Survey covered major structures like residential, commercial and other structures like compound wall, sheds, bathrooms, abandoned structures etc. Altogether, 382 buildings are identified as likely to be affected. Out of total 382 buildings, 70 are minor structures. Corridor wise impacts are illustrated in below sections and summary is presented in table 5.

- North South Corridor: This stretch having a total of 45 structures which include private and Government properties. As this link is the most sensitive stretch, consultant conducted a rapid assessment survey at this location. Hence actual number may vary as there are structures located in two layers. Among the total project stretch, most of the affected structures are residential buildings followed by commercial properties like shops, offices, go down etc.

- East West 1 Corridor: Out of 280 structures which includes commercial and other structure which includes compound wall, shed etc. and religious structures like small temples and shrine.
- East West 2 Corridor: A total of 57 structures are identified as affected, of which are commercial. Here also of structures falling in the category of other structures like Impact on Religious Properties

A total of 32 religious structures like small temples, mosque, shrines etc., were identified as affected religious structures. Category wise religious structures under all the corridors are summarized in the below Table 7-5.

Table 7-5: Category wise Religious Properties

Corridor	Temple	Church	Mosque	Total
North South incl CC1	5	5	3	13
EW1 incl CC2 & 3	20	1	0	21
EW2	11	0	0	11
Total	36	6	3	45

### 7.3.6 Impact on Government/ Community Properties

Among the total project affected buildings, 13 are identified as Government/ community properties. Category wise properties are given in the below Table 7-6.

Table 7-6: Category wise Govt./Community Properties

Corridor	Govt. Offices	Hospital	Hall	Compound Wall etc.	Total
North South	5	1	0	2	8
EW1	3	0	0	0	3
EW2	1	0	1	0	2
CC1	0	0	0	0	0
CC2	0	0	0	0	0
CC3	0	0	0	0	0
Total	9	1	1	2	13



7.3.7 Impact on Other Structures

Structures like compound wall, shed, bathrooms, abandoned structures etc., were included as other structures.

7.3.8 Impact on Tenants

As the project is in city limit, most of the buildings are having many numbers of tenants. Screening survey covers the same also and listed out a tentative figure which will further verify at the time of census survey. Category wise tenants under north south corridor, EW1 and EW2 are given in below Table 7-7.

Table 7-7: Details of Tenants

Corridor	No of Tenants	No of Employees
North South	64	96
EW1	471	222
EW2	708	1626
Total	1243	1944

7.4 LEGAL FRAMEWORK

Acts and R&R policies relevant to the project State is summarized in below section, however the Resettlement Framework for this project shall be finalized by EA prior to the preparation of Resettlement Plan.

Right of Fair Compensation and Transparency in Land Acquisition and Resettlement and Rehabilitation Act 2013

The Land Acquisition, Rehabilitation and Resettlement Bill, 2011 was introduced in Lok Sabha on 7 September 2011, passed by both the houses of parliament in 2013, and after receiving the assent of President of India, came into force as an act in January 1st , 2014. The Act has provisions to provide fair compensation to those whose land is taken away, brings transparency to the process of acquisition of land to set up factories or buildings, infrastructural projects and assures rehabilitation of those affected. This acts clearly states that each affected family irrespective of title, are eligible for R&R assistance. As per this Act, all the compensation and assistances should be disbursed to all the project affected families before taking possession of their land and assets.

The objectives of the Act are as follows:

- To ensure, in consultation with institutions of local self-government and Gram Sabhas established under the Constitution of India, a humane, participative, informed and transparent process for land acquisition for industrialization, development of essential infrastructural facilities and urbanisation with least disturbance to the owners of the land and other affected families.



- Provide just and fair compensation to the affected families whose land has been acquired or proposed to be acquired or are affected by such acquisition.
- Make adequate provisions for such affected persons for their rehabilitation and resettlement.

#### Salient features of RFCTLARR 2013

Bare minimum acquisition: Authority should try to avoid or minimise the acquisition by exploring all possible options.

Transparency in procedures: RFCTLARR 2013 assures 100% transparency in all procedures related to land acquisition. Public hearing to be conducted after giving adequate publicity on venue and time is mandatory while conducting SIA study. Feedback of project affected community and public representatives to be collected along with SIA.

Appraisal of SIA by an expert group- Studied SIA will be reviewed by an independent multi-disciplinary expert group which contains; (1) Two non-official social scientists (2) Two representatives from Gram Sabha or any PRI institution (3) Two experts in rehabilitation (4) A technical expert in the subject relating to the project.

Examination of proposals for land acquisition and SIA report by appropriate Government.

Publication of social impact assessment study- SIA report should be made available to the public in local language.

Provision for higher compensation. Nothing in the Act shall prevent any State from enacting any law to enhance or add to the entitlement enumerated under this Act which confers higher compensation than payable under this Act or make provisions for rehabilitation and resettlement which is more beneficial than provided under this Act.(S.107)

Special provision to safeguard food security: - no irrigated multi cropped land to be acquired

Payment for damage: pay or tender payment for any damage caused, and, in case of dispute as to the sufficiency of the amount so paid or tendered.

As per normal practice around 32 months' would require to take possession of land from private entity for infrastructure development projects under RFCTLARR, Act 2013. However, this may be reduced to 15 months through mobilization of more officers.

#### Relevance of RFCTLARR, Act 2013 in this project.

The Central Government has notified on January, 01, 2014 as the effective date of Act, in accordance with Sec 1(3). The acts specified in fourth schedule of RFCTLARR will have one year to adopt (i) compensation for land owners (First Schedule); (ii) rehabilitation and resettlement entitlements (second schedule); and (iii) provision of



infrastructure amenities (Third schedule).

Since, the act (Karnataka Highways Act, 1964) which is being used for land acquisition in Karnataka, has not been included in this category, Karnataka Highways Act, cannot be imposed for land acquisition. Moreover Govt of Karnataka has recently streamlined the procedure through notification.

7.4.1 The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Karnataka) Rules, 2015”

Government of Karnataka issued rules as provided in Section 109 of RFCTLARR Act 2013 namely “The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Karnataka) Rules, 2015”. Copy of gazette notification is enclosed as Appendix 7.1 of this report. These Rules, inter-alia, provide for the following.

- a) Chapter II deals with the matters pertaining to Social Impact Assessment Study (SIA) and all matters concerning the same including its publication, (Rules.3 to 13).
- b) Chapter III deals with the Process of Obtaining the Prior Consent (Rules 16-19)
- c) Chapter IV deals with the Preliminary Notification For Acquisition (Rule 20)
- d) Chapter V deals with the Rehabilitation and Resettlement Scheme and matters relating thereto (Rules 21- 38)

Rule 40 empowers the government for removal of difficulties either in the interpretation of the provisions of the Rules and implementation of the provisions.

Karnataka Industrial Area Development Board Act

Salient Features of the Section 28 of KIADB Act

- If at any time, in the opinion of the State Government, any land is required for development by the Board, or for any other purpose in furtherance of the objects of this Act, the State Government may by notification, give notice of its intention to acquire such land.
- On publication of a notification under sub-section (1), the State Government shall serve notice upon the owner or where the owner is not the occupier, on the occupier of the land and on all such persons known or believed to be interested therein to show cause, within thirty days from the date of service of the notice, why the land should not be acquired. 12
- After considering the cause, if any, shown by the owner of the land and by any other person interested therein, and after giving such owner and person an opportunity of being heard, the State Government may pass such orders as it deems fit.



- After orders are passed under sub-section (3), where the State Government is satisfied that any land should be acquired for the purpose specified in the notification issued under sub-section (1), a declaration shall, by notification in the official Gazette, be made to that effect.
- On the publication in the official Gazette of the declaration under sub-section (4), the land shall vest absolutely in the State Government free from all encumbrances.
- Where any land is vested in the State Government under sub-section (5), the State Government may, by notice in writing, order any person who may be in possession of the land to surrender or deliver possession thereof to the State Government or any person duly authorized by it in this behalf within thirty days of the service of the notice.
- If any person refuses or fails to comply with an order made under sub-section (5), the State Government or any officer authorized by the State Government in this behalf may take possession of the land and may for that purpose use such force as may be necessary.
- Where the land has been acquired for the Board, the State Government, after it has taken possession of the land, may transfer the land to the Board for the purpose for which the land has been acquired.

Section 29 of KIADB Act - 2007 compensation

- Where any land is acquired by the State Government under this Chapter, the State Government shall pay for such acquisition compensation in accordance with the provisions of this Act.
- Where the amount of compensation has been determined by agreement between the State Government and the person to be compensated, it shall be paid in accordance with such agreement.
- Where no such agreement can be reached, the State Government shall refer the case to the Deputy Commissioner for determination of the amount of compensation to be paid for such acquisition as also the person or persons to whom such compensation shall be paid.
- On receipt of a reference under sub-section (3), the Deputy Commissioner shall serve notice on the owner or occupier of such land and on all persons known or believed to be interested herein to appear before him and state their respective interests in the said land



## 7.5 CONCLUSION & WAY FORWARD

Land acquisition plan and schedules shall be prepared for the locations where ever additional land is required especially for provision of loops, ramps etc. Census survey for the project affected families also shall be conducted for the project affected families. The resettlement frame works shall be prepared in consultation with the Executive Agency. Organized public consultation shall be done in discussion with the key stakeholders.

CHAPTER – 8  
COST ESTIMATE



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## CHAPTER 8: COST ESTIMATE

### 8.1 General

The project cost estimates have been prepared based on various items of works required for the construction of the Proposed Elevated Corridors within Bengaluru Metropolitan Region, Bengaluru for different lane configuration.

The Major items rates for like Steel, Cement, Bitumen, M-Sand, Aggregates, labour and other items are from PWP IWTD SoR 2018-19, Bangalore Circle, Govt. of India.

### 8.2 Estimation of Quantities and Cost

In general, the work is to be executed as per Technical Specifications contained in "Specifications for Road and Bridge Works" (Fifth Revision- August 2015) issued.

The quantities of major items of road works have been worked out based on inventory; condition surveys pavement investigations data and geometric design output obtained from MX Software. The pavement quantities have been worked based on the geometrics and cross sections, pavement design done based on traffic and laboratory investigations. The following are the Bill wise of works, which have been estimated:

Site Clearance and Dismantling: The area considered for Site Clearance is the area within the proposed Right of Way width.

Earth Works: This item provides for roadway excavation, earthwork in embankment, sub-grade and shoulders, islands including disposal of surplus earth and unsuitable material. The earthwork quantities are based on design software MX-Road. Sub-grade having a CBR > 8 % will be taken from borrows area.

Sub-base, Base Courses: This item provides for the items of GSB and WMM for the main carriage way.

Bituminous Works: For flexible pavement, the subhead for bituminous works provides for all items of bituminous courses and surfacing.

Culverts: The estimation of quantities for culverts i.e. Box type & Hume Pipe were based on site inventory and condition survey.

Bridges and Elevated structures: The estimation of quantities for Major & Minor Bridge and elevated structures were based on site inventory, detailed design and drawings.

Drainage and Protection works: Provision under this sub-head has been made for surface, roadside drains, and Retaining wall / Reinforced Earth Wall respectively.

Traffic Signs and Road Appurtenances: Proper traffic signs were selected at required locations along the project corridor. It is reviewed considering the traffic and pedestrian safety and the number of traffic signs shall be minimum and modified if required. Centre line and edge markings required from safety point of view were considered in the quantity estimate.

Major/Minor Junctions Improvement: The junctions estimates are included in the related items as per above includes which need improvement along the highway.

### 8.3 Preamble

The project cost estimates have been prepared based on various items of works required for the construction of the Proposed Elevated Corridors within Bengaluru Metropolitan Region, Bengaluru for different lane configuration

The Major items rates for like Steel, Cement, Bitumen, M-Sand, Aggregates, labour and other items are from PWP IWTD SoR 2018-19, Bangalore Circle, Govt. of India.

### 8.4 Rates

The rates are as per the PWP IWTD SoR 2018-19, Bangalore Circle. Analysis of rates for items not given in the SoR, analysis has been carried out based on procedure s laid down in the Standard Data Book.

#### 8.4.1 Material

The Major items rates for like Steel, Cement, Bitumen, M-Sand, Aggregates, labour and other items are from PWP IWTD SoR 2018-19, Bangalore Circle, Govt. of India. The sources of material are as follows:

Bitumen	:	MRPL, Karnataka;
Emulsion	:	MRPL, Karnataka;
Steel	:	Tata/Jindal Steel, Bellary, Karnataka;
Borrow Soil	:	Borrow areas along the project road;
Aggregates	:	Bangalore Rural;
Stone Boulder	:	Bangalore Rural;
Course Sand	:	M Sand;
Fine Sand	:	M Sand



#### 8.4.2 Labour

The labour rates are considered from PWP IWTD SoR 2018-19, Bangalore Circle, Govt. of India.

#### 8.4.3 Machineries

Hire charge of machineries have been taken from PWP IWTD SoR 2018-19, Bangalore Circle, Govt. of India.

Consultancy Services for Preparation of Detailed Feasibility Report for the Construction of Proposed Elevated Corridors within Bengaluru Metropolitan Region, Bengaluru



Final Feasibility Report

Cost Estimate

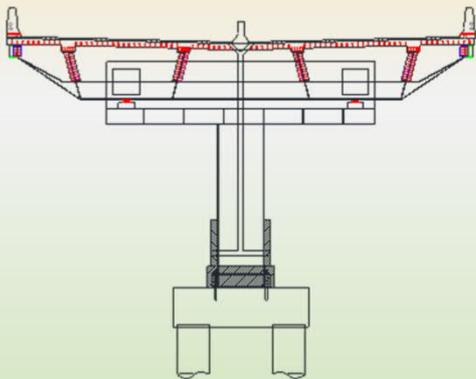
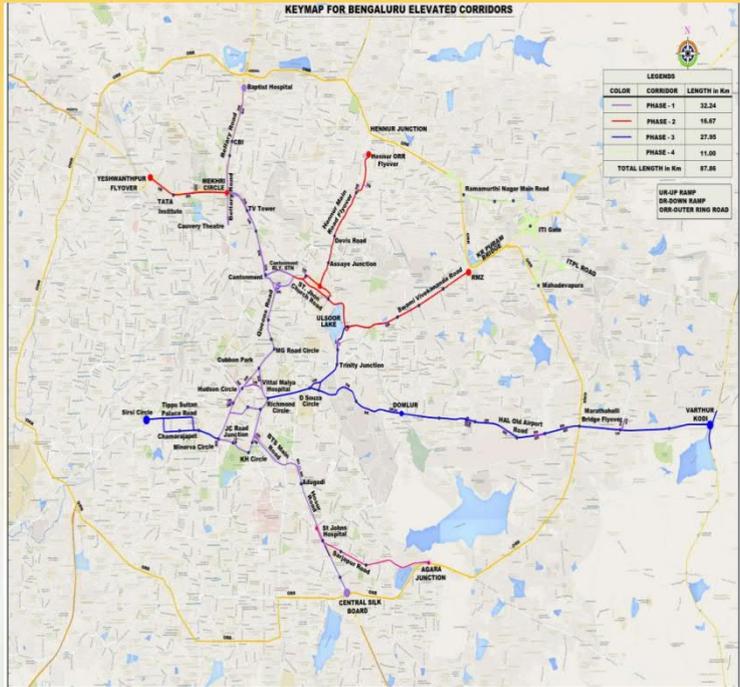
## 8.5 Total Project Cost

S. No.	Description of Item	Phase-1 (NS)	Phase-2 (EW1)	Phase-3 (EW2)	Phase-4 (ITPL)	Total
		Hebbal-Silk Board & CC1	KR Puram (ROB)-Yeshwantpur Flyover	Varthur Kodi to Sirsi Circle	Rammurthy nagar to ITPL Road	
		(INR crore)	(INR crore)	(INR crore)	(INR crore)	
1	Civil Construction Cost (on which project would be bid out)	7,002	3,033	3,989	1,287	15,310
2	Land Acquisition and Resettlement	2,717	2,154	1,500	5,183	11,555
3	Other Cost (Supervision charges, Utility shifting, Escalation etc.,)	1,134	578	760	245	2,716
4	<b>Total</b>	<b>10,852</b>	<b>5,765</b>	<b>6,249</b>	<b>6,715</b>	<b>29,582</b>



# KARNATAKA ROAD DEVELOPMENT CORPORATION LIMITED

Consultancy Services for Preparation of **Detailed Feasibility Report (DFR)** for the Construction of **Proposed Elevated Corridors** within Bengaluru Metropolitan Region, Bengaluru



## FINAL FEASIBILITY REPORT

### VOLUME-IV : ENVIRONMENTAL IMPACT ASSESSMENT REPORT

FEBRUARY, 2019



**AECOM Asia Co. Ltd.**

*in association with*

**Deloitte Touché Tohmatsu India LLP &  
Infra Support Engineering Consultants Pvt. Ltd**



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