Annexure 2.3: Transportation Design

2.7 Past studies and Inferences

2.7.6 Traffic Assessment Study

Haskoning Consulting Engineers had carried out pre-feasibility study on Kalpasar Project Project in 1998. Transportation study is one of the component of the pre-feasibility study. The report was submitted in February, 1998. Major findings summarised below :

(1) It is a pre-feasibility study and scope of work is preliminary in nature without envisaging comprehensive traffic studies;
(2) Consultants had carried out traffic volume counts and Origin-Destination surveys during June, 1996. The results of the survey were used to verify and substantiate the assumptions made;
(3) Distance savings considered in report is much higher as dam alignment was different from the current alignment. Further, along with Kalpasar link, bridge over Narmada River connecting Hansot to Dahej Road is also considered. This link will further reduce the distance between Bhavnagar and Surat;
(4) Very conservative GDP estimate in the order of 3% to 5% is considered for India. Growth in GDP considered for period 1995-2000 and 2001-2010 is 5% respectively and 4.5% whereas actual growth rate achieved during the above periods is 6.5% and 7.5% respectively;
(5) The forecast can be taken as conservative as many major projects such as DMIC, Dholera SIR and SEZs etc were not envisaged during the study period and remain unaccounted and therefore generated traffic is under estimated. Since, future developments were not known generated traffic components is taken as 20% of the diverted traffic.
(6) Toll Rates considered for Car, Bus and Truck is Rs.171, Rs.188 and Rs.256 respectively (1996 financial prices) based on willingness to pay the toll which is equal to the financial out of pocket expenses; and
(7) The road configuration of road over dam is assumed to be of 4-lane only. Traffic is kept constant beyond 2026 as lane configuration is freezed at 4-lane configuration.

L&T Ramboll Consulting Engineers Limited had carried out a Traffic Assessment Study in 2010. Comprehensive traffic surveys were carried out and traffic forecast is made by calibrating the travel demand model. The impact of all the major developments i.e. tourism, irrigation, DFC, DMIC, other industrial nodes and SEZs as well as urbanization in project influence area have been considered.

Traffic forecast for various scenarios varies from 1.66 lakh PCUs per day to 2.07 lakh PCUs per day. The study estimated 6-lane configuration till 2030 and beyond 2035, 8-lanes configuration was suggested based on traffic forecast for various horizon years. And the study mentioned that actual number of lanes to be provided will depend upon the economics of dam design, as traffic demand will be high as it will be going to be important transportation link connecting two regions of Gujarat.

Only road link is considered over Kalpasar dam and no railway link is considered. The estimated cost of road component was Rs. 6600 million at 2010 prices. The project was economically viable considering the cut-off rate of 12%.

11. Transportation

11.1Past Studies

Haskoning Consulting Engineers had carried out pre-feasibility study on Kalpasar Project Project in 1998. Transportation study is one of the component of the pre-feasibility study. The report was submitted in February, 1998. Major findings summarised below :

(1) It is a pre-feasibility study and scope of work is preliminary in nature without envisaging comprehensive traffic studies;
(2) Consultants had carried out traffic volume counts and Origin-Destination surveys during June, 1996. The results of the survey were used to verify and substantiate the assumptions made;
(3) Distance savings considered in report is much higher as dam alignment was different from the current alignment. Further, along with Kalpasar link, bridge over Narmada River connecting Hansot to Dahej Road is also considered. This link will further reduce the distance between Bhavnagar and Surat;
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(7) The road configuration of road over dam is assumed to be of 4-lane only. Traffic is kept constant beyond 2026 as lane configuration is freezed at 4-lane configuration.

Traffic Forecast provided by Haskoning Consulting Engineers is presented below.

Table 2.1: Traffic forecast by Haskoning (1998)

Year	Cars	Buses	Trucks	Total vehicles	PCUs
2000	2,639	308	2,971	5,918	12,476
2010	5,750	460	5,955	12,165	24,995
2020	11,462	657	11,018	23,137	46,487
2030	15,125	758	14,109	29,992	59,726
2040	15,125	758	14,109	29,992	59,726
2050	15,125	758	14,109	29,992	59,726

L&T Ramboll Consulting Engineers Limited had carried out a Traffic Assessment Study in 2010. Comprehensive traffic surveys were carried out and traffic forecast is made by calibrating the travel demand model. The impact of all the major

developments i.e. tourism, irrigation, DFC, DMIC, other industrial nodes and SEZs as well as urbanization in project influence area have been considered. The major findings of the study are presented below:

This study carried out traffic forecast for eight scenarios, the assumptions underlying each of the scenarios is presented below:

1. **Scenario-I** : 50% of perceived benefits considered as toll and without induced traffic;
2. **Scenario-II** : 75% of perceived benefits considered as toll and without induced traffic;
3. **Scenario-III** : 50% of perceived benefits considered as toll and with induced traffic;
4. **Scenario-IV** : 75% of perceived benefits considered as toll and with induced traffic;
5. **Scenario-V** : 50% of perceived benefits considered as toll and without induced traffic + Additional East-West link across Sabarmati river;
6. **Scenario-VI** : 75% of perceived benefits considered as toll and without induced traffic + Additional East-West link across Sabarmati river;
7. **Scenario-VII** : 50% of perceived benefits considered as toll and with induced traffic + Additional East-West link across Sabarmati river;
8. **Scenario-VIII**: 75% of perceived benefits considered as toll and with induced traffic + Additional East-West link across Sabarmati River.

Table 2. 1: Traffic Forecast for various Scenarios

Scenarios	Total Traffic	2025	2030	2035	2040	2045	2050	2055
Scenario I	**Vehicles**	31142	43188	56569	70451	79093	87150	95207
	PCUs	66608	92490	121843	152176	170843	186258	201804
Scenario II	**Vehicles**	26567	37191	50024	58741	68618	74313	80008
	PCUs	56824	79647	107745	126882	148216	158852	169588
Scenario III	**Vehicles**	32783	44992	58563	72575	80600	89254	97908
	PCUs	70118	96353	126137	156765	174098	190744	207529
Scenario IV	**Vehicles**	28098	38866	51917	60638	69516	75747	81979
	PCUs	60098	83235	111824	130980	150157	161908	173765
Scenario V	**Vehicles**	30720	42465	50697	55446	69262	75764	82265
	PCUs	65706	90941	109196	119765	149608	161936	174373
Scenario VI	**Vehicles**	26191	41989	50570	55355	69289	75717	82145
	PCUs	56020	89922	108922	119569	149667	161838	174118
Scenario VII	**Vehicles**	32517	43435	51717	56499	70297	74306	78315
	PCUs	69549	93020	111392	122039	151843	158882	166000
Scenario VIII	**Vehicles**	27796	41851	51598	56317	70324	76711	83098
	PCUs	59451	89627	111137	121647	151902	163966	176137

Traffic forecast for various scenarios varies from 1.66 lakh PCUs per day to 2.07 lakh PCUs per day.

The study estimated 6-lane configuration till 2030 and beyond 2035, 8-lanes configuration was suggested based on traffic forecast for various horizon years. And the

study mentioned that actual number of lanes to be provided will depend upon the economics of dam design, as traffic demand will be high as it will be going to be important transportation link connecting two regions of Gujarat.

Only road link is considered over Kalpasar dam and no railway link is considered. The estimated cost of road component was Rs. 6600 million at 2010 prices. The project was economically viable considering the cut-off rate of 12%.

11.2 Regional transportation network

11.2.1 Project influence area

The project influence area for the Kalpasar project covers the Saurashtra and South Gujarat regions which get benefitted due to reduced travel distance and travel time between them. The influence area in Saurashtra region comprises of following districts (i) Devbhoomi Dwarka, (ii) Jamnagar, (iii) Porbandar, (iv) Rajkot, (v) Junagadh, (vi) Amreli, (vii) Gir Somnath, (viii) Bhavnagar, (ix) Botad, (x) Morbi, and (xi) Surendra Nagar) and the influence area in South Gujarat comprises of following districts (i) Vadodara, (ii) Chhota Udaipur, (iii) Bharuch, (iv) Narmada, (v) Surat, (vi) Tapi, (vii) Navsari, (viii) Dang, and (ix) Valsad. The map showing the project influence area is presented in **Figure 2.1**.

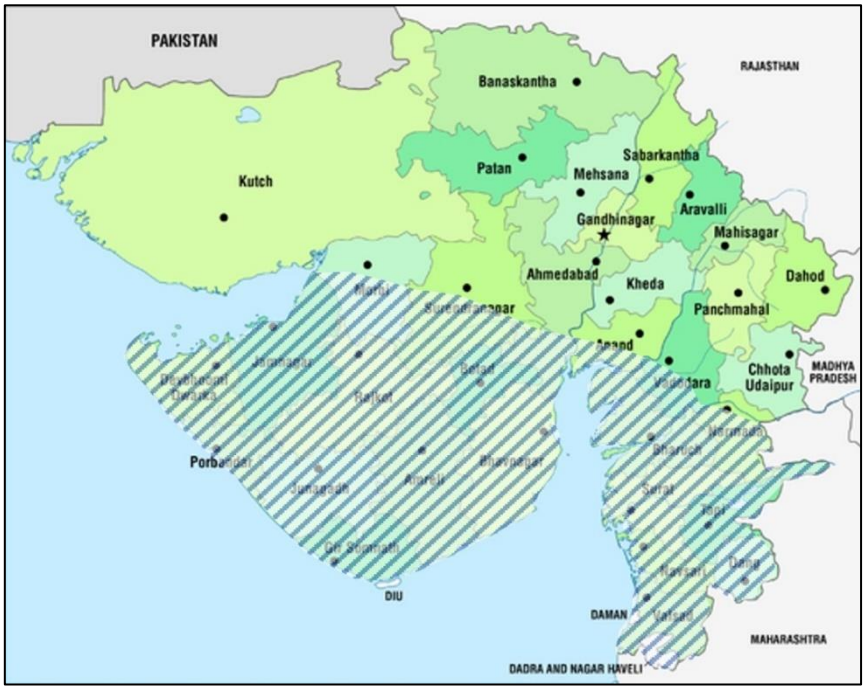


Figure 2.1: Project influence area of Kalpasar project

11.2.2 Roadways

The existing road network in project influence area is presented below in **Figure 2.2**. Proposed Kalpasar Dyke connects Paniyadra in Bharuch district to Kalatalav in Bhavnagar District. Paniyadra village is located on near Dahej - Amod Road (SH-6) and the nearby town is Gandhar. Kalatalav is about 9 km from Dholera - Bhavnagar Road (NH-751). Kalatalav is located close to Nirma factory and Salt Pans.

Figure 2.2: Map showing existing road network surrounding the Kalpasar dam project

Table 2.2: Coordinates points of the Kalpasar project alignment

Location	Longitude	Latitude
A	72°9'2.02"E	21°48'25.22"N
B	72°15'28.91"E	21°48'25.60"N
C	72°30'58.03"E	21°48'26.00"N
D	72°38'51.17"E	21°48'25.71"N

The photographs showing Kalpasar Project start points on end of Gulf of Khambhat is presented in **Figure 2.3.**

Project Start Point (Paniyadra in Bharuch)

Project End Point (Kalatalav in Bhavnagar)

Figure 2.3: Photographs of project start point on either end of Kalpasar

There are several toll plazas operational on the road network in Project influence area and the same are presented in **Figure 2.4**. The road users of Kalpasar project will save tolls on existing roads at Karjan, Bochasan, Vataman etc., once Kalpasar Project becomes operational.

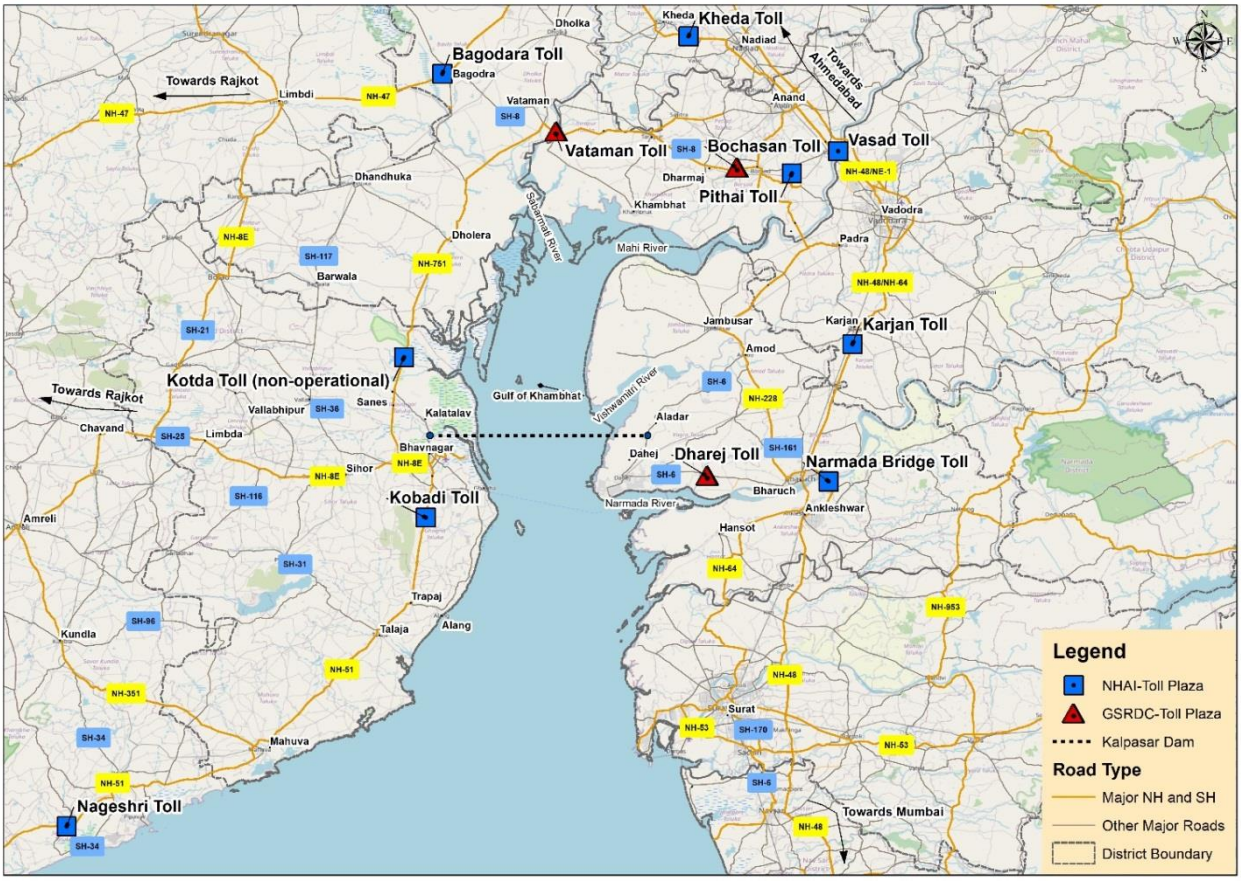


Figure 2.4: Existing toll plaza locations in the project influence area

11.2.3 Railways

Rail network surrounding the project influence falls under Western Railway (WR) zone of Indian Railways. The map showing the existing rail network is presented in **Figure 2.5.** Currently, all the trains travelling between South Gujarat and Saurashtra passes through a detour route via Ahmedabad. Once Kalpasar Rail link is developed, significant

benefits will be accrued to the users in terms of reduced travel time and travel cost. It is to be noted that the savings by Rail will be much higher as compared to the road.

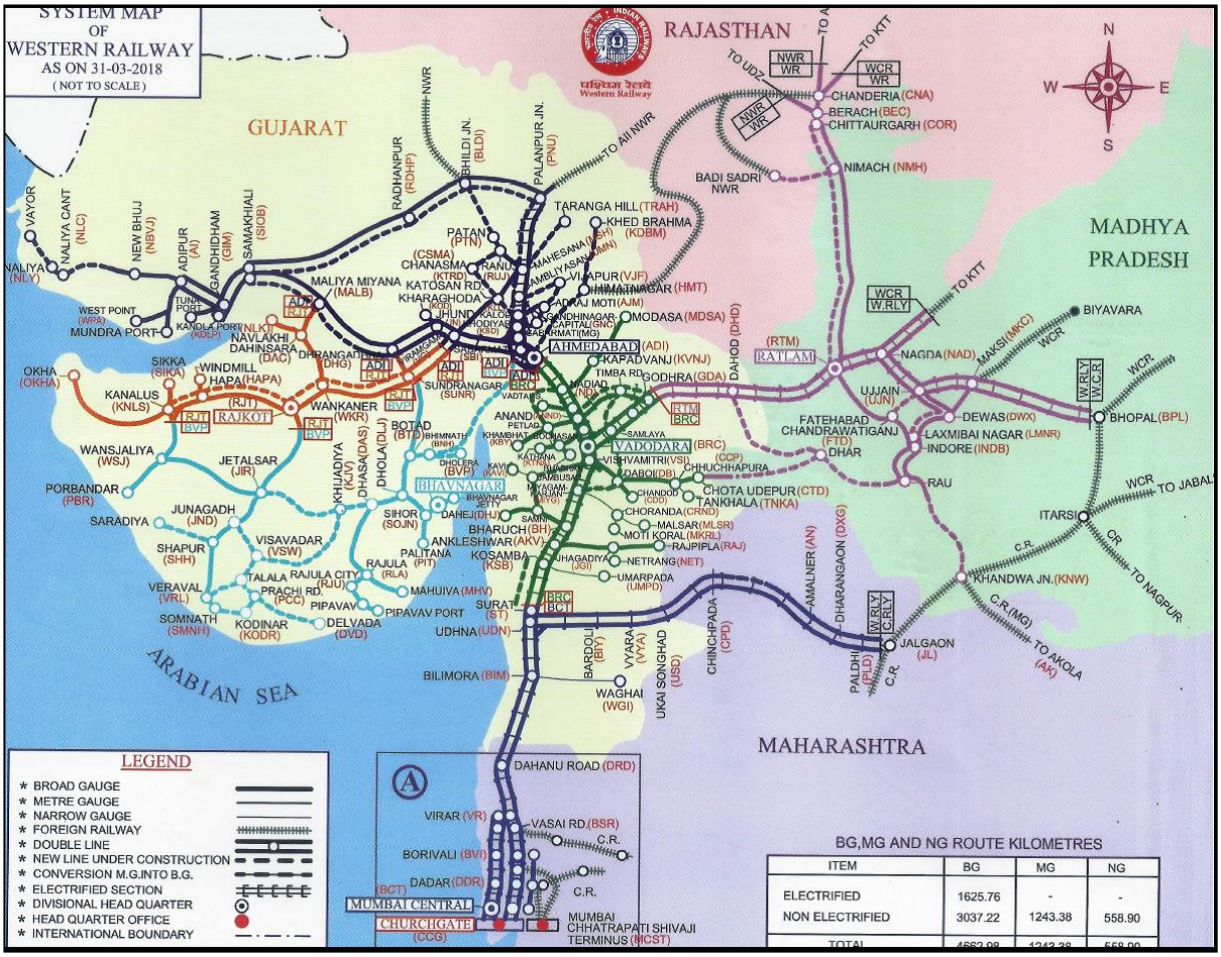


Figure 2.5: Railway network map surrounding the Kalpasar dam project

The existing Rail network comprises of broad gauge, narrow gauge and metre gauge lines. Several Narrow/metre gauge lines are being converted into broad gauge lines.

- **Impact of Transportation in the Region**

Road and Rail over dyke is one of the many components of GKDP. The total length of dyke is 30 km and including access roads on either side, it is around 60 km. At present, the traffic movement from South Gujarat to Saurashtra/ Kutch are using a route via Borsad-Tarapur-Vataman which is part of SH-8/NH-751D having 6-lane toll road.

Bhavnagar district, which is a part of Saurashtra region, is found to be having highest benefit from Kalpasar due to distance savings of around 170-210 km from different places of South Gujarat like Dahej, Surat, Hazira, Navsari, Valsad, Mumbai etc. On the other hand, the benefit accrued to Vadodara is around 30-50 km.

With regard to travel time savings on road, Dahej to Bhavnagar accounts for the maximum time saving of about 4 hr 58 min. Bhavnagar has the maximum time savings from many areas of Southern Gujarat such as Bharuch, Dahej, Surat, Hazira, Navsari, Valsad ranging from 2 hr 33 min to 4 hr 58 min.

With regard to travel time savings on rail, Bhavnagar- Dahej will have maximum time savings viz. 7 hours and 46 minutes. All train starting form Saurashtra region to South

Gujarat, Mumbai and Ratlam will have significant time savings except for Surendranagar and Jamnagar. Benefits range from 5 Hr 42 minutes to 3 Hr 33 minutes. Least travel time savings are observed for Kutch region (Bhuj) viz 1 hour 30 minutes.

The matrix showing savings from major O-D pairs for road and rail is given in sub-section 2.3.2 (c) of Annexure 2.3.

11.3 Traffic surveys and analysis

Traffic surveys are carried out to understand current travel pattern in Kalpasar project influence area. The main objectives of traffic surveys are as follows:
(1) To identify the road links which cater to the traffic movement between Saurashtra to South Gujarat and conduct traffic surveys to assess the traffic intensity and pattern;
(2) To estimate the diverted component of traffic that will use the proposed Kalpasar road/rail linkages; and
(3) To identify the future road links that will be used for dispersal of traffic after the operation of Kalpasar project.

11.3.1 Traffic surveys

Various traffic surveys are carried out to assess existing characteristics of the traffic. Various traffic surveys are carried out to assess existing characteristics of the traffic. The purpose of each of the traffic surveys is presented below:
(1) **Classified Volume Counts (CVC)** is carried out to assess the traffic intensity on existing road links that would cater to road over the Kalpasar dyke;
(2) **Origin-Destination (OD) surveys** are carried out at identified locations to capture current travel pattern in general and East-West traffic (i.e., South Gujarat to Saurashtra traffic) in particular that is likely to use Kalpasar dyke;
(3) **Turning Movement Count (TMC) surveys** are carried out to understand the turning traffic and diversions at major intersections;
(4) **Speed delay surveys** are carried out to assess the travel time and delay characteristics of road network in project influence area;
(5) **Trip Generation Surveys** are conducted at selected industrial units in Kalpasar project influence area to assess the trip generation rates; and
(6) **Truck Operators willingness to pay Surveys** are conducted to assess the willingness to pay the toll on the proposed Kalpasar transportation link.

The details of survey locations and schedule of surveys are presented in **Table 2.3.**

Table 2.3: List of traffic survey locations and schedule

No.	Location Id	Location	Road name	Type of survey	Schedule
Classified Volume Count- Mid Block					
1	CVC-1	Dahej Toll Plaza	SH-6	3 days x 24 hours	8th to 10th Feb 2022
2	CVC-2	Bharuch-Vagra Road (Near Vagara)	SH-161		9th to 11th Feb 2022
3	CVC-3	Amod-Muler Road (Near Amod)	SH-6		9th to 11th Feb 2022
4	CVC-4	Karjan Toll plaza	NH-48	7 days x 24 hours	8th to 14th Feb 2022
5	CVC-5	Padra-Borsad Road (Near	NH-228	3 days x 24	9th to 11th Feb

No.	Location Id	Location	Road name	Type of survey	Schedule
		Bhadran)		hours	2022
6	CVC-6	Borsad Toll Plaza	SH-8	7 days x 24 hours	11th to 17th Feb 2022
7	CVC-7	Vataman Toll plaza (Non-Operational)	SH-6		15th to 21th Feb 2022
8	CVC-8	Bagodara Toll plaza	NH-47		12th to 18th Feb 2022
9	CVC-9	Kotda Toll Plaza (Non-Operational)	NH-751	3 days x 24 hours	14th to 16th Feb 2022
10	CVC-10	Bhavnagar-Talaja Road	NH-51		16th to 18th Feb 2022
11	CVC-11	Limda-Sihor (Near Sihor)	NH-8E		14th to 16th Feb 2022
Turning Movement Count Location					
12	TMC-1	Jambusar, Amod and Bharuch Junction		1 Day x 24 Hours	9th Feb 2022
13	TMC-2	Jambusar Junction (Circle)			14th Feb 2022
14	TMC-3	Mahuvad/Navpura Junction (Near Padra)			9th Feb 2022
15	TMC-4	Dharmaj Junction			14th Feb 2022
16	TMC-5	Tarapur Chowkdi			14th Feb 2022
17	TMC-6	Vataman Chowkdi			21h Feb 2022
18	TMC-7	Bagodara T-Junction			18th Feb 2022
OD Survey Location					
19	OD-1	Dahej Toll Plaza	SH-6	1 Day x 24 Hours	8th Feb 2022
20	OD-2	Karjan Toll Plaza	NH-48		8th Feb 2022
21	OD-3	Borsad Toll Plaza	SH-8		11th Feb 2022
22	OD-4	Vatman Toll Plaza (Non-Operational)	SH-6		21th Feb 2022
23	OD-5	Bagodara Toll Plaza	NH-47		18th Feb 2022
24	OD-6	Kotda Toll Plaza (Non-Operational)	NH-751		16th Feb 2022
25	OD-7	Kobadi Toll Plaza	NH-51		18th Feb 2022
Other Traffic Surveys					
Trip Generation Surveys- Major Industries nodes (50 Samples)					27th Jan 2022 to Feb
Transport Operators Survey- Project Influence Area (250 Samples)					27th Jan to 20th Feb
Speed and Delay Survey- Road network in the project influence area					18th Feb 2022 to 20th Feb

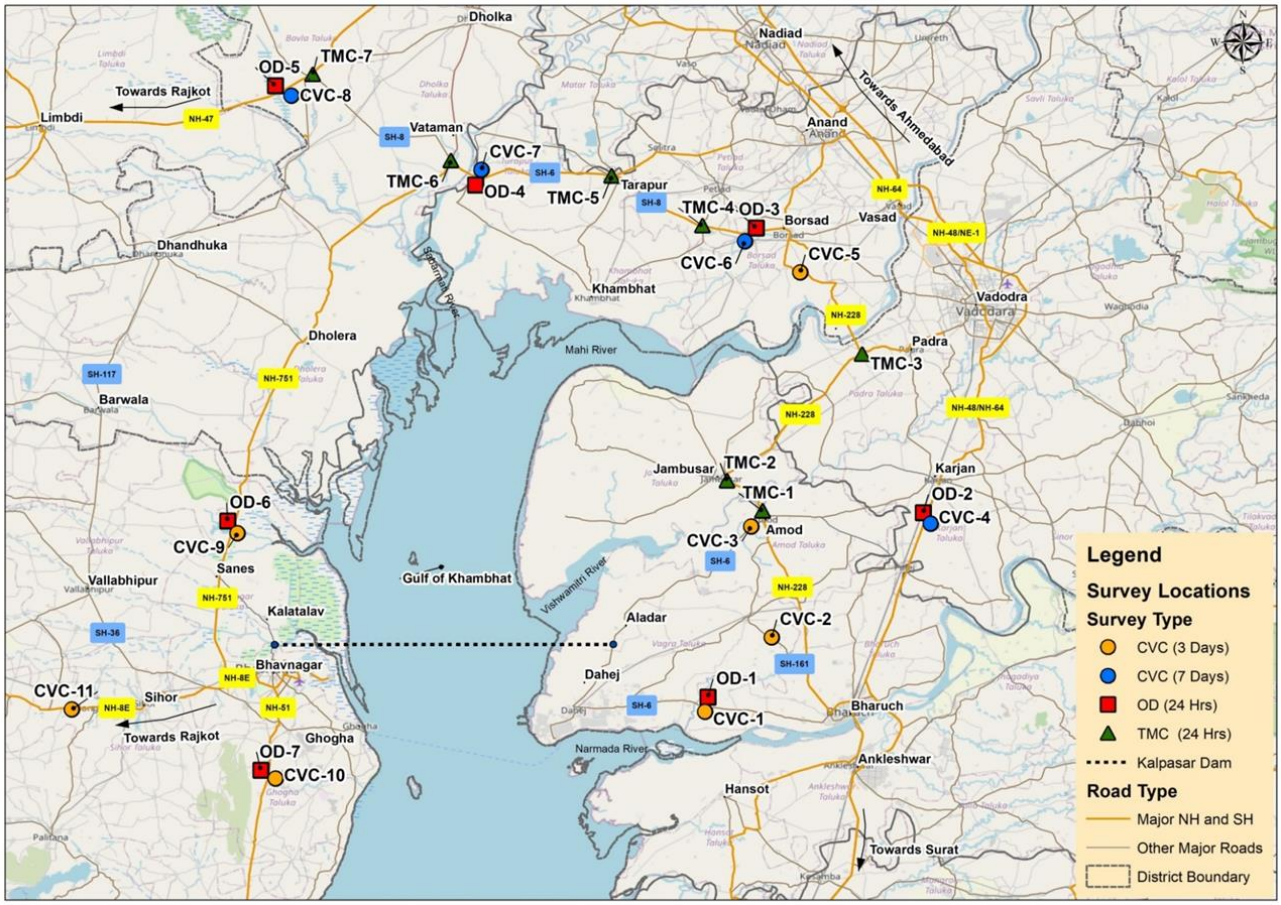


Figure 2.6: Map showing traffic survey locations

- **Classified Traffic Volume Count (CVC) survey analysis**

- **Average Daily Traffic (ADT)**

Classified traffic volume counts are carried out for 7 days/ 3 days to understand the traffic intensity. Three day classified volume counts are conducted on road links which can serve as dispersal links. The Commercial Goods Vehicles have been classified as LCV (4 tyre), LCV (6 tyre), 2 Axle Trucks, 3 Axle Trucks and Multi Axle Trucks. Private vehicles have been classified as Two Wheelers, Private Cars (Car/ Jeep/ Van/Taxi), Bus and Minibus.

Classified vehicle counts carried out at various locations are converted into PCUs based on guidelines for capacity analysis for rural areas (IRC-64-1990 "Guidelines of Capacity Analysis for rural Areas"). The recommended PCU values as per IRC are presented in **Table 2.4.**

Table 2.4: Passenger Car Units (PCU) factors recommended by IRC (Rural areas)

Sl. No	Vehicle type	PCU value
1	Truck, Bus	3.0
2	Truck Trailer, Tractor Trailer, MAV, Agricultural tractor	4.5
3	Light Commercial Vehicle	1.5
4	Passenger Car, Jeep, Pick up Van, Auto Rickshaw	1.0
5	Motorised Two Wheeler	0.5
6	Cycle	0.5

Sl. No	Vehicle type	PCU value
7	Animal drawn Vehicles (Bullock Carts)	8.0

Daily traffic volume by vehicle type and direction is added separately and averaged to determine the Average Daily Traffic (ADT). In addition to determining the number of vehicles, the equivalent passenger car units (PCUs) are also calculated.

It can be observed that the average daily traffic (ADT) on national highways varies from **15,216 PCUs** to **1,09,812 PCUs.** The highest traffic observed on NH-48 (Karjan toll plaza) and among the State Highways, Vataman-Tarapur section of SH-6 has highest traffic of **47,097 PCUs**.

- **Traffic composition**

Location wise traffic composition is arrived, and details are presented in **Table 2.18 of Annexure 2.3**. Important observations are as follows:

(1) It can be observed that proportion of passenger traffic varies from 58% to 88%;
(2) The proportion of passenger traffic is highest on SH-161-Bharuch-Vagra Road (88%) followed by NH-8E-Limda-Sihor Road (87%), NH-51-Bhavnagar-Talaja Road (82%), NH-228-Padra-Borsad Road (71%);
(3) Two Wheeler alone constitutes significant proportion (7% to 45%), Car constitutes around 22% to 47% of total vehicles; and
(4) Composition of Commercial traffic varies from 12% to 42Peak hour traffic

Peak hour traffic is estimated and presented in **Table 2.6 of Annexure 2.3**. It can be observed that peak hour traffic varies from 4.9% to 7.8% for various roads.

- **Seasonal correction factors**

Traffic varies with seasons. To account for seasonal variations, seasonal correction factors have been derived. For the estimation of seasonal correction factors, month-wise toll data for three years at Karjan Toll Plaza (2017-2019) is used. The estimated seasonal correction factors are presented in **Table 2.7 of Annexure 2.3.**

- **Average Daily Traffic (AADT)**

The Annual Average Daily Traffic (AADT) obtained after applying the seasonal correction factors is presented in **Table 2.8 of Annexure 2.3.**

➢ **Turning Movement Count (TMC) survey analysis**

Turning movement surveys are carried out at 7 locations for 24 hrs. Turning movement data is used to understand turning traffic and the same is summarised in **Table 2.9 of Annexure 2.3**. Peak hour Traffic movement for the junctions are presented in **of Figure 2.8 of Annexure 2.3.**

➢ **Origin-Destination (O-D) survey analysis**

To understand the existing travel pattern, Origin-Destination (O-D) surveys are carried out for one day at 7 locations for 24 hours. Information such as origin, destination, purpose of trip (for passenger vehicles) and commodity carried, frequency of trips etc., are collected during the survey.

As part of the OD survey, willingness to pay survey for car users is carried out at Vataman Toll Plaza. Users are asked about their willingness to pay the toll rates for the new Road on Kalpasar Project. The users are informed about the savings in travel distance and travel time before asking for their willingness to pay the toll.

- **Sample size**

O-D surveys are carried out on sample basis and the percentage of samples collected for various categories of vehicles is presented in **Table 2.10 of Annexure 2.3**.

- **Influence factor (I.F)**

O-D survey results provide a clear indication of the regions, which contribute to the traffic on existing roads in the project influence area. Number of trips originating from and destined to any zone represents the influence of that zone on the traffic. Sum of trips originating from and destined to any zone divided by twice the total number of observed trips in percentage terms gives the influence factor (I.F) of that zone. The formula for estimation of influence factor is presented below.

$$I.F = \frac{\sum Oi + \sum Dj}{\sum (Oi + Dj)}$$

The O-D matrices developed from O-D survey data is used to estimate the influence factors. Region-wise influence factors at various survey locations are presented in **Table 2.11 to Table 2.17 of Annexure 2.3**.

Based on the influence factors derived at Vataman Toll Plaza, the following inferences are drawn:
(1) Average Influence of South Gujarat, Central Gujarat and Saurashtra are 11%, 26% and 42% respectively in Commercial vehicles. The Influence of Kutch is only 2%; and
(2) Average Influence of South Gujarat, Central Gujarat and Saurashtra are 24%, 25% and 45% respectively in Passenger vehicles.

The proportion of East-West Traffic (i.e. Traffic between South Gujarat and Saurashtra and Kutch regions and vice versa) at various O-D survey locations (toll plaza locations) are derived and presented in **Table 2.5.** East-west traffic is potential traffic for Kalpasar project.

The proportion of E-W traffic at Vataman, Karjan, Borsad and Bagodara is 57.6%, 16.9%, 41.8% and 28.6% (in total tollable traffic) respectively. At present, Vataman Toll plaza is capturing all East-West traffic, which further splits to SH-6 (toward Bhavnagar) and NH-8A (Bagodara & Rajkot etc.).

Table 2.5: East-West traffic at Vataman and Karjan Toll Plaza

Vehicle type	Vataman toll plaza			Karjan toll plaza		
	total traffic	E-W traffic	% of E-W traffic	Total traffic	E-W traffic	% of E-W traffic
Car	10,706	4,865	45.40%	25,190	2,957	11.70%
Bus	1,351	1,186	87.80%	3,055	1,684	55.10%
Mini Bus	54	40	75.00%	74	40	54.50%
Tata Ace	267	155	58.20%	1,502	137	9.10%
LCV	2,111	1,513	71.70%	4,882	731	15.00%
2 Axle Truck	787	633	80.40%	2,595	425	16.40%

Vehicle type	Vataman toll plaza			Karjan toll plaza		
	total traffic	E-W traffic	% of E-W traffic	Total traffic	E-W traffic	% of E-W traffic
3 Axle Truck	1,148	592	51.60%	2,398	393	16.40%
MAV	4,386	3,007	68.60%	9,110	1,882	20.70%
Total Vehicles	20,810	11,992	57.60%	48,806	8,250	16.90%
Total PCUs	43,949	28,193	-	1,00,016	20,298	-

Although influence factors have been worked at all the O-D survey locations, Vataman toll plaza influence is more appropriate for understanding E-W traffic which is likely to use Kalpasar. Summary of zone-wise influence factors is given in **Annexure-2E.**

- **Zone wise influence factors**

Based on O-D surveys data, mode wise zone wise influence factors is analysed and presented in **Table 2.6 of Annexure 2.3.**

It is observed that **Surat, Ahmedabad District, Vadodara, Bhavnagar,** and **Rajkot zones** have significant influence as compared to other zones.

- **Trip frequency distribution**

Based on O-D surveys data, mode wise trip frequency distribution is analysed and presented in **Table 2.7 of Annexure 2.3.**

- **Trip purpose**

Trip Purpose of Passenger Vehicles are arrived at based on O-D survey data and presented in **Table 2.8 of Annexure 2.3.**

- **Commodity distribution**

Mode wise commodity distribution is analyzed based on O-D survey carried out at Vataman Toll Plaza and is presented in **Table 2.9 of Annexure 2.3**.

- **Willingness to pay survey for car users**

Willingness to pay survey for car users is carried out at Vataman, Bagodara and Borsad Toll Plaza. Users are requested to reveal their willingness to pay given the current and proposed toll rates and savings in distance and time due to the Kalpasar road link. The proposed toll rates are fixed as 50% of the perceived benefits to Road users as per the Govt. of Gujarat Policy. The surveys revealed that around 89% users are willing to pay the toll proposed for the Kalpasar project.

- **Estimation of East–West traffic**

Kalpasar project will attract Traffic between Saurashtra and South Gujarat i.e. East-West Traffic. At present East-West passes through Vataman Toll Plaza. Based on O-D data collected at Vataman Toll Plaza, the total potential E-W traffic is estimated considering zones in Saurashtra, Kutch and South Gujarat who will benefit from reduced travel time and distance.

Based on O-D data analysis, it is revealed that around 58% of the traffic at Vataman is East-West traffic and remaining traffic is either local or North-South traffic. This traffic can be taken as potential divertible traffic on to the Kalpasar and the same is presented in **Table 2.6.**

Table 2.6: Total potential East–West traffic at Vataman toll plaza

Vehicle type	East-West traffic	Total traffic at Vataman	% Share potential diverted traffic
Car	4,865	10,706	45.4%
Bus	1,186	1,351	87.8%
Minibus	40	54	75.0%
Tata Ace	155	267	58.2%
LCV	1,513	2,111	71.7%
2 Axle Truck	633	787	80.4%
3 Axle Truck	592	1,148	51.6%
MAV	3,007	4,386	68.6%
Total Vehicles	11,992	20,810	57.6%
Total PCUs	28,193	43,949	-

- **Speed and delay survey analysis**

Speed delay surveys are carried out major roads within the project influence area and section wise average speed is presented in **Table 2.11 Annexure 2.3.**

- **Trip generation survey analysis**

Trip Generation Surveys are carried at around 50 industrial units in the project Influence area to understand trip generation rates of various types of industries. Following Information is collected as part of the survey:
(1) Type of Industry, Product;
(2) Gross Area and Net Area;
(3) Total Trucks per day (In and Out); and
(4) O-D pattern (no. of trips per week, seasonal variation, origin, destination) of raw material and finished products.

Trip Generation Surveys are carried out to assess the trip generation rate of various types of industries in the project Influence area. Around 50 Industrial units are contacted. Major Industrial Activities in the Project Influence area based on the sample survey is presented in **Table 2.12 Annexure 2.3.**
Following Information is collected:
(1) Type of Industry;
(2) Type of Product;
(3) Gross Area and Net Area;
(4) Total Trucks per day (in and out); and
(5) Raw material and finished products OD pattern

The above information is used to estimate generated traffic from the proposed developments in project influence area. Based on sample survey, Sector-wise Trip Generation Rates are worked out for 13 industrial sectors and presented in **Table 2.13 of Annexure 2.3.**

Considering appropriate weightages to various types of land uses, Average trip generation rate works out to be **0.80 trucks per acre per day or 1.98 trucks per hectare per day**. This generation rate is used for all the developments proposed in the project Influence Area.

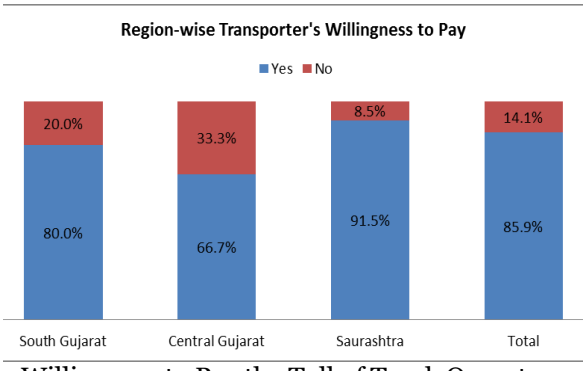
➢ **Transport operators' interview survey analysis**

Truck operator survey is carried out to assess the willingness to pay the toll for the proposed Kalpasar. In addition to willingness to pay toll information, other related information such as fleet size, major origin-destinations, the route followed, present toll rates, fuel consumptions per kilometre are also collected. Around 250 Transport agencies/roadways/carriers are contacted for the survey.

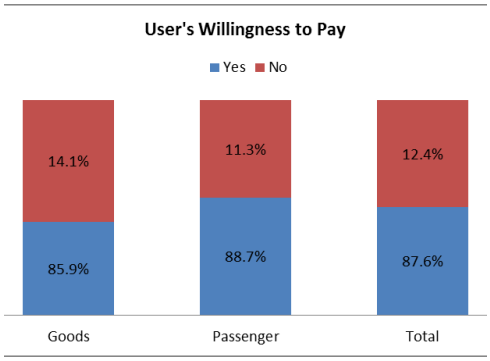
The objective of the Truck operators' survey is to assess the Willingness to pay for Kalpasar project. In addition to willingness to pay toll information such as fleet size, major origin-destinations, the route followed, present toll rates, fuel consumptions per kilometre are also collected. About 250 Transport agencies/roadways/carriers are contacted for the survey. The survey is carried out at following locations:
(1) Ankleshwar; (2)Bharuch; (3)Surat; (4) Ahmedabad; (5) Vadodara; (6) Alang; (7) Amreli; (8) Bhavnagar; (9) Jamnagar; (10) Portbandar; (11) Rajkot; and (12) Surendranagar

- **Willingness to pay the toll**

Truckers are informed about potential savings in distance if they choose to use Kalpasar link and asked their willingness to pay the toll. The results of willingness to pay of truck operators are shown in **Figure 2.7**. Around 92% of the truck operators interviewed in Saurashtra and 80% of the truck operators interviewed in South Gujarat reported their willingness to pay the proposed toll.



Willingness to Pay the Toll of Truck Operators



Willingness to Pay the Toll of Truck & Car Operators

Figure 2.7: Willingness to pay the toll

11.3.2 Socio-economic profile

The current section presents the Socio-Economic trends of Gujarat state with focus on Kalpasar project influence area. The state of Gujarat located on the western coast of India is spread over an area of 1.96 lakh sq.km (about 6% of India's geographical area) and has a population of about 604.39 lakhs (about 5% of India's total population) as per 2011 census and the current population is close 700 lakhs. Among the states in India, Gujarat is fifth in term of GDP. The profile of project influence area is given below in **Table 2.15 of Annexure 2.3**.

➢ **Demography**

- **State profile**

As per the Census of India 2011, the population and workers of Gujarat was 604.39 lakh and 247.67 lakh respectively. The average decadal population and employment growth rate from 1971 to 2011 is estimated to be 22.7% and 31.6% respectively.

The demographic profile of Gujarat State from 1971 to 2011 is presented in **Table 2.16 of Annexure 2.3**. It can be noted that on an average, employment growth rate has been higher as compared to the population growth rate. **The estimated population of Gujarat state in 2021 is 697 lakhs.**

- **Demography within Project influence area**

The comparison of the demographic profile of the state Gujarat and Project Influence Area (1991-2011) is presented in **Table 2.7**. It can be noted that share of population in project influence is about three forth of Gujarat State Population.

Table 2.7: Comparison of demographic profile of Gujarat and project influence area (1991-2011)

No.	Year	Population			Employment		
		Gujarat	PIA	Share of PIA	Gujarat	PIA	Share of PIA
1	1991	4,13,09,582	3,09,84,507	75.0%	1,66,20,519	1,21,82,959	73.3%
2	2001	5,06,71,017	3,80,67,476	75.1%	2,12,55,521	1,53,00,322	72.0%
3	2011	6,04,39,692	4,56,02,184	75.4%	2,47,67,747	1,83,29,336	74.0%

As per the Census of India, the population and employment in the project influence area in 2011 were 456.02 lakh and 183.29 lakh respectively; similarly, the WFPR was estimated to be 40.2%. The sex ratio and literacy rate in 2011 were 909 and 77.2% respectively. Further, the population and employment density were 3.10 pph and 1.26 pph respectively.

The average decadal growth rate of population and employment from 1991 to 2011 were about 21.3% and 22.7% respectively. District-wise demographic profile of project influence area for 2011 is summarised and presented in **Table 2.19 of Annexure 2.3.**

➢ **Economy**

- **Net State Domestic Product**

As per the Directorate of Economics and Statistics, Government of Gujarat, the population share of Gujarat only around 5% of the country- but contributes 8.11% share in the national GDP. Gujarat is a gateway for the international market due to large cargo handling at ports that has increased from 27.8 lakh tonnes in 1981 to 4118 lakh tonnes in 2020, a rise of about 150 times in a span of 40 years.

The average annual growth rate of GSDP and NSDP from 2015-16 to 2019-20 were 12.5% and 13.1% respectively. Prominent sectors performing and contributing towards GSDP and NSDP (2015-16 to 2019-20) are Industries, Services, and Manufacturing. The annual details of Gujarat's GSDP and NSDP are presented in **Figure 2.11, Figure 2.12 and Figure 2.13 of Annexure 2.3.**

In 2019-20, the share of the primary, secondary and tertiery sectors in Gujarat state economy is 19.4%, 44.5% and 36.1% respectively.

- **Per Capita Income (PCI)**

The per capita income of the state Gujarat as per the statistical overview report of Gujarat in 2019-20 was Rs. 2,16,329. **The average annual per capita income growth**

from 2015-16 to 2019-20 was 11.7%. Gujarat with its 2.16 lakh PCI stands higher than national average per capita income of 1.35 lakh in 2019-20.

- **Industry**

Gujarat is a leader in industrial sector such as in chemicals, petrochemicals, dairy, drugs and pharmaceuticals, cement and ceramics, gems and jewellery, textiles, and engineering. The industrial sector comprises of over 800 large industries and 453,339 micro, small and medium enterprises. **Gujarat's manufacturing sector accounts for 37.5% of State GDP, which is higher than the national average of 17%**.

Some of the industries contributing towards economic growth are:

(1) Agro-based and Food Processing Industry; (2) Chemical and Petrochemicals; (3) Information Technology; (4) Mineral-Based and Allied Industries; (5) Plastic and Allied Industries; (6) Port-Related Activities and Infrastructure; (7) Textile and Apparels Industry; and (8) Gems and Jewellery

- **Agriculture**

Out of the total state's geographical area, about 103.02-lakh hectare (2015-16) is under net cultivable area, which is around 52.5% of total area. Gujarat is one of the major producers of Tobacco, Cotton, Castor, and Groundnuts in India. The details of production of food and non-food grains in Gujarat from 2011-11 to 2018-19 are presented in **Figure 2.17 of Annexure 2.3**.

In comparison to the country's total production, in 2017-18, about 18.62% and 13.05% of Pulses and Oil Seeds is contributed by state whereas in 2018-19, around 22.39% and 11.84% of Pulses and Oil Seeds is contributed by state.

- **Irrigation**

From Kalpasar Project 10000 Mm^3 water with 50% dependability will be available; out of this 6500 Mm3 is earmarked for irrigation. **Three garland canals at about EL 50 m, EL 70 m and EL 100 m are planned to irrigate about 10.40 lakh hectares of agricultural land in 6 districts and 39 Talukas of Saurashtra.** Map showing the areas of Saurashtra region that are benefitted by Kalpasar Project is given below in

.

Table 2.8: Area under irrigation in districts of Saurashtra (2014)

No.	District	Area(Sq. Km)	Gross Irrigated Area(Ha)	% of irrigated area
1	Amreli	7397	189171	25.60%
2	Bhavnagar	7034	189341	26.90%
3	Jamnagar	14184	278208	19.60%
4	Junagadh	5093	398614	78.30%
5	Rajkot	11203	303702	27.10%
6	Surendranagar	10489	383546	36.60%
7	Porbander	2316	78597	33.90%

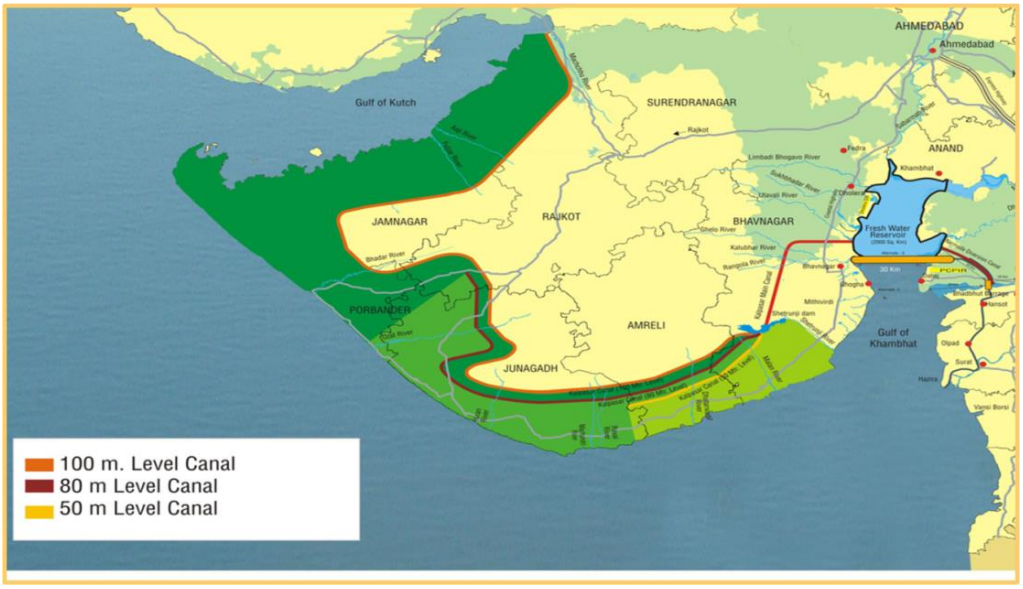


Figure 2. 8: Area getting irrigated in Saurashtra due to Kalpasar project

The surplus good food grains produced in Saurashtra is expected to be transported to rest of India i.e., South Gujarat, Central, Eastern as well as south India via the Kalpasar Road and Rail link.

- **Minerals**

As per the average annual value of mineral production in Gujarat (2011-2017), the average share of Petroleum and Natural Gas is 59%, of Major Minerals is 15%, and of Minor Minerals is 27%.

Gujarat Mineral Development Corporation (GMDC) has announced some upcoming projects all over the state for developing the mineral resources within the state and thus achieve vast array of Mineral portfolio by utilizing its rich basket. List of Upcoming projects are shown in **Table 2.8 of Annexure 2.3.**

- **Tourism**

Gujarat has wide range of tourism places such as (i) multi-cultural heritage and monuments (ii) longest coastline with 16 beaches (iii) 22 sanctuaries and 4 national parks (iv) desert i.e. Runn of Kutch (v) religious and heritage circuits, (vi) festivals, art and craft, and (vii) cuisine. List of various tourism attraction spots within the state are:
(1) Rann of Kutch; (2) Dwarka; (3) Porbandar; (4) Gir National Park; (5) Somnath; (6) Diu; (7) Daman; (8) Palitana Temple; (9) Statue of Unity; (10) Nishkalank Shiva Temple; and (11) Blackbuck National Park

The various tourism assets in the state of Gujarat are presented in **Figure 2.23 of Annexure 2.3**.

Based on the statistics, in 2018-19 the state of Gujarat had a tourism footfall of about 548.82 lakh with a predominant share of domestic tourists (99%). The average annual growth of domestic and international tourists from 2009 to 2018 is 14.7% and 19.9%. The details of the tourist footfall in the state of Gujarat are presented in **Table 2.22 of Annexure 2.3**. As per 2018-19 statistics, 72% of the tourists are from within the state, 26% of the tourists from outside Gujarat state whereas 2% of the tourists are foreigners.

The scope further growth is very high for leisure and spiritual tourism once Kalpasar project become operational with shorter connections as well as better infrastructure. Kalpasar itself will become a major leisure spot in the state of Gujarat. There is a strong possibility that tourists' inflow will continue to record high growth rate (double digit growth rates) in coming years.

Kalpasar project will create a freshwater reservoir of 2000 sq.km which is huge considering anywhere in the World. Tourism potential exists on the Dam (i.e. Dam View points) as well as water frontage on the periphery of the reservoir (i.e. Boating, hotels, and recreational activities).

- **Foreign Direct Investment**

During FY21, Gujarat has emerged as the top FDI destination, accounting for 37% total inflows. The Gujarat will continue to attract investments due to business-friendly environment.

11.3.3 Infrastructure assessment

The infrastructure has played a vital role in the socio-economic development of the state Gujarat. Transport Infrastructure comprising of Road, Rail, Airports, Ports as well as power, water, etc. have been briefly reviewed in the following section.

- **Road network**

In 2017-18, the total road network in the state was about 1.80 lakh km: consisting of about 5,456 km of National Highways and 18,784 km of State Highways. The details of road network in Gujarat and India from 2011-17 is presented in **Table 2.24 of Annexure 2.3**.

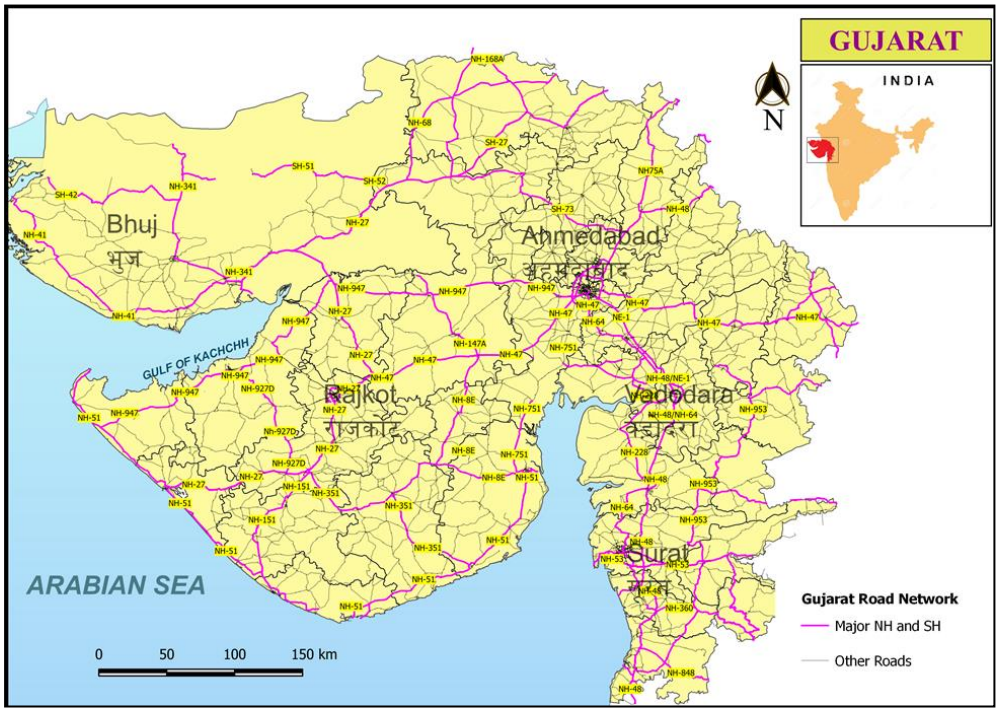


Figure 2.9: Map depicting road network of Gujarat state

- **Railway network**

The entire rail network of Gujarat is under the jurisdiction of the Western Railways, which also serves parts of the Madhya Pradesh, Mumbai, and Rajasthan.

Table 2.25 of Annexure 2.3 shows the division wise spread of running track kilometres within Gujarat State.

Map showing the classification of Broad Gauge, Meter Gauge and Narrow Gauge in Gujarat is presented in **Figure 2.10.**

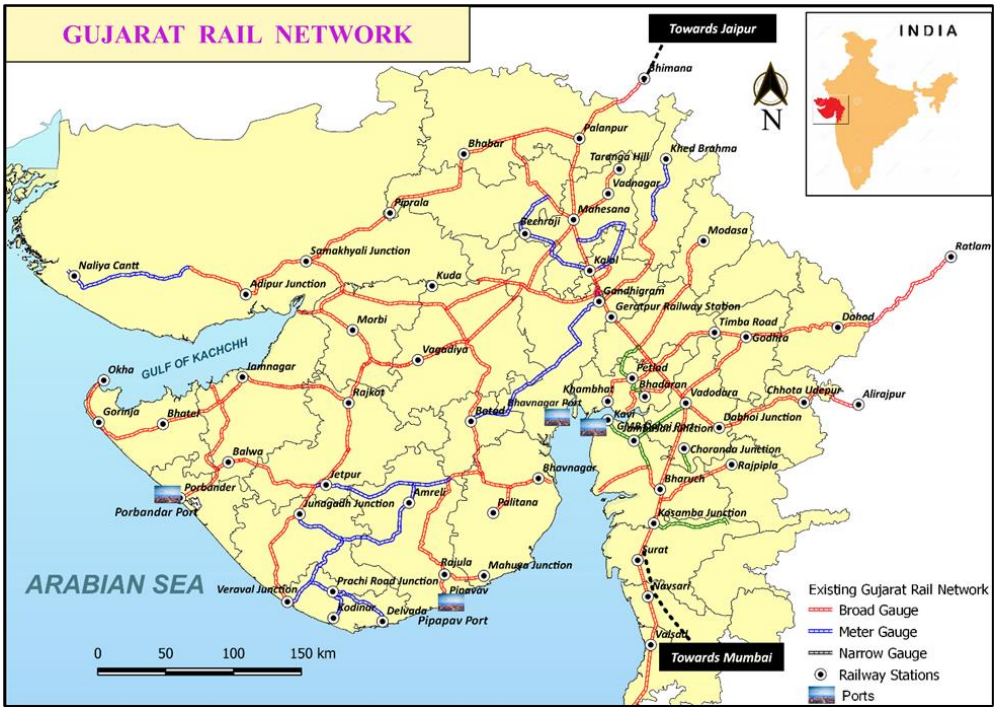


Figure 2.10: Railway network in Gujarat state

- **Passenger traffic**

As per 2019-20 statistics number of passengers being catered by western railways was 1,523.72 million passengers and moving 53,157 net ton kilometre of goods. Passenger and Goods statistics are presented in **Table 2.26 and Table 2.27 of Annexure 2.3**.

- **Capacity Utilization of Railway Network in Gujarat**

The capacity utilization of Railway Network in Gujarat from 2017-18 to 2024-25 (forecasted by WR) is presented below in **Table 2.29 of Annexure 2,3**.

From **Figure 2.11** it can be noted that 47% of the rail network in Gujarat is saturated.

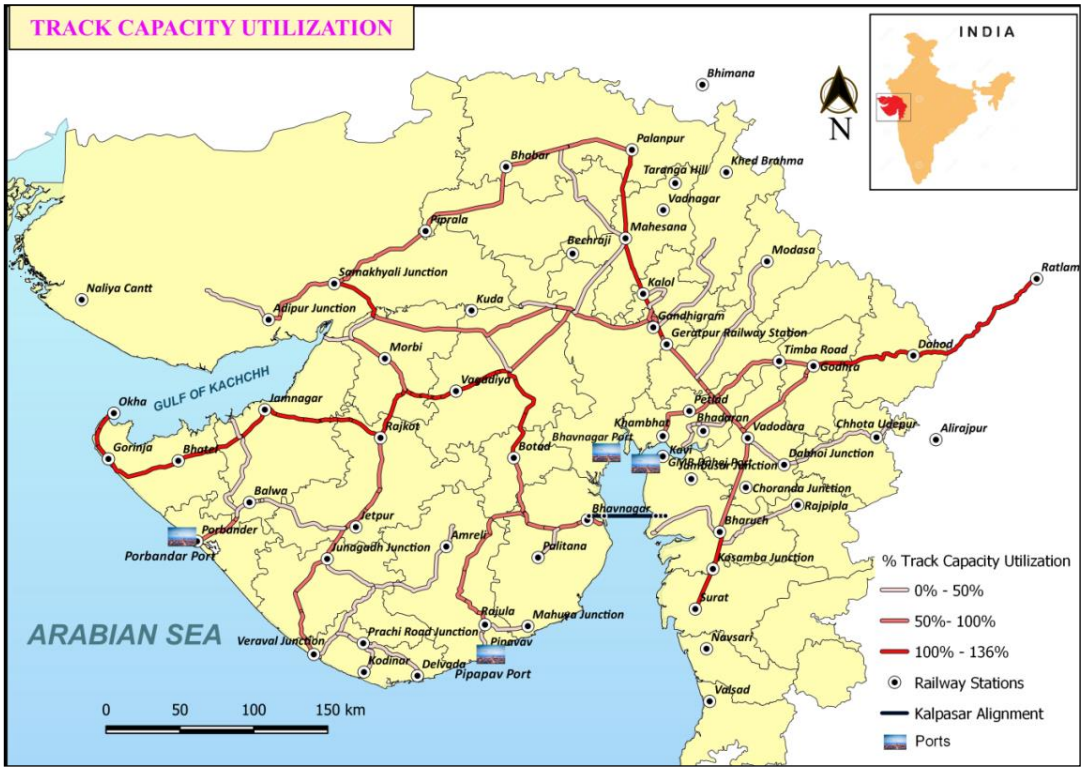


Figure 2.11: Track capacity utilization of railway network in Gujarat state (2019-20)

- **Airports**

Presently as per the Airports Authority of India (AAI), Gujarat has 19 airports i.e. 3 international, 6 domestic, 3 Domestic Civil Enclaves, 4 Private, 3 Airstrips. Further, the state government has envisaged a green field airport at Dholera Special Investment Region (DSIR) to aid the logistics requirement of the Delhi-Mumbai Industrial Corridor Project; the airport is expected to be functional by 2023. **Figure 2.12** shows various categories of airports present in the state.

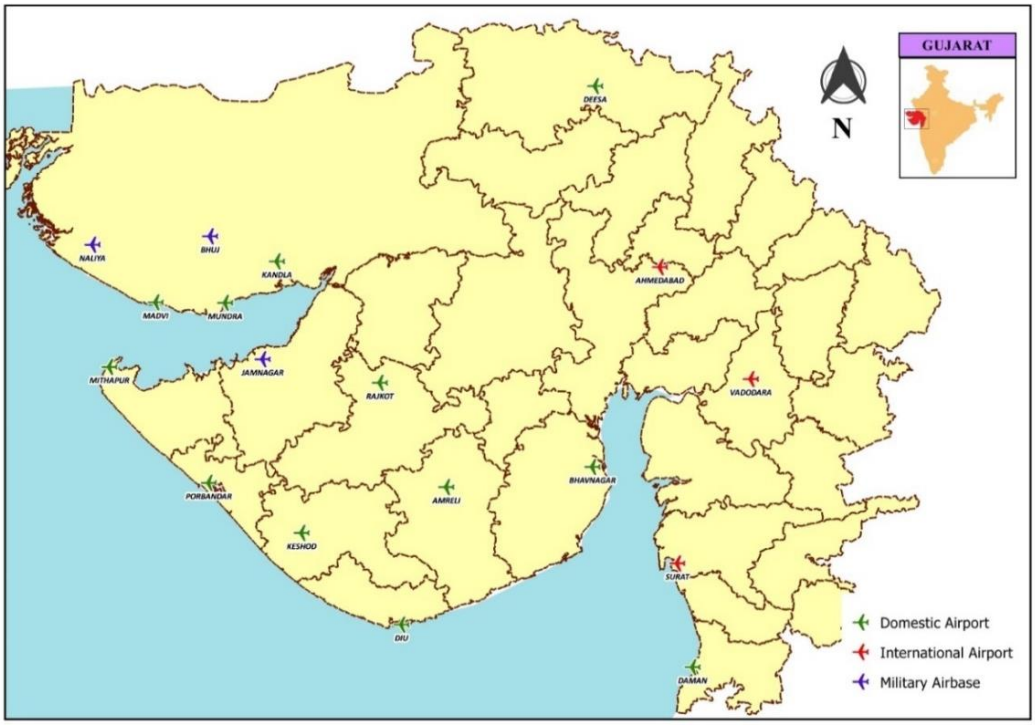


Figure 2.12: Airports in Gujarat state

Among the 16 airports, major airports in terms of passengers handled in the state are Ahmedabad, Vadodara, Surat, and Rajkot. In 2018-19, the Ahmedabad International Airport catered to about 7.36 lakh domestic and 1.74 lakh international passengers monthly (average) whereas Vadodara, Surat and Rajkot airports catered to about 0.92 lakh, 0.92 lakh and 0.28 lakh passengers monthly (average). The details of passengers catered by airports in the state of Gujarat are presented in **Table 2.30 of Annexure 2.3**.

- **Ports**

Gujarat is strategically located along the western coast of India having longest coastline of 1600 Kilometres among the Indian States, Gulf of Cambay and Gulf of Kutch provide natural navigational safety and logistical advantage. Gujarat has 48 ports spread across the regions of Saurashtra Region, Kutch, and South Gujarat. Among minor ports, 17 handle cargo whereas the remaining are utilized predominantly for fishing activities; All the ports of Gujarat are shown in **Figure** 2.13 and the details are tabulated in **Table 2.31 of Annexure 2.3**.

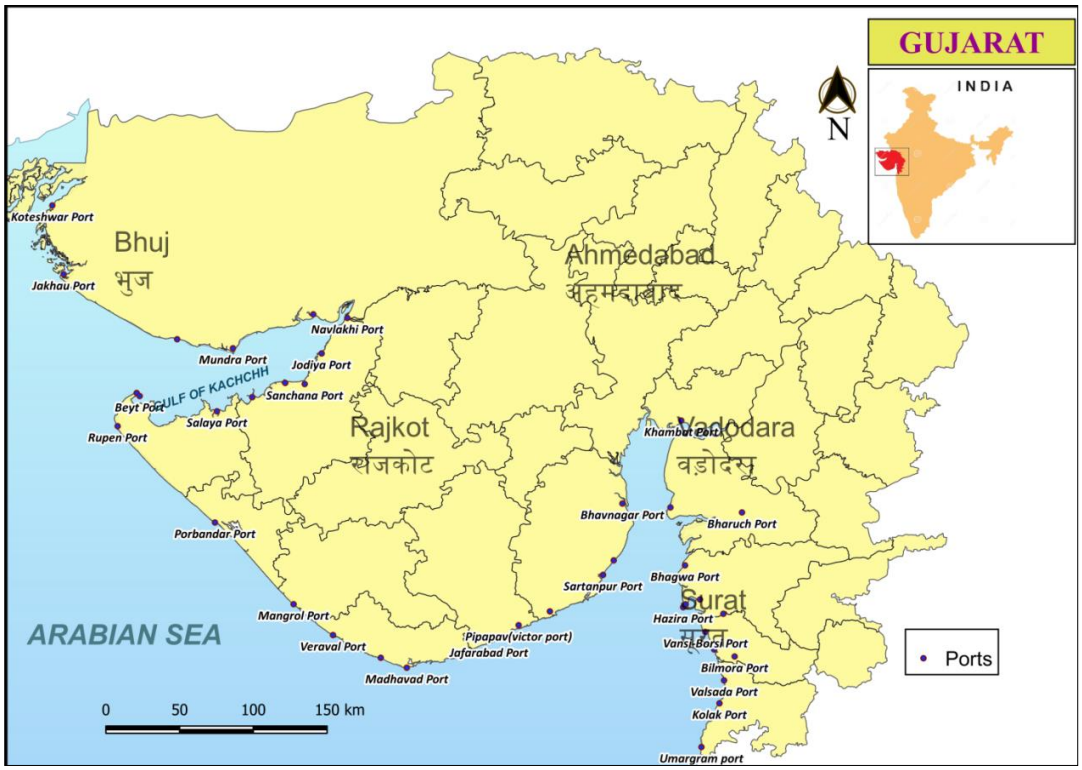


Figure 2.13: Major and minor ports in Gujarat state

As per the Gujarat Infrastructure Development Board (GIDB) in 2018-19, the traffic handled by the ports in Gujarat was about 399 MMT against the capacity of 542 MMT.

Considering the cargo markets and the hinterland connectivity, it can be noted that the hinterland of all the ports is predominantly Gujarat (mainly Saurashtra), Rajasthan, Delhi and Punjab. Therefore, the impact of existing and proposed ports in the project influence area on Kalpasar transportation link is less.

➢ **Power**

Gujarat is second most power consuming state in the country. The states' electricity demand has grown with a CAGR of about 6.1% from 2008 to 2018. In 2018-19, the state consumed about 116.3 TWh of electricity and the per capita consumption was 1,733 kWh. The state's power generation capacity in 2018-19 was 32.3 GW; main source is Coal.

As per the power sector forecast for 2029-2030, it is estimated that the state's total power capacity will be 78.4 GW and further, that there will a major shift from Coal power to Renewables based.

➢ **Water supply**

Unequal distribution of water in Gujarat is evident as it only accounts to about 2.03% of the country's total water availability. About 80% of the surface water is primarily used for irrigation, resulting in limited availability for uses like drinking, industries etc. Further, the water available in the five regions of the state is unequal where the Central and South Gujarat Regions have more that 70% of fresh water available, the Saurashtra, and Kutch regions have only 17% and 2% respectively.

Kalpasar Project will improve the water availability to Saurashtra through development of Irrigation Canals from the Dyke.

11.3.4 Major infrastructure projects in project influence area

The various major ongoing and proposed infrastructure projects ranging from road, rail, industrial corridors, SEZs etc., within the project's influence have been reviewed and presented. These projects will have a significant impact on Kalpasar project.

➢ **Road projects**

- **Road network proposals**

Road network proposals that are in various stages of implementation are summarised below.

- Delhi-Mumbai Expressway
- Ahmedabad Dholera Expressway
- Coastal Road from Dahej to Valsad
- Widening of roads connecting Sanand, Bagodra, Dhanduka, Barwala, Vallabhipur, Limbda, Bhavnagar, Amreli, Mahuva, Veraval, Porbandar, and Dwarka.
- Necklace Road along sea connecting Bhavnagar-Dahej, Dahej to NH-48 via Vagara and coastal road along Tarapur-Bhilad-Tithal-Ubhrat-Khambhat.

- Few roads that are considered for road widening are: Widening of Coastal Road between-Bhavnagar-Somnath-Dwarka, Mahuva to Amreli, Amreli to Bhavnagar, Dandi to Kalamsar via Surat, Hansot and Jambusar, Tourist corridor connecting Saputara, Ukai, Devmogra, Zarvani and Statue of Unity.

➢ **Railway**

List of on-going and future projects are presented based on Pink Book by Indian Railways and other Railway sources and the same is presented in **Figure 2.14**.

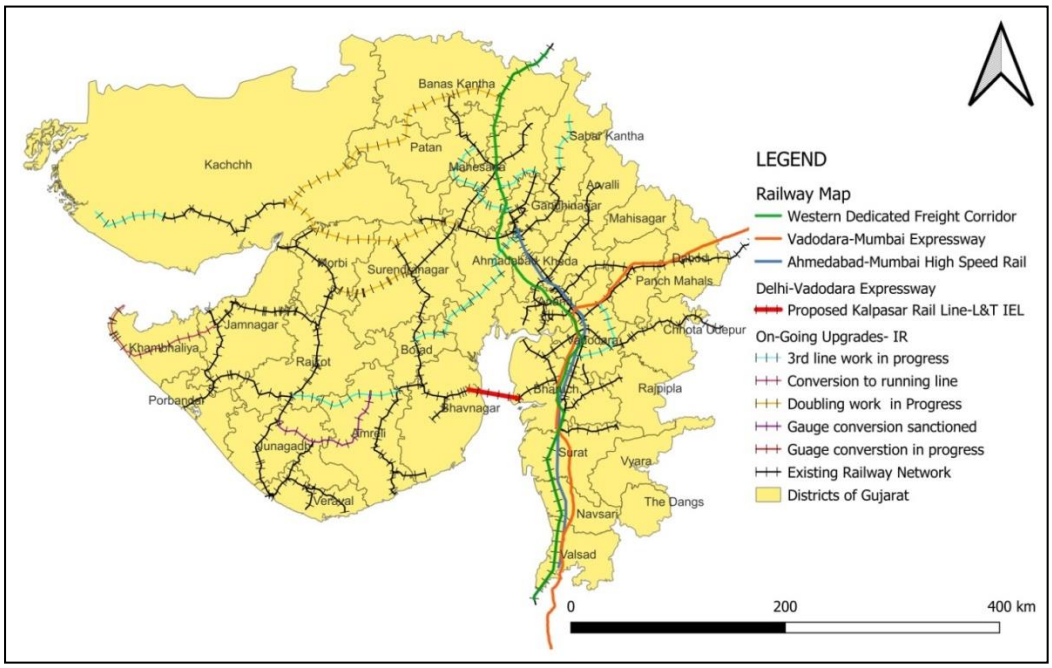


Figure 2.14: On-going and future railway projects

Detailed description of all the proposed development project is given in **sub-section 2.3.3 (d) of Annexure 2.3**.

11.3.4 Estimation of traffic growth rates

- **Road**

IRC 108:2015 suggests having multiple approaches for estimation of traffic growth rates such as:
(1) Growth factors based on past traffic trend data on study corridor
(2) Growth factors based on past registered motor vehicles in PIA
(3) Growth factors based on elasticity analysis
(4) Growth factors based on time series analysis

In general, the factors, which influence the growth of traffic are:
(1) Demographic: (i) Population (ii) Mix of population (urban vs rural), (iii) Income, and (iv) Others (tourism).
(2) Economic: (i) Gross Domestic Product at the National level, (ii) Agricultural Output, (iii) Industrial Output, and (iv) Per capita Income.

Traffic growth rate are established by giving due consideration to the above factors. Most widely used methods for forecasts of the traffic include (i) Trend Analysis, and (ii) Elasticity Approach.
(1) Trend Analysis based on Past Traffic Data: Trend Analysis is a time trend of past traffic. The future trends are derived based on past trends by extrapolation.
(2) Elasticity Method: Elasticity is defined as rate of change of traffic with 1% change in potential variables such as NSDP, per capita income and population. In elasticity method, growth in traffic is obtained by multiplying the Elasticity values with Gross National Product (GNP), per capita income or population of the regions.

- **Forecast of population and economy of India**

Future population and economic trends are critical for forecast the traffic growth rates as traffic is derived demand. Therefore, review of forecast of population and economy of India is carried and presented in this section.

- **Population**

It can be noted that during 2001-2011 for which census information was available, India recorded annual average growth rate of 1.64% whereas Gujarat has recorded a higher growth rate of 1.78%.

As per the population forecast by UN (50% prediction interval i.e. Median), the Indian population is expected to reach a peak of about 165 Crore between 2055-60. Thereafter, population is expected to decline to about 145 Crore by 2100. The trends of population growth for next 8 decades (as forecasted by UN) and the corresponding growth rates are presented in **Table 2.46, Figure 2.44 and Figure 2.45 of Annexure 2.3.**

- **Economy**

According to a report by **Observer Research Foundation (ORF)**, the Indian economy will grow at a **long-term compound annual growth rate of around five percent between 2020 to 2050.**

As per **Lancet Study, India would move to become the fourth largest economy by 2030 and the third largest by 2050. By 2100, India is forecasted to still have the largest working-age population in the world**, followed by Nigeria, China, and the USA. Despite fertility rates lower than the replacement level, immigration sustained the US workforce as per the paper.

A global report on economy prepared by **PwC** has estimated the growth of Indian economy as the second largest in the world by 2050. India can surpass US by that time. As per the report, Indian economy is likely to grow at 5% between 2021 to 2030; 4.4% between 2031 to 2040 and 3.9% between 2041 to 2050. GDP growth rate of India is given in **Table 2.47 of Annexure 2.3**.

- **Traffic growth rate based on past traffic data**

L&T Ramboll Consulting Engineers Ltd had carried the Traffic study in 2010. The traffic data of the study is compared with the traffic counts carried out as part of the current study and the derived mode-wise growth rates are presented in **Table 2.9**.

Table 2.9: Road-wise past growth rate (per annum growth rates) from 2010 to 2012

Location Name	Mode-wise Annual Growth Rates						
	Car	Bus	Mini Bus	LCV	2A Truck	3A Truck	MAV
Karjan Toll plaza	5%	2%	7%	5%	-4%	-6%	11%
Padra-Borsad Road (Near Bhadran)	8%	3%	4%	6%	-3%	-9%	15%
Vataman Toll plaza (Non-Operational)	9%	3%	1%	7%	-2%	-6%	17%
Bagodara Toll plaza	7%	2%	2%	7%	-6%	-2%	18%
Amod-Muler Road (Near Amod)	7%	-15%	-100%	6%	-8%	-9%	13%
Bharuch-Vagra Road	7%	-2%	-5%	11%	-7%	3%	11%

Location Name	Mode-wise Annual Growth Rates						
	Car	Bus	Mini Bus	LCV	2A Truck	3A Truck	MAV
(Near Vagara)							
Kotda Toll Plaza (Non-Operational)	11%	2%	5%	8%	-1%	-7%	12%

The decline in 2-Axle, 3-Axle trucks is due to increased preference for multi-axle trucks as well as LCVs due to economics of operations. Multi-axle trucks have shown double digit growth rate ranging from 11% to 18% on various roads. Decline in Buses is noticed on local roads. Major corridors show positive growth rates.

Among the above-mentioned road sections, the growth trends observed at Vataman Toll Plaza is more appropriate for Kalpasar Project since Vataman captures all the East-West Traffic. Once Kalpasar project is implemented significant proportion of traffic at Vataman Toll Plaza is expected to be diverted to Kalpasar road over dyke. Therefore, Vataman Toll Plaza growth trend is taken to be past traffic growth for the current study.

- **Growth trends of registered vehicles in Gujarat**

To assess the growth of traffic within the project's influence area, the vehicle registration trend data has been analysed. The details regarding the number of vehicles registered and the vehicle composition (2000 to 2018) is extracted from Commissionerate of Transport, Government of Gujarat and the same is presented in **Table 2.50 of Annexure 2.3**.

From the observed past traffic data over the years, it is evident that the average growth of vehicles accounts in the range of 6% for transport vehicles and 9% for non-transport vehicles. Category wise Motor Vehicles registered in the state from 2015 to 2019 are shown in **Annexure 2.3**.

Among the total registered vehicles in Gujarat in 2019-20, motorcycles/scooters dominate the total with 62.86%, followed by motor cars with 12% and mopeds by 10.2%.

Only drawback of growth rate derived from registered vehicles is that they do not always reflect ground conditions. It only shows the new vehicle registrations and the vehicles phased out from road network are not known. The net effect of both will reveal the actual growth rate of traffic on road network. Moreover, vehicle registration is reflecting economic cycles.

- **Growth rate based on elasticity approach**

The values of elasticity for the past decade (2001-2021) for Car, Bus, Trucks is 1.2, 0.875 and 1.1 as per the Road Transport Demand for 2000 AD revisited and demand forecast for 2021, Journal of the Indian Roads Congress, Oct-Dec, 2009. The elasticity values continue to decline as the economy matures and will decline to 0.5 or even lower. The elasticity values have been considered based on the developed economies and final forecast is made duly considering growth in economy and population.

- **Estimated traffic growth rate**

The final estimated traffic growth rates for the future based on past traffic growth rates and elasticity approach duly considering the growth of population, economy is presented below in **Table 2.10**.

Table 2.10: Estimated mode wise traffic growth rates for Kalpasar project

Year	LCV	2 Axle Truck	3 Axle Truck	Multi-Axle Truck	Car	Bus
2011-2021	6.00%	-2.00%	-2.00%	13.00%	8.00%	2.50%
2022-2030	4.25%	-1.40%	-0.90%	7.50%	7.50%	2.10%
2031-2040	3.50%	-1.30%	-0.70%	5.00%	7.00%	1.80%
2041-2050	3.00%	-1.20%	-0.60%	4.50%	6.00%	1.50%
2051-2060	2.00%	-0.90%	-0.40%	3.50%	5.00%	0.75%
2061-2070	1.50%	-0.45%	-0.30%	2.50%	3.00%	0.50%
2071-2080	1.00%	-0.20%	-0.10%	1.50%	1.50%	0.25%
2081-2090	0.50%	-0.10%	-0.10%	0.50%	1.00%	0.20%
2091-2100	0.25%	-0.10%	-0.10%	0.25%	0.50%	0.10%

*Source: Consultant Analysis

➢ **Rail**

- **Traffic growth rates for railway passenger traffic**

The trends of annual growth of passenger traffic from 2008 to 2018 and Growth trend for long distance AC & Non-AC passengers is presented in **Table 2.54** and **Table 2.55 of Annexure 2.3.**

The forecast of the future railway passengers considers past growth rates as well as growth in future population and GDP. Separate traffic growth rates have been considered for AC and Non-AC passengers based on Past trends, National Railway Plan-2020 as well as Consultants 'analysis and the same is presented below in **Table 2.11**.

Table 2.11: Growth rate of passenger traffic by category

Year	Growth Rate of LDAC	Growth Rate of LDNC
2021-2031	8.76%	1.73%
2031-2041	6.47%	1.50%
2041-2051	5.43%	1.41%
2051-2061	3.80%	0.70%
2061-2071	2.47%	0.35%
2071-2081	1.36%	0.18%
2081-2091	0.68%	0.09%
2091-2101	0.27%	0.04%

*Source: Consultant Analysis

- **Traffic growth rates for railway freight traffic**

As per National Railway Plan (Dec, 2020), Ministry of Railways, Government India, the share of freight by Indian Railways in 2018-19 is only 27%. As per the Plan, rail share is

expected to increase to 45% of the total freight by 2051, by increasing the speed of the trains and reducing the tariff on certain commodities as well as augmentation of infrastructure.

Traffic growth rates by Rail (for freight) considers past growth rates, National Railway Plan-2020 as well as Consultants' analysis. The estimated traffic growth rates for freight through Rail is presented below in **Table 2.12**.

Table 2.12: Growth rate of freight traffic by rail

Year	Growth Rate in Freight Traffic by Rail
2011-2021	2.94%
2021-2031	9.90%
2031-2041	4.79%
2041-2051	3.13%
2051-2061	1.72%
2061-2071	0.86%
2071-2081	0.39%
2081-2091	0.16%
2091-2101	0.05%

*Source: Consultant Analysis

11.4 Traffic demand forecast & capacity requirements

11.4.1 Travel demand model

A travel demand model has been developed to forecast the traffic on Kalpasar road link. The model is developed using CUBE software. The modelling procedure followed in CUBE software is presented in **Figure 2.15** below.

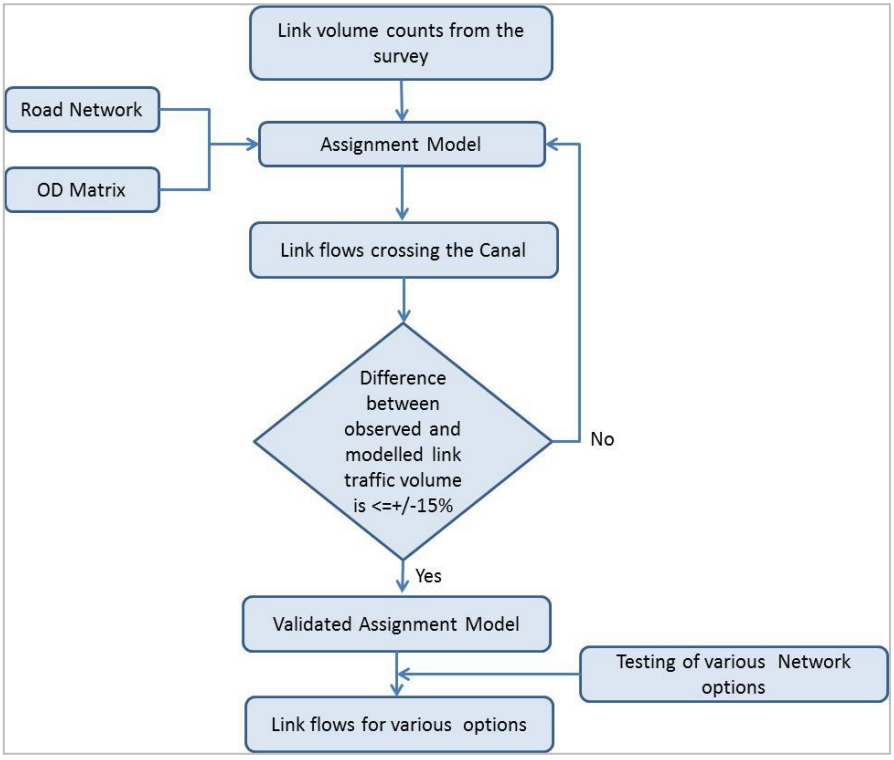


Figure 2.15: Modelling procedure

The model is responsive to congestion, travel costs and travel time savings. Model is calibrated for 24 hours period. Year 2022 is considered as the base year, 2032 is considered as opening year for road over the dyke. 2071 and 2101 have been considered as horizon year for Traffic demand forecast. The study area is divided into number of **Traffic Analysis Zones (TAZ)** for analysing the travel characteristics. Taluk boundaries are considered for dividing the study area into Traffic Analysis Zones. The total number of zoning system adopted for the study is 207 out of which 192 zones are internal and 15 zones are external. The zone map is presented in **Figure 2.16**.

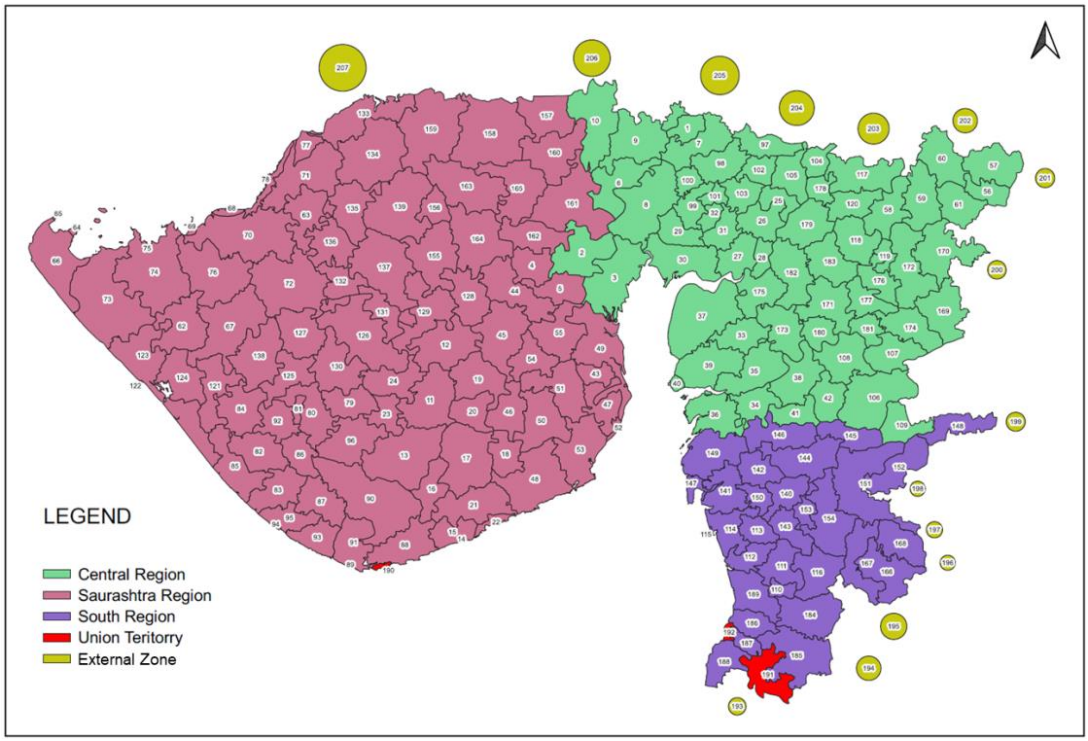


Figure 2.16: Zone map

- **Network development**

The National Highways (NH), State Highways (SH) and Major District Roads (MDR) are considered in the development of the network. Total length of network includes 14,377 Km. All links are coded as oneway links having A – node (after node) and B – node (before node) with its own characteristics.

The salient features of the coded highway network are presented in **Table 2.15 of Annexure2.3**. There are two capacity values a) for assessing lane requirements b) for capacity analysis purpose. Details about the existing toll road stretches and toll rates are collected and same is coded in the Network.

For urban road stretches, daily capacities are derived from Peak Hour capacities adopted from Indo-HCM 2017 manual. For Highways and Expressways, the daily capacities are taken directly from Indo-HCM 2017.

The form of the BPR function for speed flow is:

$$T_C = T_0 * (1 + \alpha * (v/c)^{\wedge \beta})$$

Where, T_c – Congested Link Travel time

T_0 – Link Free flow time

v - Link Volumes
c – Link Capacity
α and β – calibrated speed flow parameters

The α and β parameters are calibrated based on the observed speed and traffic volumes for various road categories. The coded highway network is presented in **Figure 2.17**.

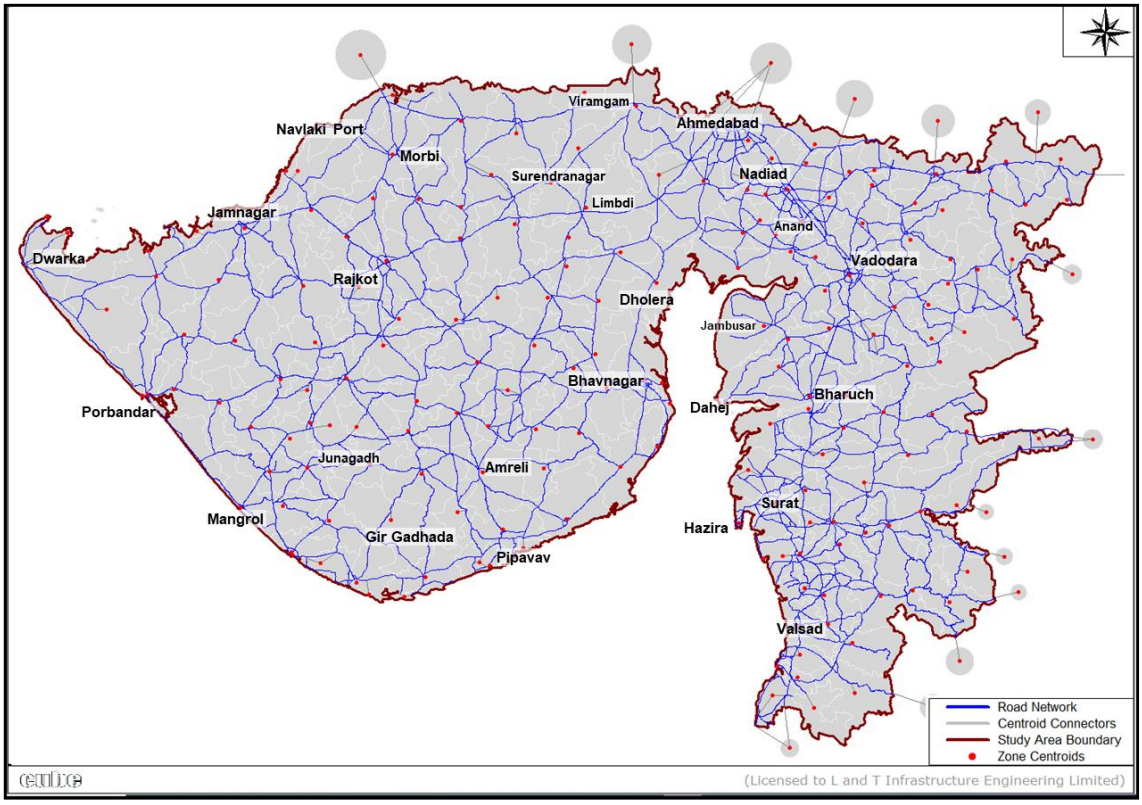


Figure 2.17: Coded highway network

➢ **Matrix Development**

- **Development of matrices for immediate project influence area**

From the primary traffic surveys, mode-wise matrices are generated for Private vehicles (Car and Two wheeler), Intermediate Public Transport (Taxi and Auto Rickshaw), Public Transport (Bus and Mini Bus), Commercial vehicles (Truck, MAV and LCV).

- **Development of matrices for the rest of Gujarat and other directional movements**

In order to include the impact of other traffic movements apart from East- West traffic movement on the network, consultants have prepared the seed matrix considering the following parameters:
(1) Population; (2) Road Connectivity; (3) Rail Connectivity; (4) Proximity to Major Port
(5) Proximity to International Airport; and (6) SEZ & any Industrial Park.

Overall rating for each TAZ's have been calculated based on the above parameters. Above factors are further sub-categorized base on size, configuration and infrastructure availability. Score is given to sub-category ranging from zero to 100 and based on the scoring a seed matrix is developed. Based on the traffic volumes and seed matrix, initial matrix is developed using CUBE Analyst module.

➢ **Validation**

Mode wise matrices of Private vehicles, IPT, Public Transport and Commercial Vehicle modes are assigned on the transport network. The network/ matrices will be checked and calibrated until the difference between assigned traffic volumes and observed traffic volumes comes with in allowable limit of +/-15%. This process will be automated by the CUBE ANALYST software. Base year observed and modelled Traffic Flow on major roads have been compiled and presented in **Table 2.16 of Annexure 2.3**.

The map showing the traffic flow diagram and Desire line diagram for the base year is presented in **Figure 2.18** and **Figure 2.18.**

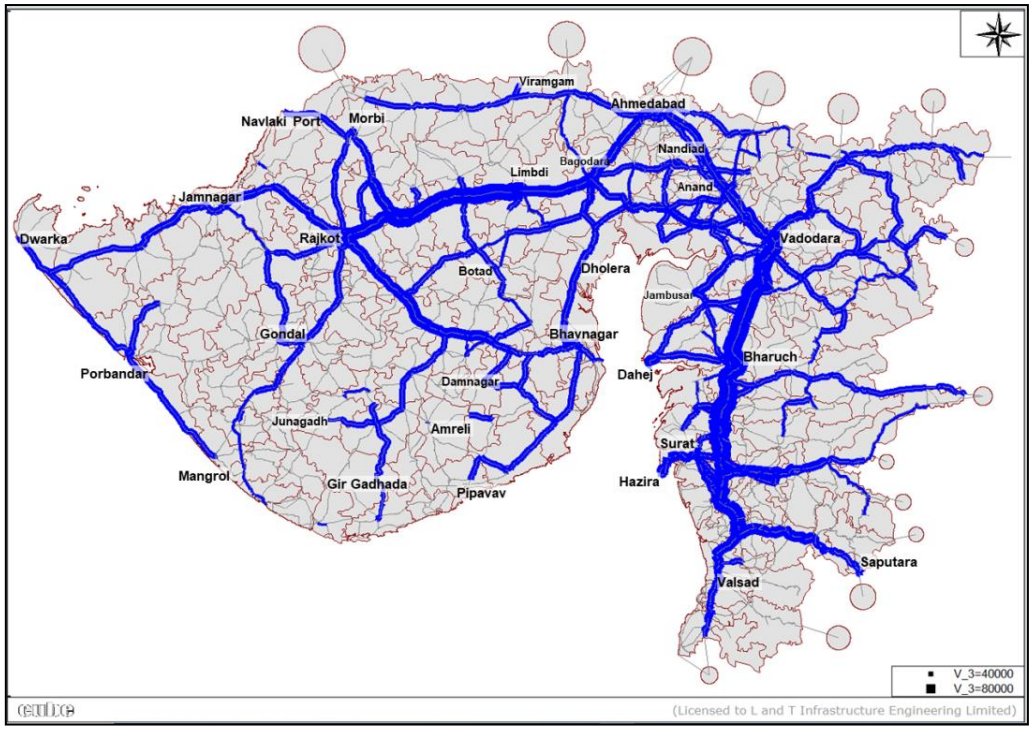


Figure 2.18: Traffic flow diagram for base year (2022)

➢ **Description of various scenarios for forecasting the traffic**

Considering the long horizon for traffic forecast and given the uncertainly in forecast the range of forecast are required so that appropriate decision can be taken on lane configuration for road development. In this regard, three scenarios (pessimistic, most likely and optimistic) have been worked out. The various underlying assumptions in various scenarios are presented below.

- **Optimistic scenario**

(1) All road network improvements (such as road widening and greenfield roads) are expected to happen as planned

(2) Travel demand is expected to grow proportionate to population and economy

(3) All the SEZ would be operational as planned

(4) 10.4 Lakh hectare additional land will be irrigated due to the Kalpasar dyke

(5) 1/3rd of the of goods generated from the irrigated crops will be transported

(6) 15 Lakh tourist per annum are expected in the year of project opening

- **Most likely scenario**

This scenario has following assumptions,

(1) Only 50% of projected SEZs would be operational;
(2) 10.4 Lakh hectare additional land will be irrigated due to the Kalpasar dyke;
(3) Only 1/5th of the of goods generated from the irrigated crops will be transported;
(4) Only 2/3rd of the expected tourist would arrive in the year of project opening;
(5) Same growth rates of optimistic scenario;
(6) All road network improvements are expected to happen in optimistic manner.

- **Pessimistic scenario**

Pessimistic scenario assumes that most of the developments will not be in the pace as expected. Following are the assumptions of pessimistic scenario,

(1) Only 25% of projected SEZs would be operational;
(2) Only 3/4th of the expected area would be irrigated;
(3) Only 1/5th of the of goods generated from the irrigated crops will be transported;
(4) Only 1/3rd of the expected tourist would arrive in the year of project opening;
(5) Reduced growth rates than that of optimistic scenario;
(6) All road network improvements are expected to happen in optimistic manner.

In General about 50% of goods generated are expected to be transported by rail.

Traffic demand forecast has been carried out at every decadal interval till 2101. It is assumed that 2032 is the opening year of the project. The base considered is 2022 and forecast has been made for every decade i.e. 2031,2041,2051,2061,2071,2081,2091 and 2101 and the same is presented in **Table 2.15.**

11.4.2 Assessment of toll rates

As per the Govt. of Gujarat Policy, Toll rates are decided based on toll rate viability, uniformity of rate in the region and restricting recovery to the tune of 50% of the perceived users' benefits. NHAI toll policy, base fee, additional toll fee due to structures, concessions, toll policy of Gujarat Government is discussed in detailed in **sub-section 2.3.4 (c).**

- **Proposed toll rates for current project**

The Kalpasar project will result in significant distance and travel time-savings for users travelling between for Saurashtra and South Gujarat region. Kalpasar Project will result in a) Fuel cost savings (due to more than 100 km reduction in distance) b) Travel time savings c) Commodity Holding Cost savings of about 2 hours d) Existing tolls.

For the purpose of fixing the toll rates, perceived benefits arising from average 100 km distance savings and 2 hours travel time savings is considered, and further 50% of savings in perceived benefits due to use of Kalpasar project is considered as Toll rates as per the Government of Gujarat Policy and the same is presented in **Table 2.13.**

Around 92% of the truck operators interviewed in Saurashtra and 80% of the truck operators interviewed in South Gujarat reported their willingness to pay the proposed toll fee. Out of all the Car users surveyed at Vataman, Bagodara and Borsad Toll Plaza, about 89% of the users are willing to pay the proposed toll fee.

Table 2.13: Proposed toll rates (in Rs.) for Kalpasar

Type of Vehicle	Fuel Savings (in Rs)	Travel Time savings (Rs) (in Rs)	Existing Toll Savings (in Rs)	Total Savings (in Rs)	Proposed Toll Rate(in Rs)
Car	909	368	445	1,722	860
Bus	2,701	193	1,460	4,354	2,175

Type of Vehicle	Fuel Savings (in Rs)	Travel Time savings (Rs) (in Rs)	Existing Toll Savings (in Rs)	Total Savings (in Rs)	Proposed Toll Rate(in Rs)
LCV	1,284	32	710	2,026	1,015
2-Axle Truck	2,138	233	1,460	3,831	1,915
3-Axle Truck	2,178	233	2,090	4,501	2,250
MAV	2,813	366	2,270	5,449	2,725

* Note-1: Proposed Toll Rate is kept at 50% perceived savings
* Note-2: Toll at **Karjan**, **Vasad**, **Borsad** and Proposed Toll at **Vataman** is considered as existing toll (The toll Rate at Vataman is considered same as that of Borsad)
* Note-3: Commodity holding Cost is calculated based on concept of commodity inventory cost as per SP30-2019 & Value of time (VOT) for Car and Bus is calculated based on as per SP30-2019.
* Note-4: Rounded off to nearest 5/- rupees.

11.4.3 Traffic demand forecast

➢ **Road**

Traffic demand forecast has been carried out at every decadal interval till 2101. It is assumed that 2032 is the opening year of the dam. The base considered is 2022 and forecast has been made for every decade i.e. 2031,2041,2051,2061,2071,2081,2091 and 2101.

- **Development of Horizon year Network**

Consultants have collected the information about future year network improvements from various authorities. The major network improvement proposals are listed in **Table 2.92 of Annexure 2.3** and the same shown **Figure 2.54 of Annexure 2.3**. The proposed new networks are added on to the existing road network. The proposed road on the dyke is coded into the future highway network.

- **Development of matrix for horizon years**

Future traffic on Kalpasar Road comprises of:
(1) Normal traffic (diverted);
(2) Generated traffic; and
(3) Induced traffic.

- **Development of Matrices for Normal Traffic Matrix for Horizon years**

Mode wise Matrices for Normal traffic for the base year is derived from the **Primary Traffic Surveys** and the matrices have been strengthened based on link counts and socio-economic parameters. These matrices have been assigned on the existing network and validated. Traffic growth rates have been applied to the validated matrices to obtain the horizon year matrices. Traffic growth rates have been estimated based on the various socio-economic scenarios and the same is presented in **Section 11.3.3**. Development of Matrices for Generated Traffic

Generated traffic is an important component of future traffic as many developments have been proposed in the project influence area. In addition to the industrial developments, Kalpasar centric developments such as Tourism and Irrigation will contribute to generated traffic.

(i) Generated traffic from new industrial developments

Phasing of Major developments is considered based on Master Plan and suitable assumptions wherever information is not available. Net development area in hectare is multiplied with trip generates rates to obtain the total commercial trips generated from the

development. Trip generation for commercial vehicles is considered as 1.7 trucks per hectare based on the primary and secondary information. All such trips are converted into Goods PCUs for the horizon years of 2025 to 2060 for span of every 5 years. Detailed assumptions are stated in **sub-section 2.3.4 (d).** The forecasted normal matrix is added with the matrix developed for future development to arrive at the total matrix.

(ii) Generated Traffic due to Tourism

Kalpasar project will create a fresh water reservoir of 2000 sq.km, which is huge considering anywhere in the World. Tourists are expected to visit dam view which can be seen from either side of the dyke. Tourism potential of Kalpasar is estimated to be 15 to 20 lakh per annum based on the review of similar projects. However, only a fraction of these tourists is likely to cross the road over dyke. Assuming one fourth of the tourists cross the Kalpasar road over the dam, the generated traffic due to tourism on Kalpasar project is estimated to be 1100 PCUs/day in the year of project opening and 6700 PCUs/day in the year 2101.

(iii) Generated Traffic due to Irrigation

From Kalpasar Project 10000 Mm3 water with 50% dependability will be available, out of this 6500 Mm3 to be earmarked for irrigation. Three garland canals at about EL 50 m, EL 70 m and EL 100 m are planned to irrigate about 10.40 lakh hectares of agricultural land of 6 districts and 39 Taluks of Saurashtra. Detailed assumptions are stated in **sub-section 2.3.4 (d).** Based on the above assumptions, around 4000 additional truck PCUs per day is expected to be generated carrying food grains between Saurashtra to South Gujarat in the year of project opening and is expected to increase to 20,000 truck PCUs in the year of 2101.

- **Traffic Forecast for various Scenarios**

Traffic forecast has been carried out for three scenarios namely Optimistic, Pessimistic and Most likely scenarios. Travel demand is estimated based on the assumptions stated in **section 2.3.4 (b).** The scenario-wise and year wise link volume on the road over the Dyke is extracted from the model and the same is presented in **Table 2.15.**

The traffic flow diagram for optimistic Scenario for the year 2101 is presented in Figure 2.19**.**

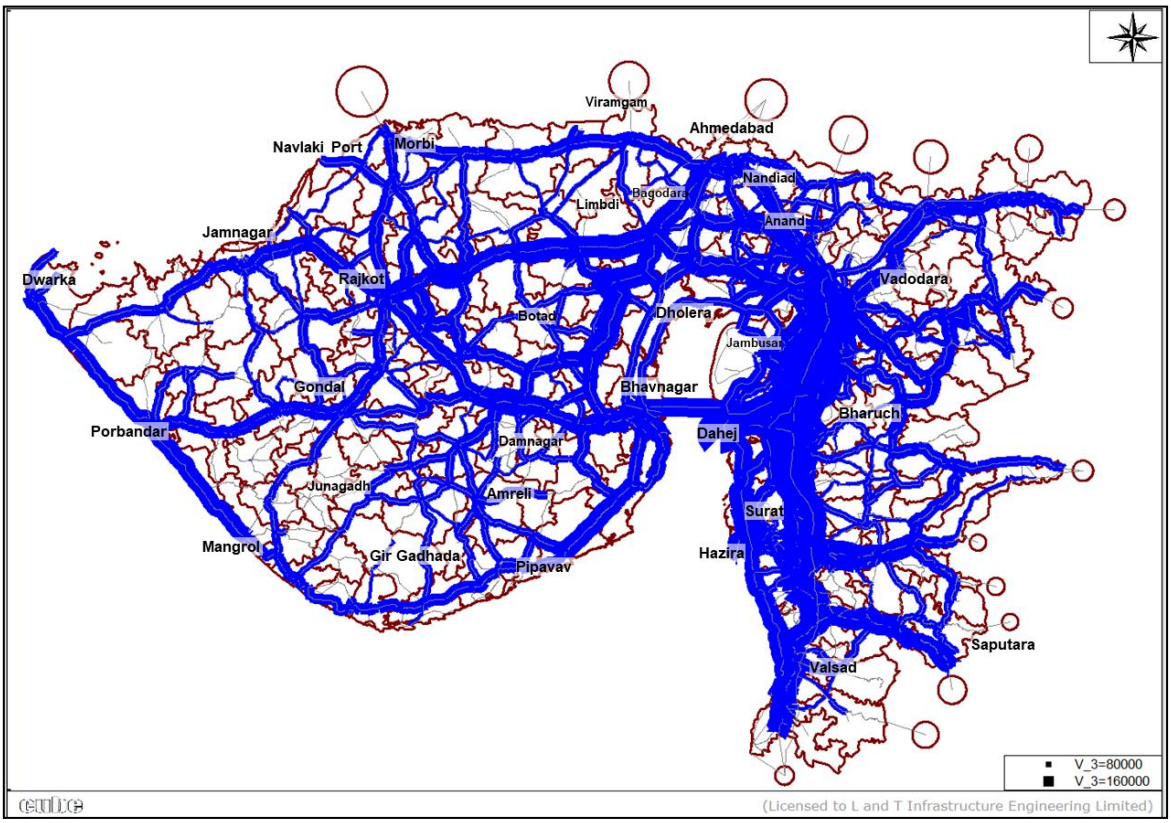


Figure 2.19: Traffic flow diagram for 2101 for optimistic scenario

➢ **Rail**

To meet the future passenger and freight demand between Saurashtra and South Gujarat, Rail link on the Kalpasar dyke is considered in addition to the multi-lane road because of its higher carrying capacity.

- **Existing railway demand**

In the absence of detailed Railway passenger O-D information, we have adopted two approaches to estimate the passenger demand on Kalpasar Rail link in the base year. The first approach is based on the current sectional passengers which is derived from the data obtained from Western Railways and multiplied with diversion potential based on the detailed O-D survey carried out for passenger vehicles (Car and Bus). Details of the approach used are discussed in **sub-section 2.3.4 (d) of Annexure 2.3.** Base year passenger demand on Kalpasar Rail link would be between 82,825 to 88,046 per day with an average value of 85,435 per day.

11.4.4 Capacity requirements

➢ **Road**

Capacity of Rural Roads for various lane configurations based on IRC is considered. In the current project, capacity augmentation is considered if any project road section reaches the design service volume corresponding to LOS C. This is the normal practice for NHAI BOT projects. The per lane capacity works out to be around 1285 PCUs/hour/lane with peak hour share of traffic of 6%.

Table 2.14: Capacity of rural roads (in PCUs)

Lane Configuration	Capacity	Design Service Volume @ LOS C**
4-lane	85,667	60,000
6-lane	1,28,500	90,000
8-lane	1,71,333	1,20,000
10-lane	2,14,167	1,50,000
12-lane	2,57,000	1,80,000
14-lane	2,99,833	2,10,000
16-lane	3,42,667	2,40,000

** Design service volumes have been rounded off; Source: IRC 64-1990, IRC-SP: 84-2014; Team analysis

Traffic forecast has been carried out for three scenarios, i.e. optimistic, most likely and pessimistic**.** However, **Optimistic scenario** has been considered for the purpose of conceptual design in view of the uncertainty in long term forecast beyond 30 years. The traffic forecast for Road over the dyke and lane requirement is presented in **Table 2.15**.

Table 2.15: Traffic forecast and capacity requirements for various scenarios

Year	Traffic Forecast (in PCUs)			Lane Requirement		
	Optimistic	Most Likely	Pessimistic	Optimistic	Most Likely	Pessimistic
2022	22,375	22,375	22,375	2	2	2
2031	52,713	49,011	45,185	4	4	4
2041	81,251	74,826	71,674	6	4	4
2051	1,21,434	1,07,860	99,920	8	8	6
2061	1,64,676	1,51,083	1,36,171	10	10	10
2071	2,06,275	1,91,816	1,70,657	14	12	12
2081	2,32,746	2,18,864	1,87,895	16	14	12
2091	2,43,709	2,22,382	1,90,625	16	14	12
2101	2,53,147	2,24,167	1,94,132	16	14	12

Based on the traffic forecast (for optimistic scenario) for road, it can be noted 6-lane will be required till 2041, 8-lane by 2051. Therefore, ROW for maximum of 16-lane needs to be considered for Road and shall be developed in phased manner based on the traffic demand.

- **Rail**

Indian Railways determines the charted line capacity manually by master chart method. Following capacity standards have been adopted for planning the railway network based on various established norms.

Table IV-16: Capacity standards for passenger and freight rail

S.No.	Configuration	Capacity (Trains/Day/Direction)

S.No.	Configuration	Capacity (Trains/Day/Direction)
1	Single line (mixed operation)	25
2	Double line (mixed operation)	60
3	Double line (mixed operation) with Automatic TCAS + ABS + CTC signalling	90
4	Double line with Automatic TCAS + ABS + CTC signalling (for dedicated passenger operations)	200
5	Single line DFC (for dedicated freight operations)	40
6	Double line DFC (for dedicated freight operations)	140

Source: National Railway Plan-India, Draft Final Report (Dec, 2020)
** Capacity of Dedicated Freight Corridor (DFC) is taken from JICA Report on DFC
Note: 1. TCAS -Train Collision avoidance system
2. ABS – Automatic block signalling
3. CTC - Centralized traffic control (CTC) is a form of railway signalling that originated

Initially, double line for mixed operations (both passenger & freight trains) is considered. However, it is found that beyond 2045, double line will be saturated. The detailed description is given in sub-section 2.3.4 (d) of Annexure 2.3. In order to meet the demand beyond 2045, there is an option of third line or option of providing two dedicated double line. The capacity utilization and train traffic forecast of dedicated passenger and freight operations (2 double track lines) are presented in **Table 2.17**.

Considering technological trends and future requirements dedicated double track is proposed for passenger trains (semi- high speed rail capable of reaching speeds upto 200 kmph) and dedicated double tracks are proposed for goods train (as per dedicated freight corridor (DFC) standards).

Table 2.17: Capacity utilization for dedicated passenger and freight lines

Year	Passenger Trains per day	Freight Trains per day	Capacity Requirement for Passenger dedicated passenger line	Capacity Requirement for dedicated freight line	Capacity Utilization for Passenger trains	Capacity Utilization for Freight trains
2022	63	10	Double track	Single track	16%	13%
2031	78	25	Double track	Single track	20%	31%
2041	119	47	Double track	Single track	30%	59%
2051	139	65	Double track	Single track	35%	81%
2061	155	77	Double track	Single track	39%	96%
2071	167	84	Double track	Double track	42%	30%
2081	174	88	Double track	Double track	44%	31%
2091	178	89	Double track	Double track	45%	32%
2101	179	89	Double track	Double track	45%	32%

Due to huge capacity, railway lines can easily accommodate spill over demand from Road thus excess demand from road traffic (if any) can be shifted to railways through

deployment of additional coaches, seamless integration for passengers and multi-modal logistics hubs for freight traffic as well as policy changes.

Therefore, considering Road & Rail as integrated solution and utilizing both road and rail capacities to the full extent, future traffic demand on Kalpasar link can be accommodated.

11.4.5 Traffic dispersal plan

(ii) Traffic dispersal plan

- **Road**

- **Bhavnagar Side**

The traffic from/to 16 lanes required to be dispersed smoothly to the existing road network on both the sides of the dyke. On Bhavnagar side, the access road to the dyke is starting from NH 751. Considering the traffic from south Gujarat to Rajkot and Jamnagar, it is proposed to extend the access road connectivity further west from NH 751 to NH 8E. Four locations are considered for major interchanges on Bhavnagar side for smooth dispersal of traffic. The proposed interchange locations are presented in **Table 2.18** and shown in **Figure 2.20.**

Table 2.18: Proposed interchange locations on Bhavnagar side

S.No	Interchange location	Chainage	Type of Interchange
1.	Near Songadh on NH 8E	00+000	Trumpet Interchange
2.	On SH 36 Crossing	09+800	Flyover with Slip roads
3.	On NH 751 Crossing	23+500	Cloverleaf interchange
4.	Near Lakdiya Pull	32+250	Flyover with slip roads

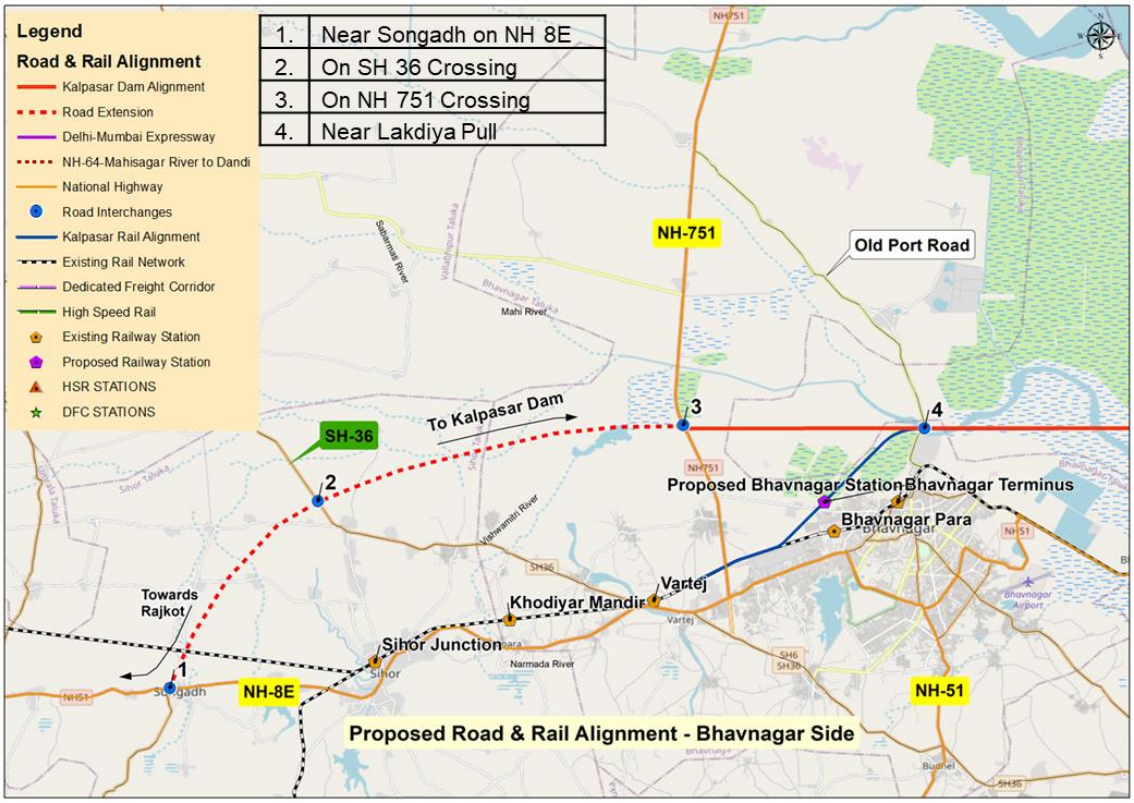


Figure 2.20: Proposed interchange locations on Bhavnagar side

The access road lane configuration is varied based on the traffic demand. The access road at the starting point (NH 8E) will have eight lane configurations. The proposed access road lane configurations for various sections are presented in **Table 2.19**.

Table 2.19: Access road lane configurations on Bhavnagar side

S.No	Section	Chainage		Lane Configuration	Traffic Volume in PCUs/Day (Year-2101)
		From	To		
1	From NH 8E to SH 36	00+000	09+800	Ten Lanes	1,60,280
2	From SH 36 to NH 751	09+800	23+500	Fourteen Lanes	2,00,644
3	From NH 751 to Lakdiyapull	23+500	32+250	Sixteen lanes	2,45,601
4	From Lakdiya Pull to Dyke	32+250	43+500	Sixteen lanes	2,53,802

- **Bharuch Side**

On Bharuch side, the access road is extended further from **'D'** point further to Bharuch – Dahej road (SH 6) for the smooth dispersal of traffic. Four interchange locations are proposed for the smooth dispersal of traffic. The proposed interchange locations are presented in **Table 2.20** and **Figure 2.21**.

Table 2.20: Proposed interchange locations on Bharuch side

S.No	Interchange location	Chainage	Type of Interchange
1.	Near Goladra on SH 6 (Dahej- Amod Road)	83+660	Flyover with Slip roads
2.	Pakhajan	93+800	Flyover with Slip roads
3.	Sadathala	98+730	Flyover with Slip roads
4.	On Bharuch – Dahej Road (SH-6)	104+500	Flyover with slip roads

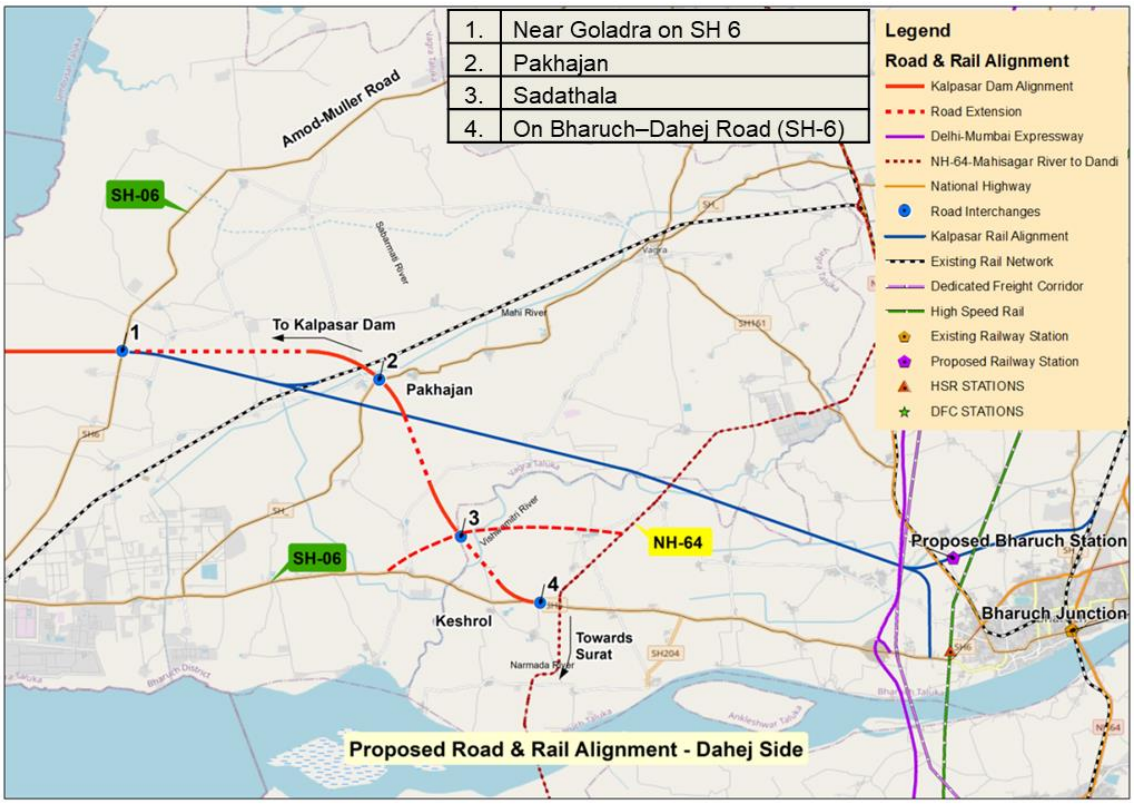


Figure 2.21: Proposed interchange locations on Bharuch side

The access road lane configuration is varied based on the traffic demand. The access road at the end point i.e. on Dahej- Bharuch road will have eight lanes. The proposed access road configurations at various road sections in presented in **Table 2.21**.

Table 2.21: Access road lane configurations on Bharuch side

S.No	Section	Chainage		Lane Configuration	Traffic Volume in PCUs/Day (Year-2101)
		From	To		
1	From Dyke to Dahej – Amod road (SH 6)	70+000	83+500	Sixteen lanes	2,53,802
2	From Dahej- Amod Road (SH 6) to Pakhajan	83+500	93+800	Twelve lanes	1,54,499
3	From Pakhajan to Sadathala	93+800	98+700	Ten Lanes	1,40,093
4	From Sadathala to Bharuch- Dahej road (SH 6)	98+700	104+500	Eight lanes	1,24,182

- **Rail**

Railway line over the Kalpasar link connects south Gujarat and Saurastra region. For effective dispersal of train passengers, the existing line is proposed to be connected with the proposed high speed rail station at Bharuch; similarly a new passenger terminal is proposed to be developed at Bhavnagar side.

To ensure continuous movement of trains from other districts of Gujarat and other states, a connecting link is proposed to connect the existing railway line for effective dispersal of train traffic.

New Railway terminal is proposed near Ramdev nagar at Bhavnagar side and at outskirts of Bharuch at Dahej side to ensure smooth dispersal of rail passengers.

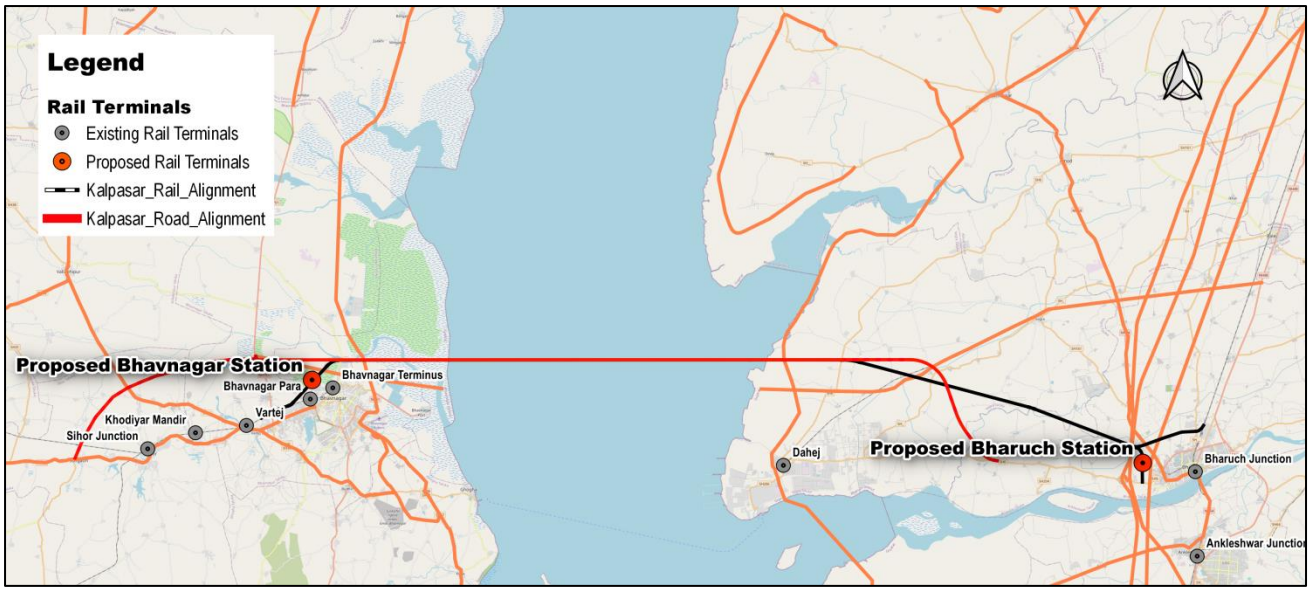


Figure 2.22: Proposed Rail Terminals

Table 2.22: Proposed Rail Terminal Location

Section of Road alignment	Chainage (in m)	Remarks
P	6+519	Proposed Bhavnagar Terminal
Q	96+511	Proposed Bharuch Terminal

13.4 Transportation

13.4.1 Road design

IRC: SP: 87 "***Manual of Specifications & Standards for Six-laning of Highways through Public Private Partnership***" and other relevant IRC codes are considered as design basis.

- **Geometric design standards**

Design speed: Ruling design speed of 100 Kmph for main carriageway and 40 kmph for service road is followed for the entire project stretch.

Carriageway width: Carriageway width of 3.5 m is considered.

Other geometric design standards such as Cross slope, sight distance, horizontal alignment design, vertical alignment design, super elevation, transition curves, at-grade intersections, grade separated intersections/interchanges, surface drainages, bus bays, truck lay bays, rest areas, road side furniture, lightings, access control is discussed in detailed in **sub-section 2.3.5 (a) of Annexure 2.3.**

Rigid pavement design: The rigid pavement type is provided considering longer lifespan and low maintenance costs which is designed according to **IRC: 58-2015 "Guidelines for the Design of Plain Jointed Rigid Pavements".**

Intelligent transport system (ITS) have been considered as per relevant IRC codes (IRC: SP: 110-2017) as well as based on the best practices in recently implemented projects in India.

- **Codes, specifications and standards**

Standard specifications and codes of practice for road bridges of the IRC: wherever applicable are followed with their latest amendments and they are listed in **Table 2.36 of Annexure 2.3**.

13.4.2Rail design

- **Introduction of semi high-speed rail in India**

Semi High-Speed Rail is proposed over the Kalpasar dyke for movement of passenger traffic. According to the Ministry of Railways, a route which has trains that run between 160 kmph to 200 kmph is considered as **semi high-speed rail**, while the routes which have trains running at speeds of less than 160 km/h are considered as conventional rail lines. According to UIC (International Union of Railways) definition, the commercial speed of over 200 km/h is the principal criterion for the definition of High-speed railways. Semi high-speed rail is cost effective and can be implemented quickly as compared to high-speed rail.

Vande Bharat train

- **Design standards for semi high-speed rail**

Design parameters for track structures are presented in **Table 2.23.**

Table 2.23: Design parameters for track structure for semi high-speed rail

Track	Track structure for speeds upto 160 kmph	Track structure for speeds from 160 to 200 kmph
Rails	60 kg & 90 UTS	71 kg & 90 UTS
Sleepers	Mono block PRC sleeper	Mono block PRC sleepers
Sleeper density	1660 no. per km.	1660 nos. per km.
Fastenings	ERC clips mark III with rubber	Same

Track	Track structure for speeds upto 160 kmph	Track structure for speeds from 160 to 200 kmph
	pad 6mm Same as col.2 thick & liner — steel or GFN	
Points and Crossings	Thick web, head hardened switches and cast manganese crossings on PRC sleepers	Same
Ballast cushion	50/300 mm depth with 150 mm sub ballast	Hard stone ballast with 300 mm cushion over 150 mm sub-ballast
Formation	Stable with penetration of ballast	Well compacted and stable
Miscellaneous	Existing track may serve the purpose	Constraints to be removed

** Values in the Table are corresponding to an Annual GMT (Gross Million Tonne) of equal or more than 5.

In order to upgrade existing tracks to cater to the semi-high speed rail, sharp curves, turnouts, fencing, track geometry and formation are to be renewed so that trains can run faster than 160 kmph.

The elements that are required apart from fixed infrastructure for running the semi-high speed rail are summarised below:
(a) WAP5 and WAP4 locomotives and LHB coaches for the trains;
(b) Provision of fencing of track all through its length for prevention of trespassing and cattle runover;
(c) Provision of clamp type lock along with thick web switches in fencing direction on main line points;
(d) Provision of Train Protection Warning System (TPWS);
(e) Provision of second distant signal or automatic signaling to meet the requirement for breaking distance for higher speed trains. In case of the absence of automatic signaling, provision of Block Providing by Axle Counter (BPAC) is necessary;
(f) Provision of Swivelling type cantilever OHE where tension in the conductors is automatically regulated, with a presage of 50/100 mm;
(g) Use of Mobile Train Radio Communication System (GSM-R) for reliable train radio communication between driver & guard and nearest station and/or control office;
(h) Minimization of level crossings by provision of ROB/RUB; and
(i) IR Standard IV interlocking system.

- **Dedicated Freight Corridor (DFC)**

In order to augment the rail transport capacity to meet the growing requirement of movement of freight traffic, the Indian Railways has been developing dedicated freight corridors along the busy trunk routes.


Dedicated Freight Corridor (DFC)

DFC is planned to decongest already saturated road network & promote shifting of freight transport to more efficient rail transport. Thus, the shift from Road to Rail is expected to offer significant reduction of Green House Gas (GHG) emissions in transport sector in India. It is expected that DFC will save more than 450 million ton of CO2 in first 30 years of operation (Ernst & Young).

- **Design Standards for DFC**

Various design parameters of DFC and their specifications are presented in **Table 2.24**. Some of the Basic Parameters proposed to be followed by the DFCs are given in the **Table 2.24** which is taken from "**Standard Schedule of Dimensions for Eastern & Western Dedicated Freight Corridors of Indian Railways**" released in January 2013.

Table 2.24: Fundamental design parameters for DFC

Parameters	Specifications
Gauge	B.G 1676 mm
Axle Load	32.5 tonne loading standard for Bridges and Formation. Track structure shall be of 25 tonnes to start with.
Traction	Electric, 2x25 Kv, 50 Hz single phase AC
Maximum Permissible Speed	100 kmph, Average speed 65-70 Kmph.
Rolling Stock	Locomotives: 9000 HP Wagons: 25 ton axle load
Double stack trains	Double-stack container train operation on the Western Corridor
Track	60 kg/m, UIC/90 UTS rails, PSC sleepers, 1660 nos./km density.
Points and Crossings	60 kg rail, 1 in 12 thick web switches
Ballast	300/ 350 mm cushion
Ruling Gradient	1 in 200 (compensated)
Curves	Maximum degree of curvature of 2.5 degree (700m radius) to ensure sustained speed potential of 100kmph; curve compensation @ 0.04% per degree of curvature.

Parameters	Specifications
Formation	Formation width: Double-line – 13.5 m, Single Line – 7.6 m; Side slope of embankment to be maintained at 2:1 ; blanket thickness as per RDSO GE :0014 specification
Moving Dimensions	Vertical MMD of 7.1 m on Western Corridor and 5.1 m on Eastern Corridor
Track Centres	6.0 m on DFC and between existing IR tracks and DFC track, min.6.0, Recommended 7.925 m.
Bridges	Standard of loading of 32.5 tonne axle load; 12 tonne/m trailing load
Loop Length	Normal loop length 750m with facilities for running Long haul trains through nominated loops of 1500m length at Junction Stations.
Signalling	Double Line: Automatic Block, with Multiple Aspect Colour Light Signalling (MACLS) except Rewari-Dadri which will be with Absolute Block System. Single line: Absolute Block, with around 10 km station spacing and Multiple aspect colour-light signalling.
Station Spacing	40 km apart on double line and 10 km on single line
Junction Stations	Western DFC: 17 Junction Stations Eastern DFC: 27 Junction Stations
Road Crossing/ Level Crossing	As far as possible there shall be no level crossing; Complete length to be fenced on both sides

13.4.3Bridge design

General functional & design requirements, guidelines & design philosophy for the design of superstructure and substructure for road loading bridges. It is understood that beyond the Dyke portion, the connectivity stretch for Roadway would cross several existing waterways, roadway and railway line. Hence, structure type includes roadway superstructure for flood regulator, major bridges, minor bridges, major rubs, minor rubs, pedestrian subways & flyovers carrying vehicular loading.

Detailed discussion on design loading, temperature effects, load combinations, design parameters such as durability, permissible stresses, design assumptions, for superstructure and sub-structure for road and rail is given in **sub-section 2.3.5 (c).**

Relevant codes/ standards for road design are as given below:
(1) Indian Railway Bridges Rules, specifying the loads for Design of Superstructure and Substructure of Bridges (with up-to-date correction slip) including Chapter – VII for the rule for the opening of Railway;
(2) Loading Standards as given in Design Criteria (specified in Employer's Requirements – Part – 2, Volume -04 of bid document);
(3) Indian Railway Schedule of Dimensions for Board Gauge;
(4) DFC Draft Schedule of Dimensions;
(5) Indian Railway Code for Practice of Plan/Reinforced and Pre-stressed concrete for general / bridge construction (Concrete Bridge Code);
(6) IRS Specifications for Steel Bridges Code;
(7) Indian Railway Bridge Manual;

(8) Indian Railways Permanent Way Manual;
(9) Indian Railways Works Manual;
(10) IRS Standard Code of Practice for design of Sub-structure & Foundation;
(11) IRS: Manual on the design and construction of well and pile foundation;
(12) IITK-RDSO guidelines of seismic design of Railway Bridges;
(13) Indian Standard Specifications;
(14) IS: 875 (all 5 parts) – Design loads (other than earthquakes) for buildings and structures;
(15) IS: 456 - Plain and reinforced concrete;
(16) IS: 2911 (Part I to IV) - Code of practice for design and construction of pile Foundations;
(17) IS: 1893 Criteria for Earthquake Resistance Design of Structures;
(18) IS: 4326 Earthquake Resistance Design and Construction of Building – Code of Practice;
(19) IS: 13920 Ductile detailing of reinforced concrete structures subjected to seismic forces;
(20) IS: 875 (Part 3) – Code of Practice for Design Loads (Other than Earthquakes) for Buildings and Structures – Wind Loads (Second Revision);
(21) IS: 1786 - High Strength Deformed Steel Bars & Wires for Concrete Reinforcement (Third Revision);
(22) IS: 432 (Part-I & Part-I) – Mild Steel, Medium Tensile Steel Bars and Hard Drawn;
(23) IS: 280 Mild steel wires for general purposes;
(24) IS: 2502 Code of practice for bending and fixing of Bars for concrete reinforcement;
(25) IS: 1343 Pre-stressed concrete;
(26) IS: 14268 Pre-stressing Strands; and
(27) IS: 1493 Design of Bored and Cast in Situ Piles Founded in Rock. - Guide lines

14.4 Roadway and Railway

14.4.1Alignment

The proposed road and rail alignment over the dyke as well as access links on either end is presented in **Figure 2.23**.

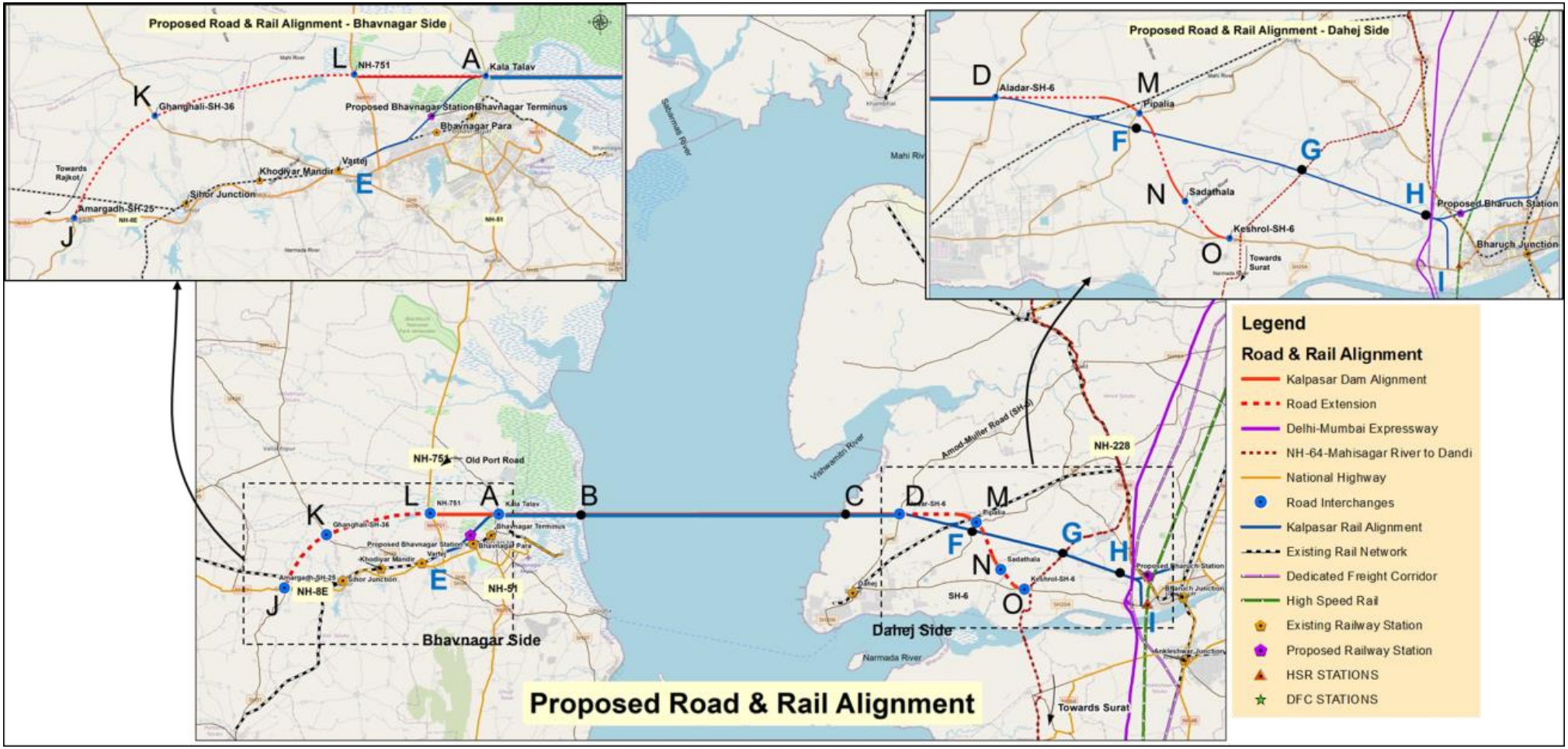


Figure 2.23: Proposed Road and Rail alignment including access links on either end

- **Road**

The detailed plan for the transport corridor has been prepared based on the capacity requirements to handle future traffic.

The description of road alignment is presented below. The major locations along the road alignment are marked in map is described below in **Table 2.25**.

Table 2.25: Road alignment chainage and location details

Section of Road alignment	Chainage (m)	Location
A	32+250	Kalatalav (Ladiyapul)
B	43+500	Gulf side of Bhavnagar
C	70+000	Gulf side of Dahej
D	83+660	Panjadara / Aladar on SH-6
J	0+000	Songadh on NH-8E
K	9+800	Ghanghali on SH-36
L	23+500	Nari on NH-751
M	93+800	Pipaliya / Pakhajan
N	98+730	Sadathala connecting NH-64 (under construction)
O	10+500	Keshrol on SH-6

The road alignment (on Bhavnagar side) connects NH-751 (point L). Further, for effective dispersal of the traffic, the alignment is extended to SH-36 at Ghangalia (point K) and Sonegadh on NH-8E (point J) as shown in **Figure 2.23**.

The road alignment (on Dahej side) connects Panjadara / Aladar on SH-6 (point D). Further, for effective dispersal of the traffic, the alignment is extended to Pipaliya / Pakhajan (point M), Sadathala connecting NH-64 (under construction) (Point N) and Keshrol on SH-6 (point O) as shown in **Figure 2.23**.

The total length of the road alignment including connectivity to various existing and proposed roads is 100 km. The break-up of distance between various points is summarised in **Table 2.26.**

Table 2.26: Length of road alignment (Section wise)

Section of Road alignment	Distance (in Km)	Remarks
A-B	11.25	Access road in intertidal zone
L-A	8.85	Access road
K-L	9.20	Access road
J-K	9.40	Access road
B-C	26.50	Dyke and flood regulator
C-D	13.75	Access road in intertidal zone

Section of Road alignment	Distance (in Km)	Remarks
D-M	10.10	Access road
M-N	5.60	Access road
N-O	5.80	Access road
Total length	100.5 km	

- **Rail**

The major locations along the rail alignment are shown in **Figure** 2.23 and tabulated in **Table 2.27**.

Table 2.27: Rail alignment chainage and location details

Section of Road alignment	Chainage (m)	Location
A	10+500	Kalatalav (Ladiyapul)
B	21+635	Gulf side of Bhavnagar
C	48+135	Gulf side of Dahej
D	62+000	Panjadara / Aladar on SH-6
E	0+000	Nari Railway Station
F	72+000	Pipaliya / Pakhajan
G	82+000	Cholad
H	92+000	Munubar
I	97+425	Bharuch
P	6+519	Proposed New Terminal at Bhavnagar
Q	96+511	Proposed New Terminal at Bharuch

- The rail alignment runs parallel to the road alignment at point A - Kalatalav (Ladiyapul), point B- Gulf side of Bhavnagar, point C- Gulf side of Dahej and point D- Panjadara / Aladar on SH-6.

- The rail alignment on Bhavnagar side deviates from road alignment at point A - Kalatalav (Ladiyapul) connecting Nari Railway Station (point E) from Kalatalav (Point-A) and merges with the existing rail alignment.

- The rail alignment on Dahej side deviates from road alignment at point D Panjadara / Aladar on SH-6 and passes through Pipaliya / Pakhajan (point F), Cholad (point G), Munubar (point H) and connects the existing railway line at Bharuch (point I).

- New Railway terminals are proposed near Ramdev nagar at Bhavnagar side and at outskirts of Bharuch at Dahej side. The total length of the rail alignment is 97.425 km.

The break of distance between various points is summarised in **Table 2.28.**

Table 2.28: Length of rail alignment (Section wise)

Section of Road alignment	Distance (in Km)	Remarks
A-B	11.25	Intertidal zone
B-C	26.50	Dyke and flood regulator
C-D	13.75	Intertidal zone
E-A	10.50	Proposed Bhavnagar Terminal
D-F	10.0	Access Rail Line
F-G	10.0	Access Rail Line
G-H	10.0	Access Rail Line
H-I	5.425	Proposed Bharuch Terminal
Total length	97.425km	

14.4.2 Cross section

The proposed cross section of the transport corridor for the optimistic scenario (Roadway comprising of 16 lanes (8 lanes in each direction) and Railway comprising of dedicated passenger & freight rail lines is presented in **Figure 2.24** as well as in **Annexure-2K and Annexure-2L.**

Some of the features of the cross-section are presented below:

(1) Lane width of 3.5 m;
(2) Median width of 6 m (as per 6-lane manual);
(3) Paved shoulder of 1.5 m and earthen shoulder of 1.0 m on either side of the carriageway;
(4) Multi-utility lane of 4 m is considered on either side of the carriageway. It will accommodate emergency parking, truck layby, utility, drop-off, landscaping and ITS components;
(5) Pedestrian drop off zone of 3 m is considered which is basically footpaths with other amenities such as seating arrangements etc.,
(6) On LHS side (reservoir side), a tree zone of 5 m has been proposed so that lighting will not affect the fish or other aquatic life during the night side;
(7) A setback distance of 3 m is considered between the Road and Rail corridors; and
(8) A total width of 40 m is considered for rail corridor as per the Railway norms in which 20 m. is allocated for passenger rail and 20 m for freight rail.

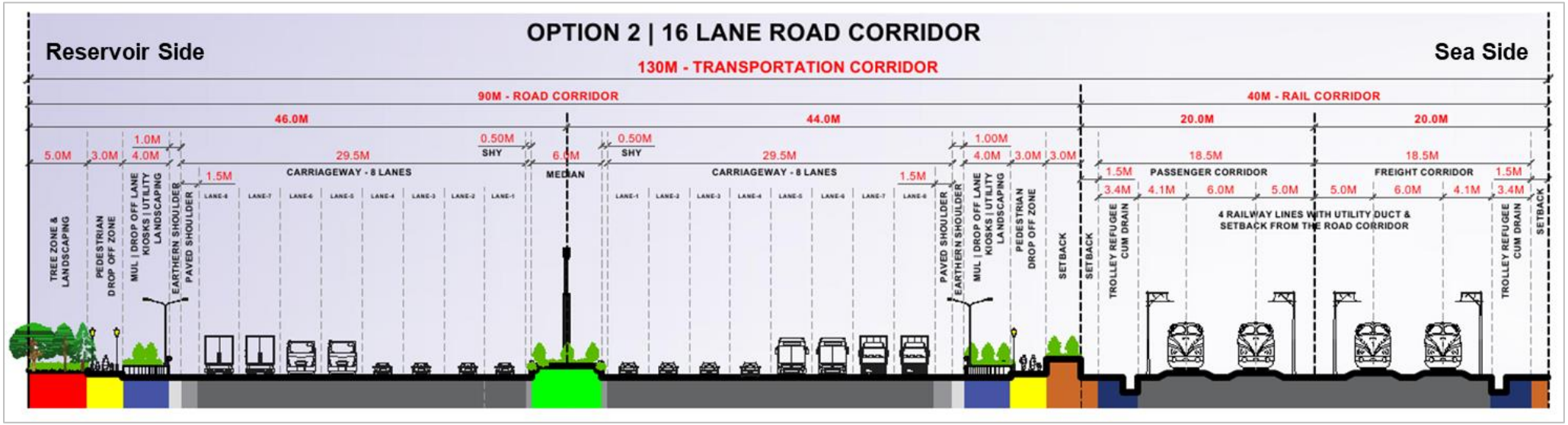


Figure 2.24: Proposed cross section of road & rail corridor (Option 1: 16 lane road corridor)

18.Design

18.1 Design basics

➢ Inputs for Detailed Project Report

Consultants have collected various inputs required for design of road, rail and bridge components from NCCR and the same is presented below:
(1) Dyke alignment as well as alignment of access roads;
(2) Topographic data for Dyke and approach road portion (60 m length);
(3) Cross-section of dyke and transportation corridor; and
(4) Geo-technical report

The alignment of dyke and transport corridor including road network in the vicinity of Kalpasar dyke is presented in **Figure 2.25**.

Figure 2.25: Alignment of Kalpasar dyke and access roads

Proposed dyke cross-section as provided by NCCR is presented in **Figure 2.26**. The width of transport corridor proposed is 130 m to accommodate the road and rail alignment. NCCR has supplied the topographic survey data of dyke portion and till the nearest access roads (NH-751 on Bhavnagar side and SH-6 (Dahej - Aladar section) covering the A to D for about 60 km. Beyond 60 km, the access roads and interchange designs have been based on the google pro imageries.

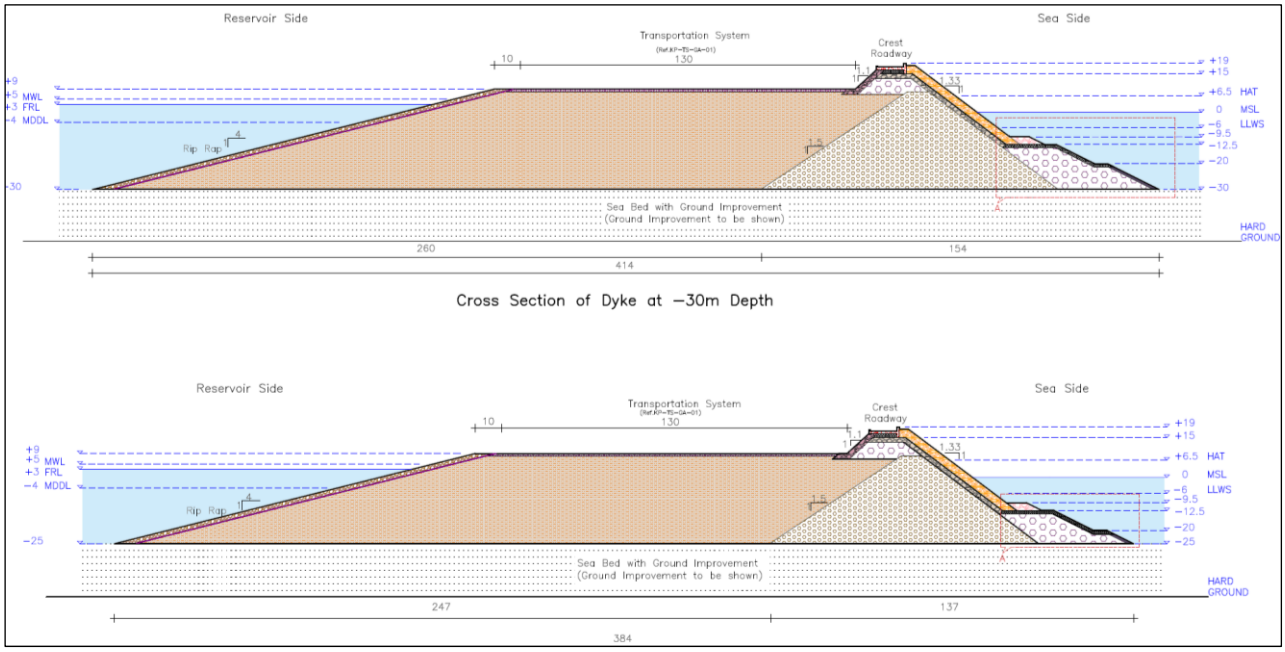


Figure 2.26: Cross-section of Kalpasar Dyke

Summary of Geotechnical report is presented in the following sections. The entire stretch is divided into 7 zones of which, one zone lies in the intertidal region of Bhavnagar, 4 zones lies in the Gulf region, 1 zone lies in the Spillway region and remaining 1 zone lies in the intertidal & tidal land region of Dahej.

Those 7 zones are as follows:
(1) Zone 1: Intertidal region in Bhavnagar; (2) Zone 2: Channel A in Gulf region;
(3) Zone 3: Channel B in Gulf region; (4) Zone 4: Channel C in Gulf region;
(5) Zone 5: Channel D in Gulf region; (6) Zone 6: Spillway area; and
(7) Zone 7: Intertidal & tidal region at Dahej

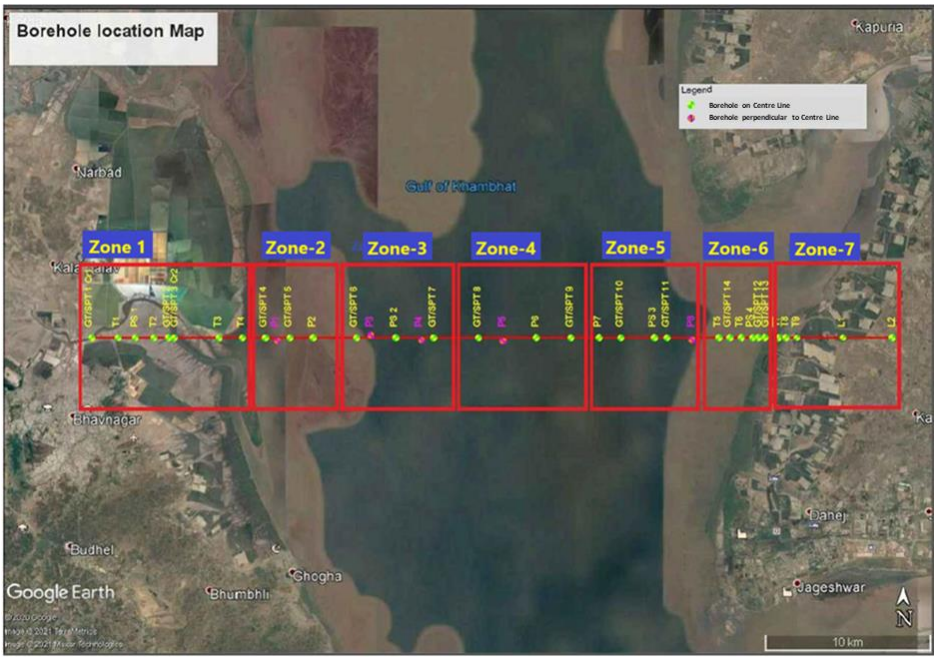


Figure 2.27: Zone bifurcation of Bore-log data

Following are the zone-wise observations on bore-log data. It can be observed that presence of soft clay and very loose to loose silty sand layers in top soil strata may cause excessive settlement. Suitable ground improvement techniques are required to be adopted to overcome settlement and to improve the bearing capacity. Further details of the bore log data collected by NCCR for this study is given in **sub-section 2.3.5 (a).**

(a) Base line conditions and challenges

Canal diversion : It is proposed by Kalpasar Department, the water way on the Bhavnagar side will be diverted. In view of the above, no bridges are considered over the waterways in the inter-tidal zone.

Extension of access road till the major road: As per the initial concept from NCCR, the access is terminating on NH-751 (Ahmedabad-Bhavnagar Road of 4-lane configuration) on Bhavnagar side and on SH-6 (Dahej-Aladra section which is a 2-lane configuration) on Bharuch side. Terminating the Kalpasar road link on SH-6 (Dahej-Aladra section which is a 2-lane configuration) is not suggested as traffic needs to pass through Dahej industrial area. In view of above, it is proposed to extend the access road further joining the SH-6 (Dahej-Bharuch section) which is currently of 6-lane configuration. The access road requirements have been considered for horizon years is included in the current report.

Soil Improvements in inter tidal zone : It is observed that presence of soft clay and very loose to loose silty sand layers in top soil strata may cause excessive settlement. Suitable ground improvement techniques may be adopted to overcome settlement and to improve the bearing capacity.

Dispersal challenges : The capacity augmentation of existing regional network needs to be carried out considering the 16-lane traffic from Kalpasar in the phased manner. The proposed Kalpasar Road link needs to be connected at various locations including necklace road along the coast (proposed), NH-48, Delhi-Mumbai Expressway and upcoming regional roads. Dispersing huge traffic on the regional network will be a challenge as existing road networks are not planned to absorb the huge quantum of traffic. Thus, it is imperative that traffic needs to be dispersed at multiple locations rather couple of locations as there is a limitation of augmentation existing regional road network. With respect to railway traffic, upgradation of existing terminals and planning for new terminals is required. This issue is addressed in the current report.

Land acquisition: Though no land acquisition is required for access roads in the intertidal zones, Land acquisition may be required beyond the inter tidal zone for planning the road and rail links. It is especially required at the proposed interchanges which will connect with existing road network. Kalpasar transportation link will generate huge amount of traffic and therefore widening of all the existing regional network will be required. Similarly, LA may be required for proposed passenger and freight terminals for the railways. This shall be taken up during detailed design stage.

Existing crossings : Vehicle Under Pass (VUP), Pedestrian Under Pass (PUP) and Cattle Under Pass (CUP) are required to be considered for existing vehicle cross roads, pedestrian paths and cattle paths respectively. Similarly, ROB/RUBs will be required for crossing the existing and proposed railway lines and bridges are required to be considered for crossing the water ways. This issue has been addressed based on the available information.

Security hold area : As per the requirement from security perspective, there shall be provision of physical checking or screening of vehicles (in certain situations). This should ideally be carried out at the interchange locations. However, since it is very difficult to get the huge land parcel at interchange locations, it is suggested that security hold area can be planned in inter-tidal zone where sufficient land is available. In view of the above, suitable ramps can be planned so that vehicles can be diverted to security hold area and can merge with access roads once checking is completed. The concept plan for the same is presented in the report.

Planning for long horizon : Planning for long horizon is the major challenge as it is difficult to predict the future for a long horizon considering rapid transformation of socio-economic characteristics as well as evolution of future technologies. In view of the uncertainties, traffic is forecasted for three scenarios (pessimistic, most likely and optimistic).

18.2 Design of Roadway

18.2.1Plan and profile

The plan and profile of Road corridor including the interchanges and traffic dispersal on either side of the dyke is presented in this section.

Road alignment accessing Kalpasar dyke starts at Sonpuri in Bhavnagar side and passes through Ghangali, Nari and Lakdiya Pull before connecting Kalpasar dyke, similarly the road alignment at Dahej side starts at Keshrol and passes through Sadathala, Pakhajan, Goladra before connecting the Kalpasar Dyke. The plan and profile of the proposed road alignment is presented with drawing numbers **RD-PP-01 to RD-PP-21 and the cross-section of the proposed road alignment is presented with drawing numbers RD-TCS-001 to RD-TCS-005** in **Annexure – 2K.**

Smooth dispersal of traffic from Kalpasar dyke can be achieved by providing interchanges at 8 locations as shown in **Table 2.29**

Table 2.29: Proposed Interchange Locations

S.No	Interchange location	Chainage	Direction	Type of Interchange
1	Near Songadh on NH 8E	00+000	Bhavnagar	Trumpet Interchange
2	On SH 36 Crossing	09+800	Bhavnagar	Flyover with Slip roads
3	On NH 751 Crossing	23+500	Bhavnagar	Cloverleaf interchange
4	Near Lakdiya Pull	32+250	Bhavnagar	Flyover with slip roads
5	Near Goladra on SH 6 (Dahej- Amod Road)	83+660	Bharuch	Flyover with Slip roads
6	Pakhajan	93+800	Bharuch	Flyover with Slip roads
7	Sadathala	98+730	Bharuch	Flyover with Slip roads
8	On Bharuch – Dahej Road (SH-6)	104+500	Bharuch	Flyover with slip roads

18.2.2Road Bridge Structures

Structural elements related to road such as bridge at flood regulator, interchanges and bridges in approaches are summarised in **Table 2.47, Table 2.48 and Table 2.49 of Annexure 2.3** respectively.

18.2.3Pavement design

Rigid pavement is considered for Road taking into considering high intensity of the rainfall in the region, minimal maintenance requirements and durability.

18.2.4Transportation facilities

Following project facilities are required and the same have been provided.

(1) Truck lay bye;
(2) Bus bays;
(3) Way side amenities such as hotels, truck repair facilities etc.); and
(4) Security hold area for checking the vehicles

18.3 Design of railway

The plan and profile of Rail corridor including the approach railway line on either side of the dyke as well as integration with existing regional rail network is presented in this section.

18.3.1Plan and profile

Rail alignment on Dahej side starts at Bharuch and connects Kalpasar dyke at Panjadara, similarly in Bhavnagar side the rail alignment starts at Nari railway station and connects Kalpasar dyke at Lakdiya Pull.

New Railway terminals are proposed near Ramdev Nagar at Bhavnagar side and at outskirts of Bharuch at Dahej side.

Table 2.30: Proposed rail terminal locations

S. No	Station Name	Chainage(km)	Remarks
1	New Bhavnagar	7.030	Passenger Terminal
2	New Bhavnagar	7.050	Freight Terminal
3	New Bharuch	95.800	Passenger Terminal
4	New Bharuch	96.100	Freight Terminal

The plan and profile of the proposed rail alignment are presented in Annexure-2L with drawing numbers RL-PP-001 to 024 and railway cross-sections are presented in drawings RL-TCS-001 and 002**.**

18.3.2Railway Bridge Structures

Bridge structures identified for rail loadings are listed in **Table 2.51 & Table 2.52 of Annexure 2.3.**

- **For single track Branch line from Ch: 87+500 of Main line**

Rail loading bridge structures for the single track branch line connecting the Kalpasar link with the existing Delhi-Mumbai mail railway line is shown in **Table 2.53 of Annexure 2.3**.

18.3.3Formation Design

In a general way, collectively refers to the layers comprising blanket, prepared subgrade/Subgrade.

Boundary (interface) between ballast and top of blanket or prepared subgrade/Subgrade (where blanket layer is not provided) is called formation top.

Pressure on Formation and sub-soil:

As good design practice, typical values for the maximum pressure on formation at bottom of ballast should not exceed 0.3MN/m2 or3 kg/cm2, and the pressure on sub-soil should not exceed 0.1MN/m2 or1 kg/cm2 generally.

Top Width of Formation:

It should be adequate to accommodate tracks laid with concrete sleepers and standard ballast section (minimum 35cm depth) and have minimum cess width of 90cm on either side.

Additional Width of formation will have to be provided to cater for increase in extra widening of ballast shoulder and extra clearances required on curves. It shall be regulated/provided in accordance with extant instructions as per the Indian Railway Schedule of Dimensions (IRSOD) &Indian Railway Permanent Way manual (IRPWM).

Cross Slope of Formation:

The top of formation should have a cross slope of 1 in 30 from center of the formation towards both sides for single line/multiple lines in new construction. In case of doubling or multiple line construction works in existing lines, the cross slope of 1 in 30 should continue from the edge of the existing formation towards cess/drain side (single slope) to avoid any stagnation of water between two tracks. However, if the cross slope of existing embankment is steeper than 1 in 30 due to any reason, the configuration of 1 in 30 cross slope shall be maintained in the new line while ensuring proper drainage conditions at the same time to avoid any stagnation of water in between tracks, by adopting appropriate measures as per site conditions.

Erosion Control System:

The design should provide for a suitable and cost-effective erosion control system considering soil matrix, topography, and hydrological conditions.

Borrow Pits:

It will be necessary to keep borrow pits sufficiently away from the toe of the embankments as far as possible at the extreme of Railway land but normally not less than 3m plus the height of the embankment to prevent base failures due to lateral escapement of the soil. Existing borrow pits, close to the toe of bank may be filled or their depth should be taken into account in analyzing slope stability of the bank.

Methods of Formation Rehabilitation:

All formation rehabilitation schemes need to be framed by Railways. Help of an expert may also be taken if required. It is the responsibility of executive authority to ensure that formation rehabilitation work is carried out in accordance with rehabilitation scheme and adequate control is exercised in execution. However, RDSO may also be approached to provide consultancy on weak formation, if required.

In general, following points may be kept in view while planning for rehabilitation:

(A) In developing rehabilitation schemes, stretches having similar soil characteristics and Embankment performance should also be included simultaneously;
(B) Cause(s) of instability of formation should be analyzed and accordingly rehabilitation measures formulated. There may be requirement to re-profiling of slope along with laying the blanket and other measures;
(C) Geo synthetics may also be used along with laying of blanket for formation rehabilitation as an alternative, in consultation with RDSO as required; and
(D) The method of laying of blanket should be appropriate depending on site conditions/requirements.

18.4 Structural design

18.4.1Structural design for road bridge superstructure at Flood Regulator

Structural arrangement of Roadway bridge at Flood regulator is a PSC I-Girder superstructure supported over the wall piers of Flood regulator. 100 Nos. of 22m (EJ to EJ) span is provided for each carriageway. Details of Superstructure along with Cross section & plan are shown in **Figure 2.28** and **Figure 2.29** respectively.

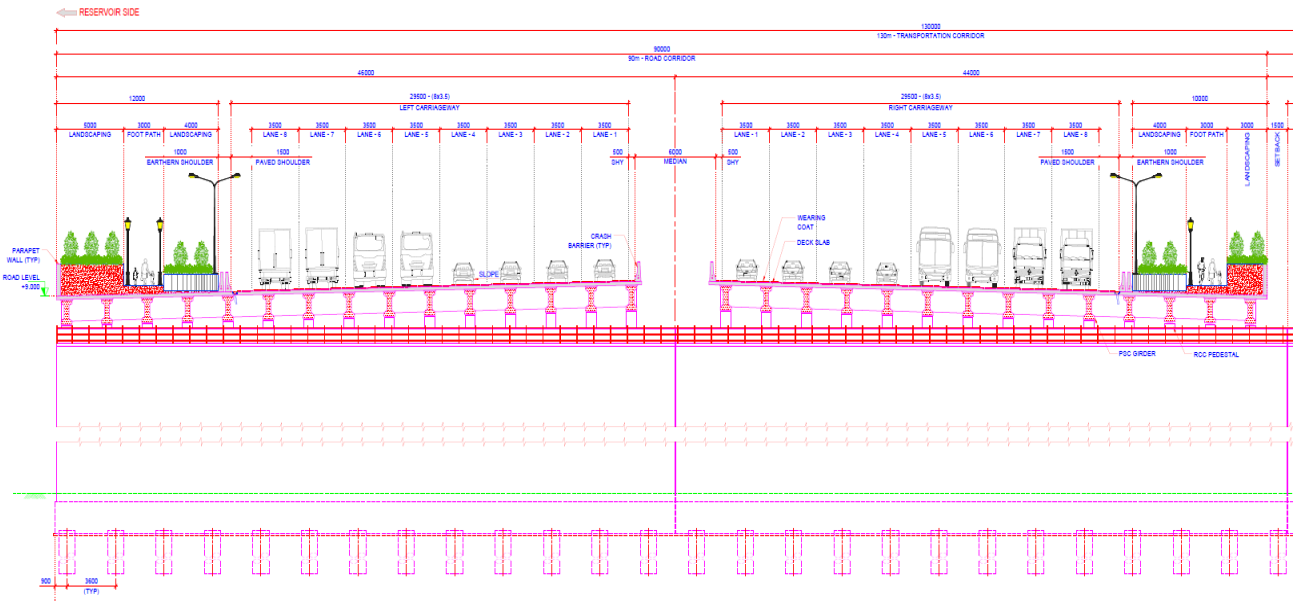


Figure 2.28: Cross section of road bridge **s**uperstructure at Flood regulator

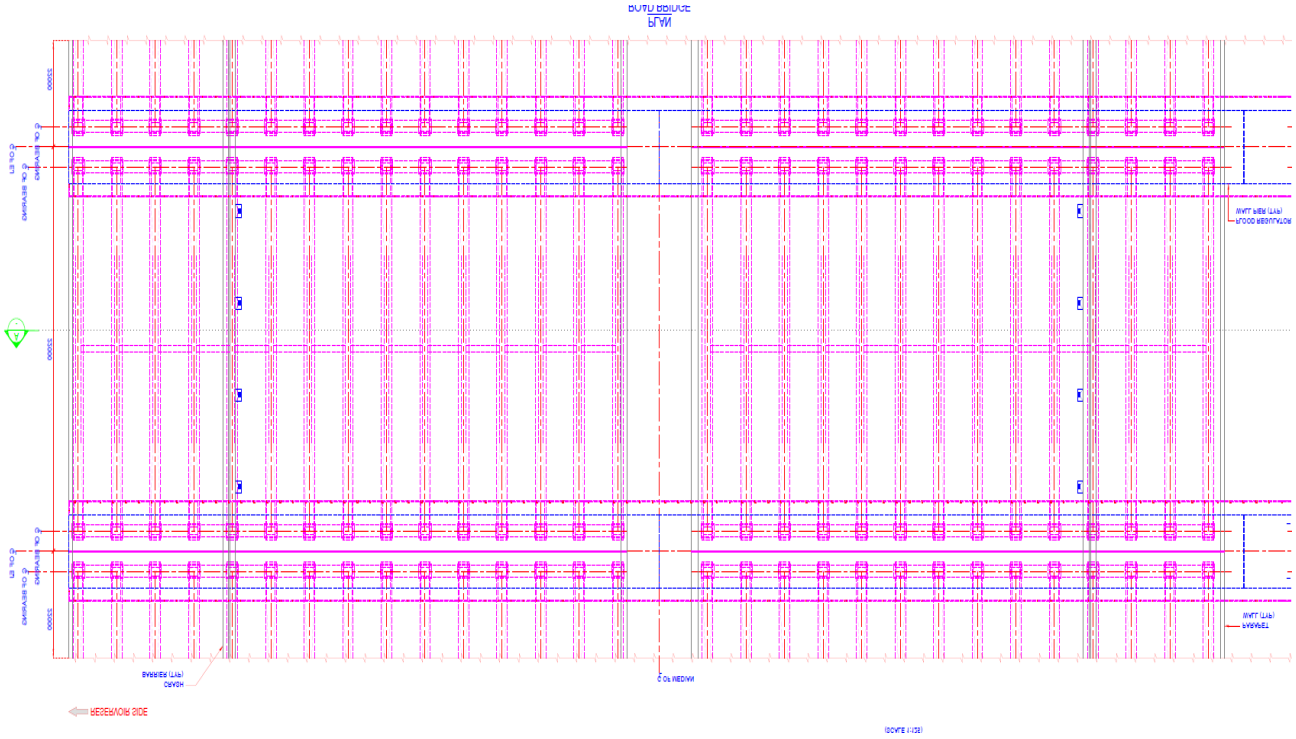


Figure 2.29: Plan of road bridge superstructure at Flood regulator

Individual superstructure is provided for each carriageway. Provision for footpath, MUL and landscaping is also provided in the superstructure. Specifications are as follows:
(1) Left & Right carriageways are provided for roadway traffic. Individual superstructure is provided for each carriageway. Provision for footpath, MUL and landscaping is also provided in the superstructure;
(2) Left carriageway deck slab is supported by 15 No. of PSC Post tensioned I-Girders & Right carriageway deck slab is supported by 14 No. of PSC Post tensioned I-Girders
(3) The Post tensioned I-Girders are precast elements;
(4) Deck slabs & Diaphragm are Cast In-situ elements;
(5) End diaphragms are provided at the two support locations of each span;
(6) Individual span length is 21m (EJ to EJ) considering clear opening between the flood regulator wall as 18m and width of flood regulator wall as 3m;
(7) The Girders are supported by Elastomeric bearings for transferring vertical loads;
(8) The bearings are provided over the pedestal. The pedestal rests over the flood regulator wall piers;
(9) The above structural arrangement has the advantage of casting multiple girders at a time in fabrication yard, carrying out post tensioning and then transporting to site and erecting it. The shuttering for cast In-situ deck slab cab be supported from the erected Girders itself;
(10) Road level considered is +9m, Pier top level is +7m.
(11) The construction depth considered for Superstructure is around 2m, in which PSC I Girder is of 1.4m depth and Deck slab of 0.2m depth.
(12) The PSC I-Girder superstructure is supported on wall piers which is supported over pile foundation;
(13) Width of wall pier considered is 4m. Bed level considered is -7m. Pile cap top level considered is -7.5m. Clear span of 18m is maintained between the adjacent wall piers of flood regulator; and
(14) Piles of 1.2m diameter is considered;
(15) The Design requirements, guidelines & design philosophy is as per the provisions mentioned in design basis section.

Detailed drawings, BOQ & costing details are provided in **Annexure 2.3**. The Design requirements, guidelines & design philosophy are explained in design basis section.

- **Details of PSC I-Girder:**

Plan and cross section of the prestressed concrete I-girder for roadway is shown in **Figure 2.30** & **Figure 2.31** respectively.

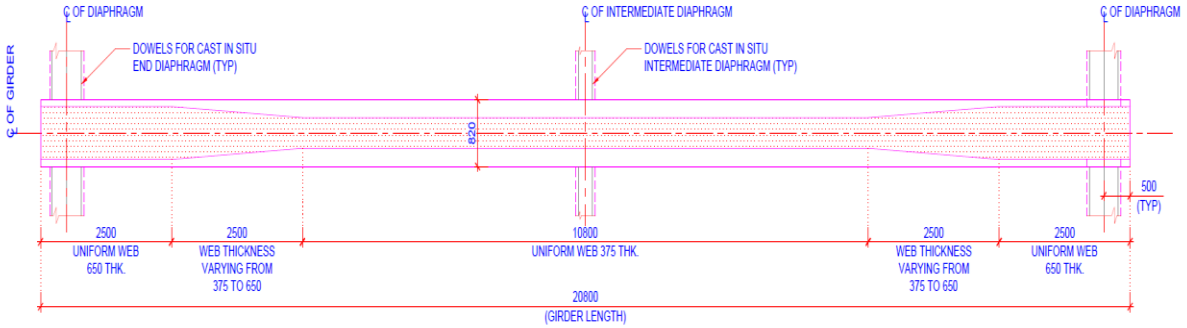


Figure 2.30: Plan of PSC I-Girder

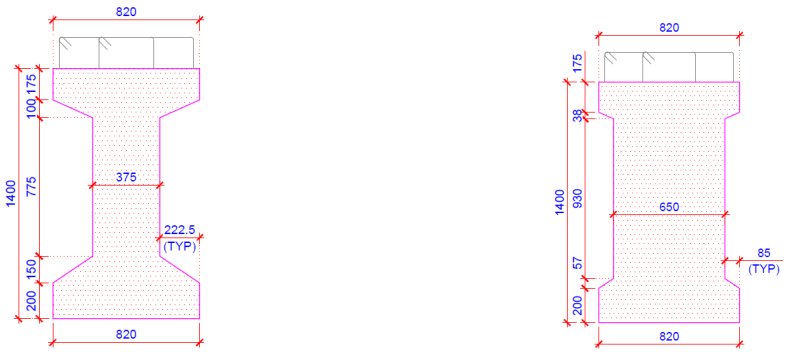


Figure 2.31: Cross section of PSC I-Girder (at Midspan & at Support)

- **Details of Crest Road Superstructure:**

PSC I-Girder superstructure arrangement is proposed for Crest road over the breakwater with deck width of 11.5m and span of 22m (EJ to EJ). The details of the same are presented below:

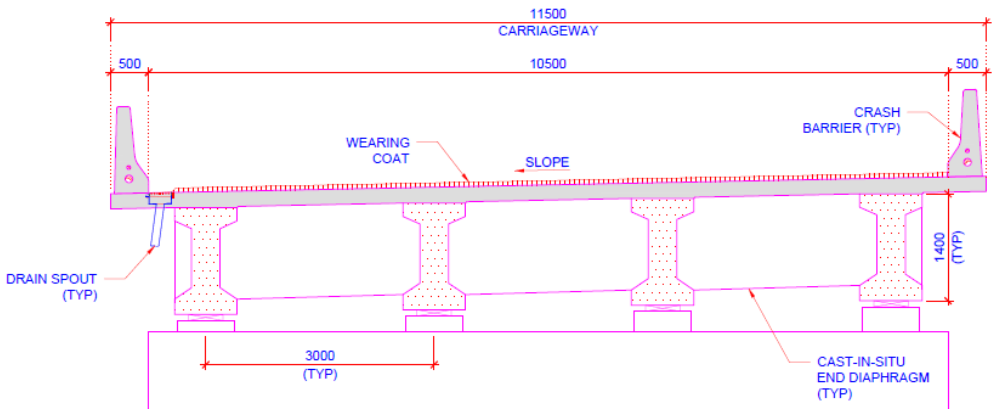


Figure 2.32: Cross section of Crest Road bridge superstructure

- **Details of Substructure supporting roadway superstructure:**

Wall piers of 4m width are proposed to support the Left & Right Main carriageway superstructure. Pile foundation is proposed.

Pier top level = +7m

Bed level = -7m

Pile cap top level = -7.5m

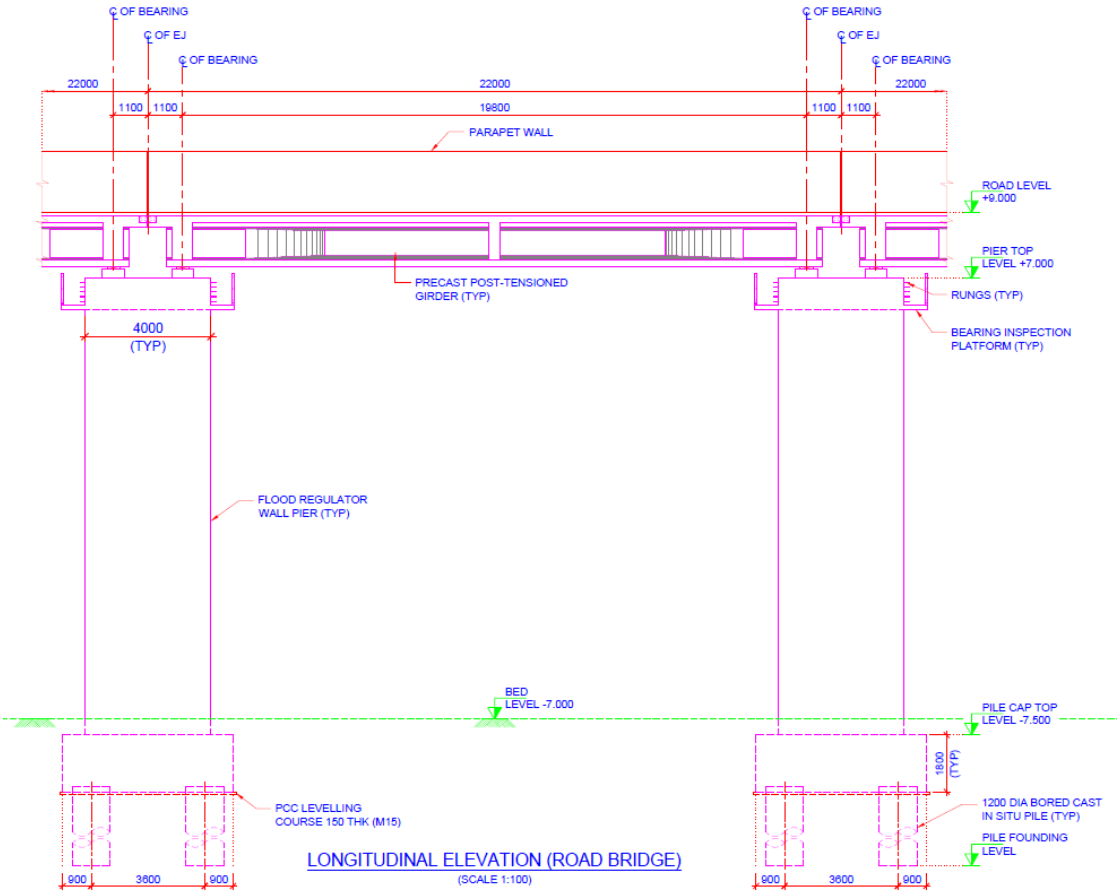


Figure 2.33: Elevation of wall pier supporting roadway superstructure

18.4.2Structural arrangement for rail bridge superstructure in Flood Regulator

Structural arrangement of Railway bridge at Flood regulator is a PSC I-Girder superstructure supported over the wall piers of Flood regulator. 100 Nos. of 22m (EJ to EJ) span is provided for each track. Details of Superstructure along with cross section & plan are shown in **Figure 2.34** and **Figure 2.35** respectively.

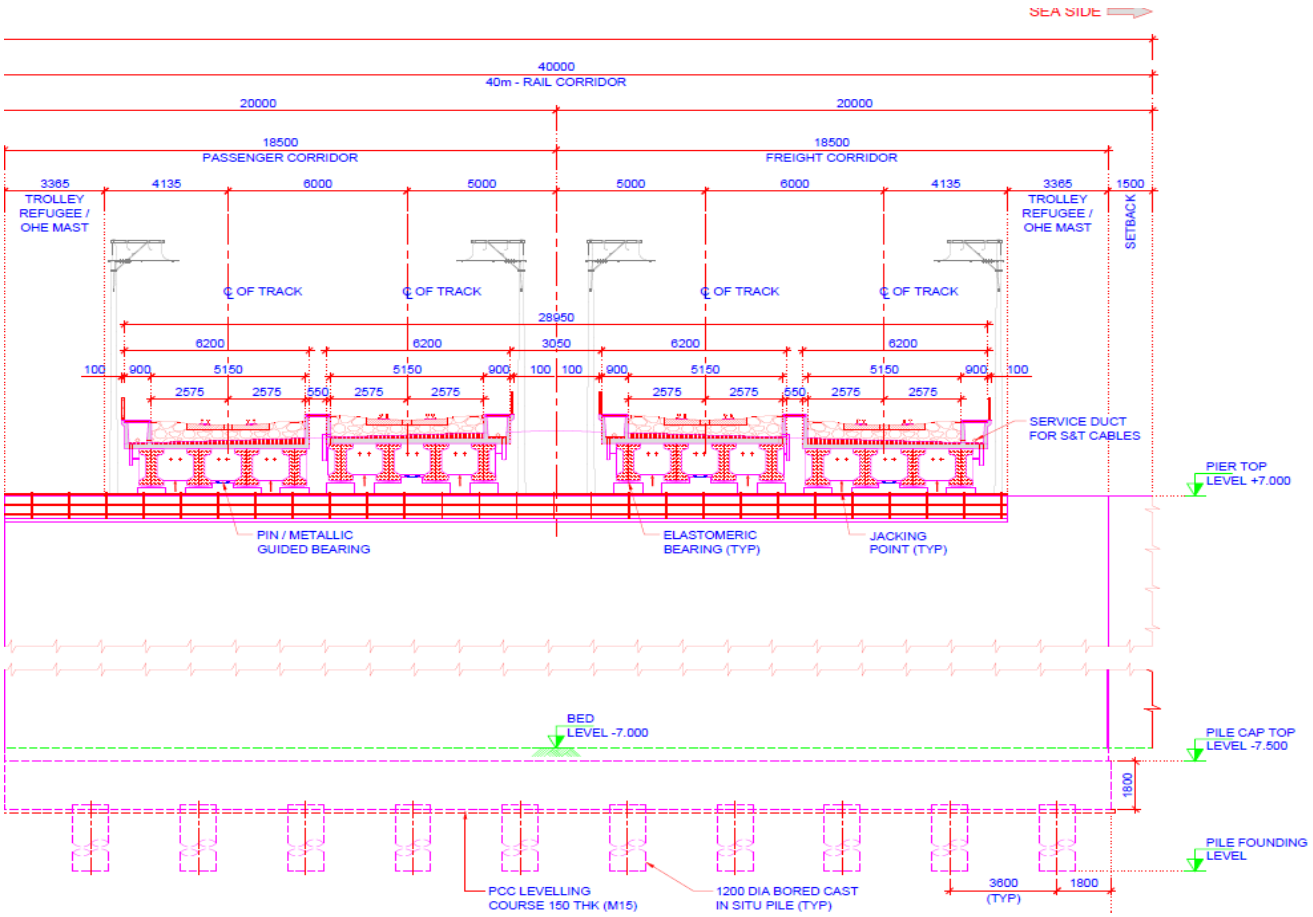


Figure 2.34: Typical Cross section of Rail bridge at Flood regulator

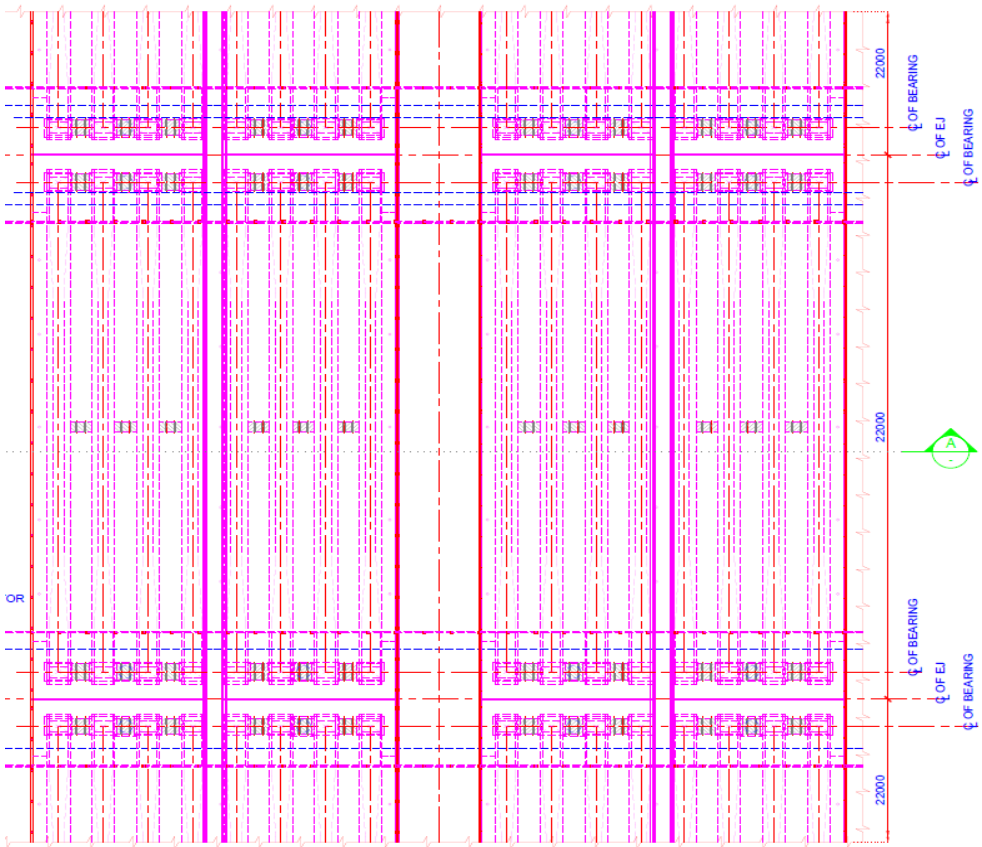


Figure 2.35: Typical Plan of Rail bridge at Flood regulator

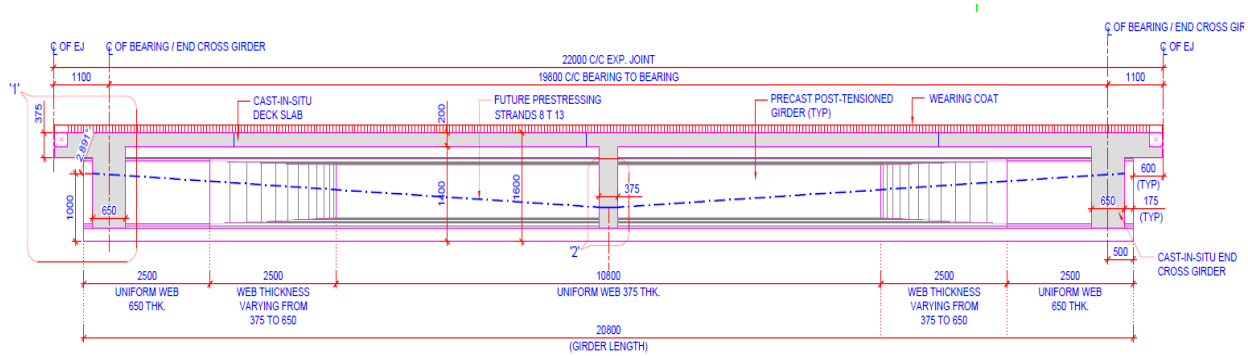
Specifications of Railway Super-structure are as follows:

(1) A total of 4 Tracks are proposed for railway line;
(2) Each track is provided with an individual superstructure with deck slab of 6.2m width;
(3) Each deck slab is supported by 4 No. of PSC Post tensioned I-Girders;
(4) The Post tensioned I-Girders are precast elements;
(5) Deck slabs & Diaphragm are Cast In-situ elements;
(6) End diaphragms are provided at the two support locations of each span;
(7) Individual span length is 22m (EJ to EJ) considering clear opening between the flood regulator wall as 18m and width of flood regulator wall as 4m;
(8) The Girders are supported by Elastomeric bearings for transferring vertical loads and Diaphragms are supported by Pin/Guided bearings to provide longitudinal & transverse restraints;
(9) The bearings are provided over the pedestal. The pedestal rests over the flood regulator wall piers;
(10) The above structural arrangement has the advantage of casting multiple girders at a time in fabrication yard, carrying out post tensioning and then transporting to site and erecting it. The shuttering for cast In-situ deck slab cab be supported from the erected Girders itself;
(11) Formation level considered is +9m, Pier top level considered is +7m;
(12) The construction depth considered for Superstructure is around 2m, in which PSC I Girder is of 1.4m depth and Deck slab of 0.2m depth. ;
(13) The PSC I-Girder superstructure is supported on wall piers which is supported over pile foundation;
(14) Width of wall pier considered is 4m. Bed level considered is -7m. Pile cap top level considered is -7.5m. Clear span of 18m is maintained between the adjacent wall piers of flood regulator;
(15) Piles of 1.2m diameter is considered;
(16) The Design requirements, guidelines & design philosophy is as per the provisions mentioned in design basis section; and
(17) Detailed drawings, BOQ & costing details are provided in subsequent sections

The Design requirements, guidelines & design philosophy is explained in design basis section

- **Details of PSC I-Girder:**

Plan and cross section of the prestressed concrete I-girder for railway structure is shown in Figure 2.36



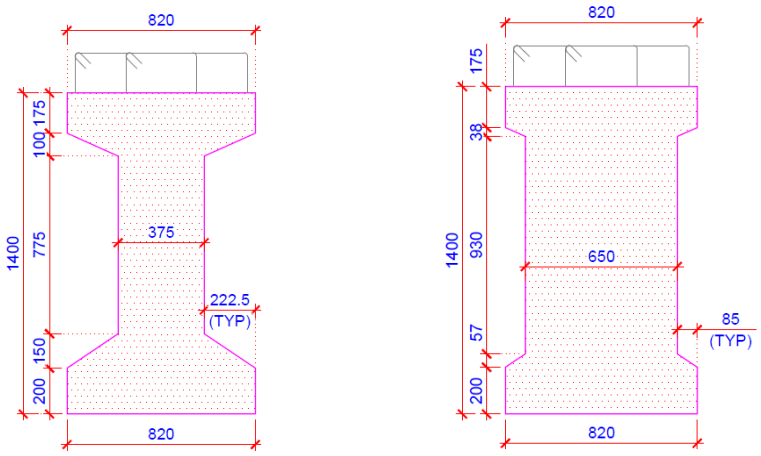


Figure 2.36: Cross section of PSC I-Girder (at Midspan & at Support)

- **Details of Substructure supporting railway superstructure:**

Wall piers of 4m width are proposed to support the railway superstructure. Pile foundation is proposed.

Pier top level = +7m

Bed level = -7m

Pile cap top level = -7.5m

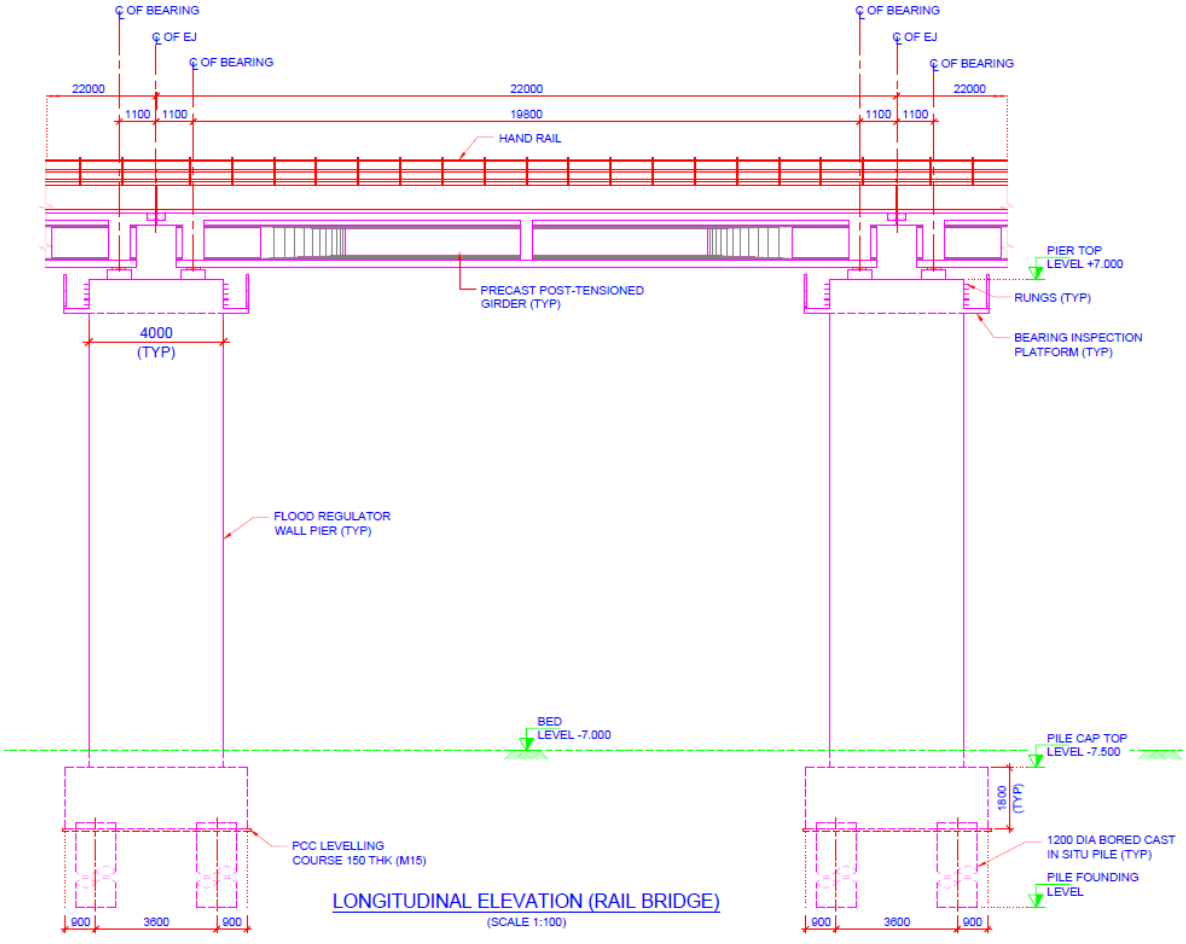


Figure 2.37: Elevation of wall pier supporting railway superstructure

18.5 Discussion

18.5.1Summary

Total length of road alignment is 100.5 Km, for effective dispersal of traffic from the Kalpasar Dyke it is proposed to extend the road on both sides (Bhavnagar and Bharuch side) of the dyke and traffic shall be dispersed effectively from the proposed interchanges at 8 locations. Interchange locations are summarized below in **Table 2.46**.

Table 2.31: Interchange location for Kalpasar

S.No	Interchange location	Chainage	Direction	Type of Interchange
1	Near Songadh on NH 8E	00+000	Bhavnagar	Trumpet Interchange
2	On SH 36 Crossing	09+800	Bhavnagar	Flyover with Slip roads
3	On NH 751 Crossing	23+500	Bhavnagar	Cloverleaf interchange
4	Near Lakdiya Pull	32+250	Bhavnagar	Flyover with slip roads
5	Near Goladra on SH 6 (Dahej- Amod Road)	83+660	Bharuch	Flyover with Slip roads
6	Pakhajan	93+800	Bharuch	Flyover with Slip roads
7	Sadathala	98+730	Bharuch	Flyover with Slip roads
8	On Bharuch – Dahej Road (SH-6)	104+500	Bharuch	Flyover with slip roads

Total length of rail alignment is 97.5 Km, proposed railway alignment is integrated with existing railway line on Bhavnagar side and Bharuch side. New railway terminals are proposed at 2 locations, one at Bhavnagar side and another at Bharuch side. The chainage detail of the proposed rail terminals is described below in **Table 2.47**.

Table 2.32: Chainage detail for proposed rail terminal

S.No	Chainage (m)	Direction	Location
1	6+519	Bhavnagar	Ramdev Nagar (Outskirts of Bhavnagar)
2	96+511	Bharuch	Outskirts of Bharuch (connecting HSR line)

Road alignment is designed as a National Highway with design speed of 100 Kmph. Median opening is provided at 5km interval for the purpose of emergency U-Turn.

Rail alignment is designed as semi-high speed rail for passenger line and as a dedicated freight corridor (DFC) for freight line.

Structural components of both road and rail are designed as PSC Post tensioned I-Girder with cast In-situ deck slab with a span of 21m. Design loadings and load combinations are considered as per prevailing IS and IRC standards.

18.5.2Recommendations

Road over the Kalpasar dyke is designed with highway standards. It is recommended to provide road interchanges at 8 locations for smooth dispersal of traffic as described in **sub-section 2.3.4 (d) (iii) of Annexure 2.3**.

Passenger railway system over the Kalpsar dyke is designed with semi high speed rail standards and the freight railway system is designed with dedicated freight corridor standards. Railway terminals are proposed at 2 locations (one at Bhavnagar side and another at Bharuch side). It is recommended to integrate the proposed railway alignment with the high-speed rail station at Bharuch which is under construction. For continuous flow of train traffic from other regions of Gujarat and other states of India, a connecting railway line is recommended to connect the proposed railway link over the Kalpasar dyke with the Delhi-Mumbai mainline.

21.7 Transportation Aspects

21.7.1 ITS components

Intelligent Transportation Systems (ITS) is essential tool in managing real-time traffic management and incident management on Kalpasar road link where large traffic volume is required to be handled. There should be institutional arrangement for management of traffic as ITS is only a tool. The broad institutional arrangement is discussed in the following section. The proposed ITS system for Kalpasar road link is presented in below.

ITS facility and equipment is an indispensable component for any major highway project. Accordingly, the ITS shall be installed on viaducts and the Bridge portions on Kalpasar transport corridor from commencement of operation. The typical ITS system for Highways is presented in **Figure 2.38**.

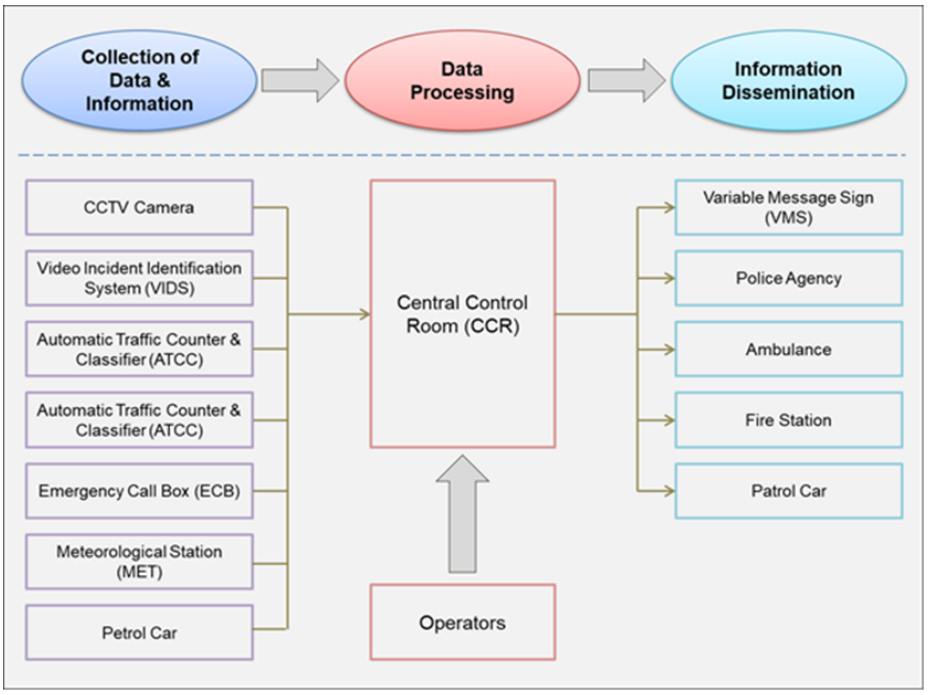


Figure 2.38: Typical ITS system for highways

ITS applications work on principle of information collection, processing and dissemination. The data is collected from instruments such as CCTV, ECB, MET and ATCC. The collected data is transmitted to central control room through optical cable which are laid along the transportation corridor. Further processed data is sent back to site to VMS to the road users as well as relevant agencies such as Highway operator (or toll operator such NHAI or state PWD), Traffic Police, Patrol Vehicles, Government and Private Hospitals etc., Highway operator shall maintain Patrol vehicle, Ambulance, towing vehicles, cranes and establish the first aid centres at suitable locations. Along the transport corridor, no hospitals are available, thus there is a need to establish the hospital with trauma care on either end of the project. Patrol vehicles shall have features such as high-tech mobile surveillance, speed guns, cameras and e-challan machines and vehicle tracking system.

Traffic management usually consists of the following works:
(1) Provision of traffic information to the road users;
(2) Monitoring/surveillance of the traffic conditions;
(3) Regulation or control of traffic in case of emergency, accident and traffic congestion;
(4) Rescue of, or assistance to, broken-down vehicles; and
(5) Clearance of the accident site.

Highway users will be provided with following information:
(1) Accident which has not been cleared;
(2) Vehicle(s) stopping on the carriageway including shoulder;
(3) Any hazardous obstacle on the carriageway;
(4) Closure of the toll road;
(5) Maintenance works and other events occurring on the carriageway, shoulder or adjacent area of the toll road with or without traffic regulation; and
(6) Hazardous weather condition, such as heavy rain

In addition to the above, ambulance service shall be provided. Traffic control is carried out by Traffic Police to enforce the legislations relevant to the road traffic. The activities that fall under the traffic control include the followings:
(1) Regulation of speeds;
(2) Regulation of overtaking;
(3) Regulation of stopping/parking; and
(4) Checking licences, No pollution certificate etc.

The function of various components of ITS is presented in **Table 2.33** and described in subsequent sections.

Table 2.33: ITS components

Component	Function
CCTV	Monitoring of traffic condition, traffic congestion and accidents etc. Operation such as zoom, turning by remote control from the traffic control centre
ATCC (Automatic Traffic Counter-cum-Classifier)	Measurement of traffic volume Classification of vehicle type

Component	Function
Video Incident detection System (VIDS)	Speed of vehicle Incidents such as stoppage of vehicles, illegal parking, accidents, queue formation etc., and should generate automatic alerts
Weigh-in-motion (WIM) based over-weight detection and capture of vehicle information using ANPR	Enforcement of over-loading Judgment of vehicle type
MET (Meteorological Observation System)	Monitoring of weather condition of Kalpasar Dyke Precipitation, fog, wind direction, wind velocity
ECB (Emergency Call Box)	System to enable reporting of incidents to the traffic control centre at the time of first aid in a disaster, trouble, and accidents, etc
VMS (Variable Message Sign)	Dissemination of information such as road condition and weather condition
Patrol Car (Traffic Police and Highway Operator)	Rescue operation for accident/ broken-down vehicle Warning to drivers on hazardous road condition Actions to remove obstacles Repair works of defects of road facilities

Detailed description of various ITS components is given in **sub-section 2.3.8 (a)**. The quantity of various ITS components for Kalpasar road corridor of about 100Km are presented in **Table 2.34**.

Table 2.34: Deployment plan for roadside facilities

S No	System	Equipment	Interval (Km)	Location	Quantity
1	Data Collection	CCTV (On Road)	0.2	Both Direction of Road	1,005
2		Automatic Incident Detection System (VIDS)	0.33	Both Direction of Road	610
3		Emergency Call Box (ECB)	2	Both Direction of Road	102
4		Meteorological Station (MET)	7	Both Direction of Road	9
5		Automatic Traffic Counter cum Classifier (ATCC)		At Entry Points	7
6		Automatic Speed Detection System	2	Both Direction of Road	409
7		Automatic Number Plate	2	Both Direction of	409

S No	System	Equipment	Interval (Km)	Location	Quantity
		Detection (ANPR)		Road	
8		Weight In Motion Detection System		At Entry Points	16
9		Height Detection System		At Entry Points	16
10	Processing and Monitoring	Central Control Room		At One End	1
14	Data Dissemination	Variable Message Sign (VMS)	10	At entry point and over the Dyke	22
16	Transmission	Optical Fibre Cable	4 Cables	Whole Length (m)	4,01,200
17		Power Cable	4 Cables	Whole Length (m)	4,01,200

21.7.2Toll systems

Currently, tolling on national highways based on FASTag supplied and deployed by the Indian Highways Management Company Ltd. (IHMCL). FASTag was introduced in 2016 and made compulsory in February 2021 reaching 30 M users in March 2021. Around, 97% of vehicles in India pay toll using FASTag. FASTag, however, has one major limitation. It is not 100 % seamless. For the RFID tag to be scanned and electronic payment to be made, vehicles still need to stop at toll gates, even though for seconds.

In order to improve the toll collection process, Government of India plans to introduce the **GNSS technology based tolling system** or **Automatic Number Plate Reader (ANPR) cameras**. This is expected to improve the toll collection and improve the traffic management. The description of these systems is presented in the following section.

- **GNSS Technology based Tolling System**

Under the global positioning technology-based electronic toll collection, virtual gantries (a virtual road charging point equivalent to a traditional road charging toll gantry) monitor the entry and exit of vehicles on the tolled section. There is no toll collection booth or physical gantries mounted with high resolution cameras to scan the vehicles passing underneath them, registering their tags and registration numbers. Instead, vehicles will be equipped with an on-board global positioning device. Users' bank account and vehicle details, including registration number and type of vehicle, will be seeded into the device. While using the toll road network, the on-board unit autonomously determines the position of the vehicle by using a Global Navigation Satellite System (GNSS). GNSS essentially refers to a satellite or a constellation of satellites that provides positioning navigation and timing (PNT) services. Once the toll section is identified, the on-board global positioning device begins a fully automated tolling process. The vehicle movement data is transmitted by the vehicle mounted unit to the back office of the service provider. The back office, in turn, determines the toll charges to be deducted based on parameters, including the distance of the tolled section used and the type of the vehicle, among others. For rolling out satellite-based tolling, India will soon start the process of geo fencing of the entire National Highway network in the country.

In Europe, is GNSS-based toll collection systems is successfully implemented such as the Stockholm congestion tax, the Austrian truck toll, the German Toll Collect, the toll system in Slovakia or the French Eco-tax. Each European GNSS-based tolling system has a

compliance (payment) rate above 98% or 99%. The illustration of GNSS based toll collection for trucks (in Germany) are shown **Figure 2.39**.

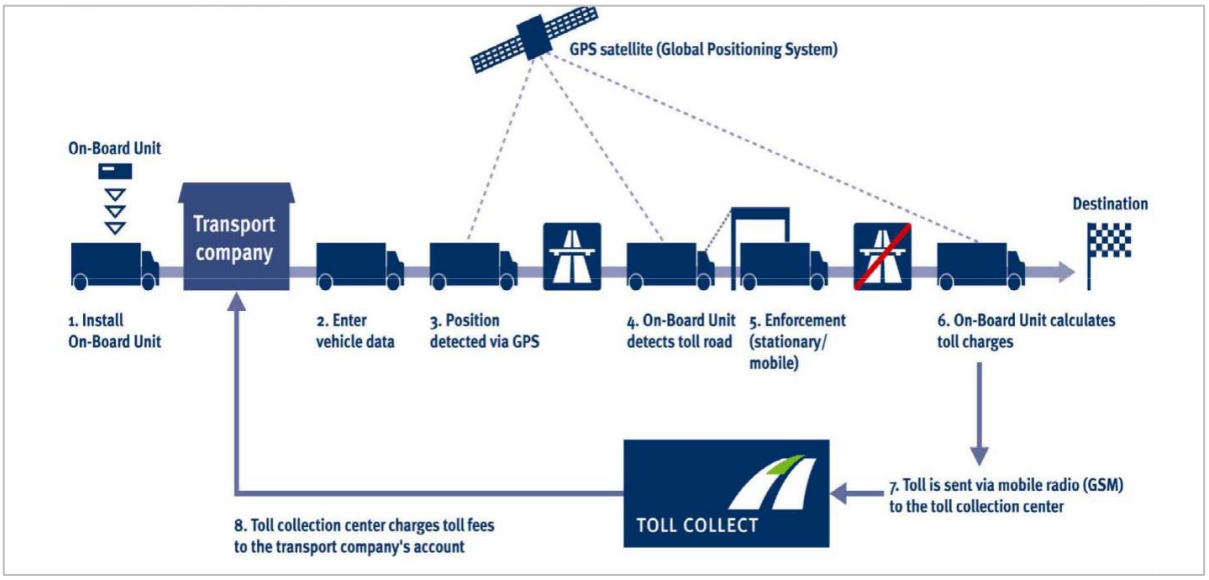


Figure 2.39: GNSS based toll collection (in Germany)

GNSS-based tolling can have many advantages compared to electronic toll collection systems currently in place in India. It will save time for passengers and cargo consignments as neither will they have to wait in long queues, nor will they have to stop at every toll booth. They can make payments at once through online platforms GNSS-based systems make a greater variety of charging schemes technically feasible; systems can be more easily expanded and scaled-up with low investment and the OBUs installed on vehicles for the use of GNSS can be used for additional value-added services to the end-users. However, such systems also bear their own challenges related to accuracy, privacy, and standardisation. In India, while all new commercial vehicles are coming with vehicle tracking systems, the Government will need to come up with some plan to install GNSS technology in old vehicles which will have a widespread effect.

GNSS technology based tolling system is suggested for Kalpasar Project due to many advantages such as no need of physical toll plaza, unhindered movement of traffic and ease of tolling etc.

- **Automatic Number Plate Reader (ANPR) Cameras**

Recently, union ministry of road transport and highways has planned to remove all the toll plazas on the national highways and introduced Automatic Number Plate Reader (ANPR) cameras to reduce congestion at the toll plazas.

Automatic Number Plate Reader (ANPR) cameras will read vehicle number plates and automatically deduct toll from the linked bank accounts of vehicle owners. Entry and exit of toll roads will have cameras capable of reading number plates. At present not all number plates in India can be read, and only those that have come after 2019 will be registered by the cameras. The government, in 2019, had come up with a rule mandating passenger vehicle to have company-fitted number plates, and only these number plates can be read by cameras.

Issues with Automatic Number Plate Reader (ANPR): The success of ANPR cameras will depend on creating an ecosystem that is in sync with the requirements of the camera. The biggest issue during the trials is when things other than the nine-digit registration

number are written on number plates, such as 'Govt of India/Delhi'. There is a difficulty in reading number plates on trucks, as most of the time they are hidden or soiled.

To conclude, physical toll plazas will be defunct in future. Either, GNSS technology based tolling system or automatic number plate reader (ANPR) cameras will be used for toll collection and therefore, physical toll plazas are not considered in the report.

21.7.3Security systems

As per the requirement from security perspective, there shall be provision of physical checking or screening of vehicles (in certain situations). The plan of the proposed security area is presented in **Figure 2.40**.

This should ideally be carried out at the interchange locations. However, since it is very difficult to get the huge land parcel, it is suggested that security hold area can be planned in inter-tidal zone where sufficient land is available. In view of the above, suitable ramps can be planned so that vehicles can be diverted to security hold area and can merge with access roads once checking is completed.

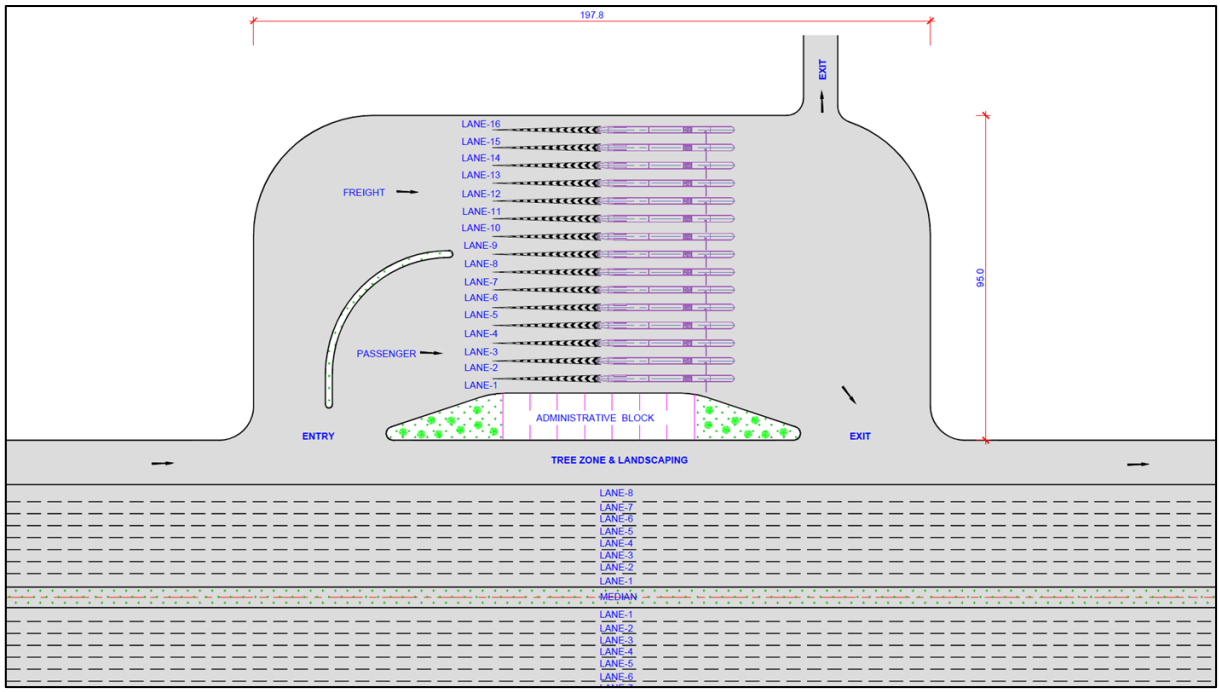


Figure 2.40: Plan of proposed security area in Kalpasar

22.Construction

22.1 Kalpasar project materials

Detailed description and specification of various construction materials of road and rail is given in sub-section 2.3.14 (a) of Annexure 2.3.

22.4 Construction Sequence

22.4.4Transport Corridor

(a)Formation

Formation comprises of Blanket and, Prepared subgrade. Depending upon techno-economic considerations, it can be Single layer or Two-layer construction. For construction of a new line, it is important to ensure that the track bed layers (Blanket/Prepared subgrade/Subgrade) have the appropriate mechanical characteristics and are of adequate thickness.

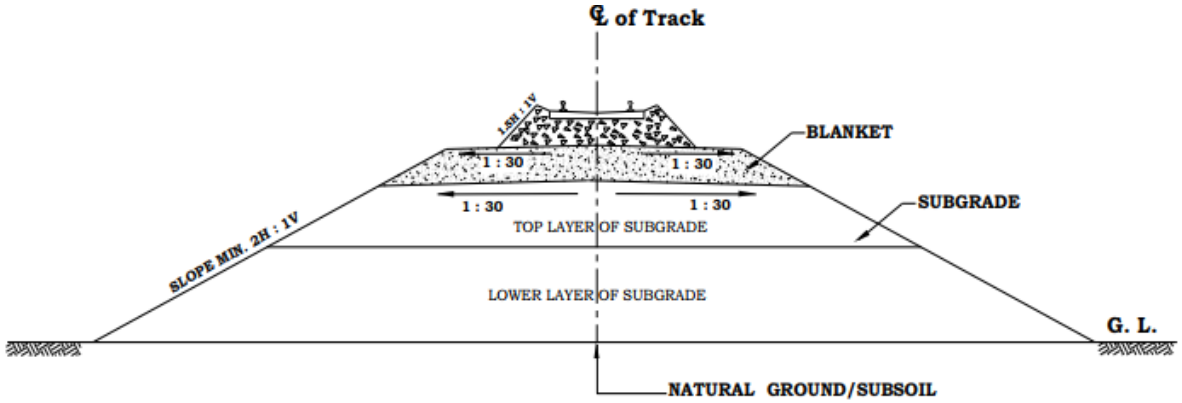


Figure 2.41: Single layer formation

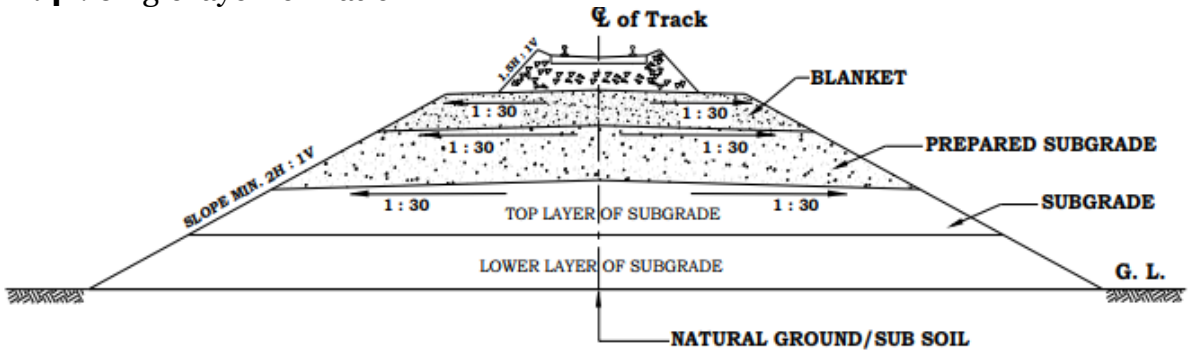


Figure 2.42: Double layer formation

Detailed specifications and thickness of formation layer construction is given in **sub-section 2.3.9 (b) of Annexure 2.3.**

Embankment and Formation Layer Construction:

The minimum height of the embankment above ground level or highest flood level (HFL) whichever is higher should not be less than one meter to ensure proper drainage and avoid trespassing.

Total required thickness of formation layers as specified in Para 3.10 for blanket, prepared sub-grade &Subgrade-Top Layer, should be provided/ensured uniformly in embankment/cutting for effective stress dispersal.

The specification of soil strata below the ground level (GL) must be ascertained from the results of soil exploration.

For effective stress dispersal, required total uniform thickness of formation layer (Blanket, Prepared sub-grade &Subgrade/Top Layer) shall be ensured in cuttings as well as in embankments, even where embankment height is less than about 1.5m or total uniform required thickness.

It is further explained below:

For Embankment: Where the height of embankment is less than required total uniform thickness): If the specification of sub-soil meets the required specification of blanket/prepared subgrade/subgrade-top layer, up to required total depth of uniform thickness below ground level, then there will be no need of excavation, else the excavations will be done below ground level as per the requirement, to satisfy the provision of total uniform thickness for effective stress dispersal.

For Cutting: If the specification of sub-soil does not meet the required specification of blanket/prepared subgrade/subgrade-top layer i.e. total required uniform thickness, below the proposed level of excavation in cuttings, the excavation level for cuttings shall be enhanced to the level so as to satisfy the total required uniform thickness requirement.

(b) Road and Bridges (Approaches, and flood regulator)

- **Construction Sequence of Roads**

Emabankment/ Subgrade Construction

The materials used in embankments, subgrades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, reclaimed material from pavement, fly ash, pond ash, a mixture of these or any other material as approved by the Engineer. Such materials shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment. The following types of material shall be considered unsuitable for embankment:

a) Materials from swamps, marshes and bogs;
b) Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Pt in accordance with IS: 1498;
c) Materials susceptible to spontaneous combustion;
d) Materials in a frozen condition;
e) Clay having liquid limit exceeding 50 and plasticity index exceeding 25; and
f) Materials with salts resulting in leaching in the embankment.

The size of the coarse material in the mixture of earth shall ordinarily not exceed 75 mm when placed in the embankment and 50 mm when placed in the sub-grade. However, the Engineer may at his discretion permit the use of material coarser than this also if he is satisfied that the same will not present any difficulty as regards the placement of fill material and its compaction to the requirements of these Specifications. The maximum particle size in such cases, however, shall not be more than two-thirds of the compacted layer thickness.

The material to be used in subgrade shall conform to the design CBR value at the specified dry density and moisture content of the test specimen. In case the available materials fails to meet the requirement of CBR, use of stabilization methods in accordance with Clauses 403 and 404 of MORT&H specifications or by any stabilization method approved by the Engineer or by the IRC Accreditation Committee shall be followed.

Granular Sub-Base

This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as sub-base or lower sub-base and upper sub-base (termed as sub base hereinafter) as necessary according to lines, grades and cross-sections shown on the drawings or as directed by the Engineer.

The material to be used for the work shall be natural sand, crushed gravel, rushed stone, crushed slag, or combination thereof depending upon the grading required. Use of materials like brick metal, Kankar and crushed concrete shall be permitted in the lower sub-base. Gradings III and IV shall preferably be used in lower sub-base. Grading V and VI shall be used as a sub-base-cum-drainage layer. The grading to be adopted for a project shall be as specified in the Contract. Where the sub-base is laid in two layers as upper sub-base and lower sub-base, the thickness of each layer shall not be less than 150 mm. Immediately prior to the laying of sub-base, the subgrade already finished to Clause 301 or 305 of MORT&H specifications as applicable shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water, if necessary and rolled with two passes of 80–100 kN smooth wheeled roller.

The sub-base material of the grading specified in the Contract and water shall be mixed mechanically by a suitable mixer equipped with provision for controlled addition of water and mechanical mixing. So as to ensure homogenous and uniform mix. The required water content shall be determined in accordance with IS: 2720 (Part 8). The mix shall be spread on the prepared subgrade with the help of a motor grader of adequate capacity, its blade having hydraulic controls suitable for initial adjustment and for maintaining the required slope and grade during the operation, or other means as approved by the Engineer.

Wet Mix Macadam Sub-Base/Base

This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared sub-grade/sub-base/ base or existing pavement as the case may be in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as necessary to lines, grades and cross-sections shown on the approved drawings or as directed by the Engineer. The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75 mm. When vibrating or other approved types of compacting equipment are used, the compacted depth of a single layer of the sub-base course may be up to 200 mm with the approval of the Engineer.

Coarse aggregates shall be crushed stone. If crushed gravel/shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set.

Wet Mix Macadam shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/ positive mixing arrangement like pug mill or pan type mixer of concrete batching plant. The plant shall have following features:

i) For feeding aggregates– three/ four bin feeders with variable speed motor;
ii) Vibrating screen for removal of oversize aggregates;
iii) Conveyor Belt;
iv) Controlled system for addition of water;
v) Forced/positive mixing arrangement like pug-mill or pan type mixer;
vi) Centralized control panel for sequential operation of various devices and precise process control; and
vii) Safety devices.

Optimum moisture for mixing shall be determined in accordance with IS:2720 (Part-8) after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm size. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the

optimum value by more than agreed limits. The mixed material should be uniformly wet and no segregation should be permitted.

Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub-grade/sub-base/base in required quantities. In no case shall there be dumped in heaps directly on the area where these are not to be laid nor shall their hauling over a partly completed stretch be permitted. The mix may be spread by a paver finisher.

The paver finisher shall be self-propelled of adequate capacity with following features:
i) Loading hoppers and suitable distribution system, so as to provide a smooth uninterrupted material flow for different layer thicknesses from the tipper to the screed;
ii) Hydraulically operated telescopic screed for paving width up to to 8.5 m and fixed screed beyond this. The screed shall have tamping and vibrating arrangement for initial compaction of the layer; and
iii) Automatic levelling control system with electronic sensing device to maintain.

Prime Coat over Granular Base

This work shall consist of the application of a single coat of low viscosity liquid bituminous material to a porous granular surface preparatory to the superimposition of bituminous treatment or mix. The work shall be carried out on a previously prepared granular/ stabilized surface.

The primer shall be cationic bitumen emulsion SS1 grade conforming to IS: 8887 or medium curing cutback bitumen conforming to IS: 217 or as specified in the Contract.

The correct quantity of primer shall be decided by the Engineer and shall be such that it can be absorbed by the surface without causing run-off of excessive primer and to achieve desired penetration of about 8-10 mm.

Primer shall not be applied during a dust storm or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 100C. Cutback bitumen as primer shall not be applied to a wet surface. Surfaces which are to receive emulsion primer should be damp, but no free or standing water shall be present. Surface can be just wet by very light sprinkling of water.

The primer shall be applied by a self-propelled or towed bitumen pressure sprayer equipped for spraying the material uniformly at specified rates and temperatures. Hand spraying shall not be allowed except in small areas, inaccessible to the distributor, or in narrow strips where primer shall be sprayed with a pressure hand sprayer, or as directed by the Engineer.

The granular surface to be primed shall be swept clean by power brooms or mechanical sweepers and made free from dust. All loose material and other foreign material shall be removed completely. If soil/ moorum binder has been used in the WBM surface, part of this should be brushed and removed to a depth of about 2 mm so as to achieve good penetration.

After preparation of the road surface as per Clause 502.4.2, the primer shall be sprayed uniformly at the specified rate. The method for application of the primer will depend on the type of equipment to be used, size of nozzles, pressure at the spray bar and speed of forward movement. The Contractor shall demonstrate at a spraying trial, that the equipment and method to be used is capable of producing a uniform spray, within the tolerances specified.

A primed surface shall be allowed to cure for at least 24 hours or such other higher period as is found to be necessary to allow all the moisture/volatiles to evaporate before any subsequent surface treatment or mix is laid. Any unabsorbed primer shall first be blotted with a light application of sand, using the minimum quantity possible. A primed surface shall not be opened to traffic other than that necessary to lay the next course.

Tack Coat

The work shall consist of the application of a single coat of low viscosity liquid bituminous material to existing bituminous, cement concrete or primed granular surface preparatory to the superimposition of a bituminous mix, when specified in the Contract or as instructed by the Engineer.

The binder used for tack coat shall be either Cationic bitumen emulsion (RS 1) complying with IS:8887 or suitable low viscosity paving bitumen of VG 10 grade conforming to IS:73. The use of cutback bitumen RC:70 as per IS:217 shall be restricted only for sites at sub-zero temperatures or for emergency applications as directed by the Engineer. The type and grade of binder for tack coat shall be as specified in the Contract or as directed by the Engineer.

Bituminous material shall not be applied during a dust storm or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 10°C. Where the tack coat consists of emulsion, the surface shall be slightly damp, but not wet. Where the tack coat is of cutback bitumen, the surface shall be dry.

The tack coat shall be applied by a self-propelled or towed bitumen pressure sprayer, equipped for spraying the material uniformly at a specified rate. Hand spraying shall not be permitted except in small areas, inaccessible to the distributor, or narrow strips, shall be sprayed with a pressure hand sprayer, or as directed by the Engineer.

The surface on which the tack coat is to be applied shall be clean and free from dust, dirt, and any extraneous material, and be otherwise prepared in accordance with the requirements of Clauses 501.8. The granular or stabilized surfaces shall be primed as per Clause 502. Immediately before the application of the tack coat, the surface shall be swept clean with a mechanical broom, and high pressure air jet, or by other means as directed by the Engineer.

No dilution or heating at site of RS1 bitumen emulsion shall be permitted. Paving bitumen if used for tack coat shall be heated to appropriate temperature in bitumen boilers to achieve viscosity less than 2 poise. The normal range of spraying temperature for a bituminous emulsion shall be 20°C to 70°C and for cutback, 50°C to 80°C. The method of application of tack coat will depend on the type of equipment to be used, size of nozzles, pressure at the spray bar, and speed or forward movement. The Contractor shall demonstrate at a spraying trial, that the equipment and method to be used is capable of producing a uniform spray, within the tolerances specified.

The tack coat shall be left to cure until all the volatiles have evaporated before any subsequent construction is started. No plant or vehicles shall be allowed on the tack coat other than those essential for the construction.

Dense Bituminous Macadam

The specification describes the design and construction procedure for Dense Bituminous Macadam, (DBM), for use mainly, but not exclusively, in base/binder and profile corrective courses. The work shall consist of construction in a single or multiple layers of DBM on a previously prepared base or sub-base. The thickness of a single layer shall be 50 mm to 100 mm.

The bitumen shall be viscosity grade paving bitumen complying with the Indian Standard Specification IS:73, modified bitumen complying with Clause 501.2.1 in MORT&H technical specifications or as otherwise specified in the Contract.

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. They shall be clean, hard, durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. Where the Contractor's selected source of aggregates has poor affinity for bitumen, the Contractor shall produce test results that with the use of anti-stripping agents, the stripping value is improved to satisfy the specification requirements. The Engineer may approve such a source and as a condition for the approval of that source, the bitumen shall be treated with an approved anti-stripping agent, as per the manufacturer's recommendations, at the cost of the Contractor.

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36 mm sieve and retained on the 75 micron sieve. These shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter. Natural sand shall not be allowed in binder courses.

The bitumen content required shall be determined following the Marshall mix design procedure contained in Asphalt Institute Manual MS–2. The Fines to Bitumen (F/B) ratio by weight of total mix shall range from 0.6 to 1.2. The binder content shall be selected to obtain 4 percent air voids in the mix design. The Marshall method for determining the optimum binder content shall be adopted as described in the Asphalt Institute Manual MS-2. Where maximum size of the aggregate is more than 26.5 mm, the modified Marshall method using 150 mm diameter specimen described in MS-2 and ASTM D 5581 shall be used.

The Contractor shall submit to the Engineer for approval at least 21 days before the start the work, the job mix formula proposed for use in the works, together with the following details:

i) Source and location of all materials;

ii) Proportions of all materials expressed as follows:

a) Binder type, and percentage by weight of total mix;

b) Coarse aggregate/Fine aggregate/Mineral filler as percentage by weight of total aggregate including mineral filler;

iii) A single definite percentage passing each sieve for the mixed aggregate;

iv) The individual grading of the individual aggregate fraction, and the proportion of each in the combined grading;

v) The results of mix design such as maximum specific gravity of loose mix (Gmm), compacted specimen densities, Marshall stability, flow, air voids, VMA, VFB and related graphs and test results of AASHTO T 283 Moisture susceptibility test;

vi) Where the mixer is a batch mixer, the individual weights of each type of aggregate, and binder per batch;

vii) Test results of physical characteristics of aggregates to be used; and

viii) Mixing temperature and compacting temperature.

In case of modified bitumen, the temperature of mixing and compaction shall be higher than the mix with viscosity grade bitumen. The exact temperature depends upon the type and amount of modifier used and shall be adopted as per the recommendations of the manufacturer. In order to have uniform quality, the plant shall be calibrated from time to time.

The general provisions of Clauses 501.6 and 501.7 in MORT&H technical specifications shall apply, as modified by the approved laying trials. The compaction process shall be carried out by the same plant, and using the same method, as approved in the laying trials, which may be varied only with the express approval of the Engineer in writing. It shall be ensured that the traffic is not allowed without the approval of the Engineer in writing, on the surface until the dense bituminous layer has cooled to the ambient temperature.

Dense Graded Bituminous Materials shall be measured as finished work either in cubic metres, tonnes or by the square metre at a specified thickness as indicated in the Contract drawings, or documents, or as otherwise directed by the Engineer.

Bituminous Concrete

This work shall consist of construction of Bituminous Concrete, for use in wearing and profile corrective courses. This work shall consist of construction in a single layer of bituminous concrete on a previously prepared bituminous bound surface. A single layer shall be 30 mm/40 mm/50 mm thick.

Dry Lean Cement Concrete Sub-Base

The work shall consist of construction of (zero slump) dry lean concrete sub-base for cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations, in connection with the work, as approved by the Engineer. The design parameters of dry lean concrete sub-base, viz., width, thickness, grade of concrete, details of joints, if any, etc. shall be as stipulated in the drawings.

The Contractor shall indicate to the Engineer the source of all materials with relevant test data to be used in the dry lean concrete work sufficiently in advance and the approval of the Engineer for the same shall be obtained at least 45 days before the scheduled commencement of the work in trial length. If the Contractor later proposes to obtain the materials from a different source during the execution of main work, he shall notify the Engineer with relevant test data for his approval at least 45 days before such materials are to be used.

If the subgrade soil contains soluble sulphates in a concentration more than 0.5 percent, sulphate resistant cement conforming to IS: 6909 shall be used. Cement to be used may preferably be obtained in bulk form. It shall be stored in accordance with stipulations contained in Clause 1014 and shall be subjected to acceptance test prior to its immediate use.

Fly-ash upto 20 percent by weight of cementitious material (cement+flyash) may be used along with 43/53 grade cement may be used to replace OPC cement grade 43 up to 30 percent by weight of cement. Fly-ash shall conform to IS:3812 (Part 1) and its use shall be permitted only after ensuring that facilities exist for uniform blending through a proper

mechanical facility with automated process control like batch mix plant conforming to IS:4925 and IS:4926.

The mix shall be proportioned with a maximum aggregate cementitious material ratio of 15:1. The water content shall be adjusted to the optimum as per Clause 601.3.2 in MORT&H technical specifications for facilitating compaction by rolling. The strength and density requirements of concrete shall be determined in accordance with Clauses 601.7 and 601.8 in MORT&H technical specifications by making trial mixes. Care should be taken to prevent one size of aggregate falling into the other size of the hopper of the feeding bin while loading the individual size of aggregates into the bins.

The optimum water content shall be determined and demonstrated by rolling during trial length construction and the optimum moisture content and degree of compaction shall be got approved from Engineer. While laying in the main work, the lean concrete shall have a moisture content between the optimum and optimum +2 percent, keeping in view the effectiveness of compaction achieved and to compensate for evaporation losses.

The cement content in the dry lean concrete shall be such that the strength specified in Clause 601.3.4 is achieved. The minimum cement content shall be 150 kg/cu.m of concrete. In case flyash is blended at site as part replacement of cement, the quantity of flyash shall not be more than 20 percent by weight of cementitious material and the content of OPC shall not be less than 120 kg/cu.m.

The average compressive strength of each consecutive group of 5 cubes made in accordance with Clause 903.5.1.1 shall not be less than 10 MPa at 7 days. In addition, the minimum compressive strength of any individual cube shall not be less than 7.5 MPa at 7 days. The design mix complying with the above Clauses shall be got approved from the Engineer and demonstrated in the trial length construction.

The Dry Lean Concrete shall be laid on the prepared granular drainage layer. The pace and programme of the Dry Lean Concrete sub-base construction shall be matching suitably with the programme of construction of the cement concrete pavement over it. The Dry Lean Concrete sub-base shall be overlaid with concrete pavement only after 7 days of sub-base construction.

Plant mix lean concrete shall be discharged immediately from the mixer, transported directly to the point where it is to be laid and protected from the weather by covering the tipping trucks with tarpaulin during transit. The concrete shall be transported by tipping trucks, sufficient in number to ensure a continuous supply of material to feed the laying equipment to work at a uniform speed and in an uninterrupted manner.

Lean concrete shall be placed by a paver with electronic sensor on the drainage layer or as specified in the Contract. The equipment shall be capable of laying the material in one layer in an even manner without segregation, so that after compaction the total thickness is as specified. The paving machine shall have high amplitude tamping bars to give good initial compaction to the sub-base. One day before placing of the dry lean cement concrete subbase, the surface of the granular sub-base/drainage layer shall be given a fine spray of water and rolled with a smooth wheeled roller.

The compaction shall be carried out immediately after the material is laid and levelled. In order to ensure thorough compaction, rolling shall be continued on the full width till there is no further visible movement under the roller and the surface is well

closed. The minimum dry density obtained shall not be less than 98 percent of that achieved during the trial length construction in accordance.

No heavy commercial vehicles like trucks and buses shall be permitted on the dry lean concrete sub-base. Construction vehicles at slow speed may be permitted after 7 days of its construction with the prior approval of the Engineer.

Cement Concrete Pavement

The work shall consist of construction of un-reinforced, dowel jointed, plain cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross sections shown on the drawings. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations in connection with the work, as approved by the Engineer.

The Contractor shall indicate to the Engineer the source of all materials to be used in the concrete work with relevant test data sufficiently in advance, and the approval of the Engineer for the same shall be obtained at least 45 days before the scheduled commencement of the work in trial length. If the Contractor subsequently proposes to obtain materials from a different source during the execution of main work, he shall notify the Engineer, with relevant test data, for his approval, at least 45 days before such materials are to be used.

Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer, but preference shall be to use at least the 43 grade or higher. Cement to be used may preferably be obtained in bulk form. If cement in paper bags is proposed to be used, there shall be bag-splitters with the facility to separate pieces of paper bags and dispose them off suitably.

Site mixing of fly ash shall be permitted only after ensuring availability of the equipments at site for uniform blending through a specific mechanised facility with automated process control like batch mix plants conforming to IS:4925 and IS:4926. Site mixing will not be allowed otherwise. The Portland Pozzolana Cement produced in factory as per IS: 1489-Part I shall not have fly-ash content more than 20 percent by weight of cementitious material. Certificate from the manufacturer to this effect shall be produced before use.

Admixtures conforming to IS:9103 and IS:6925 shall be permitted to improve workability of the concrete and/or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete with respect to strength, volume change, durability and have no deleterious effect on steel bars. The particulars of the admixture and the quantity to be used, must be furnished to the Engineer in advance to obtain his approval before use. Satisfactory performance of the admixtures should be proved both on the laboratory concrete trial mixes and in the trial length paving. If air entraining admixture is used, the total quantity of air shall be 5±1.5 percent for 31.5 mm maximum nominal size aggregate.

Coarse aggregates shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. The maximum size of coarse aggregate shall not exceed 31.5 mm for pavement concrete. The fine aggregates shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform

to IS:383. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter. The fine aggregates shall have a sand equivalent value of not less than 50 when tested in accordance with the requirement of IS:2720 (Part 37).

Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456.

After approval by the Engineer of all the materials to be used in the concrete, the Contractor shall submit the mix design based on weighed proportions of all ingredients for the approval of the Engineer vide Clause 602.3.4. The mix design shall be submitted at least 30 days prior to the paving of trial length and the design shall be based on laboratory trial mixes using the approved materials and methods as per IRC:44 or IS:10262.

When Ordinary Portland Cement (OPC) is used the quantity of cement shall not be less than 360 kg/cu.m. In case fly ash grade I (as per IS:3812) is blended at site as part replacement of cement, the quantity of fly ash shall be upto 20 percent by weight of cementitious material and the quantity of OPC in such a blend shall not be less than 310 kg/cu.m. The minimum of OPC content, in case ground granulated blast furnace slag cement blended, shall also not be less than 310 kg/m3. If this minimum cement content is not sufficient to produce concrete of the specified strength.

The characteristic flexural strength of concrete shall not be less than 4.5 MPa unless specified otherwise. Target mean flexural strength for mix design shall be more than 4.5 MPa + 1.65s, where s is standard deviation of flexural strength derived by conducting test on minimum 30 beams. The ratio between the 7 and 28 day strength shall be established for the mix to be used in the slab in advance, by testing pairs of beams and cubes at each stage on at least six batches of trial mix. The average strength of the 7 day cured specimens shall be divided by the average strength of the 28 day specimens for each batch, and the ratio "R' shall be determined. The ratio 'R' shall be expressed to three decimal places.

The workability of the concrete at the point of placing shall be adequate for the concrete to be fully compacted and finished without undue flow. The optimum workability for the mix to suit the paving plant being used shall be determined by the Contractor and approved by the Engineer. The Contractor shall carry out laboratory trials of design mix with the materials from the approved sources to be used as per IRC:44. Trial mixes shall be made in presence of the Engineer or his representative and the design mix shall be subject to the approval of the Engineer.

The proportions determined as a result of the laboratory trial mixes may be adjusted, if necessary, during the construction of the trial length. Thereafter, neither the materials nor the mix proportions shall be varied in any way except with the written approval of the Engineer.

- **Construction sequencing for Bridges Structures**

Construction sequence for Bridge structures:

(1) Initially process starts with the site clearance. In the present case, it is the seabed that needs to be made accessible for construction of foundation. Sufficient dewatering technique shall be adopted. In case of bridge in approaches, site needs to be made accessible for construction of foundation;

(2) Piles are bored cast In-situ type. Piling activity shall be carried out by means of underwater concreting techniques in waterway section and in approach road section piling activity shall be carried out with normal piling techniques;
(3) Further, pile cap shall be cast in-situ after the section of seabed is made free from water in water way section and in approach road section the pile cap shall be cast in-situ after the soil is excavated to required extent. Dowels shall be projected from pile-cap for the construction of wall piers in flood regulator portion and for the construction of abutments/piers in approach road section;
(4) Wall piers shall be cast in-situ with pedestals on top of it;
(5) Post-tensioned I-Girders shall be casted at casting yard. The location of casting yard shall be suitably identified. Prestressing of I-Girders shall be done at casting yard itself.
(6) The girders shall then be transported to the location of flood regulator over the embankment constructed beyond the flood regulator;
(7) The Girders shall be lifted and placed in position over the wall piers/abutment cap/pier cap with the help of cranes. The girders shall be temporarily supported over the wall piers/abutment cap/pier cap;
(8) Diaphragm and deck slab shall be cast in-situ by taking support for shuttering from the girders;
(9) After 28 days of casting of Deck slab and diaphragm, the entire superstructure shall be now lowered and supported over the bearings. Installation of bearings shall be carried out by this time;
(10) Further, wearing coat for road bridges and other components over the deck slab shall be constructed; and
(11) For railway bridges, further activity included laying of wearing coat, ballast filling, laying of sleepers and then rail.

25. Benefits of the Project

25.3 Transportation

The construction of the dyke cum road is expected to generate direct and indirect benefits. The direct economic benefits that will accrue because of the project include VOC and travel time savings. The following categories of benefits for Kalpasar have been quantified in monitory values:
(1) Savings in Vehicle Operation Costs (VOC);
(2) Savings in Value of Passenger Time (VOT); and
(3) Carbon credits.

Broadly benefits can be quantified both for Road and Railways and the same are described in the following sections.

(a) Savings in Vehicle Operation Costs (VOC)

Savings in vehicle operation cost is accounts for distance savings to the passenger and commercial vehicles. Savings is calculated by assessing the cost savings before and after the project. Based on the analysis of distance between major origin-destination pairs, an average distance a vehicle will take to traverse from various regions of South Gujarat to Saurashtra before Kalpasar project is 489 Km, while after the project the average travel distance will 374 km. Hence an average distance savings of 115 Km has been considered for economic viability analysis and the VOC were obtained based on primary surveys conducted in this study and vehicle operation cost for train is calculated based on the inputs from Indian Railways year book and they are presented in **Table 2.35**.

Table 2.35: Mode Wise Vehicle Operating Cost (VOC)

Veh Type	Car	Bus	Mini Bus	LCV	Trucks	MAV	Passenger Train	Freight Train
VOC per Vehicle (Rs. per Km)	7.4	14.8	11.1	14.8	24.4	30.5	816	5,682

(b) Savings in Value of Time (VOT)

Time cost savings due to reduction in travel distance and reduction in congestion due to Kalpasar project were accounted for savings in value of time. Hourly wage rate were considered for calculating the VOT savings for passenger vehicles & passenger rail, suitable conversion factors were considered for vehicle units to train units. Commodity holding cost estimated based on IRC-SP: 30-2019 were considered for calculating savings in VOT of commercial vehicles. Details of the VOT considered for this study is presented in **Table 2.36.**

Table 2.36: Mode wise Value of Time (VOT)

Mode	Car	Bus/train	Mini Bus	LCV	Trucks	MAV
VOT per Vehicle (Rs. Per Hour)	369	2,602	781	13.6	98.5	155.2

(c) Carbon credits

A carbon credit is a generic term for any tradable certificate or permit representing the right to emit one tonne of carbon dioxide or carbon dioxide equivalent. Carbon Credit is maintained in the form of an Electronic Certificate, similar to that of a De-Materialized (Demat) Share Certificate.

Carbon credits and carbon markets are a component of national and international attempts to mitigate the growth in concentrations of greenhouse gases (GHGs). **One carbon credit is equal to one ton of carbon dioxide, or in some markets, carbon dioxide equivalent gases**. The different greenhouse gases have differing amounts of effect measured in units of Global Warming Potential (GWP). The GWP unit is defined as the greenhouse forcing due to one unit of CO_2 in its lifetime.

- **Emission trading**

An emission trading (also known as cap and trade) is a market-based approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants.

A central authority (usually a governmental body) sets a limit or cap on the amount of a pollutant that can be emitted. The limit or cap is allocated or sold to firms in the form of emissions permits which represent the right to emit or discharge a specific volume of the specified pollutant. Firms are required to hold a number of permits (or credits) equivalent to their emissions. The total number of permits cannot exceed the cap, limiting total emissions to that level.

Firms that need to increase their emission permits must buy permits from those who require fewer permits. The transfer of permits is referred to as a trade. **In effect, the buyer is paying a charge for polluting, while the seller is being rewarded for having reduced emissions**. Thus, in theory, those who can reduce emissions most cheaply will do so, achieving the pollution reduction at the lowest cost to society.

The Kyoto mechanism is the only internationally-agreed mechanism for regulating carbon credit activities, and, crucially, includes checks for additionality and overall effectiveness. Its supporting organisation, the United Nations Framework Convention on Climate Change (UNFCCC), is the organisation with a global mandate on the overall effectiveness of emission control systems, although enforcement of decisions relies on national co-operation.

The GHGs considered under the Kyoto Protocol are Carbon Dioxide, Methane, Nitrous Oxide, Hydro fluorocarbons, per fluorocarbons, and sulfur hexafluoride. Kyoto Protocol has the provision for four international mechanisms that allow for flexibility in achieving GHG emission reductions. The four mechanisms are bubble policy, joint implementation (JI), clean development mechanism (CDM), and international emissions trading (IET).

- **Emission from transport sector**

Emissions from the transport sector depend mainly on type of transport and fuel apart from type of combustion engine, emission mitigation techniques, maintenance procedures and vehicle age. The major pollutant emitted from transport are Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Nitrogen oxides (NO_x), Nitrous oxide (N_2O), Sulphur dioxide (SO_2), Non-methane volatile organic compounds (NMVOC), Particulate matter (PM) and Hydrocarbon (HC). Diesel is used in public passenger and cargo vehicles, while private two wheelers, light motor vehicles (passenger), cars and jeeps use gasoline.

Table 2-37: Emission from different vehicle types in India (g/km)

MODE	Car	Bus	M.Bus	LCV	2 Axle Truck	3 Axle Truck	MAV
CO2	216.0	515.2	515.2	515.2	515.2	515.2	515.2
CO	1.4	3.6	3.6	5.1	3.6	3.6	3.6
NOx	0.4	12.0	12.0	1.3	6.3	6.3	6.3
CH4	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SO2	5.2	1.4	1.4	1.4	1.4	1.4	1.4
PM	0.1	0.6	0.6	0.2	0.3	0.3	0.3
HC	0.2	0.9	0.9	0.1	0.9	0.9	0.9

Source: Emissions from India's transport sector: State wise synthesis, T.V. Ramachandra et. al.

- **Global warming potential**

Global warming potential (GWP) is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by convention equal to 1). GWP is calculated over a specific time interval and this time interval must be stated whenever a GWP is quoted or else the value is meaningless.

Under the Kyoto Protocol, the values of GWP calculated for the IPCC (Intergovernmental Panel on Climate Change) Assessment Report (as given in Table 6-3) are to be used for converting the various greenhouse gas emissions into comparable CO_2 equivalents.

The GHGs with relatively long atmospheric lifetimes (e.g., CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined.

However, the short-lived GHGs such as water vapor, carbon monoxide, tropospheric ozone, ozone precursors (e.g., NOx, and NMVOCs), and tropospheric aerosols (e.g., SO2 products and carbonaceous particles), vary regionally so it is difficult to quantify their global radiative forcing impacts. No GWP values are attributed to these gases, which are short-lived and spatially inhomogeneous in the atmosphere.

Table 2.38 GWP values for greenhouse gases

Common Name	Chemical Formula	GWP for given Time Horizon		
		20 yr	100 yr	500 yr
Carbon dioxide	CO_2	1	1	1
Methane	CH_4	82.5 ± 25.8	29.8 ± 11	10.0 ± 3.8
Nitrous oxide	N_2O	273 ± 118	273 ± 130	130 ± 64
Oxides of Nitrate	NO_x	Not available		
Sulphur Dioxide	SO_2	Not available		
Particulate Matter	PM	Not available		
Hydrocarbons	HFC-32	2693 ± 842	771 ± 292	220 ± 87
	CFC-11	8321 ± 2419	6226 ± 2297	2093 ± 865

Source: 2021 IPCC AR6, Table 7.15

- **Reduction in emission due to Kalpasar**

Reduction in emissions due to distance savings via GKDP road are quantified based on the number of vehicles and distance saved in a year per different vehicle type, as follows:

$$Ei = 365^* (\sum \text{Veh-km}_{\text{without GKDP}} - \sum \text{Veh-km}_{\text{with GKDP}}) * Eijkm$$

Where,
Ei = emission of GHG (i) in tons
Ei, j, km = emission of GHG (i) in tons from vehicle type (j) per driven kilometre

- **Calculation of carbon credit**

The reduction in emissions calculated in tons for different gases are converted to CO_2 equivalents by multiplying with the corresponding GWP values of gases.

Table 2.39 Carbon credits in million tonnes

Year	Carbon Credit in Million Tonnes	Carbon Credit in Million Rs
2041	5,20,460	625
2051	7,51,985	902
2061	9,99,929	1,200
2071	12,43,215	1,492
2081	13,85,112	1,662

Year	Carbon Credit in Million Tonnes	Carbon Credit in Million Rs
2091	14,53,845	1,745
2101	15,00,156	1,800

(d) Toll Revenue

One of the benefits of road over the Kalpasar dyke is revenue generated due to Tolling of vehicles using the Kalpasar transportation link. As there is a huge savings incurred due to the Kalpasar transportation link, small proportion of savings can be charged as a toll from the vehicle users for revenue generation.

Toll revenue is calculated for optimistic scenario. Table 2.40 shows the toll rate considered for revenue estimation. Distribution of vehicle frequency using Kalpasar road link based on primary and secondary data is shown in Table 2.41.

Toll revenue is accounted for inflation and the summary of toll revenue generated from the Kalpasar road link is given in
Table 2.42.

Table 2.40: Proposed Toll Rates for Kalpasar Road Link

Mode	Car	Bus	Mini Bus	LCV	2 Axle Trucks	3 Axle Trucks	MAV
Toll	860	2,175	355	1,015	1,915	2,250	2,725

Table 2.41: Distribution of Vehicle Frequency using Kalpasar Road Link

Frequency	Car	Bus	Mini Bus	LCV	2 Axle Trucks	3 Axle Trucks	MAV
Single Trip	0%	60%	60%	13%	8%	10%	10%
Daily Pass	11%	11%	35%	34%	23%	35%	33%
Monthly Pass	89%	29%	5%	53%	69%	55%	57%

Table 2.42: Summary of Toll Revenue in Rs. Crores.

Year	2032	2041	2051	2061	2071	2081	2091	2101
Vehicles	18,062	27,138	40,951	56,301	71,752	80,539	85,370	88,365
Total Revenue (Rs. per annum)	1,525	3,440	7,216	13,734	21,966	31,659	38,468	45,704

In the year of project opening (2032), total traffic that is expected on the Kalpasar road link is 18,062 vehicles per day which will grow to 88,365 vehicles per day in the year 2101.

Revenue generated in the year 2032 will be 1,525 crores per annum, which is expected to grow to 45,704 crores per annum in the year 2101.

27. Socio-Economic Impact Assessment

27.4 Economic Impact

- **Agriculture**

From Kalpasar Project 10000 Mm3 water with 50% dependability will be available, out of this 6500 Mm3 to be earmarked for irrigation. Three garland canals at about EL 50 m, EL 70 m and EL 100 m are planned to irrigate about 10.40 lakh hectares of agricultural land of 6 districts and 39 Taluks of Saurashtra.

At present land under irrigation in Saurashtra district is around 15 lakh hectares (as per 2004 statistics). In this context adding 10.4 lakh hectares of land due to Kalpasar will have a profound impact on agricultural output.

- **Transport**

Transport corridor over the Kalpasar dyke will bring huge savings in distance, travel time and promotes economic growth in the region due to reduced logistics cost. There will be an average savings of 115 km in travel distance and minimum travel time savings of 2 hours for the vehicles travelling between south Gujarat and Saurashtra region.

- **Industry**

Kalpasar project will create fresh water reserve which will help in growth of water based industries in Khambhat region. In addition, it will boost the growth of already proposed special investment regions in the project influence area namely Dholera, Pipavav, Vadodara-Ankleshwar region, Aliyabet, PCPIR.

- **Tourism**

Kalpasar project will create a fresh water reservoir of 2000 sq.km, which is huge considering anywhere in the World. It will create a large water frontage. It is expected hotels and other facilities and infrastructure necessary will be created around the frontage area formed by the lake. However, most tourists are expected to visit dam view which can be seen from either side of the dam. Tourism potential of Kalpasar is estimated to be 15 to 20 lakh per annum based on the review of similar projects.

28. Development of Khambhat Region

28.2 Transportation Development – Khambat region:

Khambhat region will have an accelerated development due to various road and rail projects.

Various major road network improvement projects that are in various stages of implementation within project influence area are summarised below,

- Delhi-Mumbai Expressway
- Ahmedabad Dholera Expressway
- Coastal Road from Dahej to Valsad
- Widening of roads connecting Sanand, Bagodra, Dhanduka, Barwala, Vallabhipur, Limbda, Bhavnagar, Amreli, Mahuva, Veraval, Porbandar, and Dwarka.
- Necklace Road along sea connecting Bhavnagar-Dahej, Dahej to NH-48 via Vagara and coastal road along Tarapur-Bhilad-Tithal-Ubhrat-Khambhat.

Some of the major railway development projects within project influence area are,

- Western Dedicated Freight Corridor
- Delhi Mumbai Industrial Corridor

- Mumbai-Ahmedabad High speed rail

Detailed description of abovementioned projects are given in sub-section 2.3.3 (d).

Following are the impacts due to above mentioned development projects:
(1) Various investment regions/ industrial areas are expected to be developed in phases and Dholera SIR is the first node taken up for development as part of DMIC project in Gujarat;
(2) Logistics Parks to be developed in Palanpur, Ahmedabad, Vapi and Vadodara in Gujarat; will boost infrastructural development in general and power sector in particular;
(3) DFC has potential to trigger western industrial corridor i.e., Delhi-Mumbai Industrial Corridor; and
(4) Vapi, Bilimora, Surat, Bharuch, Vadodara, Anand, Ahmedabad, and Sabarmati will get boost in tourism, employment and economies of the cities and towns within the project's influence area due to development of world-class railway stations and maintenance depots.

As per 2011 census, Khambhat region had a population of 4.7 million, which is projected to have a population of 5.6 million in the year 2021 based on past year growth trend. In the year 2031 and 2041, Khambhat region is assumed to have a same growth rate as that of previous decade due to project opening. The population in Khambhat region is projected to be around 10 million in the period of 2071-2101.

Table 2.43: Projected Population in Khambhat Region

Year	Population in Lakhs	(CAGR (%)
2011	47.02	-
2021	56.10	1.8%
2041	79.83	1.8%
2071	99.85	0.7%
2101	106.61	0.2%

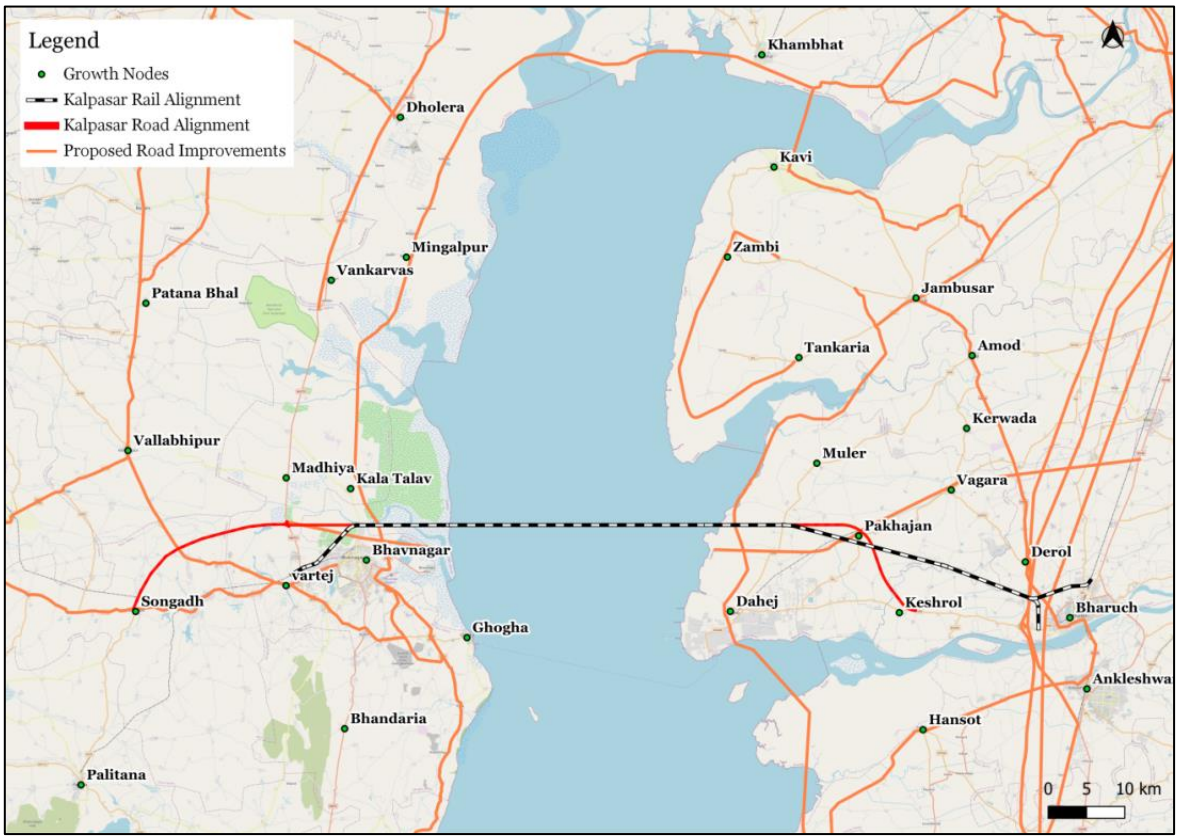


Figure 2.43: Accelerated Growth Nodes due to Kalpasar Project

Bharuch and Bhavnagar is expected to grow rapidly similar to Surat once Kalpasar Project is implemented. A regular commuter rail will be introduced to connect Bhavnagar to Surat via Bharuch. This is expected to trigger business travel. Bharuch will become major hub for various transportation modes as it will have excellent access to dedicated freight corridor (DFC), high-speed rail (HSR), Delhi-Mumbai expressway and Kalpasar road and rail linkages.

Various other small towns and villages such as Pakhajan, Keshrol, Dahej, Muler, Amod, Vagara, Jambusar, Tankaria, Zambi, Hansot, Zambi, Khambhat, Dholera, Vankarvas, Kala Talav, Ghogha, Vartej, Madhiya, Vallabhipur, Songadh, Bhandaria and Pallitana are expected to have an accelerated growth due to transport link over the Kalpasar dyke and they are shown in **Figure 2.43**.

In order to ensure smooth dispersal of traffic from Kalpasar link, access roads are proposed to be developed on Bharuch side as well as at Bhavnagar side.

8 interchanges are proposed to be developed at Songadh on NH 8E, SH 36 Crossing, NH 751 Crossing, Lakdiya Pull, Goladra on SH 6 (Dahej- Amod Road), Pakhajan, Sadathala and Bharuch – Dahej Road (SH-6). All this connecting roads are expected to have an accelerated growth due to improved connectivity between south Gujarat and Saurastra region.

Overall the above projects will improve the regional connectivity and ensures sustainable growth of Khambhat region.

34. Conclusion

(a) Summary

Kalpasar Project with a multi-lane road and rail over the dyke will provide a new transportation link between South Gujarat and Saurashtra reducing the distance between these two regions substantially and will bring about profound change in travel pattern. These regions will benefit immensely due to reduced logistics costs which will pave the way for competitiveness and increased economic activity.

Traffic has been forecasted on Kalpasar transportation link by developing a travel demand model till 2101 duly taking into account future demographic and economic scenarios. Traffic forecast has been made for three scenarios (optimistic, most-likely and pessimistic). The summary of traffic forecast and lane requirements for Road are presented below in **Table 2.44**.

Table 2.44: Summary of traffic forecast and lane requirement for road system

Year	Traffic Forecast on Road (in PCUs)			Lane Requirement (Road)		
	Optimistic	Most Likely	Pessimistic	Optimistic	Most Likely	Pessimistic
2022	22,375	22,375	22,375	2	2	2
2031	52,713	49,011	45,185	4	4	4
2041	81,251	74,826	71,674	6	4	4
2051	1,21,434	1,07,860	99,920	8	8	6
2061	1,64,676	1,51,083	1,36,171	10	10	10
2071	2,06,275	1,91,816	1,70,657	14	12	12
2081	2,32,746	2,18,864	1,87,895	16	14	12
2091	2,43,709	2,22,382	1,90,625	16	14	12
2101	2,53,147	2,24,167	1,94,132	16	14	12

Rail traffic forecast has been carried based on the existing rail passenger and freight movements, future projects and likely shift of traffic from road to rail. Initially, double track for mixed operations has been considered, however, by 2045, double line will be saturated. In order to meet the traffic demand beyond 2045, there is an option of third line or option of providing of two dedicated double line (one for passenger and one for freight operations). Considering the long horizon and uncertainty in forecast, it is suggested to have dedicated operations for passenger and freight separately. Further, Rail can take surplus demand from road and it is most sustainable mode of transport and offers much more capacity than road.

The dedicated operations will allow higher speed of operations for passengers and more load carrying capacity and timely delivery of goods (as against the existing practice of prioritizing the passenger operations, which is resulting in average speed of 25 kmph for freight trains).The traffic forecast, Capacity requirement and capacity utilization of dedicated passenger and freight operations (2 double track line) is presented below in **Table 2.45.**

Table 2.45: Traffic forecast and capacity utilization for rail system

Traffic Forecast for Railway System

Year	Passenger Trains per day	Freight Trains per day	Capacity Requirement for Passenger dedicated passenger line	Capacity Requirement for dedicated freight line	Capacity Utilization for Passenger trains	Capacity Utilization for Freight trains
2022	63	10	Double track	Single track	16%	13%
2031	78	25	Double track	Single track	20%	31%
2041	119	47	Double track	Single track	30%	59%
2051	139	65	Double track	Single track	35%	81%
2061	155	77	Double track	Single track	39%	96%
2071	167	84	Double track	Double track	42%	30%
2081	174	88	Double track	Double track	44%	31%
2091	178	89	Double track	Double track	45%	32%
2101	179	89	Double track	Double track	45%	32%

For the purpose of planning the transport corridor, optimistic scenario has been considered in view of the long horizon of traffic forecast. Based on the Traffic forecast (for Optimistic Scenario), 16-lanes and 2 double Rail lines (one for passenger and one for freight train will be required) is proposed. The required ROW for the Transportation Corridor is 130m to accommodate 16 lane Road and Two double Rail lines.

Total length of road alignment is 100.5 Km, for effective dispersal of traffic from the Kalpasar Dyke it is proposed to extend the road on both sides (Bhavnagar and Bharuch side) of the dyke and traffic shall be dispersed effectively from the proposed interchanges at 8 locations. Interchange locations are summarized below in **Table 2.46**.

Table 2.46: Interchange location for Kalpasar

S.No	Interchange location	Chainage	Direction	Type of Interchange
1	Near Songadh on NH 8E	00+000	Bhavnagar	Trumpet Interchange
2	On SH 36 Crossing	09+800	Bhavnagar	Flyover with Slip roads
3	On NH 751 Crossing	23+500	Bhavnagar	Cloverleaf interchange
4	Near Lakdiya Pull	32+250	Bhavnagar	Flyover with slip roads
5	Near Goladra on SH 6 (Dahej- Amod Road)	83+660	Bharuch	Flyover with Slip roads
6	Pakhajan	93+800	Bharuch	Flyover with Slip roads
7	Sadathala	98+730	Bharuch	Flyover with Slip roads
8	On Bharuch – Dahej Road (SH-6)	104+500	Bharuch	Flyover with slip roads

Total length of rail alignment is 97.5 Km, proposed railway alignment is integrated with existing railway line on Bhavnagar side and Bharuch side. New railway terminals are proposed at 2 locations, one at Bhavnagar side and another at Bharuch side. The chainage detail of the proposed rail terminals is described below in **Table 2.47**.

Table 2.47: Chainage detail for proposed rail terminal

S.No	Chainage (m)	Direction	Location
1	6+519	Bhavnagar	Ramdev Nagar (Outskirts of Bhavnagar)
2	96+511	Bharuch	Outskirts of Bharuch (connecting HSR line)

Road alignment is designed as a National Highway with design speed of 100 Kmph. Median opening is provided at 5km interval for the purpose of emergency U-Turn.

Rail alignment is designed as semi-high speed rail for passenger line and as a dedicated freight corridor (DFC) for freight line.

Structural components of both road and rail are designed as PSC Post tensioned I-Girder with cast In-situ deck slab with a span of 21m. Design loadings and load combinations are considered as per prevailing IS and IRC standards.

ITS facility and equipment is an indispensable component for a fully access-controlled toll road. Accordingly, the ITS shall be installed on viaducts and the Bridge portions from commencement of operation.

Block cost estimates for road and rail components have been estimated for dyke section and approach road sections. Road cost is estimated based on prevailing SOR rates in Gujarat. Road costing is estimated under the following heads:
(1) Civil; and
(2) ITS

Delhi schedule of rates were used for deriving the block cost estimates for Rail components Railway costing is estimated under the following heads:
(1) Civil;
(2) Electrical;
(3) Mechanical; and
(4) Signalling & Telecommunication

The summary of block cost estimates for dyke section and approach road section is given for road and rail is given in Table 2.48. The above cost does not include the land acquisition cost.

Table 2.48: Summary of block cost estimates (road and rail)

S.No.	Description-total	Total Amount	Total Amount in Rs. Crore
Road Cost			
1	Highway Civil Cost	56,60,24,00,121	5,660.24
2	Road Structural Cost	35,48,78,08,218	3,548.78
3	Intelligent Transport System (ITS) Cost	75,73,60,040	75.74
4	Environmental Charges due to Road @ 1% of civil cost	56,60,24,001	56.60
Sub-Total - Road		**93,41,35,92,380**	**9,341.36**
Rail Cost			
5	Rail Civil Cost	44,24,83,63,294	4,424.84

S.No.	Description-total	Total Amount	Total Amount in Rs. Crore
6	Rail Signalling, Telecommunication and Electrification Cost	12,21,67,89,216	1,221.68
7	Rail Mechanical Cost	1,15,83,608	1.16
8	Rail Structural Cost	17,54,86,68,995	1,754.87
9	Environmental Charges due to Rail @ 1% of civil cost	44,24,83,633	44.25
Sub-Total - Rail		**74,46,78,88,746**	**7,446.79**
Total Cost (Road & Rail)		**1,67,88,14,81,126**	**16,788.15**

Block cost estimates for road component is estimated based on prevailing SOR rates in Gujarat. Whereas block cost estimates for rail components is estimated using Delhi schedule of rates. Total cost of various components such as civil works, electrical, mechanical and ITS facilities for both dyke section and approach road section is **Rs. 16,788.15 Cr**, while the total cost for road component alone is **Rs. 9,341.36 Cr** and the total cost for rail component alone is **Rs. 7,446.79 Cr**.

The Total cost in dyke section alone is **Rs. 8,094.25 Cr**, while the total cost for road component alone is **Rs. 5,266.74 Cr** and the total cost for rail component alone is **Rs. 2,827.51 Cr**. The above cost does not include the land acquisition cost.

Table 2.49 gives the summary of EIRRs and NPVs for selected scenarios.

Table 2.49: Results of economic analysis

Scenario	Economic Parameter	Base Case	Sensitivity-I	Sensitivity-II	Sensitivity-III
Optimistic	EIRR	59.8%	57.2%	56.7%	54.2%
	NPV (in Million Rs)	3043972.8	3029759.3	2573163.4	2558949.9
Most Likely	EIRR	57.8%	55.2%	54.8%	52.3%
	NPV (in Million Rs)	2720821.7	2706608.2	2298485.0	2284271.5
Pessimistic	EIRR	55.8%	53.3%	52.9%	50.4%
	NPV (in Million Rs)	2436490.1	2422276.6	2056803.1	2042589.6

The NPV of the stream of net benefits have been computed using prevailing discount rate of 12%, which is cut off rate for the economically viable project. The details of cost & benefit streams for all the scenarios are given in **Annexure-2N**.

The project gives the EIRR of 59.8% for optimistic scenario and for base case. This indicates that the project is viable. The sensitivity analysis estimates the lowest EIRR at 50.4%. This indicates that the project is viable even under the worst condition of increase in project cost by 15% and decrease in benefits by 15% considering pessimistic scenario.