15 -ാം കേരള നിയമസഭ

3 -ാം സമ്മേളനം

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സിൽവർലൈൻ റെയിൽ പദ്ധതി

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(എ)	നിർദിഷ്ട തിരുവനന്തപുരം- കാസർഗോഡ് സിൽവർലൈൻ റെയിൽ പാതയ്ക്കായി ഫീസിബിലിറ്റി സ്റ്റഡി നടത്തിയിട്ടുണ്ടെങ്കിൽ പഠന റിപ്പോർട്ടിന്റെ പകർപ്പ് ലഭ്യമാക്കുമോ; ഇല്ലെങ്കിൽ പ്രസ്തുത പഠനം നടത്തുന്നതിന് സ്വീകരിച്ചിട്ടുള്ള നടപടി വിശദമാക്കുമോ?	(എ)	ഫീസിബിലിറ്റിസ്റ്റഡി നടത്തിയിട്ടുണ്ട്. റിപ്പോർട്ടിന്റെ പകർപ്പ് അനുബന്ധമായി (സി.ഡിയിൽ) ചേർത്തിട്ടുണ്ട്.

സെക്ഷൻ ഓഫീസർ

KERALA RAIL DEVELOPMENT CORPORATION LTD

FEASIBILITY REPORT FOR SEMI HIGH SPEED RAIL CORRIDOR FROM THIRUVANANTHAPURAM TO KASARAGOD

KRDCL

SYSTRA

FEASIBILITY REPORT (VERSION 1)

FEASIBILITY REPORT FOR SEMI HIGH SPEED CORRIDOR FROM THIRUVANANTHAPURAM TO KASARAGOD

IDENTIFICATION TABLE

Client/Project owner	Kerala Rail Development Corporation Limited (KRDCL)
Project	Semi High Speed Corridor From Thirvananthapuram To Kasaragod
Study	Feasibility Report For Semi High Speed Rail Corridor From Thirvananthapuram To Kasaragod
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	Consolidation			
	Check			
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1. EXECUTIVE SUMMARY

Kerala Rail Development Corporation Ltd. (KRDCL) is a joint-venture company of the State of Kerala and Ministry of Railways to execute projects that are specific to the local needs. KRDCL has appointed Systra as the General Consultant for the project. The proposed new railway line in the state of Kerala as 3rd and 4th line from Thiruvananthapuram to Kasaragod is being planned as a Semi High-Speed (SHS) Line for the Design Speed of 200Kmph. Government of Kerala took approval of Ministry of Railways to build this line as a stand-alone Semi high speed line. Railway Board's letter No. 2018/Infra/12/33 dated 16.10.18 which conveys MOR's agreement to the state's proposal says:

"The matter has been examined. Ministry of Railways supports the proposed project as a stand-alone elevated rail corridor of Government of Kerala and will render any technical advice/support as and when required in the course of execution of the project"

1.1 EXISTING ROAD AND RAIL NETWORK:

Kerala has 1.62 lakh kilometres of roads which is 4.2% of India's total length which is quite high considering that Kerala accounts for 2.7% of the total population of India. In other terms, the length of roads per lakh population is 509 km, which is higher than the national average of 321.3 km, and the density of roads is 417 km/100 sq. km, which is far ahead of the national average of 109.39 km/100 sq. km. Total route length of railways in Kerala is 1148 km which accounts for 1.7% of total IR's route length of 67,368 km.

The existing railway network and highways in the state are not amenable to faster travel. Average speed on road and by trains is among the lowest of all regions of the country. The average speed of journey by rail and road in the state is about 30% to 40% lower than in the neighbouring states. The journey become even slower in the rainy seasons with high intensity of rainfall in the months of May to August because of deterioration in the condition of the roads and railway lines. Because of the adverse terrain, there is little scope of economically raising speed of trains on the existing railway line in the corridor. Widening of the existing highways in the state has brought about some improvement in the speed of travel. Plans to build a six-lane expressway have been going on since a long time. Speed of travel on the railway tracks has stagnated for the past many years because of massive requirement of land acquisition for such a highway. There is a widespread realization that the economic and social life in the state of Kerala suffers from slow speed of travel on its existing highways and railways. With the above in mind, the Government has decided to build the Thiruvananthapuram - Kasaragod corridor as a Semi high-speed line, covering the coastal region which is the most densely populated region of the state.

Technical feasibility and financial viability of this SHSR line is largely dependent on the following three quite distinctive factors:

- Cost of construction of the line could be high because of the uniquely unfavourable terrain and ground conditions in the corridor. This would mean that a large part of the line may have to be carried in tunnels, viaducts/bridges and high cuttings/embankments. Besides, the cost of land acquisition and compensations for displacement and rehabilitation would also be high because of high cost of land in the coastal plains and the mid-highlands through which the line would pass.
- The other challenge was posed by what is termed as "urban sprawl" in the state. In the state of Kerala it manifests itself in the form of numerous small towns and cities all over the state. So, it would be a challenge to locate the stations on the SHSR line.

- The third challenge comes from the fact that this line is to be built as a standalone line with no integration with the existing IR line in the corridor.

1.2 TRAFFIC STUDY

The proposed SHSR project envisages Semi High-Speed Rail connectivity between Thiruvananthapuram and Kasaragod with intermediate stoppings at key economic centres such as Kollam, Kottayam, Kochi, Thrissur, Calicut and Kannur.

Infrastructure on the transport sector for the intercity travel in the state is mostly by road, and rail. Kerala has 1.62 lakh kilometres of roads which is 4.2% of India's total length. Most of Kerala's west coast is accessible through the National Highways namely NH 66 (old NH17), NH 544 (erstwhile NH 47) and NH 49. The poor condition of the roads and high number of vehicles are one of the basic reasons for the increased road accident index in the State. The Southern Railway under Thiruvananthapuram and Palakkad division operates the railway network throughout the state, connecting all major towns and cities.

The patronage forecast presented in this Feasibility Study Report is mainly based on the previous study reports and the Traffic and Stated Preference Surveys carried out by the earlier studies. The patronage forecast considered the 10 stations recommended in the DPR for the HSR line by DMRC and is primarily based on the Generalised Cost, which is well established in economic theory and used in the traffic assignment models. To derive the probability of shift from existing modes (i.e. Rail, Bus & Car) to SHSR, generalized cost of SHSR is compared with the generalized cost of competing modes.

The estimated ridership in the horizon years 2024, 2028, 2040 and 2051 is estimated as 67740, 82266, 116681 and 147120 respectively. The corresponding PHPDT is estimated as 1330, 1640, 2460 and 3100.

From the fare sensitivity analysis, it is observed that maximum fare revenue corresponds to a fare of Rs 2.75 – Rs 3.00 per km. Though the optimum fare for SHSR is around Rs 3.00 per km, considering the higher ridership at lower fares, the Government/ Authorities may finalise appropriate fare so that the system could be effectively utilised to its full capacity.

As part of the traffic study, different options available to enhance the ridership and revenue of SHSR as well as better utilisation of SHSR infrastructure have been identified. These include, transport integration measures at SHSR terminals, provision of park and ride facilities, connectivity between SHSR and major economic growth centres, introduction of RORO and Parcel services, operation of Tourist Train circuits, operation of Aggregate train services, etc.

Detailed traffic surveys and travel demand modelling for traffic projection, including detailed discussions with the stakeholders and urban planning experts, will be undertaken during DPR stage of the study.

Drive mode shift from Conventional vehicles

As Kerala is densely populated and most of the commuters depend on the conventional polluting vehicles such as cars and buses. Proposed SHSR and the associated aggregate services will shift the commuter mode of transport from the conventional vehicles to efficient Semi High Speed Rail Transport. Some of the key points which enhances the mode shift to SHSR is listed below.

- Improves the travel time substantially compared to conventional mode of transport.
- Improvement in the quality of transportation which in turn improves the quality of life.
- Reduced maintenance cost of conventional vehicle.
- Congestion free and hazzle free transport.
- Last mile connectivity using aggregate services and feeder services.
- Reduction in loss of productivity due to health disorders resulting from pollution.
- Substantial reduction in road accidents.
- Reliability of the SHSR Transport.
- Savings in fuel consumption

Interconnection of SHSR mode of transport with major airports, major commercial and industrial hubs and important bus stands in Kerala.

While the above justifies the need for a semi high speed rail based transport system for Kerala, the selected system is a standalone type transport with standard gauge rail system on the Thiruvananthapuram – Kasaragod route at a speed of 200 KMPH to cover all the major cities in 1.5 to 3 hours of train run duly integrating with existing Indian Railways at two stations for the benefit of interstate and long distance travellers.

1.3 METHODOLOGY FOR ALIGNMENT DESIGN FOR THIRUVANANTHAPURAM – KASARAGOD SHSR LINE:

The alignment has been designed based on the obligatory points provided by KRDCL for providing the Stations at most suitable locations accordingly. Following have been the main factors which played important role while designing the alignment;

- Difficult terrain and geology of the state
- Design the alignment connecting obligatory points of the project
- The dispersed urban population in the state with even the biggest cities having less population
- High cost of the land in the state

The alignment has been prepared keeping in focus all the basic technical requirements for a SHSR line with techno and economic considerations. To cut down land requirement as much as possible, cause less dislocation for the population in congested areas, cause least hindrance to the movement of people and vehicles on the roads, highways and streets, boats and ferries in the canals and backwaters, following strategies have been adopted;

- Alignment has to be economical
- Easy to construct
- To be built at safe level to avoid any submergence of the track during the flood
- Safe from land slide in cuttings or embankment failure during operation
- To serve the traffic potential areas based on obligatory points of the project provided by KRDCL
- To serve the important railway stations as much as possible to have the integration

As the detailed topographical survey and the Soil investigations will be done after approval of the alignment planned in Feasibility Report, the Google Earth has been used for obtaining ground data (X, Y and Z coordinates) for digital terrain modelling for drawing contours and preparing tentative alignment. Google Earth has also been used as an aid to examine all physical features like water ways, lakes, backwaters, forests, roads, railways, canals, cities, and other habitations with field inspections of critical locations. The Z coordinate (i.e. the vertical height) along the chosen alignment has been rechecked by DGPS survey and corrections applied in the overall alignment. The detailed topographical survey will be done during DPR.

Key details of the alignment are given in the table below:

Table 1: DETAILS OF THE ALIGNMENT

DETAILS OF THE ALIGNMENT	
Route Length: 531.450	
Type of structure	**Length (%age of route length)**
TUNNELS	2.430 Km (0.5%)
BRIDGES	12.045 Km(2.27%)
VIADUCTS	57.030Km (10.74%)
EMBANKMENTS	236.330Km (44.48%)
CUTTINGS	200.220 Km (37.69%)
CUT & COVER	23.415Km(4.40%)

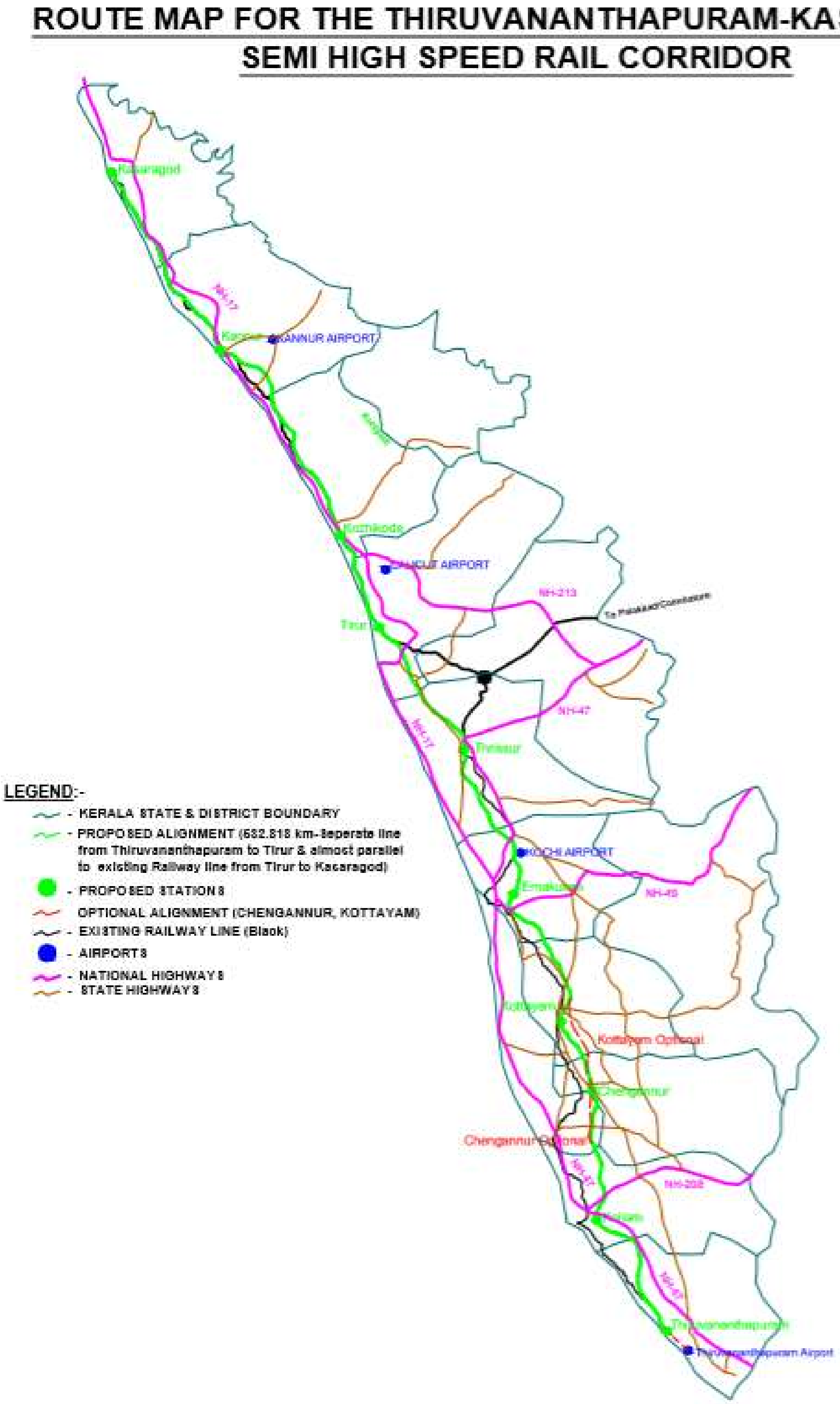


Figure 1: Road Map for Thiruvananthapurm-Kasaragod Semi High Speed Line

The alignment has been prepared on the alignment philosophy which says that in a region with unfavourable terrain and ground conditions, feasibility of construction of a stable and safe railway line at a reasonable and affordable cost in the desired timeframe is largely determined by the chosen alignment. Ease of operation and maintenance of the line would also be controlled by the alignment. After assessing various possible alignments under each strategy, it was decided to make the alignment avoiding the hillocks/mounds and waterlogged low valleys and terraces of the midlands to the bare minimum. Careful consideration was given for identifying structure types that are both structurally capable and economical, while leaving room for aesthetic considerations. The main types of structures that would go into building the line are the following: tunnels, viaducts, bridges, embankments, cuttings, cut & cover, special ground strengthening and slope stabilization structures, road-over/under bridges and cuttings, retaining walls, buildings, fences etc.

The details of the alignment are given in the Chapter 7: Alignment Study, Route Description and Stations. The alignment will require to be finetuned during DPR stage on the basis of detailed topographical and Soil investigation surveys.

1.4 THE ALIGNMENT THROUGH THE MAIN CITIES AND STATION LOCATIONS:

Finding a way to carry a new railway line to the city centre or as close to it as possible such that the city population can reach station in a short distance, is often the most difficult part of preparing alignment. The alignment that could be prepared will cross the main cities in the corridor in the following manner;

Thiruvananthapuram:

This station is proposed on the right hand side of existing Kochuveli Station parallel to the existing second terminal station of Thiruvananthapuram for integration with existing railway station. One Depot with workshop is proposed at this station where there is sufficient private land available for acquisition. An extension for 4.351 Km to connect the international airport and to have an aggregate station inside the airport if the airport authorities give necessary permission can be explored during DPR Stage.

Kollam:

This Station is proposed at a distance of 6.719 Km away from existing Railway Station almost parallel to the recently opened bypass for want of suitable location at city center. However the place now proposed is a fast developing area with lot of access to approach the station.

Chengannur and Kottayam:

These stations are now proposed at distances of 4.530 Km and 4.850 Km respectively from existing railway stations for want of places near city centers. These stations are proposed near to the MC road an important State Highway in the state. However effort is being taken to shift these locations to city centers as far as possible and proposed as optional and the coordinates are furnished in Table 2. The feasibility will be explored at time of DPR.

Ernakulam:(Kochi)

This station is now proposed at distance of 10.388 Km for want of places near city centers and existing Railway Stations. However this station is proposed near the Infopark and proposed Smart City offices. There is a proposal to extend the existing Metroline to this area and the proposed Metro Station is nearby. The Collectorate also is very nearby. Moreover the proposed site is within Corporation and very fast developing area. One more option via international airport at Kochi can be explored during DPR Stage.

Kannur:

This station is now proposed at distance of 1.377 Km very close to the existing Railway Station for want of place near the existing Railway Station. However the proposed site is within Corporation, very fast developing area with lot of access to it.

Thrissur, Tirur and Kozhikode

These stations are proposed on the left hand side of existing Railway Stations parallel to the existing Railway for integration with existing railway stations.

Kasaragod:

This station is proposed on the left hand side of existing Railway Station parallel to the existing station for integration with existing Railway Station. One Depot is proposed at this station where there is sufficient private land available for acquisition at a comparatively lesser cost.

The station details are given in the table below:

Table 2: PROPOSED STATION LOCATIONS

SL NO	STATION NAME	LATITUDE	LONGITUDE	CHAINAGE IN meter	INTER-STATION DISTANCE In km
1	Thiruvananthapuram At Kochuveli	8°30'44.88"N	76°53'52.43"E	600	0.600
2	Kollam	8°53'40.55"N	76°39'27.09"E	55600	55.000
3(a)	Chengannur	9°20'19.39"N	76°38'39.02"E	109300	53.700
3(b)	Chengannur-Optional	9°18'15.95"N	76°38'19.74"E	105532 (approx.)	-
4(a)	Kottayam	9°37'24.15"N	76°33'54.23"E	142800	33.500
4(b)	Kottayam-Optional	9°34'34.27"N	76°32'18.04"E	137800 (approx.)	-
5	Ernakulam	10°00'39.84"N	76°22'33.47"E	195500	52.700
6	Thrissur	10°30'34.39"N	76°12'20.59"E	259600	64.100
7	Tirur	10°55'3.75"N	75°55'18.25"E	317050	57450
8	Kozhikode	11°14'45.53"N	75°45'35.17"E	358000	40.950
9	Kannur	11°52'56.73"N	75°21'47.30"E	448773	90.773
10	Kasaragod	12°29'28.37"N	74°59'15.57"E	530890	82117
	Depot Locations				
1	Thiruvanathapuram Depot at Kochuveli	8°30'44.72"N	76°53'52.03"E	0	0
2	Kasaragod Depot	12°29'21.51"N	74°59'8.45"E	530890	530.890

1.5 REQUIREMENT OF LAND

To drastically cut down land requirement, cause less dislocation for the population in congested areas, cause least hindrance to the movement of people and vehicles on the roads, highways and streets, boats and ferries in the canals and backwaters we have adopted the following strategies:

Carry the line through the backwaters, paddy field and by the side of canals on viaducts with appropriate engineering solutions for stabilizing and strengthening the foundations of the viaducts. The line will pass through a total length of 88 km through cultivated land (paddy fields). About 44 km of the line will be in low lying regions and rivers and 1.050 km along canals. It is estimated that saving of cost of land, will be more than covering the cost of engineering solutions to the problem of low bearing capacity in these regions. If the alignment is shifted to be placed on a higher ground, which parts are thickly populated and dislocation and cost of land would multiply.

It is better to carry the alignment along the existing railway track where there is less population along the track. Because, 11% of the alignment is on viaduct, most of the highways and important roads will be carried under the track. It will be possible to provide full height (5.5m clear passage) crossings for most of the roads at the embankments also. At the minor roads and streets, low height (3.6m clearance) subways are proposed. The road crossings will be provided in such a manner that there is a full height road crossing at every five kilometers. About 718 road-over bridges/road under bridges shall be provided to meet this criterion.

Because there are only 4 tunnel of 2.43 km in total on the alignment, roads will be built along almost the entire alignment for carrying out construction activities. After construction is completed, maintenance of the roads may be given to the local government so that the roads can be used as public roads.

As per the alignment proposed in the study, out of the total corridor length of 531.45 km, the approximate alignment length in each category of land are given below:

- Wet land and land interior with no road (88 Kms)
- Dry land with road connectivity (60 Kms),
- small town land (50 Kms)
- Mid and large town land (40 Kms)
- City center land (3 Kms at Kochi)
- Government land (40 Kms)
- Railway Land (60 Kms).
- Balance rural area(190Km)

The above shows that the alignment goes through low cost land in about 378 Kms (wet land + government land + Railway land +Rural area) out of 531.45Km which constitute 71% of the alignment. Added to this is the fact that about 4.16 Kms is also expected to go over the backwaters and rivers, and by the side of water channel and poramboku land, which shall not incur any land acquisition costs.

Total requirement of land is estimated to be 1226.45 Ha as under:

- Private land: 1074.19 Ha
- Government land: 107.98 Ha
- Railway land along the existing line: 44.28Ha

1.6 TRACK, VIADUCTS/BRIDGES, TUNNELS AND EMBANKMENT/CUTTINGS:

The alignment has been prepared keeping in focus all the basic technical requirements for a SHSR line with techno and economic considerations. To cut down land requirement as much as possible, cause less dislocation for the population in congested areas, cause least hindrance to the movement of people and vehicles on the roads, highways and streets, boats and ferries in the canals and backwaters, it has been preferred we have adopted the following strategies;

- Viaduct preferably less than 20 m
- Bank height not to be more than 6 m in normal case
- Cutting depth up to 8 m normally
- Cut and cover has been considered for depth exceeding 8m and tunnel if the depth is more than 16 m and have adequate cover of 6 m.
- Proposed formation level kept at least 1m above the HFL

The ground stabilization techniques will have to be explored during execution of the project to overcome the problem of low bearing capacity. Internationally, hollow cylindrical friction piles of large diameters (1.6 to 2.0 m) have been extensively used to cross large stretches of marshy ground on viaducts/bridges. In south-east Asia where similar ground conditions have been encountered in construction of railway lines and buildings, piled mat foundations have been used in low bearing capacity ground.

For laying a railway line for 200 kmph train operation, the geometrical tolerances of railway tracks are quite stringent compared to normal mixed traffic lines for 100 to 160 kmph. So, the performance standards for the settlement of embankments, formation in cuttings, and foundations of viaducts and bridges are also very stringent for such semi high-speed lines. Because of the stringent requirement of total settlement and relative settlement of the ground for high speed lines, the issue of stability of the line has to be critically examined. For viaducts, the main challenge shall be regarding the lateral bearing capacity of the soil/rocks around the pile foundations where the line will be passing through the wetlands. In some stretches it may be enough to increase the depth of the piles.

Another important aspect is railway embankment and cutting designs suitable for high speed. During execution stage it is proposed to be looked into critically and designed by DDC. Cuttings are likely to be in soft soils and soft rocks, the ground at the base of the cuttings shall also require detailed design of the ground during execution stage.

Ballasted track is considered except for tunnels which will be reviewed during execution stage. Typical cross section for viaducts and embankments for different heights and ground conditions are given in this report. The structures have been designed for ROW of about 20 m embankments, 25m cuttings and 15 m for viaducts.

Access road running along the line will be required during construction and later for operations, including rescue and relief in accidents, and maintenance of the line. So a road of minimum width of 5.5m is proposed.

1.7 Rolling Stock & Depot:

Rolling Stock is an important asset and proper planning is required in selecting its right type and design. There are a variety of semi-high speed and high-speed rolling stock series in the world, because specifications of rolling stock have been dependent on not only technological factors but also the geographical conditions of where this train is operated. EMU (Electric Multiple Unit) trains are recommended for using in Thiruvananthapuram- Kasaragod Corridor because of the inherent advantages like the better operating parameters and travel time, faster acceleration and deceleration, better adhesion, reduced axle load, more suited for regenerative braking, higher Energy Efficiency etc. In addition, it will enable full use of the floor area of a train for passengers, and thus increase the transportation efficiency. This also has the effect of minimizing the design load for construction if EMU for SHSR are chosen. Moreover, this choice would allow a cost reduction.

The proposed train set is a 9 (nine) car train, which consists of six motor cars and three trailer cars, designed considering technical features of rolling stock of Thiruvananthapuram- Kasaragod Corridor and to provide adequate frequency of train operations. Train length is to be increased up to 12/15 cars from the year 2028 onwards to meet the PHPDT demand by augmentation of suitable multiples of additional motor cars and trailer cars. Approximate Passenger capacity of around 675 for 9-car train length has been considered. Space must be earmarked for service area, pantry, luggage, toilets etc. in each car, thereby reduction in paid area per car. Also, with multiple classes of travel being offered in the train services, the total passenger capacity gets limited because of 2+2 seat/3+2 seat and 3+3 seat combinations. Also, total available capacity is not always fully utilized on account of passenger load factor. Exact passenger capacity can be worked out during detailed design of floor layout at the time of DPR and detail design.

Rolling stock technical data and operating parameters

Track Gauge	:	1435 mm
Type of Train	:	EMU train set
Maximum speed	:	200 kmph
Numbers of cars per train	:	9 extendable to 12/15 in future
Car body width	:	3.4m (maximum)
Car body material	:	Aluminium
Power System	:	2 x 25 kV AC
Braking system	:	Regenerative brake, Electric/ Pneumatic brake blending
Emergency braking distance	:	<1800m
Traction circuit and configuration	:	VVVF inverter control using IGBT and asynchronous traction motor
Seating arrangement	:	2+2 Business class 3+2 Standard class 3+3 low fare and short distances

DEPOTS:

Rolling stock depot is an important infrastructure to be designed for proper maintenance of rolling stock. It consists of fully equipped workshop, sick lines and inspection lines for proper maintenance and stabling lines for proper storage to cater the following:

- Workshop - to perform overhauling and major maintenance schedules involving lifting
- Inspections - Scheduled inspections
- Storage of trains - Stabling lines

For efficient traffic control, car depots are set up near terminal stations i.e. Thiruvanthapuram and Kasaragod. Inspection lines has been planned at both the terminal stations i.e. Thiruvanthapuram and Kasaragod and workshop lines has been planned at Thiruvananthapuram only. Based on the maintenance flow and size of the maintenance facilities, the workshop will be designed to carry out the demanded maintenance level. Table shows the functions and roles of the various depots in this plan.

Table 3: Function and Inspection Classification

Station	Function		Inspection Classification			
	Depot	Workshop	General Inspection	Bogie Inspection	Daily and Regular inspection	Unscheduled maintenance
Trivandrum Depot and workshop	•	•	•	•	•	•
Kasaragod Depot	•				•	•

Hence it is recommended to plan the following.

- One Depot cum Major Workshop at Thiruvananthapuram.
- One Depot at Kasaragod (for inspections)
- Stabling Lines
    - Mostly at Kasaragod
    - Minimum number at Thiruvananthapuram to minimize the space requirement at Thiruvananthapuram
    - Few lines at Cochin and Thrissur, which will facilitate train operation in case of phased completion project and skewed train operation as a regular measure in Thiruvananthapuram - Cochin section

1.8 POWER SUPPLY AND TRACTION:

Un-interrupted electric power supply is essential for a Semi High Speed Rail system for running trains, Operation Control Centre, tunnel ventilation, station services (lighting, air-conditioning, firefighting and alarm system, lifts and escalators, Signalling and Telecommunications, Depot services (Inspection Shed, Workshop and Pit, wheel lathe etc.) and other maintenance infrastructure. EHV supply at the voltage level of 220/110 kV must be obtained from the Kerala State Electricity Board ltd (KSEBL) to the various Receiving/Traction Substations for train operation and a 33kV/ 11kV supply to be obtained from KSEBL, for the operation of auxiliary systems at Stations and Depot.

The power supply and OHE is designed to cater the speed of 250 kmph of train services. Traction power supply is proposed to derive from dedicated double circuit transmission line 220 kV /110 kV of state electricity board. The feeding system will be single phase AC 50 Hz, 2x25 kV with Auto transformer (AT) feeding system to suit the semi high-speed train operation. The Over Head Equipment (OHE) is of simple catenary type, regulated suitable for the speed of 250 kmph.

The spacing of traction sub stations (TSS) will be approximately 70-80 km. The distance between traction substation (TSS) and Sectioning and paralleling post (SP) will be approximately 30 - 40 km and Sub

sectioning and paralleling post (SSP) will be placed between SP and TSS. Auto transformer feeding at regular intervals will be provided.
The tentative power requirement and energy consumption for traction and auxiliary based on peak hour demand is estimated and given in Table- 4

Table 4: tentative power requirement and energy consumption for traction and auxiliary

Year	2024	2030	2040	2051
Power Demand (MVA)	85	100	140	175
Energy consumption (million units)	277	342	436	517

It is also proposed to meet the power requirement from the renewable energy sources (Solar and Wind) to the maximum extent.

Solar Power Generation

Solar energy is the best form of sustainable energy. Solar electricity or photo voltaic (PV) technology converts sunlight directly into electricity. It is recommended to have the following provisions for the generation/purchase of solar energy

- Provision of fixing Solar panels on the roof top of the buildings (roof top of all station building, depot building, Traction substation, Viaduct etc).
- Provision of Ground mounted solar system, where free land is available for a longer period.
- Provision of Solar plants in intra state/ interstate.
- It is proposed to use solar energy to use maximum extent while thriving for 100% from solar energy.

1.9 Signalling & Train Control System:

The Signalling and Train Control System shall provide the highest security level for means of an efficient Train Control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.

ERTMS (European Railway Traffic Management System) Level-2 is the most performant train control system in the world and brings significant advantages in terms of maintenance costs savings, safety, reliability, punctuality and traffic capacity.

The present feasibility study provides the main design of Signalling and Train Control system for operation of the line with design speed 250 Kmph and associated sub system like Communication, Power supply, Surveillance system for monitoring and safety etc. in order to comply the requirements of the such Semi high-speed rail corridor, the proven system ERTMS Level -2 with GSM-R. LTE system can be considered if the system is matured at the time of executing the project and if cost arrives less than GSM-R system.

The Signalling & Train Control (ERTMS level-2) description for a Semi High-Speed rail corridor requires the following main sub-system:

- ETCS level-2 System
- GSM-R /LTE System
- Interlocking System (EI/CBI) suitable for ETCS Level-2 and GSM-R/LTE system
- Electric Point Machine
- Automatic Train Supervision (ATS)
- Track Vacancy Detection system (Axle counter)

- Operation Control Centre (OCC) with backup BCC
- Fall-Back Block System
- Tunnel Alarm and other Safety System

1.10 Communication System:

The communication system is backbone for Signalling & Train Control system, SCADA system, Automatic Ticketing system, Safety & Security system etc. and provide communication service for information to Passenger, Administrative management, Operation & maintenance, Emergency control etc. requirements of high-speed train network. The Communication facilities proposed are helpful in meeting the requirements for following:

- Supplementing the Signalling system for efficient train operation.
- Exchange of managerial information
- Crisis management during emergencies
- Passenger information system

The Communication system for a Semi High-Speed rail corridor requires the following sub-systems:

- GSM-R/LTE System with Radio System and Trainborne equipments
- Backbone Transmission Network (with SDH & GbEN)
- Telephone system (IP PBX exchange system)
- Centralised Digital Recording System (CDRS)
- Passenger Address System (PAS)
- Passenger Information and Display System (PIDS)
- Time Distribution System with GPS system
- Closed Circuit Television System (CCTV)
- Facility -Supervisory Control and Data Acquisition (F-SCADA)

1.11 Ticketing & fare collection System:

Semi High-Speed railways are expected to be used more often by people who try to use their time effectively than in the existing railways where much time is taken for travel. Such business people tend to use the online system for reservation, rather than waiting in line at ticket windows, so a need for internet reservation is probably higher for high speed railways than for existing railways.

Semi High-Speed Railway Transportation system is expected to handle a large volume of passengers. The ticketing System shall provide world class ticketing facility to the passenger. The ticketing system shall be computerized system for effective management of the process of reservation, ticket issue and inspection with a view of improving the convenience of users.

The ticketing and fare collection system of Semi High-Speed Rail corridor requires the following sub-systems:

- Centralized Computer Ticketing System
- Station Computer System
- Cash Handling equipment's
- Automatic Gate with card reader
- Ticket Vending Machine (TVM)

- Ticket office Machine (TOM)
- Mobile Ticket Machine
- Portable Processing unit (PPU)
- Mobile ticketing (Scanner & Printer)

1.12 TRAIN OPERATION PLAN

A train service plan or operation plan has been prepared for the SHSR, which includes proposed service types, service frequency distribution, rolling stock requirement, kilometre running of rolling stock for train services. The key information is summarized in following subsections.

1.12.1 SERVICE PLAN

The SHSR System ridership estimates are used in developing the operations and service plans to provide the minimum level of service as 1 hour or lower to satisfy the ridership estimates except in Kannur-Kasaragod section where 1.5 hour peak headway is considered sufficient. Ridership demand is assumed to reach peak levels during a three-hour period in the morning and again in the afternoon. Train service density would be greatest during these periods, reverting to a slightly lower level of service during the remainder of the day.

Trains would run in diverse patterns between various terminals. The basic service types are envisioned:

- Limited-stop trains, which would skip selected stops along a route to provide faster service between stations.
- Frequent-stop trains, which would focus on regional service.
- Aggregator services which may have additional intermediate temporary stops between two SHSR stations to facilitate more and more people to access the service and avail high speed service from SHSR stations. Its implementation needs to be further examined and refined at DPR stage.
- RORO service for Truck/ heavy vehicles/ light vehicles to utilize infrastructure to the maximum.
- Tourist Circuit trains for tourists.

Most of the passenger trains would provide limited-stop services and offer a relatively fast run time along with connectivity among various intermediate stations. Multiple limited-stop patterns would be provided, to achieve a balanced level of service at the intermediate stations. The service plan envisions atleast one limited stop train per hour in each direction, all day long throughout the line. However, in main high demand section between Thiruvananthapuram and Kozhikode, passenger service will be available at 30 minutes initially and lower frequency in later years of the project life.

These service plans provide a useful initial estimate of the level of service that matches projected long-range demand on the SHSR System. As the System is implemented and both the operating plan and the ridership estimates are refined, it will be possible to make informed benefit and cost trade-offs to develop the most appropriate mix of limited and all-stop services, which will affect the trip times between stations and the frequency of service offered at each station for each route.

The estimated traffic figures do not include the commuter passenger count. Therefore, the requirement of trains is considered only for long distance journey passengers based on seating capacity of the trains which is considered approximately 75 seats per car. However, additional capacity is provided in the form of trains for aggregator service which can also account for commuters.

Aggregate Services

To provide the connectivity to SHSR, for the commuters located away from the stations, Aggregate services are proposed. Rolling Stock required for aggregate services shall be of same design of SHSR Rolling Stock with reduced passenger capacity. Other infrastructures required to facilitate the aggregate services shall be provided such as additional stations and platforms in the appropriate location along the SHSR alignment. Aggregate Services shall be operated with proper timetable in such a way that it will not impact the run time of SHSR normal operation.

RORO Services

Roll On Roll Out services are proposed on the same track of SHSR for transporting conventional good vehicles such trucks, lorries etc. Electric locomotives with special types of wagons shall be used to transport the Trucks and associated infrastructures also required to provide along the alignment for loading and unloading the trucks. It will lead to fast transport of the goods in the Thiruvananthapuram-Kasargod corridor duly reducing the road travel, pollution and road congestion. This will also facilitate better utilization of SHSR infrastructure.

Last Mile Connectivity

Moving forward most of the last mile connectivity could be through electric vehicles. To promote the green vehicle, adequate facilities, including charging and parking facilities for the electric vehicles, will be included in the SHSR terminal design. The provision of park and ride facility at the terminal is an essential element in increasing the patronage so that they could have a comfortable last mile connectivity to their home/ work center.

In addition to above mentioned facilities, the interconnection with other mode of transport such as airport, conventional railways, bus stands and major industrial hubs will improve the last mile connectivity considerably.

1.12.2 COACH CAPACITY

The capacity calculations are based on proposed rolling stock specification which proposes approximate 75 passengers per, on an average. Thus a 9-car train has estimated seats for 675 passengers and a 12-car train has seating capacity of 900 passenger.

1.12.3 SERVICE FREQUENCY

The demand can be met in the years 2024 and 2028 by running 9 car trains and in years 2040 and 2051 by 12 car trains. The maximum time interval between train (i.e. maximum headway) will be 60 minutes or lower, except in Kannur-Kasaragod section where it may go up to 2 hours. The peak hour frequency will be 2 tph in 2024 and more than 2 tph in 2030 with 9 car trains and more than 2 trains per hour in 2040 and 3 trains per hour in 2051 with 12 coach train.

Table 5: Horizon Year 2024-2051 Minimum Service Frequency/ Maximum Headways

Service		2024	2028	2040	2051
Train Consist		9-Car	9-Car	12-Car	12-Car
Peak/ Off-peak Hour Headway (min.)	Trivandrum-Kozhikode	22.5/40	18/30	16/27	13/21
	Kozhikode- Kannur	36/60	28/46	28/46	23/38
	Kannur- Kasaragod	90/120	90/120	90/120	90/120

1.12.4 ROLLING STOCK REQUIREMENT

The Rolling Stock requirement estimated for years 2024 to 2051 is indicated in following table:

Table 6: Horizon Year 2024-2051 Service Plan Revenue Rake requirement

Requirement	2024	2028	2040	2051
Train Consist	9-Car	9-Car	12-Car	12-Car
Bare Minimum Trains	21	26	28	35
Maintenance Reserve	2	3	3	4
Operation reserve	1	1	1	1
Bare Minimum Cars required	189	234	336	420
Total Cars required	216	270	384	480

1.12.5 VEHICLE RUNNING KM

The Rolling Stock train kilometres estimated for years 2024 to 2051 are indicated in following table. The estimate assumes uniform daily service throughout the year.

Table 7: Horizon Year 2024-2051 Service Plan Revenue Train Sets Required at Each Terminal to Start Weekday Morning Train Service

Section	2024			2028			2040			2051		
	No. of Trips	Daily Train KM (x10 3)	Daily Car KM (x10 6)	No. of Trips	Daily Train KM (x10 3)	Daily Car KM (x10 6)	No. of Trips	Daily Train KM (x10 3)	Daily Car KM (x10 6)	No. of Trips	Daily Train KM (x10 3)	Daily Car KM (x10 6)
Trivandrum -Kozhikode	28	10.0	0.12	34	12.2	0.15	40	14.3	0.17	50.0	17.9	0.21
Trivandrum -Kannur	24	10.8	0.13	36	16.1	0.19	36	16.1	0.19	52.0	23.3	0.28
Trivandrum -Kasaragod	20	10.6	0.10	20	10.6	0.10	20	10.6	0.10	20.0	10.6	0.10
Total/ year	26280	11450	125.78	32850	14195	158.7	35040	14978	168.1	44530	18900	215.2

1.12.6 DEPOT AND STABLING REQUIREMENT

Following table provides proposed stabling facilities at stations and Depots.

Table 8: Storage/ Layup Track (Sidings) Requirements at stations

Location	Number of tracks (15-car storage)
Trivandrum	4 nos.
Kochi	2 nos.
Thrissur	4 nos.
Tirur	2 nos.
Kozhikode	2 nos.
Kasaragod	4 nos.

Table 9: Storage/ Layup Track (Sidings) Requirements at Depots

Location	Number of tracks (15-car storage)		
	Stabling	Inspection	workshop
Trivandrum Depot	10 nos.	4 nos.	6 nos.
Kasaragod Depot	15 nos.	4 nos.	0 nos.

1.12.7 MAINTENANCE PLAN:

A broad plan for maintenance of the SHSR assets has been proposed as below:
There will be a maintenance organization set up which will be responsible for the repair and maintenance of all assets of the SHSR. The organization will consist of engineers, skilled staff and managerial personnel. Some unskilled staff will also be there for manual labour intensive work.

Maintenance of different assets will be done on a preventive maintenance principle which includes direct maintenance. This means that the condition of assets will be monitored intensively through periodic inspections, onboard computerized monitoring systems and from feedback of operating staff like train operators, station staff etc. This requires a high degree of computerization on the SHSR where asset condition data will be continuously fed into the computer and reports generated will be available to all maintenance staff. Computerized Maintenance Management Systems (MMS) are now available or can be developed for the SHSR.

For track maintenance the basic approach for high speed rail system is that track should be built to such standards as to require less frequent maintenance. For example tamping of track is normally done once in four to six years. Rail fractures are rare. Methodologies for predicting the rate of deterioration have been developed by SHSR systems worldwide. Based on these existing methodologies and computer programs a system shall be developed for this line before start of train operations on the line.

For track maintenance an important part will be removal of long wavelength defects in track once in 3 to 5 years depending on the rate of deterioration of track geometry in a section. Regular measurements of track geometry by Track Recording Cars, and cracks in rail by USFD Rail Testing Cars shall be the main basis for planned track maintenance activities. A comprehensive Track Management System suitable for the needs of SHSR shall have to be developed before construction of the line is completed. Important capabilities and a system architecture for the TMS shall have to be identified at the DPR stage. Planning for other aspects of track maintenance shall have to be identified at the DPR stage.

At the DPR stage, a comprehensive outline for the various requirements of maintenance of the SHSR track considering the local needs on this line should be prepared.

Minor attention to lineside and station equipment will be done at site during night or off-peak service hours. For any major repairs or scheduled maintenance, the item will be brought to the maintenance depot. For attention to fixed assets, this work will be done during non-train operating hours or by taking a block.

An integrated maintenance depot will be set up at Thiruvananthapuram to undertake maintenance of Rolling Stock as well as S&T, Electrical and Civil engineering equipment. A sub depot at Kasaragod will also be set up, mainly for stabling trains but also for carrying out petty repairs or emergency repairs.
All departments must coordinate their working during traffic block hours so that the possession is effectively utilized.

All crucial safety related maintenance work must be done in house with trained staff of the SHSR. Some non-core activities like building maintenance, electric substation maintenance, road transport, housekeeping work etc. can be outsourced to private parties.

Maintenance of certain assets like the signalling system, rolling stock etc can be given to the supplier of the system, but this must be covered by strict contractual obligations and responsibilities in case of accidents.

Annual maintenance contract must be given for sophisticated sub systems like computer network, S&T equipment modules, POH of track machines and locomotives etc. The work done by the private parties must be strictly monitored by the SHSR staff.
Renewal of assets must be done after their economic life is over. The time of renewal will depend on the condition, the stated life of the asset as per the manufacturer, intensity of use etc.

1.12.8 SAFETY MANAGEMENT IN SHSR:

Key Safety Measures

Key safety measures necessary for SHSR are listed hereunder for implementation:

- Prevention of derailment and collision between trains
- Prevention of the invasion of obstacles
- Segregation of operation and maintenance work hours, and adequate blocks for planned maintenance of track, OHE etc
- Prevention of accidents on platforms
- Rescue Operation provisions

Prevention and Mitigation of Disasters:

The SHSR is envisioned as Safe and reliable transport system to transform lives of its beneficiaries. However, given the natural ground conditions along the corridor between Thiruvananthapuram to Kasaragod which include unfavourable soil condition, sea-shore related risks, high temperature, heavy rains in the monsoon and uneven terrain, it requires robust foundations and special structures. In structure designing, it is important not to guarantee stability of track even in the monsoon season. To protect the line infrastructure and trains and minimize loss of life and property due to the natural disasters, a disaster prevention system to automatically collect disaster prevention data is recommended. To augment safety against high winds and flooding of the rivers and backwaters in the rainy season a network of automatic rainfall and wind monitoring system shall be provided. Automatic river water level recording system shall also be provided. Accumulated rainfall will be monitored by a precipitation gauge installed in each demarcated section of the line. When a threshold value is crossed train operations will be restricted or stopped. High winds are unlikely to require any imposition of speed restrictions. Feasibility of a more extensive and sophisticated wind speed monitoring system may be examined in detail at the DPR stage.

1.12.9 SAFETY MANAGEMENT:

Safety management in SHSR is proposed in the report which highlights the basic concept applicable for such railways, safety measures to be adopted, disaster management and general considerations for safety in SHSR. Development of an effective and efficient safety mechanism to ensure safety without compromising efficiency and effective service is critical for success of a SHSR system. It is broadly based on following concept:

- Selection of facilities and rolling stock to cope with high-speed operation and establish a comprehensively harmonized modern mechanism.
- Elimination or minimization of the human intervention on safety critical elements by technological means or fool-proofing.
- Adoption of highly redundant systems for important safety equipment/ facilities to improve reliability and ensure fail-safe principle is applied comprehensively and followed strictly.
- Take measures to avoid the effect of windstorms, floods, earthquakes and other damages caused by natural phenomena as far as possible. An appropriate system for monitoring rainfall, river water level and wind speeds shall be developed and installed before operations are begun.
- Minimising rail fractures in the track by effective rail flaw detection
- Introduce equipment/facilities to minimize accidents due to obstacles falling on track (e.g. automobiles) and other troubles and institute legal/regulatory measures against deeds to compromise the safety of train operation.

1.13 ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT:

Transport systems bring enormous benefits to society providing access and mobility that are essential for modern societies and economic growth. However, transport activities have many undesirable external impacts as well, such as CO_2 emissions, congestion, accidents, land use and many more. The urge to fight these challenges is therefore pushing economies towards more efficient, and sustainable solutions. Rail, and particularly Semi High-Speed Rail (SHSR), is an important means for meeting these challenges and contribute to sustainable mobility development.

Semi High-Speed Rail offers tangible advantages over other transport modes such as air, conventional rail and private vehicles for medium to long distance journeys. Considering the evaluation of complete life cycle of transportation systems in terms of sustainability, SHSR is one of the most efficient mode of transport. At the same time it combines many of the attributes that we most desire while travelling such as speed, reliability, comfort and safety.

By not only encouraging a shift from traditional road transport for lengthy journeys in either cars or coaches, SHSR is contributing to congestion reduction and its associated pollution. By providing a suitable alternative for traditional transport modes of travel, which is greener and more energy efficient, it is contributing to the transport industries' need to reduce Greenhouse gas (GHG) emissions.

The Semi High-Speed Rail corridor will start reducing emissions from 2024 onwards after its commissioning, the first year of operation, as passengers switch over from conventional rail, cars and buses to SHSR. The annual GHG emission reductions forecasted for the horizon years 2024, 2028, 2040, and 2051 are presented in Table below. GHG savings are worked out as per the projected ridership. GHG savings are directly related to ridership. Higher the ridership, greater the GHG emission savings.

Table 10 : GHG Emission Reduction

Horizon Year	Greenhouse Gas Reduction (Tonnes CO_2e/Year)
2024	213897
2028	237664
2040	293175
2051	381898

The SHSR line has the potential to greatly improve transportation and benefit the economy and social life of the people of Kerala. The environmental and social assessment ascertains that the Project is unlikely to cause any significant environmental and social impacts. The SHSR is committed to employ 'Best Practice' for the management of environment and social effects of the project.

Environmental and social impact assessment in detail is described in chapter no. 11 of this report.

Greenfield Project

Proposed Semi High-Speed project will be a Greenfield Project during the Project Construction Phase as well as Operation Phase. The impact of the SHSR project on Environment will be negligible by using advance technologies available worldwide during construction and operation phases. With the help of advance technologies, the effect of pollution, noise & vibration, seismicity will be reduced significantly. Some of the important effects on Environment is listed below which helps in achieving 100% Greenfield project.

- The project will create many employment opportunities which are a benefit both in economic and social sense.
- The construction workers required for the project will provide ready market for various goods and services, leading to several business opportunities for small-scale traders
- This project will require large quantities of construction materials, which will increase revenue for local businesses
- Compared to other mode of transport, SHSR requires less land. In addition to this, feasibility study ensures specific protection measures for the environmental sensitive areas such as viaduct, bridges etc.

- Improved transport efficiency
- Improved socio-economic condition
- Reduced congestion and reduced accidents
- Reduction in Environment pollution such as air pollution, noise pollution etc.
- Reduced Greenhouse emission and improved Carbon Credits
- Appropriate compensatory plantation using suitable native species or pollution tolerant species will be initiated

1.14 Detailed Project Cost Estimates

1.14.1 Capital Cost

The cost estimate has been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, environmental protection, rehabilitation, etc. at May, 2019 price level. In order to arrive at realistic cost of various items, costs of the project have been derived from similar executed project in similar scenario.

The proposed corridor of Semi high speed rail corridor between Thiruvananthapuram and Kasaragod would be constructed at an approximate cost of 56,442.85 Crore at FY 19 prices. This includes all central and state taxes. However, this cost is exclusive of ESMP, Design, PMC & Contingency fee. The total cost of land acquisition works out to 11407.5 Crores. However, a Joint Development agreement (JDA) is proposed with the land owners due to which the upfront cash out for land works out to 6844 Crores. With JDA, the total project cost works out to be 55765 Crore (inclusive of Taxes, ESMP, Design, PMC & Contingency fee) at FY 2019 prices (refer Table 11A). The total cost of EIA and R &R works out to 1811 crores at FY 19 price levels. The total completion cost (escalated) is 66079 Crores with the completion period of 5 years (i.e. FY 2024).

Table 11 : Abstract Of Cost Estimate

S. NO	Item	Amount (in Cr)
1	Land	
1.1	Private land	
	Wet land/ no road	4,933.87
	Dry land	2,260.35
	Small town	1,130.17
	Mid - Large town	692.69
	Bridges, Backwaters and Poramboke	0.00
1.2	Government land	100.26
1.3	Railway land	295.30
1.4	Station land	1,250.22
1.5	workshops & depots	744.63
		11,407.49
1.6	Cost of land for Rehabilitation (to be identified)	1,711.12
		13,118.61

S. NO	Item	Amount (in Cr)
2	Alignment and Formation	
2.1	Tunnelling: Cut and cover	
	Upto 17m depth normal/weak ground	881.88
	Upto 17m depth strong ground	1,555.48
	Tunnelling: TBM method	486.00
2.2	Viaduct	
	8 m high viaduct	781.95
	10 m high viaduct	1,893.44
	15 m high viaduct	988.25
	20 m high viaduct	1,125.76
2.3	Embankment	
2.3 a	On all terrain (2 m high)	143.99
	On all terrain (2 m high) sand column	80.94
	On all terrain (2 m high) stone column	147.68
	On all terrain (2.5 m high)	190.34
	On all terrain (2.5 m high) sand column	97.07
	On all terrain (2.5 m high) stone column	140.27
	On all terrain (3.6 m high)	706.55
	On all terrain (3.6 m high) sand column	280.30
	On all terrain (3.6 m high) stone column	361.84
	On all terrain (6 m high)	1,803.05
	On all terrain (6 m high) sand column	903.89
	On all terrain (6 m high) stone column	1,175.35
2.3 b	Cutting in all soils 2 m	166.79
	Cutting in all soils 4 m	189.80
	Cutting in all soils 5.2 m	495.47
	Cutting in all soils 8 m	505.89
2.4	Bridges	727.23
2.5	ROBs (mostly in cuttings one span)	5,744.00
		21,573.22
3	Stations	

S. NO	Item	Amount (in Cr)
3.1	Type A 12 m wide platform at ground (incl lifts and escalators)	351.34
	Type A 12 m wide platform elevated(incl lifts and escalators)	106.05
	Type B 10 m wide platform at ground (incl lifts and escalators)	193.26
	Type B 10 m wide platform elevated (incl lifts and escalators)	100.12
3.2	OCC and administrative bldg	100.00
3.3	ASS and MEP arrangements	50.00
		900.77
4	All Depots & miscellaneous	
4.1	Depot at Kochuveli (Thiruvananthapuram) including work shop and siding track and other infra, MEP and ASS	200.00
4.2	Depot at Kasargod including work shop, system and siding track and other infra, MEP and ASS	200.00
4.3	Track recording car, USFD rail testing car, Rail grinding machine, Cantenary installation car etc	125.00
4.4	Accident relief Train and other equipments	175.00
4.5	Track machines & track depot including sidings	200.00
4.6	safety & rescue and relief in tunnels and viaducts, including tunnel ventilation	135.00
4.7	Automatic River water level monitoring system, rain fall monitoring system and wind speed monitoring system	25.00
4.8	Track machine and track depots	50.00
		1,110.00
5	Permanent way	
5.1	Ballasted track for embankments, viaduct and yards	4,453.56
5.2	Ballastless track	463.00
		4,916.56
6	Traction and power supply incl. OHE , ASS etc	
6.1	Elevated Section/ At Grade Section	1,834.00
6.2	Underground Section – Tunnel	16.00
6.3	Depot – OHE	60.00
6.4	RSS/ TSS (including Cabling Extra High Tension from source to RSS)	480.00
		2,390.00
7	Signalling , communication and Ticketing	

S. NO	Item	Amount (in Cr)
7.1	Signalling- GSM-R / LTE & Main line incl. OCC/BCC including Station and Depot including safety equipment	1,789.92
7.2	On Board Equipment	25.00
7.3	Communication - Main Line, Station and Depot	359.04
7.4	Ticketing & Fare collection	80.00
7.5	Other safety equipment	10.00
		2,263.96
8	Rolling Stock & RORO Civil Cost	
8.1	Rolling stock (SG) – Passenger	3,510.00
8.2	Rolling Stock – RORO	420.00
8.3	RORO - including parking for 40 trucks and ramp and ancillary facilities	600.00
		4,530.00
9	Staff quarters and Barracks	
9.1	Staff quarters for O&M	50.00
		50.00
10	Others	
10.1	Shifting of Utilities	333.50
10.2	Multi modal Integration	45.00
10.3	Security	7.50
		386.00
11	Training Facilities & Machine in training centre including Overseas training	75.00
		75.00
12	Total for all items except land	38,195.51
13	Land	13,118.61
14	Taxes	5,128.73
	Total capital cost	**56,442.85**

Table 11 A: Cost Breakup for JDA provision

Total Project Cost including Land cost, taxes & duties at FY 2019 price (as shown in Table 11)	56,442.85 Crore
Land Cost	11,407.5 Crore
60% of Land Cost due to JDA	6,844.5 Crore
Total Project Cost with 60% Land cost, taxes & duties at FY 2019 price	51,879.9 Crore
(ESMP + DPR + PMC + Contingency) Cost including Taxes	3,885.1 Crore
Total Project Cost (with JDA provision)	**55,765 Crore**

1.15 FINANCIAL ANALYSIS

The project is proposed to have a construction period of 4 years. Although construction is expected to get over by March 2024, the cash flow will spill over to March 2025:

Table 12 : Expenditure Phasing

Phasing Assumptions for with taxes	Costs	FY 21	FY 22	FY 23	FY 24	FY 25 - Start of Phase 1
Land - Considering JDA and removing 40% of the cost	6844	50%	50%			
R&R and ESMP	1811	50%	50%			
Design	1019	50%	50%			
PMC	2216	5%	20%	35%	30%	10%
Contingency	1671			10%	40%	50%
Civil	37739	10%	30%	30%	20%	10%
Others	14779		20%	40%	30%	10%
TOTAL (Escalated)	66079	8359	18857	18102	13880	6880

The commercial operation would start from the FY 25. Escalation is considered as 5% p.a. from FY 19 onwards. The completed project cost (without IDC) is calculated as Rs. 66079 Crores.

1.15.1 FIRR Analysis

The Financial Internal rate of return has been calculated in two scenarios – With concession period of 30 years and concession period of 50 years. The financial internal rate of return at completion cost basis with farebox and non fare box revenue with additional revenue sources (Other Income) from improved FSI along the development corridor (TOD) and cess from stamp duty works out to 5.6 % with concession period of 30 years and 8.1 % concession period of 50 years. This is the project IRR without imposition of the capital structure.

1.15.2 Financial Plan

- Bi-lateral funded loan @ 1.4 % per annum

In this case, the Government of Kerala and Government of India are major contributors with cash equity contribution about 7720 Cr. each. Equity IRR works out to 8.9 % with concession period of 30 years and 11 % with concession period of 50 years.

Table 13 : Project Capital structure – SPV Mode loan @1.4%

Capital Structure (Cr.)		
Debt	**34454**	**52%**
IDC	**727**	**1%**
Equity		
Ministry of Railways	7720	12%
Government of Kerala	7720	12%
GoK - Land EIA and R&R	8656	13%
SubOrdinated Debt		
GoI	3564	5%
GoK	3564	5%
Total	**66405**	
Other Equity - Deferred Revenue (Real Estate for PD)	3485	

The phasing of the equity and term loan contributions are detailed as follows:

Table 14 : Phasing of equity and loan term – SPV Mode loan @1.4%

PARTICULARS	Year wise contribution					
	FY 21	FY 22	FY 23	FY 24	FY 25	TOTAL
State Government						
State Taxes (SGST)	474	1031	959	735	365	3564
Construction Cost	281	1844	2593	1974	1011	7703
Front End/ Commitment Fee	17.2				0	17
Sub Total (State Government)	772	2875	3552	2709	1376	11285
State Government						
Land, EIA and R&R	4328	4328	0	0	0	8656
Sub Total (GoK)	4328	4328	0	0	0	8656
Central Government						
Central Taxes (CGST)	474	1031	959	735	365	3564
Construction Cost	281	1844	2593	1974	1011	7703
Front End/ Commitment Fee	16.7				0	17
Sub Total (Central Government)	772	2875	3552	2709	1376	11284
JICA						
Construction Cost	2452	8812	11093	8694	4128	35181
Sub Total (JICA)	2452	8812	11093	8694	4128	35181
TOTAL	8324	18891	18197	14112	6880	66405
State Government						
Other Equity - Deferred Revenue (Real Estate for PD)					3485	3485

1.16 Economic Analysis

The economic appraisal has been carried out within the broad framework of Social Cost Benefit Analysis Technique. It is based on the incremental costs and benefits and involves comparison of project costs and benefits in economic terms under the "with" and "without" project scenario. The EIRR in economic terms works out to 16.08%. Sensitivity analysis of the EIRR with Capital cost increase by 20%, O&M costs increased by 20%, Target beneficiaries reduced by 20%, Delay in accrual of benefit by 1 year and Combined adverse condition has been carried out :

Table 15 : EIRR And Sensitivity Analysis

Details	EIRR (%)	ENPV @14% (Rs Million)	MIRR (%)	SV
Main Evaluation (Base Case)	16.08%	55,780	12.49%	
20% Capital Cost Overrun	13.22%	(25,078)	11.70%	13.8%
20% O&M Cost Overrun	15.73%	45,689	12.38%	110.6 %
20% Decrease in Project Benefits	12.23%	(46,325)	11.39%	10.9%
One Year Delay in Implementation	16.10%	49,383	12.50%	
All Four Tests Combined	9.52%	(1,20,053)	10.49%	

1.17 FINAL RECOMMENDATIONS

The following are the main findings of this feasibility study for the semi High-Speed Rail corridor from Thiruvananthapuram to Kasaragod:

- The unique terrain and landforms in the coastal region and the Mid-Highlands which lie between the Western Ghats in the east and the Arabian Sea in the west have resulted in a very dispersed population in these two landform regions of Kerala where about 90% of the state's population lives.
- The terrain and landforms of the region is also responsible for the slow speed of travel by surface transport (road and rail). The average speed of travel by road and rail is among the lowest of all regions of the country at about 30 to 40% lower than in the neighboring states.
- The total cost of project of 531.45 Km length is Rs 56,442.85 Crore including land cost and taxes. The project FIRR works out to be approx. 5.6% & 8.1% with the concession period of 30 years & 50 years respectively. The Equity IRR works out as 8.9% & 11% with the concession period of 30 years and 50 years respectively and Economic IRR works out to 16.08%.
- There is possibility of an important indirect benefit of building this SHS line in the state. Since the beginning of railways more than 150 years ago the railways have led to the growth of large cities and shift of rural population from villages to towns and cities and formation of the mega cities of today that are driving the economic growth of the countries. This trend continues today. This also raises the possibility that by providing faster and efficient inter-city travel, the SHR Line can lead to a gradual shift of population from the smaller cities and towns to the larger cities. This would result in more urban population in the larger cities of the state that is essential for higher economic growth in a modern economy.
- The SHSR line is expected to reduce journey time from Thiruvananthapuram to Kasaragod from 12 to 14 hours by road and rail to 3 hour 30 minutes to 4 hours depending on the type of service. The journey time may be further reduced when faster tilting trains are introduced in future.
- The line will reduce pollution on the roads, safety on roads would also improve with reduced congestion, and dependence on oil which is import dependent commodity would also reduce.
- For meeting the long-term transport needs of the state, construction of a SHSR line is expected to be a more practical, as it requires much less land acquisition and could be less costly to build than a six-lane segregated expressway
- The SHSR line is expected to boost tourism in the state by providing speedy comfortable daytime travel across the state which is full of tourist attractions like beaches, backwaters, and places of historical interest and religious importance.
- Planned urban development of the cities along the corridor, and development of new cities along the SHSR line can be used to drive benefits for the socio-economic development in the regions served by the line. Planned urban development can be in the form of vertical development in the central part of the city and other parts by providing shorter access time to the SHSR stations.

Based on the assumptions made in the report and the exhausted examination of technical feasibility of a semi High-Speed line from Thiruvananthapuram and Kasaragod**, it has been concluded that construction of the line is technically feasible and financially viable and it is recommended to construct the semi high speed corridor** to have higher mobility, meet the traffic growth and economic development of the State.

2. INTRODUCTION

2.1 Project Background

The Government of Kerala is in the process of constructing a Semi High Speed Railway Line between Thiruvananthapuram and Kasaragod and the mandate of conducting the technical study has been entrusted to Kerala Rail Development Corporation Limited (KRDCL), a Joint Venture Company between Government of Kerala and Ministry of Railways. KRDCL has in turn engaged the services of SYSTRA, a consulting and engineering firm which is a world leader in transport infrastructure, to prepare a Detailed Project Report for the project and this Feasibility report is the first deliverable leading to preparation of the Detailed Project Report.

2.2 Scope of work

Scope of the work is to carry out a feasibility mination of technical feasibility of a semi High-Speed line from Thiruvananthapuram and Kasaragod, it has been concluded that construction of the line is technically feasible and it is recommended to construct the semi high speed corridor to have higher mobility, meet the traffic growth and economic development of the state.

More detail on the traffic projection and field survey including detail discussion with the stake holders and urban planning experts to be undertaken during DPR stage. study for a Semi High speed Rail corridor between Thiruvananthapuram and Kasaragod leading to preparation of a Detailed Project Report. Based on the draft tentative alignment prepared during this report, the tentative length of the corridor is around 531 km. The study has been based on the data collected through the following primary surveys:

- Traffic Surveys
- Topographic Surveys and
- Geo-Technical Surveys

Figure 2: Kerala Rail Map

In addition to these surveys, secondary data shall be collected by the consultant from various agencies like the Client KRDCL, Ministry of Railways, other State Government departments and other stakeholder agencies. First a Feasibility Report shall be submitted, which once approved will be followed by a Detailed Project Report.

The figure above shows the existing Rail network in the state of Kerala. However, even with this Rail infrastructures in place, the Railway is not in position to introduce more trains, increase the average speed of the trains from the present (~ 60 Kmph) or increase the frequency of passenger trains mainly due to the following reasons.

2.2.1 High utilization of the existing Rail corridor

The table below shows the present utilization of the existing rail corridor between Thiruvananthapuram and Kasaragod. It indicates that the existing IR corridor already saturated.

Table 16 : Utilization of existing rail corridor between Thiruvananthapuram and Kasaragod

Section	Length (km)	Traction and system of working	Year	% utilization
TVC- SRR	327	Electric and absolute block system	2018	**113%** (ERS-KTYM_KYJ section
SRR- KGQ	294	Electric and absolute block system	2018	**80%** (SRR- CLT) section

Source: Working time table

2.2.2 Technical difficulties in removing the existing permanent speed restrictions

There are 111 permanent speed restrictions in the TVC – SRR (Shoranpur Jn.) section and 45 in the SRR – KGQ section. These are mostly on account of the existing sharp curves and steep gradients, weak embankments and deep cuttings. These cannot be removed without incurring heavy expenditure and in most of the cases are not practical to execute. Hence these permanent speed restrictions shall continue to exist and will not allow higher speed on the existing and new corridor, if planned parallel, to the existing railway corridor.

2.2.3 Inadequate platform and terminal facilities at Trivandrum yard

Thiruvananthapuram is the terminal station yard for both Mail/Express and passenger trains, being the State's capital city. As the existing platforms are fully occupied normally therefore there is a need of exclusive platforms if new trains are introduced. This has been brought out in the RRTS study conducted by MRVC. The adjacent line from the existing platform No's. 5 are the pit lines 6, 7, 8, 9 and 10. As the Trivandrum Yard is land locked between two main roads on either side, there is no scope for providing adequate new platforms/ pit lines. To ease this there was a proposal to move some of the train maintenance facilities to adjoining stations Kochuveli or Nemom. However, this has not happened till date. This is one of the key reasons why the SHSR will not get connected to Trivandrum yard.

Too many long-distance trains starting from Thiruvananthapuram capital city, which is at one end of the Rail corridor, especially at the peak morning and evening hours.

Thiruvananthapuram being the capital city requires trains to reach at peak hours in the morning and evening. Hence most of the mail/ express trains and passenger trains are planned to reach the city at these peak hours. This peak hour rush, coupled with the near saturation track utilization, makes it difficult for new trains to be introduced on the existing rail corridor.

2.2.4 RAIL BASED TRANSPORT SYSTEM FOR KERALA: High Speed Rail Corridor

Another Rail based transport system explored by the GOK was the high-Speed rail (HSR) corridor between Thiruvananthapuram and Kannur. The HSR DPR is often mentioned in discussion as there is a tendency by various stakeholders to compare the Semi High-Speed rail corridor with the High-Speed Rail corridor. Estimated Cost of the HSR line is given in the table below:

Table 17 : Cost details of High-speed Rail

Sl NO	Name of corridor	Distance in Km	Estimated cost without taxes (Rs / Crore)	Estimated cost with central taxes and land cost (Rs/Crore)	Estimated cost with all taxes, octroi, & land cost (Rs/ Crore)
1	Thiruvananthapuram to Kannur	430.00	77,361.00	86,735.00	90,663.00

Source: Executive summary of DMRC DPR for High speed rail, table 0.47 cost details

The high cost of High-speed rail is majorly attributed to: higher track design parameters like flat curves, grades, long tunnels (longest tunnel is about 20 km) and high viaducts and cuttings. Given the high cost, the state government decided to wind up the Kerala High Speed Rail Corporation ltd. So, the only rail based Intercity transport presently under consideration of the GOK is the SHSR line now under this study.

2.2.5 METHODOLOGY FOR THE STUDY TEAM:

The aim of the team is to design a techno-economic alignment based on the obligatory points provided by KRDCL. Because of the unique and very difficult terrain in the region. It was decided at the start of this study, that to assess technical feasibility and financial viability of the proposed line, it would be necessary to prepare an alignment after carefully examining all relevant factors related to terrain and landforms in addition to the essential requirements and parameters of a SHSR line

2.2.6 RAIL BASED TRANSPORT SYSTEM FOR KERALA: Benefits

The Rail based transportation system will have the following benefits for Kerala:

- Direct benefits like travel time savings, travel cost savings and environmental cost savings
- Indirect benefits of employment generations & reduction in accidents on road.
- Add to state revenues through likely increase in tourism.

Environmental cost saving is the benefit of environmental cost savings estimated from vehicle kilometres, quantity and unit cost of emission by air pollution and vehicle type. Indirect benefit includes generation of employment in different sectors like manufacturing, tourism and agriculture along the corridor.

2.2.7 RAIL BASED TRANSPORT SYSTEM FOR KERALA: Impacts

2.2.7.1 COMMERCE

The SEMI HIGH SPEED Rail (SHSR) corridor, by providing speedy and safe transport facilities shall enable many agriculturalists, industrialists, businessmen, professionals and all other workers to travel from Thiruvananthapuram and other cities faster along the corridor for their needs. The SHSR is also planned by the Client to ease the movement of merchandise and goods from the hinterlands of Kerala and other places of production, to the centres of consumption. Thus, SHSR has the potential to stimulate the agricultural and industrial growth and the internal and external trade of Kerala.

Government of Kerala (GOK) has identified the following land parcels* for infrastructural development like SMART cities and/or real estate development. The SHS rail corridor could provide the much-needed connectivity (subject to technical feasibility) for these potentials Infra/production centres. By providing the connectivity to these locations, the business entities and population can also be brought in as stakeholders to the project to share the overall cost of the project.

Table 18 : The details of land of the plantation corporation of Kerala Ltd *(The total area has not been surveyed)*

Sl No.	Estate	Area (H.a)	Districts	Remarks
1	Kodumon Group	2,866.6880	Pathanamthitta	Leased land from Forest Department
2	Kalady Group	3,776.4993	Ernakulam & Thrissur	Leased land from Forest Department
3	Thannithode	699.3500	Pathanamthitta	Leased land from Forest Department
4	Perambra	943.0000	Kozhikode	Leased land from Forest Department
5	Rajapuram	1,522.9100	Kasaragod	Leased land from Forest Department
6	Mannarghat	513.0300	Palakkad	Leased land from Forest Department
7	Nilambur	435.9380	Malappuram	Leased land from Forest Department
8	Cheemeni	1227.1100	Kasaragod & Kannur	Leased land from Revenue Department (125 H.a – Own Land)
9.	Kasaragod	2065.0000	Kasaragod	Own Land

Source: KRDCL

* Source : KRDCL

2.2.7.2 INDUSTRY

Kerala is not strong in the industrial sector and thus GOK can explore the possibility of manufacturing the Rolling stock and other parts of Rolling stock of SHSR, as part of the procurement agreement, in the Palakkad railway coach factory area announced in the 2008-09 Railway Budget. Wherein about 239 acres of land acquired by GOK, is lying vacant. Secondly, speedy rail network through SHSR may contribute to the growth of the Industry.

2.2.7.3 TOURISM

SHSR could bring in fundamental changes in the field of tourism in “GOD’s own country”. Tourism is today Kerala’s largest and fastest growing industry in terms of revenue. Tourism earns large sum of foreign exchange without export of tangible products from the state. Kerala has a landscape fit for a Tourism based semi high-speed rail travel, with all greenery, back waters and hills all around the corridor (depending on the finalized alignment). Semi High-Speed rail with option of VISTA DOME coaches or exclusive luxury coaches called ‘Tourist cars’ with cooking facilities, in addition to the upper-class coaches which can have extra amenities like additional bathrooms, sitting cum-dining rooms etc. can act as a magnet for attracting more tourists. So, a fast and safe Semi High Speed Rail service can lead to considerable increase of tourism in Kerala.

References

India do not have any railways that can be classified as New high-speed rail (more than 200 Kmph) or semi high-speed rail (up to 200 Kmph). The current fastest train in India is the **Gatimaan Express** with a top speed of 160 km/h and runs between Delhi and Jhansi. So, this project is in a new territory as far as Indian Rail scenario is concerned. Hence references for the semi high speed rail in Indian context is not readily available as a result of which the following references have been used for the preparation of this report. More references shall be added during the further study if required.

- FEASIBILITY REPORT OF CONSTRUCTION OF 3RD & 4TH LINE BETWEEN TRIVANDRUM AND KASARAGOD FOR RUNNING OF SEMI HIGH SPEED TRAINS – Prepared by Kerala Rail Development Corporation Ltd. TRIVANDRUM
- Kerala High Speed Rail Corridor between Trivandrum and Kannur Detailed Project Report – June 2016, Prepared by DMRC
- Technical Assistance Consultant’s Report of People’s Republic of China: Lanzhou-Chongqing Railway Project Financed by the Asian Development Bank
- EUROPEAN STANDARD (UIC) Railway applications – Track - Track alignment design parameters - Track gauges 1435 mm and wider - Part 1: Plain line
- Geo technical aspects for the construction of Shinkansen by Dr. M FUJII
- Delhi-Chandigarh Semi High-Speed Project SEMI HIGH SPEED TECHNICAL FEATURES REPORT
- Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor by Japan International Cooperation Agency (JICA) and Ministry of Railways, Republic of India (MOR)
- California High Speed Rail project: Typical cross sections
- Site visits
- Various presentation and discussions with Client KRDCL and the other stakeholders

3. PROJECT OBJECTIVE

3.1 Project Description

The project involves preparation of a Feasibility Study followed by the Detailed Project Report for Semi High Speed Rail corridor between Thiruvananthapuram and Kasaragod in the state of Kerala as per obligatory points provided by KRDCL.

3.2 General setting of the project

The corridor will traverse the distance between Thiruvananthapuram and Kasaragod and the exact places of the corridor shall be understood after the finalization of the alignment to connect the obligatory points as per KRDCL requirements to touch all the important cities of Kerala depending on the traffic forecast, technical limitations, design parameters, availability of land, stake holder requirements and other financial considerations.

3.3 Rivers, lakes and back waters

Though small, Kerala is a land affluent in water sources. 44 rivers water the land, of which 41 are west flowing and 3 flow east. Apart from these 44 main rivers, their tributaries and distributaries and a countless number of streams and rivulets crisscross the land making it green and fertile in addition to serving as inland waterways. Aside from these rivers, Kerala is bestowed with several lakes and backwater lagoon which add to the beauty of the land. The most important of Kerala’s forty-four rivers include the Periyar (244 km in length), the Bharathapuzha (209 km), the Pamba River (176 km), the Chaliyar river (169) the Chalakudy Puzha (144 km), the Kadalundipuzha (130 km), and the Achancoil (128 km). Most of the remainder are small and entirely fed by the Monsoons. Vembanadu lake with an area of 260 sq.km is the largest in the state. Shastamkotta lake is the largest natural fresh water lake.

3.4 Public transport in Kerala

Kerala presents a varied relief throughout its length and breadth and is well connected to the rest of India by air, rail, road and water ways.

- Airways: There are four airports in Kerala, located at Thiruvananthapuram, Kochi, Kozhikode and Kannur of which the first two are international airports. Helicopter and air taxis were also tried between Kochi and Trivandrum but proved to be prohibitively expensive
- Railways: The Indian Railways/ Southern Railway line runs through the state, connecting most major towns and cities. The railway network in the state is controlled by three divisions of Southern Railway, namely Trivandrum Railway Division, Palakkad Railway Division and Madurai Railway Division. Kerala's major railway stations are Kannur, Kozhikode, Shornur Junction, Palakkad Junction, Thrissur, Ernakulam Junction, Alappuzha, Kottayam, Chengannur, Kayamkulam Junction, Kollam Junction and Thiruvananthapuram Central.
- Roadways: Kerala has eight National Highways which run for about 1811.52 km. Kerala has narrower National Highways compared to other parts of India[†]. Kerala is the only state, other than Goa, which has requested for narrower highways in the state. NHAI upgrades highways to a minimum 4-lane, 60-meter-wide, grade-separated highway or a better standard across India. But in Kerala, National Highways are being upgraded to 45-meter-wide highways. The reason cited by

[†] Wikipedia

the State Government was the difficulty and disinterest in Land Acquisition, which is the responsibility of the State Government.

Kerala's first six lane National Highway is coming up on the NH 544 between stretches of Thrissur and Wadakkanchery. Kerala's first and biggest six lane tunnel highway is also coming up on the stretch at Kuthiran in Thrissur district. The work for the Kuthiran highway tunnel is almost complete. It is in the Kochi -Thrissur-Palakkad- Walayar stretch of four-lane NH 544, which is a part of North-South and East-West Corridor of the Indian highway system.

The list of the NH in the state, the route location and the length are given below:

Table 19 : List of NH and agency in Kerala

S No	New NH No	Route	Length(km.)
1	NH 66	Thalappady-Parassala	669.437
2	NH 544	Walayar- Edappally,Ernakulam	160
3	NH 85	Bodimettu-Kundannor,Ernakulam	167.61
4	NH 183	Kollam-Sasthamkotta-chegannur-Kottayam-Vandiperiyar-Kumily	190.3
5	NH 183A	Kollam Titanium Jn-Sasthamcotta-Adoor-Pathanamthitta-Vandiperiyar	145
6	NH 185	Adimali-Cheruthoni-Painavu-Kumily NH 183	98
7	NH 744	Kollam-Aryankavu	81.28
8	NH 766	Kozhikode-Muthanga	117.6
9	NH 966	Ramanattukara-Palakkad	125.304
10	NH 966A	Kalmassery-Vallarpadam	17
11	NH 966B	Kundannoor-Willington Island	5.92
		Total	**1811.52.km**

Source: Wikipedia

There are 72 state highways in Kerala. Of them, MC Road (Main-Central Road), proposed Hill Highway (Kerala) and Main Eastern Highway are the longest. The respective State Highway number is displayed on the top of all milestones (black in colour in green background) on the respective road. Kerala Transport Corporation and private bus operators operate local bus services at regular intervals.

- Buses: Kerala is one of the highly urbanized states in India (47.7 per cent as per Census 2011) and has a significant number of people covering long distances between 200Km to 300km. Cities in Kerala rank high in Public Transport Accessibility Index and City Bus Transport Supply Index with a high penetration of public transport buses. The composition of public bus system, 38 percent, is one of the highest in the country. This also follows the fact that Kerala has the highest vehicle per population ratio of one vehicle for every five individuals with estimates showing that by 2017, every household will have a vehicle, on average.

Kerala is unique for its high public transport modal share, thanks to the role played by private-operated buses. Kerala has two major public bus transport systems – State controlled KSRTC and private-operated buses, which run inter-city, intra-city and inter district (administrative) services. The private-operated buses constitute 77 percent of the entire passenger transport segment in Kerala with KSRTC, the only STU, operating 5984 schedules in Kerala.

- Water ways: It is the inland canals that connect the rivers from one to another. Important places of commercial interest are situated on these river banks. The State Water Transport Department is the agency providing waterways facilities to the people. Coastal shipping and Inland Navigation Department (CSIND), State Water Transport Department (SWTD) and Kerala Shipping and Inland Navigation Corporation (KSINC) are the agencies responsible for the development of Inland Water Transport in Kerala. Apart from the water ways in the backwaters and interconnecting canals, Kerala also has a National water way No. 3. The West Coast Canal or National Waterway No. 3 is a 168-km stretch of this inland navigational route located in Kerala and runs from Trivandrum to Kasaragod and was declared a National Waterway in 1993. In addition to this main stretch, Champakara and Udyogmandal canals are navigable and connect the industrial centres of Kochi to Kochi port. The study team has also explored the possibilities of taking the alignment along the National waterway as it would reduce land acquisition since it is mostly Government land/ "*Porampokku"*. However, this shall be subject to technical feasibility and other commercial considerations.

4. REVIEW OF EXISTING DATA & REPORTS

4.1 Indicators in Kerala Transport Policy

The draft transport policy says that;

"The quality of transport system in Kerala requires much improvement. Although road transport dominates the transportation scenario in the state, people depend on railways for long haul transport needs. The service levels in train journeys are far from satisfactory. Reservation of seats and berths in general are not available on demand and one has to book tickets more than one month in advance. The public transport system is unreliable, costly and remains very rudimentary.

The motor vehicle population in Kerala, which was around 2 lakhs in 1980, has almost level playing field with the element of inter-modal and intra-modal competition, thereby ensuring organizational efficiency and individual viability".

The road transport infrastructure of the state consists of over 3.3 lakh kms of road and road density in Kerala is 852km per 100 square km (which includes classified & non-classified roads) and it is far ahead of the national average of 387 km/100 sq.km[‡]. But in Kerala, the most important challenge in the road sector involves building all-weather roads connecting each village. The draft policy and the study on this policy (by ASSOCHAM) suggest that the vehicle population is increasing in Kerala, but the development of roads might have hit a saturation point, for multiple reasons. Therefore, Kerala may need a transport system which can integrate with the structure of different modes functioning as distinct entities. In this context, a Rail based transport system, running along the whole length of Kerala, distinct but offering seamless integration, shall be the ideal solution to the transport needs of Kerala as it can move people/ freight fast and in large Nos., occupying comparatively less Right of way (ROW) compared to other modes.

History of High-speed rail project in Kerala. Historically, the Thiruvananthapuram–Mangalore high-speed rail corridor was mooted in the 2009-10 budget speech of the LDF government. The project was cleared by the State Cabinet in February 2010[§]. The Kerala State Industrial Development Corporation (KSIDC) was appointed as the nodal agency to develop the project. In September 2011, a special purpose vehicle, the Kerala High Speed Rail Corporation Ltd. (KHSRC) was formed to implement the project. The Delhi Metro Rail Corporation (DMRC) conducted the pre-feasibility study of the project. Following which KHSRC requested DMRC to submit a detailed project report (DPR).

DMRC submitted the DPR to the GOK (copy provided to the consultant by the Client KRDCL) in the year 2018 with a total cost of Rs 90,663.00 Crores, including taxes. However, now this HSR project has been scrapped by the Government and office of KHSRCL has also been closed. It is also to be noted that Trivandrum- Kannur High speed rail corridor was **NOT PART** of the 7 corridors identified in the HIGH-SPEED RAILWAY vision of Indian Railways.
It is also to be noted that Trivandrum-Trissur portion is part of corriodr No 6 already identified for HSR of Vision of Indian Railways

[‡] Economic times report

[§] Wikipedia

Table 20 : Seven corridors planned for HSR in India

Corridors	Route	Length
Corridor 1	Pune- Mumbai- Ahmedabad	Approx. 680 Km
Corridor 2	Delhi- Chandigarh- Amritsar	Approx. 480 Km
Corridor 3	Delhi- Agra- Lucknow- Varanasi- Patna	Approx. 1,000 km
Corridor 4	Howrah- Haldia	Approx. 140 Km
Corridor 5	Hyderabad- Dornakal- Viajayawada- Chennai	Approx. 780 Km
Corridor 6	Chennai- Benagaluru- Ernakulam- Thiruvananthapuram	Approx. 1020 Km
Corridor 7	Delhi- Jaipur- Jodhpur	Approx. 530 Km
	Total	4630 Km

Source: (i) Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor FINAL REPORT

(ii) Budget speech.

4.2 Kerala's plan for introducing Semi High-Speed Rail corridor

The next attempt by the GOK was exploring the possibility of having a Semi high speed rail corridor between Thiruvananthapuram and Kasaragod and this study is part of that plan. KRDCL was entrusted with the study and they submitted a pre-feasibility report to GOK with a cost estimate of INR 46769.00 Cr, including land for elevated and separate corridor (510Km).

4.3 Challenges to the introduction of Semi High Speed Rail in Kerala

The Kerala Semi High-speed Rail corridor, being a green field project, may have long gestation period and will be highly capital intensive. Thus, a strong will, consensus and strategic thinking is required at the apex level for implementing it in a programmed manner in view of the merits and importance of this project for Kerala. As expected in case of any huge infrastructure project, various Government departments and agencies shall be required to work for the project. Coordination among Central Government Ministries, State Governments and Government Agencies are thus a must for the successful implementation of the project.

4.3.1 Land acquisition

Land acquisition is critical in SHSR project due to its stringent alignment requirements. As SHSR corridors pass through conurbations and or sensitive land, public protests are to be dealt with carefully by implementing agencies. So, a correct mix of alignment choices between grade/ elevated/ tunnels is a must.

If KRDCL feel appropriate, there could be a new approach of participatory land acquisition coupled with negotiated purchase, where in the land owner is treated as an equity holder of the project rather than a disposable entity owning a parcel of land.

4.3.2 Environmental issues of Drainage/ monsoon and noise

Unique to Kerala, it has two rainy seasons. They are the southwest monsoon and the Northeast monsoon. The southwest monsoon, *Edavapathi* (in *Edavam Malayalam month*) comes in the month of June and the Northeast monsoon, *Thulavarsham* (in *Thulam Malayalam month*) starts in mid-October and finally ends around mid-November. The monsoons in Kerala do not take the form of incessant rain over days and weeks. The typical pattern is that it rains for a few hours followed by interludes of sunshine, leading to alternate wetting and drying of track and fittings. These monsoons shall create problems of flooding if the low-lying lands are filled up for the project. This situation is to be avoided and hence the consultants have tried to avoid filling up the paddy fields for stations and alignment, to the extent possible. Another issue related to the monsoon is the drainage of water along the SHSR corridor. The continuous embankments and viaducts along the corridor, shall collect a lot of rain water like an umbrella and these needs to be properly drained to avoid flooding and to keep the embankments safe. One way to mitigate this problem would be to make water bodies like small ponds along the corridor, like the temple/*kaaavu* ponds Kerala had in the near past. Another issue with the monsoon is that it creates alternate wetting and drying conditions for the tracks and fittings and concrete (of via duct). The track fittings could get loose, rust, etc. affecting strict maintenance tolerances of track and fittings. So, a robust **RAMS** (*Reliability, Availability, Maintainability and Safety procedure*) may be adopted for construction and maintenance of the corridor.

4.3.3 Safety issues along the corridor

The recent floods in Kerala, the Okhi cyclone and the Kasturirangan/ Madhav Gadgil reports on the western Ghats Ecology, etc. have all created certain questions among the public about safety of these kind of infrastructure projects. The project planning should take care of the natural safety hazards of landslides, flooding, drought, Tsunami, etc. along the corridor.

4.3.4 Lack of quality construction material/ contractors/ supervision

Cement, metals (steel mostly), embankment and moorum earth and mineral aggregates in the form of coarse aggregate, fine aggregate (sand), track ballast are required in train/ truck loads for this project. The quantum of materials required for this project has not been calculated at this level of study, but one can normally appreciate the huge volume required for a 530km+ Rail corridor project. From recent experiences of Railway doubling projects and strict vigilante mode of quarry control in the state, it is almost certain that Kerala alone will not be able to satisfy the material requirement for this project especially when the construction period is set for 7 to 10 years.

Unfortunately, negative publicity, arising mostly out of ignorance and partly motivated, is a reality for all these infrastructure projects[**]. It is also “gossiped” that agencies competing for a pie in the project also create negative publicity for the technology/ methodology of the project. To mitigate this problem, regular and controlled dissemination of information regarding the project is essential. KRDCL may employ the services of a PRO agency for the project, to create public awareness and necessary support from the public.

4.3.5 Policy frame work

Robust policy framework is required for the seamless implementation of the project. The policy frame work shall ensure that the various stake holders of the existing system may work in tandem resulting from the integration of this new rail-based corridor into the system. Seamless integration is the result of careful planning which should start during the design phase of the project. Towards this, along with the client KRDCL, the consultants shall interact with the various stake holders listed below. Seamless integration shall also assure the public and investors of the project.

4.3.6 Stake holders

The list of potential stake holders for this project are given below and may have to be revised during the course of the study. It would be beneficial to the project if more stake holders, who can generate revenue to the project, is brought in for the financial viability of the project.

[**] Concept of the Pathos of Distance. Nietzsche's “pathos of distance,” the notion that values are created by a few gifted and lofty individuals, as the basis for a wide-ranging investigation into the ethics of the moderns (i.e. relating to the present or recent times as opposed to the remote past).

Table 21 : List of stake holders

Sl no	Stakeholder	Role Contributed	Involvement
1	KRDCL	Project Team	High
2	SPV (for execution)[††]	Project execution	High
3	GOK	Investment in the Project, land	High
4	Indian Railway	Joint venture investment with GOK/ investment in the project	High
5	Corridor Land owners	Due to land acquisition	High
6	Funding agency	% Total investment, Financed through loan	High
7	Passengers	Project Users	High
8	MPs, MLAs, Local bodies	Public opinion, negotiation, waste management	High
9	Media	Public Information	Medium
11	Environmental Clearance	KRDCL needs to get Environmental Clearances whereever required	Medium
12	Companies Contractors	Construction & Operations	High
13	Revenue department	Land acquisition/ development	High
14	State PWD	Project connectivity, maintenance, Corridor ROW development (tentative)	High
15	Inland Navigation department	Integration with the corridor/ land development	Medium
16	Plantation corporation	Land parcel, if required for the project	High
17	IT department	Generation of revenue to SPV	High
18	Oil companies	Generation of revenue to SPV	High
19	Advertising Agencies	Generation of Revenue for SPV	Medium
20	KSEB	Power supply and transmission, cabling	High
21	Water and waste Water department	Maintenance of sewage system and garbage	High
22	Kerala Police	Maintaining law and order during construction, operation & parking	Medium
23	Smart city projects/GOK	Development of smart cities along the corridor	High
24	SYSTRA MVA	Research for the project and DPR	Medium
25	NGOs	Concern about the local community	High
26	Environmental and Pollution Control Board	Research on the project & its impact on environment	Medium
27	Local Communities	High Concern about the effect of the project	High
28	CISF	Safety and Security	High
29	Agricultural department	Due to alignment crossing agricultural fields, drainage issues and water body	Medium
30	ALIND	If land used by the project	High
31	FACT	If land used by the project	High

Source: Study team

[††] Ref KRDCL report page 41

5. SCOPE OF TRAFFIC STUDY

As part of the Feasibility Study of Semi High Speed Rail (SHSR), connecting Thiruvanthapuram and Kasaragod, detailed study of existing transportation system and travel characteristics of Kerala State has been undertaken. Information on the demographic and socio economic factors, influencing the travel pattern have also been compiled. Review of earlier traffic studies have been carried out, along with the methodology adopted and salient findings. The same is summarised in this section.
The broad scope of traffic estimation and forecast study includes:

- Review of earlier study reports;
- Critical examination of the travel demand models developed during the earlier studies, along with the major assumptions used in the development of those models;
- Evaluation of ridership projection reported in the earlier reports;
- Compilation of necessary additional data from secondary and primary sources and update the data base;
- Estimation of ridership on the proposed Semi High Speed Rail System between Thiruvananthapuram and Kasaragod;
- Ridership forecast for the horizon years, including station wise boarding/ alighting and section load for identified fare structure;
- Various options which can be considered to enhance the ridership and revenue of SHSR.

This section of the Feasibility Report provides ridership forecast of SHSR for different horizon years, which is primarily based on the data compiled from earlier study reports.

5.1 Study Area and Demographic Profile

5.1.1 Introduction

Kerala, the greenest state, located on the southernmost tip of India, blessed with excellent tropical weather and networked by 44 rivers, 34 lakes, canals, ponds, and paddy fields, is popularly known as God's Own Country. This lush green strip of land lying between the Arabian sea and the steep Western Ghats has an area of about 38,863 sq. km and is inhabited by about 33.41 million people as per Census 2011.
Kerala stretches for about 580 km along the Arabian Coast, varying in width from roughly 30 km to 120 km. It is bordered by the states of Karnataka in the north, Tamil Nadu in the east and Arabian Sea in the west and south. The administrative capital of Kerala is Thiruvananthapuram, which is a major destination for tourists. Kochi and Kozhikode are the other two major cities with lot of industrial developments.
The proposed SHSR project envisage Semi High Speed Rail connectivity between Thiruvananthapuram and Kasaragod, with intermediate stops at key economic centres of the State, such as Kollam, Kottayam, Kochi, Thrissur, Calicut, and Kannur. This section of the chapter gives a brief introduction to the Kerala State profile, along with other important aspects such as demography, socio-economic profile, economy and employment. Figure 3 given below presents the study area map of the proposed SHSR project.

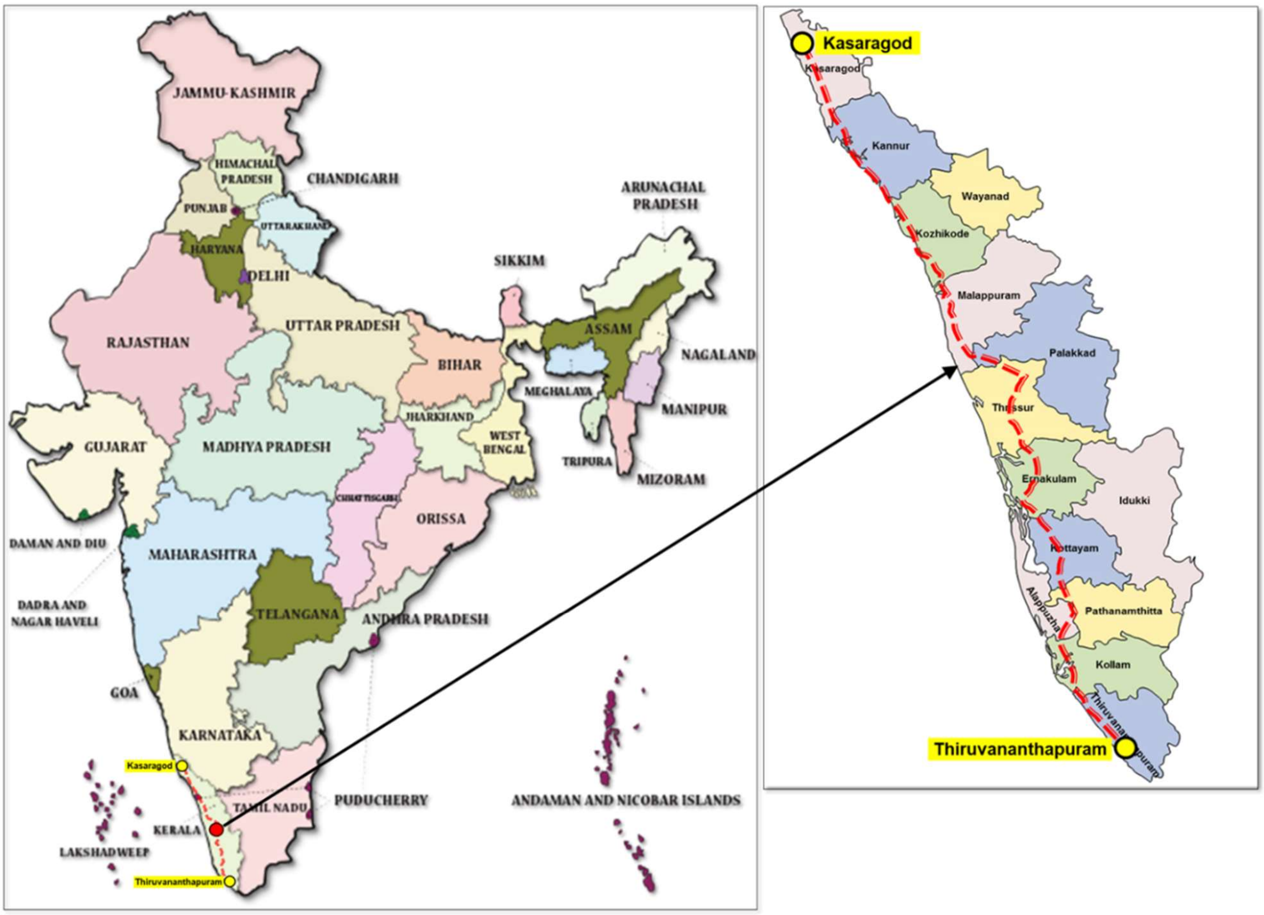


Figure 3: Study Area Map

5.1.2 Demographic Profile

As per Census 2011, the population of Kerala State was recorded as 33.41 million persons comprising of 16.03 million males and 17.38 million females with a decadal growth rate of 4.81%, which is lowest amongst the states of India. Kerala's share in the total population of India is only 2.76%. Kerala has a different sex ratio profile of 1084 women per thousand men. During the previous decade (1991-2001), the decadal growth rate was observed to be 9.04% and the core reasons for the decline in growth rate were decline in fertility and net out-migration. The district-wise population in Kerala is presented in Table 22. Malappuram District has the highest population of about 44.4 lakhs in the year 2017, followed by Kerala's capital city, Thiruvananthapuram with 33.47 lakhs; while the lowest population is observed in Wayanad district with a population of about 8.4 lakhs. As per Census 2011, the density of population of Kerala is 860 persons / sq. km as compared to 382 persons/ sq. km at an all India level.

Table 22 : Population of Kerala

District	1991	2001	2011	2017*
Kasaragod	1071508	1204078	1307375	1379091
Kannur	2251727	2408956	2523003	2602238
Wayanad	672128	780619	817420	842536
Kozhikode	2619941	2879131	3086293	3226115
Malappuram	3096330	3625471	4112920	4439921
Palakkad	2382235	2617482	2809934	2931854
Thrissur	2737311	2974232	3121200	3225843
Ernakulam	2817236	3105798	3282388	3407138

District	1991	2001	2011	2017*
Idukki	1078066	1129221	1108974	1094573
Kottayam	1828271	1953646	1974551	1982082
Alappuzha	2001217	2109160	2127789	2143334
Pathanamthitta	1188332	1234016	1197412	1175608
Kollam	2407566	2585208	2635375	2655423
Thiruvananthapuram	2946650	3234356	3301427	3347613
Total	29098518	31841374	33406061	34453369

* Source: Vital Statistics Division, DES, Kerala & Census of India

5.1.3 Socio-Economic Profile

Kerala has the highest quality of life index in the country, a high literacy rate at 94% against country's literacy rate of 74% and has a good socio – economic status compared to other Indian states. Kerala's health indicators and life expectancy are close to those of developed countries. Achievements in health and education fronts were to a large extent possible through infrastructure investments. It also has had an edge over many other States in social and economic infrastructure, such as road transport, medical institutions and healthcare facilities.

Kerala is a Consumer State and the economy mainly depends on agriculture (mainly coconuts) and with a very few industries. Tourism has grown to be the fund generating industry. The upcoming of IT and allied industries coupled with small and agro-based has a lot to look forward in future in terms of economy of Kerala which are willing to exploit the yet-to-be tapped resources. The state has witnessed significant migration, especially to the Gulf Cooperation Council (GCC) region during the Kerala Gulf boom and is thus heavily dependent on the remittances from the large expatriate community, which contributes more than a fifth of GSDP. Certain Socio-Economic aspects of the state are discussed below.

5.1.4 Economy

Kerala's Gross State Domestic Product (GSDP) grew at 7.18% in 2017-18 in constant (2011-12) prices, which is higher than the 6.22% growth recorded in 2016-17. At current prices, the growth rates of GSDP in 2017-18 and 2016-17 were 11.42% and 9.67% respectively. The growth rates of Gross Value Added (GSVA) at basic prices in constant (2011-12) prices were 5.94% and 4.67% in 2017-18 and 2016-17 respectively. The GSVA growth rate in current prices was 10.37% in 2017-18 and 8.62% in 2016-17. Per capita GSDP in real terms grew at 6.65% in 2017-18 as against 5.70% in 2016-17.

In 2017-18, the contribution from primary, secondary, and tertiary sectors to the GSVA at constant prices (2011-12) was 10.85%, 27.40% and 61.75% respectively. At current prices, the primary, secondary, and tertiary sectors contributed 13.20%, 24.24% and 62.56% respectively to the GSVA during this period. Table 23 presents the GSDP of Kerala from year 2011-12 to year 2017-18.

Table 23 : GSDP of Kerala

Gross State Domestic Product of Kerala							
Item	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17(P)	2017-18(Q)
GSDP at Current Prices (Rs. In Lakhs)	36404788	41231300	46504121	51256405	56199361	61635704	68676443
GSDP at Constant (2011-12) Prices (Rs. In Lakhs)	36404789	38769346	40278133	41995555	45121002	47928990	51369589

Gross State Domestic Product of Kerala							
Item	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17(P)	2017-18(Q)
NSDP at Current Prices (Rs. In Lakhs)	32802112	37138412	41726497	46061432	50590997	55595370	61923259
NSDP at Constant (2011-12) Prices (Rs. In Lakhs)	32802112	34861581	36470677	38213426	41115015	43839422	46988233
Per Capita GSDP at Current Prices (Rs.)	108666	122471	137515	150824	164554	179580	199101
Per Capita GSDP at Constant (2011-12) Prices (Rs.)	108666	115158	119105	123573	132116	139645	148927
Per Capita NSDP at Current Prices (Rs.)	97912	110314	123388	135537	148133	161981	179523
Per Capita NSDP at Constant (2011-12) Prices (Rs.)	97912	103551	107846	112444	120387	127729	136225

Source: Department of Economics and Statistics Kerala, 2017

Kerala has been ahead of other Indian States in achieving demographic and human development indicators. In achievement of Sustainable Development Goals (SDGs 2018) by the States in India as computed by the NITI Aayog, Kerala ranks first along with Himachal Pradesh, with a score of 69 against national average of 57. Kerala ranks first in SDGs relating to health, education, and gender equality. Public investment in educational infrastructure and quality is a priority and as a consequence the enrolment of students in Government and Government aided schools has increased. Table 24 presents the GSDP of all states of India for year 2016-17(Q). Figure 4 shows the comparison of percentage growth rate of Kerala & India (by economic activity) at constant prices. Figure 5 presents the per capita income of Kerala and India.

Table 24 : GSDP of All States

S No	State/UT	2016-17(Q)				
		GSDP		Per Capita Income		Growth Rate of GSDP at (2011-12) Prices (%)
		At Current Prices	At Constant (2011-12) Prices	At Current Prices	At Constant (2011-12) Prices	
1	Goa	62661	51847	375554	308827	12.50
2	Delhi	616826	514871	300793	249555	8.60
3	Chandigarh	31823	26631	237599	207000	6.30
4	Sikkim	20020	15339	27552	206178	6.70
5	Haryana	547396	434608	180174	143211	8.70
6	Puducherry	27739	21629	174743	137088	7.80
7	Uttarakhand	195606	162451	161102	133246	6.90
8	Maharashtra	2257032	1826296	165491	133141	10.00
9	Gujarat	1162287	984453	156527	131853	10.10

S No	State/UT	2016-17(Q)				
		GSDP		Per Capita Income		Growth Rate of GSDP at (2011-12) Prices (%)
		At Current Prices	At Constant (2011-12) Prices	At Current Prices	At Constant (2011-12) Prices	
10	Kerala	621700	481839	163475	128550	7.40
11	Telangana	659074	511482	159856	122684	10.10
12	Karnataka	1132393	874395	157436	120496	7.50
13	Himachal Pr.	126020	109564	150285	119386	6.40
14	Tamil Nadu	1270490	1009145	150036	117806	4.30
15	A & N islands	6649	5566	136824	113796	9.30
23	Nagaland	21488	15511	90168	63568	5.80
24	West Bengal	879167	657883	83126	61245	7.90
25	J & K	126847	102206	78163	59924	5.40
26	Meghalaya	27228	22051	73291	58826	6.80
27	Madhya Pr.	647304	469393	74590	53047	12.30
28	Assam	254341	200790	67303	52416	5.10
29	Jharkhand	235560	194475	59799	49174	11.20
30	Manipur	21066	16989	58501	46756	3.40
31	Uttar Pradesh	1250213	974120	51014	38934	7.30
32	Bihar	487628	361504	34409	28485	11.30
	All India	15253714	12196006	103870	82229	7.1

Source: Department of Economics and Statistics, Government of Kerala, 2017

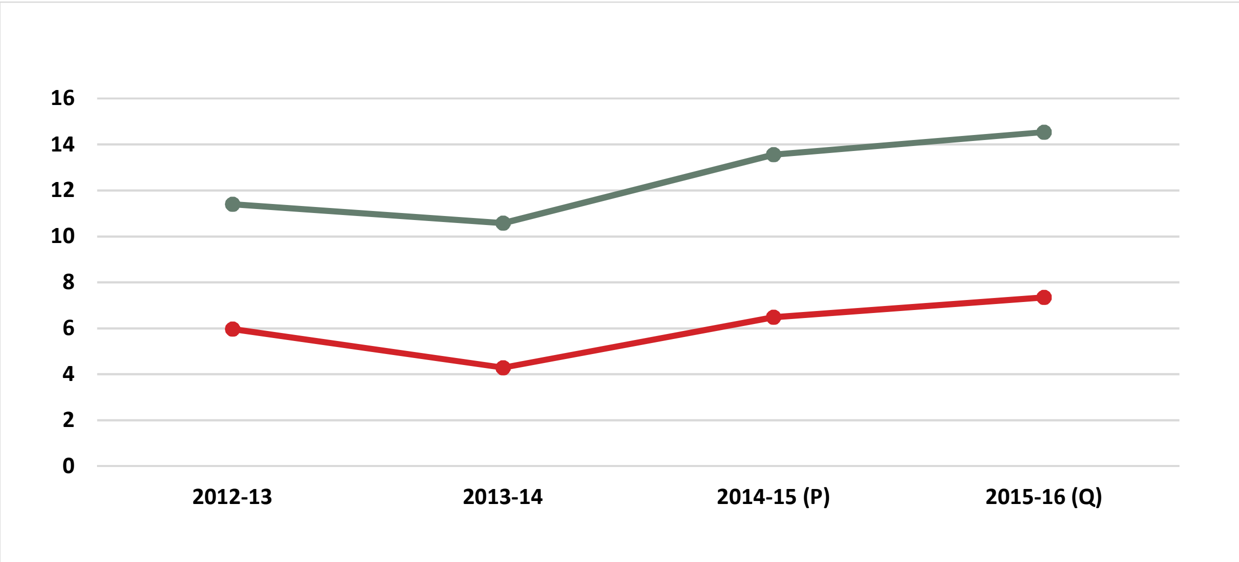


Figure 4: Percentage Growth Rate of Kerala & India

Source: Department of Economics and Statistics, Government of Kerala, 2017

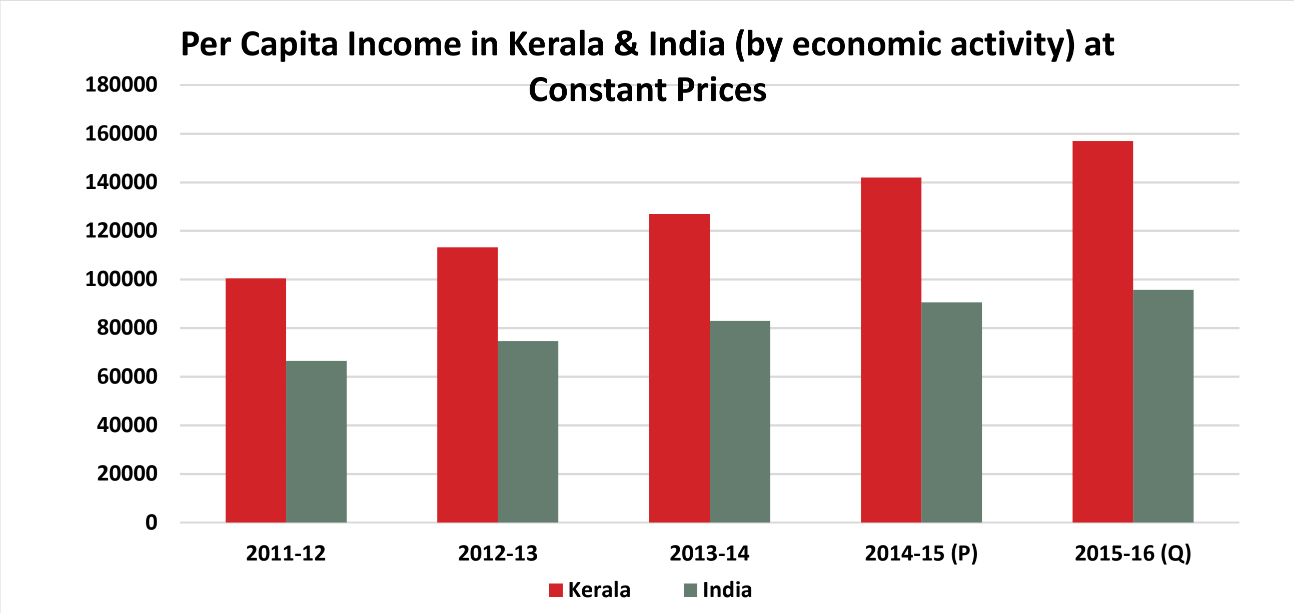


Figure 5: Per Capita Income in Kerala & India

Source: Department of Economics and Statistics, Government of Kerala, 2017

5.1.5 Employment in the Organised Sector

In Kerala, employment in the organised sector has remained more or less stagnant, showing only a marginal increase from 10.89 lakh in 2012 to 12.14 lakh in 2018. The reason behind this trend is due to the movement of the labour force to the sectors which provides more employment in the State.
The organised sector comprises private and public sectors and it is noteworthy that private sector employment is steadily increasing since 2011 onwards. In 2018, out of 12.14 lakh persons employed in the organised sector, 5.54 lakh (46%) are in the public sector and 6.60 lakh (54%) are in the private sector. Within the public sector employment 46% are employed in State Government, 11% in Central Government, 24% are in State quasi-institutions, 4% in LSGIs and 15% are in Central quasi-institutions.
Data on District-wise employment as on March 2018 reveals that Ernakulam and Wayanad are the two Districts which respectively accounted for the highest and lowest employment. Total organised sector employment in Ernakulum District is 2.47 lakh persons, which accounted for 20% of the total employment of the State. Whereas in Wayanad, the employment under the organised sector is 0.35 lakh persons, which accounted for 3% of the total employment. In Kerala, men outnumbered women in public sector employment and women outnumbered men in private sector employment. The share of men is 66% of public sector employment while that of women is 51% of total private sector employment. Thiruvananthapuram and Idukki are the two Districts which respectively accounted for the highest and lowest women participation in public sector employment. In Thiruvananthapuram, 31,037 women are employed in the public sector followed by Ernakulam (22,849), Thrissur (21,891) and Kollam (18,783). Whereas in Idukki, 3,387 women are employed in the public sector followed by Kasaragod (6,502), Wayanad (6,814), and Pathanamthitta (8,266).

5.1.6 Tourism in Kerala

Kerala is one of the most popular tourist destinations in the country. Kerala is a leader in India when it comes to destination management, tourism promotion as well as tourist arrivals. Kerala tourism map is shown in Figure 5(a). The total annual tourists to Kerala constitute 48% of Kerala population. Key characteristics of tourism in Kerala are as follows:

- Number of Foreign Tourists in 2018: 10,96,407
- Number of Foreign Tourists in 2017: 10,91,870
- Number of Foreign Tourists in 2016: 10,38,419

- % Growth: 2.75% per annum

- Number of Domestic Tourists in 2018: 156,04,661
- Number of Domestic Tourists in 2017: 146,73,520
- Number of Domestic Tourists in 2016: 131,72,535

- % Growth: 8.84% per annum

Figure 5(a): Kerala Tourism Attraction Map

Source: Kerala's Approach to Tourism Development: A Case Study Ministry of Tourism & Culture, Government of India

The trends in annual domestic and foreign tourist arrivals in Kerala are shown in Table 25. About 0.42% and 6.35% increase was observed during 2017-18 for foreign and domestic tourist arrivals respectively.

Table 25 : Yearly Tourist Arrivals

Year	No. of Domestic Tourist Visits	% of Increase	No. of Foreign Tourist Visits	% of Increase	Total No. of Tourists	% of Increase
2006	6271724	5.47	428534	23.68	6700258	6.47
2007	6642941	5.92	515808	2.37	7158749	6.84
2008	7591250	14.28	598929	16.11	8190179	14.41
2009	7913537	4.25	557258	-6.96	8470795	3.43
2010	8595075	8.61	659265	18.31	9254340	9.25
2011	9381455	9.15	732985	11.18	10114440	9.29
2012	10076854	7.41	793696	8.28	10870550	7.48
2013	10857811	7.75	858143	8.12	11715954	7.78
2014	11695411	7.71	923366	7.6	12618777	7.71
2015	12465571	6.59	977479	5.86	13443050	6.53
2016	13172535	5.67	1038419	6.23	14210954	5.71
2017	14673520	11.39	1091870	5.15	15765390	10.94
2018	15604661	6.35	1096407	0.42	16701068	5.94

Source: Kerala Tourism Statistics; Dept. of Tourism, Government of Kerala

The district wise tourist arrivals have been detailed in the Table 26. This data highlights the regional locations where the highest and lowest shares of tourists are attracted to. Maximum share of tourists (both Foreign and Domestic) are attracted to Ernakulam District (44.5% and 22.1% respectively).

Table 26 : District-wise Foreign and Domestic Tourist Arrivals

S No	District	Foreign Tourists			Domestic Tourists		
		2018	2017	% Variation over 2017	2018	2017	% Variation over 2017
1	Thiruvanathapuram	342761	420719	-18.53%	2712387	2505333	8.26%
2	Kollam	9086	6227	45.91%	400222	381829	4.82%
3	Pathanamthitta	1953	2003	-2.50%	192813	164494	17.22%
4	Alapuzha	95522	75037	27.30%	511490	433456	18.00%
5	Kottayam	43287	32350	33.81%	524821	468593	12.00%
6	Idukki	44833	42285	6.03%	1257403	1090086	15.35%
7	Ernakulam	488175	453973	7.53%	3446889	3285088	4.93%
8	Thrissur	11333	10775	5.18%	2497278	2642546	-5.50%
9	Palakkad	1967	1711	14.96%	509883	474180	7.53%
10	Malappuram	17610	18451	-4.56%	565914	520832	8.66%
11	Kozhikode	18388	13106	40.30%	1052783	932345	12.92%
12	Wayanad	11607	8995	29.04%	888141	815624	8.89%
13	Kannur	5763	5123	12.49%	768038	695655	10.41%
14	Kasaragod	4122	1115	269.69%	276599	263459	4.99%
Total		1096407	1091870	0.42%	15604661	14673520	6.35%

Source: Kerala Tourism Statistics; Dept. of Tourism, Govt. of Kerala

5.1.7 Regional Connectivity

Infrastructure on the transport sector for the intercity travel in the state is mostly by road, and rail. Kerala has 1.62 lakh kilometres of roads which is 4.2% of India's total length. Most of Kerala's west coast is accessible through the National Highways namely NH 66 (old NH17), NH 544 (erstwhile NH 47) and NH 49. The poor condition of the roads and high number of vehicles are one of the basic reasons for the increased road accident index in the State. The Southern Railway under Thiruvananthapuram and Palakkad division operates the railway network throughout the state, connecting all major towns and cities.

5.1.8 Railways

The total rail network in Kerala is 1148 Km in length, with 200 stations and serving 13 routes. There are 6 inter–state railway stations, with 5 towards Tamil Nadu and 1 towards Karnataka. Kerala's major railway stations are Alappuzha, Aluva, Chengannur, Ernakulam Junction (Kochi), Ernakulam North (Kochi), Kannur, Kasaragod, Kayamkulam Junction, Kollam Junction, Kottayam, Kozhikode, Palakkad Junction, Shornur Junction, Thalasseri, Thrissur, Valanchery, Thiruvalla, Thiruvananthapuram Central and Vadakara.
ICRA Management Consulting Services Limited (iMaCS) conducted Willingness to Pay (WTP)/ Stated Preference Surveys on board of the AC Train Coaches & Deluxe Buses and the same data is used in the present study for preliminary patronage forecast. The present railway fare between Thiruvananthapuram & Kasaragod is as follows:

- I AC: Rs 2205
- II AC: Rs 1270
- III AC: Rs 885

Table 27 presents the existing railway fares in Rs per km for Thiruvananthapuram- Kasaragod route.

Table 27: Existing Railway Fares

Class	Fare (Rs per km)
I AC	3.84
II AC	2.29
III AC	1.54
Jan Shatabdi	1.50
Garib Rath	0.96
Sleeper Class	0.62

There are a few trains between Thiruvananthapuram -Kasaragod & Kochu Veli- -Kasaragod and some of them are not running daily. The details of these trains are presented in Table 28.

Table 28: Trains between Thiruvananthapuram - Kasaragod & Kochuveli - Kasaragod

S No	Train No.	Train Name	From	To	Departure Time	Arrival Time	Journey Time (in Hours)	Journey Speed (kmph)
1	12431	Rajdhani Exp	Thiruvananthapuram	Kasaragod	19.15	4.33	9.19	62.9
2	22633	Nizamuddin Exp	Thiruvananthapuram	Kasaragod	14:15	1:13	10.97	53.53
3	19577	Jamnagar Exp	Thiruvananthapuram	Kasaragod	10:55	20:58	10.03	58.5
4	16604	Maveli Express	Thiruvananthapuram	Kasaragod	18:45	6:48	12.05	48.71
5	16606	Ernad Exp	Thiruvananthapuram	Kasaragod	3:35	15:48	12.22	48.05
6	16334	Veraval Exp	Thiruvananthapuram	Kasaragod	15:45	3:39	11.54	49.58
7	16336	Gandhi Dham Exp	Thiruvananthapuram	Kasaragod	16:05	3:39	11.34	50.87
8	16346	Netravathi Exp	Thiruvananthapuram	Kasaragod	9:30	21:43	12.22	48.05
9	16650	Parasuram Exp	Thiruvananthapuram	Kasaragod	6:20	19:23	13.05	44.98
10	16629	Malabar Exp	Thiruvananthapuram	Kasaragod	19:00	9:29	14.48	40.53
11	12202	LTT Garib Rath	Kochuveli	Kasaragod	8.45	18.48	10.03	58.5
12	12217	Sampark Kranthi	Kochuveli	Kasaragod	9.15	18.48	9.33	61.58
13	12483	Amritsar Express	Kochuveli	Kasaragod	9.15	18.48	9.33	61.58
14	22114	KCVL LTT SF Exp	Kochuveli	Kasaragod	0.35	11.14	10.39	54.88
15	22659	Dehradun Exp	Kochuveli	Kasaragod	8.45	18.48	10.03	58.5
16	19331	KCVL INDORE	Kochuveli	Kasaragod	11:00	20:58	9.58	58.5
17	19259	KCVL BVC Exp	Kochuveli	Kasaragod	11:31	1:55	11.23	51.32
18	19261	Porbandar Exp	Kochuveli	Kasaragod	11:00	20:58	9.58	58.5
19	16312	KCVL SGNR Exp	Kochuveli	Kasaragod	15:45	2:09	11.24	51.32
20	16347	Mangalore Exp	Kochuveli	Kasaragod	20.35	10.08	13.33	43.33

Source: IRCTC

5.1.9 Air

Kerala has four major international airports in the districts of Thiruvananthapuram, Kochi (Nedumbassery), Kozhikode (Karipur) and Kannur, which links this region domestically and with the rest of the world. The international airport at Kannur was recently opened, whose peak hour passenger capacity is 2000 passengers, including both international and domestic. As per the Information Memorandum prepared by SBI CAPS, the airport is expected to have an approximate annual traffic of 1.65 million International and 0.16 million Domestic passengers.

The intercity travel between the three airports (Kochi, Thiruvananthapuram and Kozhikode) account to only 4% of the total trips produced to any of the three airports. Thus, the share of air trips for the intercity travel can be considered as negligible.

5.1.10 Transport Characteristics

The newly registered motor vehicle population details, collected from Kerala Motor Vehicles Department, for the FY 2014-15 and 2015-16 are presented in Table 29. The growth in newly registered vehicles during 2015 – 2016 is 1.70%. Table 30 and Figure 7 present the growth in motor vehicles in Kerala since 2011 to 2017.

Table 29: Newly Registered Vehicles in Kerala

Vehicle Class	1st April 2014 to 31st March 2015				1st April 2015 to 31st March 2016			
Goods Vehicles	LGV	MGV	HGV	Total	LGV	MGV	HGV	Total
	18318	1756	2869	22943	17711	1909	3413	23033
Contract Carriage	LMV	MPV	HPV	Total	LMV	MPV	HPV	Total
	41771	506	488	42765	37339	548	494	38381
Stage Carriage	LMV	MPV	HPV	Total	LMV	MPV	HPV	Total
	36	12	850	898	77	82	1644	1803
Others				479				592
Total Transport Vehicles				67085				63809
Total Non Transport Vehicles				807719				796401
Total Vehicle Count				874804				860210

LGV: Light goods vehicle; MGV: Medium Goods Vehicle; HGV : Heavy Goods Vehicle; LMV: Light Motor Vehicle; MPG: Medium Passenger Vehicle; HPV: Heavy Passenger Vehicle.

Table 31 presents the district wise vehicle registration as on 31st March 2017 and Figure 6 indicates the composition of registered motor vehicles.

Table 30: Growth of Motor Vehicles in Kerala Since 2011 To 2017

Category - wise Growth of Motor Vehicles in Kerala since 2011 to 2017															
Years	Goods Vehicles		BUSES		Cars And Station Wagons			Auto-rickshaws	Scooter/Motor Cycles	Tractors	Tillers	Trailers	Others	Total	Percentage increase over the previous year
	Four Wheelers and above	Three Wheelers including tempos	Stage Carriages	Contract Carriages/ Omni buses	Cars	Taxis	Jeeps								
2011-2012	322450	128452	21457	124290	1226691	175638	73700	575763	4127227	13740	5399	2407	68325	6865539	14%
2012-2013	354296	206901	34161	137731	1358728	128250	74167	602547	5041495	14183	5399	2744	88071	8048673	17%
2013-2014	373218	140278	28386	132144	1538246	194358	73700	663241	5288529	15030	5414	2411	93011	8547966	6%
2014-2015	411347	154610	31286	145645	1702926	214214	73700	730999	5828816	15297	5967	1657	103781	9420245	10%
2015-2016	419813	136938	42707	64051	2070665	107567	0	610235	6472335	14213	187	699	232403	10171813	8%
2016-2017	438709	142792	44291	68036	2264904	118661	0	630609	7071039	14236	699	236061	0	11030037	8%
Source: Motor Vehicles Department															

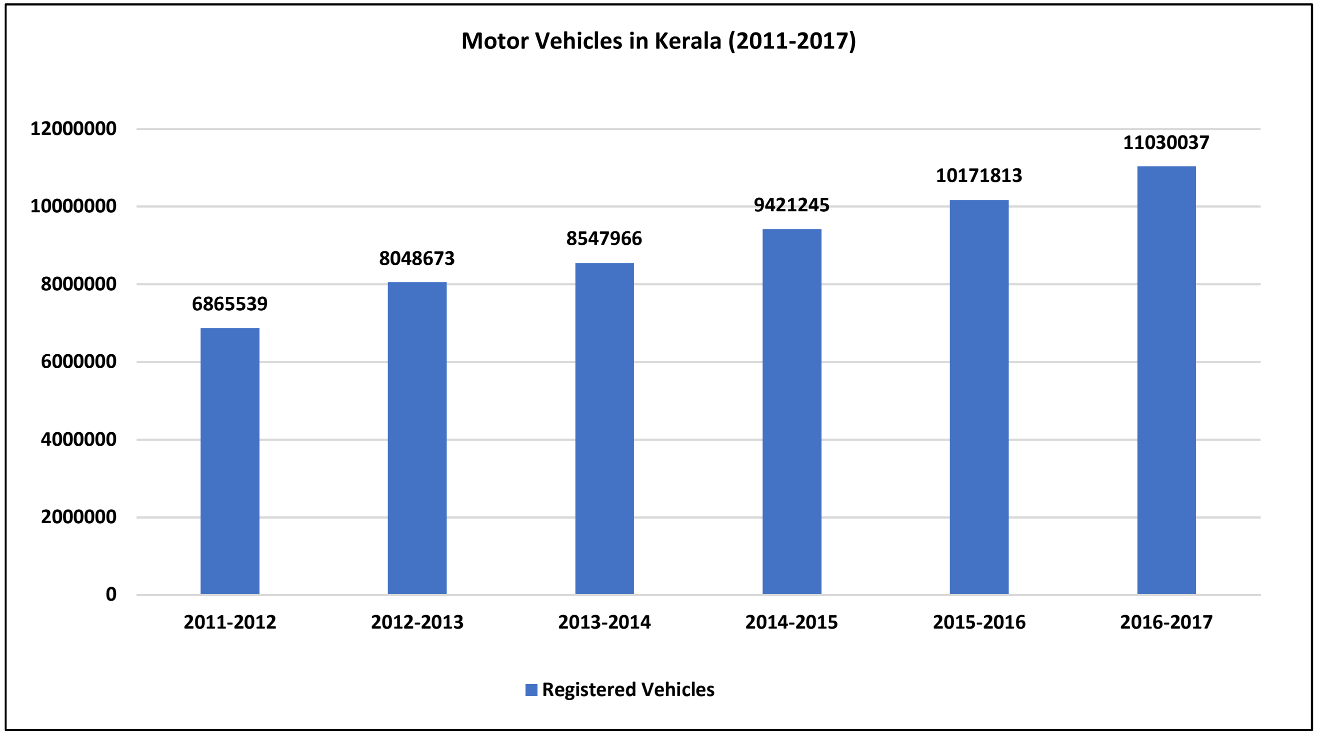


Figure 7: Motor Vehicles in Kerala

Table 31: District Wise Vehicle Registration as on 31st March 2017

S No	District	Good Vehicles		Buses		Four Wheelers		Auto Rickshaws	Two Wheelers	Tractor/Trailors			Total
		Four Wheelers and above	Three Wheelers Including Tempos	Stage Carriage	Contract Carriages/Omni Buses	Cars	Taxis			Tractors /Trailers	Tillers	Trailers	
1	Thiruvananthapuram	37928	12761	14036	10687	302946	10348	74878	911225	741	143	25397	1401090
2	Kollam	29953	9740	1293	4574	154931	6078	50941	505136	646	31	14895	778218
3	Pathanamthitta	15720	5731	728	2527	116359	5772	25496	277968	353	2	10974	461630
4	Alappuzha	27276	8930	1316	4820	128514	10370	29220	538302	672	38	13422	762880
5	Kottayam	32154	7773	2713	5335	186932	8961	42042	384341	659	34	19365	690309
6	Idukki	12424	3111	1293	1760	51454	3797	22459	115171	422	12	7632	219535
7	Ernakulam	72791	17680	4138	10732	365264	20689	59953	1081129	2119	147	40557	1675199
8	Thrissur	40086	15088	4361	8037	216252	12574	61613	768648	2160	66	21114	1149999
9	Palakkad	26593	12192	2197	4247	110921	7260	45927	519685	3244	118	12524	744908
10	Malappuram	51686	19128	3344	4927	197608	6583	78351	612807	1559	35	22907	998935
11	Kozhikode	36025	14679	3712	4108	173622	10223	53411	704832	434	35	15247	1016328
12	Wayanad	8517	3342	673	783	31412	3167	13761	89163	698	8	4692	156216
13	Kannur	35292	10399	3799	4076	151585	9365	47483	387836	299	6	16383	666523
14	Kasaragod	12264	2238	688	1423	77104	3474	25074	174796	230	24	10952	308267
Total		438709	142792	44291	68036	2264904	118661	630609	7071039	14236	699	236061	11030037
Source: Motor Vehicles Department													

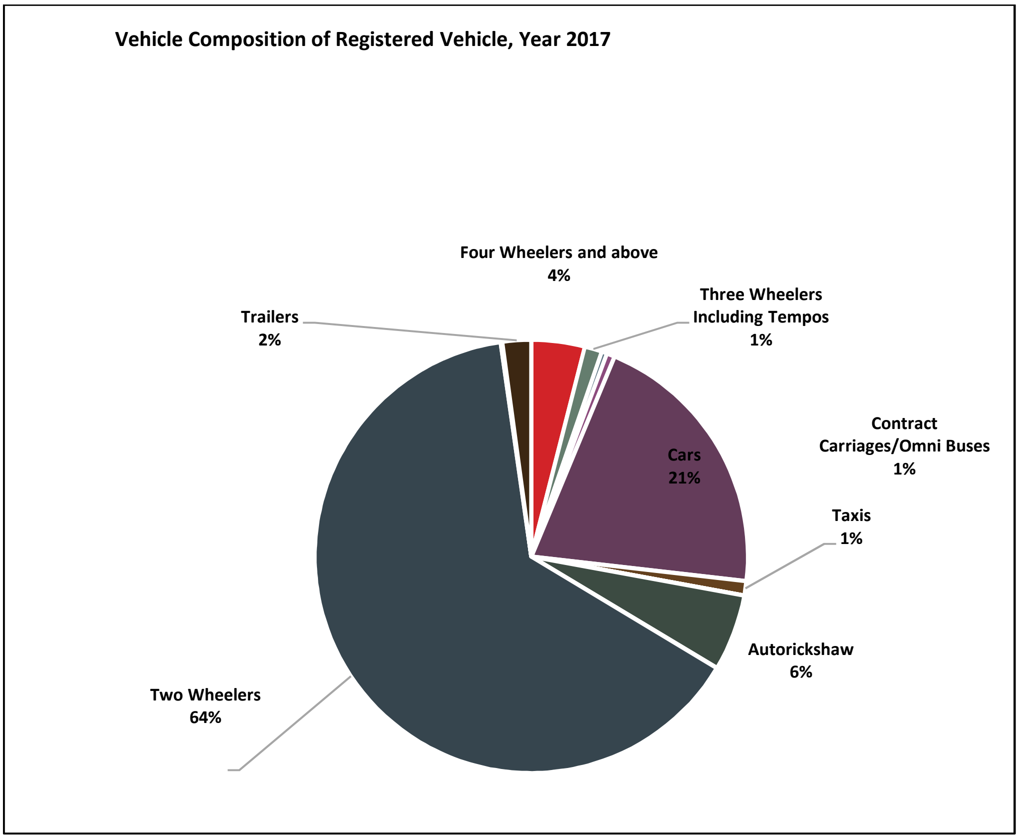


Figure 6: Vehicle Composition of Registered Motor Vehicles

5.1.11 Road Accidents

Road accidents in the state are among the Nation's highest. Kerala stands third in terms of road accidents with an average of about 4300 deaths and 45,000 injuries every year. Though Kerala accounts for only about 3% of the Indian population, it contributes to about 10% of total road accidents. Kerala was the third in comparison with other largest states like Maharashtra and Tamil Nadu in terms of road crashes and causalities.

Rapid motorization in the number of vehicles registered in the state, has created an intense pressure on the road infrastructure. In addition, the increased number of accidents in the State is also a growing concern.

Road accident remains to be the third major cause of death and disability in Kerala. In the year 2018, around 40,181 accidents were recorded which resulted in 4303 deaths and 45458 injuries. At an average, 11 people die every day in Kerala and 125 get injured in road accidents. About 45% accidents take place on National Highways and State Highways, which results in 55% of road fatalities. Pedestrians and bike users account for around 80% of road accident deaths in Kerala. The trend of road accidents in Kerala since 2001 is shown in Figure 7. District wise road accident details for year 2017 (1st January to 31st December) is presented Table 32.

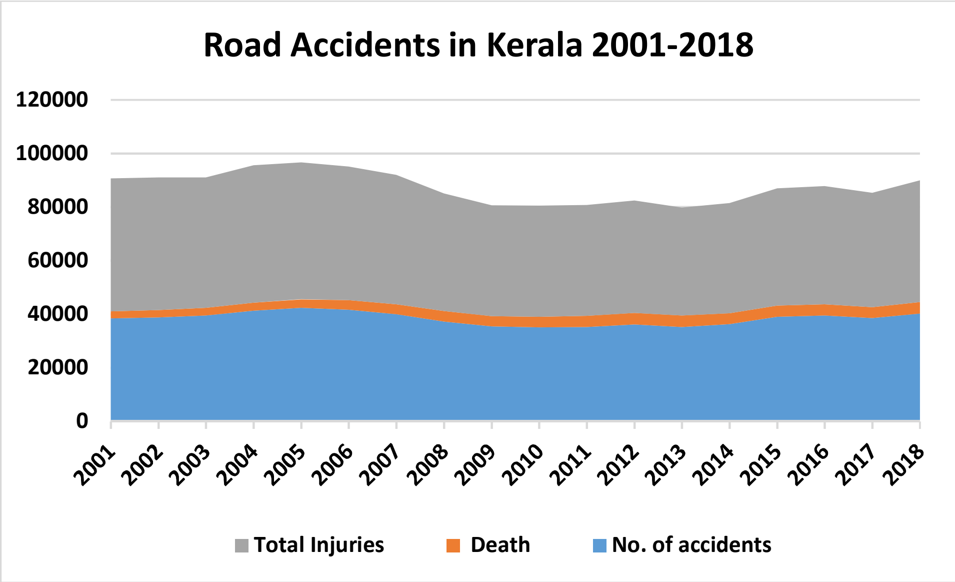


Figure 7: Trend of Road Accidents in Kerala 2001-2018

Source: keralapolice.org

Table 32: District wise Road Accident Details (Year 2017)

Details of Road Accidents In Kerala for the Period from 1st January 2017 to 31st December 2017																					
District	Number of				Type of Road			Types of Vehicles involved in the Accidents										Cauuse of Accident			During	
	Cases	Died	Gr.inju	Injured	NH	SH	OR	Kbus	Pbus	Lorry	Mini	Car	Jeep	Auto	Twlr	Other	Nkno wn	Rash	Dru	Othr	Day	Night
Thiruvananthapuram City	2113	172	1757	740	330	21	1762	100	42	35	55	679	12	349	2026	66	4	2054	11	48	1514	599
Thiruvananthapuram Rural	3146	325	2884	481	587	381	2178	144	93	74	128	753	21	417	3110	107	8	3055	0	91	2323	823
Kollam City	1780	213	1545	218	896	0	884	58	99	59	84	578	11	212	1688	135	8	1737	1	42	1243	537
Kollam Rural	1426	201	1246	343	285	200	941	68	87	63	75	388	29	225	1259	50	3	1401	0	25	1061	365
Pathanamthitta	1521	120	1293	429	0	228	1293	68	98	43	49	568	23	260	1278	64	10	1493	2	26	1187	334
Alappuzha	3114	407	2437	1074	1162	464	1488	93	135	138	163	917	12	356	3026	326	10	3066	0	48	2122	992
Kottayam	2846	277	2378	573	246	692	1908	99	225	100	136	1106	52	412	2286	119	25	2812	0	34	2156	690
Ernakulam City	2503	137	1717	883	748	286	1469	82	260	123	107	926	14	282	2216	169	10	2471	3	29	1890	613
Ernakulam Rural	3294	287	2564	959	650	756	1888	81	210	169	182	966	43	438	3134	157	5	3246	1	47	2470	824
Idukki	1105	89	796	540	217	352	536	56	85	33	56	393	113	237	741	30	5	1088	0	17	866	239
Trissur City	1384	106	967	581	106	412	866	22	169	80	54	490	11	201	1186	58	2	1367	3	14	971	413
Trissur Rural	2882	275	2291	941	826	874	1182	78	223	106	144	868	22	390	2561	211	13	2851	0	31	1954	928
Palakkad	2442	384	1508	1136	485	611	1346	34	205	174	115	653	37	369	2193	107	13	2416	0	26	1748	694
Malappuram	2339	385	1822	861	631	467	1241	59	250	225	106	825	48	421	1784	79	15	2321	0	18	1755	584
Kozhikkode City	1467	184	1068	476	396	31	1040	46	247	96	48	490	24	181	1192	45	11	1442	1	24	987	480
Kozhikkode Rural	1650	179	1338	571	521	435	694	48	209	105	67	484	57	241	1402	70	6	1640	0	10	1233	417
Wayanadu	660	68	468	290	174	223	263	31	50	31	26	216	32	126	481	23	5	658	1	1	473	187
Kannur	1862	214	1198	1242	424	364	1074	51	228	113	86	625	37	378	1318	71	5	1846	0	16	1387	475
Kasarakodu	936	108	456	600	309	246	381	34	56	73	44	370	20	156	653	31	7	930	0	6	674	262
State Total	38470	4131	29733	12938	8993	7043	22434	1252	2971	1840	1725	12295	618	5651	33534	1918	165	37894	23	553	28014	10456

5.1.12 KSRTC Bus Fleet Composition

Kerala State Road Transport Corporation (KSRTC) operates around 6500 buses in Kerala which is used by around 3.1 million people on daily basis. Table 33 and Figure 8 presents the fleet composition of KSRTC. Table 34 presents the details of each type of buses i.e. number of buses, scheduled km, passengers per day etc.

Table 33: KSRTC Fleet Composition

Bus Type	No of Buses	Percentage
City	6	0.09%
City Fast	202	3.15%
Double Decker	2	0.03%
Mini Bus	0	0.00%
Ordinary Bus	3500	54.61%
Fast Passenger	1326	20.69%
Super Fast	420	6.55%
Super Express	53	0.83%
Silverline Jet	4	0.06%
Super Deluxe	137	2.14%
Garuda	12	0.19%
Scania	27	0.42%
JNnURM A.C.	190	2.96%
JNnURM Non A.C.	529	8.25%
Vestibule	1	0.02%
Electric Buses	0	0.00%
Total	6409	100%

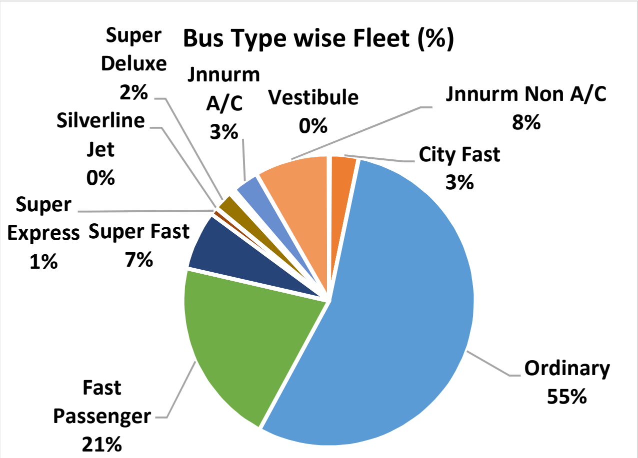


Figure 8: Fleet Composition

Table 34: KSRTC Bus Fleet Details

Bus Type	Bus Code	No. of Buses	Scheduled Kilometers per Day	Operated Kilometers per Day	Passengers per Day	Average Earning per Km (Rs.)	Average Earning per Bus per day (Rs.)
City Fast Passenger	CFP	309	41436	54452	207856	51	9011
City Bus	CTY	153	22265	22773	80154	39	5699
Fast Passenger	FP	1140	525879	516356	563507	43	19197
Limited Stop Fast Passenger	LSFP	181	88438	85677	80119	41	19203
Limited Stop Ordinary	LSOR	631	159285	173456	330322	35	9841
MULT	MULT	5	5066	4437	410	46	40049
Ordinary	ORD	2694	499191	550050	1570329	37	7514
Scania	SCAN	15	20074	19772	1958	54	71978
Super Deluxe	SDLX	59	50896	54146	17005	36	32747
Super Express	SEXP	32	23856	23886	5539	36	26243
Super Fast Passenger	SFP	249	157893	155588	105491	43	26885
Town to Town	TT	254	77610	84305	109257	35	11902
Total/Average		5722	1671890	1744899	3071945	41	23356

Source: KSRTC

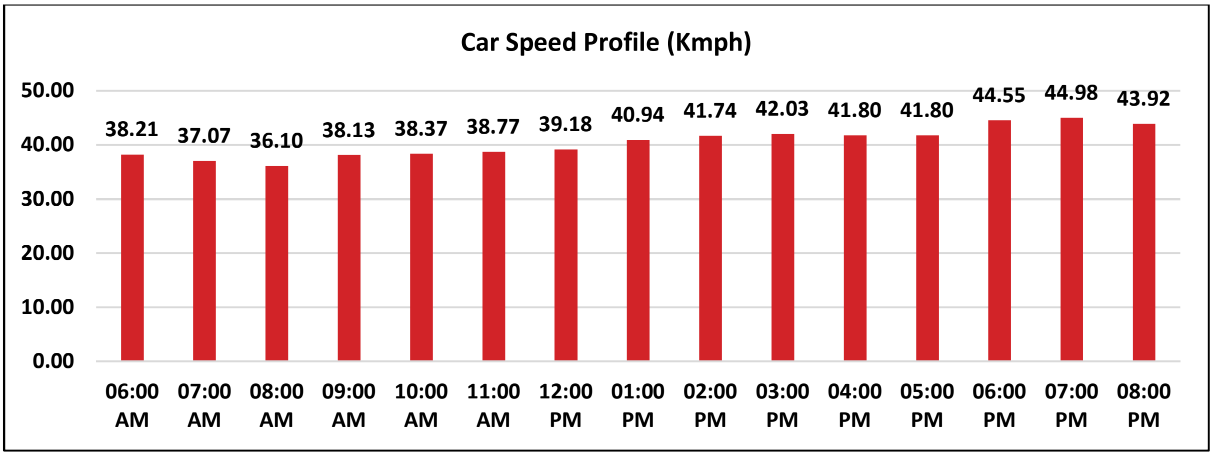
5.1.13 Speed Profile of Car

The distance between Thiruvananthapuram to Kasaragod (via NH 66) is around 556 km. The average speed of car from Thiruvananthapuram to Kasaragod, during various hours of starting time at Thiruvananthapuram, has been derived using google maps and is presented in Table 35.

Table 35: Speed Profile of Car (Thiruvananthapuram-Kasaragod)

Car Speed Profile (Kmph)																
ROUTES	DISTANCE	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM
Thiruvananthapuram to Kasaragod (Via NH 66)	556km	38.21	37.07	36.10	38.13	38.37	38.77	39.18	40.94	41.74	42.03	41.80	41.80	44.55	44.98	43.92

Graphical presentation of the same table is presented below:



5.2 Traffic Surveys Conducted by IMaCS

The following surveys were conducted by IMaCS in the year 2017, as part of the Additional Traffic and Transportation study for High Speed Rail Corridor between Thiruvananthapuram to Kannur/ Mangalore in Kerala:

- Classified Traffic Volume Count Survey including Occupancy
- Origin Destination (OD) Survey
- On-board Willingness to Pay Survey – Detailed Stated Preference Survey advocated on board deluxe buses and AC Train coaches.

5.2.1 Classified Traffic Volume Count Survey

Classified Traffic Volume Count Surveys were carried out at 11 identified locations across the study corridor. The surveys were organised during August – September 2017. The traffic count surveys were conducted on 24 hours basis for 3 days (including a weekend). Directional classified traffic volume counts were analysed by IMaCS to study Average Daily Traffic (ADT), Peak Hour Flows and Traffic Composition. A map showing the location of traffic count and OD Surveys is shown in Figure 9. Traffic Volume counts conducted at 11 locations along the project corridor provided an insight to the traffic intensity and composition on various stretches of the corridor. Table 36 presents the average 24 hours traffic volume (year 2017) observed at all the 11 locations.

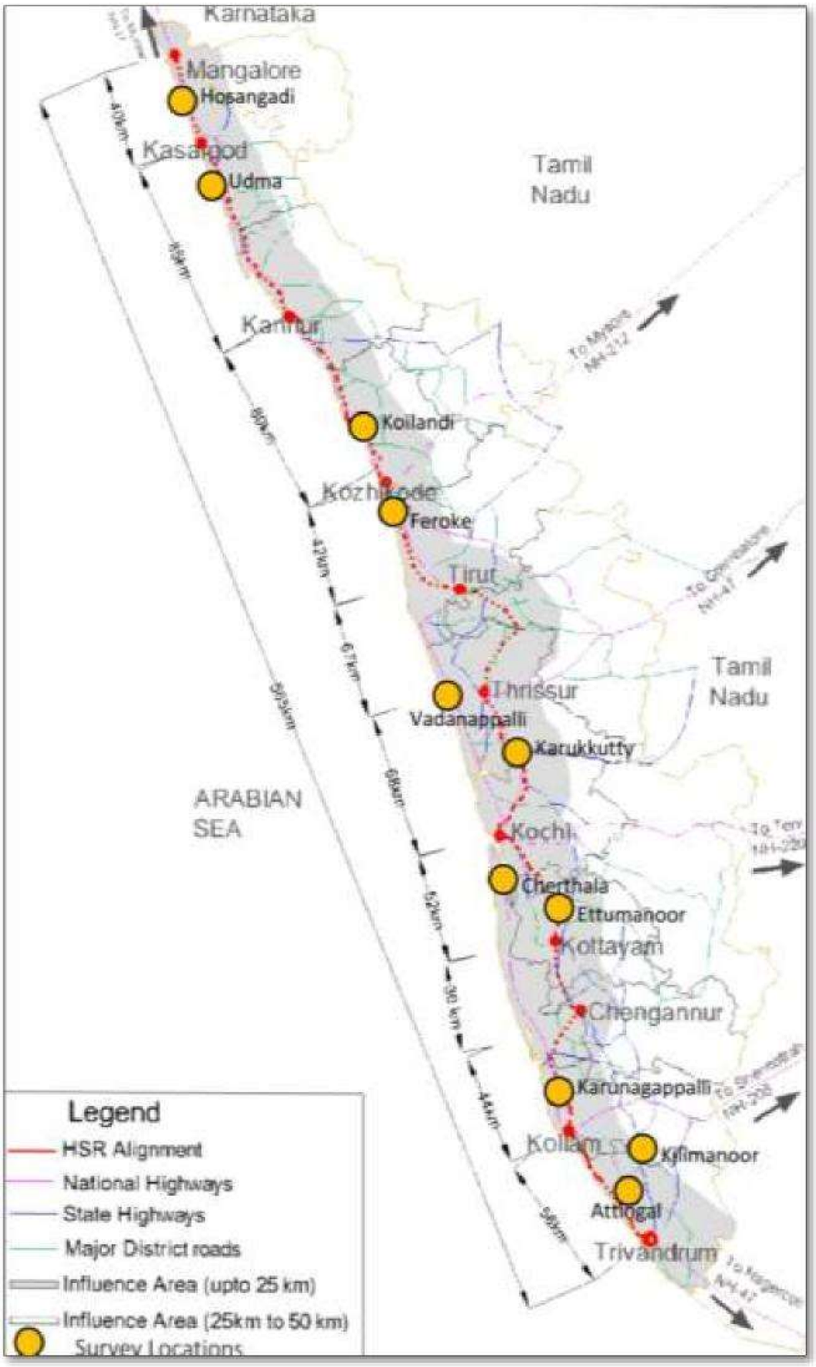


Figure 9: Locations of Traffic Volume Count and OD Surveys

Table 36: Traffic Volume Count Summary (24 hour volumes)

ID	Location Name	Road Stretch (Direction)	Direction Wise Vehicles	Total Vehicles	Direction wise PCU	Total PCU
M1	Attingal	Thiruvananthapuram to Kollam	11,252	22,205	12,172	23,913
		Kollam to Thiruvananthapuram	10,953		11,741	
M2	Killimanooor	Thiruvananthapuram to Chengannur	15,864	33,544	17,987	37,994
		Chengannur to Thiruvananthapuram	17,680		20,007	
M3	Karungapally	Kollam to Chengannur	10,318	20,574	10,946	22,250
		Chengannur to Kollam	10,256		11,304	
M4	Ettumannoor	Kottayam to Kochi	10,436	31,377	11,500	34,142
		Kochi to Kottayam	20,941		22,642	
M5	Chertala	Kollam to Kochi	12,723	26,741	14,425	30,346
		Kochi to Kollam	14,018		15,921	
M6	Karukutty	Kochi to Thrissur	17,974	34,086	18,569	35,000
		Thrissur to Kochi	16,112		16,431	
M7	Vadanapalli	Thrissur to Kozhikode	14,617	30,215	16,687	34,394
		Kozhikode to Thrissur	15,598		17,707	
M8	Feroke	Valanchery to Kozhikode	28,009	53,074	28,953	55,041
		Kozhikode to Valanchery	25,065		26,088	
M9	Koyillandi	Kozhikode to Kannur	17,546	34,894	18,965	37,951
		Kannur to Kozhikode	17,348		18,986	
M10	Udma	Kannur to Kasaragod	9,421	22,028	10,202	22,917
		Kasaragod to Kannur	12,607		12,715	
M11	Hussangiri	Kasaragod to Mangalore	10,864	22,025	11,842	23,977
		Mangalore to Kasaragod	11,161		12,135	

Source: IMaCS, December 2017

It can be observed from the above table that the highest traffic flow of 53,074 vehicles (55,041 PCUs) was observed at Feroke (Valanchery to Kozhikode-Location M8). The lowest flow of 20,574 vehicles (22,250 PCUs) was observed at Karungapally (Kollam to Chengannur-Location M3).

Annual Average Daily Traffic (AADT) was estimated considering the seasonal correction factors which are derived considering tourist traffic variation and the variation in Rail passenger data throughout the year. The estimated AADT (year 2017) is presented in Table 37.

Table 37: Annual Average Daily Traffic (AADT)

Location	Location	ADT	AADT
1	Thiruvananthapuram-	22205	21614
2	Thiruvananthapuram-	33544	32651
3	Kollam-Chengannur	20574	20027

Location	Location	ADT	AADT
4	Kottayam-Ernakulam	31377	30542
5	Kollam-Ernakulam	26741	26030
6	Ernakulam-Thrissur	34086	33179
7	Thrissur-Kozhikode	30215	29411
8	Tirur-Kozhikode	57812	56273
9	Kozhikode-Kannur	34894	33965
10	Kannur-Kasaragod	22028	21441
11	Kasaragod-Mangalore	22026	21439

Source: IMaCS, December 2017

5.3 Vehicular Composition

Classified Traffic Volume Counts also provided valuable insight into the vehicular composition of the traffic in the study area. The observed traffic composition during the survey of IMaCS is shown in Figure 11.

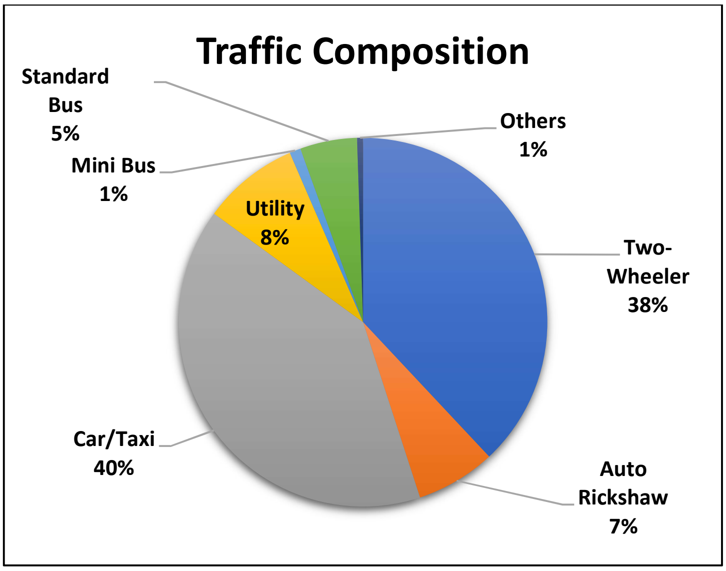


Figure 11: Traffic Composition

Vehicular composition recorded during the traffic volume count showed that majority of the traffic comprised of cars (40%) and two-wheelers (38%), while mini bus recorded the negligible share of around 1%.

5.4 Peak Hour

Table 38 shows the peak hour traffic details (year 2017) observed at all the traffic count survey locations, including their observed peak hour time, its associated traffic and the peak hour factor at the particular location. The average peak hour factor was observed to be 7.79% and the observed average peak hour PCU is 2514.

Table 38: Peak Hour Traffic characteristics

ID	Location	Road Stretch	Peak Hour			Total		Peak Hour Factor
			Time	Vehicles	PCU	Vehicles	PCU	
M1	Attingal	Thiruvananthapuram-Kollam	10:00 - 11:00	2,168	2,229	22205	23,914	9.32%
M2	Killimanooor	Thiruvananthapuram-Chengannur	10:00 - 11:00	2,197	2,542	33544	37,994	6.69%
M3	Karungapally	Kollam-Chengannur	14:15 - 15:15	1,529	1,566	20574	22,249	7.04%
M4	Ettumannoor	Kottayam-Kochi	14:15 - 15:15	1,557	1,594	31377	34,142	4.67%
M5	Chertala	Kollam-Kochi	15:30 - 16:30	2,397	2,476	26741	30,345	8.16%
M6	Karukutty	Kochi-Thrissur	11:45 - 12:45	2,332	2,370	34086	35,000	6.77%
M7	Vadanapalli	Thrissur-Kozhikode	17:00 - 18:00	2,302	2,620	30215	34,394	7.62%
M8	Feroke	Valanchery-Kozhikode	18:00 - 19:00	4,892	4,745	53074	55,041	8.36%
M9	Koyillandi	Kozhikode-Kannur	16:00 - 17:00	3,028	3,075	34894	37,951	8.10%
M10	Udma	Kannur-Kasaragod	10:00 - 11:00	2,158	2,210	22028	22,917	9.64%
M11	Hussangiri	Kasaragod-Mangalore	9:30 - 10:30	2,156	2,231	22026	23,977	9.30%
Average				2,429	2,514	30,069	32,539	7.79%

Source: IMaCS, December 2017

5.4.1 Vehicle Occupancy Survey Analysis

Vehicle Occupancy surveys conducted as part of IMaCS study, provided an insight about the number of passengers travelling by various modes at different locations. The average occupancy observed for various modes, Car, Taxi, Mini Bus and Bus was 1.3, 3.4, 12.9 and 28.5 respectively. The average mode-wise occupancy observed at the traffic count locations is shown in Table 39.

Table 39: Average Occupancy at Traffic Count Locations

Location	Fast Passenger Vehicle					Mini Bus		Buses	
	Two-Wheeler	Auto	Car/Van	Taxi	Utility	Public	Regional	Public	Regional
M1	1.61	1.7	1.55	3.5	4.37	12.97	13.82	31.51	34.6
M2	1.34	1.58	1.33	3.8	3.75	12.66	12.53	30.77	30.74
M3	1.15	1.16	1.15	2.59	2.46	8.23	7.72	19.53	19.57
M4	1.19	1.13	1.21	3.34	3.34	12.73	8.5	34.5	26.69
M5	1.34	1.34	1.35	3.83	3.82	13.67	13.73	33.12	31.63
M6	1.26	1.21	1.22	3.56	2.97	9.68	10.04	23.65	24.18
M7	1.25	1.24	1.25	3.36	3.35	11.3	9.4	27.97	27.83
M8	1.28	1.28	1.29	3.64	3.64	12.92	10.4	31.36	31.41
M9	1.16	1.14	1.16	3.21	2.47	10.18	10.5	21.94	24.86
M10	1.43	0.88	1.39	3.24	3.18	13.13	24.7	29.56	20.61
M11	1.22	1.11	1.21	3.27	3.65	11.5	32.86	34.09	37.2
Average	1.3	1.3	1.3	3.4	3.4	12.9		28.5	

Source: IMaCS, December 2017

5.4.2 Origin Destination Survey

The Origin – Destination (OD) survey was conducted by IMaCS in the year 2017 to understand the existing travel pattern on the project corridors. OD survey of the passengers was conducted at the 11 identified locations, where the Classified Traffic Volume Surveys were conducted. The study area has been divided into 92 Traffic Analysis Zones (TAZ), based on which the analysis has been carried out. The OD survey covered mainly the long-distance passengers using Car, Taxi, Mini Bus and Bus.

Based on the Origin Destination Survey and other secondary data, IMaCS have developed separate mode wise matrices for car, taxi and bus. Both car and bus passengers have been considered as potential users for HSR. In order to arrive at the target group of bus users, a factor was derived based on the Fleet composition of KSRTC as on October 2017 (refer Table 40). IMaCS have considered Super Express, Silver Line, Super Deluxe, Super-Fast, Garuda, Scania, AC, and Express Non-AC as potential users of HSR.

It is pertinent to highlight that only about 15% of the bus passengers are travelling by AC and super express services. Around 78% of the passengers are using ordinary bus services.

Table 40: KSRTC Bus Fleet Composition

S No	Category of Bus	Number	Share
1	Super Express	52	0.80%
2	Super-Fast	403	6.30%
3	Silver Line	5	0.10%
4	Super Deluxe	141	2.20%
5	Garuda	12	0.20%
6	Scania	17	0.30%
7	AC	190	3.00%
8	Express Non-AC	525	8.20%
9	Fast Passenger	1168	18.30%
10	Ordinary	3865	60.60%
Total		6378	100%

Source: IMaCS, December 2017

5.4.3 Railway Origin Destination Matrix

SHSR study area falls under the jurisdictional division of Thiruvananthapuram Zone and Palakkad Zone and the data of these two zones were collated by IMaCS and combined. The major Trip producing and attracting zones include Thiruvananthapuram, Kochi and Ettumannoor (Kottayam). The railway data was mapped to the adopted zoning system and zone wise matrix was developed. AC, First Class, Sleeper and Chair Car were considered as potential users of High Speed Rail, which constitute to about 30% of the total passengers. The existing daily rail OD between major towns as mapped to proposed HSR stations, estimated by IMaCS is 73000 in the year 2017. The proportion of rail passengers as per the category of travel is compiled by IMaCS and the same is presented in Table 41.

Table 41: Category wise Rail passengers

Type/Class	% Share
2 AC	0.13%
3 AC	0.50%
ACC	0.44%
II Exp/Mail	23.46%
II Ordinary	69.26%
SL Exp/Mail	5.94%
I Ordinary	0.24%
1A	0.01%
I Exp/Mail	0.02%

Source: IMaCS, December 2017

5.4.4 Willingness to Pay Survey

Willingness to Pay survey was carried out, by IMaCS in the year 2017, on-board deluxe buses and AC train coaches that ply on the identified study corridor. This survey was conducted to understand the user perception, travel characteristics and willingness to shift to HSR System. Using the questionnaires, the user was asked questions regarding their socio- economic characteristics and travel pattern. Designed as a stated preference survey, WTP would help in assessing the user's willingness to shift to HSR with several important factors such as Cost, Time and Frequency, that may affect the decision to choose the mode of transport for commuting. The response of the same was used for evaluating the shift to HSR from other competing modes.

The trains and buses that ply on the study corridor were identified for the purpose and surveyed. The survey was conducted, by IMaCS, at the four major stations proposed along the HSR viz. Thiruvananthapuram, Kochi, Kozhikode and Mangalore. Each Scenario in the questionnaire refers to a set or combination of Travel Cost, Time and Frequency for both HSR and the present mode, for an average trip length of 200 km. Each of the six scenarios consist of variations in Travel Time, Travel Cost and Frequency of HSR Service. The six scenarios considered for the survey are given in Table 42.

Table 42: WTP Survey Scenarios for Average Trip Length of 200 km

Scenario	Mode	Fare (Rupees)	Travel Time (Minutes)	Frequency (Minutes)
1	Bus	450	240	30
	Train	400	190	120
	HSR	900	40	5
2	Bus	450	240	30
	Train	400	190	120
	HSR	900	50	15
3	Bus	450	240	30
	Train	400	190	120
	HSR	800	45	5
4	Bus	450	240	30
	Train	400	190	120
	HSR	750	50	15
5	Bus	450	240	30
	Train	400	190	120
	HSR	1000	40	10
6	Bus	450	240	30
	Train	400	190	120
	HSR	1000	50	10

Source: IMaCS, December 2017

The user was asked to respond to the scenarios, whether under the particular scenario he/she would be willing to Shift to SHSR from their present mode. The responses were classified into distinct categories:

- Definitely travel by present mode,
- Probably Travel by present mode,
- Indifferent,
- Probably by HSR,
- Definitely by HSR,
- No response.

Table 43: Scenario wise Response – WTP Survey

Scenario	Definitely Prefer to Present Mode	Possibly Prefer Present Mode	Indifferent	Possibly Prefer HSR	Definitely Prefer HSR	No Response	Total
Scenario 1	12	9	1	0	0	0	22
Scenario 2	16	16	8	2	0	2	44
Scenario 3	16	28	13	10	7	14	88
Scenario 4	45	52	42	18	9	16	182
Scenario 5	38	61	43	13	11	56	222
Scenario 6	14	36	22	11	1	5	89
Total	141	202	129	54	28	93	647
Percentage	21.80%	31.20%	19.90%	8.30%	4.30%	14.40%	100%

Source: IMaCS, December 2017

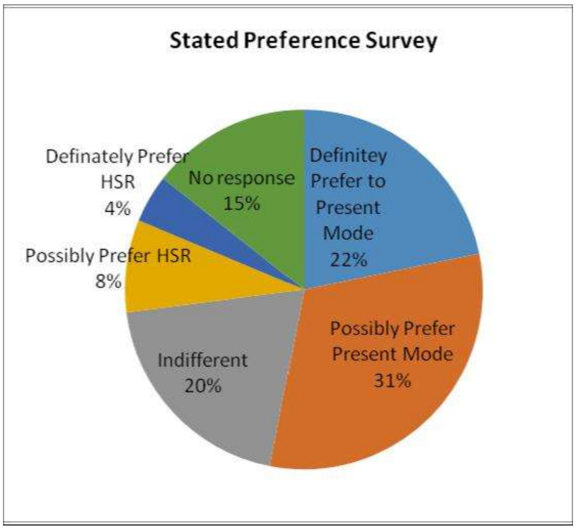


Figure 10: Stated Preference Survey Summary

Source: IMaCS, December 2017

5.5 Methodology Adopted by IMaCS for Travel Demand Forecast

It appears that the entire four stage modelling was carried out by IMaCS using the CUBE software. However, it is not very clear why Multinomial Logit (MNL) Model was used separately. MNL models are generally used to assess the probability of candidate traffic shifting to a new transport system (HSR) from their existing mode of travel. Multinomial Logit Model assess the possibility of a choice selection amongst multiples choice variables taking into consideration the utility values. In this case, the equation aims to assess the possible shift to HSR from Train, Bus & Car. The probability of shift from other competing modes is assessed based on certain study parameters. The equation used is as follows:

Pn(i) = (eVin) / (∑jeCn*eVin)

Where:

Pn (i) is probability that traveller n chooses mode i.

Utility for traveller n and mode i = Uin = Vin + εin

Numerator is the utility for mode 'i' for traveller 'n' and denominator is the sum of utilities for all alternative modes Cn for traveller n.

Utility equation:

U = a0 + a1x1 + a2x2 + .+ anxn

Where U is the utility derived, x1, x2 and xn are the attributes denoting travel and other socioeconomic parameter of travellers and 'a' denotes their respective coefficients.

The total number of potential users (candidate traffic) for HSR and the % shift, for the year 2020 as per IMaCS study is as follows;

		% Shift
Car	: 170,931	22%
Bus*	: 86,685	21%
Rail**	: 85,655	19%

* Super Express, Silver Line, Super Deluxe, Super Fast, Garuda, Scania, AC, and Express Non AC bus passenger trips were considered

** AC, FC, Sleeper Class, Chair Car and all Mail/ Express passenger trips were considered.

5.5.1 HSR Daily Ridership

The estimated daily ridership by IMaCS for the Option 2 – Thiruvananthapuram – Kasaragod is presented in the below table. The ridership corresponds to a fare of Rs 5 per km.

Table 44: Estimated Daily HSR Ridership

Horizon Year	Daily Ridership
2020	85,332
2028	1,27,556
2040	1,83,012
2051	2,33,042

Source: iMaCS Study, 2017

5.6 Preliminary Ridership Forecast

The patronage forecast presented in this section is mainly based on the earlier study reports and the traffic and other surveys carried out by these earlier studies. The patronage is estimated assuming that the alignment and stations of SHSR would be as recommended in the Detailed Project Report (DPR) for the HSR. Stated preference survey carried out by IMaCS was mainly used in assessing the preliminary ridership forecast for SHSR. The patronage forecast is primarily based on the Generalised Cost, which is well established in economic theory and used in the traffic assignment models.

- Generalised cost consists of monetary and non-monetary costs of a journey
- The generalized cost, GC, is worked out for Public Transport modes, as

*GC = Cost (Fare) + Travel time * VOT + Discomfort*

- The generalised cost, GC, is worked out for Private Vehicles (Car) as

GC = Distance Travelled x VOC + VOT x Travel Time + Discomfort

To derive the probability of shift from existing mode (i.e. Rail, Bus & Car), generalized cost of SHSR is compared with the generalized cost of competing modes. Probabilities of shift from the existing modes is calculated based on the equation below:

Probability of Shift (SHSR) =

$$GC_{CP} / (GC_{CP} + GC_{SHSR})$$

Where GC_{CP} = Generalized cost of Competing Mode

GC_{SHSR} = Generalized cost of Semi High Speed Rail

**only Bus & Rail passengers*

The potential travel demand (Candidate Traffic) for SHSR, from various modes of transport, viz. Car, Rail and Bus, between Thiruvananthapuram and Kasaragod were assessed based on the IMaCS study of 2017. The main assumptions used for the preliminary ridership forecast are:

- The alignment and stations of SHSR are more or less similar to the DPR of HSR carried out by DMRC
- Length of the corridor: 531.45 km
- Average journey speed : 130 Kmph
- SHSR Fare : Rs 2.75 per km (@ today's price level)
- SHSR considered as Intercity Service and not Commuter Service
- Headway : 60 minutes

Moreover, to understand the probability of shift of car passengers, car passenger's generalised cost has also been added to the database of IMaCS. Based on the calculations, probabilities of shift of Bus, Train and Car passengers have been derived. Mode wise shift was assessed across major competing modes as per the following:

Bus, Rail & Car - using the average shift as obtained from the model and adjusting the estimates for overall passenger trips in the study area. Using the generalized cost of travel, the probable shift from train, buses and car have been estimated. The total shift from each mode to SHSR, including induced trips, is estimated considering average fare of SHSR as Rs. 2.75 per km.

5.6.1 Ridership Forecast

Station wise boarding and alighting of passengers for the proposed SHSR, between Thiruvananthapuram and Kasaragod, is estimated considering the probability of shift from the respective mode of transport (i.e. Bus, Train & Car) and the potential (candidate) traffic estimated based on IMaCS study.

As indicated earlier, the patronage forecast is based on HSR alignment and stations (10 stations). The daily boarding and alighting at SHSR stations and the section load for horizon years 2024, 2028, 2040 and 2051 are presented in Table 45 to 48. Peak hour Section Load (PHPDT) summary is presented in Table 49.

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Table 45: Daily Ridership Forecast: Horizon Year 2024

Station Name	Boarding	Alighting	Section Load	
			Forward	Reverse
Thiruvananthapuram	14,536	13,408	0	13,408
Kollam	4,123	4,040	14,536	14,216
Chengannur	2,161	2,134	15,428	14,895
Kottayam	4,356	4,400	16,133	14,291
Kochi	12,405	12,263	15,484	15,297
Thrissur	9,063	9,161	16,632	13,967
Tirur	2,334	1,707	15,204	14,311
Kozhikode	8,591	9,797	16,175	8,474
Kannur	8,511	9,043	9,132	1,661
Kasaragod	1,661	1,787	1,787	0
Total	67,740	67,740	16,632	15,297

Source: SYSTRA Estimate, 2019

Table 46: Daily Ridership Forecast : Horizon Year 2028

Station Name	Boarding	Alighting	Section Load	
			Forward	Reverse
Thiruvananthapuram	17,997	16,283	0	16,283
Kollam	5,045	4,941	17,997	17,265
Chengannur	2,686	2,600	19,082	18,089
Kottayam	5,329	5,407	19,993	17,355
Kochi	15,105	14,976	19,182	18,577
Thrissur	11,081	11,251	20,532	16,962
Tirur	2,162	2,118	18,748	17,379
Kozhikode	10,477	11,223	19,209	10,291
Kannur	10,366	11,237	11,374	2,017
Kasaragod	2,017	2,230	2,230	0
Total	82,266	82,266	20,532	18,577

Source: SYSTRA Estimate, 2019

Table 47: Daily Ridership Forecast: Horizon Year 2040

Station Name	Boarding	Alighting	Section Load	
			Forward	Reverse
Thiruvananthapuram	26,459	23,939	0	23,939
Kollam	7,390	7,213	26,459	25,621
Chengannur	4,012	3,879	28,318	26,884
Kottayam	7,771	7,860	29,714	26,035
Kochi	22,559	22,372	28,775	27,818
Thrissur	13,753	14,276	30,746	22,851
Tirur	3,225	3,160	25,257	23,468
Kozhikode	13,132	13,988	25,938	15,341
Kannur	15,388	16,688	16,956	2,992
Kasaragod	2,992	3,307	3,307	0
Total	1,16,681	1,16,681	30,746	27,818

Source: SYSTRA Estimate, 2019

Table 48: Daily Ridership Forecast : Horizon Year 2051

Station Name	Boarding	Alighting	Section Load	
			Forward	Reverse
Thiruvananthapuram	33,377	30,198	0	30,198
Kollam	9,328	9,106	33,377	32,304
Chengannur	5,117	4,947	35,704	33,915
Kottayam	9,776	9,890	37,485	32,836
Kochi	28,324	28,086	36,292	35,097
Thrissur	17,364	18,022	38,791	28,846
Tirur	4,074	3,995	31,882	29,594
Kozhikode	16,500	17,572	32,710	19,412
Kannur	19,457	21,101	21,456	3,802
Kasaragod	3,802	4,203	4,203	0
Total	147,120	147,120	38,791	35,097

Source: SYSTRA Estimate, 2019

Table 49: Peak Hour Sectional Load (PHPDT)

Station Name	Forward					Reverse				
	2020	2024	2028	2040	2051	2020	2024	2028	2040	2051
Thiruvananthapuram	0	0	0	0	0	870	1,070	1,300	1,920	2,420
Kollam	940	1,160	1,440	2,120	2,670	920	1,140	1,380	2,050	2,580
Chengannur	1,000	1,230	1,530	2,270	2,860	970	1,190	1,450	2,150	2,710
Kottayam	1,050	1,290	1,600	2,380	3,000	930	1,140	1,390	2,080	2,630

Station Name	Forward					Reverse				
	2020	2024	2028	2040	2051	2020	2024	2028	2040	2051
Kochi	1,000	1,240	1,530	2,300	2,900	1,000	1,220	1,490	2,230	2,810
Thrissur	1,080	1,330	1,640	2,460	3,100	910	1,120	1,360	1,830	2,310
Tirur	990	1,220	1,500	2,020	2,550	970	1,140	1,390	1,880	2,370
Kozhikode	1,050	1,290	1,540	2,080	2,620	550	680	820	1,230	1,550
Kannur	590	730	910	1,360	1,720	110	130	160	240	300
Kasaragod	120	140	180	260	340	0	0	0	0	0
Total	1,080	1,330	1,640	2,460	3,100	1,000	1,220	1,490	2,230	2,810

Source: SYSTRA Estimate, 2019

Table 50 presents the summary of daily ridership and PHPDT for SHSR between Thiruvananthapuram and Kasaragod. The ridership corresponds to a fare level of Rs 2.75 per km (@ today's price level) and considering 10 stations as per DPR.

Table 50: Summary of Ridership on SHSR

Year	Daily Ridership	Maximum Section Load (PHPDT)
2024	67,740	1,330
2028	82,266	1,640
2040	116,681	2,460
2051	147,120	3,100

Source: SYSTRA Estimate, 2019

5.6.2 Fare Sensitivity Analysis

Fare sensitivity analysis is carried out for the horizon year 2024, considering different fares (i.e. from Rs 1 per km to Rs 8 per km) for SHSR. Daily ridership for each fare was estimated and corresponding annual fare revenue was calculated. Average trip length of SHSR, for the horizon year 2024 is considered as 200 km. Comparison of annual fare revenue and daily ridership for different fares is shown in Table 51 and Figure 11. From the Table and Graph, it can be observed that maximum fare revenue corresponds to a fare of Rs 2.75 – Rs 3.00 per km. Though the optimum fare for SHSR is around Rs 3.00 per km, considering the higher ridership at lower fares, the Government/ Authorities may finalise appropriate fare so that the system is effectively utilised to its full capacity.

Table 51: Fare Sensitivity Analysis

Fare of SHSR (Rs/Km)	Annual Fare revenue (Rs Cr)	Dailly Rider Ship
1.00	886	121,300
1.50	1152	105,200
2.00	1300	89,000
2.75	1362	67,800
3.00	1364	62,300
3.50	1339	52,400
4.00	1294	44,300
5.00	1179	32,300
6.00	1069	24,400
8.00	870	14,900

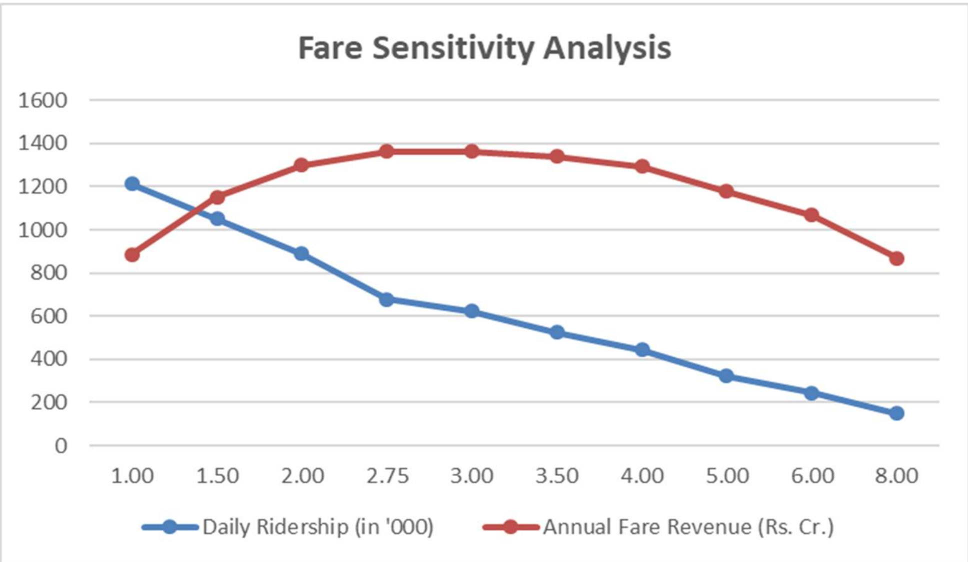


Figure 11: Fare Sensitivity Analysis

5.6.3 Concluding Remarks on Ridership Forecast

The ridership forecast provided in this chapter is preliminary and is based on the past study reports and the data collected during earlier studies. The ridership estimates and forecasts could be refined based on detailed information collected through primary and secondary surveys, including Traffic Surveys and Stated Preference Surveys, proposed to be undertaken at the DPR stage of SHSR.

5.7 Scope for further enhancement in ridership and revenue of SHSR

As part of the study, evaluation of different options that could be considered for enhancement of ridership and better utilisation of SHSR facilities has been undertaken. These are based on the various factors and options considered by other rail operators in India and abroad. Details of possible options that could be considered to increase ridership and revenue are discussed in the following paragraphs.

Since all the proposals discussed in this section need detailed studies to assess the specific demand as well as planning and design of suitable facilities, detailed viability of the proposed schemes will be carried out in the DPR stage of the project.

5.7.1 Transport Integration at SHSR Terminals

Proper transport integration measures for the passenger and goods traffic at the SHSR terminals would help to enhance the SHSR ridership and revenue, as traffic generated at various activity and economic growth centres within the influence area of the Terminals could be easily transferred to the SHSR system. SHSR terminals need to be designed to facilitate easy transfer of passengers and freight traffic to other modes of transportation.

A few of the SHSR terminals are located close to the stations of existing North- South broad gauge rail line connecting Thiruvananthapuram and Kasargode, ensuring easy transfer facilities. In the case of SHSR terminals located away from the existing rail stations, detailed plans will be worked out to provide connectivity through suitable public transportation system, details of which will be provided in the DPR.

Apart from Thiruvananthapuram and Kochi, other airports in Kerala are located away from the SHSR main terminals. It is very important to provide fast and efficient transportation system connecting these airports and the SHSR terminals so that people travelling to Kerala could use any of the airports and reach their final destination city within a short time using the SHSR system. This in turn would increase the patronage of the SHSR system. In the case of Kochi Airport, direct connectivity from Airport to SHSR system is possible by developing Aggregate Stations near Nedumbassery Airport and providing suitable people mover system connecting the Airport and Aggregate Station. Public transport system like LRT or BRT could be considered for connecting Kozhikode and Kannur airport to the SHSR system.

On similar lines, proper transport integration measures need to be designed to facilitate easy transfer of bus passengers through modifications in the bus routing plans, to provide linkages to the SHSR terminals.

Taking into consideration the possibility of introducing RORO service and Parcel service, suitable loading and unloading bays for the goods vehicles need be incorporated in the design of SHSR terminals. Segregated entry and exit routes for the goods vehicles will also be considered to minimise conflict with passenger traffic, based on availability of land. The integration measures proposed for the private passenger vehicles are discussed in the next paragraph.

5.7.2 Provision of Park and Ride Facilities at Terminals

Private vehicle users are a major component of the SHSR ridership demand and adequate facilities need to be provided to these intercity passengers. Kerala state being an urban-rural continuum, there would be drastic changes in the outlook of the public, regarding their place of residence and place of work, once the SHSR system is made operational. Since intercity travel could be made with ease and comfort, more work places and business parks would be created in hitherto underdeveloped areas, away from the city centres, within the influence area of SHSR terminals. Also many people would prefer to stay away from their work centres in unpolluted environments, so that they could use the SHSR system to travel long distances in short time at relatively low cost.

These intercity commuters in SHSR need suitable facilities at the terminals and on-board, to make their travel in SHSR an enjoyable experience. The provision of park and ride facility at the terminal is an essential element in increasing the patronage so that they could have a comfortable last mile connectivity to their home/ work centre. In case there are constraints in developing the park and ride facilities within the terminal premises, provision of park and transfer facility as well as multi-storeyed parking garage could be developed at reasonable distance from the terminal based on the demand for parking. Electric vehicles including driverless vehicles could be operated from these parking garage to the SHSR terminal free of cost by KRDCL, to transfer the private vehicle passengers to SHSR system.

Moving forward most of the last mile connectivity could be through electric vehicles. To promote the green vehicle, adequate facilities, including charging and parking facilities for the electric vehicles, will be included in the SHSR terminal design.

5.7.3 Introduction of RORO facilities and Parcel Services

Out of several means of transportation such as road, rail, water and air; road and rail have proven to be responsible for moving maximum volume of cargo throughout India. While the railway traffic share in 1950-51 was tremendous 80%, roadways managed to take over 65% by 2011-12. National Transport Development Policy Committee predicts that the projection of freight movements by road vs. rail transportation would be 50:50 by 2031-32, as compared to the scenario of 65:35 in 2017. There is an assumption of 15% increase in railway transportation within the next 15 years, which is focused to reduce environmental pollution and encourage green transportation. This will impel logistics industry to take up the rails and water as more eco-friendly transportation modes.

Considering the vision of National Transport Development Policy Committee, KRDCL will try to contribute in the promotion of environmentfriendly transportation of freight through RORO facilities and parcel services. This will also facilitate better utilization of SHSR infrastructure. The viability of introducing RORO transportation facilities and Parcel Services at selected terminals will be evaluated.Details of type and volume of cargo that could be considered for parcel services will be assessed based on secondary data on parcel services and through sample survey of freight forwarding agencies.

Preliminary cost-benefit analysis of transportation of goods vehicles through the RORO facilities showed that there will be marginal reduction in operational cost for long haul goods vehicles, especially for vehicles travelling from Thiruvananthapuram to Kasargode and beyond, when the fares charged by the Konkan railway for RORO services were used as the basis of comparison. Apart from operational cost, there will be considerable savings in travel time, accident, pollution and congestion costs.

Number of trucks likely to be transported through RORO freight services will be estimated based on sample survey of truck operators in Kerala. Detailed studies will be carried out in the DPR stage to establish the technical and financial viability of introducing RORO services, both from the KRDCL and freight transport operators point of view, based on the demand, cost and system capacity.

5.7.4 Operation of Tourist Train Circuits

Kerala, the God's Own Country, is a major tourist attraction for both domestic and foreign tourists. Growing at a rate of 13%, the tourism industry is a major contributor to the state's economy.
The proposed SHSR system will connect most of the major tourist centres in Kerala and will provide a convenient and fast mode of transport for both domestic and foreign tourists. Kerala is well known for its beaches, backwaters in Alappuzha and Kollam, mountain ranges and wildlife sanctuaries. Other popular attractions in the state include the beaches at Kovalam, Varkala, Kollam and Kappad; backwater tourism and lake resorts around Ashtamudi Lake, Kollam; hill stations and resorts at Munnar, Wayanad, Nelliampathi, Vagamon and Ponmudi; and national parks and wildlife sanctuaries at Periyar, Parambikulam and Eravikulam National Park. The "backwaters" region—an extensive network of interlocking rivers, lakes, and canals that centre on Ashtamudi Lake, Kollam, also see heavy tourist traffic. Heritage sites, such as the Padmanabhapuram Palace, Hill Palace, and Mattancherry Palace, are also visited. The city of Kochi ranks first in the total number of international and domestic tourists in Kerala.
Taking into account the great potential to tap the tourism travel potential in Kerala, KRDCL could consider operating Tourist Trains, connecting many of the tourist centres in Kerala, similar to the 'Royal Rajasthan on Wheels'.
Detailed studies need to be conducted to identify the travel demand of both domestic and foreign tourists in Kerala, along with the major tourist centres visited in Kerala and duration of stay, and willingness to travel in the tourist train. Based on the travel demand to various tourist destinations, alternative tourism circuits could be worked out for operation of Tourist Train. The financial viability of the proposed Tourism Circuit train also needs to be established.
If found a viable proposition, the tourist train will help in better utilisation of the available facilities and increase the revenue generation potential of SHSR, apart from creating a branding image for SHSR system both in the domestic and international transportation market.

5.7.5 Introduction of Aggregate Train Services

Another innovative way of increasing the ridership and better utilisation of SHSR facilities is to operate short distance Train Services between the SHSR terminals, with stops at two or three major traffic generating towns. These trains will be operated among the possible 9 blocks of stations, prior to the arrival of scheduled SHSR trains at the stations. For example, aggregate train service could be operated between Thiruvananthapuram and Kollam, with possible stops near Attingal, Varkala/Paripally or Chathanur, in between the regular service schedule of Thiruvananthapuram- Kasargode SHSR.
The objective of operating these services is to provide easy accessibility to the passengers at the intermediate stations, to that of the SHSR system. This would enhance the market share of SHSR due to the reduction in the travel time and the ease of interchanging to the main system, for larger population unserved by the SHSR directly.

Based on assessment of population and economic activities of Municipal and Census towns along the proposed alignment of the SHSR, possible towns that could be considered for developing Aggregate stations between the major Terminals of SHSR will be identified.
Detailed studies need to be carried out to assess the exact location for developing the Aggregate stations at the identified towns based on site surveys, availabilty of land and accessibility. Also, the the traffic demand from the intermediate stations and the willingness of passengers likely to use these services need to be assessed based on secondary and primary data. Similarly from the supply side, detailed analysis needs to be carried out to ascertain the viability of operating such services and the cost involved.

5.7.6 Viability of long distance passengers using SHSR for part journey

There are many long distance inter-state passengers travelling to different parts of the country from major stations in Kerala. Many of these passengers can reduce their travel time, if they make the initial part of the onward journey from Kerala or the final part of their return journey to Kerala by SHSR. The benefit will be more for passengers travelling through Konkan line from Thiruvananthapuram onwards. For passengers travelling to Chennai, Bangalore, Hyderabad and beyond, there could be travel time savings for passengers travelling from certain stations.
These passengers will have the disadvantage of multiple transfer and increased waiting time at the interchange stations. The difficulty will be more for elderly passengers and passengers travelling with luggage.
The viability of long distance passengers using SHSR for their part journey needs to be established, considering the percentage of passengers likely to make such transfers based on threshold travel time savings and willingness to transfer.

5.7.7 Connectivity between SHSR and major economic centres

The direct and indirect effects of SHSR infrastructure will have a positive impact on the economic growth and development of the region and State. Apart from providing fast and improved accessibility, the project will have multiplying effect on the economy of the state. It will bring along trade and investment opportunities to the underdeveloped regions of the State. It will also provide access to goods, services, and employment opportunities in these regions through the multiplier effect. Thus the development of the SHSR will trigger lot of economic growth centres all along the corridor, apart from the land parcels developed by KRDCL, as part of making the project financially viable.
It is important to identify the existing major economic growth centres as well as major developments envisaged in the future. Major development proposals listed out in the city improvement plans and by different development agencies like KSIDC, KINFRA, KIIDC, KIF, etc.,within the influence area of SHSR, need to be studied in detail, so as to understand the location and type of developments coming up in future and provide suitable transport connectivity from the nearest SHSR terminal. As part of the study, preliminary information on some of the proposed major developments in different districts of the state have been compiled based on secondary information collected from various development plan reports and the same is presented in below table. The list may not be exhaustive but will be updated based on more detailed information compiled during the course of the study.
Details of the existing transport connectivity to these growth centres will be identified and information on the missing linkages as well as improvements required in the existing linkages will be identified. Based

on the traffic generation potential of these growth centres suitable transportation facilities will be planned to provide easy accessibility and transfer to SHSR system.

Table 52: Details of Industrial/ Infrastructure Development Projects Planned in Kerala

Sl. No.	District	Project	Location	Area	Unit	Implementing agency	Investment (Rs. Crores)
1	Thiruvananthapuram	Life Science Park	Thonnakkal	125	acre		301
2	Thiruvananthapuram	Downtown project	Technopark	4,500,000	sqm		2,000
3	Thiruvananthapuram	Shopping Mall of Lulu	Aakkulam	110,000	sqm	Private	2,000
4	Thiruvananthapuram	ICTT	Vizhinjam			Private	8,000
5	Thiruvananthapuram	Waterway Development	Paravathy puthanar				333
6	Thiruvananthapuram	Technocity	Pallippuram	390	acre		5,000
7	Thiruvananthapuram	Technocity Phase	Kazhakkoottam	10	acre		
8	Thiruvananthapuram	Light Metro	Thiruvananthapuram			KRTL	4,219
9	Thiruvananthapuram	Global Ayurveda Village	Thonnakkal			KINFRA	33
10	Kollam	Design factory for promotion of MSE	Punalur	60,000	sqf	KINFRA	
11	Kollam	Technopark	Kundara	44	acre		
12	Alappuzha	Backwater tourism	Alappuzha				72
13	Alappuzha	MEGA FOOD PARK	Alappuzha	68	acre		130
14	Alappuzha	Beach development	Chethy				42
15	Ernakulum	Design factory for promotion of MSE	Mazhavannoor	150,000	sqf	KINFRA	140
16	Ernakulum	Technology Innovation centre	Kalamasserry KINFRA hi-tech park	125,000	sqf		32
17	Ernakulum	Tourism development project	Bhoothathankettu				
18	Ernakulum	Purified water plant	Malankara Dam site				
19	Ernakulum	Petrochemical and Pharma Park	Kochi	600	acre		1,264
20	Ernakulum	Cancer centre	Kochi				310
21	Ernakulum	Waterway Development	Ernakulum			KSINC	1,364

Sl. No.	District	Project	Location	Area	Unit	Implementing agency	Investment (Rs. Crores)
22	Ernakulum	Electronic manufacturing cluster	Kochi			KINFRA	156
23	Ernakulum	Exhibition cum convention centre	Kakkanad			KINFRA	71
24	Ernakulum	INKEL city	Angamaly	30	acre	INKEL	
25	Ernakulum	Multi product and services park	Angamaly	23	acre	INKEL	
26	Ernakulum	Edu health city	Panakkad	183	acre	INKEL	
27	Ernakulum	National University of Advanced Legal Studies	Ernakulam	10,370	sqf		
28	Idukki	Design factory for promotion of MSE	Nadukani	120,000	sqf	KINFRA	
29	Idukki	Design factory for promotion of MSE	Rajakumari	60,000	sqf	KINFRA	
30	Malappuram	Tourism development project	Chamravattom reservoir				
31	Malappuram	Cancer centre	Malappuram				170
32	Malappuram	SME park	Panakkad	40	acre	INKEL	
33	Palakkad	Design factory for promotion of MSE	Ottappalam	125,000	sqf	KINFRA	
34	Palakkad	Solar P V Floating Park	Malampuzha				
35	Palakkad	MEGA FOOD PARK	Palakkad			KINFRA	121
36	Palakkad	Defense park	Ottappalam			KINFRA	232
37	Kozhikode	Shopping Mall of Lulu	Mankavu	10	acre		1,000
38	Kozhikode	Light Metro	Kozhikode			KRTL	2,509
39	Kozhikode	Advanced Tech Park	Ramanattukkara	80	acre		
40	Kannur	Design factory for promotion of MSE	Thalasserry	60,000	sqf	KINFRA	
41	Kannur	Port development	Azheekkal Port				496
42	Kannur	IT Hub and Park	Panayathamparambil				

Sl. No.	District	Project	Location	Area	Unit	Implementing agency	Investment (Rs. Crores)
43	Kannur	Handloom cum International Exhibition centre	Thazhe Chovva spinning mill				
44	Kannur	Modern international sports complex	Malikapara mbil				
45	Kannur	New International convention centre	Chelora				
46	Kannur	Film Institute and Editing Centre	Elayavoor				
47	Kannur	Fish Research centre with farming	Aayikkara				
48	Kannur	Tourism development project	Payyambala m,				
49	Kannur	Tourism Development project	Pulluppikad avu,				
50	Kannur	Tourism development project	Vaaram kadavu				
51	Kannur	Tourism development project	Thottada beach				

All the above options detailed out in this section along with suitable transport policy measures to promote public transportation will help to enhance the ridership and revenue of proposed SHSR system apart from speeding up the economic development of the region and state.

6. BASIC DESIGN PARAMETERS

Since Indian Railway is yet to evolve standards for SHSR Lines, following design parameters (for Standard Gauge, 1435mm) as shown in the Table 57 below have been adopted for checking the Feasibility of the Semi High Speed Corridor on the basis of standards prevalent on the major railway systems outside India in Europe, USA, China and Japan. Following are some of the references:

- KRDCL's letter no. P.4005/KRDCL/2018 dated 29.03.19
- Track Alignment Design Parameters- Part 1 (European Standard, EU13803-1-June 2010)
- Technical Memorandum: Alignment Standards for Shared Use Corridors TM 1.1.6
- Commission Regulation (EU) No. 1299/2014 for interoperability

For the feasibility study for semi high-speed rail corridor, Standard Gauge has been adopted for a standalone project as per directions from KRDCL being the project as standalone system.

Table 53: Basic Planning Parameters

Sl. No.	Parameter	Value
1	Maximum Speed	Design Speed - 200 kmph for Passenger Train
		120 - 160 kmph for Fast Freight
2	Maximum Static Axle Load	17 - 19 Tonnes for Passenger Train
		22.5 Tonnes for High Speed Freight (120 - 160 kmph)
3	Spacing of Tracks	4.5m
4	Width of Rolling Stock	3.4m
5	Gradient	
	Ruling Gradient	1 in 60 (Max continuous grade to be limited to 6Km)
	Limiting Gradient	1 in 50 (Restricted to ramping in tunnel approaches or extreme site constraint locations only) (Max continuous grade to be limited to 3Km)
	Station Yards	1 in 650 maximum for At grade stations (to be verified again before execution) 0% (Level) for Elevated stations
6	Turn-outs for Main Line	1 in 16
7	Horizontal Curves	
	Minimum permissible Radius	1850m
	Limiting radius for Station approaches	650m restricted to 2km length
8	Maximum Cant	160mm
	Maximum Cant Deficiency	100mm 240mm for tilting coaches @ 250Kmph
	Maximum Cant Excess	100mm (To be re-verified when Goods trains are introduced)

Sl. No.	Parameter	Value
9	Vertical Curves	
	Desirable Radius	14000m or above
	Limiting Radius Vertical curve length	8000m 20m minimum
10	Width of Formation	12m
11	Right of Way	18m - 25m
12	Tunnel Cross-Section Area	76m² (Width 12.75m), (Height 9.5m)
13	Desirable minimum Gradient in Tunnels and Cuttings (with summit curve for drainage)	1 in 400
14	Clearance Below Viaducts	5.5m/3.6m
15	Platform Length	410m
16	Type of Traction	25KV AC 50Htz
17	Type of Train	(a) EMU Train Set with 50% - 75% Motoring Axle (b) Loco Haul Freight Train
18	Type of Signaling	ERTMS-2 with GSM-R

6.1 Track and Line Structural Systems

Planning of the civil engineering system of the project is all about creating the various components like bridges, viaducts, embankments, track, yards and station buildings for the project. The purpose shall be to build these structures in the most efficient, safe, sustainable, and environmentally friendly way possible. Effort is made in this report to make sure that these structures are made to cater to the serviceability, quality and maintainability and in general of value in return for money spent on the project. More specific design information will be developed during the Detailed Project Report (DPR) stage to support equipment and construction specifications.

6.1.1 Ballasted and Ballast Less track:

Its is obvious that the construction cost of ballasted track is less as compare to the cost of the ballast less track but Ballast less track has many other advantages also. The cost in Pre-feasibility Report of 18.03.2019 was on the basis of adoption of ballasted track in all sections except the tunnels. KRDCL while communicating the comments / observations on the Prefeasibility Report dated 18.03.2019 vide their letter no. No. P.4005/KRDCL/2018 dated 25.03.19 has raised the issue of maintainability of ballasted track as well as resonance vibratory effect in the speed range of 200-250Kmph in case of ballasted track is adopted on the viaducts. KRDCL has advised that expert opinion to be obtained on the issue. The issue is important and needs to elaborated in view of the Geology and climatic conditions of the Kerala State. Best suited option will be adopted after due diligence however at this stage the cost has been estimated based on adoption of ballasted track in all sections except the tunnels, which may have to be revised as per decision later during DPR or execution stage.

6.1.2 Track

In view of the above, as of now ballasted track is considered except for tunnels for estimate purpose, which will require to be revised as per decision later during DPR or execution stage. The system proposed is double line track with Standard Gauge 1435mm on PSC sleepers with approved fitting embedded in ballast over designed formation for Embankments and Cuttings and viaduct. The dynamic gauge works out to 1507mm (1435+72).

- RAILS

60 E1 head hardened (UIC 60),1080 Grade Rails continuously welded with elastic fastenings for the Main lines and Running lines and 60E1(UIC 60) ,880 Grade Rails for depots and other sidings.

- SLEEPERS

The sleepers proposed for the track is 2.60 m long PSC Standard Gauge at 600 mm c/c. PSC sleeper for standard gauge will be designed by MRT's laid principle guidelines of Indian Railway and the same shall be approved by competent authority.

- BALLAST

Basic Quality Ballast should be hard durable and as far as possible angular along edges/corners, free from weathered portions of parent rock, organic impurities and inorganic residues crushed from Preferably Igneous rock. Ballast should be cubical in shape as far as possible. Ballast shall preferably be machine crushed.

6.1.3 Physical properties.

Ballast sample should satisfy the following physical properties in accordance with IS:2386 Pt. IV-1963 when tested.

- **Issue of Drainage:** Good drainage gains importance due to higher speed of the trains and high rainfall in the state. The monsoons shall create problems of flooding if the low-lying lands are filled up for the project. The continuous embankments and viaducts along the corridor shall collect a lot of rain water like an umbrella and these needs to be properly drained out.
  One way to mitigate this problem would be to make water bodies like small ponds along the corridor, like the temple/*kaaavu* ponds Kerala had in the near past. In addition to these, proper drainage in all cross sections are provided to drain these storm water to nearby water bodies. A proper drainage system has to be planned for the project later, before the construction phase.

- **Right of way (ROW):** The issue of land acquisition is another important issue which is reflected in the optimum Right of way (ROW) proposed in this Feasibility report. As result of the land reforms, the land holdings are distributed among a vast population of the state. This coupled with the high population density has resulted in the marginalization of land which is unique to Kerala. In other states, the typical scenario are the villages surrounded by vast flat agricultural lands, where the alignment engineering is not technically tested. That model will not work in Kerala conditions.

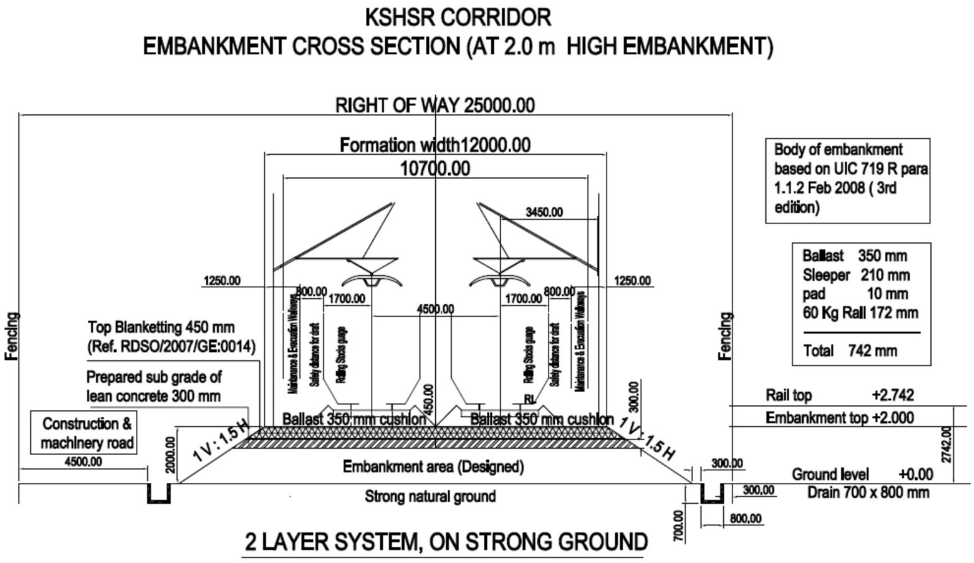
The average land holding size is smallest in Kerala. Marginal farmers with an area less than one hectare and dominated by home stead farming of 10-20 cents is a special characteristic of Kerala. So, acquisition of land for any project usually leads to total relocation of households resulting in resistance to acquisition, high land cost and rehabilitation cost. To mitigate this problem, it is proposed to restrict 25m ROW for embankments and cuttings and 15 m ROW for viaducts with 10m extra space during construction.

- **Road for Construction and Maintenance:** Side road are required during the construction and maintenance of the corridor and will become essential in case of an accident along the corridor. So, road width not less than 4.0 m is considered in the cross section to provide single lane road. Though roads on either side of the cross section are ideal, this will increase the land required for the project but is avoided to reduce the land cost. It is also a fact that Kerala is having a lot of village and city road network and hence road on one side shall suffice.

- **Arriving at the right mix of alignment choice- grade/ elevated/ tunnels corridor:** This issue is an offshoot of the Physiography of Kerala. There could be more than one alignment solution consequent to the topography of this corridor. Arriving at the right mix of choice of grade/ elevated / tunnel corridor is the major challenge as it is linked to cost, safety and technology requirements. The solution shall be to arrive at the optimum solution considering the possible risks like flooding, landslides etc. It is the consultant's opinion that the alignment proposed meets mitigation of these possible risks and also shall also be the cheapest proposal. Notwithstanding all these, a robust RAMS (Reliability, Availability, Maintainability and Safety procedure) shall be proposed for the construction and maintenance of the corridor before the construction stage.

- **Standard Cross sections:** The tentative cross sections of the various structural components for this corridor have been prepared to assess the realistic cost at this stage. In stretches vulnerable to ponding and water logging during the monsoon rains, special ground strengthening measures shall be necessary regarding which further studies shall be carried out at the DPR stage.
- **Embankment Cross sections:** The tentative cross-sectional profile used for this feasibility report is given below, with the estimated cost for each based on DSR 2016 and with 47.5 cost index.

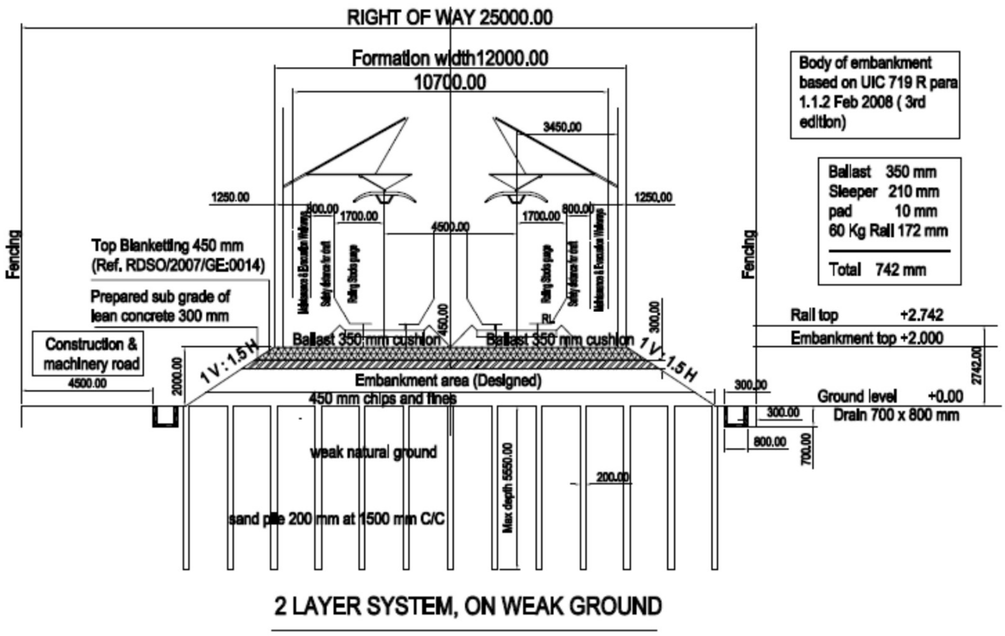
- **Embankment 2 m high on strong ground:** 2 m high embankment shall be the least height embankment for the corridor. This shall be used on good stable ground. Drainage and road width on one side is given as described earlier.



Embankment, 2 m high on strong ground

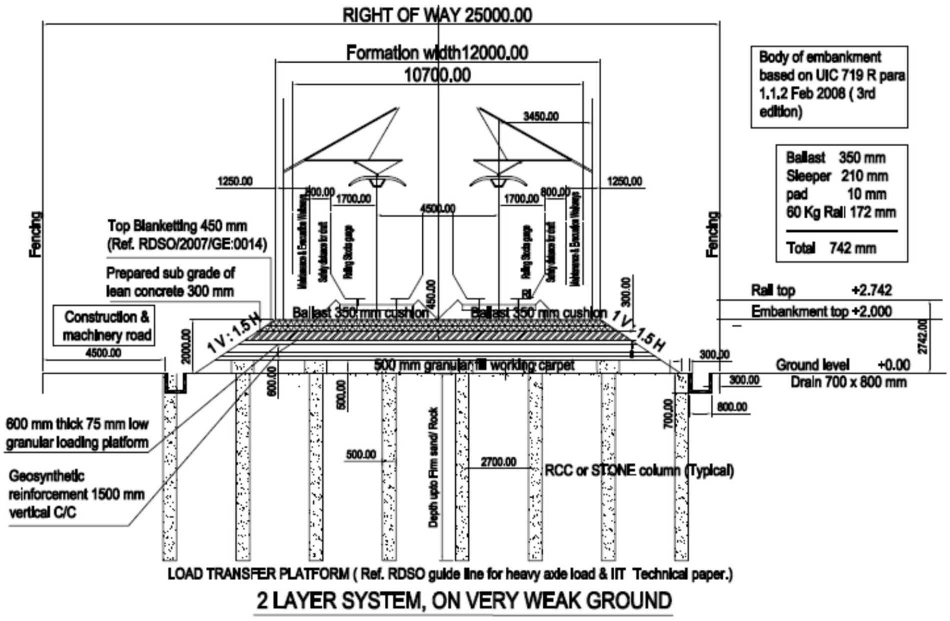
Source: Study Team

- **Embankment 2 m high on weak ground:** Here soil stabilization with sand pile is proposed as per the soil stabilization concept plan.



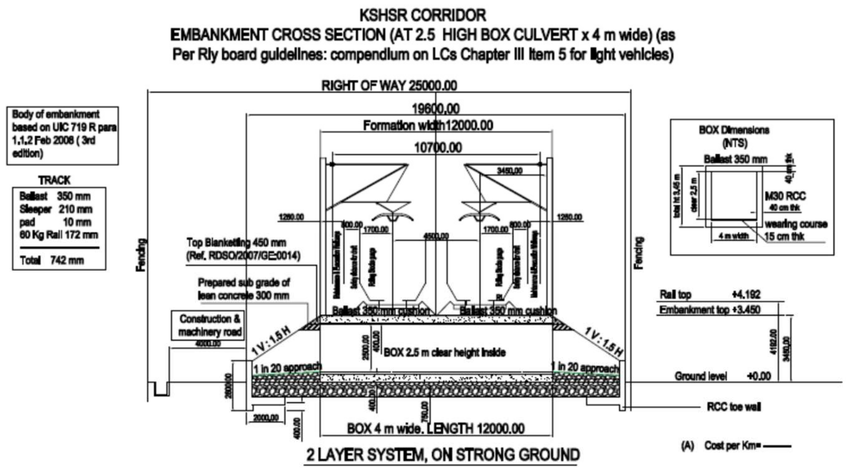
Embankment 2 m high on weak ground

- **Embankment 2 m high on very weak ground:** Here soil stabilization is proposed with stone column with loading frame.



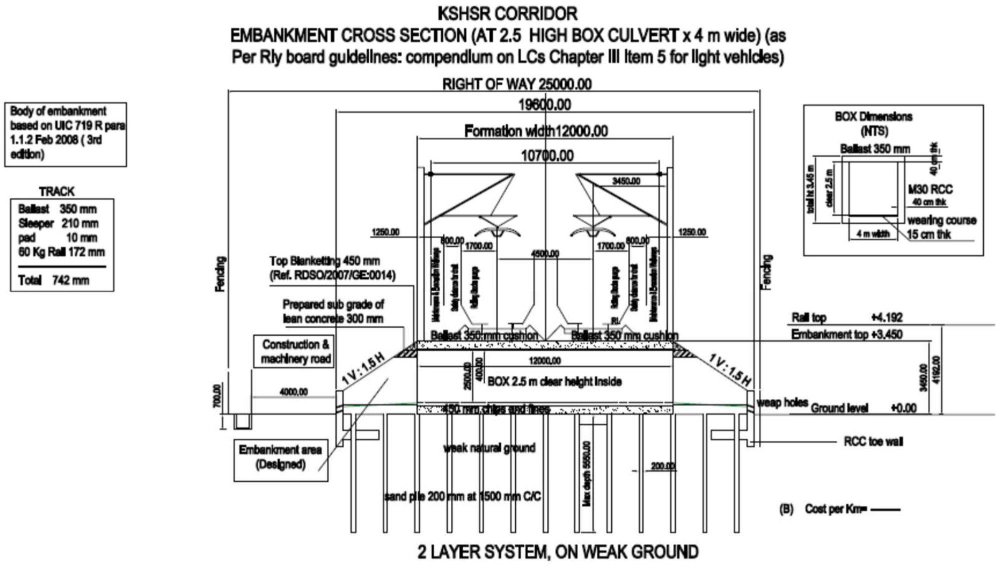
Embankment 2 m high on very weak ground

- **Embankment with 2.5 clear box, to be provided at every 500 m along the corridor:** The corridor is to be fenced for safety of trains and the public. So, corridor crossing is ensured, whether approach road is available or not, by providing BOX 2.5 clear at every 500 meters. 2.5 m clearance is provided to clear an ambulance but the final clearance height shall be fixed in consultation with the local bodies and state government, based on the Railway experience.
  Where the semi high speed corridor is laid adjacent to the existing conventional Indian Railway track, provision of these crossing boxes shall be done in consultation with the Indian Railways as it could result in unauthorised crossing over the conventional rail track.



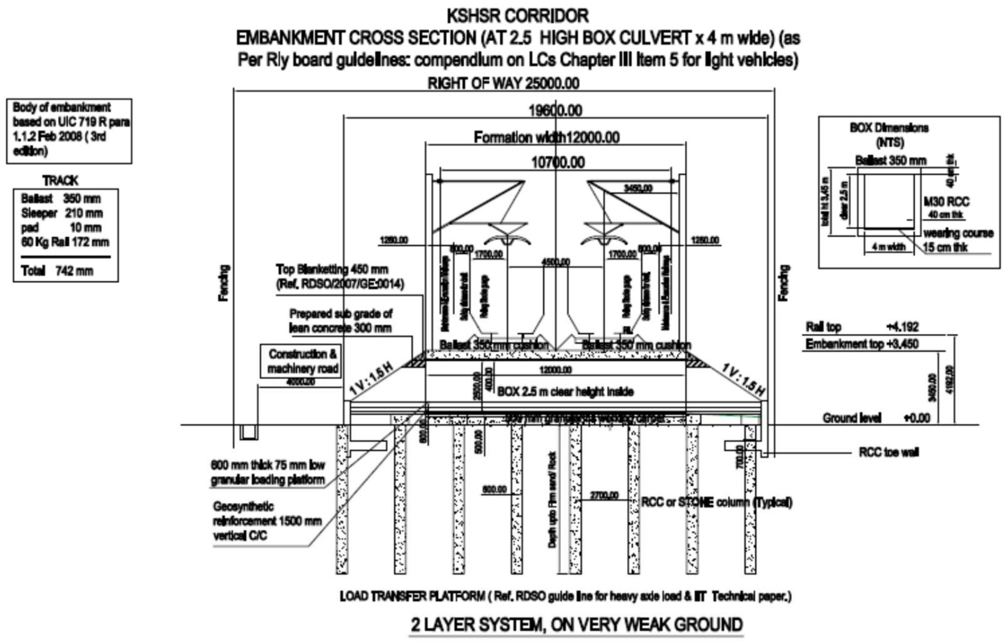
Embankment with 2.5 m clear box on strong ground

- **Embankment with 2.5 clear box, on average ground:** with sand piles



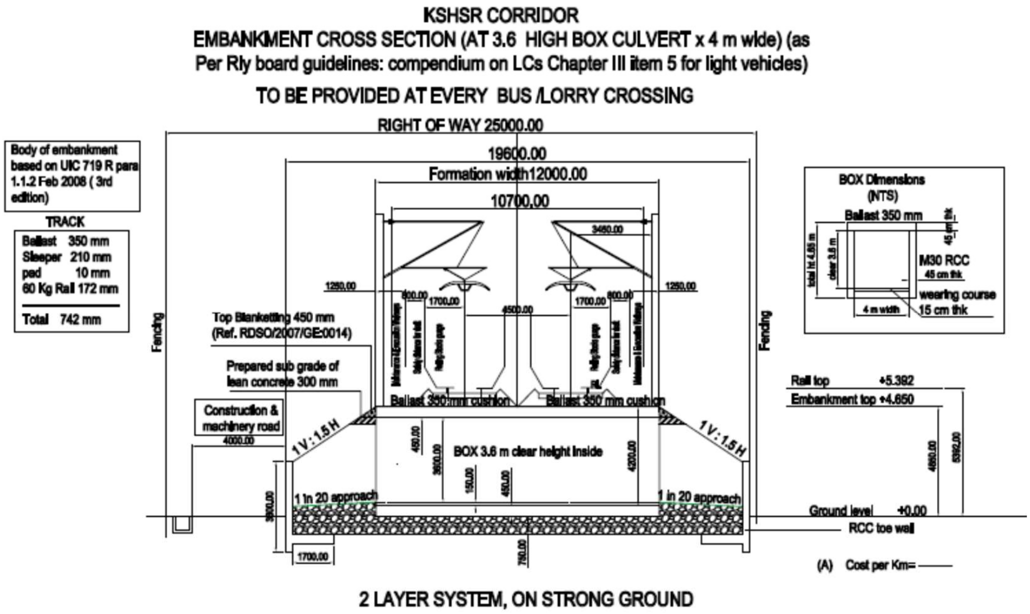
Embankment with 2.5 clear box, on weak ground

- Embankment with 2.5 clear box, on weak ground: with stone columns



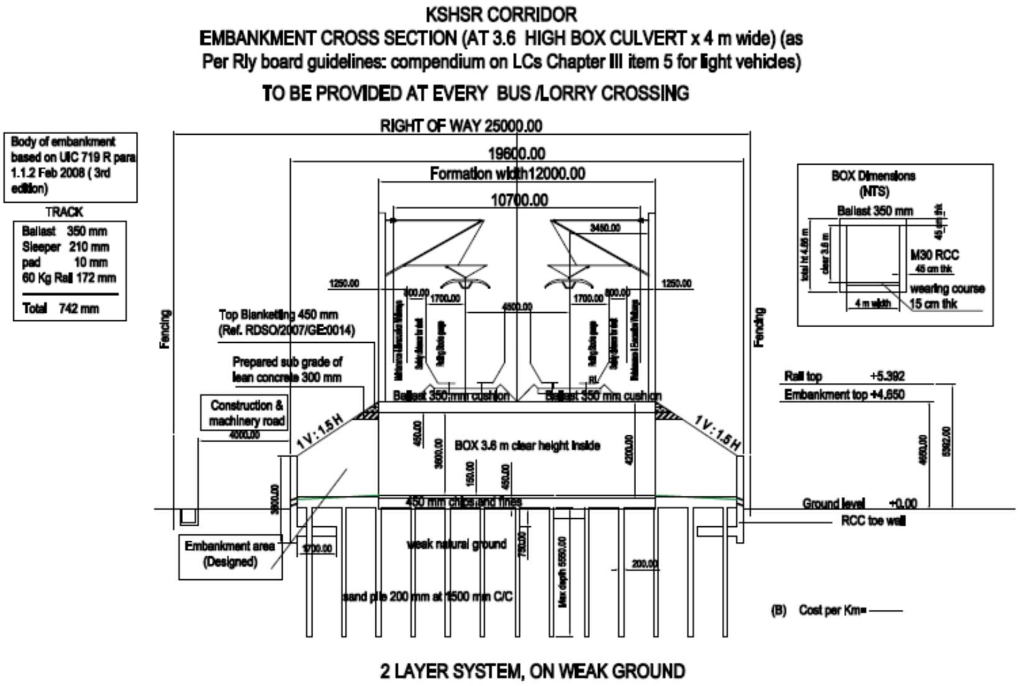
Embankment with 2.5 m clear box, on very weak ground

- Embankment with 3.6 clear box (clearance as per norms), is considered at every bus/ lorry road crossing along the corridor but the final clearance height shall be fixed in consultation with the local bodies and state government, based on the Railway experience where in the clearance was increased to 4.5 m for sugar cane/ agricultural produce crossing.



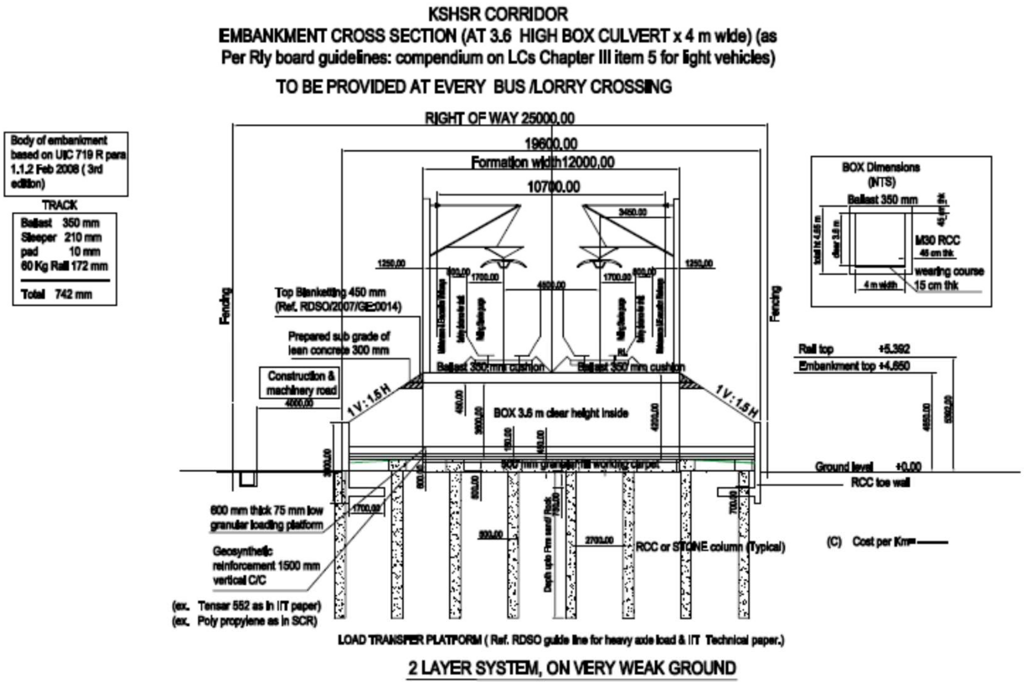
Embankment with 3.6 clear box on strong ground

- Embankment with 3.6 clear box, on average ground, on sand pile:



Embankment with 3.6 m clear box on weak ground

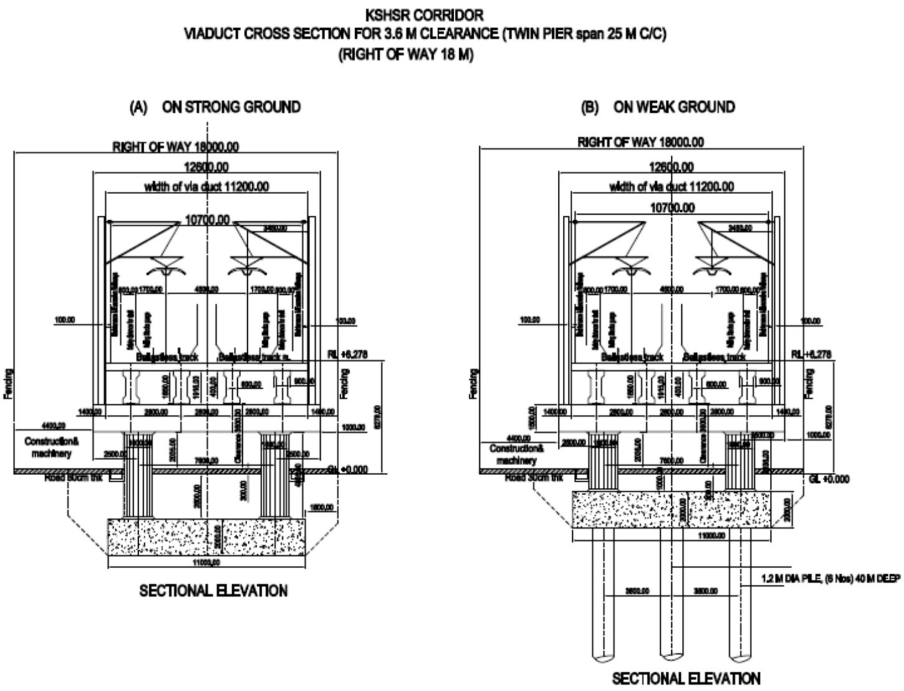
- Embankment with 3.6 clear box, on weak ground, on stone column:

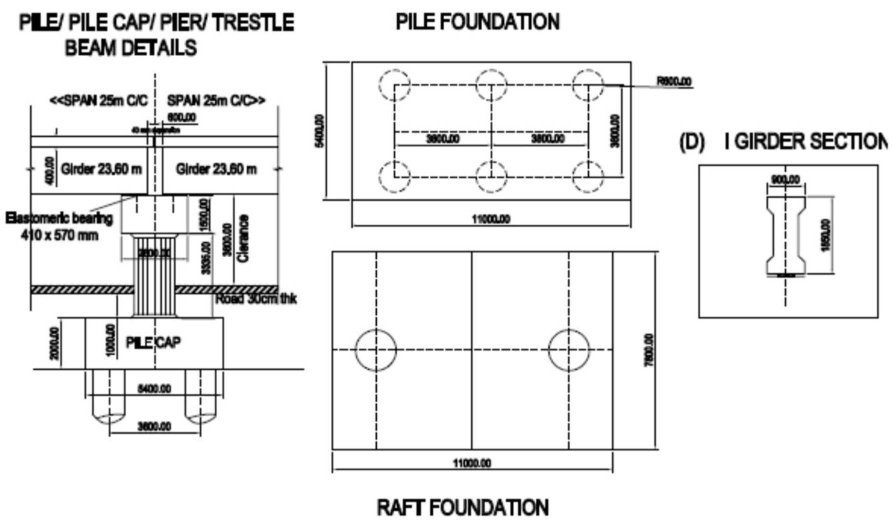


Embankment with 3.6 m clear box on very weak ground

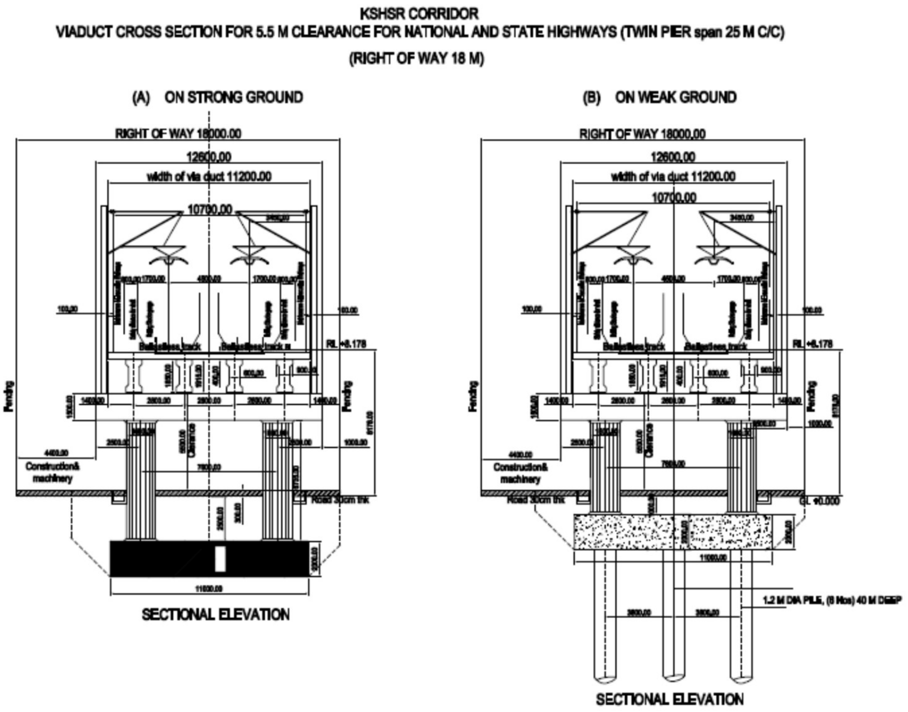
- **Viaducts.** Some of the tentative cross-sections of viaducts for 3.6 m clearance and 5.5 m clearance for NH/ SH are made for strong ground (raft foundation), weak ground (1.2 m diameter pile, 6 Nos of 25 m depth) and for very weak ground (1.2 m diameter piles, 6 Nos of 60 m depth). The PSC girder span of each is limited to 24.4 m and the c/c distance is 25 m. The cost is estimated for each 25 m span and then this is made to per m span by dividing by 25, to arrive at the unit cost per m of viaduct. In stretches vulnerable to waterlogging and viaducts in or near backwater and paddy fields, deeper piles have to be provided. Hollow cylindrical pile foundation have been used outside India to cross marshy ground. This and other foundation systems (like piled rafts) for overcoming the problem of low bearing capacity in marshy ground shall be examined at the DPR stage.

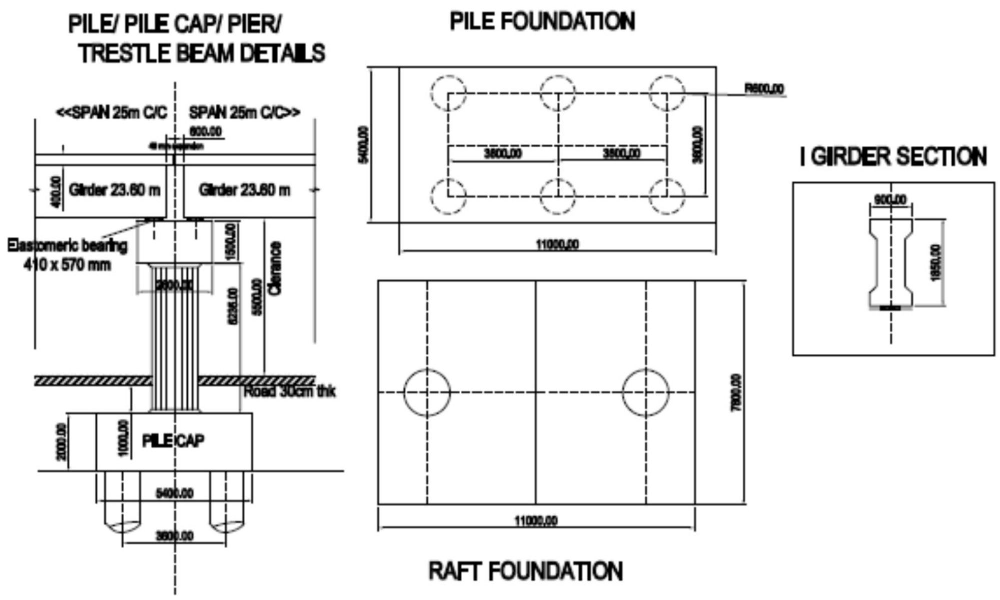
- **Viaduct cross section for 3.6 m clearance (twin pier- span 25 m c/c)**;



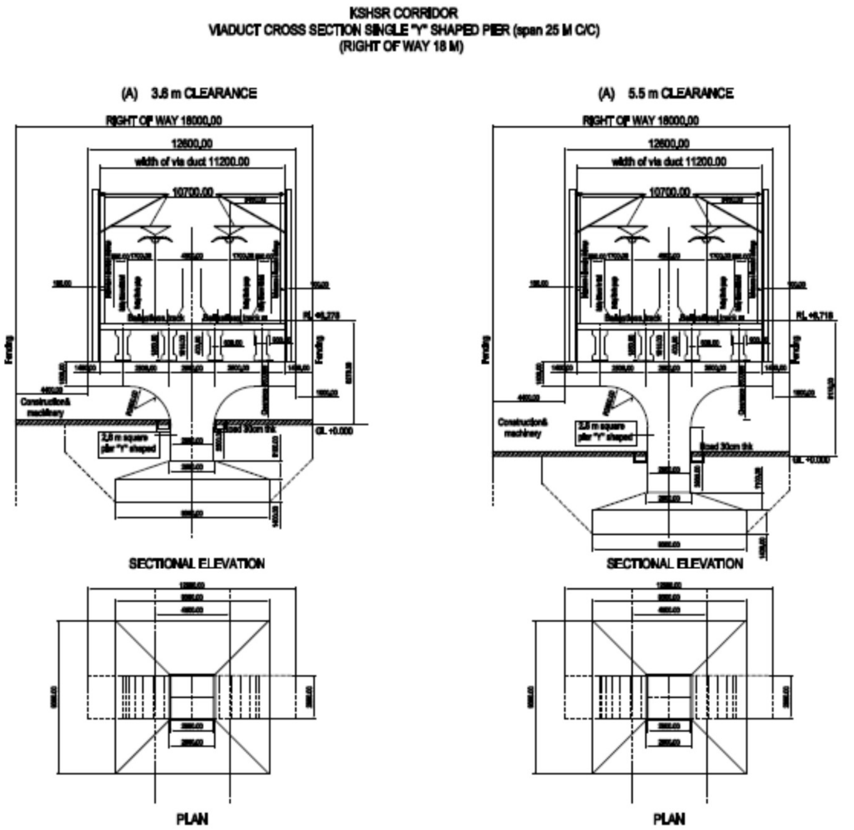


- **Viaduct cross section for 5.5 m clearance (twin pier- span 25 m c/c)**



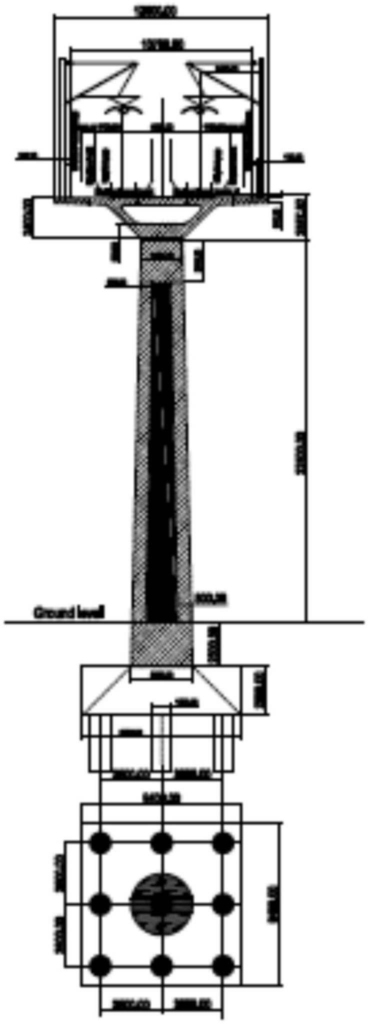


- **Viaduct cross section for 3.6 m & 5,5 clearance (Single “Y” pier- span 25 m c/c) on strong ground**;



- **Viaduct 20 m high on single hollow pier and with Box girder**

The passage of trains over these high viaducts can cause extreme vibrations on the bridge. The effects of bridge vibrations are two-fold causing (1) structural damage in extreme cases and (2) unpleasant psychological and physiological reaction on humans. These dynamic effects of semi high-speed trains on high viaducts are important issues are to be studied for the design of the structures, as well as for the consideration of safe running conditions of the trains. The relevance of this study is mainly for the safety of the traffic, considering both internal actions such as the hunting motion as well as external actions such as wind or earthquakes. These studies may be done before the detailed design and execution of this project. However, for the Feasibility study, the unit costs are arrived at based on the available Railway resources and this shall be subject to review during the DPR/ detailed design stage.



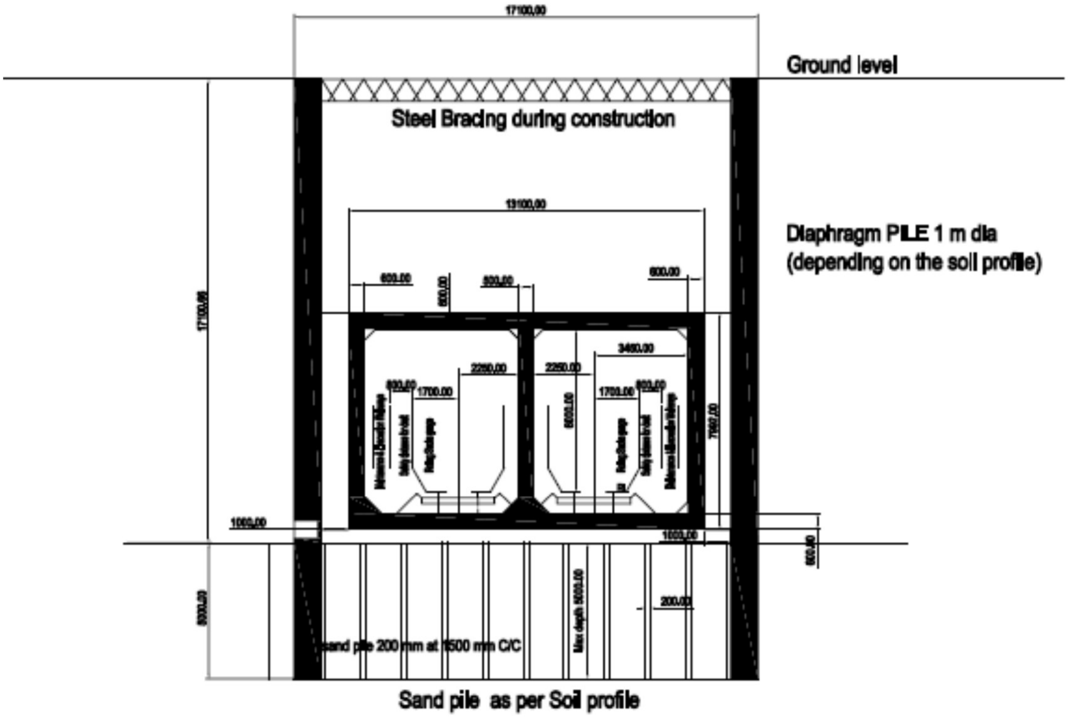
- **Tunnel /Cut and cover**

Tunneling differs from the construction of other infrastructure in a plethora of ways. The main issues that distinguish tunnels from other infrastructure arise from the risk involved with excavation through unknown ground conditions and the numerous individual cost drivers that contribute to the overall cost. These cost drivers include but are not limited to the following direct and indirect factors, all of which cannot be accurately assessed at this feasibility report stage.

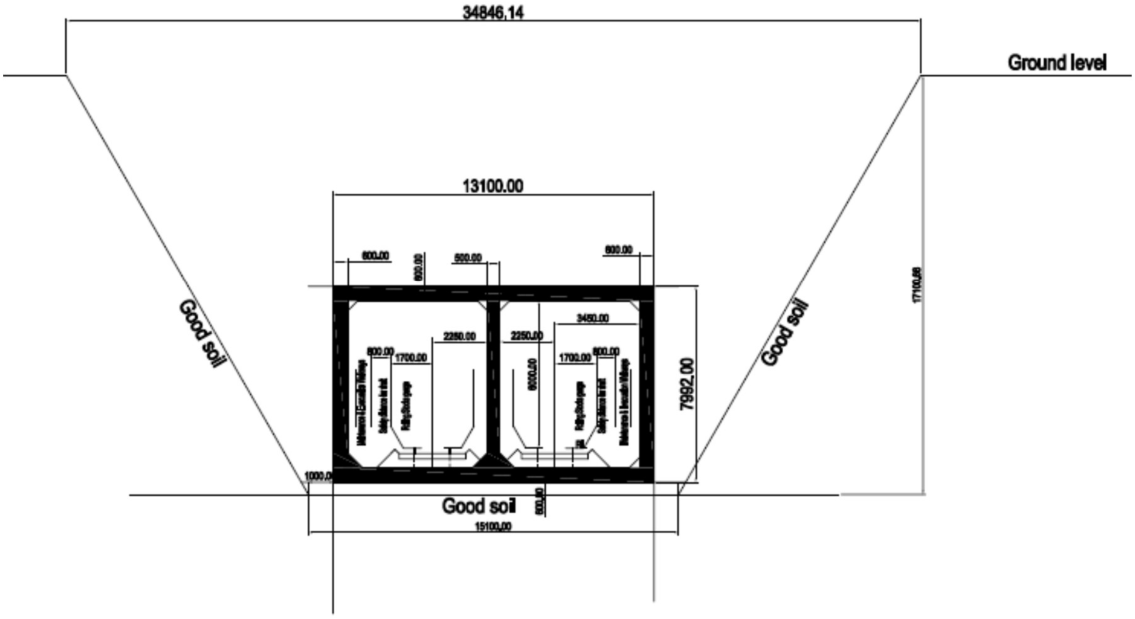
The cost drivers include Geology, Excavation Type, Materials/Plant, Length, Face Area, Depth, Lining Type, Market Competition, Contract Type and Cost of Bidding.

Geology along this corridor can range from soft sands and gravel to extremely hard rock and often includes fault lines and water permeation issues. A full-fledged site investigation is to be completed during the initial design stages of the project to account for and plan for various ground conditions. Varying geologies necessitates different methods of excavation, which include cut and cover, drill and blast, road headers, and tunnel boring machines (TBMs). However, subject to revision during the DPR stage, the following cross sections are proposed for the cut and cover type of Tunneling.

  - On weak to Normal ground

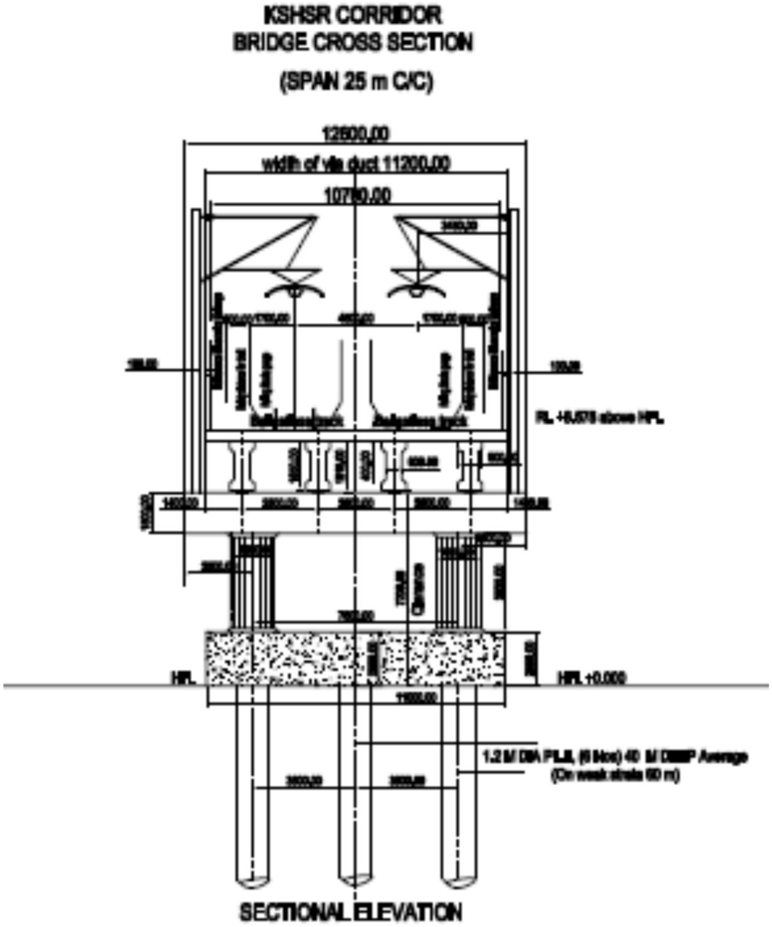

17100.00
Ground level
Steel Bracing during construction
13100.00
Diaphragm PILE 1 m dia
(depending on the soil profile)
1000.00
sand pile 200 mm at 1500 mm C/C
200.00
Sand pile as per Soil profile

* On very strong ground

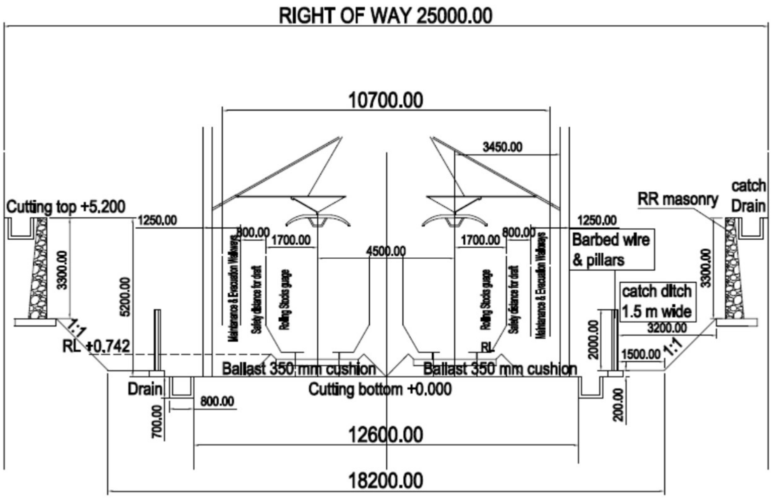


Bridges: The bridges are considered to be on twin pier columns and piles. The foundations are considered to be piles 1.2 m diameter, 6 Nos taken to 40 m depth and 60 for weak strata (like Ernakulam area). The clearance for the bridges is proposed at 5 m for normal waters and 7.2 m for water ways.

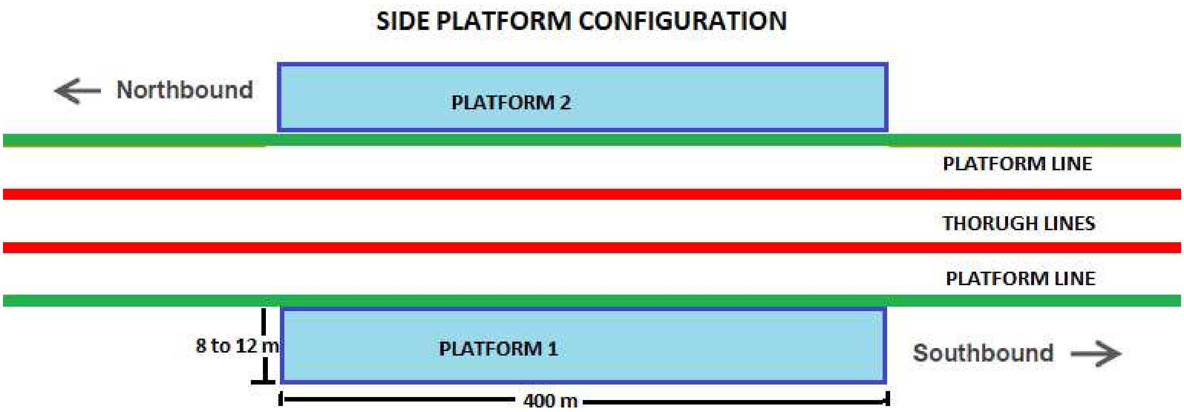
- Bridge CS for 5m & 7.2 m clearance



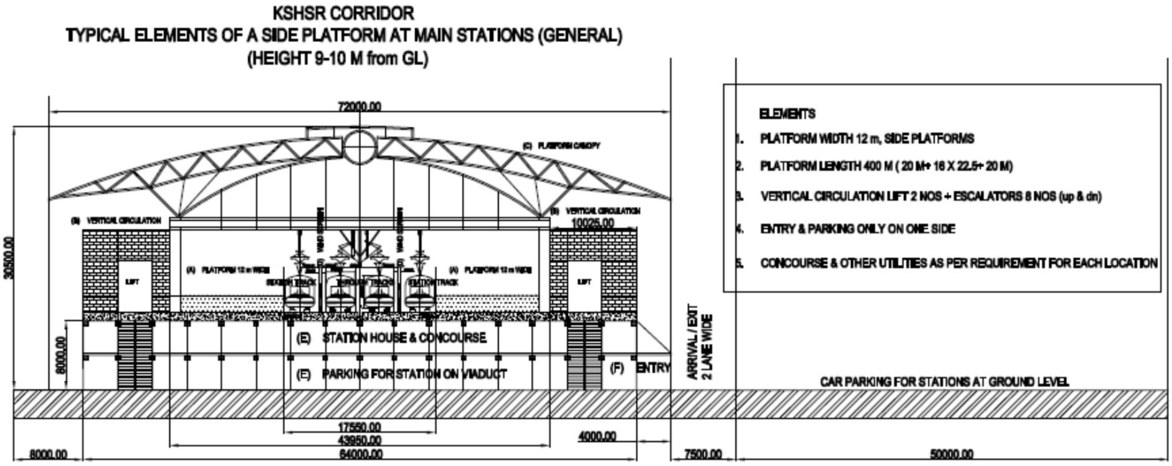
Cutting: The cutting is restricted to Right of way of 25 m to reduce the land cost. This is achieved by side slope of 1:1 at the bottom and RR masonry retaining wall at the top portion as shown in the cross section below. A catch ditch is provided with 2 m high barbed wire fencing through out to prevent cattle, stone and other materials falling on to the track. Catch water and side drains are provided to ensure proper drainage of the section. Estimated cost for 5.2 m depth of cutting as per this cross section is ₹ 62,626,934.00 per Km.



- Station building: Side platform configuration is adopted for the stations to reduce the width of land for the station building, especially since some are on viaduct. The length of platform is kept at 410 meters to accommodate 16 cars and the width of platforms vary between 10 to 12 m, depending on the importance of the station.



Cross section of a major station, on a viaduct is given below. The stations at each location shall be designed during the DPR stage and this schematic sketch is made for this Feasibility report stage to arrive at a cost for each of the stations.



Three type of stations are proposed for the corridor, with different platform widths, parking and station concourse. The station A type has 12 m width of platforms, B type station has 10 m width of platform Land area for the stations are also considered as 25 Acres (10 Ha) for A type stations, 17 Acres (7 Ha) and 9 Acres (3.7 Ha) for B & C respectively. **The cost of stations, excluding land costs are given below:**

SL	Station	Type	PF width	station area	Cost in crores	ground/ viaduct
			(in M)	(in sq. m)		
1	Thiruvananthapuram	A	12 m	3,600.00	70.27	Ground
2	Kollam	A	12.00	3,600.00	70.27	Ground
3	Chengannur	B	10.00	3,000.00	64.42	Ground
4	Kottayam	A	12.00	3,600.00	70.27	Ground
5	Kochi	A	12.00	3,600.00	70.27	Ground
6	Thrissur	B	10.00	3,000.00	100.12	Viaduct
7	Tirur	B	10.00	3,000.00	64.42	Ground
8	Kozhikode	A	12.00	3,600.00	106.05	Viaduct
9	Kannur	B	10.00	3,000.00	64.42	Ground
10	Kasaragod	A	12.00	3,600.00	70.27	Ground
				Total	**750.77**	**Crores**

List of codes and specifications

For the study, the following codes and specifications have been used:

A. Indian Codes and specifications

- RDSO Guide lines vide Report No. RDSO/2007/GE: 0014.
- IS 15284 (Part 1) for Design and construction for ground improvement — guidelines part 1 stone columns

- 15284 (Part 2) for Design and construction for ground improvement — guidelines part 2 pre consolidation using vertical drains shall be used for the design part during the DPR stage.
- National environmental policy 2006
- The right to fair compensation and transparency in land acquisition., rehabilitation and resettlement act 2013
- Ministry of Environment, Forest and Climate change NOTIFICATION dated 18th Jan 2019
- Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor: Design Parameters

B. International codes and specifications

- UIC 719 R and- Earth works and track bed for Railway lines
- UIC 776- 1 R Loads to be considered in Railway bridge design
- EN 13803-1 European standard. Railway applications – Track- Track alignment design parameters – Track gauges 1435 mm and wider- Part 1: plain line
- GE/GN 8573: Railway Group Guidance Note. Guidance on Gauging
- GM/RT 2149: Kinematic Gauging Requirements for Railway vehicles. Railway Group standard.
- California High Speed Train Design Criteria
- California high Speed Train Project: Technical memorandum. Alignment standards for shared use corridors
- California High Speed Train Project. Technical Memorandum. High speed equipment Structure Gauges
- TRANFIKVERKET. Technical system standard for high speed tracks, requirements.
- ADB Technical Assistance Consultants report- Nanning – Kumming Railway capacity Enhancement project
- Commission regulation (EU) NO 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the “infrastructure “sub system of the rail system in the European union.
- International Union of Railways. High speed department. Design of new line speeds of 300-350 kmph state of the art. First Report
- Track Geometry for high speed Railways. A literature survey and simulation of dynamic vehicle response
- BS 8006-1:2010: Code of practice for strengthened/reinforced soils and other fills
- Critical Velocity of High-Speed Train Running on Soft Soil and Induced Dynamic Soil response: Department of Civil Engineering, Key Laboratory of Soft Soils and Geo environmental Engineering, MOE, Zhejiang University, China
- Dynamic Amplification of Deformations in Railways due to High-Speed Traffic on Soft Ground: Department of Civil Engineering, Aalborg University
- Analysis and Evaluation of Railway Track Systems on Soft Soil: Track bed Thickness Design and Dynamic Track-Soil Interaction
- Geotechnical Issues in Design and Construction of Viaducts of the Taiwan High Speed Rail by Z. C. Moh , Moh and Associates, Inc., 11F., No. 3, Tunhwa South Road, Taiwan

- Ground Treatment Design for 200km Electrified Double Tracks Railway Project at Northern Peninsular Malaysia by Tan Yean-Chin G&P Geotechnics Sdn Bhd, Malaysia, Lee Peir-Tien G&P Geotechnics Sdn Bhd, Malaysia
- Ground Improvement for a High-Speed Railway near Madrid (Spain) by Carlos S. Oteo, Javier Oteo, Violeta González and Cristina Fort
- HIGH-SPEED RAILWAY LINES ON SOFT GROUND: DYNAMIC BEHAVIOUR AT CRITICAL TRAIN SPEED C. MADSHUS AND A. M. KAYNIA Norwegian Geotechnical Institute, Oslo, Norway
- Piled raft foundations by H G Paulos, Geotehnique
- Reinforced piled embankment for a high-speed railway over soft soil: a numerical and analytical investigation. Yan Zhuang (corresponding author) Hohai University, Geotechnical Research Institute Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, China
- STUDY OF BRIDGE APPROACH AND TRACK TRANSITION DEGRADATION: Factors and Mitigation: U.S. Department of Transportation Federal Railroad Administration
- Mass stabilization manual compiled by European companies.

6.2 Rolling Stock

6.2.1 Introduction

Rolling Stock is an important asset and proper planning is required in selecting its right type and design. There are a variety of semi-high speed and high-speed rolling stock series in the world, because specifications of rolling stock have depended on not only technological factors but also the geographical conditions of where this train is operated.

Factors to be considered for type and design selection of rolling stock (Reference - UIC report on rolling stock):

A. **Technical**

The basic technical aspects which should be considered are:

1. What the basic dimensions should be?

- Track Gauge (Broad Gauge, Standard Gauge, Metre Gauge or Narrow Gauge)
- Loading gauge (strongly affect the capacity)
- Axle load (strongly affect the infrastructure)
- Train length
- Car length
- Distributed or Concentrated power (advantages and disadvantages)
- Articulated or Non-articulated formation (advantages and disadvantages)
- Double decker trains (increase capacity?)
- Floor height
- Ceiling height

2. What will determine Running Performance?

- Maximum speed (decided by the basic system parameter)

- Acceleration and deceleration (strongly related to the operation needs)
- Drives and controls
- Current collection

3. What should be considered for Safety?
- Running stability
- Signalling
- Communication
- Crash resistance (designs to prevent loss of life)
- Fire safety
- Crosswind resistance
- Security
- Derailment

4. What should be considered for Environmental issue?
- CO2 emission and energy consumption (what is key technology?)
- EMC
- Noise (problematic in case of speed increase)
- Ground vibration
- Life Cycle Assessment (need all analysis of whole life)

5. What would be the issue in Aerodynamics (for HSR speed) and what should be done for them?
- Aerodynamic resistance (what is the key?)
- Tunnel micro-pressure waves (noise problem around tunnel portal)
- Pressure fluctuation from passing trains running through tunnels
- Flying ballast (acknowledged in recent experience)
- Riding comfort by aerodynamic fluctuation

6. What is the topic for increasing Comfort?
- Ride comfort (what are key points)
- Noise abatement in the passenger saloon
- Tilting system
- Airtight structure (crucial in case of tunnel running), Air conditioning
- Extreme climatic conditions (this is not only for comfort but for reliability)

B. **Commercial and human factors:**
1. What are the main topics for commercial and human factors?
- Ergonomics (human-machine interface)
- Accessibility for Person Reduced Mobility (more and more important for future rolling stock)
- Driver desk and cab design

- Cabin design
- Passenger service

2. What should be considered for Cabin design?

- Capacity (most concerned for commercial point of view)
- Seating (seating and service category, Flexible seating, Seat dimension. These depends on the commercial policy)
- Windows (how large the size is?)
- Doors (what should be the optimum?)
- Toilets (what should be considered for keep comfortable)
- Luggage storage space
- Easy cleaning concept
- External design image

3. What should be considered for Passenger service?

- Information network (what will be the future?)
- Catering service

C. **Other Technical aspects**

1. Are there any other technical aspects to be considered? Body and body structure (material and structure)

- Power and braking system (system and device)
- On board train control and information system (huge possibility of effective train control and effective train management)
- Compressors
- Automatic coupling system

The controlling criteria are reliability, low energy consumption, lightweight, higher passenger per unit capacity and high energy efficiency leading to lower annualized cost of service

D. **Basic Characteristics of conventional high speed / High speed rolling stock:**

Common basic characteristics are:

- Self-propelled, fixed composition and bi-directional
- High level of technology
- Limited axle load (14 to 16 tonnes)
- Higher tractive power
- Power electronic equipment: GTO, IGBT
- Control circuits. Computer network. Automatic diagnosis system
- Aerodynamics for above 250kmph
- In cab signalling systems
- Several braking systems and blending
- Improved commercial performances

- High level of R.A.M.S. (Reliability, Availability, Maintainability and Safety)
- Technical and safety requirements (compliance with standards)
- Compatibility with infrastructure (track gauge, loading gauge, platforms, catenary etc.)

E. **Comparison/Analysis:**

- **Basic factors of HS rolling stock**

The basic factors and dimensions of rolling stocks are track gauge, maximum operation speed, traction system; Train-set formula, body width and body materials. Table 54 and Table 55 respectively show the typical series of semi-high speed and high-speed rolling stocks in major countries from the view point of basic factors.

Table 54: Basic Factors of Semi-HSR Rolling Stock

Items	Type of EMU				
	CRH1	CRH2	CRH3	CRH5	CRH380
Marshalled form	2x (2M+1T) + (1M+1T)	(4M+4T) / (6M+2T)	2x(2M+1T) + 2T	(3M+1T) +(2M+2T)	(3M+1T) +(2M+2T)
Seating capacity	668	610	610	620+2	
Marshalling quantity (t)	420.4	359.7	380.0	451.0	
Marshalling length (m)	213.5	201.4	200.0	451.0	451.0
Operating speed (km/h)	200	200/300	350	200	200
Length of the vehicle front (mm)	26950	25700	25675	27600	27600
Length of the middle vehicle front (mm)	26600	25000	24775	25000	25000
Vehicle width (mm)	3328	3380	2950	3200	3200
Vehicle height (mm)	4040	3700	3890	4270	4270
Axle type of MU	Bo' - Bo'	Bo' - Bo'	Bo' - Bo'	Bo' - Bo'	
Bogie wheel base (mm)	2700	2500	2500	2700	2700
Bogie center distance (mm)	17.500	17.500	17.375	17.500	17.500
Bogie wheel diameter (mm)	915-835	860-790	860-790	890-810	890-810
Axle /kerb weight (t)	≤ 16	≤ 14	≤ 14	≤17/ 16	
Total traction power (kW)	5500	4800/7200		5500	5500
Single motor power (kW)	275	300	500	550	550
Tonnes - average power (kW/t)	13.08	13.34	21.05	12.19	12.19
Starting tractive effort (kN)	325	237	300	300	300
Starting acceleration (m/s^2)	0.5	0.406	0.406	0.6	0.6
Emergency braking distance(m)	≤2000	≤1800	≤1800	≤2000	≤2000

Table 55: HSR Rolling Stock

Country	Japan	France	Italy	Germany	Spain	South Korea	Taiwan	China
Maximum operation speed (km/h)	320	320	300	300	300	300	300	300
Train-set formula	EMU	Loco	Loco / EMU	Loco / EMU	Loco / EMU	loco	EMU	EMU
Car-body width (mm)	3350-3380	2814-2904	2750-3000	2950-3020	2830-2960	2904-2970	3380	3200-3380
Typical series	E5	TGV-R	AGV	VelaroD	S103	KTX-II	700T	CRH 380A
Formula	EMU	LOCO	EMU	EMU	EMU	LOCO	EMU	EMU
Body-material	Al	Steel	Al	Al	Al	Al	Al	Al
Passenger capacity (seats)	731	375	450	444	403	363	989	480
Power (kW)	9600	8800	7500	8000	8800	8800	10260	9600
Power/seats (Kw/seats)	13.13	23.47	16.67	18.01	21.84	24.24	10.37	20.00

1) Track gauge and 2) Maximum speed: As discussed and fixed in the basic parameters design, the track gauge is Standard Gauge (1435mm) and the maximum speed is 200 kmph for non- tilting and 250 kmph for tilting trains to be introduced at a later stage.

3) Traction system (EMU or Loco system regarding power system?)

Fig 12 shows the outline comparison between concentrated (loco) and distributed (EMU) power train as to how the propulsion and driving system is arranged.

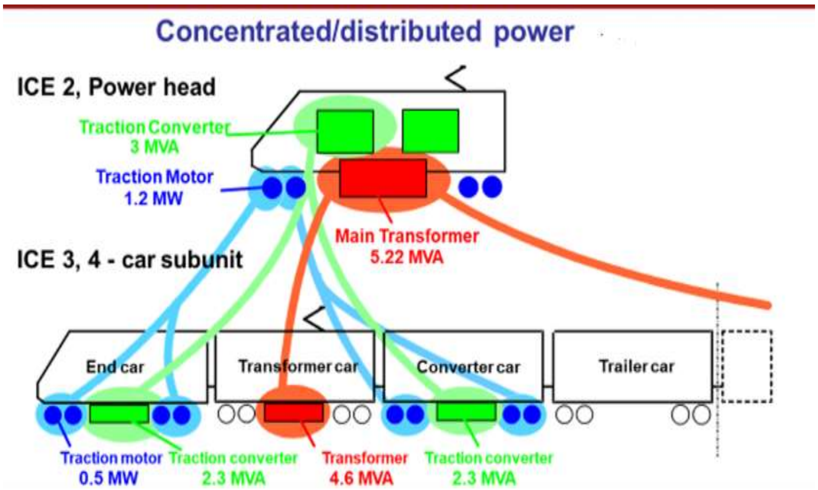


Figure 12: Comparison of Concentrated and Distributed power scheme

Now a days, the trains at the maximum speed of over 200 km/h normally use fixed train sets, while combining two sets into one as necessity arises to cope with fluctuation of transport demands. Regarding power distribution of these fixed train sets, there are two types. One is concentrated power system (Loco system) and the other is distributed power system (EMU) adopted by Japan, China and ICE-3 in Germany for its latest train compositions.

In conventional railway, Loco system was a main stream of long-distance train. Regarding semi- high speed and high-speed trains, both Loco and EMU had advantages and disadvantages in some view points, and they have been used respectively in accordance with their role.

Recently, as the maximum operation speed is increasing, even in the conventional high-speed trains, adoption of EMU system become dominant, because of the advantages of EMU have exceeded. The followings are advantages of EMU system.

F. **Traction performance & traveling time:**

The main aim of passenger train is to reduce travelling time between stations, acceleration/deceleration performance is a particularly important factor especially for running short distance and having many stops. Traction force depends on adhesion force between a rail and wheel. Weight of locomotive is restricted, so resulting restriction of traction power. EMU have a lot of comparatively small power system, but the total is over locos power. EMU has greater acceleration/ deceleration performance, due to utilizing effectively the adhesion force. EMU realize acceleration over 0.8 m/sec/sec, while Loco under 0.4 m/sec/sec, resulting shorter traveling time. Hence EMU is having better performance factor of acceleration/ deceleration, adhesion, tractive power besides travelling time.

G. **Passenger capacity**

Passenger capacity is one of most important factors of higher speed rolling stock. Higher capacity is an advantage for profitability, as long as it doesn't infringe passenger comfort. Locomotive cars and the power cars are not available for passenger space, while all of EMU can accommodate passenger in all the cars. Therefore, EMU can have higher passenger capacity. Comparison of passenger capacity among typical rolling stocks under same train-length condition is shown in Table 56. EMU has higher capacity than loco by 20% approximately.

Table 56: Comparison of passenger capacity

Series	TGV-R(France)	ICE-3(Germany)	E2 (Japan)
Type	Loco	EMU	EMU
Train-length	200 m	200 m	200 m
Body-Width	2904 mm	2950 m	3380 mm
Passenger capacity	375 seats	444 seats	630 seats

H. **Energy efficiency**

Energy efficiency directly affects operation cost and reduction in CO_2 emission. Regenerative braking is essential to reduce energy consumption and is used instead of mechanical brakes for stopping a train. Same as traction power, regenerative braking power of locomotives is not enough to stop a train smoothly, coaches of a train set need to use mechanical braking system which wastes braking energy. On the other hand, EMU has enough regenerative brake power due to multiple power system equipped. Regeneration ratio of EMU is higher than that of loco system.

I. **Maximum axle load**

The axle load of Locomotive is heavier than that of EMU because it needs larger adhesion force which relates to axle load. The heavier axle load gives the larger stress on rail and civil infrastructure, and it results in increasing maintenance and construction cost. EMU has realized maximum axle load under 16 tons, while Loco have remained more than about 17 tons.

J. Redundancy of main component EMU has multiple main components; it might be able to operate in spite of one or two units break downs. EMU has higher redundancy than loco system.

K. Maintenance of rolling stock

Formerly, power system needed a great quantity of maintenance. In recent years, thanks to progress in the field of power electronics; AC motors with IGBT/VVVF controllers which are almost without maintenance are now in the mainstream; it reduced maintenance work and cost of power system. And regarding EMU, the interval of maintenance for mechanical braking system is prolonged due to utilization of regenerative braking. The deference of maintenance cost between EMU and loco system is not so much at present.

L. **Flexibility of train set**

Whichever type is adopted-EMU or Loco-, solid configuration of train set is recently used for semi/ high speed trains. For flexible train services, automatic coupling systems to connect two train sets mechanically and electrically is developed. Flexibility is same in both types.

M. **Riding comfort:**

Loco system has an advantage in riding comfort because power system and other equipment which generate noise and vibration are not installed on passenger coaches. As technical development is proceeding such as power system, reduction/ insulation against noise and vibration and so on, the difference is decreasing.

N. **Higher possibility of electrical failures produced by the entrance of water, and moisture, due to:**

- loss of airtightness in the electrical blocks.
- entrance of moisture in non-airtight electrical blocks under the car bodies.

O. Whole train set idling, if one coach is defective.

However, with the advent of better technology and RAMS specification, the failure rates have greatly come down. Hence the drawbacks are no more significant issue.
In summary, the advantages of distributed power trains are:

- Higher passenger capacity for a fixed length train.
- Reduced axle load more evenly distributed along the train.
- Higher number of drive axles.
- higher acceleration and better adhesion.
- More suited for regenerative braking
- Possibility of installing a higher traction power.
- Improved throughput & Improvement in Line capacity
- Energy Efficiency
- Reduced maintenance of assets
- Improved reliability
- Reduction in Pollution

Formerly Loco system was adopted for High Speed (HS) trains mainly in Europe. The recent trend is towards distributed power system-EMU-due to several advantages mentioned above.

P. Germany changed adopting design from Loco type (ICE-1, 2) to EMU since 2000 at the inauguration of ICE-3.
Q. China has decided design policy that EMU system should be adopted for HSR at the beginning of HSR development in 2004.
R. Alstom which is the supplier of TGV: one of the most famous Loco systems for HSR: has already developed AGV which is next-generation HS train under the distributed traction system.

Hence, it is recommended for EMU type distributed power train, as the recent trend is adopting EMU system for HS train and mainline services.
Loading gauge, Car body width and Seat arrangement
Loading gauge:
The loading gauge means the contour of rolling stock (maximum height and width) to guarantee safety of train operation against bridges, tunnels and other structures. Table 57 shows maximum body width of Rolling Stock in typical high speed /HSR. The rolling stock gauge used for conventional high speed varies from 2,900mm to 3,400 mm in width.

Table 57: maximum body width of Rolling Stock in typical high speed /HSR

Country	Track Gauge	Max. body Width of RSs
Japan(HSR)	1435	3350~3380
France	1435	2896~2904
Germany	1435	2950~3020
Italy	1435	2750~3000
Spain	1435 or 1668	2830~2960
China	1435	3200~3380
Taiwan	1435	3380
South Korea	1435	2904~2970
India(conventional)	1676	3240~3250

Car body width and seat arrangement

The loading gauge widely used in Europe is the "UIC loading gauge, type C," to limit car body width to 3,150 mm or less. Therefore, standard cars have a car body width of 3,000 mm or less, with ordinary train sets designed to a structure having 4-seats arrangement (two 2-seats arrangement). In contrast, Japan, China and Taiwan adopted a loading gauge to make the car body width 3,400 mm or less to make 5-seat arrangement (2-seats/3-seats arrangement) possible. Table 58 shows the loading gauge and car body widths adopted in different countries.

Table 58: Loading gauge and car body widths

Country	Japan		France		German		Italy	
Class	Series E 5	Series E 4	TGV-R	TGV-D	ICE1	ICE3	ETR-500	AGV-Itaro
Car body width (mm)	3350	3380	2904	2896	3020	2950	2860	3000
Seat Arrangement	2+3	3+3 2+3	2+2	2+2	2+2	2+2	2+2	2+2
Country	**Spain**		**China**		**Taiwan**		**South Korea**	
Class	S100	S103	CRH-2C	CRH - 3	700T		KTX - 1	
Car body width (mm)	2904	2950	3380	3260	3380		2904	
Seat Arrangement	2+2	2+2	2+3	2+3	2+3		2+2	

To have 6-seat arrangement (two 3-seats arrangement), the armrests is provided only at the aisle side of 3-seats arrangement. While comfort is downgraded, and the aisle width is made smaller in this design, it might be one option to provide lower-price seats. This arrangement can be considered for lower fare class, short distance trains and aggregator trains. Figure 13 shows seat arrangement of 5 or 6 seats arrangement. To realize 6-seats arrangement with comfort kept unchanged, the car body width has to be extended beyond 3,400 mm, which hasn't been experienced yet in the world. Figure 14 shows the arrangement of seats and aisle of 2+3 arrangement and 3+3 arrangement

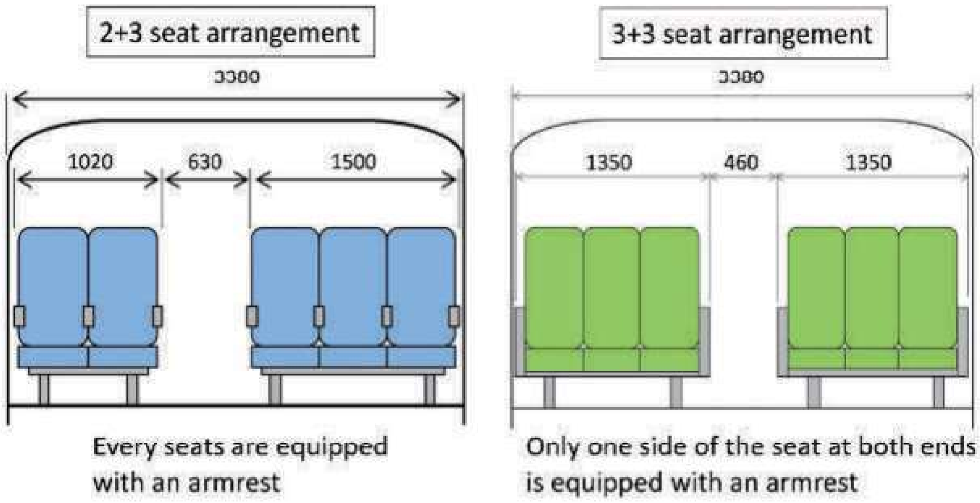


Figure 13: arrangement of seats and aisle of 2+3 arrangement and 3+3 arrangement

The seats can be designed to facilitate rotating and reclining facilities. Figure 14 shows the rotating and reclining facilities.

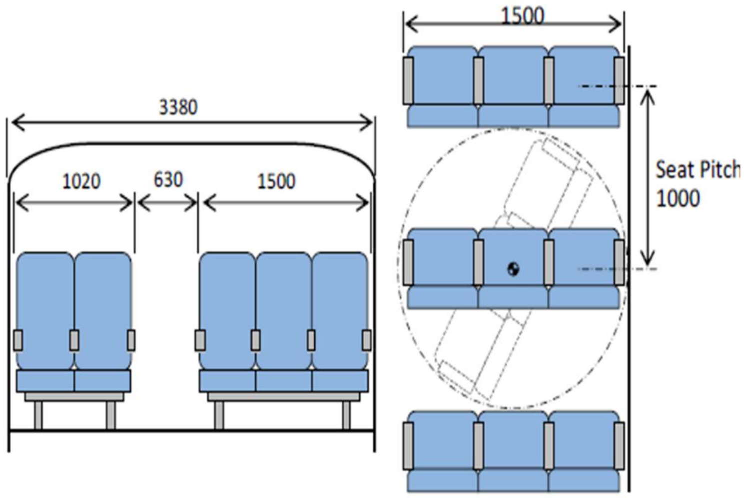


Figure 14: rotating and reclining facilities

Seating arrangement of 2+3 seats for standard class and 2+2 for executive class is recommended. 3+3 seating for aggregator and short distance trains with lower fare may also be considered.

Car body materials

Among the semi high-speed railways in the world, the car bodies are made of steel or an aluminium alloy. Aluminium alloy is lighter than steel and is highly resistant against corrosion. So aluminium alloy is mainly used for semi high speed/HSR which strongly requires light weight body structure. Table 59 shows materials used for car body structures in different countries.

Table 59: Materials used for car body structures

Country	Japan		France		German		Italy	
Class	Series E 5	Series E 4	TGV-R	TGV-D	ICE1	ICE3	ETR-500	AGV-Itaro
Car body width (mm)	Al.alloy	Al.alloy	steel	Al.alloy	Al.alloy	Al.alloy	Al.alloy	Al.alloy
Country	**Spain**		**China**		**Taiwan**		**South Korea**	
Class	S100	S103	CRH-2C	CRH - 3	700T		KTX – 1	
Car body width (mm)	Steel	Al.alloy	Al.alloy	Al.alloy	Al.alloy		Steel	

The entire length of Thiruvananthapuram to Kasaragod corridor runs parallel to the coastal line and has a highly corrosion environment. Hence Aluminium car body is recommended.

- **Summary of Recommendation**

Based on comparison and analysis of world rolling stocks, recommendation is summarized below.

- Regarding train formation, EMU with distributed type should be adopted
- To put the rolling stock into operation on the proposed section, the maximum speed at 200 kmph rolling stock, non-tilting type is planned initially and 250 kmph tilting type rolling stock will be introduced in future when the need arises as defined in the basic planning parameter, confirming safety and reliability.
- Wide body type, Car body width from 3200mm to 3,400 mm, should be selected for providing more comfort keeping passenger capacity with a formation of 5-seats arrangement. It can also realize two 3-seats arrangements.
- Table 60 summarises the recommendations of basic parameter of the rolling stock**.**

Table 60: Recommendations of basic parameter

Sr no	Item	Dimension	Remarks
1	Train Type	EMU	Formation 9 cars (tentative). To be extendable to 12/15
2	Maximum speed	200	Normal train at inauguration. Tilting train of higher speed at a future date with the same infrastructure
3	Car body width	3,400mm (Maxi)	Wide body type
4	Seat arrangement	2+2 Business class 3+2 Standard class 3+3 for low fare class	Standard car, business class Rotating and reclining
5	Car body materials	Aluminum alloy	

- Types of train:

- Formation: Articulated /Non-articulated

From the viewpoints of manufacturing cost and ride comfort, articulated or non-articulated trains are not significantly different from each other, despite that their technologies have developed to satisfy different requirements. Whereas articulated train sets are advantageous for maintenance to the extent that they incorporate fewer bogies in number, they require cumbersome operation for train set composition/decomposition. This means that either system has merits and demerits simultaneously. Figure 15 shows the sketch of Non-articulated and articulated bogies.

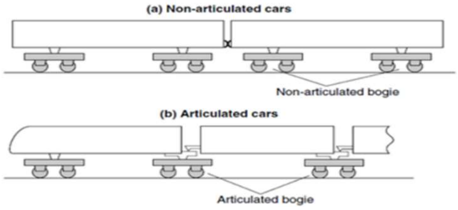


Figure 15: sketch of Non-articulated and articulated bogies

One of the most outstanding differences is the size of effective space appropriated for passengers, in that the articulated system has more car-end sections in number to reduce the effective space for passengers. Figure 16 compares the articulated and non-articulated trains in which the ratio of effective space of articulated bogie system is taken as 90% of that of non-articulated bogie system.

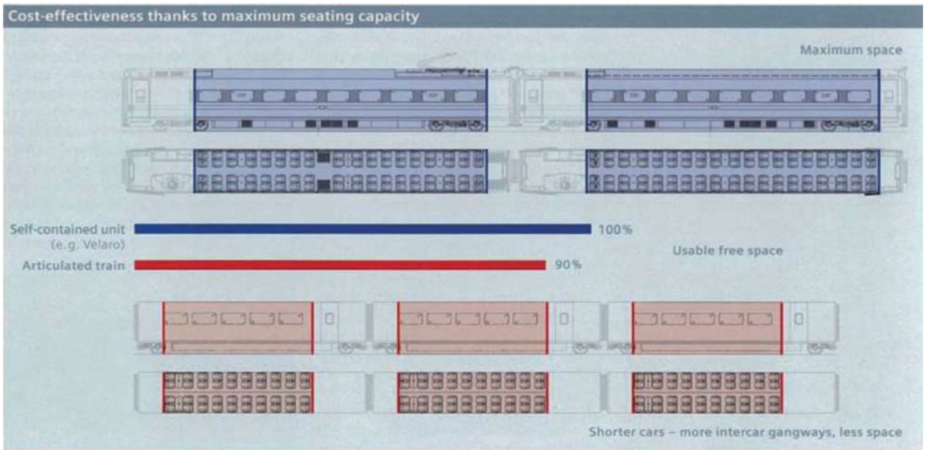


Figure 16: articulated and non-articulated trains

Articulated has lower capacity than non-articulated by 20% approximately. Therefore, it is easier to realize mass-transport with the non-articulated bogie system than with the articulated bogie system.

- **Tilting Trains:**

As a train goes into a curve, it produces substantial centrifugal force towards the outside of the curve. By tilting the train inward, this centrifugal force is balanced by a force into the inner curve and passenger discomfort is reduced. Modern tilting trains allow to achieve higher speeds on existing curved routes without costly track improvements.

Trains capable of tilting the car bodies inwards in curves are called tilting trains. Tilting trains can be divided in two groups: a) the naturally tilted trains and b) the actively tilted Trains.

Natural tilt relies on physical laws with a tilt center located well above the Center of gravity of the car body. In a curve, under the influence of lateral acceleration, the lower part of the car body then swings outwards. In active tilting, the tilt is actuated by a computer-controlled powered mechanism when the train negotiate the curve. Figure 17 shows the images of tilting trains

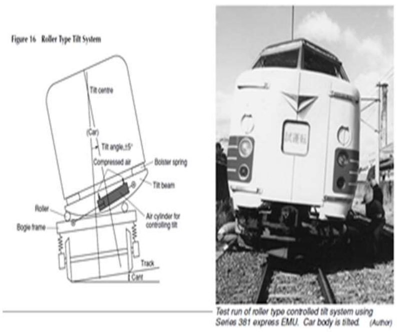
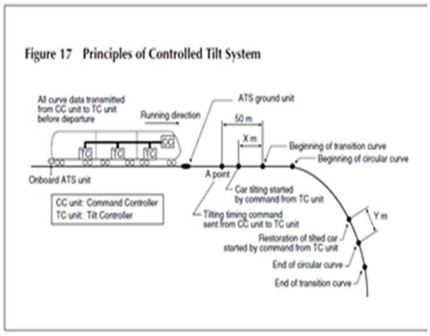
 Tilting train	 Passive tilting	 Active tilting contol

Figure 17: tilting trains

Advantage of tilting trains:

- Shorter travel times due to the ability to reach higher speed in curves.
- Higher speed can be achieved with same track structure and curves.

Drawbacks:

- More stress on the tracks in curves, due to a higher speed in curves.
- Car motions of low frequencies (under 1 Hz) may create problem (nausea) for small percentage of passengers.

Recommendation: -

As discussed in the basic parameter setting, the tilting trains with the speed potential of 250 kmph can be considered in future to cater for higher traffic and speed requirement. The detail design can be worked out that time duly taking the technology available in future course of time.

- **Variable Gauge Train**

A variable gauge system allows railway vehicles in a train to travel across a break of gauge caused by two railway networks with differing track gauges. The train changes the gauge automatically when changing from one gauge to another gauge without stopping.

Fig 18 shows 250 kmph variable gauge EMUs for 1,668 mm and 1,435 mm gauges. They change the gauge in a specific facility at around 10kmph speed.

Figure 18: 250 kmph variable gauge EMUs for 1,668 mm and 1,435 mm gauges

Advantages of variable gauge trains:

- Shorter journey times, because of changing gauge in the train.
- Better passenger comfort, because train changes are not necessary.

Drawbacks:

- Higher maintenance costs (more complex bogies).
- Little experience and no experience in India.

Variable gauge train can be considered only, if the present corridor (SG) is planned for an interoperability with the existing Indian Railway corridor (BG). The speed potential, signalling system, train control and driving system and the SOD tolerances are completely different and hence interoperability by variable gauge train is not possible with the existing system. However, during the discussion, it was also clarified that the Thiruvananthapuram - Kasaragod semi- high speed KRDCL corridor under study is a standalone corridor.

Hence variable gauge train is not recommended for the present. However, it can be considered if required, in future when Indian Railways upgrade the system.

- **Basic performance**

Maximum speed:

The maximum speed is set at 200 kmph to shorten the traveling time, aiming at 250 kmph with tilting trains in the future stage.

Acceleration and Deceleration:

The main aim of HS train is to reduce travelling time between stations. Acceleration/deceleration performance is a particularly important factor especially for running short distance and having many stops. The important factors for high-speed railways are not only starting acceleration but also acceleration performance at higher speed and reserve available at the final balancing speed. These factors are determined by the traction system performance set according to rolling stock weight, ambient temperature and other conditions of specification.

Furthermore, the traction system performance governs energy consumption and capacity/weight of components. It is required, therefore, to set appropriate performance ofacceleration/deceleration in consideration of the distance between stations and pattern/frequency of train operation. To cut the travel time and energy consumption, the initial acceleration at approximately 0.6 to 0.7 m/sec/sec may be set. The exact parameter can be worked out during detail design stage.

- **Main structure and equipment**
  - **Body structure**

As discussed, and recommended, the body structure can be of Aluminium material.

  - **Propulsion system**

High power is needed compared to conventional train to achieve the acceleration and speed. For reasons of commercial service reliability, it is also essential to have high power available as a precaution against breakdowns (redundancy). Three-phase traction is possible with the development of power electronics with high power GTO and IGBTs and that made possible the use of lighter, more powerful and reduced-size traction motors. Several independent power converters can easily be installed. High percentage of regeneration is easy and achievable with use of 4Q converters with electrification system 25 kV, 50Hz.Figure 19 shows the typical propulsion system

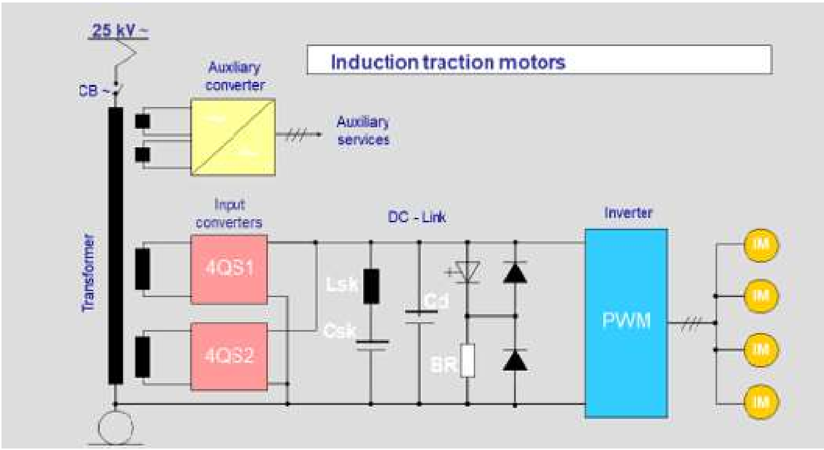


Figure 19: typical propulsion system

  - **Traction Motors:**

As a result of the development of power electronics technology, the AC motor driving system controlled by VVVF inverter is now used in wide ranges. In the case of EMU type rolling stock, AC induction motors and AC synchronous motors are used. Induction motors are more advantageous in that they feature a simple structure, high reliability and low costs.

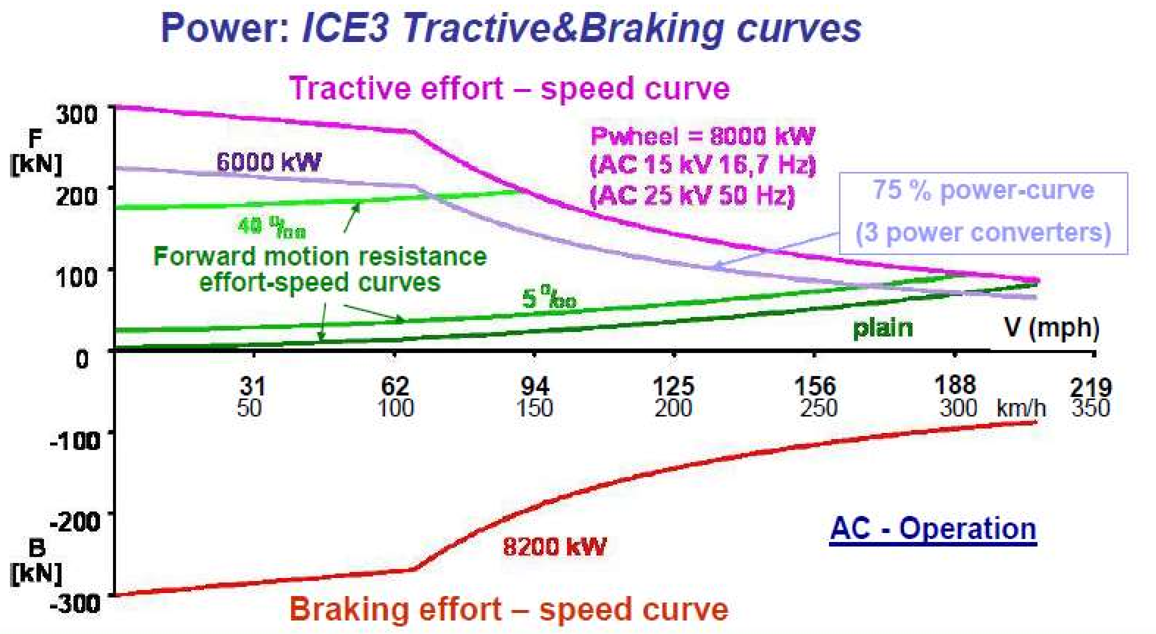


Figure 20: Traction and braking curves

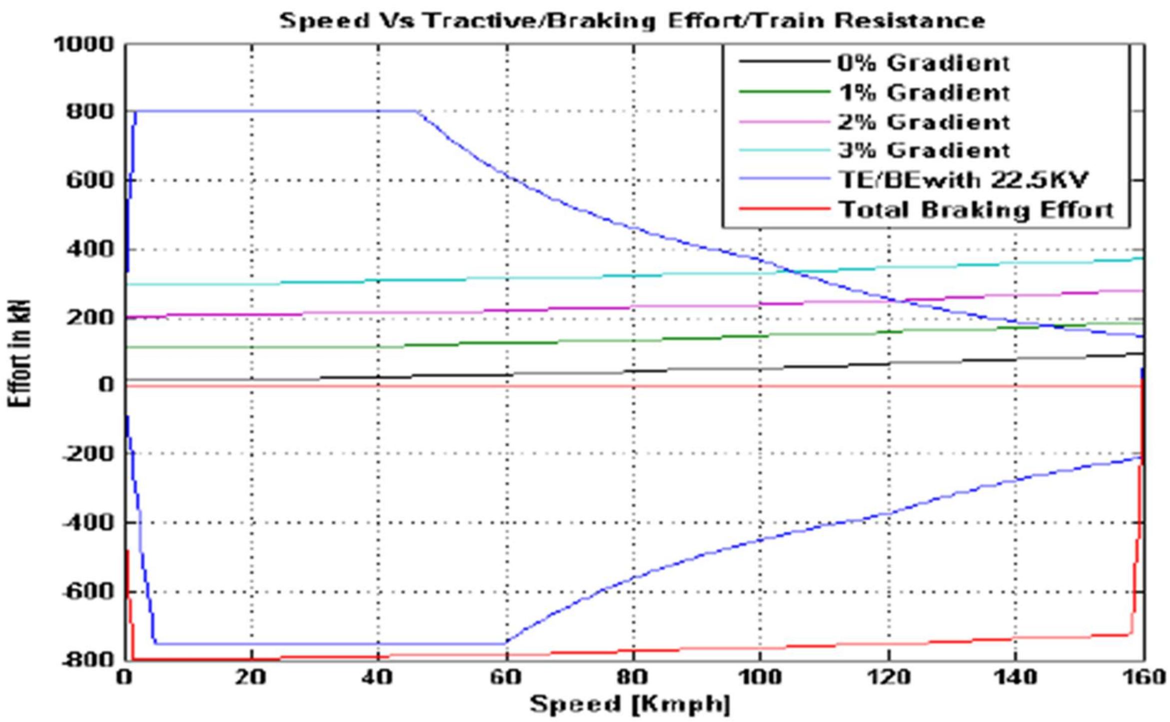


Figure 21: Tractive effort and braking curves and train resistance of 16 car T18 train by ICF

- **Traction unit**

EMU type trainset is composed of multiple traction units, each having a transformer, converter-inverters and traction motors. Attention shall duly be paid to the traction unit to ensure environment-compatible propulsion performance, guarantee redundancy against component failure, underfloor component layout with weight distribution and unify spare parts through standardization of components.
Normally a traction unit is composed of two converter-inverter sets, each controlling a set of traction motors, installed in combination under a transformer, thereby driving the traction motors in total.

- **Propulsion system Configuration**

AC Induction motors with IGBT / VVVF controllers with built in redundancy can be used. The number of driven axle can be approximately 50% to 75 %. The detail design may be done at the DPR and specification stage.

- **Braking system**

System configuration
One of the most essential components for high-speed railways is a brake system to safely stop trains running at high speed, as a large quantity of kinetic energy to be eliminated in higher speed trains.
Generally, the following brakes in combinations are used in such trains:

Electrical Braking
- Regenerative
- Rheostatic
- Eddy current

Mechanical (friction) braking
- Tread
- Disk
- Semi disk

Brake systems adopted for EMU type semi high-speed /HSR rolling stock across the world perform blending control to combine regenerative, pneumatic and eddy current brakes to cut power consumption by regenerating power and reduce wear of abrasive friction brake parts. The regerated power is sent back, which can be used by other trains and other uses. Axle and wheel mounted disk in case of trailer coaches and wheel mounted disk brakes in case of motor coaches are normally used as a pneumatic brake. Table 61 shows comparison of braking system used in EMU trains in different countries. Figure 22 shows the axle and wheel mounted disk brakes

Figure 22: axle and wheel mounted disk brakes

Table 61: Comparison of braking system used in EMU trains in different countries

Series	Japan Series E5	German ICE3	China CRH-2C	Taiwan 700T
Braking system	Regenerative brake Pneumatic brake	Regenerative brake Pneumatic brake Eddy current brake	Regenerative brake Pneumatic brake	Regenerative brake Pneumatic brake
Driven axle	Wheel mounted disk	Wheel mounted disk	Wheel mounted disk	Wheel mounted disk
Trailing axle	Wheel mounted disk Axle mounted disk	Wheel mounted disk Axle mounted disk	Wheel mounted disk Axle mounted disk	Wheel mounted disk Eddy Current disk

Other braking systems used:

- Induction brakes (Foucault or Eddy-current).
- Electromagnetic shoes.

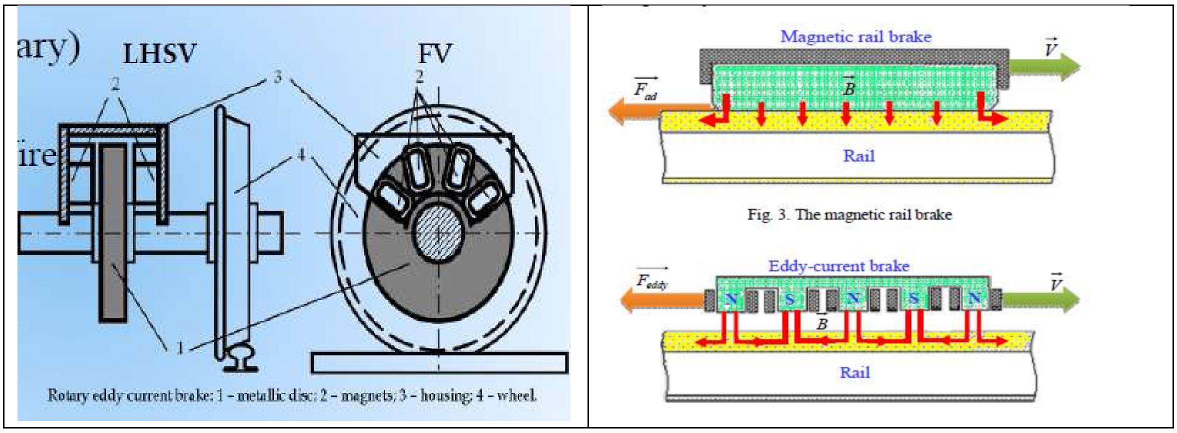


Figure 23: Eddy current brakes

Advantages: Shorter stopping distances.

Drawbacks: Problems to the infrastructure: Track erosion, harmonic interferences, etc.

- Aerodynamic brakes:

Fig 24 shows the basic principle of aero dynamics brake

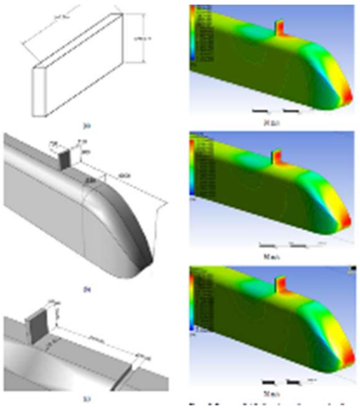


Figure 24: basic principle of aero dynamics brake

This brake is effective at high speed more than 300 kmph and they are not widely used, and they are not widely used for semi high-speed range.

Recommendation

For the speed range of 200kmph, to cut power consumption, an electric command type electric/pneumatic brake blending control system should be adopted to use regenerative brakes as far as possible, with insufficient braking force compensated by pneumatic brakes. Two braking categories, service and emergency brakes should be adopted.

A. Control circuits:

The control circuits are the vital part of a High-Speed train. They consist of interconnected computers (networks along the train). All the train equipment is connected to the computer networks. By means of the control circuits the driver and crew give orders to the train devices. The control circuits are redundant. Normally a control circuit takes the train control (master) and the others are in stand-by (slaves).

In case of failure of the master controller, a slave device takes control automatically and starts working as a master.

B. Signalling and Train control system:

The Signalling system proposed to be adopted in this corridor ETCS level 2 or equivalent. The train should be compactable to this. Cab signalling is recommended.

- **Running gear**

Bogie

To ensure safety for semi-high speed rolling stock, bogies are one of the most important components, for which fundamental requirements are to guarantee speed performance free from hunting and strength of parts of bogies. Among the bogies now used by high-speed railways in the world, the current mainstream is the lightweight bolster-less bogie composed of side frames and cross beams to eliminate bolsters.

Suspension

To guarantee high-degree ride comfort by absorbing vibration of rolling stock in running, the running gear is normally equipped with a secondary air suspension system and dampers to effect appropriate damping force.

- **Other items for safety and Passenger comfort are**
  - Running stability
  - Communication system for train control
  - Crash Worthiness
  - Fire Safety
  - Noise reduction in passenger cabin
  - Air tightness
  - Air conditioning
  - Passenger information network
  - Doors and Windows
  - Toilets
  - Luggage storage area
  - Facilities & provisions for differently abled persons
  - Catering

The above features to be provided may be worked out in the detail design/ specification stage.

- **Recommendation for Rolling Stock Plan**

Based on comparison and analysis described above, an example of proposed rolling stock plan for Thiruvananthapuram- Kasaragod corridor of KRDCL is shown in Table 62. However, these parameter can be worked in more detail during the DPR and detail specification stage based on the requirements.

Table 62: proposed rolling stock plan for Thiruvananthapuram- Kasaragod corridor of KRDCL

Train set composition and configuration	**9 car train sets Extendable to 12/15 car train sets in future**	**EMU type Non-articulated**
Maximum speed	200 kmph.	
Acceleration (Approx.)	0.6 to 0.7 m/sec/sec	Initial acceleration
Average deceleration	0.7 to 0.8 m/sec/sec	Emergency braking rate of 1.2 to 1.3 m/sec/sec
Maximum axle load	16 Tonne or less	The lighter is preferable
Car body width	3,400mm (maxi)	
Passenger capacity (Approx.)	675 persons: 9-car train set	
Seating arrangement	5-seat (2+3) arrangement 4-seat (2+2) arrangement	Standard class Business class 6-seat (3+3) arrangement is possible for lower fare
Car body structure	Aluminum structure	
Type of bogie	Bolster-less type	Air spring suspension system
Track gauge	Standard gauge- 1,435 mm	

Supply power system	AC 25 kV 50 Hz	
Approximate Electric load of 9-car train	5.0 MVA (Approximately)	
Traction circuit and configuration	VVVF inverter control Using IGBT and asynchronous traction motor	
Braking system	Regenerative brake Electric/Pneumatic brake blending	Normal and Emergency
Emergency braking distance	< 1800 m	

6.3 Power Supply & Traction systems

6.3.1 Overview

Indian Railways, and Metro rails, purchase electric power from various state electricity boards at different voltage, normally 220/132/110/66 kV. The arrangement of AC traction is given in figure 25

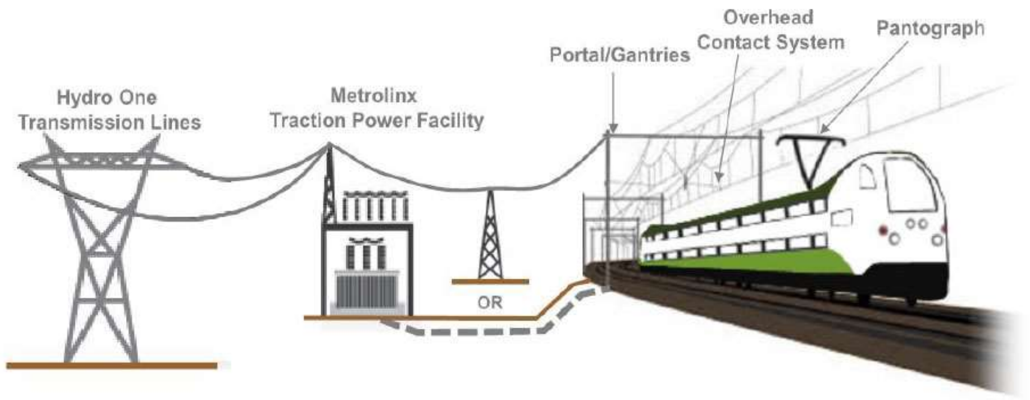


Figure 25: arrangement of AC traction

In AC traction arrangement, the incoming supply will step down to 25kV AC and attaches to Over Head equipment (OHE) for serving the Traction supply to the Rolling stock.

Over view of the power supply installation in Trivandrum to Kasaragod Semi High-Speed Rail corridor

- It is powered by double lines taken from the transmission network 220/110kV of Kerala State Electricity Board Limited (KSEBL)
- The feeding system will be single phase AC ,50 Hz ,2x25 kV, Auto Transformer (AT) feeding system
- The standard voltage of the system is 25kV
- The traction system shall be as follows
    - There will be a spacing of 70 to 80 km between the Traction Substations(TSS)
    - The distance between sectioning and paralleling post (SP) and traction substation(TSS) will be approximately 30-40 Km and sub-sectioning and paralleling post (SSP) will be placed in between SP and TSS

- There will be Auto transformer feeding at regular intervals

➢ In Trivandrum to Kasaragod corridor of Semi High Speed Rail, the overhead system and power supply system are designed for 250kmph speed, as per the design parameter specified.

6.3.2 Power requirement (Traction and Auxiliary loads)

For any Semi High-Speed Rail Transit System, un-interrupted power supply is essential for running the Train, Operation Control Centre, Tunnel ventilation, Station services (Lighting, Air-conditioning, Firefighting and alarm system, Lifts, Escalator, Signalling and Telecommunications etc), Depot Services (Inspection shed, Workshop and Pit wheel lathe etc) and other maintenance infrastructure.

For the operation of Semi High Speed Rail from Trivandrum to Kasaragod corridor, an EHV supply at the voltage level of 220/ 110kV to be obtained from the Kerala State Electricity Board ltd (KSEBL) to the various Receiving/Traction Substations, distributed in the mentioned corridor.

The requirement of power for the traction and auxiliary loads are estimated considering the tentative peak hour demands.

Table 63 shows the Power requirement and Energy consumption (approximate) for the years of 2024,2030, 2040 and 2051 for the tentative train operation plan.

Table 63: Power requirement and Energy consumption (approximate)

Trivandrum to Kasaragod Corridor	**2024**	**2030**	**2040**	**2051**
Power Demand (MVA)	85	100	140	175
Energy consumption (million units)	277	342	436	517

6.3.3 Factors considered for Railway Power supply design

➢ Quality of power collection and voltage to the train during operation - depends on source of power, supply system, feeding system and OHE arrangements

➢ Quality of mechanical interaction between contact line and train pantograph at rated speed - depends on design of OHE, Pantograph, Rolling stock vibrations and Track

➢ Reliability and availability during operation - depends on Power source, equipment reliability and redundancy

➢ Maintainability and maintenance management of electrical installations - depends on maintenance philosophy and maintenance organization

6.3.4 Need for High reliability of Power supply

The power supply system is being designed to cater to a PHPDT requirement of the corridor during peak hours when maximum number of trains are expected to run and is designed for the requirement upto the year 2051. Incidences of any power interruption, apart from affecting train running, will cause congestion at stations. Interruption of power at night is likely to cause alarm and increased risk to the travelling of the public. Lack of illumination at stations, non-visibility of appropriate signages, disruption of operation of lifts and escalators is likely to cause confusion, anxiety and ire in commuters, whose tolerance level are low on account of stress. Effect on signal and communication may affect train operation and passenger

safety as well. Therefore, the reliable and continuous power supply is mandatory for efficient train operations.
To ensure the reliability of power supply, it is essential that both the sources of Supply and connected transmission & distribution networks are reliable and have adequate backup for station auxiliary loads.

6.3.5 Sources of Power Supply

In Kerala, the transmission voltage is opted as 220kV,110kV and 66 kV. This 220kV,110kV and 66kV network is available all along the proposed corridor. There are seventeen 220kV substations, one hundred and twenty-nine 110kV substations and eighty-three 66kV substations available in Kerala.
The transmission sector of KSEBL comprises of two zones namely North and South, and a System Operation wing each headed by a Chief Engineer (Transmission - North) with its headquarters at Kozhikode and the South zone headed by the Chief Engineer (Transmission-South) with its headquarters at Thiruvananthapuram. The system operations wing with headquarters at Kalammassery is responsible for the real-time management of Kerala Power System and the activities connected with communication and protection fields.
To maintain the adequate reliability, it is proposed to avail two input sources of 220/110kV voltage level to each of the traction substation of the proposed corridor.
Table 64 shows the availability of Grid Substations in the corridor, from where power can be availed for train operation.

Table 64: Availability of Grid Substations in the corridor

RSS No	Location of Grid Substation
1	Pothencode (GSS)
2	Mavelikkara (GSS)
3	Eramalloor (GSS)
4	Cherpu (GSS)
5	Pokkai (GSS)
6	Ulliyeri (GSS)
7	Mundayad (GSS)
8	Mavungal (GSS)

6.3.6 Electrification system for HSR / Semi HSR

The system which uses electrical power for traction system i.e. for **Railways**, Metros, Trams, Trolleys, etc. is called electrical traction. The track electrification refers to the type of source supply system that is used while powering the electric locomotive systems. Selecting the type of electrification depends on several factors like availability of supply, type of an application area, or on the services like urban, suburban and main line services, etc.
Presently, two types of electric traction systems are being adopted in India

- Alternating Current (AC) electrification system
- Direct Current (DC) electrification system

Worldwide, 25kV AC electrification system is adopted for the main line railways and High-Speed Train services and DC electrification system is used for mainly metros and tramways etc.
There are three types of 25 kV, AC electrification systems are available for mainline railways and HSR;

- 25kV system without Booster Transformer
- 25 kV with Booster Transformer (BT)
- 2x25 kV System with Auto Transformer (AT) feeding

Table 65 shows the history of feeding systems adopted for different High-Speed Rails in the world

Table 65: History of feeding systems adopted for different High-Speed Rails in the world

Year	Country	Feeding System	Traction substation spacing (Approximately)
1964	Japan (Tokaido)	1x25 kV with Booster Transformer	20km
1972	Japan (Sannyo)	2x25 kV	50km
1981	France (PSE)	1X25 kV without BT's (Partly 2x25 kV)	30 km (1x25kV) 90km (2x25 kV)
1989	France (Atlantique)	2x25 kV	60 - 70km
1991	Japan (Tokaido)	Converted to 2x25 kV	40km
2005	France (PSE)	Converted to 2x25 kV	60 km

Table 66 shows the feeding system adopted for High Speed Rails in major countries world over

Table 66: feeding system adopted for High Speed Rails in major countries world over

Year	Country	Feeding System
2004	South Korea (KTX)	2x25 kV
2006	U.K (HS1)	2x25 kV
2007	France (LGV Est)	2x25 kV
2007	Taiwan (HSR)	2x25 kV
2008	Spain (Madrid to Barcelona)	2x25 kV
2009	Italy (Rome to Napoli)	2x25 kV
2011	Japan (Kyushu)	2x25 kV
2011	China (Beijing to Shanghai)	2x25 kV

1. Standards for the electric installations

The standards for the electric installations of the major sections in the subject countries, where HSRs are in operation is listed in Table 67

Table 67: Standards for the electric installations

Name of Country	Japan	Taiwan	South Korea	China	France	Germany	Spain	Italy
Section	Tokyo to Morioka	Taipei to Zuoying	Seoul to Busan	Beijing to Tianjin	Paris to Boudercourt	Koln to Rhein/Main	Madrid to Lieda	Rome to Napoli
Total length (km)	496	345	412	115	301	197	447	205
Feeding Voltage(kV)	25	25	25	25	25	15	25	25
Frequency (Hz)	50	60	60	50	50	16.7	50	50
Feeding system	AT	AT	AT	AT	AT	1x15kV	AT	AT
Overhead equipment (OHE)	Compound catenary		Simple Catenary			Simple catenary with stitch wire	Simple catenary with stitch wire	Simple catenary

6.3.7 Receiving / Traction substation and Power feeding equipment

6.3.7.1 Design criteria for Power supply and OHE systems

As per the design parameter specified, the system is designed for running the train at a speed of 250kmph.The power supply and OHE system is designed to cater the speed of 250kmph and the load requirement up to the year 2051.

6.3.7.2 Points to be considered while selection of Receiving /Traction Substation

- Availability of Grid substation (GSS) in near by location of the alignment
- Capacity of traction transformer, train density and voltage regulation
- Norms for locating the Traction substations based on the capacity of Transformer and Voltage regulation

Table 68 shows the voltage of overhead contact line according to the standard EN50163/IEC 60850, the voltage of the 25kV power supply system are:

Table 68: Voltage of overhead contact line according to the standard EN50163/IEC 60850

Classification	Voltage
Permanent maximum voltage	27.5 kV
Nominal/standard voltage	25 kV
Maximum during 5minutes	29 kV
Permanent lowest voltage	19 kV
Minimum during 10 minutes voltage	17.5 kV

- Traction substations shall be approachable by road and preferably by railway for better connectivity by road and rail

6.3.7.3 Receiving / Traction Substations

Presently, two types of receiving substation/Traction substations are used in railways and metros

1. Air insulated Substation (Outdoor)
2. Gas Insulated Substation (Indoor)

1. Air insulated Substation (Outdoor)

Figure 26 shows schematic diagram of 220/110kV ,25kV AC traction outdoor type substation and figure 26(a) shows the general equipment arrangement in the substation

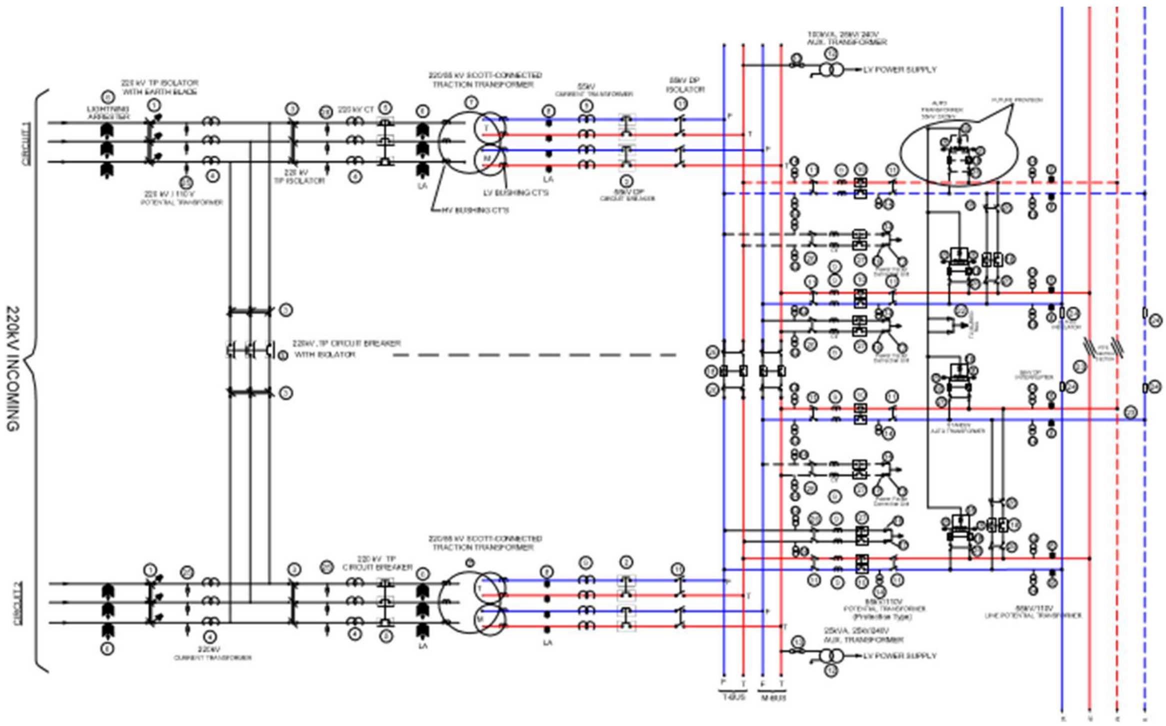


Figure 26: Schematic diagram of 220/110kV ,2x25kV AC traction outdoor type substation

Figure 26(a): General equipment arrangement in the substation

2. Gas Insulated Substation (GIS) (Indoor type)

Figure 27 shows schematic diagram of GIS substation and Figure 28 shows the general equipment arrangement in the substation

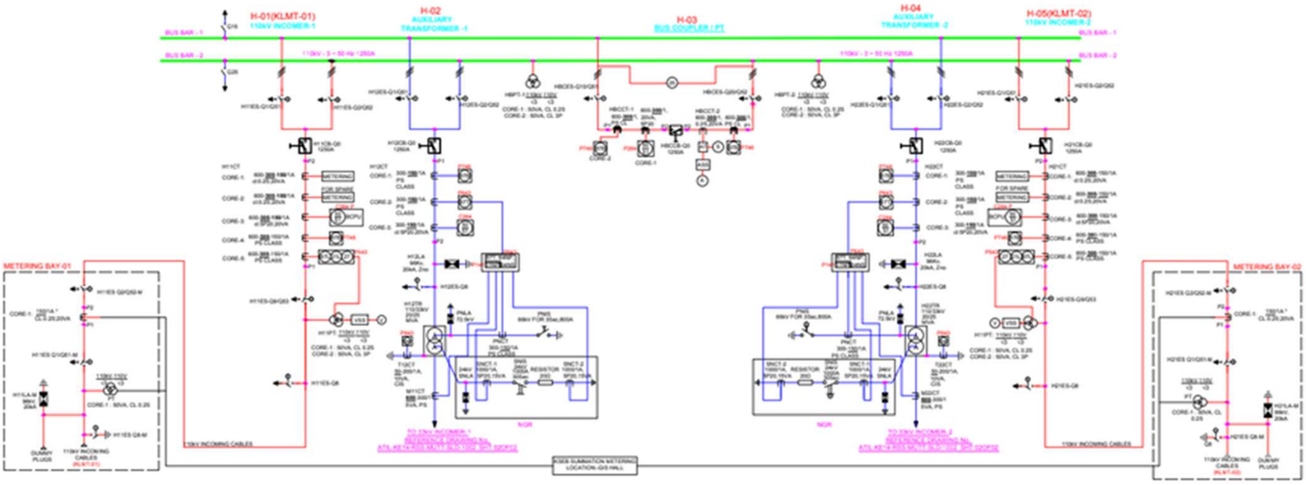


Figure 27: Schematic diagram of GIS substation

Figure 28: General equipment arrangement in the substation

6.3.7.4 Table below shows the comparison between GIS and AIS

Table 69: comparison between GIS and AIS

Comparison	GIS	AIS
Media used for "Busbar" insulation	SF6	Air
Media used for "Switching"	SF6	Air, Oil, SF6 or Vacuum
Safety	More safety	Less safety
Reliability	More reliable	Less reliable
Maintenance	No maintenance required for 5 years	Every year maintenance and based on the operation
Maintenance producers	Experts required for maintenance	Experts are not required
Area	less area required	Large area required
Capital cost	High	Low
Installation	Easy and don't require much time for assembly	Required much time for assembly

Table below shows the land requirement of conventional outdoor type substations

Table 70: land requirement of conventional outdoor type substations

Sr No	RSS voltage	Plot Size (Mtr x Mtr)	Area (Sqm)
1	220 kV	150 x 110	16500
2	110 kV	140 x 100	14000

Requirement of land for GIS will be considerably less but the cost of substation works will increase by nearly 8 Crore. Considering the high land cost in Kerala, the overall cost difference between AIS and GIS may even come down.

Recommendation: -

To achieve the desired reliability, it is recommended to provide 8nos of Traction substations in this corridor. This will enable to feed 2x 25 kV traction supply to the corridor with a maximum speed of 250 kmph .

The exact location of the Receiving cum Traction substation can be decided during the DPR stage.

6.3.7.5 Traction Transformer

The maximum current of conventional lines is 600A whereas higher current shall be required for High-speed rails. Therefore, it is essential to have larger capacity of traction transformer. The tentative capacity of traction transformer is 40/60 MVA
To minimise the voltage fluctuations in the incoming side of traction substation, On-load tap changer (OLTC) to be installed.

6.3.7.6 Connection method of Transformer

There are various transformer connection methods available for transferring 3 phase voltage to 1 phase or 2 phase voltage ie for handling considerable amount of power. The most common connection method used for the Traction transformers in high speed rails are

1. Scott connection
2. V- connection

Figure 29 shows the Scott and V- connection method adopted for traction transformers

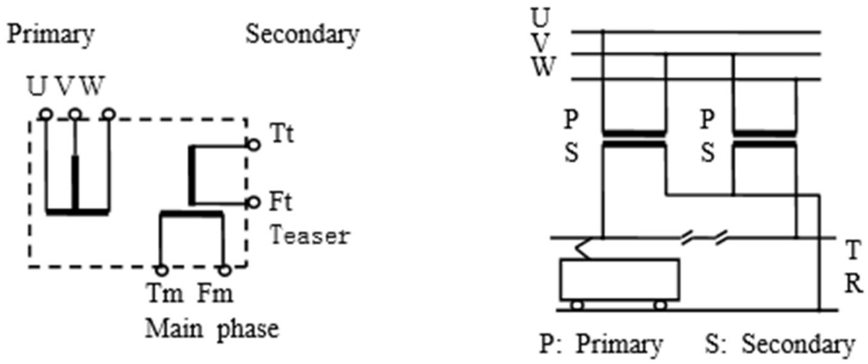
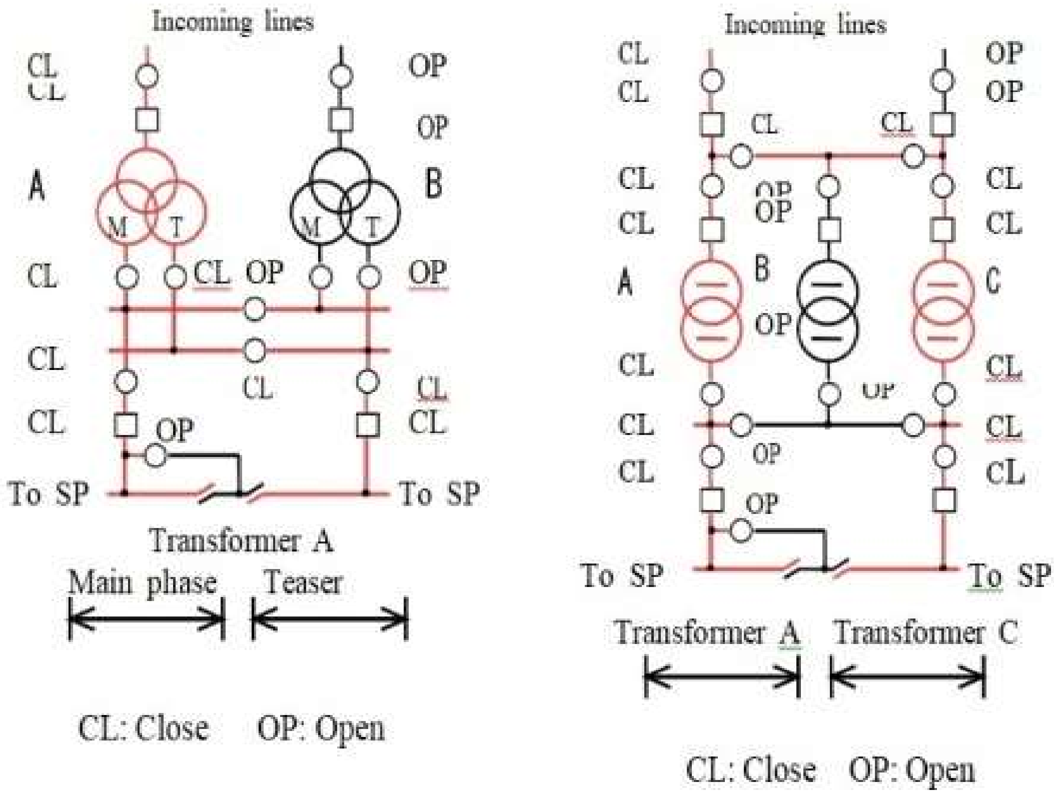


Figure 29: Scott connection method and V- Connection method

6.3.7.7 Connection of feeding Transformers and operating method

Figure below shows the Scott connection method feeding to the High-Speed Rails. In this type of connection two transformers will be provided to feed the traction supply at the substation. One transformer will feed the main line railway supply and the other one will act as hot standby supply

Figure below shows V - connection method feeding to High Speed Rails, in this type of connection three transformers will be provided to feed the traction supply at the substation. Two transformers will feed the main line railways supply and the third one will act as hot stand by supply.



Scott and V-connection

6.3.7.8 Calculation of voltage unbalance rate

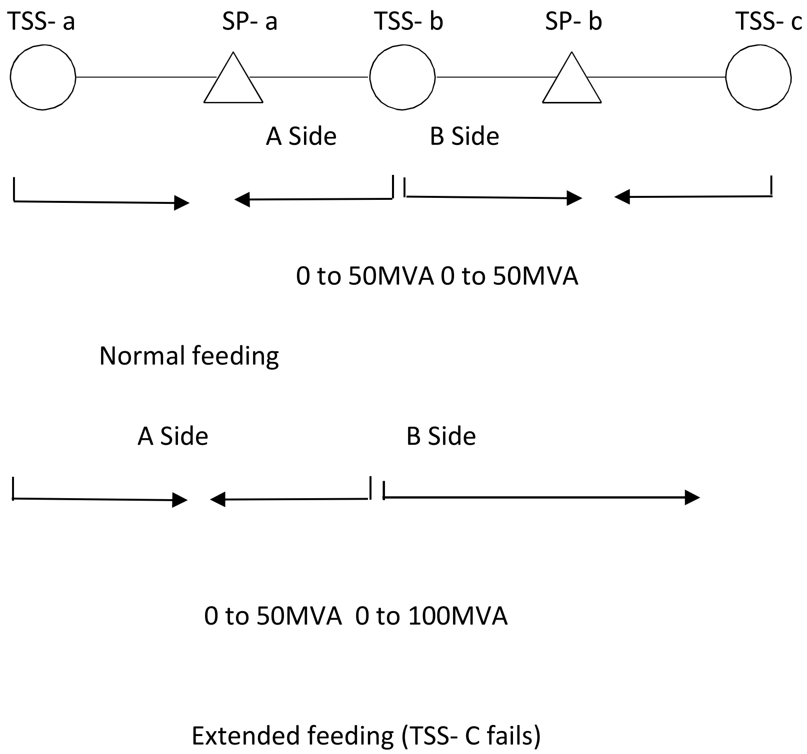
The following formula is used for calculating voltage unbalance rate due to the connection method of the transformers

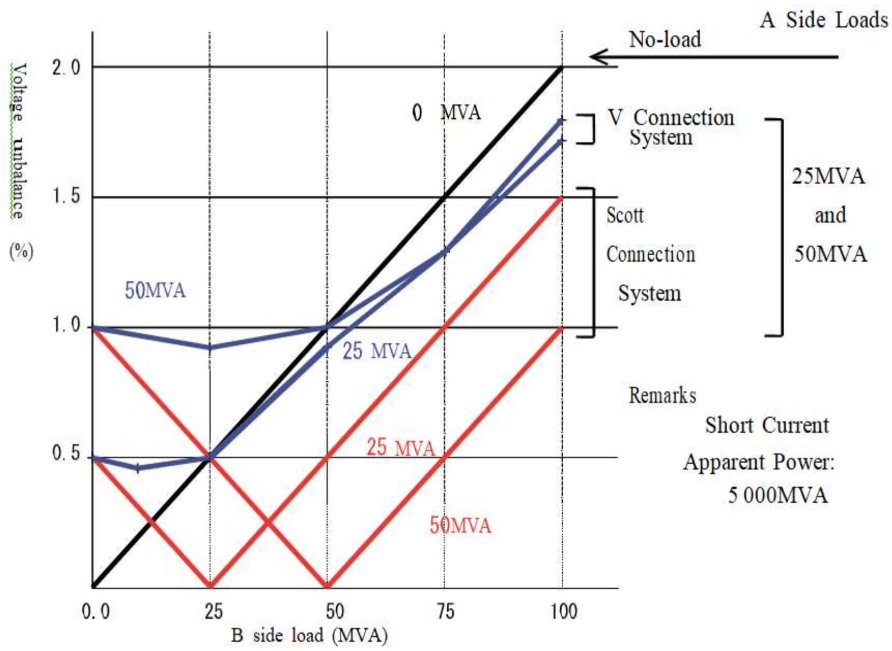
1. Single phase Transformer   u   = $(E_s \times I / P_s) \times 100\%$
2. V - Connection Transformer   u   = $(E_s \times \sqrt{(I_a^2 + I_b^2 - I_a \times I_b)}/ P_s) \times 100\%$
3. Scott connection Transformer   u   = $(E_s \times |(I_m - I_t)| / P_s) \times 100\%$

Where,

u - Voltage unbalance rate (%)
E_s - Line Voltage (KV)
P_s - Short current apparent power (kVA)
I - Line current (Single phase in Ampere)
I_a, I_b - Line current (V- connection in Ampere)
I_m, I_t - Line current (Scott connection in Ampere)

The calculation is done depending on the load conditions as shown in Figure below shows the calculation result of the unbalanced rate. Voltage unbalance rate is the same in any connection when the load in one direction only. However, if there are loads in both directions, the unbalanced rate is smaller than V-connection in case of Scott connection.





Calculations result of the unbalanced rate

6.3.7.9 Transformer Connection method adopted for High speed rails

Table 71 shows the connection method of Transformer adopted for different high-speed rails internationally by major countries.

Table 71: connection method of Transformer adopted for different high-speed rails internationally by major countries

Type of connection method	Name of Country
Scott Connection	Japan, Taiwan, South Korea, France
V – connection	France, Italy, China

To sum up the advantage of the Scott connected transformers over V- connected transformers are:

a) The incoming circuit can be simplified.
b) The number of traction transformers is reduced.
c) The power supply voltage unbalance is reduced.

6.3.7.10 Kerala State Electricity Board Ltd (KSEBL) requirement

The transmission authorities of Kerala are insisting southern railway, railway traction consumer, for provision of Scott connected traction transformer for reducing the level of voltage unbalancing.
Indian Railways are also adopting Scott connected transformers for their traction substations

Recommendation

Considering the advantages and to comply the requirements of KSEBL, it is recommended to provide Scott connected Traction Transformer in substations.

6.3.7.11 Feeding system

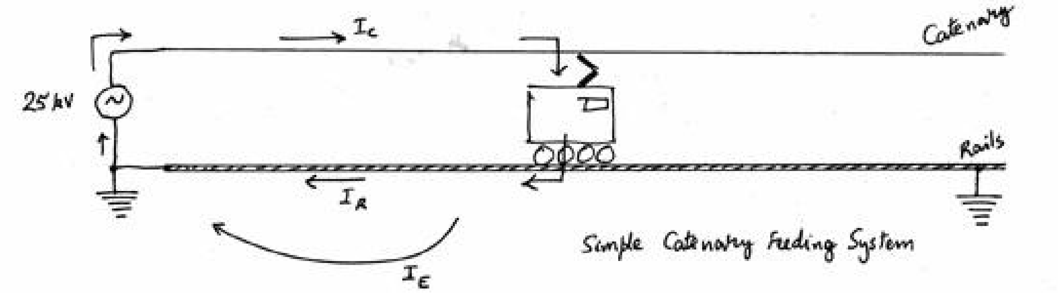
Electricity is supplied to the electric rolling stock through overhead contact wire for operation. In AC traction system, the outflow current is induced to the nearby communication lines, causing inductive problems to the communication lines. A feeding system shall be adopted with suitability to control the outflow of current to the ground.
Presently, there are two types of feeding systems adopted in railways and High- speed Rails, which are

1. 25 kV Traction System
2. 2x 25 kV traction System

6.3.7.11.1 25kV Traction System

- **25kV System (without Booster Transformer)**

Figure below shows the arrangement of this feeding system. In this system, the power supply is fed directly to the catenary wire. Feeder droppers are provided to direct the current from catenary to contact wire. Pantograph collects the current from contact wire and return through the running rails.

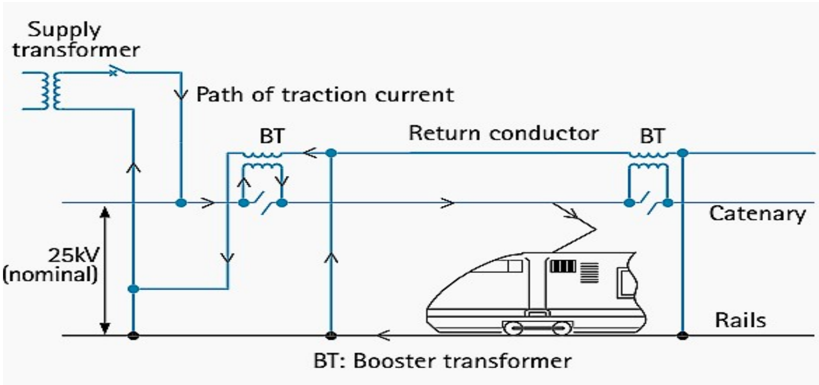


Single 25kV system

- The simplest feeding system
- Possibility of induction effect to the communication lines
- Higher rail potential than other feeding system

- **25kV with Booster Transformer feeding System (BT)**

Figure below shows the arrangements of feeding system, in this type of arrangement booster transformers are provided at regular intervals to avoid /nullify the inductive disturbance to the communication line as some percentage of the return current will find an easy path through the earth (leakage current). The BT will restrict the leakage current from the return rail path.

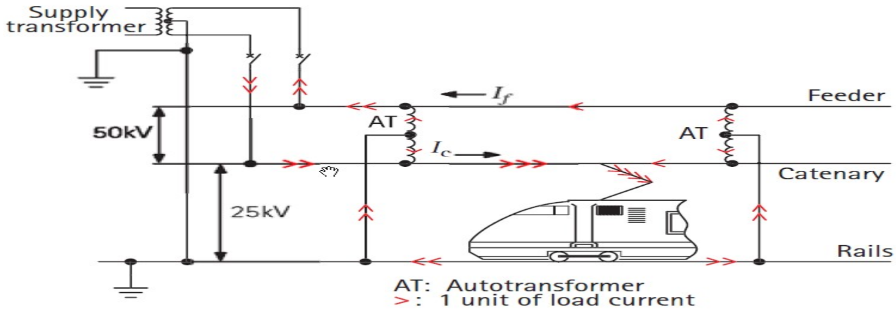


Single 25kV with Booster Transformer feeding System (BT)

- A feeding system that uses a booster transformer
- Effective in reducing induction to communication lines
- Need a Booster Transformer section
- Complicated contact wiring in the Booster Transformer system as the booster transformer system requires the sectioning at each booster transformers, which causes electrical and mechanical inconvenience for the contact wire and pantograph at high speed
- Considerable impedance in the feeding system

6.3.7.11.2 2x 25 kV system with Auto Transformer (AT) feeding system

Figure below shows the 2X25kV Auto transformer feeding system. The 2x25 kV system is based on the idea of distributing the voltage along the line at higher potential (50kV) and feeding the train at 25 kV. For this, the substations feed the system at 50 kV and through intermediate autotransformer centers supply power to the rolling stock.



2x 25 kV system with Auto Transformer (AT) feeding system

- A feeding system that uses an Auto transformer
- Suitable for supplying more power because it can carry feeding voltage higher than that carried by an overhead contact line
- The spacing between substation will be more
- Approximately a 10 km interval between two auto transformers
- Interference of communication lines will be reduced/eliminated
- It can control the leakage of current from Rail to the Ground

6.3.7.12 Comparison between 1x25 kV system and 2x25 kV system

a. for equal volumes of traffic, reduce the line voltage drops by 3 and so improve the output of the traction circuit.
b. for the same number of substations, to double the traffic,
c. to position the substations better with respect to existing HT lines.
d. to reduce considerably electromagnetic and telephone disturbance with respect to the residents and railway installations.
e. to present no discontinuity of contact wire at the auto transformers, whereas in the booster-transformer system, the sectioning at each booster-transformers causes serious electrical and mechanical inconvenience for the contact wire and the pantographs, particularly at high speed.
f. Improved voltage regulation and reduced transmission line losses
g. Increased traction substation spacing
h. Improved load factor as number of train fed per feeding post are more

Table 72 shows the comparison of electrical aspects of 1x25 kV and 2x25 kV System

Table 72: comparison of electrical aspects of 1x25 kV and 2x25 kV System

	1 x 25 kV system	2x 25 kV system
Line Voltage	A	a
Line Voltage drop	A	a/3
Line Current	B	b/2
Electrical loss	C	c/4
Disturbance	D	Reduced considerably
Continuity of contact in normal conditions of circulation	4-25 km neutral section sectioning post (Booster Transformer)	25 - 80 km neutral section

Table 73 shows the main parameters involved for cost comparison.

Table 73: main parameters involved for cost comparison

	Cost	
	1x25 kV System	2x 25kV System
Substation	A	a’ < a/2
HT lines	B	b’<b
At stations	O	c
Catenaries	D	d’>d
Cables along the track	F	f’<f
PTT protections	G	g’<<g
Total	P	P’

Theoretically, for the same train power supply quality, if P’<P, the 2x25kV is chosen

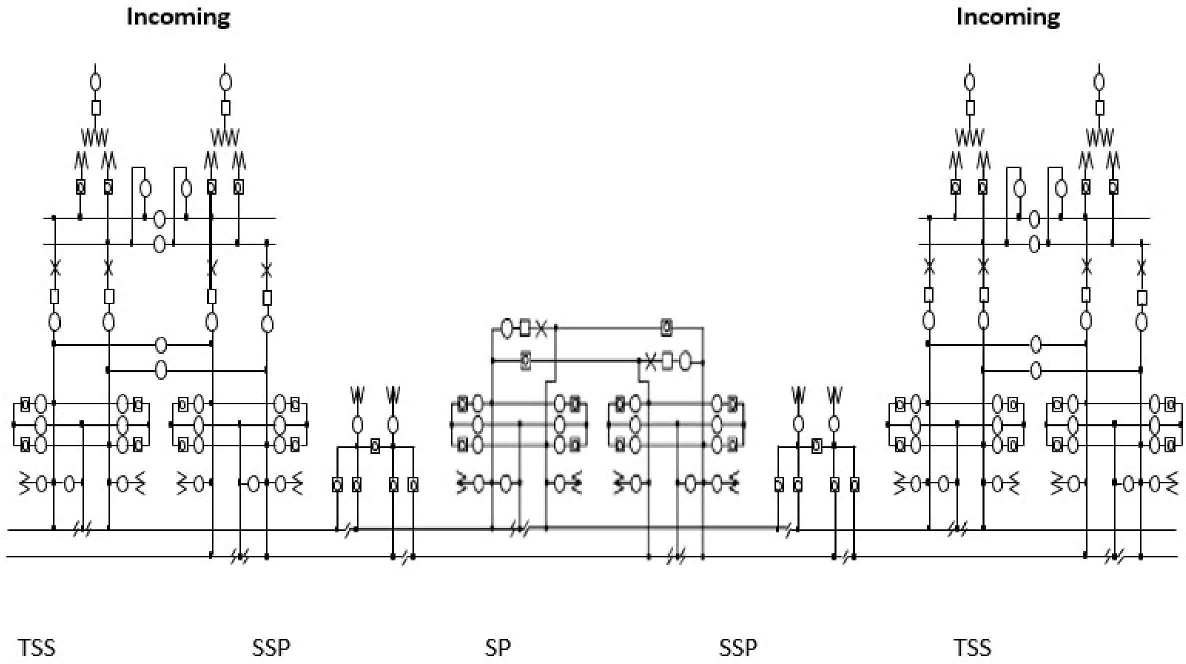
Indian Railways has the experience in operating the 2x25kV feeding system for the Bina - Katni - Anupur - Bishrampur/Chirimiri line which was opened in the year 1996. Also, the Dedicated Freight Corridor (DFC) project, which is under construction, has adopted the 2x25kV system.

Recommendation: -

Considering the advantages of 2x25 kV system and the international acceptance of 2x25kV feeding system for High Speed Rail operation, it is recommended to provide 2 x25 kV system in this corridor.

6.3.8 Standard power supply network

Figure below shows the schematic arrangement of standard power supply network of AC traction - Traction substation (TSS), Sectioning and Paralleling post (SP) and Sub sectioning and Paralleling post (SSP)



Standard power supply network

6.3.9 Overhead Equipment System

Electric trains collect supply from the overhead wire through pantograph. Current collectors are electrically conductive and allow current to flow through to the train and back to the feeder station through the steel wheels on one or both running rails.

Following points shall be considered while designing the OHE system

- Must have the characteristics meeting train speed and current requirements
- Must be at uniform height above rail to optimise pantograph power collecting characteristics, so entire equipment must have uniform spacing constant and handling rigidity
- Must have minimum vibration and motion to ensure smooth pantograph passage during High speed operation or strong wind
- Must have strength to withstand vibration, corrosion, heat etc.

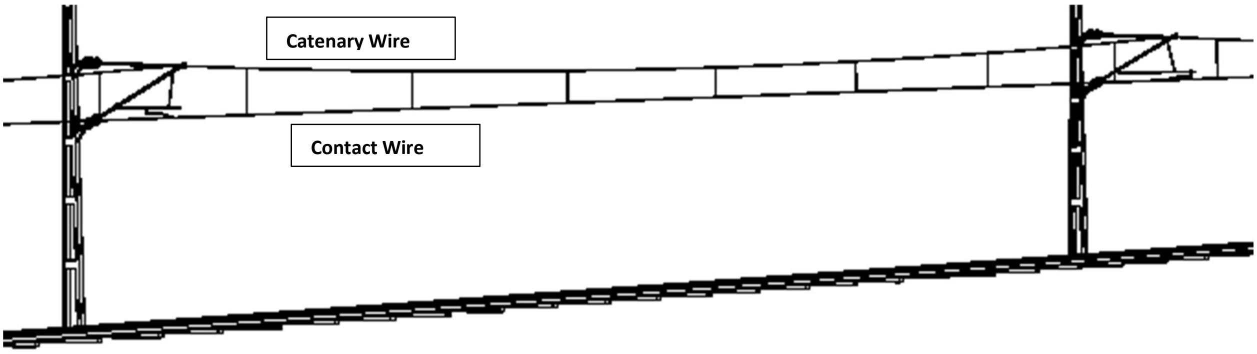
6.3.10 Types of catenary system

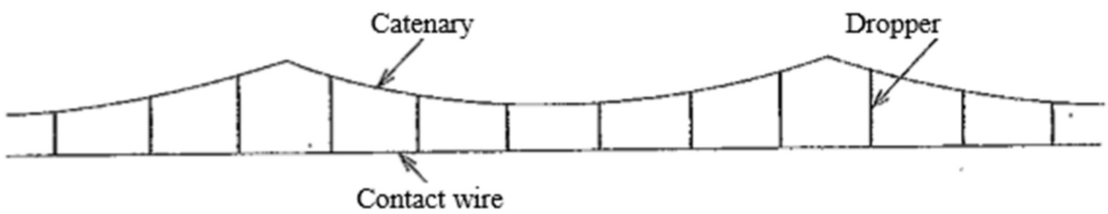
There are 3 types of catenary system adopted for mainline railways and High-Speed railways

1. Simple catenary system
2. Simple catenary with stitch wire system (Y- stitch)
3. Compound catenary system

6.3.10.1 Simple catenary system

Figure below shows the arrangement of simple catenary system. This system consists of catenary, droppers and a contact wire. This catenary system is adopted in France, Italy, China and South Korea for the operation of High Speed Rails





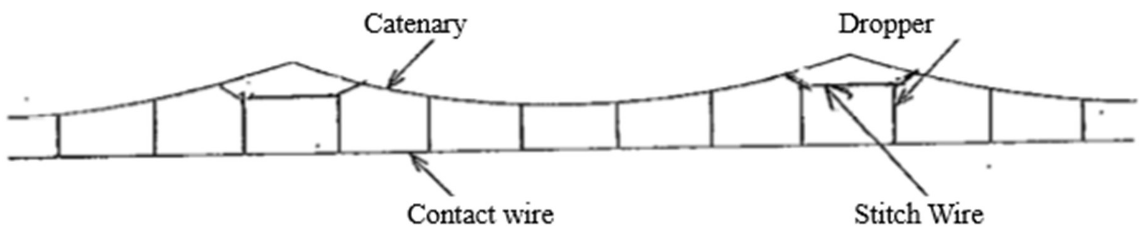
Simple catenary system

6.3.10.2 Simple catenary with stitch wire system (Y- stich)

Figure below shows the arrangement of simple catenary with stitch wire system. This system consists of a Y-stitch wire introduced between the catenary and contact wire. The height difference of contact wire between mid-span and supports will be compensated by using this type of OHE .When the temperature change takes place, the vertical movements of the points, where the stitch wire fixed to an uncompensated catenary wire, in conjunction with the change in catenary wire length and tensile force causes the contact wire at the support to be raised and lowered similarly to the high changes at the middle of span .

The spring effect at the stitch wire achieves a considerably better match of the elasticity at the supports to the elasticity of the mid span.

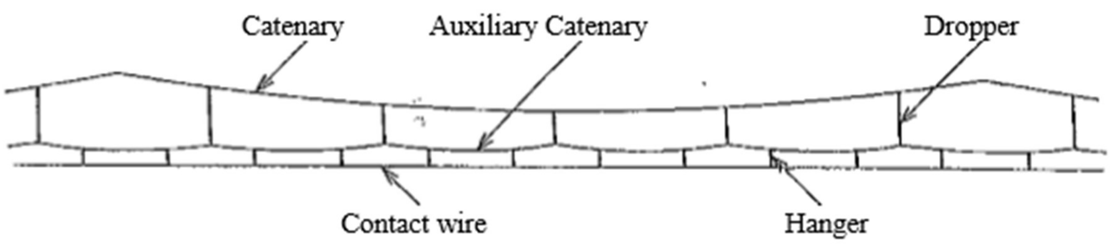
In Germany, this system is adopted for the operation of High Speed Rails and conventional lines.



Simple catenary with stitch wire system (Y- stich)

6.3.10.3 Compound catenary system

Figure below shows the arrangement of compound catenary system. This system consists of one main catenary, auxiliary catenary and a contact wire. The auxiliary catenary wire placed between main catenary and contact wire. Auxiliary catenary connects the main catenary and contact wire by means of droppers, which helps to eliminate variation elasticity. However, the good running characteristic of this type of installation are offset by the increased material requirements and significant higher installation effort.



Compound catenary system

Table below shows the types of overhead equipment used for high-speed rails in different countries.

Table 74: types of overhead equipment used for high-speed rails in different countries

Type of Overhead equipment	Name of Country
Simple Catenary	France, Italy, China, South Korea
Simple Catenary with Stitch wire	Spain, Germany
Compound Catenary	Japan, Taiwan

Table below shows the characteristics of overhead equipment adopted for high-speed rails in different countries.

Table 75: Characteristics of overhead equipment adopted for high-speed rails in different countries

Name of country	Japan	China	France	Germany
Overhead Equipment	Compound Catenary	Simple catenary	Simple Catenary	Simple catenary with stitch wire
Catenary wire	Galvanizing steel 180mm2 2 450daN	Bronze 120mm2 2100daN	Bronze 116mm2 2000daN	Bronze 120mm2 2100daN
Auxiliary catenary wire or stitch wire	Hard Drawn Copper 150mm^2 980daN	None	None	Bronze 35mm^2 350daN
Contact wire	Bronze 170mm^2 1960daN	Cu Mg 150mm^2 3000daN	Bronze 150mm^2 2600daN	Cu Mg 120mm^2 2700daN
Span length	50m	60m	54m	65m
Maximum operational speed	320km/h	300km/h	320km/h	300km/h
Allowable current	1 000A	---	800A	-

Recommendation

In this project, it is proposed to use simple catenary system with higher cross section of catenary and contact wire for high speed operation for the speed of 250 kmph.

Table below shows the details of the proposed system in this project.

Table 76: Proposed system Over Head Equipment (OHE) system

Item	Main line
Type of overhead equipment (OHE)	Simple catenary
Catenary wire	120mm^2, Cu alloy
Contact wire	150mm^2, Cu alloy
Negative feeder	300mm^2, Aluminium
Standard span	59 - 63 mtr (normally)

6.3.11 Neutral Section

Neutral Section is a short insulated dead overhead equipment separating sectors fed by two adjacent substations which are normally connected to different phases and is provided between two TSS.

6.3.11.1 Types of Neutral section

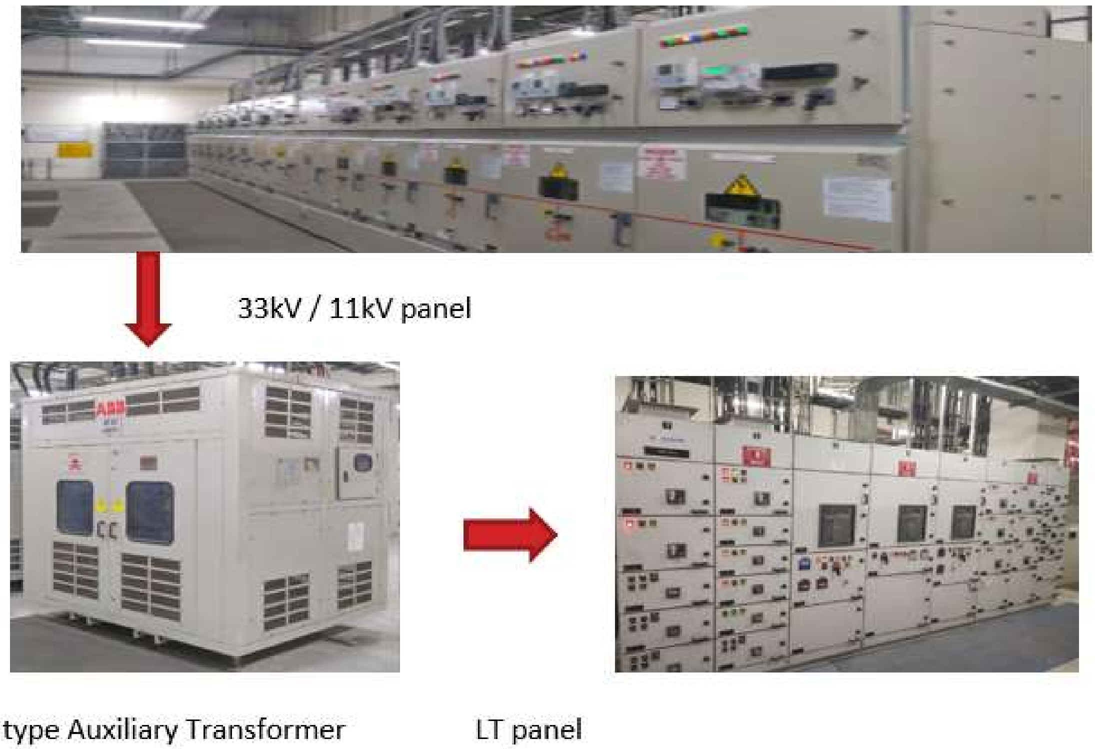
There are three types of neutral section used, which are namely
(1) Conventional Type
(2) Short Neutral Section - Section Insulator and Poly Tetra Fluro Ethylene (PTFE) type
(3) Dynamic Neutral Section or ASNS type
The type of neutral section will be decided in the DPR /detailed design stage.

6.3.12 Auxiliary Supply arrangement for Stations and Depot

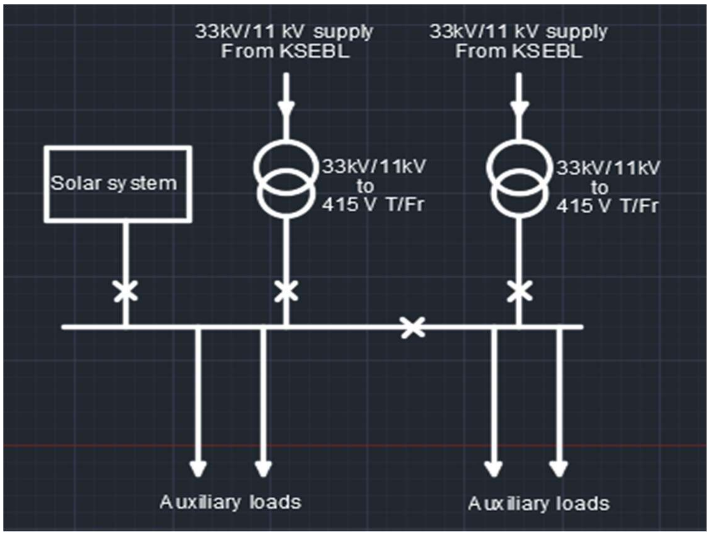
A separate HT connection of 33kV or 11kV to be availed from KSEBL to cater the Auxiliary loads of Stations and Depot. Auxiliary sub-stations (ASS) are envisaged to be provided at each station and Depot. Two dry type cast resin transformers (33/11KV to 0.415kV) of 500/630/1000kVA capacity are proposed to be installed at the stations and Depot.

A provision to be made in 33/11 kV panel of stations to add the third transformer in future to meet the load increase and function of property developments, if required

Figure below shows equipment arrangement of Auxiliary Substation - 33/11 kV panels, Dry type transformer and LT panels and schematic arrangement of Auxiliary substation.



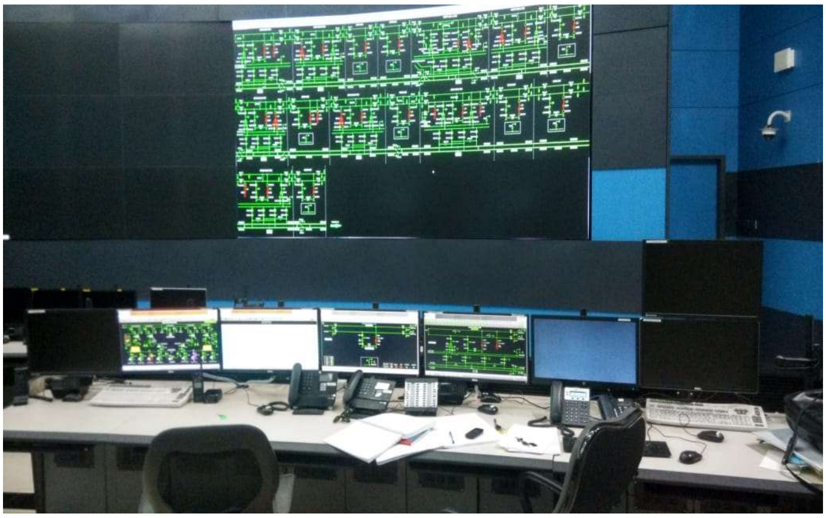
Equipment arrangement of Auxiliary Substation



Schematic arrangement of Auxiliary Substation

6.3.13 Supervisory Control and data acquisition system (SCADA)

The entire system of the power supply (Traction & Auxiliary) to be monitored and controlled from a centralized Operation Control Centre (OCC) through a SCADA system, is provided in the below figure. Modern SCADA system with intelligent remote terminal units (RTUs) to be provided for Stations, wayside and Receiving Substation /Traction substations .



Supervisory Control and data acquisition system (SCADA)

To monitor and control the Traction and Auxiliary power supply in main line and Depot, a Traction power controller shall be available in the Operation Control Centre round the clock.

SCADA system involves:

A. **Supervision:**

Traction Power Controller (TPC) supervises the receiving sub-stations, Traction network as well as 33kV/11kV/415V auxiliary sub-stations from OCC through SCADA system.

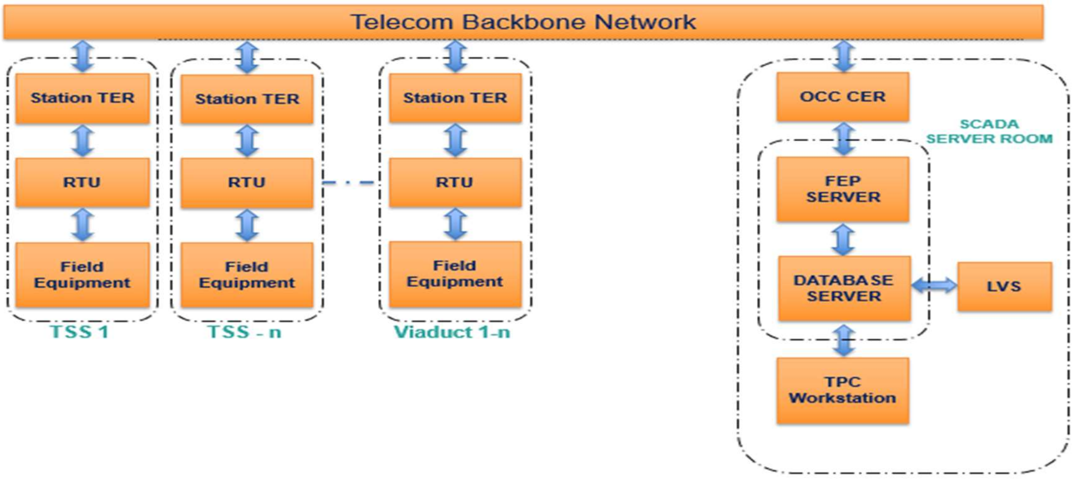
B. **Control:**

Traction Power Controller (TPC) performs control operations of circuit breakers, Disconnector switches, isolators and tap changers provided in different substations as per need.

C. **Data acquisition:**

Process information is stored on a process database and a report database in the form of event list, alarm list, graphs and measurement reports.

Figure below shows the architecture of SCADA system



Architecture of SCADA system

The overall remote control and data acquisition system essentially consists of the following

1. Operation Control Centre (OCC)
2. Backup control centre (BCC)
3. Depot control Centre (DCC)
4. Backbone ring network
5. Station , TSS and Viaduct RTUs

6.3.14 Energy cost reduction

As the energy cost in High-Speed Rail system is one of the major cost, which may be approximately 25 % of the (O&M) cost, during the revenue operation, the following measures are considered to bring down the cost:

1. Reducing the consumption
   - Energy Saving designs of system and equipment
   - Energy Saving Measures

2. Supply at cheaper rate
   - Availing concessional tariff from distribution companies with intervention of State Government
   - Renewable power at cheaper rate

6.3.15 Energy Saving Measures

Energy charges constitute a substantial portion of its operation and maintenance (O&M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The traction power consumption increases with an increase in train frequency /composition in order to cater more traffic. The proposed system of High-speed Rail includes the following energy-saving features.

- Modern rolling stock with 3 phase VVVF drive and lightweight Aluminium body coaches to be proposed, which has the benefits of low specific energy consumption and almost unity power factor
- Rolling stock has regeneration features and it is expected that 15% of total traction energy will be regenerated and fedback to 2x25kV OHE to be consumed by nearby trains
- Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (20%,50%&100%) and the relevant circuit can be switched on the requirements preferably with automatic operation .
- Machine room less type lifts with gearless drive has been proposed with 3 phase VVVF drive. These lifts are highly energy efficient.
- The proposed heavy-duty public service escalator will be provided with 3 phase VVVF drive, which is energy efficient and improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by the passenger.
- The latest state of energy efficient star rated electrical equipment (Transformer, motors, HVAC, light fittings etc) to be incorporated into the system design.

6.3.16 Renewable Energy

KRDCL proposes to use solar and other renewable energy for this project as a green energy and sustainable project.

6.3.16.1 Solar Energy

Solar energy is the best form of sustainable energy. Solar electricity or photo voltaic (PV) technology converts sunlight directly into electricity. It is recommended to have the following provisions for the generation/purchase of solar energy

- Provision of fixing Solar panels on the roof top of the buildings (roof top of all station building, depot building, Traction substation, Viaduct etc)
- Provision of Ground mounted solar system, where free land is available for a longer period
- Provision of Solar plants in intra state/ interstate

Clearance/ No objection certificate (NOC) to be obtained before commencement of the work / evacuation of solar energy

1. Preliminary approval shall be obtained from KSEBL and Electrical inspectorate before commencing the installation work
2. After completion of the installation work, Sanction to be obtained from Electrical inspectorate
3. Signing of connection Agreement with KSEBL
4. Signing of Banking agreement with KSEBL

Figure below shows the mounting arrangements of solar panels in roof top and Ground

	
Rooftop Solar System	Ground-mounted Solar System

Mounting arrangements of solar panels in roof top and Ground

The table below shows the tentative plant capacity of Stations, Depot, Traction substation, viaduct and free land available in Depot.

Table 77: Tentative plant capacity of Stations, Depot, Traction substation, viaduct and free land available in Depot

Sr No	Location	Tentative Plant Capacity (in MWp)
1	Station Building and other service building	15
2	Depot Building and other depot area	5
3	Viaduct, compound wall fencing and track side	80
	Total	**100 MWp**

6.3.16.2 Wind Energy

Wind energy describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. A generator can convert mechanical power into electricity. The provision to purchase wind energy to be explored.

Wind Mill

Clearance/ No objection certificate (NOC) to be obtained before commencement of the work / evacuation of wind energy

1. Preliminary approval shall be obtained from Agency for Non - conventional Energy and Rural Technology (ANERT)
2. After completion of the installation work, Sanction to be obtained from National Institute of Wind Energy (NIWE)
3. Signing of connection Agreement with KSEBL
4. Signing of Banking agreement with KSEBL

6.3.17 Models adopted for Renewable Energy

There are different types of execution models available in India:

1. **RESCO Model**

A Renewable Energy Service Company (RESCO) is an Energy service company, which provides energy to the consumers from renewable energy sources, usually solar photovoltaics, wind power or micro hydro.
The main characteristics of a RESCO are:

- The household serviced does not own the generation equipment, which is owned by an external organization (RESCO)
- The user does not carry out maintenance, all maintenance and repair service will be done by RESCO;
- The user shall pay the energy charge per unit consumption

2. **CAPEX Model**

In this type of model all the capital and operational expenses shall be borne by the user.

6.3.18 Sustainable Transportation

This project is committed to develop an environmentally and economically sustainable, long term alternative to the current transportation systems in Kerala, which will increase transportation efficiency ,use 100 percentage of renewable energy and incorporate additional sustainability practices.
Although rail is one of the world's oldest transportation methods, it continues to be one of the most energy efficient ways to move large number of people. Experience both in India and abroad illustrate that rail travel provides an efficient alternative for the traveller , who wants to reach key ,central destinations and important cities without the delay and hassle of air travel , and in a faster ,less polluting ,safer and more efficient method than driving .
In 2024, it is estimated that 67740 passengers will use SHSR corridor between Thiruvananthapuram and Kasaragod, which requires approximately 277 million units of energy. In 2051, approximately 517 million units of energy will be required to transport 147120 passengers among the stations between Thiruvananthapuram and Kasaragod. The energy required to move similar numbers of passengers by car would be thrice the energy required for SHSR.
For operation , 2x25kV ,50Hz Auto transformer feeding system is adopted for the main line operation and each of the traction substations is located at approximately 70 km spaced along the alignment .
The system will also capture the energy from the braking and deceleration of the train .This energy, estimated to be nearly 15 percentage of the total power for the system. This can be used by other trains. Energy - efficiency and maximizing recovery of electricity are just part of the plans.In 2024 , it is proposed to adopt a policy goal to run operations with 100 percentage of renewable energy . Through proper planning and co-ordination with utility companies and regulatory agencies ,it is proposed to achieve this goal to procure or producing enough renewable energy to feed into the grid to offset the amount the train uses.
This net zero approch means that renewable energy developers can find the most economical locations to develop and distribute energy to the grid .Simultaneously ,through a formal call to industry process, it is proposed to ascertain the capacity, and the strong interest companies ,to provide renewable energy to

the system.In addition , it is being explored to produce solar or other renewable energy generation on semi high speed rail canopies , roof and maintenance facilities as well as other structures .
In this fashion , the semi high speed rail system will be ahead of the clean transportation curve and leading by example.

6.3.18.1 Rail as Green as we can make it

KRDCL is proposing to develop a sustainability policy in collaboration with Indian Institute of Management (IIM)- Ahmedabad and other nodal agencies . A preliminary meeting was held with IIM - Ahmedabad and more initiative to be launched to make the basic frame work and policies to be adopted .
Strategies proposed to be adopted during construction include items such as requirements for recycling all steel and concrete; diversion of construction waste from landfills through reuse and recycling; use of new,low emission construction equipment and replacement of inefficient truck engines and irrigation pumps. KRDCL will be also working with agencies to implement an urban forestry program to offset green house gas (GHG) emissions associated with construction .This program will deliver additional benefits such as providing shade and recreation for communities within the train corridor.
The Station buildings, depot , administrative building and other service buildings may be designed based on the platinum rating standard of Indian Green Building Council (IGBC)
So what's bottom line for high speed rail as it relates to energy future? Starting in 2024,during the system's first year of operation ,KRDCL anticipates a ramp - up in usage as travellers begin to make the switch from driving or flying to take high speed rail. Every subsequent year,as the system is projected to increase riders, it is expected continued reductions in GHG emissions as well as criteria air pollutants.
Cumulatively , by 2028 the high speed rail system will divert approximatley 2,37,663 tonnes of carbon dioxide equivalent . By 2051 , the system will divert approximately 3,81,899 tonnes of carbon dioxide equivalent.

Hence, the proposed semi high speed rail is a game changing form of sustainable transportation , first of its kind in india and may also be few in the world.

6.4 Rolling Stock Depot

6.4.1 Rolling stock Depot and Maintenance Facilities

Rolling stock depot is an important infrastructure to be designed for proper maintenance of rolling stock. It consists of fully equipped workshop, sick lines and inspection lines for proper maintenance and stabling lines for proper storage. Fig below shows a bird eye's general view of Car Depot.

Figure 30: Car Depot

6.4.2 Maintenance system and equipment / facilities for rolling stock

Appropriate maintenance of rolling stock, which consists of preventive and breakdown maintenance, is a key to guarantee safe and reliable operation of railways and an inevitable/essential basis for safe and highly reliable operation of rolling stock. Therefore, a plan described in this chapter is just a tentative one, the purpose of which is that it provides a tangible figure, based on which project cost estimation is performed for feasibility study.
Despite that the equipment/facilities at depots and workshops are an important infrastructure to be used for 50 to 100 years, they shall be able to flexibly cope with changes and developments of rolling stock.

6.4.3 Maintenance System

Maintenance system is as follows:

Table 78: Maintenance Inspection Level Frequency

Inspection Level Frequency	Frequency
Level 0A	4,000 – 5,000 km
Level 1A	20,000 km
Level 1B	80,000 km
Level 1C	240,000 km
Level 1D	480,000 km
Level 2A	1,200,000 km
Level 2B	2,400,000 km

Each of the inspection level consists in the following main tasks:

1. Every 4,000 – 5,000 km, a Level 0 inspection taking about 1½ hour lead time is undertaken.

The waste collection tanks of WC closed toilets are emptied, and fresh water tanks are refilled. Eventual major defects (e.g. malfunctioning doors) are rectified.

Furthermore, safety tests are conducted. This includes:

- Checking the pantograph force applied to the overhead line
- Cleaning and checking for cracks in the pantograph's rooftop insulators inspecting transformers for leakage
- Checking the pantograph's current collector for wear
- Visual inspection of wheel sets and bogies.

2. Every 20000 kilometers, a Level 1A inspection taking about 2½ hour lead time is carried out.

During this inspection, the brakes, the on-board signaling systems and the anti-skid equipment are checked as well, in addition to the operations of the previous level.

After 80000 kilometers, the train undergoes a Level 1B inspection, lasting eight hours, which includes brakes thorough check, as well as air conditioning and the bar-restaurant equipment check. The batteries are also checked, as well as the seats and the passenger information system.

3. Once the train has reached 240000 kilometers, the Level 1C inspection requires a check of the electric traction motors, the axle boxes, the wheel sets and the couplers.

Like Level 1B inspection also Level 1C inspection is usually carried out in two modules taking eight hours each.

4. About once a year (when reaching around 480000 km) the Level 1D takes place, divided in three modules lasting eight hours each. Additionally, to the other check-up phases, it includes checks of the pneumatic systems, the transformer cooling, and maintenance works inside the passenger compartment.
5. The Level 2A Revision is carried out after 1.2 million km. It includes a thorough checkup of all components of the train and is carried out in two- five days modules.
6. The seventh and final scheduled maintenance step is the Level 2B, which happens when the trains reaches 2.4 million kilometers. At this step all the train bogies are exchanged for new ones completely overhauled. All major train components are disassembled and checked. This step also takes two- five days periods, considering the time for dismounting and replacing equipment. The time for off-line components overhaul has to be considered apart.

The above level of maintenance activities over years of experience have been consolidated into maintenance schedule for high speed trains as tabulated below.

The maintenance system simply consists of four stages, as Table 79 shows, with a rolling stock inspection system and equipment/facilities established, put in use and operated since inauguration to attain high-quality, safety and stability.

Table 79: Periodic Maintenance

Type		Period	Maintenance Content
Train Preparation		After each leg	Car cleaning, servicing, water supply, other work
Light Maintenance	Daily Inspection	24 hours	Check status of bogie, wheels, pantograph, doors and other items while cars are connected. Check train functions inspect pantograph contact strips and brake linings. Replace consumable for brakes, pantographs and other items.
	Regular Inspection	30,000 km or 20 days	Train function test through the driving-cab monitoring system. Inspects/checks the mechanical functions of controllers and the brake riggings. Inspection of controllers for VVVF inverters and thyristor phase control systems. Inspectors check the wheel treads, wheel systems and axles for flaws, check the driving gears and also check the brake lining for wear and replace.
Heavy/ Maintenance	Bogie Inspection	600,000 km or 1 years	Principal bogie components are disassembled. Inspect the wheel sets, wheels, axles, driving gears, traction motors and riggings. All of the bogies are exchanged wit spar bogies that have already been inspected. After the bearings are removed, wheel sets are subject to visual inspection of the bearing portions, ultrasonic flaw detection for axel-wheel fitting portions and wheel cutting for tread re-profiling. After completion of the bogie inspection, each bogie is subjected is to a car running test as a final check under the same conditions as those of actual train operation.
	General Inspection	1,200,000 km or 2 years	The general inspections conducted on every part of cars. Bogies and all major components are disassembled from the carboy Cars, air-conditioners, pantographs and some other components are exchanged with spares that have already been inspected and maintained under a spare component circulating system
	Protective Device Inspection (for ATC)	90 days	Also perform on board day leg inspector of function related to protective devices.

Type		Period	Maintenance Content
Other Maintenance	Ultrasonic Flaw Inspection	30,000 km Or 30 days	Perform ultrasonic inspection of wheels when monthly inspection is performed to check for any flaws.
	Wheel Reprofiling	100,000 km	Use wheel profiler to correct wheel shape and maintain ride comfort level.

6.4.4 Policy of the semi- high speed / high speed rolling stock safety control system and features of maintenance

It has been planned on the following fundamental concept:

1. A mechanism and equipment/facilities to guarantee high-level safety and reliability and maintenance of high-speed rolling stock
- Maintenance based on the preventive maintenance
- Inspection/test equipment/facilities to keep the train in best condition and to prevent derailment / collision / accidents
- Implementation of maintenance by workers having high-level of skills and knowledge of maintenance services and managers having high-level managing power.

2. Installation of equipment/facilities for rolling stock depots and workshops to constantly shop out highly safe and reliable rolling stock
- Quality control with high-precision inspection/test apparatus for digital-ATC and other security devices
- Quality control by severe limit control for trucks, wheel-sets and other running gears
- Check of truck performance after fabrication with a high-speed truck running test apparatus.
- Car body air tightness test

3. Efficiency improvement for inspection/repair services
- Efficiency improvement for bogie inspection bogie exchanging equipment/ facilities and the spare parts/components circulating system
- Efficiency improvement for bogie relocating work with mobile temporary trucks
- Efficiency improvement for parts inspection/repair with conveyor lines.
- Automation of inspection/test apparatus
- Railway cars are also equipped with car-borne monitoring devices to memorize and store on-condition data, which is used for analysis of failures and operating conditions of cars when they are under inspection/repair at depots and workshops and can also be sent to depots and workshops before their entry for inspection/repair through telecommunication lines to allow the recipient maintenance organizations to perform in-advance assessment of rolling stock conditions, thereby contributing to efficiency improvement and optimization of inspection/repair services at depots and workshops.

6.4.5 Functions and scales of facilities at depot

The rolling stock depot caters the following:

- Workshop - to perform overhauling and major maintenance schedules involving lifting
- Inspections - Scheduled inspections
- Storage of trains - Stabling lines

For efficient traffic control, car depots are set up near terminal stations ie. Thiruvanthapuram and Kasaragod. Inspection lines has been planned at both the terminal stations i.e. Thiruvanthapuram and Kasaragod and workshop lines has been planned at Thiruvananthapuram only. Based on the maintenance flow and size of the maintenance facilities, the workshop will be designed to carry out the demanded maintenance level.

6.4.5.1 Function and inspection Classification at Depots

The car depots are divided into two types: the ones that store trains and perform daily inspection, regular inspection, and unscheduled maintenance and the ones that have workshop facilities to perform bogie inspection and general inspection.

Table below shows the functions and roles of the various depots in this plan.

Table 80: Function and Inspection Classification

Station	Function		Inspection Classification			
	Depot	Workshop	General Inspection	Bogie Inspection	Daily and Regular inspection	Unscheduled maintenance
Trivandrum Depot and workshop	•	•	•	•	•	•
Kasaragod Depot	•				•	•

6.4.5.2 Inspection Cycle

The function allocated to the depots mentioned above is based on an optimal rolling stock maintenance and management system implemented to enhance safe and reliable train operation. They are planned based on the inspection cycle as shown in Table below:

Table 81: Inspection Cycle

Kind of Inspection	Daily Inspection	Regular Inspection	Bogie Inspection	General Inspection
Interval	48 hours	30,000 km or 20days	6,00,000 km or 1 year	12,00,000 km or 2 years

6.4.6 Design of depot- cum- workshop facilities

The following facilities are required to be provided in the Depot cum Workshop and the exact detail of layout and machinery & plant will be done in the DPR. Figure hereunder shows the outline of various facilities.

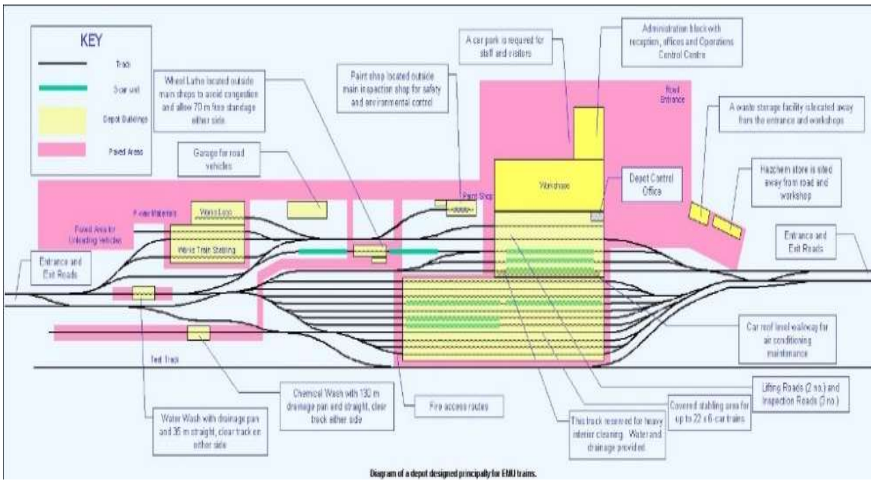


Figure 31: Depot with various facilities

1. Stabling lines at depot:
2. Inspection Bay at depot-cum-workshop:
3. Workshop Bay at depot-cum- Workshop

6.4.7 Arrangement of facilities

6.4.7.1 Car Delivery Area

There shall be rail connectivity between the Depot and mainline and all trains due for scheduled/ unscheduled works shall reach the depot by rail.

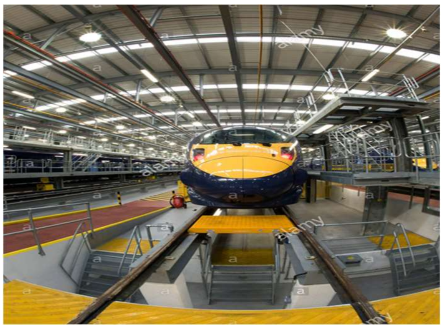
However, in case of newly procured coaches, which are transported by road, these shall reach the Depot-cum Workshop by the road on trailers. To unload the coaches and bring them to the track, provision of space, along the side of shunting neck, has to be made for unloading of cars and other heavy materials. The unloading area should be easily accessible for heavy duty hydraulic trailers.

6.4.7.2 Operational Features

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed/workshop area. Movement from depot to the main line is to be so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line should be feasible. Operation Control Centre (OCC) controls the movement of trains from main line to depot and Depot control center (DCC) to manage the movement of train within depot. The detail to be planned during DPR stage and detail layout.

6.4.7.3 Infrastructure Facilities

I. Inspection and Workshop facilities:



II. Lifting Jacks

III. Stabling Lines in Depot:

IV. Car body automatic cleaner
V. Painting Shop-Painting facility should be available for Aluminium Car body.
VI. Heavy Cleaning Shed
VII. Wheel lathe

VIII. Power Supply
IX. Compressed Air Supply
X. Water Supply, Sewerage and Drainage Works
XI. Ancillary Workshop
XII. Watch Towers
XIII. Administrative Building
XIV. Shed and Buildings
XV. Train Operators Booking Office
XVI. Plant and Machinery

6.4.8 Recommendation

It is recommended to plan the following:

1. **One Depot cum Major Workshop at Thiruvananthapuram.**
2. **One Depot at Kasaragod (for inspections)**
3. **Stabling Lines**

- Mostly at Kasaragod
- Minimum number at Thiruvananthapuram to minimize the space requirement at Thiruvananthapuram
- Few lines at Cochin and Thrissur, which will facilitate train operation in case of phased completion project and skewed train operation as a regular measure in TVC - Cochin section

6.4.9 Cost estimate

Detailed list of machinery and plants shall be finalised in due course based on the Rolling stock design. However, a cost provision of INR 200 Crores for Machinery and plant equipment is to be kept in estimation for both depot-cum workshop at Thiruvananthapuram and Kasaragod.

6.5 Signalling System

6.5.1 Introduction

For train operations beyond 160 Kmph, the Signalling and Train Control System requirement becomes still more stringent due to the fact that above 160Kmph speed it is not possible for driver to continuously watch the line side signals and also the response time of Signalling and Train Control System becomes important. It is necessary to improve the safety level & ensuring the safety of train movements.
The Signalling and Train Control System shall provide the highest security level for means of an efficient Train Control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.
From Thiruvananthapuram to Kasaragod approx. 531 Km, Semi High Speed (SHS) rail corridor is to be planned with a designed speed of 250 Kmph. For this corridor the system requires the following minimum facilities:

- Highest security level to ensure the operational activities
- Ensuring safety in train movements
- High quality of service
- Real Time Multimedia information to control room

Overlooking a wayside signal may cause a serious accident when train run at such a high speed of 250 Kmph. The automation of train movements was gradually developed from the need to enforce signal commands so that drivers could not allow trains to pass beyond their limit of movement authority. Therefore the following is necessary:

- To indicate allowable maximum speed on on-board monitor continuously
- To control brake automatically in case of over speed

The Automatic Train Control (ATC) has to support the performance goal of any high-speed project including maximum speed, trip times and headway that meet UIC mandated practices and function for Signalling system Including High Speed Automatic Train Control.
The following ATC system with dynamic speed profile used on high speed lines all around the world are:

- ETCS Level -2 (European System)
- Digital -ATC (Japanese System)
- CTCS Level-3 (Chinese System)
- TVM-430 (Transmission Voie-Machine) -French System
- LZB (Linienzugbeeinflussung)-German System

No single standard signalling system is available in the world. Any of the above ATC system with dynamic speed profile may be used on high speed lines in order to have Centralized Train Control System.

6.5.2 Standardization of System

The European Railway Traffic Management System (ERTMS) is major industrial project developed by eight UNIFE members in close cooperation with the European Union, Railways Stakeholders and GSM-R Industry.

ERTMS Benefits:

- **Increased capacity:** As a continuous communication-based Signalling system
- **Higher Speeds:** ERTMS allows for a maximum speed up to 350 Kmph
- **Higher reliability rates:** ERTMS may significantly increase reliability and punctually
- **Lower production costs:** one proven, harmonized system easier to maintain
- **Reduced Maintenance costs:** ERTMS-2, trackside Signalling is optional

The command and control subsystem chosen, which is a standardized, interoperable ATP/ATC system called ERTMS/ETCS (or simply ETCS)

- **ERTMS, to refer to the whole standard programme or railway platform**
- **ETCS, to refer to the Signalling System, component of ERTMS**

To allow the communication between trains, trackside and railway operation control centre, the subsystem chosen is GSM-R, the international wireless communications standard for railway communication and applications. The ERTMS programme can be defined as combination of ETCS and GSM-R subsystems**.**

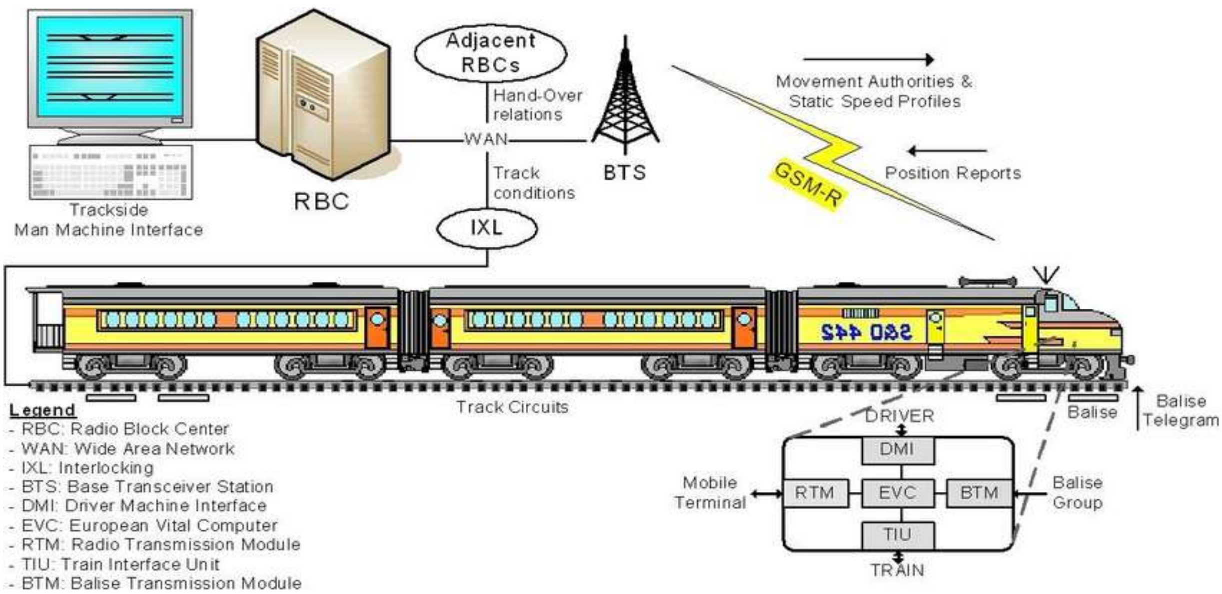


Figure 32: Overview of ERTMS/ETCS with GSM-R Network

6.5.3 ETCS levels

ETCS is divided into different functional level (to match customer's needs). The definition of the levels depends on how the railroad is equipped and the way in which information is transmitted to the train.

6.5.3.1 ETCS -Level 1

ETCS level -1 is cab signalling system that can be superimposed on the exiting signalling system that leaves the fixed signal lateral system (national signalling and track release system) in place. Eurobalise radio beacons pick up signal aspects from the trackside signals via signal adapters and telegram LEU Encodes and transmit them to the vehicle as **Movement Authority** (MA- permission to cross one or more block sections) together with route data at fixed points.

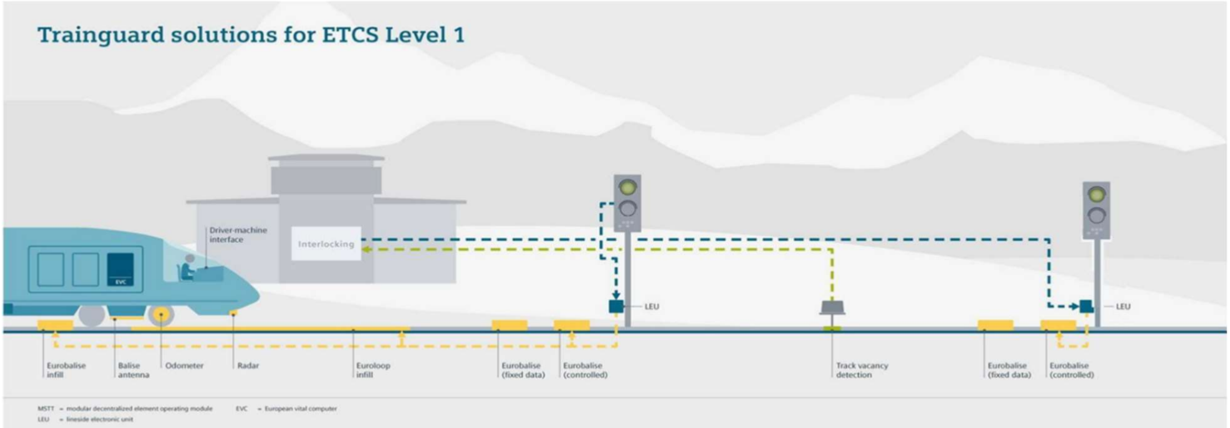


Figure 33: Overview of ERTMS/ETCS Level -1 System

6.5.3.2 ETCS level 2

ETCS level-2 is digital radio-based signal and train protection system. Movement Authorities are given to the driver in order to allow the train to move itself on the track and most of the signals are displayed in the trainbone cab, substituting the lateral traditional signals. Thus, apart from a few indicator panels like overriding and board signals (these panels marks the extreme points of a block section or of the ETCS Level-2 area). It is therefore possible to work without lateral trackside signalling.

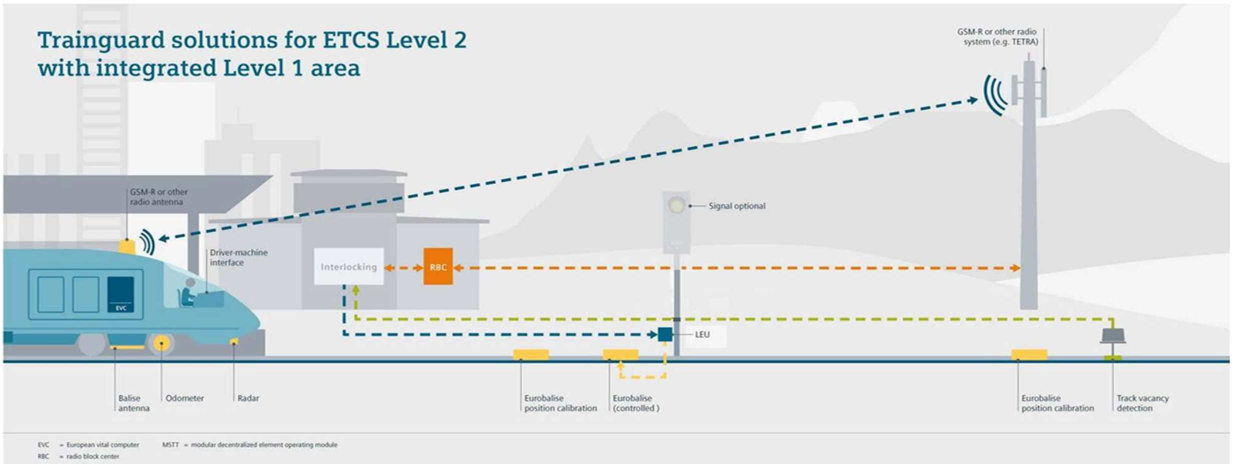


Figure 34: Overview of ERTMS/ETCS Level -2 System

Train separation system use the term of **Virtual Signals** because the concept of a traditional railways signal, like fixed light lamps, is physically moved to the train DMI (Driver Machine Interface unit).
However, with track-release signalling devices like Track Circuits, the train integrity supervision still remains in place at the trackside. All the trains automatically report the exact position and direction of the travel to the RBC (Radio Block Centre) at regular intervals, through the GSM-R radio Network.
Train movements are monitored continually by RBC. Any movement authority is transmitted to the train continuously via GSM-R together with speed information and route data, as shown in the Figure below.

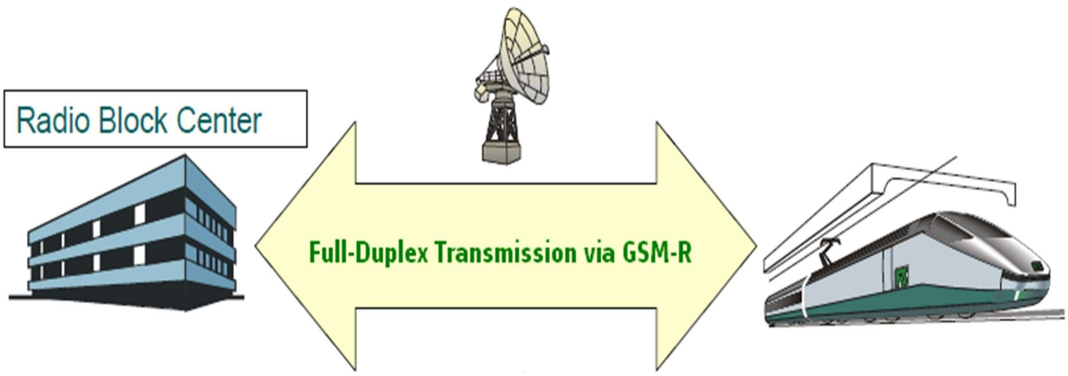


Figure 35: Exchange of information between RBC and Trainbone

The Eurobalise are used at this level as passive positioning beacons or electronic milestones. Between two positioning beacons the train determines its position via sensors. The positioning beacons are used in this case as reference points for correcting distance measurement errors. The on-board computer continuously monitors the transferred data and the maximum permissible speed.
The ETCS Level-2 constitutes a continue ATP/ ATC with interoperable Cab Signalling and fixed block with block sections.

Table 82: Comparison of Main Feature of ETCS Level-1 & ETCS Level-2

Main Features of ETCS Level	On Board Compatibility of System	
	ETCS Level 1	ETCS Level 2
Lineside signals	Applicable	**Optional**
Track vacancy detection system	Applicable	Applicable
Eurobalise as position markers	Applicable	Applicable
Cab signalling	Applicable	Applicable
Continuous speed monitoring	Applicable	Applicable
Intermittent data transmission	Applicable	Applicable
Continuous data transmission	**Optional** via **Euroloop**	Applicable via **GSM-R**

6.5.4 Architectural Description of ETCS Level -2

ETCS level – 2 on high speed new line is becoming standard in Europe and other Non -European countries also. ERTMS has been designing to be the most performant train control system in world.

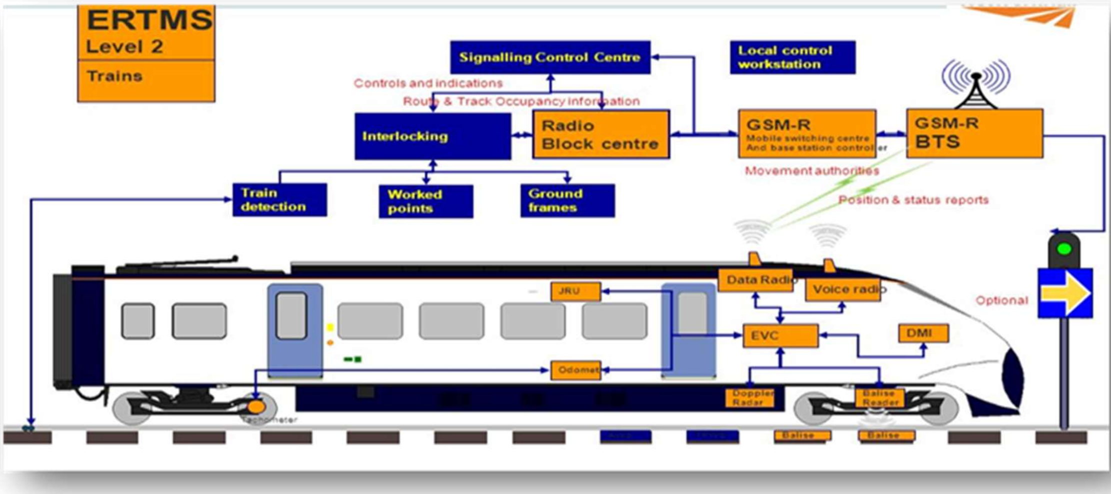


Figure 36: Architecture of ETCS Level-2 System

High speed and high capacity rail line can be equipped with a complex transport system equipped with an ETCS Level-2 signalling system solution, able to control train movements, in order to guarantee the safe and regular traffic operations. The whole Ground systems comprise the power and telecommunication HSSS (High Speed-Signalling System) and a ground trackside subsystem with:

- Train control and distance separation subsystem (ETCS)
- Line management subsystem -Interlocking System (IXL)
- Automatic Train Supervision subsystem (ATS)

The Trainbone System comprises mainly:

- EVC (European Vital Computer)
- DMI (Driver Man Interface)
- Odometry subsystem

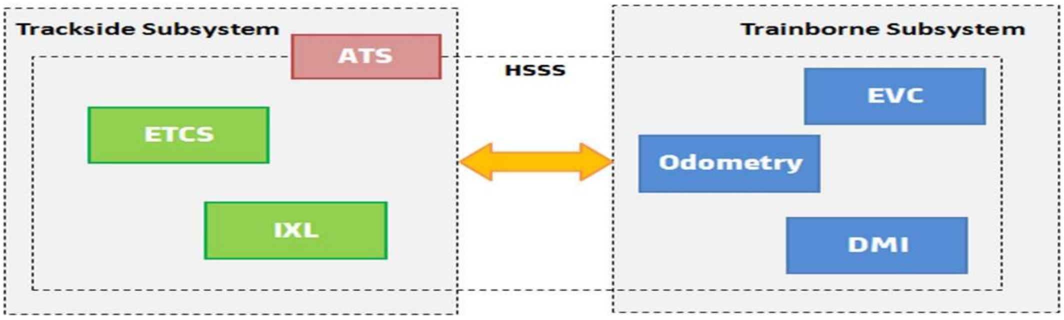


Figure 37: High speed /High capacity transport system

6.5.5 ETCS Level-2 Trackside Equipment

The main component of ETCS Level-2 of track side equipment are required to send information like movement authority, position of train and details of track section for running of safely for the train.

6.5.5.1 Radio Block Centres (RBC)

The RBC is a device used at ETCS Level - 2 acting as a centralised safety unit which, using radio connection via GSM-R, receives train position information and sends movement authorisation and further information required by the train for its movement. The RBC interacts with the interlocking to obtain signalling-related information, route status, etc. It is also able to manage the transmission of selected trackside data and communicate with adjacent RBC's.

The most important functionality for RBC on ERTMS level - 2 is to transmit the movement authority to the onboard unit. The information transmission is made up of the following phases:

- Interlocking system controls and supervises the trackside equipment and sets the routes according to traffic control requests.
- Interlocking system transmits the information of set routes or elements to RBC.
- RBC calculates the movement authority for each unit according to the information obtained.
- RBC transmits the movement authority to each unit in the RBC area.
- On-board unit calculates the braking curves and supervises the permitted speed

RBC has the static information about the railway track layout and track elements. The dynamic information for calculating the movement authority is needed from the interlocking system. This means that either the route information or statuses of trackside elements is required from the interlocking system.

6.5.5.2 Eurobalises (Balise)

Balise is an electronic beacon or transponder placed between the rails of a railway as part of an automatic train protection (ATP) system. A balise which complies with the European Train Control System specification is called a Eurobalise. Eurobalise use for sending the ETCS message to trains.

Figure 38: Balise/Transponder -Eurobalise

The Eurobalises needs no external power supply as it is energised by the passing train. In response to radio frequency energy broadcast. Once energised, the balise transmits an electronic telegram back to train. Balise group consists of one to eight balises. Each balise is uniquely identified within Balises group and each balise group also has a unique identity. Balise group are used to help the train determine its direction of travel. The train normally determines its direction of travel from the order in which it passed over the balise group. Direction is more quickly established when a balise group consist of two or more balises. Multiple balises, within a balise group, permit the transmission of more data. This also allows for redundancy as the same message can be transmitted from more than one balise. If one balise fails to be read for whatever reason, the other balise may be read thereby ensuring delivery of telegram. Collectively, the telegrams from a balise group from an electronics message.

The Eurobalise system consists of:

- Balise: beacons, fixed or controlled type, situated along the railway track, which are energised and enabled to transmit only when the train antenna is above them;
- On-board transmission system: consisting of the antenna unit and Balise Module Transmission (BTM) function;
- Trackside signalling system: consisting of the Lineside Electronic Unit (LEU) and other external equipment involved in the signalling process.

6.5.5.3 Network Transmission Gateway (NGT)

The NTG (Network Transmission Gateway) is an interface gateway between signalling equipment network and GSM-R subsystem network. The NTG converts the information coming from the RBC into GSM-R protocol and vice versa, allowing the communication between the RBC and with ERTMS/ETCS level-2 equipped trains.

6.5.5.4 Lineside Encoder Unit (LEU)

The LEU (Lineside Encoder Unit) is the safe equipment that interfaces between the Interlocking and other external system, and the switchable Eurobalises installed on the track. This equipment is able to interface with several switchable Eurobalises at the same time. It sends the suitable predefined ERTMS/ETCS messages, according to the information received from the Interlocking or external system.

6.5.5.5 Marker Boards for indicating exact location

The ETCS marker board are installed along the track at each end of block section. They are used to indicate to the train driver the exact location where he needs to stop the train in the case of end of movement authority.

6.5.6 ETCS Level-2 Trainborne Subsystem

The trainborne subsystem placed in the train is a computerised system to supervise the train movement. The trackside ETCS system communicates with trainbone subsystem in order to allow the safe train movement.

The ERTMS trainborne equipment includes the following main subsystems:

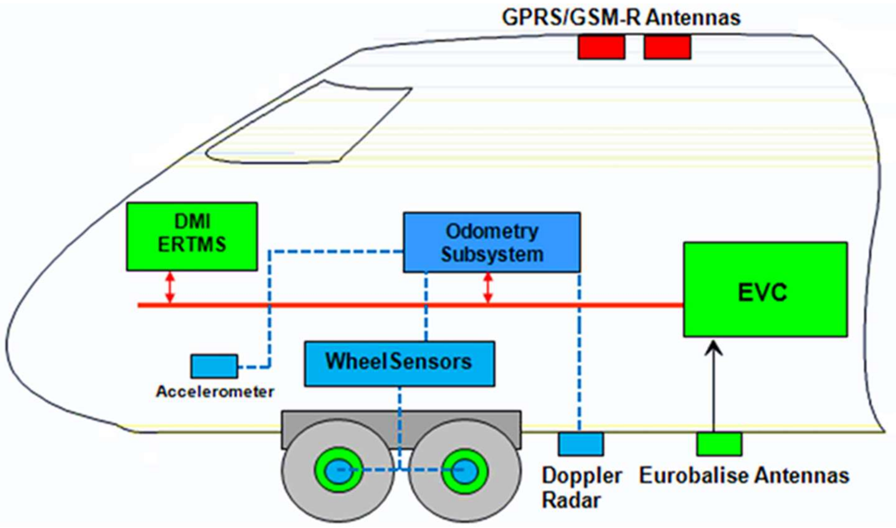


Figure 39: Simplified On-Board Subsystem

6.5.6.1 EVC (European Vital Computer)

EVC (European Vital Computer) is the on-board computer, which safely processes the trainborne functions on the basis of the following:

- Information received from the wayside equipment
- Data introduced by the driver
- Data coming from on-board sensors

The driver can interface with EVC trough the DMI (Driver Machine Interface)

6.5.6.2 DMI (Driver Man Interface)

The DMI (Driver Man Interface) is the main means of interaction between the driver and the system. DMI display driving information in the drive cab and information are transmitted by wayside RBC & RBC to on board equipment.

DMI is used to:

- Display signals and indications via a monitor in every driver cab
- Acquire entered data end enable specific functions via a series of keys and buttons
- Achieve technical interoperability on the driver side.

DMI (Driver man Interface) monitor display:

- Instantaneous speed
- Warning intervention time
- Maximum speed permitted
- Target Speed
- Target distance
- Release speed

- Break details

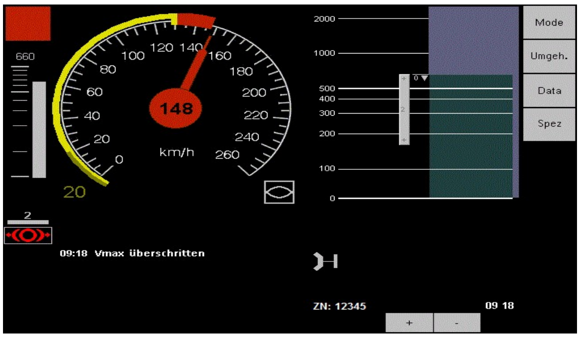


Figure 40: DMI-Monitoring display unit

6.5.6.3 Odometry Subsystem

The odometer is responsible for calculating the distance run by the train, typically consisting of redundant tachometry and radar, able to calculate distance, speed and acceleration.
The Odometry is a technique for estimating position and speed of a vehicle on wheels, based on information from sensors for the measurement of the covered distance. An odometer measures the covered distance of a vehicle by sensing the rotations of its wheels, featuring from a given size\radius.

6.5.6.4 Radar

Based on the Doppler principle, the radar sensor gives an image of the ground displacement in order to provide information about train speed and covered distance.
Microwaves transmitted by aerial are reflected by ground. The Frequency difference between emitted and received radiation, proportional to train speed, is computed by a processing unit. The radar sensor contains embedded software and is powered by the train battery.

Figure 41: Radar

6.5.6.5 Train Interface (TI)

The TI is the interface that allows the ETCS to exchange information (e.g. ETCS will receive the status of the direction controller through the TI) and issue commands to the rolling stock (e.g. ETCS will send the rolling stock the command to apply the brakes)

6.5.6.6 Juridical Recording Unit (JRU)

The Juridical Recorder Unit provides 'black box' functions, i.e. it stores the most important data and variables from train journeys, allowing later analysis.

6.5.6.7 Balise Transmission Module (BTM)

The BTM is a module inside the ERTMS/ETCS on-board equipment for intermittent transmission between track and train, which processes signals received from the onboard antenna and retrieves application data messages from a balise.

6.5.7 Global System for Mobile Communications – Railway (GSM-R)

GSM-R sub-system of European Rail Traffic Management System (ERTMS), is used for voice and data communication. The system is based on GSM and EIRENE – MORANE specifications which guarantee performance at a speed up to 350 kmph without any communication loss.

The GSM-R allows a better and constant contact between the crew and the ground (service communications and emergency management) and allows the exchange of data between systems and information technology. This system also provides voice and data communication between the track and train, based on standard GSM using frequency specification reserved for rail application with certain specific and advance function.

With the GSM-R system**,** the railway infrastructure equipped with a mobile radio system will meet an efficient and integrated, communication needs and data communications related with rail operations, including the control, safety, and journey of trains.

6.5.7.1 GSM-R Frequency Band

The frequency of GSM-R networks can differ slightly from country to country. GSM-R uses a lower extension of the 900MHz frequency: 876 MHz — 915 MHz for uplink and 921 MHz — 960 for downlink. In Europe, the 876 MHz to 880 MHz and the 921 MHz to 925 MHz bands are used for data transmission and data reception respectively. Channel spacing is 200 kHz. In China, GSM-R occupies a 4 MHz wide range of the E-GSM band (900 MHz-GSM).

The GSM-R transmits on a frequency band in the range 900 MHz reserved for railway operations in Europe and provides communication services ground to train, both during normal circulation in cases of emergency.

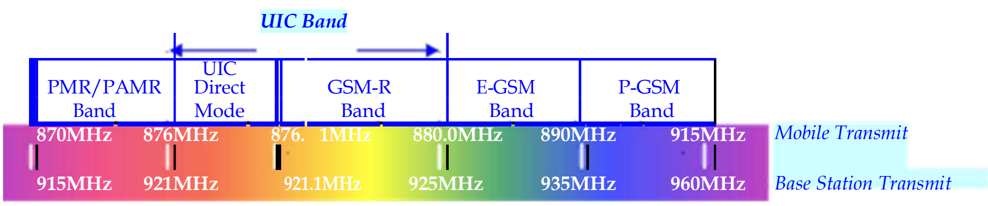


Figure 42: GSM-R Frequency allocation in 900 MHz Band

Every GSM-R network requires constant, uninterrupted service and high availability - especially while moving at high speeds through diverse terrain. The GSM-R standard offers a flawless handover and guaranteed performance at speeds up to 350 kmph. As the GSM-R signalling information is carried directly to the train itself, it makes higher speeds and a greater traffic density possible while ensuring a high level of safety.

6.5.7.2 GSM-R main subsystem:

GSM-R is used for voice communication with the traffic controller and for data communication between the train and the RBC (Radio Block Centre).

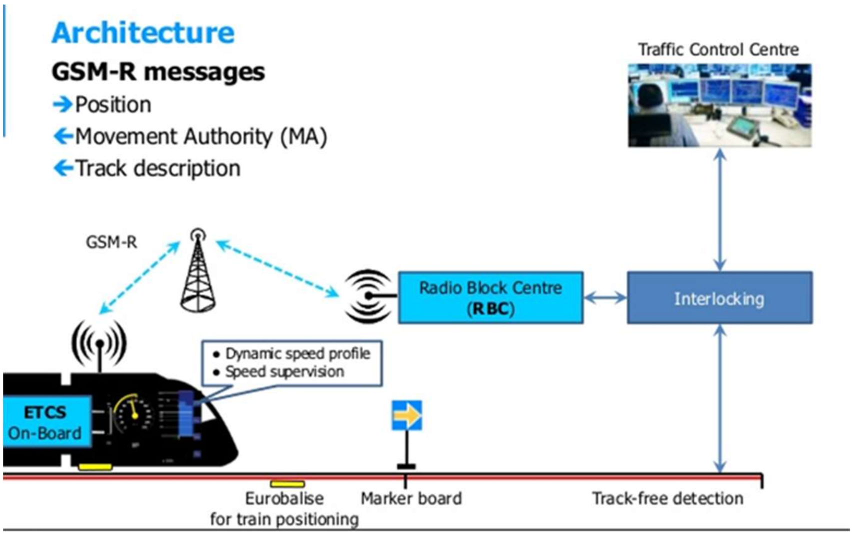


Figure 43: Architecture with ETCS Level- 2 and GSM-R

The following main network equipments are required:

- **Base Station Controller (BSC)**

A base station controller (BSC) is a critical mobile network component that controls one or more base transceiver stations (BTS). BSC responsible for functions to provide interfaces to BTS and Transcoding unit, equipment management & supervision, Radio Channel Allocation and Monitoring, Traffic management, Handover procedures, Configuration Data & Software Storage, Failure Detection and Processing, Performance Management etc.

- **Mobile Switching Center (MSC):**

The MSC is the central component of the NSS. It performs the call processing and switching functions of the system. In particular, it provides the functionality needed to handle a mobile subscriber, such as network registration, authentication, location updating, handovers, and call routing to roaming subscribers. It also provides the connection to other networks (such as the PSTN, Railways internal networks, neighbouring GSM-R networks).

- **Base Transceiver Station (BTS):**

BTS located along the track ensure a continuous radio signal for cab radios at all points on the railway. Repeaters could be used to provide coverage in specific areas.

It provides wireless interface for the transmission of data between Interlocking system and Train Onboard equipments. The BTS device and the MSC are connected by optical transmission network. In tunnel, repeaters shall be installed as Master and Slave configuration and they also connected to BTS through Optical network. It provides High level of signal coverage and in case of Fault or Outage of one BTS the adjacent BTS provide ETCS Level 2 Radio Coverage and GSM-R Traffic Channel.

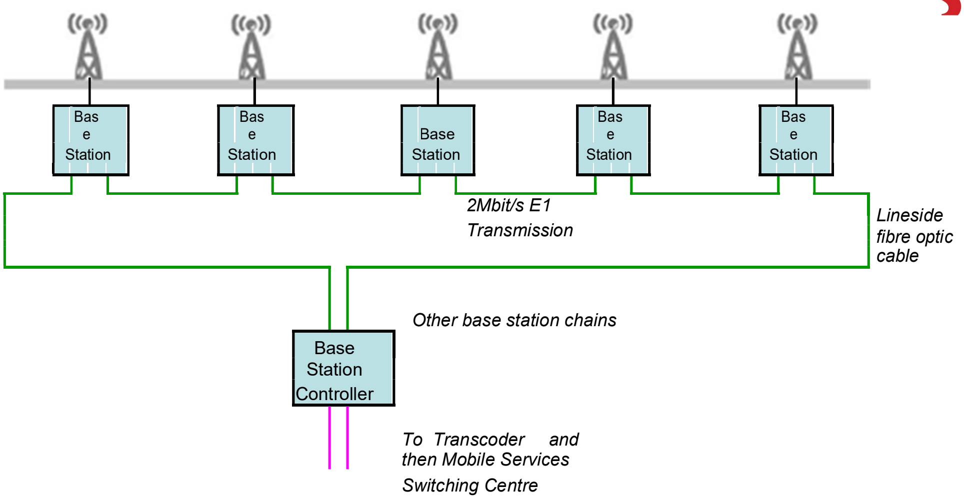


Figure 44: Base Station Sub-system (BSS) loop architecture of the GSM-R system

Global System for Mobile Communications (GSM-R) with limited capabilities, to fourth-generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability in future. Hence, modern technologies, such as long-term evolution (LTE), have to be evaluated as possible railway communication technologies to replace GSM-R in the future. LTE system can be considered if the system is matured at the time of executing the project and if cost arrive less than GSM-R system.

6.5.8 Interlocking System (IXL)

Interlocking is not an ERTMS component, but it plays an important role in the signalling system. Interlocking guarantees safety for train movements or routes and ensures that the route for a specific train is maintained and that incompatible routes are not simultaneously established. Interface between the interlocking and ERTMS trackside subsystem is necessary in almost all ERTMS structures.

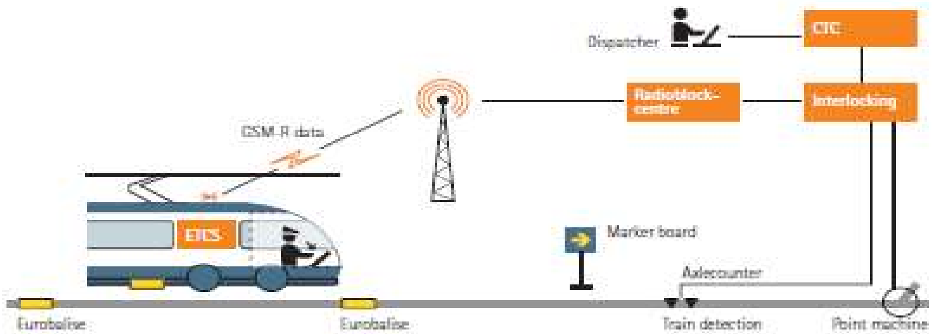


Figure 45: ERTMs level-2 with Interlocking System

The control system that deals with the line management and, thus, the routing of trains, is called interlocking.

The interlocking system processes the information concerning with the trackside signalling system in order to set the safe route for the train and interfaces with the centralised traffic control and the RBC. A station consists of a number of parallel rails greater than two and their switches, which give the possibility to route trains on different tracks. The path of a train leaving a station from the beginning is called route.

The electronics interlocking/ computer base Interlocking (EI/CBI) will be provided for operation of points & crossings and setting of routes.
The interlocking shall be provided, interface with the trackside signalling equipment, surveillance equipment, the RBC, GSM-R/LTE and the CTC equipment's.

6.5.9 Electric Point Machine

The point machine required for a high-speed rail line shall be high power and reliable, that is, to provide connected rail with strong force, to endure strong vibration and have robust lock function. The electromechanical point machine provides the electrical drive of the switch, its locking, and detection in end positions, which is highly recommended for High Speed rail line.
In addition to the internal locking and to ensure safety, the point machine is equipped with an internal "anti-veering "device to counter vibration effect caused by passing rolling stock. The point machine can be easily adapted to any network or interlocking.

6.5.10 Automatic Train Supervision (ATS)

The ATS (Automatic Train Supervision) subsystem is devoted to supervising the railway traffic circulation and to perform the diagnostics of the equipment of the system, Interlocking/RBC equipment included.
It supports the complete Traffic Management life cycle, with functions to plan, regulate and optimize the train traffic circulation, to manage the infrastructure state, to monitor and to perform diagnostic of all involved equipment.
All those functions share a single integrated Human Machine Interface for displaying real-time status of the railway line, managed by a human supervision.

6.5.11 Track Vacancy Detector

In high speed rail system in the world, Axle Counter and AFTC are used widely. Both systems are proven and safest train detection device for high speed rail systems. The axle counter is cost effective system so that it is widely used in both in Europe and outside.

Advantages of Axle Counter System:

- It is not affected by weather condition.
- It achieves train detection at high speed of 350 Kmph.
- It can cover very long section up to 15 Kms.
- It does not get affected either by flooding of track or poor maintenance of tracks.
- It does not require insulating rail joints; thus, rails can be continuously welded. This reduces track maintenance cost, low wear and tear of tracks and vehicles and in addition to increased traveling comfort.

The main components of the system are:

- Outdoor equipment (detection points in the track area)
- Information transmission equipment (cables)
- Indoor equipment (evaluation, indication & resetting)

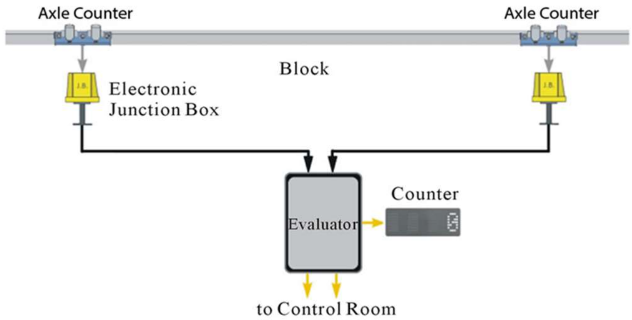


Figure 46: Axle Counter System

The Axle counter is the cost-effective alternative system available. In view of above advantages and on account of the prevailing weather condition & hilly terrain of Kerala. Axle counter is proposed for track detection system for this new Semi High Speed rail line.

6.5.12 Operation Control Centre (OCC)

The Operation Control Centre (OCC) is main brain of any high-speed rail corridor, which support safety and sustainable train operation in high speed rail. OCC System will help in real time monitoring and better management of trains. The Operation Control Centre (OCC) play big role in management of Train operation and supervision of all other facilities like signalling & telecommunication, power supply, traction system, Track system, rolling stock and other safety sub system, etc.

The Operation Control Centre (OCC) should have the following minimum system requirements:

- Operation & Control management System
- Supervise train traffic on line System
- Assignment /Instruction and information to train driver
- Maintenance management of system at Station, Depot and Line
- System surveillance for monitoring of critical systems
- Passenger facilities and information systems
- Safety and Security management system
- Notification for stations and staff of O&M
- Prevention system for Natural hazard like earthquakes, heavy rainfall, strong wind etc.
- Trouble shooting in case of emergency and accident.

The Operation Control Centre (OCC) have following main part as

- Centralised Control Room
- Centralised (S&T) Equipment room
- Maintenance Room
- Training Room
- Power Supply Room
- Depot control Room

The high-speed train Operation Control Centre (OCC) is normally located at one of the terminal station or central station in depot near to the line.

In case of failure of main OCC due to any problem/emergency such as earthquake, heavy fire, building collapse, power failure etc., the Backup Control Centre (BCC) equipments immediately start up to support the system. The BCC shall be similar to main OCC with full redundancies of all Systems. The Main OCC and Backup (BCC) shall be provided for this new rail corridor in order to avoid risk. The OCC & BCC shall be provided at different location.

6.5.13 Fall -Back Block System

In case equipment of ETCS Level-2 fails and becomes unavailable, the Fall-back Block system can temporarily be worked to maintain safety and smooth operation with the help of line side Signals provided at each interlocking. When the Fall-Back Block system is operated, it is necessary to check no other trains exits in the protection area to keep safety operation at first. To detect trains between stations, axle counter device will be used. The Fall -Back Block system shall be provided on the Semi High-Speed Rail corridor by using line side Signals and Axle counters.

6.5.14 Tunnel Alarm and other Safety System

Tunnel supporting systems play a significant role in ensuring the safety of passengers, personnel, and emergency responders inside a tunnel in case an incident occurs.Tunnel alarm activates the alarming device installed in the tunnel on the basis of approaching train information received from interlocking system. On receiption of alarm/warning , the railway maintenace staff working inside the tunnel shall be escape to the safety area.
The Tunnel Alarm and other safety system shall be provided on the line like- Earthquake,Rain fall, Wind ,Hot Axle, Rail Temperature detection etc.

6.5.15 Recommendation for Signalling & Train Control System

The Signalling and Train Control System shall provide the highest security level for means of an efficient Train Control, ensuring safety in train movements. It assists in optimization of rail infrastructure investment and running of efficient train services on the network.
ERTMS (European Railway Traffic Management System) Level-2 is the most performant train control system in the world and brings significant advantages in terms of low maintenance costs, safety, reliability, punctuality and traffic capacity. ERTMS is the combination of European Train Control System (ETCS) and GSM (Global System for Mobile Communications) for Railways (GSM-R).
Nowadays it is in use in many parts of the Europe like Sweden, Belgium, Netherlands, Australia, Denmark, Italy, Spain, Switzerland, France, Romania, Greece, UK and Turkey. The use of ERTMS is not limited to Europe. Mexico, South Korea, China, New Zealand, India and Taiwan also use ERTMS functions from systems that were used previously in Europe. GSM-R provides a safe platform for voice and data communication without loss at speeds up to 350 kmph.
The present feasibility study provides the main design of Signalling and Train Control system for operation of the line with design speed 250 Kmph, as also the associated sub system like Power supply, Surveillance system for monitoring and safety etc. In order to comply with requirements of such high-speed rail corridor, the proven system ERTMS Level -2 with GSM-R system is proposed. However, LTE system can be considered if the system is matured at the time of executing the project and if the cost arrive less than GSM-R system.

The Signalling & Train Control (ERTMS level-2) description for a Semi High-Speed Rail Corridor requires the following main sub-system:

1. ETCS level-2 System
2. GSM-R /LTE System
3. Interlocking System (EI/CBI) suitable for ETCS Level-2 and GSM-R/LTE system
4. Electric Point Machine
5. Automatic Train Supervision (ATS)
6. Track Vacancy Detection system (Axle counter)
7. Operation Control Centre (OCC) with backup BCC
8. Fall-Back Block System
9. Tunnel Alarm and other Safety System

6.6 Communication System

6.6.1 Introduction of Communication System

The communication system is the backbone for Signalling & Train control system, SCADA system, Automatic Ticketing system, Safety & Security system etc. and provides communication service for information to Passenger, Administrative management, Operation & maintenance, Emergency control etc. requirements of high-speed train network.

Overcoming increasing traffic, ensuring passengers safety and security during their journey, improving travel comfort, providing real time multimedia information and access to social networks in stations or in motion are some of the key challenges that train/metro operators are facing today.

To meet all these requirements, train operators need to put in place broadband telecommunication networks, using a variety of technologies whether fixed or wireless. Heterogeneity of these networks is becoming a real headache for train operators and infrastructure managers: WI-FI, GSM-R, LTE Satellite, 3G/4G networks.

6.6.2 Ground-to-Train Communication

Telecommunication System is becoming a key component in the formulation of strategy by Railway operators and infrastructure managers. The system shall be cost effective and operational efficiency on the following domains:

- Operation of the Transportation system
- Safety and Security
- Passenger experience

Telecommunications also contribute to the brand image of system operators and in some cases may even add to revenue (Utilities telecom business model).

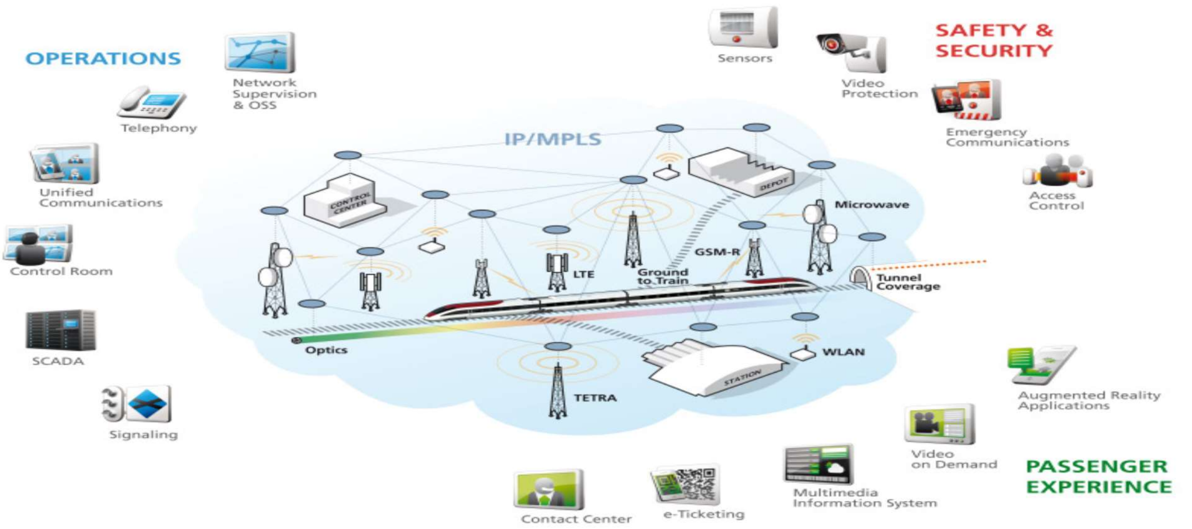


Figure 47: Communication as the backbone for converged rail operations

6.6.3 Wireless Technology comparison:

The selection of an optimal wireless communication system for Railways and metro system need to consider many performance parameters and service attributes such as voice support, vital traffic, priority, availability, frequency band, commercial maturity. The figure below compares these different technologies in terms of performance and industrial support.

Table 83: Wireless technology comparison

Technology Comparison					
Service	**GSM-R**	**TETRA**	**P25**	**WiFi**	**LTE**
Operational Voice support	+	+	+	VoIP	VoIP
Broadband Data Support	<10kb/s	<10kb/s	<100kb/s	<10kb/s	<10kb/s
All IP (Native)	-	-	-	+	+
P2T/ Call set up Time	1 to 5 s	250ms	800ms	100ms	100ms
Handover Mechanism	Standard	Standard	Standard	Proprietary	Standard
Priorities/ Pre-emption	+	+	+	3 Levels/ No	9 Levels/ Yes
Choice for operating Frequency	900MHz UIC	400MHz PMR	700MHz + VHF	2.4/ 5.x GHz	400MHz to 3.5GHz

6.6.4 History of Global System for Mobile Communications – Rail (GSM-R) system

GSM-R is built on GSM technology, and benefits from the economies of scale of its GSM technology heritage, aiming at being a cost-efficient digital replacement for the existing incompatible in-track cable and analogue Railway radio networks.

The standard is the result of over ten years of collaboration between the various European Railway companies, with the goal of achieving interoperability using a single communication platform. GSM-R is part of the European Rail Traffic Management System (ERTMS) standard and carries the signalling information directly to the train driver, enabling higher train speeds and traffic density with a high level of safety.

The specifications were finalised in 2000, based on the European Union-funded MORANE (Mobile Radio for Railways Networks in Europe) project. The specification is being maintained by the International Union of Railways project ERTMS. GSM-R has been adopted by 38 countries across the world, including all member states of the European Union and countries in Asia, Eurasia and northern Africa.

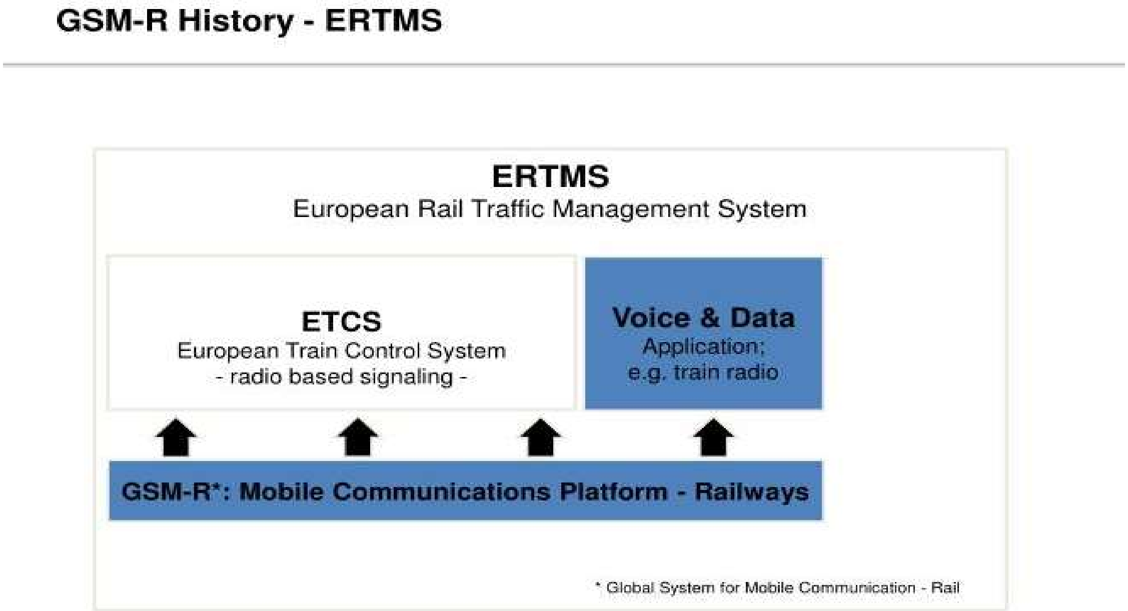


Figure 48: ERTMS/GSM-R System

GSM-R is a secure platform for voice and data communication between Railway operational staff, including drivers, dispatchers, shunting team members, train engineers, and station controllers. It delivers features such as group calls (VGCS), voice broadcast (VBS), location-based connections, and call pre-emption in case of an emergency. This will support applications such as cargo tracking, video surveillance in trains and at stations, and passenger information services.

GSM-R is typically implemented using dedicated base station masts close to the Railway, with tunnel coverage effected using directional antennae or 'leaky' feeder transmission. The distance between the base stations is 3–4 km. This creates a high degree of redundancy and higher availability and reliability.

6.6.4.1 Current GSM-R Coverage

GSM-R was fully operational on several Railways. Countries such as Norway and Netherlands were well ahead, providing full GSM-R coverage on all lines. Italy provides almost 10,000 kilometers of GSM-R covered Railways, while many of France's high-speed trains, such as the LGV Est Européenne and TGP Pos, also run on the GSM-R standard. The first high speed train to fully depend on GSM-R for communications was Germany's ICE from Saarbrücken to Paris (France). New routes are getting covered with GSM-R every year inside Europe, but increasingly also outside of the EU. In Northern Africa GSM-R is currently being implemented, while GSM-R feasibility studies are being finalized in Russia, Argentina, Brazil and the USA.

6.6.5 Overview of GSM-R System

Vital applications related to signalling and control/command of equipment. Such applications require generally a low bandwidth (typically in the range of 10 to 100 kbps) but a very high degree of availability (at least 99.99%), robustness and liability (typically a packet error rate of 10-3 for an approximately 200-byte packet length). Such performance indicators have equally to be fulfilled under high speed mobility (handover timing when a mobile terminal must change its connection from one fixed base station to another). These vital applications are typically CBTC (Communication Based Train Control) in case of metros or ETCS (European Train Control System) in case of Mainline trains.

The Railways industry has also been using wireless systems for operational applications since many years. Indeed, many mainline railway operators have deployed GSM-R networks both for operational voice communications between train drivers / train controllers and also to carry train signaling (ETCS level-2).

GSM-R sub-system of European Rail Traffic Management System (ERTMS), is used for voice and data communication. The system is based on GSM and EIRENE – MORANE specifications which guarantee performance at speeds up to 350 kmph, without any communication loss.

GSM-R, Global System for Mobile Communications – Railway or GSM-Railway is an international wireless communications standard for Railway communication and applications.

Global System for Mobile Communications (GSM-R) with limited capabilities, to fourth-generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability in future. Hence, modern technologies, such as long-term evolution (LTE), have to be considered to replace GSM-R in the near future. LTE system can also be considered if the system is matured at the time of execution of the project and if cost arrives less than GSM-R system.

6.6.5.1 Implemented of GSM-R

GSM-R offers a secure transmission of voice, data and applications and is therefore used as the layer on which security and train tracking applications run.

The radio sub system of the GSM-R network is typically implemented using base transceiver stations and communication towers with antennas which are placed next to the Railway with intervals of approximately eight to twenty kilometers. Through GSM-R, trains have a constant circuit switched digital modem connection to their respective train control center. If the modem connection is lost, the train will automatically stop. This modem operates with higher priority than normal users. The enhanced Multi-Level Precedence and Pre-emption service (eMLPP) provides different levels of precedence for call set-up and for continuity in case of handover, giving trains a higher priority than other users.

On top of that, GSM-R is also used for applications such as video surveillance, passenger information systems and cargo tracking.

6.6.5.2 GSM-R Frequency Spectrum

The frequency of GSM-R networks can differ slightly from country to country. GSM-R uses a lower extension of the 900MHz frequency (876 MHz -915 MHz for uplink and 921 MHz -960 for downlink). In Europe, the 876 MHz to 880 MHz and the 921 MHz to 925 MHz bands are used for data transmission and data reception respectively. Channel spacing is 200 kHz. In China, GSM-R occupies a 4 MHz wide range of the E-GSM band (900 MHz-GSM).
The System uses Ultra High Frequency (UHF) band being suitable for mobile communication. Radio System in the future is proposed to work within 1.6 MHz wide range of 900 MHz band which is regulated by the Wireless Planning and Co-ordination (WPC).
GSM-R network requires typically 900 MHz band, 873-880 uplink and 918-925 downlinks. The European Union directives for GSM-R spectrum allotment are enforceable in Europe, however it is not mandatory in other countries. Nevertheless, it is a pre-requisite to obtain the license to use a HSR dedicated bandwidth. The spectrum currently used by Indian Railways (frequencies uplink 907.8-909.4 & downlink 952.8-954.4) has only 8 pairs of spot frequencies in GSM Band.
Every GSM-R network requires constant, uninterrupted service and high availability - especially while moving at high speeds through diverse terrain. The GSM-R standard offers a flawless handover and guaranteed performance at speeds up to 350 kmph. As the GSM-R signaling information is carried directly to the train itself, GSM-R makes higher speeds and a greater traffic density possible while increasing the level of safety.

6.6.6 GSM-R System configuration

A new UIC GSM-R project group has replaced this EIRENE and MORANE group for new functionalities, Defining operational specifications, specifications evolution, etc. The System function, basic specification and configuration are detailed below.

6.6.6.1 Base Station Subsystem (BSS)

A mobile station (MS) communicates with a base station subsystem (BSS) through the radio interface. The BSS is connected to the network switching subsystem (NSS) which support the switching functions, subscriber profiles and Mobility Management.
The BSS contains of three parts:

- Base transceiver Station (BTS)
- Base Station Controller (BSC)
- Transcoding & Rate Adaption Unit (TRAU).

6.6.6.2 Base Transceiver Station (BTS)

BTS located along the track ensures a continuous radio signal for cab radios at all points on the railway. Repeaters could be used to provide coverage in specific areas.
It provides wireless interface for the transmission of data between Interlocking system and Train Onboard equipments. The BTS device and the MSC are connected by optical transmission network. In tunnel, repeaters shall be installed in Master and Slave configuration and they are also connected to BTS through Optical network.

It provides High level of signal coverage and in case of Fault or Outage of one BTS the adjacent BTS provide ETCS Level-2 Radio Coverage and GSM-R Traffic Channel. At every about 3-4 Km on track, the BTS field equipments shall be installed.

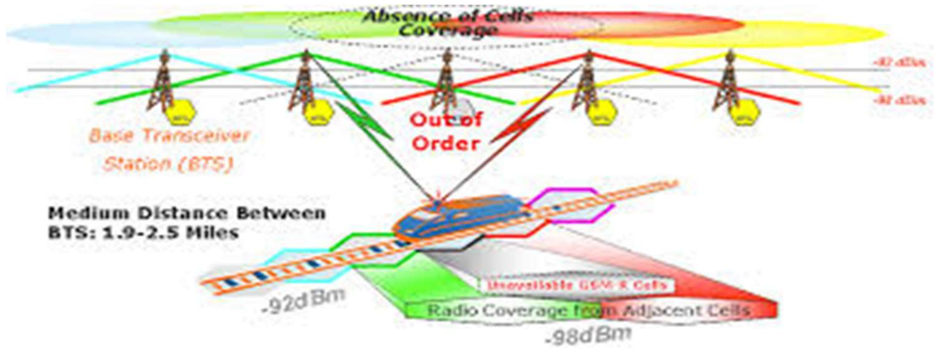


Figure 49: GSM-R system -BTS

6.6.6.3 Base Station Controller (BSC)

A base station controller (BSC) is a critical mobile network component that controls one or more base transceiver stations (BTS). BSC is responsible for functions to provide interfaces to BTS and Transcoding unit, Equipment Management & Supervision, Radio Channel Allocation and Monitoring, Traffic management, Handover procedures, Configuration Data & Software Storage, Failure Detection and Processing, Performance Management, etc.

6.6.6.4 Transcoding and Rate Adaptation Unit (TRAU)

TRAU, performs transcoding function for speech channels and Rate Adaptation (RA) for data channels in the GSM network. It connects the base station subsystem with the core network. TRAU is used to compress and de-compress transmitted speech information. The Network is based on Time Slots and uses 64kbps. To optimise the Radio Network compression (e.g. 16kbs, 8kbs, etc.) compression is required. It shall be designed for the highest reliability, Multicodec capability, Stand-alone unit capability and Interface with the local/remote maintenance terminal.

6.6.6.5 Mobile Switching Center (MSC)

The MSC is the central component of the NSS. It performs the call processing and switching functions of the system. In particular, it provides the functionality needed to handle a mobile subscriber, such as network registration, authentication, location updating, handovers, and call routing to roaming subscribers. It also provides the connection to other networks (such as the PSTN, Railways internal networks, neighboring GSM-R networks, etc.).

6.6.7 GSM-R Network Structure

Since the integrated wireless network for Railway delivers the important data related to the safety of the train operation (including the train position, train operation control, and train status monitoring), wireless communication network should have much higher availability than that of common commercial network. Thus, by duplicating wired network equipment as well as wireless coverage, as shown in below figure, train terminals always have the hot standby function. In other words, the end terminal can receive the data from two base stations at the same time. The network should be designed to avoid any interference with failures of a certain network/base station.

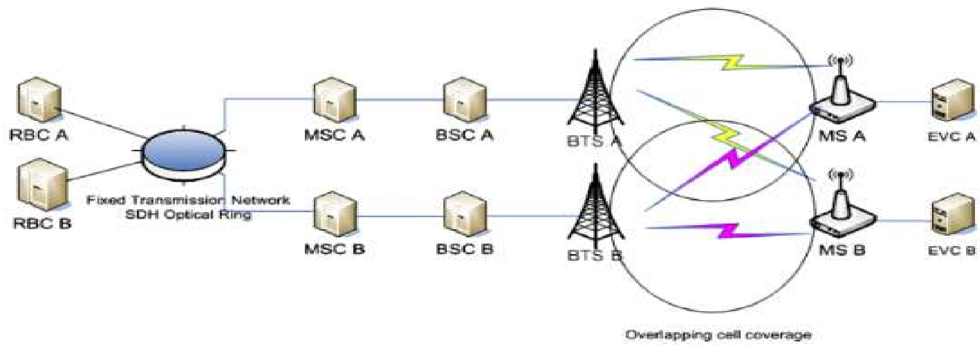


Figure 50: Fully duplicated network with overlaid radio cell coverage for GSM-R

As per Railway applications requiring high degree of reliability will mandate use of the multidrop loop GSM-R architecture. The interleaving of BTS of two different loops will decrease the consequences of a single BTS or BSC failure. Radio coverage shall not be provided less than 98% on track line (with tunnel area). The network structure design is prepared by taking mini 250Km/h speed into account for successful handover. This fully duplicated network with overlaid radio cell architecture is proposed for the new Semi High Speed rail corridor.

6.6.8 GSM-R System Function

GSM-R is able to offer more functionality than the public GSM networks, such as group calls, priority calls, functional addressing and location-dependent addressing. GSM-R is suitable for both voice and data (SMS, GSM-data, GPRS). Following are the unique characteristics of GSM-R system:

- Rapid connection building
- Emergency calling
- Multiple call priorities
- Group communication (broadcast)
- Guaranteed coverage along all railway lines (including railway tunnels)
- Very high reliability for railway safety and carrier requirements.
- The network monitoring & troubleshooting
- The network has many functions (e.g. location-dependent addressing, functional numbering, group communication, etc.)

The typical key function of GSM-R network is highlighted below:

6.6.8.1 Control and Protection (Automatic Train Control/ETCS and ERTMS)

The GSM-R sub-system of European Rail Traffic Management System (ERTMS), is used for voice and data communication. The system is based on GSM and EIRENE – MORANE specifications which guarantee performance at speeds up to 350Kmph, without any communication loss.

GSM-R allows the communication between trains, trackside and railway operation control center, the subsystem chosen is GSM-R, the international wireless communications standard for railway communication and applications. The ERTMS programme can be defined as combination of ETCS and GSM-R subsystems.

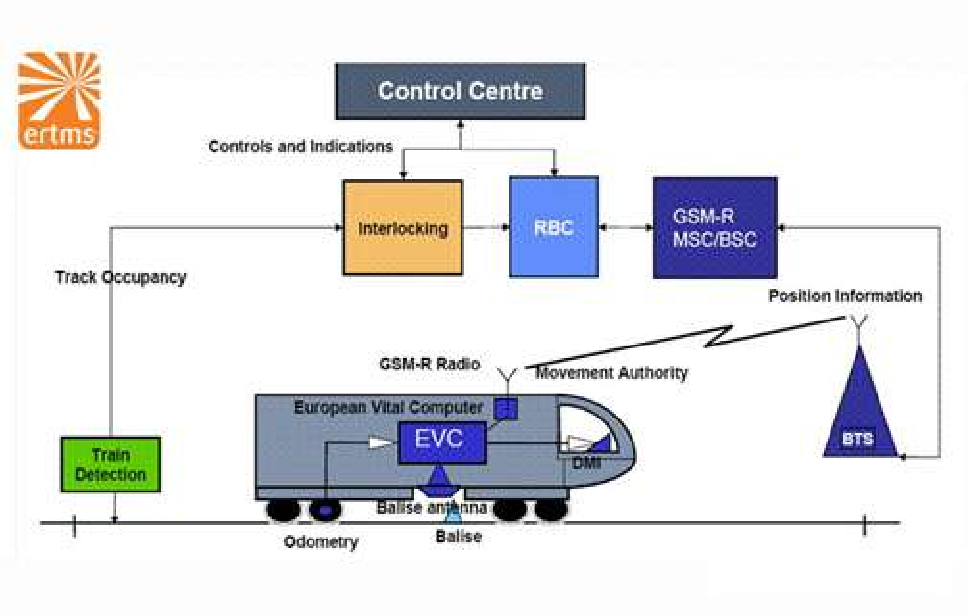


Figure 51: ERTMS- ETCS + GSM-R Architecture

The Radio Block Center (RBC) is a device used at ETCS Level-2 acting as a centralised safety unit which, using radio connection via GSM-R, receives train position information and sends movement authorisation and further information required by the train for its movement. The RBC interacts with the interlocking to obtain signalling-related information, route status, etc. It is also able to manage the transmission of selected trackside data and communicate with adjacent RBC's. The most important functionality for RBC on ERTMS level-2 is to transmit the movement authority to the onboard unit.

6.6.8.2 GSM-R Handset for Operational Voice communication

GSM-R is a digital radio system for Railways based on GSM technology. GSM-R can be used for voice and data communications as well as for traffic control for railways (ETCS, Electronic Train Control System).
Additional railway-specific characteristics include advanced speech call items (ASCI) such as voice group call service (VGCS) and voice broadcast service (VBS) to communicate to a group of handsets simultaneously and facilities are:

- Broadcast messages from controllers to certain groups of trains in a controller area
- Broadcast messages from trains or shunting team members to controllers or other mobiles in a defined area
- Conduct group calls between train drivers and controllers over pre-defined areas

- Conduct group calls between trackside workers, shunting team members, station staff and similar groups, typically over local areas.

Figure 52: GSM-R Handset

GSM-R handset are like cellular mobile phones but are more robust. They also offer extended functionality and a different user interface to utilize the additional applications.

6.6.9 Train Borne Radio Set communication between Controller and Driver

The train radio is required for the communication of a train controller with the train drivers and vice versa. There are two major function of a dedicated type, a voice system and a data system. Voice & data function for traffic control, operational broadcasting, line communication, etc.

Figure 53: GSM-R Train Borne Radio Set

Main function of train radio is to facilitate the communication between train drivers and controller, emergency call, shunting, operational call, depot operation, etc.

6.6.10 GSM-R Dispatcher

The GSM-R Dispatcher subsystem is required for controller at OCC and Depot. The central switching matrix which interfaces with all components of the GSM-R. Main dispatcher switch provides interconnection between various communication systems as well as dispatcher terminals. Main dispatcher switch interfaces towards MSC, Voice recording System and dispatcher terminal. In combination with dispatcher terminals the PABX is the basic component to build up a GSM-R System. It supports rail specific features like prioritized calls as well as supplementary services according to EIRENE standard.

Figure 54: GSM-R Dispatcher Terminal

Dispatcher terminal provided at OCC, Stations, Depot and other important locations of line. Dispatchers at OCC shall have the highest priority to communicate to any stations, depot etc. via the dispatch telephone. The terminal has following function like calling facilities, Full duplex hands free operation, Call Forwarding, Waiting, Hold & Queues, Direct Access Keys, Histories, Group call, Broadcast Calls, Conference, Functional Addressing, Call Priority Level, Text Messaging, etc.

6.6.11 Backbone Transmission Network (BTN) using OFC

Backbone Transmission Network (OFC) to give end to end communication connection between distant places and to provide connectivity through every site location along the section will be provided. The optical fiber shall provide enough transmission bandwidth to cater for all operational requirements of this rail line network and spare for future expansion of system requirement. The OFC system is required to transmit Voice, Data, Video, Ethernet, Signals between Depot, OCC, Stations and other track side locations.

The optical fiber cable shall provide common transmission backbone network for Telecom, Signalling, Power, SCADA and other systems which are formed by the two outdoor single mode optical fiber cables. The OFC cable shall be laid on both side of track with full redundancy for all system requirement. A minimum 144 fibers optical cable shall be provided for backbone transmission network for all the system.

6.6.12 Synchronous Digital Hierarchy (SDH) network

SDH is a standard technology for synchronous data transmission on optical media. It utilizes light-emitting diodes (LED) or lasers for synchronous optical fiber communication. SDH can improve network reliability and performance, offers much greater flexibility and lower operating and maintenance costs. The SDH equipment provides the flexibility of configuration to Terminal, Add Drop Multiplexer, Regenerator and Cross Connect. By using the protection mechanisms of SDH network as well as the Network Management functionalities, a redundant 1-ring structure is implemented to assure the continuity of all communications in case of any possible fiber cable failure by automatically re-routing traffic over the alternative paths.

The SDH Equipment shall support "Ethernet Over SDH" (EOS) transport capability at Fast Ethernet Interface and Optical Gigabit Ethernet Interfaces. IP network shall have important data like transmission of train control signal therefore the network requires high reliability.

Main communication network provides a highly reliable multiple single path in 4-fiber Multiplex Section Shared Protection Ring (MS-SPR) topology with STM-16/64 covering signal equipment rooms in Stations, Depots and OCC. The 4-fiber MS-SPR topology can be used upto 100% for protection channel or for extra traffic, support ring switch and span switch.

This SDH network consists of STM-64 as main communication network and SDH (minimum STM 16/64) based system will be adopted with SDH nodes at every Station, Depot and OCC. A Network Management System (NMS) shall be installed at OCC. And the network shall be synchronized with master clock system.

6.6.13 Gigabit Ethernet Network (GbEN)

To support relatively less important facilities for the rail operation viz. CCTV, Ticketing system, Maintenance management system and PA, Clock, PIDS, Telephone System, SCADA etc., a Gigabit Ethernet network shall be used. Redundant Layer-3 switch at each Station, Depot OCC shall be provided. This network shall use the same OFC as the SDH network. The network is supposed to be 10 Gigabit Ethernet network. The communications network shall be configured as LAN and WAN. LAN shall be responsible for train operations and maintenance tasks within each passenger station and WAN shall be responsible for mutual communications between the stations and between depot and the central computer system. To maximize the reliability and survivability, each equipment and each transmission line are configured as a dual system.

6.6.14 Telephone system

The telephone system provides voice, fax, email, video and data communication between railway personnel both internally and external for train operation management. Telephone system will consist of IP PBX exchange (Internet Protocol Private Branch), Dispatcher telephone, Emergency Telephone, IP Phone (Voice & Video) etc. Help points also provides for passengers for assistance inside the stations. The Telephone System shall consist of the following subsystems:

6.6.14.1 IP PBX telephone exchange

The IP PBX is highly reliable state of art, non-blocking, ISDN compatible IP PBX telephone network for Voice, facsimile and data communication service throughout the rail corridor. IP PBX network equipped with IP PBX switch, line and trunk interface units and different types of telephone sets for communication. It also interfaces to radio system to enable radio user to initiate and receive call from IP PBX extension or from PSTN telephone. IP PBX network also interface with Public addressing System to broadcast message & announcement to station and other strategic location

6.6.14.2 Dispatch telephone system

Dispatcher system is provided at OCC. The Dispatch telephone system shall provide at each Station, Depot, Workshop, Maintenance depot, Substation, Signal & Telecommunication equipment room and other line side location for communication. An integrated communication console will be provided at OCC.

Dispatchers at OCC shall have the highest priority to communicate to any stations, etc. The system shall ensure instant, uninterruptible, communication between key points.

6.6.14.3 Voice Over IP Phones System

The Voice Over IP telephone communication system provides telephone lines over IP network using proven protocols such as H.323, SIP etc. for Stations, Depot and OCC. The system ensures instant, uninterruptible, real time audio/video communication between key points. OCC system shall have highest priority to communication to any station or line side location.

6.6.14.4 Unified Messaging Application (UMA)

This is provided for IP PBX system with facilities such as Email, Voice mail, Faxes, Conferencing & Collaboration and inbuilt Soft phone. The Unified Messaging Application is accessible from desktop clients and supports features such as making calls, sending, replying, forwarding Voice messages and recording live conversation and accessing the IP PBX services. UMA supports Unified directory that allows the IP Phone, Soft phone user to call by name and identify their correspondents. A Conferencing and Collaboration application also provided for all types of IP Phones (soft-phones included) under UMA for Audio Conferencing, Data collaboration & Video Conferencing.

6.6.14.5 Emergency Telephone system

The system shall provide a highly reliable and high availability telephone communications as a means of reporting and aiding a response to emergency situations that may arise in tunnels. The system shall be simple in operation to allow use of telephones by untrained staff, emergency services staff and anyone from the general public that may be caught up in an emergency in a tunnel. The wayside telephone shall be interconnected by Backbone system (OFC) on IP PBX exchange system.

The Emergency telephone shall be installed at following locations:

- Wayside telephone sets shall be installed at every approx. 500m interval in underground and tunnel section.
- Wayside telephone sets shall be installed at every approx. 3000m of interval in open section such as embankment and viaduct.
- Emergency telephone shall be installed at each station platforms and passenger area.

6.6.15 Centralised Digital Recording System (CDRS)

A centralized digital Recording System (CDRS) shall be provided at OCC with enough recording capacity for minimum 30 days for continuous operation like Radio, Telephone, PAS/PIDS, etc. The CDRS shall record all telephone conversations of all dispatchers at OCC and at Stations. The Telephone System shall be interfaced with a Centralised Digital Recording System for recording of designated telephone lines including emergency telephone lines.

Radio conversation shall be recorded by CRDS located at OCC. Emergency announcement on Train borne PA system initiated from Radio console at OCC shall also be recorded.

6.6.16 Passenger Information Display System (PIDS)

The passenger information system is based on the multimedia and network technology. The system is installed in the OCC, Station and Depot wherein the display terminal will display multimedia information to passengers. The passengers will timely and accurately know the train operation information and public announcement information. Under normal circumstances, the PIDS system provides train travel time information, and advertising, etc. In emergency events (such as fire) the PIDS system is used to provide the emergency evacuation messages. The equipments of passenger information system will be deployed in the OCC and stations. OCC subsystem is mainly responsible for the system configuration, media edit, layout edit, equipment status monitoring, preview broadcast effect, interfaces and network management.

6.6.17 Passenger address System (PAS)

Public Address System (PAS) provides broadcasting of voice messages to passengers / staff in all Stations, Depots and OCC. It can also be used for emergency evacuation broadcast in case of emergencies. It includes speaker and amplifier linked to the station. The Public Address System (PAS) and Passenger Information Display System (PIDS) shall be coordinated automatically to provide real time passenger audio broadcast and visual information at each station.

It will have capability for Different Live or Recorded announcements to separate Zones or Group of Zones simultaneously within a station. In addition to announcements from Designated Hand Portable Radios to a set of pre-defined Zones at each station.

The OCC is the global control centre for the PIDS/PAS system. From the OCC system wide control of Station Control Rooms (SCRs) is possible. The SCR is the local PIDS/PAS installation exists in each station. It manages the local PIDS/PAS system of that station. In case of audio broadcasting relating to emergency, fire and evacuation messages from OCC and Station Control Room shall be recorded in the Centralised digital recording system at OCC.

6.6.18 Time distribution System (TDS)

Time Distribution system is to provide exact and reliable time information throughout the rail infrastructure in the form of analogue and digital clocks in addition to time information for electronic system. The Time Distribution System (TDS) consists of primary Master Clock located at OCC, one secondary Master Clock located at BCC and Slave Clocks including Analogue and Digital Clocks in Stations and Depot.

The Time Distribution System (TDS) mainly includes three equipment which meets total functional requirements as

- Primary Master Clock
- Secondary Master Clock
- Analogue and Digital Clocks

Time reference, usually a GPS-time-signal receiver, will be provided to correct the time deviations of the Master clock timeserver. These time deviations are mainly caused by frequency drifts and aging of the internal quartz-oscillator of the Master clock. Master clock timeserver generates the time-/date-information for the slave clocks and computer-controlled systems such CCTV, PIDS, PA System, Radio, PAS, PIDS, Signalling, Power, SCADA, Telephone system, etc.

6.6.19 Closed Circuit Television System (CCTV)

CCTV system is based on the latest network video technologies, making use of sophisticated computer-controlled systems through cameras to ensure effective surveillance of an area as well as to create temper proof video recording for post event analysis. CCTV system shall be provided for real-time and visual supervision through the wall displays, selecting specific location or all the public area in stations as well as in OCC, Tunnel area, substations, radio tower location, depot area, and other important locations of line. It will also provide the integration of CCTV with access control of important rooms & locations.

CCTV system will consist of transmission equipment, remote camera, controller, monitor and video recorder. CCTV camera signals from selected area will be recorded by video recording device. CCTV monitor will be provided for displaying real-time pictures of each camera and recording playback.

6.6.20 Facility -Supervisory Control and Data Acquisition (F-SCADA)

F-SCADA (Supervisory Control and Data Acquisition) can realize that dispatchers in OCC confirm and monitor condition of equipment and data on measurers for disaster information, so they can precisely instruct train crews and maintenance staffs and control train operations to prevent failures. F-SCADA continuously monitors equipment status in OCC. In case of equipment failure, the information is transmitted to OCC in real time and displayed on the monitor with buzzing sound. In addition, F-SCADA terminals are installed at each maintenance office and equipment failure information can be obtained there at the same time as OCC.

The F-SCADA shall directly monitor the main equipments of Signalling & Telecom, Power and other safety system of network.

6.6.21 Recommendation for Communication system

As enumerated above, the communication system is backbone for Signalling & Train Control system, SCADA system, Automatic Ticketing system, Safety & Security system, etc. and provides communication service for information to passenger, Administrative management, Operation & maintenance, Emergency control etc. requirements of a semi high-speed train network.

The Communication facilities proposed are helpful in meeting the requirements for:

- Supplementing the Signaling system for efficient train operation.
- Exchange of managerial information
- Crisis management during emergencies
- Passenger information system

Global System for Mobile Communications (GSM-R) with limited capabilities, to fourth-generation (4G) broad-band systems that offer higher data rates, e.g., long-term evolution (LTE). It is thus relevant for HSR to replace the current GSM-railway (GSM-R) technology with the next-generation railway-dedicated communication system providing improved capacity and capability in future. Hence, modern technologies, such as long-term evolution (LTE), have to be evaluated as possible railway communication technologies to replace GSM-R in the future. LTE system can be considered if the system is matured at the time of executing the project and if cost arrives less than GSM-R system.

The Communication system for a Semi high-speed rail corridor requires the following sub-systems:

- GSM-R/LTE System with Radio System and Trainborne equipments
- Backbone Transmission Network (with SDH & GbEN)
- Telephone system (IP PBX exchange system)
- Centralised Digital Recording System (CDRS)
- Passenger Address System (PAS)

- Passenger Information and Display System (PIDS)
- Time Distribution System with GPS system
- Closed Circuit Television System (CCTV)
- Facility -Supervisory Control and Data Acquisition (F-SCADA)

6.7 Ticketing and Fare Collection System

6.7.1 Introduction

Kerala is the first state in India planning to provide the Semi High-Speed Rail with design speed of 250 Kmph. The passengers traveling from Trivandrum to Kasaragod (531 Kms approx.) will take about 4-hour journey time.

The High-Speed Railway transit system is expected to handle large volume of passengers. Ticket issue and fare collection will play a vital role in the efficient and proper functioning of the system. To achieve this objective, ticketing system should be simple, easy to use/operate and maintain, easy for accounting facilities, capable of issuing the fare media types selected, easily modifiable for quick fare policy changes and require optimum manpower overall. The Ticket and Fare Collection systems to be implemented for the Semi High-Speed Rail will ensure that:-

a. **The correct fare value is collected from any of the passenger using the system, and**
b. **No unauthorized personnel are allowed to travel on the transport mode**

The ticketing system shall be a computerized system for effective management of the process of reservation, ticket issue and inspection with a view to improving convenience of users. The ticketing process shall have both Online and In-person capabilities enabling passengers to book tickets online or take it in-person from the Ticket window. A passenger with a valid ticket shall enter and exit through automatic gates at boarding and de-boarding stations without any manual intervention by railway staff. This Ticketing System will hereafter be referred to as Automatic Fare Collection System (AFC System).

6.7.2 Overview of Ticketing system

In the High-Speed Railway the ticketing and fare collection system is generally built up in three layers:

I. **Reservation process:** The process in which passengers book tickets in a prescribed way, by using online booking (by Internet booking) or Ticket Vending machine or ticket office machine.
II. **Ticket issuing process**: Booked ticket is issued through printer, mobile, Ticket Vending machine or ticket office machine according to the reservation number. Whatever may be the mode of booking the reservation and ticket issuing will be processed in a sequence.
III. **Ticket Inspection process**: Passenger tickets are checked to confirm their validity. Inspection is conducted at both the time, during entry and exit in addition to during on board.

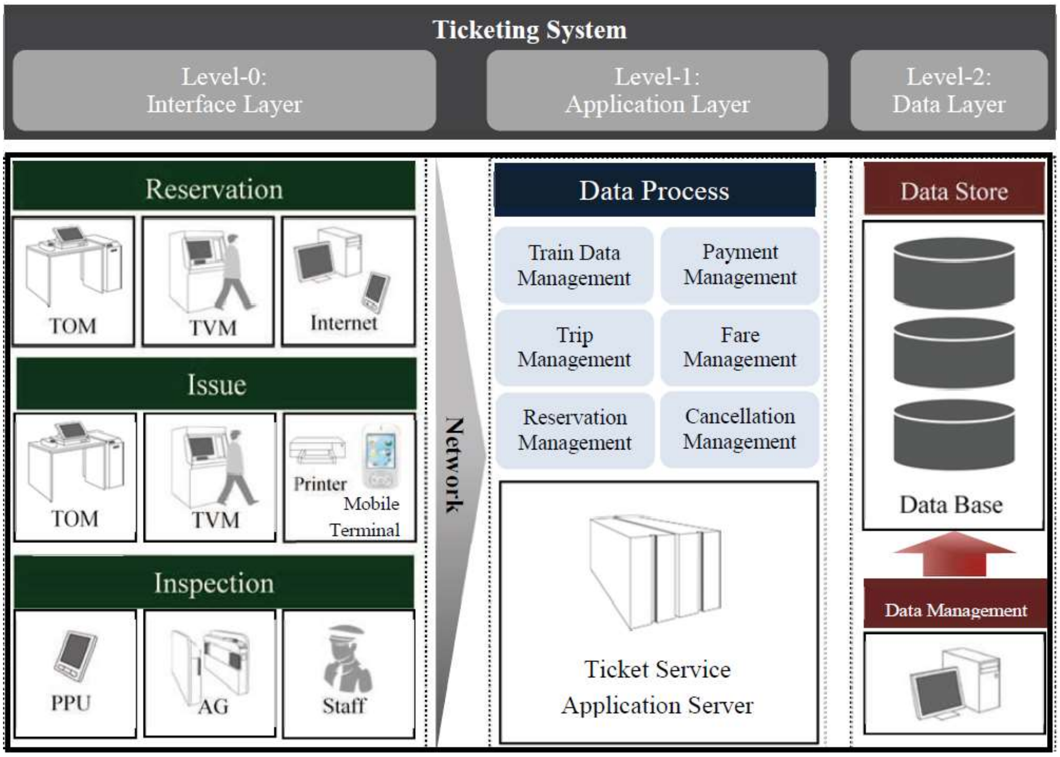


Figure 55: Ticketing System Structure

The data used throughout the ticketing system is stored in the database connected to the application server. When any of the processes is done, a relevant channel on the interface layer inquires the application server, and then receives transaction results as an answer from the server. Multiple requests are sent concurrently from station machines and the online system, so the application server needs to respond effectively to them and ensure that no improper transactions occur, including dual issuing.

6.7.3 Ticketing Systems for high Speed railways in other countries

According to the operation and management system, service offered to passenger, technology & equipment used etc., the ticketing system is different in its architecture. Different countries use different system for AFC. The ticketing system mainly depends upon the following points:

- **Medium of Ticket:** Tickets used by other countries in high-speed railway/ metro are either one/ combination of paper tickets, magnetic tickets, IC cards and e-tickets by using internet (online/ mobile app).
- **Reservation and Ticket Issuing:** Reservation of ticket can be through ticket windows, TOM/TVMs at stations and online system through the Internet/ mobile application.
- **Ticket Inspection:** Inspection of ticket is required at station entry/ exit as well as on - board for checking the validity and data record. The system for Inspection of tickets is dependent upon the medium of ticket. In case of magnetic ticket or IC card, its validity is checked by a reader equipped at the automatic gate. The validity of an e-ticket is confirmed by reading information printed or displayed on the mobile terminal. On-board inspection (by conductor) is necessary to check passengers who do not use the seat and train designated

on the ticket. On-board inspection is primarily done by the conductor according to the printed chart of reserved seats.

Table 84: Ticketing system structure for high speed railway in other country

Country	Ticket Medium	Reservation	Inspection	Payment
Japan (Shinkansen)	Magnetic, Paper, e-ticket, IC, Mobile Device	Windows Internet, Ticket Vending machine	Automatic Gate, Conductor	Cash, Debit/Credit Card
Germany (Intercity express)	Paper, e-ticket	Windows Internet, Ticket Vending machine	Conductor	Cash, Debit/Credit Card
France (Grande vitesse)	Paper, e-ticket	Windows Internet, Ticket Vending machine	Conductor	Cash, Debit/Credit Card
UK (Pendolino)	Paper, e-ticket, Mobile Device	Windows Internet, Ticket Vending machine	Conductor	Cash, Debit/Credit Card
Taiwan (HSR)	e-ticket, Magnetic	Windows Internet, Ticket Vending machine	Automatic Gate Conductor	Cash, Debit/Credit Card

Source: compiled by study team

6.7.4 Ticketing System Description for High Speed line

High Speed railways are expected to be used more often by people who try to use their time effectively than in the existing railways where much time is taken for travel. Such business people tend to use the online system for reservation, rather than waiting in line at ticket windows, so a need for internet reservation is probably greater for Semi High Speed railways than for existing railways.

Semi High Speed Railway Transportation system is expected to handle a large volume of passengers. The Ticketing System handles reservation, ticket Issuing and Inspection processes. The ticketing System shall provide world class ticketing facility to the passenger. After booking the ticket either by online / offline, reservation and ticket issuing are processed in a sequence by central ticketing system server. Passenger's tickets are checked to confirm their validity during inspection process. Inspection of tickets is conducted at the time of both entering/ exiting the concourse, or on board.

Centralized computer ticketing server is connected through via backbone transmission network (BTN) with application servers. All the data used in ticketing process system is stored in database of centralised ticketing system server. After completion of ticketing process, centralized server shall communicate the transaction result to application server.

6.7.5 The Ticketing System for Semi High Speed (SHS) rail line (Standalone) is proposed with the following basic requirements:

6.7.5.1 Centralized Computer System:

The system shall handle all functionalities of ticketing process, management, access control, fare management, payment, financial requirements, settlement between different registered operators. The system shall generate financial report and management reports. The system is responsible for internal and external interface with all ticketing process through gateway and third party. The system software and hardware shall ensure, secured transaction, processing of ticket and payment using appropriate high-level security technology. The system shall ensure the ability to obtain complete and clear data backup and recovery of operation process. Central computer system shall be in redundant configuration and located at OCC and BCC.

6.7.5.2 Station Computer System & Equipments:

The Station Ticketing system shall handle all the fare collection equipments & machines. The Station server will control all the activities of all the machines. All the station servers will be linked to the central computer at OCC through the backbone transmission network (BTN). The following mini equipment's will be required at each station:

A. Station local Server for management of station equipments and processing of data from/to the station equipments.
B. Ticket office machine (TOM) for reservation and issue of ticket operated by station staff
C. Ticket vending machine (TVM) for reservation and issue of ticket by operation of customer.
D. Cash handling equipment for counting currency.
E. Automatic gate for inspection ticket validation on entry and exit.
F. Portable Processing unit (PPU) and Mobile ticketing equipment (Scanner & Printer)

Figure 56: Ticketing system equipment

6.7.5.3 Ticketing Terminals and information point:

The ticketing terminal/ sale point are to be provided at all the stations. All the station should have ticket windows and ticket vending machine/ticket office machine. Provision should also be made for some mobile ticket counter near crowded area in the city. The passenger information system should be provided at each station, where passenger get all information of train schedule, timing, tickets, etc.

6.7.5.4 Ticket booking system:

The ticket booking facility shall be provided through on-line, offline, ticket windows, Mobile ticketing counter, ticket vending machine/ticket office machine. The ticket medium shall be Paper, Magnetic, IC and e- ticket (by mobile app, computer). Ticket medium depends upon the booking process chosen by customer. All the necessary information should be mentioned in all type of tickets. All the tickets should be provided with Security code/Quick Response Code (QR)/ Barcode for verification. The passengers shall be able to make ticket payment by cash, credit/ debit card and net- banking.

6.7.5.5 Issuing of Ticket:

All type of tickets shall be with necessary details as mentioned below:

A. Ticket number & Passenger name record (PNR)
B. Passenger Name, Age & Sex (as per identity proof)
C. Details of Train, Coach & Seat Number
D. Train Departure & Arrival time
E. Boarding Station and De-boarding Station
F. Date & Time of booking and Travel date
G. Fare and Paid Service detail
H. Security code/ Quick Response Code (QR)/ Barcode etc.

Figure 57: Sample of ticket with security code/ QR/ Barcode

6.7.5.6 Inspection of Ticket:

The inspection of ticket shall be administered at station entry and exit points by automatic gate and on board by conductor by manually or by using Portable Processing unit (PPU) /Mobile ticketing (Scanner & Printer). These devices are commonly used for on board inspection of ticket, which download the reservation information from main ticketing server to make sure that tickets are consistent with the given information.

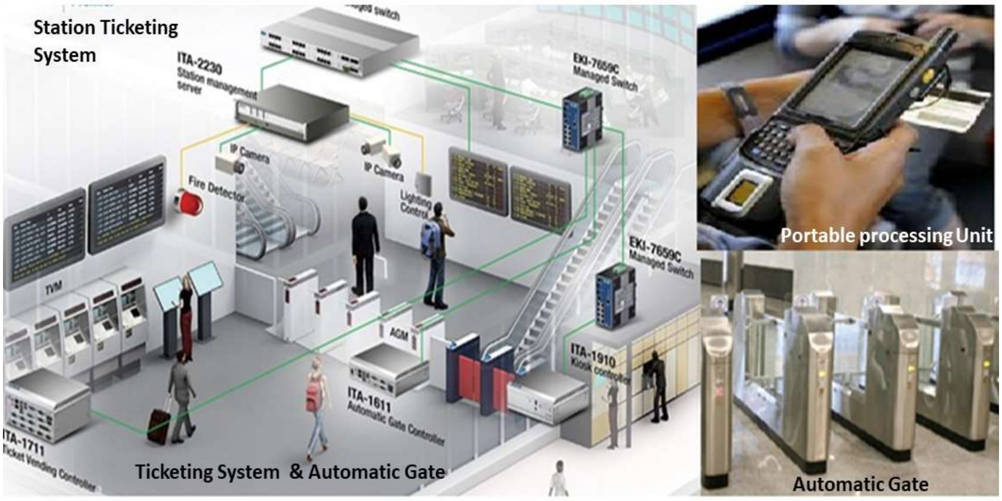


Figure 58: Automatic Gate & PPU

6.7.5.7 Facility for passenger:

The passengers can book reserved/ unreserved ticket, bulk ticket, multiple trip/monthly ticket, promotion/ discounted ticket etc. The system shall provide for cancellation/ modification/ re-scheduling, refund and surcharge etc. During online and offline ticketing process passengers have facility to select their seat. The system shall provide information like coach wise seating plan view, pricing details and availability of seat to allow the user to make an informed decision for selection of seat at time of booking.

6.7.6 Recommendation for Ticketing and Fare collection System

Semi High-Speed Railway Transportation system is expected to handle a large volume of passengers. The ticketing System shall provide world class ticketing facility to the passenger. The ticketing system shall be computerized system for effective management of the process of reservation, ticket issue and inspection with a view to improving convenience of users.

The Ticketing and fare collection system of Semi High-Speed Rail corridor requires the following sub- systems:

- Centralized Computer Ticketing System
- Station Computer System
- Cash Handling equipment's
- Automatic Gate with card reader
- Ticket Vending Machine (TVM)
- Ticket office Machine (TOM)
- Mobile Ticket Machine
- Portable Processing unit (PPU)
- Mobile ticketing (Scanner & Printer)

7. ALIGNMENT STUDY, ROUTE DESCRIPTION AND STATIONS

7.1 TERRAIN, LANDFORMS AND POPULATION

The speed of trains and road vehicles on Kerala's highways and railway lines is on the average of 30% to 40% i.e. less than the average speed in most other parts of India.

The modern societies all over the world have experienced that, as the economy grows there is increased demand for faster travel. Undoubtedly, as evident from the plans to build expressways and high-speed lines in the state and upgrade the existing ones in the past decade, socio-economic growth of the state is being constrained by the state's slow highways and railways and there is an urgent need to address this problem.

To find the root cause of slow speed of travel, it is necessary to take a closer look at the unique landforms of Kerala that form the coastal plains and the mid-highlands, which lie between the Western Ghats mountain range in the east and the Arabian Sea in the west. That is why finding a suitable alignment for building a stable and safe high-speed line running almost in the full length of the state from Thiruvananthapuram to Kasaragod is a very challenging task. Building this line would require marshalling of engineering skills and innovations to optimise the cost. Despite the costs and the challenges, the fact remains that the state needs a rail-based means of fast travel for its socio-economic growth which has been constrained for the past many years by the slow speed of surface transport.

Kerala is a narrow stretch of land sandwiched between the Western Ghats in the east and Arabia Sea in the west. Kerala has width from 35 to 120 kms with an average of about 65 km. The land is traversed by 44 rivers of which 41 have their course towards the Arabian Sea. They take their origin from the Western-Ghats and flow west until they drain into either the backwaters or flow into the Arabian Sea. The total annual rainfall of the state varies from about 4500 mm in the northern Kerala to about 2000 mm in the south. Ernakulam and Thrissur Districts receive rainfall 3210 mm and 3160 mm respectively which are above the state average. The rivers are mainly monsoon fed and most of them are perennial in character. The coast line, which is full of endless sandy beaches, is remarkably straight with mild curves.

Based on the topography, the entire region can be divided into three zones from west to east (See the schematic diagram in Figure below).

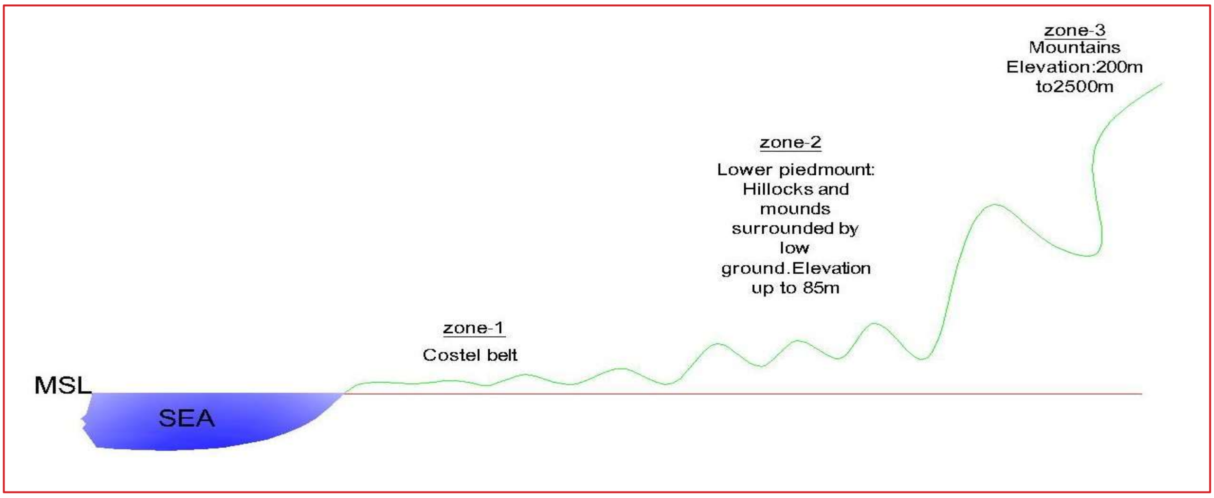


Figure 59: The topographic divisions of the state of Kerala

Zone 1

The coastal plains and the backwaters are an area of estuaries, lagoons, alluvial plains, and beach ridges and dunes fringing the coast. It covers about 20% of the area of the state with elevation ranging between 0m and 15m. It has a maximum width of about 25 Km near Alappuzha. The coastal plains are full of backwaters, which are a chain of brackish lagoons and shallow lakes lying parallel to the Arabian Sea coast. The network of the backwaters includes five large lakes linked by canals, both manmade and natural, fed by 41 rivers, and extending more than half the length of Kerala state. The backwaters have been formed by the action of waves and shore currents creating low barrier islands across the mouths of the many rivers flowing down from the Western Ghats range. Vembanad lagoon is the largest waterbody extending about 83 km parallel to the coast from north of Varkala to Azhikode in the north of Kochi with six major rivers flowing into it. Kuttanad, south of the Vembanad lagoon is a deltaic formation of mainly four rivers Achankovil, Pampa, Manimala, and Meenachil. The second largest lagoon is the Ashtamudi at Kollum, which has a length of 16 km and a total width of 15 km.

Zone 2

The lower piedmont, also referred as mid-highlands, consists of intensely dissected west-east sloping surface of the earth with hillocks and mounds surrounded by wide water courses and lowlands which have been formed by the swiftly flowing rivers and streams. This region occupies nearly 50% of the state's total area. The region's unique landform of alternating sequences of hillocks and mounds surrounded by low grounds with elevation difference ranging from 20m to 80m between the high and low grounds has been formed by rivers, which have been changing their course over the millennia as they dissected the earth, leaving behind the lowlands around the present-day hillocks and mounds. In the rainy season, when the low-lying areas around the hillocks and mounds are waterlogged, the region looks like a sea with a dense cluster of islands when seen from above (See the figure 61 & Google Earth image of the region near Kayamkulam, north of the Ashtamudi Lake in Figure 62).

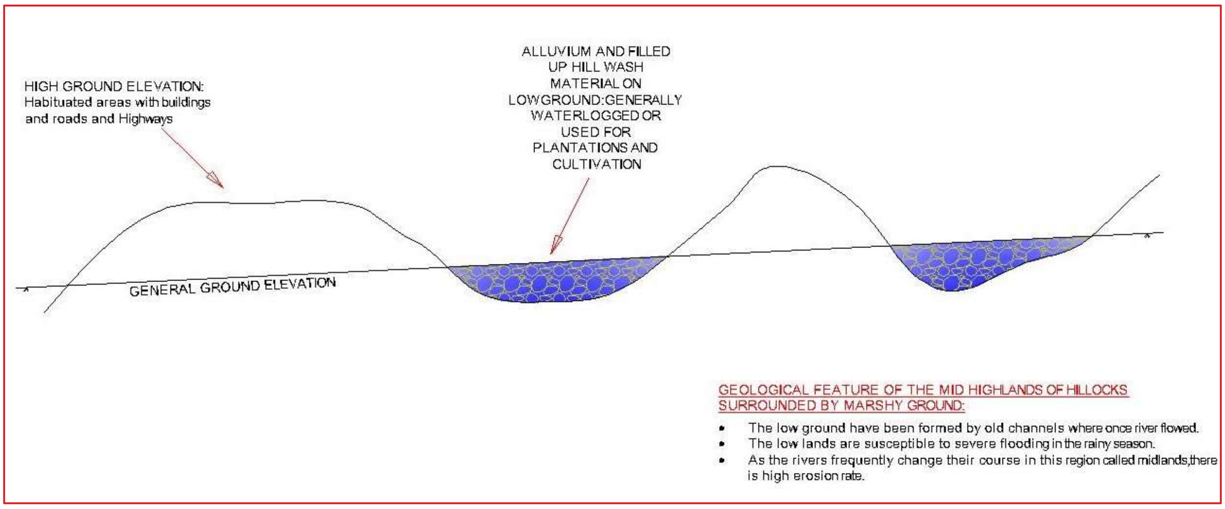


Figure 60: The unique landform of the mid-highland region of Kerala

AERIAL VIEW OF THE MID-HIGHLANDS NEAR KAYAMKULAM

Figure 61: Aerial view of the mid-highlands near Kayamkulam

Zone 3

The rugged topography of the Western Ghats mountain and the lower piedmont with an elevation ranging from 600 to 2500 m and 100 to 600m respectively. It occupies about 30% of the state's total area.

The result of the above two landforms between the Arabian Sea and mountains of the Western Ghats is that in the rainy season large areas are occupied by water bodies and several other areas with undulating terrain are inundated with water. So, only a small proportion of the land is free from water and inundation round the year. People in these regions live in scattered patches of high ground. The larger cities like Thiruvananthapuram, Kollam, Kannur, Kottayam, Chengannur, and Thrissur have come up where there are large areas of high ground. Kochi/Ernakulam is a rare example of a large city built on low ground near the sea coast (with houses built on pile foundations), like Venice in Europe on the Adriatic Sea. There are very few large villages to be found in the mid-highlands, and hamlets are scattered all over wherever there is high ground to build houses that would be safe from the flood waters. Between Kozhikode and Kasaragod, the midland topography of alternating mounds and waterlogged low ground is more pronounced. The towns and cities in the midlands here are small and more dispersed. For example, in district Malappuram there are several cities and towns like Malappuram itself, Kottakal, Manjeri, Tirur, Ponnani, Nilambur, and Valanchery, but none has a very large population. By contrast, the coastal belt has larger cities and there is less scattering of the urban population. (See the Google Earth image of the region near the north of Thiruvananthapuram figure 82).

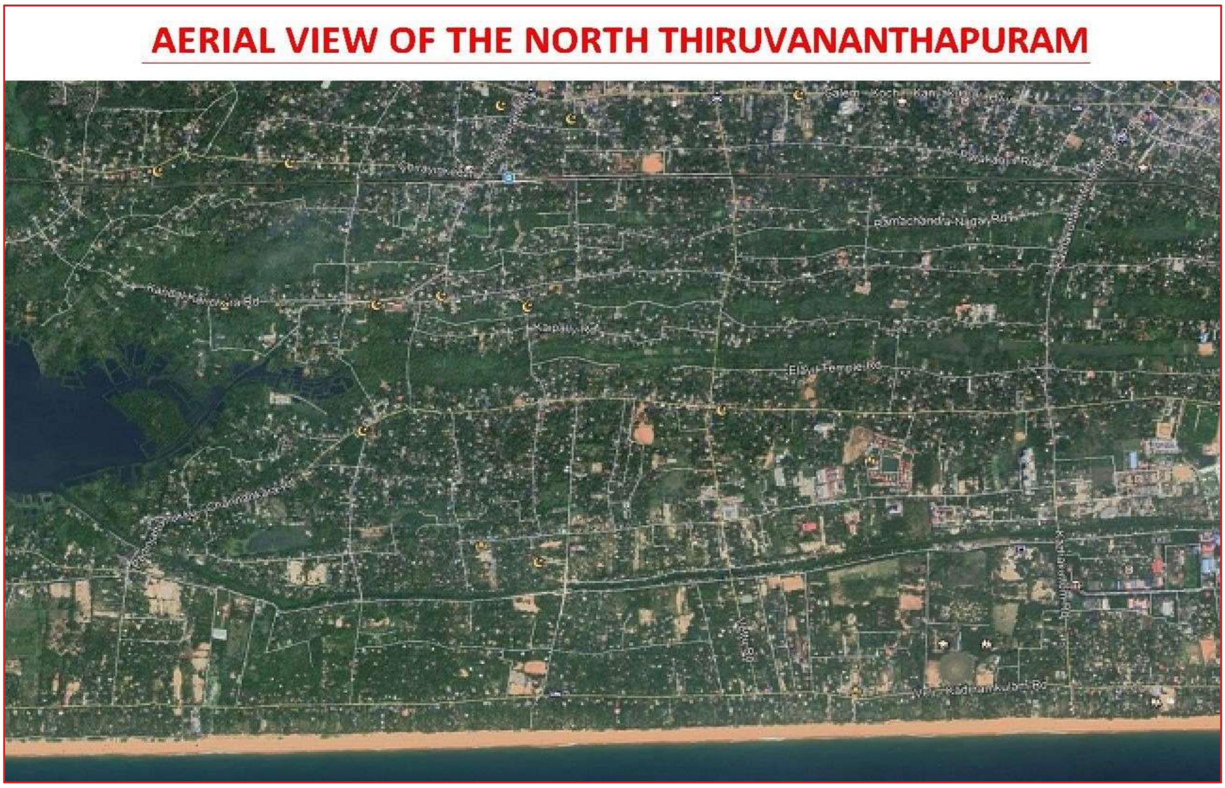


Figure 62: Aerial image in the north of Thiruvananthapuram

The above aerial image in the north of Thiruvananthapuram shows how inhabitations have grown parallel and close to the highways and other roads which are built on the higher ground

These unique landforms, which together cover about 70% of the state's land area, have resulted in slow speed of surface transport. The highways basically find high ground by connection patches of high ground in a sequence. The result is that the roads are highly curved and there are steep gradients as the roads move up and down between the alternating low and high ground.

The railway lines have been laid in a slightly different manner: basically, closer to the low ground as they traverse the region on cuttings in the slopes of the hillocks and mounds and on high embankments in low lying flats.

Both the railway lines and roads are badly affected in the rainy season because of waterlogging in the region. Speed is relatively better in portions where the railway line and roads are situated in the flat terrain.

These landforms and the dispersed population present a serious challenge to building a high-speed railway line. Additionally, in the coastal plains the main problem is of low bearing capacity which is encountered almost everywhere. The soils of the coastal plains are likely to be very deep with sandy texture. Rock, and stiff soils are usually encountered at more than 30 to 50 m depth. The sand content of the soil near the surface, ranges from 80% and clay up to 15%. Even though these soils have high water table, the water holding capacity is likely to be poor due to the predominance of the sandy strata. In the backwaters, the content of silt and clay is relatively higher. In the paddy field of Kuttanad, sandy clay loam to clay is the predominant soil. On the other hand, in the midland's undulating terrain with waterlogged regions surrounding the hillocks and mounds, the main suspect is of the instability of cuttings in laterite soil/rock which is the dominant material on the surface at up to several meter depth. Further, because, high embankments would need accurate design after due analysis before actual execution in the lowlands which are prone to water logging and flooding. Preferably, the semi high-speed line would have to be carried over the lowlands between the hillocks on high viaducts. Alternatively, the line would have to be carried in tunnels laid at shallow depth below the ground by avoiding both the hillocks and the lowlands.

(See figure 83)

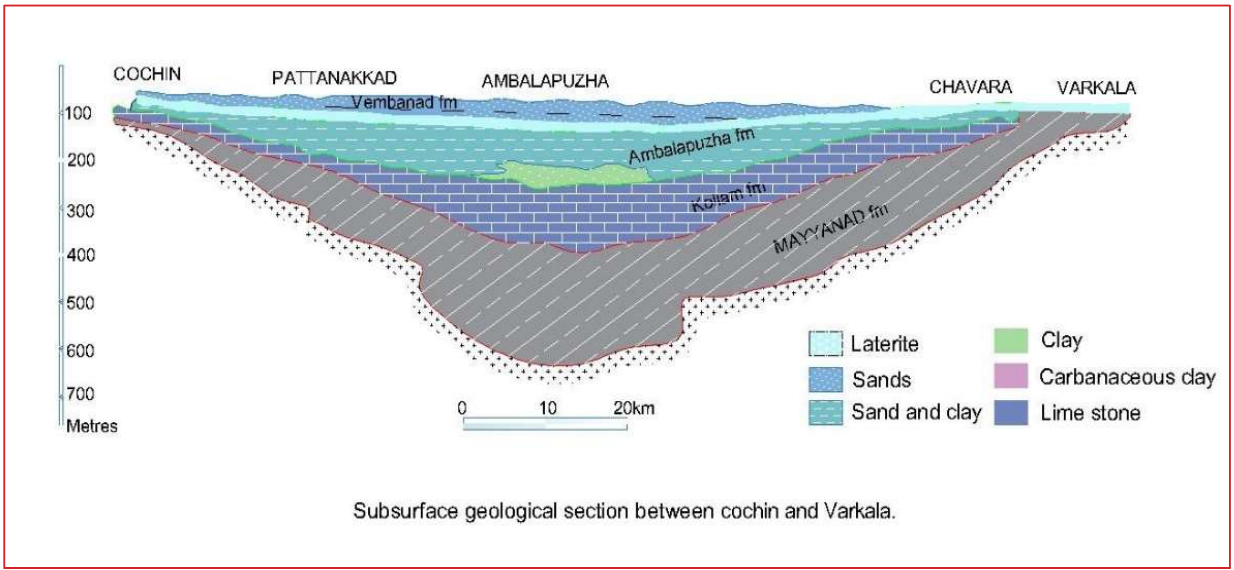


Figure 63: Cross section of the ground along the coastal plains from Varkala to Kochi

In view of the above, the alignment has been designed in order to serve the maximum population by semi highspeed line after examining the various factors and the magnitude of problems posed by the ground conditions.

7.2 Methodology for the study team:

The aim of the team has been to design a techno-economic alignment based on the route connecting obligatory points provided by KRDCL for providing the stations at most suitable locations accordingly. Following have been the main factors which played important role while designing the alignment;

- Difficult terrain and geology of the state
- Design the alignment connecting obligatory points of the project
- The dispersed urban population in the state with even the biggest cities having less population
- High cost of the land in the state

The alignment has been prepared keeping in focus all the basic technical requirements for a SHSR line with techno and economic considerations. To cut down land requirement as much as possible, cause less dislocation for the population in congested areas, cause least hindrance to the movement of people and vehicles on the roads, highways and streets, boats and ferries in the canals and backwaters we have adopted the following strategies;

- Bank height not to be more than 6m in normal case
- Cutting depth up to 8 m normally
- Cut and cover has been considered for depth exceeding 8 m and tunnel if the depth is more than 16 m and have adequate cover of a minimum of 6 m.
- Proposed Formation level kept at least 1m above the HFL

In addition to above, following basic principles of the design of alignment has been adopted;

i. Alignment has to be economical
ii. Easy to construct
iii. To be built at safe level to avoid any submergence of the track during the flood
iv. Safe from land slide in cuttings or emabankment failure during operation
v. To serve the traffic potential areas based on obligatory points of the project provided by KRDCL
vi. To serve the important railway stations as much as possible to have the integration

- As the details topographical survey and Soil investigations will be done after approval of the alignment planned in Feasibility Report, the Google Earth has been used for obtaining ground data (X, Y and Z coordinates) for digital terrain modelling for drawing contours and preparing tentative alignment. Google Earth has also been used as an aid to examine all physical features like water ways, lakes, backwaters, forests, roads, railways, canals, cities, and other habitations with field inspections of critical locations. The Z coordinate (i.e. the vertical height) along the chosen alignment has not been rechecked by DGPS survey due to urgency in submission of the Feasibility Report. However detailed topographical survey will be done during DPR.

Based on the obligatory points provided by KRDCL along with the tentative route, to economise the cost of the project, by default choice has been to keep the alignment in bank or cutting. Viaduct of nominal single height of about 8-15m has been considered whereever required as per site constarints as discussed with KRDCL from time to time during presentations of the alignment. At only unavoidable locations, the height of viadut is relaxed to upto 20m for only short stretches to avoid provisions of tunnels and so to minimise the cost. Whereever feasible, the road locations has been crossed through RUBs to minimise the height of bank/ viaducts or depth of cuttings. Further, fine tuning of the alignment to minimise the heights of bank/ viaducts or depth of cuttings will be done during DPR when the deatiled topographial survey plans and data will be available. This all will require a critical review and detailed design before execution due to site and geologcal complexity.

In the regions with unfavourable terrain and ground conditions, following alignment philosophy has been evolved for feasibility of construction of a stable and safe railway line at economical cost.

- Within the constraints of the obligatory points for the line, the alignment preferably to be located as to avoid terrain that is inherently unsuitable for laying a railway line, such as landslide-prone areas and unstable hill slopes, geological fault lines and other major discontinuities, marshy ground and waterlogged areas, etc. At unavoidable sections where the alignment has to pass through such areas due to site constraints, then its cost-effective engineering solution has to be done during execution of the project to avoid any adverse conditions after construction

- In regions of adverse terrain, geological and geotechnical conditions, it has to be ensured that alignment does not require construction of ;
  - Large bridges, high viaducts and high embankments in areas with low bearing capacity,
  - High cuttings in the landslide-prone slopes, and
  - Tunnels in the collapsible rock strata.

  Smaller structures with less cost, are easier to construct and put lesser load and pressure on the ground. As, at this stage its is difficult to judge about the geology of the region correctly, a due care is to be taken during exectuion of the project for all such structures by enagaging the expert agencies and DDCs.
- The general placement and direction of an alignment will largely depend on the main natural and human barriers to be crossed and the obligatory points if any. For example, in the case of a line meant primarily for passenger services in a corridor (which is the case with the subject semi high-speed line), the general direction and placement of the alignment will depend on how best to carry the line nearer to the likely densely populated core of the cities with minimum disturbance.
- Other important factors like cost of land acquisition and dislocation, and impact on the environment (forests and the wildlife, streams and other water bodies, fragile biospheres) also need to be carefully seen. In our casethe Forest and Wild life areas have not been included anywhere in in the alignment.
- The Engineer entrusted with the responsibility of preparing the preliminary alignment, has to start acquiring first hand knowledge of the ground conditions by visiting the critical sections and identify locations/regions that would be prone to landslides, flood, tidal waves and tsunamis, and other natural calamities. The alignment team has carried out several field inspections to assess ground conditions, population patterns and other features.

7.3 OPTIONS OF ALIGNMENT

After careful consideration of all relevant factors, possiblity of optimum alignment has been broadly identified: alignment along coastal area and an alignment passing through the lower piedmont (Mid Highlands). The salient features which has the mixed pros and cons of each of the locations as discussed in the table below:

ALIGNMENT IN COASTAL BELT	ALIGNMENT IN MID HIGHLANDS
We can have comparatively more stable ground with some water-logged areas. Can have backwaters and paddy fields needs to be avoided/negotiated favorably.	Uneven ground stability because of alternating sequence of hillocks and mounds and lowlands with deep deposits of alluvium. Laterite an altered material with several unfavorable engineering characteristics likely at depths of 10m to 30m in the region.

The alignment can be mostly on low height viaducts, embankments and cuttings.	The alignment may require high cuttings, high viaducts or tunnels. Alignment has to be designed carefully for economic design.
The alignment may neglect other suburban outlets	The alignment can serve other suburban outlets of the state

The due deligence has been taken in consultation with KRDCL to adopt the optimum alignment along Coastal area or through mid-highlands as per requirements of the project to serve the populated areas. The alignment at few locations have been close to the sea but at a distance of 200 m for 600 m length due to site constriants near existing Pallikkara Railway station . However, this can be reveiwed during DPR or execution stage. Other important aspects of this alignment are as under:

i. Near the sea coast the line has to be carried at a minimum elevation of 10m above the MSL. This will insulate the line from effects of any possible large tsunami waves. The Tsunami of the year 2004, which is believed to be one of the largest in recorded history of earth, wherein the highest waves were reported to be 3m to 5m.

ii. In proximity to the main beaches and area of fishing, the line will be carried on viaducts to minimize any adverse effects on the movement of people and their activities. The piers can be appropriately designed to merge with the landscape for better aesthetics to enhance the natural beauty of the beachfront. The alignment can be further refined at the DPR or execution stage to minimize any impact on the beaches and activities of the fishermen.

iii. To augment safety against high winds and flooding of the rivers and backwaters in the rainy season a network of automatic rainfall and wind monitoring system required to be provided. Automatic river water level recording system should also be required. Accumulated rainfall will be monitored by a precipitation gauge installed in each demarcated section of the line. When a threshold value is crossed train operations will be restricted or stopped. High winds are unlikely to require any imposition of speed restrictions.

In order to determine the feasibility of proposed semi high speed rail route, three alignment options have been studied. These alignment options are hereunder;

- *Option 1: Alignment all along (mostly) the existing railway line from Kasaragod to Tirur (222 Km approx.) and mostly through new areas from Tirur to Thiruvananthapuram (310 Km approx.).*
- *Option 2: Aligment entire along the existing railway line duly following the prevailing railway standards/parameters.*
- *Option 3: Alignment along the existing railway line but as per semi high speed standards/parameters.*

All three alignment options were studied in detail and found Option 2 & 3 are either technically not feasible or having tough challenges to meet the standards of semi high speed rail operations. Option 1 has been concluded as the best feasible alignment option considering the following technical reasons;

- *Desired speed @200 KMPH is possible.*
- *Least disturbance to railway structures/stations*
- *Minimum requirement of re-structuring of existing ROBs/RUBs.*
- *Passes through lesser congested stretches.*
- *Passes through lesser costly land areas such as wet land and paddy field areas for about 140 Kms out of total length of 532 Kms..*
- *Lesser number of buildings/structures would be affected as compared to other options.*
- *Construction would be easy and safer as compared to other alignment options.*

The salient features of the alignment are given in the Table below.

DETAILS OF THE ALIGNMENT	
Route Length: 531.45	
Type of structure	**Length (%age of route length)**
TUNNELS	2.430 Km (0.5%)
BRIDGES	12.045 Km(2.27%)
VIADUCTS	57.030Km (10.74%)
EMBANKMENTS	236.330Km (44.48%)
CUTTINGS	200.220 Km (37.69%)
CUT &COVER	23.415Km(4.40%)

The proposed alignment passes through the backwaters in 5 km, and about 70 km in paddy fields. In backwater stretches, the alignment is preferred to be carried on viaducts so that there is no hindrance to movement of boats, ferries etc. Total length of bridges to cross the rivers and waterways is 10 km.
To ensure the safety of the track from relative settlement of the ground due to likley low bearing capacity of ground, it is proposed to engage a DDC for emabankment design by taking due care of Geology, soil investigations of SHSR corridor to design and advice the best soultion for Ground stabilization to overcome the problem of low bearing capacity. Any cost if found additional and over than the provision kept in FR or DPR on this account will reqire to be specailly approved by the Govt.
To minimise the land requirement following strategies have ben adopted whreever possible:

i. Carry the line through the side of canals on viaducts with appropriate engineering solutions for stabilizing and strengthening the foundations of the viaducts.

7.3.1 Alignment Crossing of the existing Roads

It has been the basic principle of the alignment design of the project that adopted alignment is economical and safe. Accordingly, it has been the choice of the alignment designer to keep the height of the formation as minimum as possible subject to atleast 1m above the HFL of the area. Accordingly, at the minor roads low height (3.6m clearance) subways are considered. For the major roads (5.5m clearance) subways/ bridges are considered. Where ever feasible, the road locations has been crossed through RUBs to minimise the height of bank/ viaducts or depth of cuttings.

The provision of providing roads along the railway alignment more importantly in regions where there are no roads in the vicinity has been directed by KRDCL and Kerla Govt in a meeting on 16.04.19 and we may go for more land acquisition on this account for further development of the potential areas, which currently lie unexplored. Accordingly provision of 4m wide road has been kept whereever feasible. Cost on account of road however has not been charged to the project.

7.3.2 Geometric Design Norms

The geometrical design norms are based on international practices adopted for similar metro systems with standard gauge on the assumption that the maximum permissible speed on the section is limited to 80 km/h. Planning for any higher speed is not desirable as the ultimate average inter-station distances will be only about one Km and trains will not be able to achieve higher speed.

The standards adopted for horizontal and vertical alignments are as under:

7.3.2.1 HORIZONTAL ALIGNMENT

Abstract of important features based on the planning parameters given in the **Chapter 7 : Planning parameters** is as under which has been used for alignment design;

	Radius (Elevated Section)
Preferred:	1850 m and above
Minimum:	650 m on station approaches only

All stations are Kept On Straights:

Maximum permissible cant (Ca) : 160 mm

Maximum cant deficiency (Cd) : 100 mm for normal coaches and 240mm for tilting coaches

Maximum cant excess (Ce) : 100 mm (To be reviewed later when goods trains are introduced with their minimum speed in the section

7.3.2.2 Transition curves

Minimum length of Transitions of Horizontal curves in (m)as per EN Code is as under.
i)0.444 times actual cant in mm or
ii) 0.00555 times of Ca*Vm(Where Ca is the actual Cant & Vm is the designed speed) or
iii)0.0051 times of Cd* Vm(Where Cd is the actual Cant defficiency & Vm is the designed speed)
whichever is higher.
No overlap is allowed between transition curves
Minimum straight between two Transition curves: either 20 m or NIL.
Minimum curve length between two transition curves in the middle of curve also is 20 m

7.3.2.3 VERTICAL ALIGNMENT

Gradients adopted are on the basis of the planning parameters given in the **Chapter 6 : Planning parameters;**

7.3.2.4 Gradients

Normally the stations shall be on level stretch. In limiting cases station may be on a grade of 0.15 %. Between stations, generally the grades may not be steeper than 1.67 % (i.e. 1 in 60). In excaptional cases it can be 2%. However the steepest gradient adopted is 1.67 and this grade is compensated on curves.

7.3.2.5 Vertical Curves

Vertical curves are to be provided when change in gradient exceeds 0.2%. However it is recommended to provide vertical curves at every change of gradient.
Minimum radius of vertical curves adopted based on En formula 0.35 V*V (where 0.35 is a constant and' V' is the speed.
Exemptional limit for radius of vertical curve is R =0.13 V*V for hollow vertical curves and 0.16 V*V for the crest.
Accordingly the minimum radius is 14000 m with exemptional limit for hollow and crest vertical curves are 5200 m and 6400 m respectively.
However the minimum cuveture adopted for complete section is 14000 m.
Minimum length of vertical curve required as per En code is 20 m and the same is adopted throughout.

7.4 STATION AND DEPOT LOCATIONS

The station locations are based on the obligatory points provided by KRDCL. Stations and depot locations on the alignment are shown in the table given below:

Table 85: PROPOSED STATION LOCATIONS

SL NO	STATION NAME	LATITUDE	LONGITUDE	CHAINAGE IN M	INTER-STATION DISTANCE In Km
1	Thiruvananthapuram At Kochuveli	8°30'44.88"N	76°53'52.43"E	600	0.600
2	Kollam	8°53'40.55"N	76°39'27.09"E	55600	55.000
3a	Chengannur	9°20'19.39"N	76°38'39.02"E	109300	53.700
3b	Chengannur-Optional	9°18'15.95"N	76°38'19.74"E	105532 (approx.)	-
4a	Kottayam	9°37'24.15"N	76°33'54.23"E	142800	33.500
4b	Kottayam-Optional	9°34'34.27"N	76°32'18.04"E	137800 (approx.)	-
5	Ernakulam	10°00'39.84"N	76°22'33.47"E	195500	52.700
6	Thrissur	10°30'34.39"N	76°12'20.59"E	259600	64.100

SL NO	STATION NAME	LATITUDE	LONGITUDE	CHAINAGE IN M	INTER-STATION DISTANCE In Km
7	Tirur	10°55'3.75"N	75°55'18.25"E	317050	57.450
8	Kozhikode	11°14'45.53"N	75°45'35.17"E	358000	40.950
9	Kannur	11°52'56.73"N	75°21'47.30"E	448773	90.773
10	Kasaragod	12°29'28.37"N	74°59'15.57"E	530890	82.117
	Depot Locations				
1	Thiruvanathapuram Depot at Kochuveli	8°30'44.72"N	76°53'52.03"E	0	0
2	Kasaragod Depot	12°29'21.51"N	74°59'8.45"E	530890	530.890

7.5 DESCRIPTION OF THE PROPOSED ALIGNMENT

The alignment for SHSR line has been planned keeping all the constraints of the region in the mind as discussed in this chapter. Even then at few locations, it has become necessary to have more than one option for the proposed alignment. It has been discussed hereunder in subsequent paragraphs.

Finding a way to carry a new railway line to the city center or as close to it as possible such that the city population can reach station in a short distance, has been often the most difficult part of preparing alignment. Considering all the factors as discussed above, proposed alignment going through the obligatory locations is as under;

The alignment starts from Station Thiruvananthapuram and passes through Stations Kollam,Chengannur,Kottayam,Ernakulam,Thrissur,Tirur,Kozhikkod,Kannur and terminates at Kasaragod Station.

The alignment passes through the following districts such as Thiruvanandapuram,Kollam, alappuzha,Pathanamthitta,Kottayam,Ernakulam, Thrissur,Malappuram,Kozhikkod, Kannur and Kasaragod.It passes through through the existing Railway Stations adjacent to at Thiruvananthapuram (At Kochuveli), Thrissur,Tirur Kozhikkod and Kasaragod for integration with Indian Railway Stations. Other stations Kollam,Chengannur,Kottayam and Ernakulam passes at a distances of 6719m,4530m,4850m and 10388m respectively. At Kannur the Station is adjacent to the existing railway line but is at a distanceof 1377 m away from existing station.

The alignment also passes parallal to Indian Railway existing lines between chainages 310.206-386.907, 410.270-417.573 and 440.373-531.408 between existing Thirunavaya and Kasaragod Stations.

The details of alignment through the main cities and station locations is given in para 1.4 of Chapter 1: Executive Summary.

There are 7 Religious Structures and 4 high raised building infringing the the present proposed alignment. The possibilities of shifting the alignment at these locations will be explored at the DPR stage.

It is proposed to connect the Thiruvananthapuram air port with a single track and an aggregate station at airport as shown in attached Index Map as optional. If airport Authorities permits it can be incuded in the DPR stage. The total length involved is 4.351 Km. For arriving the cost this length has not been included at this stage.

Another Proposal to connect International air port at Kochi also has been shown as optional in the Index map attached below. It starts from chainage 195.000 and ends at chainage 229.250. Possibilites of connecting this airport will be explored at the time of DPR. Other two airports are far away from the alignment and hence no proposal have been made to connect them.

One more propoposal to bring the present proposed Chengannur and Kottayam Stations near to city center between chainage 89.800 and ends at chainage145.300 is being explored and is shown as optional. However this will also be explored at the time of DPR.

The total lenth of the line is 531.45 Km. An index map showing the route, Stations and optional lines is attached below for ready referance.

The detailed horizontal profile, vertical profile, curve details, station locations, etc. for proposed alignment are shown in the separate volume of this Feasibility Report as "Annexure-Drawings".

ROUTE MAP FOR THE THIRUVANANTHAPURAM-KASARAGOD SEMI HIGH SPEED RAIL CORRIDOR

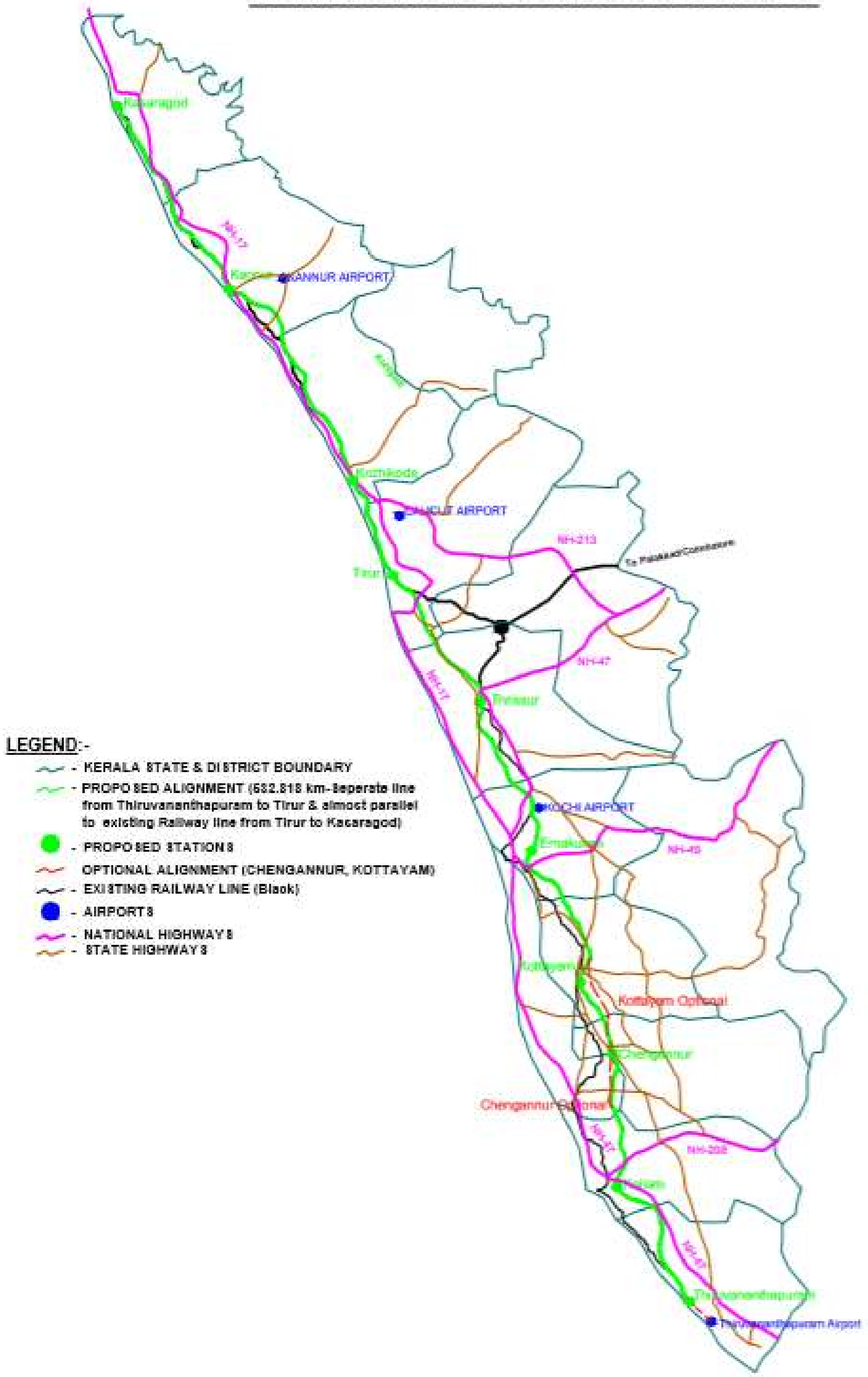


Figure 64: Route Map for Thiruvananthapuram Kasaragod Semi High Speed Line

8. TRAIN OPERATION MAINTENANCE AND SAFETY

8.1 Introduction

This summary provides background information on the intended service and operations of the proposed Trivandrum - Kasaragod Semi High Speed Rail (SHSR) System to provide sufficient detail for the planning of proposed SHSR Train operations. Recognizing that the system is still at a relatively early stage of the planning process, and that many operational issues remain to be resolved, this section summarizes how the system is envisioned to operate at this point in project planning.

The SHSR System will cover 531.45 route-kilometres and service is planned to start in 2024, beginning in Trivandrum, running through Kochi, Thrissur, Kozhikode, Kannur and traveling north to Kasaragod. The phasing of the project is yet to be finalized.

Proven train technologies similar to those used in other countries with established high-speed train systems (for example: Japan, France, Germany, Great Britain, Spain, Korea and China) will be used. This technology includes steel-wheel-on-steel-rail, entirely electric power, state-of-the-art safety and signalling systems, and automated train control. This technology, although new to India in mainline operation, was introduced in Japan in 1964, France in 1981, and in many other countries within the past two decades.

The SHSR will operate primarily on exclusive (dedicated) track with provision to share the route with other passenger or freight rail operations, if found feasible. The route (alignment) will be constructed either at-grade, in an open trench, in a tunnel, or on an elevated guideway, depending on the terrain, physical constraints, environmental impacts and community input along each section. The system will predominately be within, or adjacent to, existing rail or highway right-of-way to reduce potential environmental impacts and minimize land acquisition, wherever possible.

8.2 Service Plan Overview

8.2.1 Service Plan (2024)

The full build-out of the SHSR System is expected to be ready for the operation of revenue service in 2024. The full build system will provide semi high speed train service to passengers from Trivandrum to Kasaragod with 13 intermediate stops including Kollam, Kochi, Kozhikode and Kannur among others.

The list of stations identified at this stage is provided in table hereunder:

Table 86: Stations with Chainage

S.NO.	STATION NAME	CHAINAGE
1	THIRUVANANTHAPURAM	600
2	KOLLAM	55600
3	CHENGANNUR	109300
4	KOTTAYAM	142800

S.NO.	STATION NAME	CHAINAGE
5	ERNAKULAM	195500
6	THRISSUR	259600
7	TIRRUR	317050
8	KOZHIKODU	358000
9	KANNUR	448773
10	KASARGOD	530890

A portion of the new dedicated high-speed track may be built early and used for testing and commissioning of the high-speed trainsets as they are received from the manufacturer. In addition, early revenue service over a portion (or portions) of the line may be planned, once sufficient trainsets have been commissioned and are ready for service. Detailed service and operations planning for these interim stages has not yet been undertaken.

The corridor is proposed to be designed to be operable as a permanent, stand-alone system. While estimated to be operational by 2024, the section may be opened in stages and the extensions to operational part of line could be added to the network subsequently as corresponding sections are completed.

8.3 Service Plans

Concept level rail operations and service plan has been developed to serve several purposes:

- Confirm the level of service assumptions (travel times and service frequencies between station pairs) used to develop the estimates of system ridership and revenue
- Validate the operational feasibility of the desired level of service at a conceptual level
- Identify operable patterns of train service, particularly the general requirements for non-stop or limited-stop trains to pass slower trains that need to make a greater number of (local) stops along the route (i.e., the locations and frequencies of occurrence of these "overtakes" at various times of day)
- Provide a basis for an order of magnitude estimate of the number of train sets and overall rolling stock fleet requirements for the full corridor
- Provide a basis for estimating platform track and storage track capacity to support operations at the end and intermediate terminal stations
- Provide a basis for sizing train storage and maintenance facilities throughout the SHSR System.
- Provide a basis for planning passenger-handling operations at SHSR stations, which can be used to help size and configure station facilities.

The SHSR System ridership estimates are used in developing the operations and service plans so the level of service that would be provided at each station is generally equivalent to the level of service assumed in developing the ridership and revenue estimates for the SHSR System. Ridership demand is assumed to reach peak levels during a three-hour period in the morning and again in the afternoon. Train service density would be greatest during these periods, reverting to a slightly lower level of service during the remainder of the day.

Currently, slightly more service is assumed during the three hour peak periods in the morning and late afternoon than during off-peak hours, consistent with expected ridership peaking. However, it will be further refined as traffic pattern is made clear in final traffic study reports.

Trains would run in diverse patterns between various terminals. The basic service types are envisioned:

- **Limited-stop trains, which would skip selected stops along a route to provide faster service between stations.**
- **Frequent-stop trains, which would focus on regional service.**
- **Aggregator services which may have additional intermediate temporary stops between two SHSR stations to facilitate more and more people to access the service and avail high speed service from SHSR stations. Its implementation needs to be further examined and refined at DPR stage.**
- **RORO service at night for Truck/ heavy vehicles/ light vehicles to utilize infrastructure to the maximum.**

Most of the passenger trains would provide limited-stop services and offer a relatively fast run time along with connectivity among various intermediate stations. Multiple limited-stop patterns would be provided, to achieve a balanced level of service at the intermediate stations. The service plan envisions at least one limited stop train per hour in each direction, all day long throughout the line. However, in main high demand section between Trivandrum and Kozhikode, passenger service will be available at 30 minutes initially and lower frequency in later years of the project life.

These service plans provide a useful initial estimate of the level of service that matches projected long-range demand on the SHSR System. As the SHSR System is implemented and both the operating plan and the ridership estimates are refined, it will be possible to make informed benefit and cost trade-offs to develop the most appropriate mix of limited and all-stop services, which will affect the trip times between stations and the frequency of service offered at each station for each route.

The estimated traffic figures do not include the commuter passenger count. Therefore, the requirement of trains is considered only for long distance journey passengers based on seating capacity of the trains which is considered approximately 75 seats per car. However, additional capacity is provided in the form of trains for aggregator service which can also account for commuters.

There is also provision for operation for Tourist circuit trains whenever planned for operation. Tourist circuit trains are special trains, with additional leisure facilities operated at premium prices for tourists, similar to Indian Railways.

8.3.1 Horizon Year (2024)

Initial revenue service is expected to begin in 2024 with bare minimum requirement of 24 trains of 9-car each.

Figure below presents the estimated level of train service along various SHSR sections that is required to deliver the appropriate choices of train stopping patterns to riders at all stations and satisfy the projected daily ridership demand in year 2024.

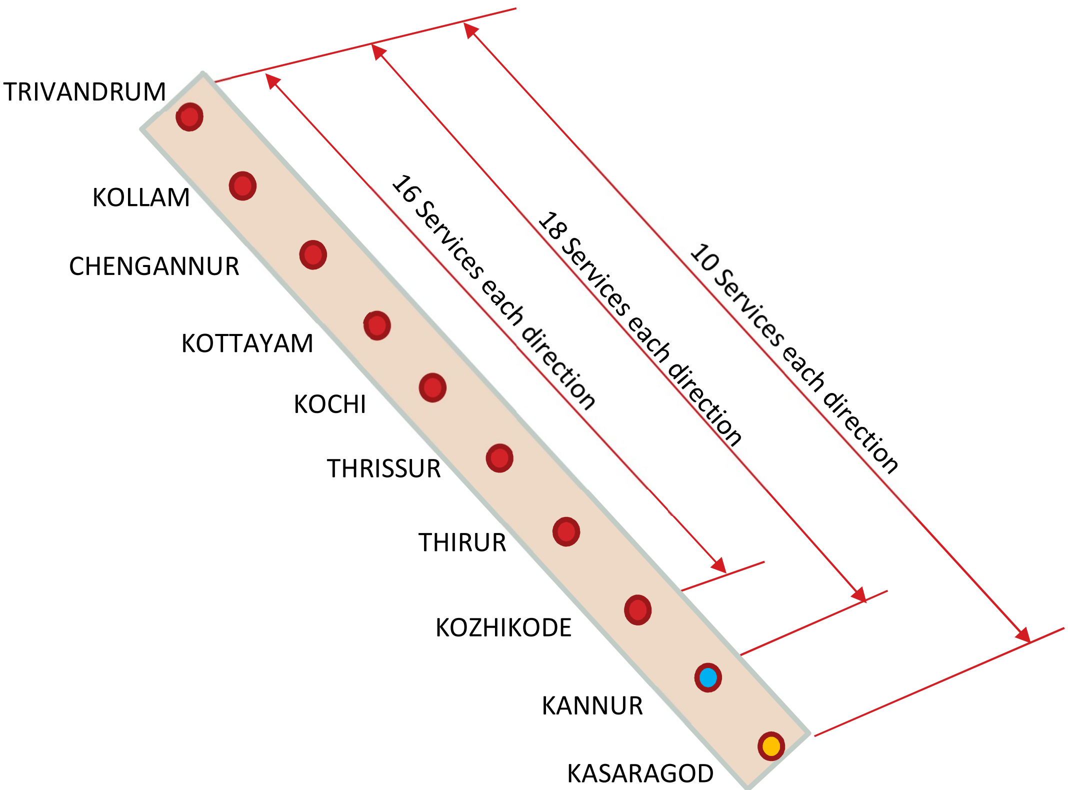


Figure 65: Year 2024 Service Plan – Daily Train Service Density

This service plan concept estimates that 10 services will run from Trivandrum-Kasaragod per direction each day. Similarly, 18 services each will run between Trivandrum and Kannur each direction per hour and 16 services each will run between Trivandrum and Kozhikode each direction per hour.

However, Hourly Trip distribution can be adapted as per traffic demand peak and lean periods. Peak hour minimum headway required is estimated to be 22.5 minutes for year 2024.

The Trip distribution shall be further optimized based on actual traffic pattern and stabling facilities provided accordingly at intermediate stations.

8.3.2 Horizon Year (2028)

Initial revenue service is expected to begin in 2028 with bare minimum requirement of 30 trains of 9-car each.

Figure hereunder presents the estimated level of train service along various SHSR sections that is required to deliver the appropriate choices of train stopping patterns to riders at all stations and satisfy the projected daily ridership demand in year 2028.

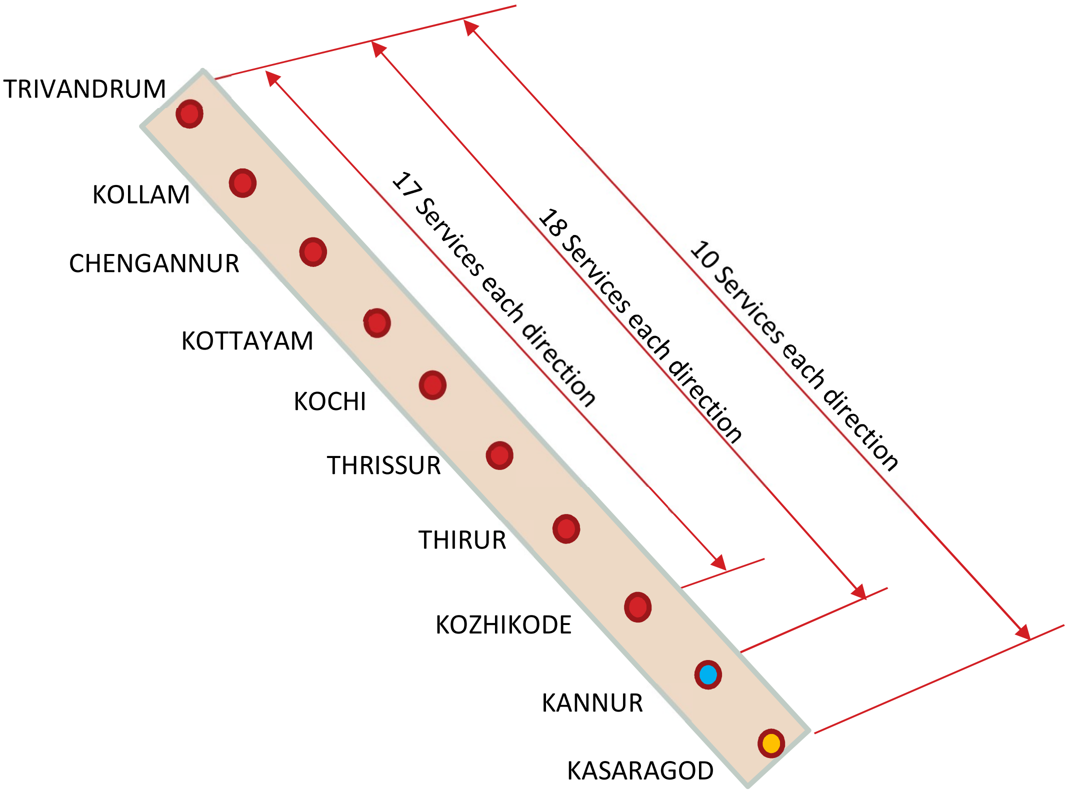


Figure 66: Year 2024 Service Plan – Daily Train Service Density

This service plan concept estimates that 10 services will run from Trivandrum-Kasaragod per direction each day. Similarly, 17 services each will run between Trivandrum and Kannur each direction per hour and 10 services each will run between Trivandrum and Kozhikode each direction per hour.

However, Hourly Trip distribution can be adapted as per traffic demand peak and lean periods. Peak hour minimum headway required is estimated to be 18 minutes for year 2028.

The Trip distribution shall be further optimized based on actual traffic pattern and stabling facilities provided accordingly at intermediate stations.

8.3.3 Horizon Year (2040)

In year 2040, minimum 48 services each direction per day are planned with a bare minimum requirement of 32 trains of 12-car each.

Figure below presents the estimated level of daily train service along various SHSR sections that is required to deliver the appropriate choices of train stopping patterns to riders at all stations and satisfy the projected daily ridership demand in the horizon year of 2040.

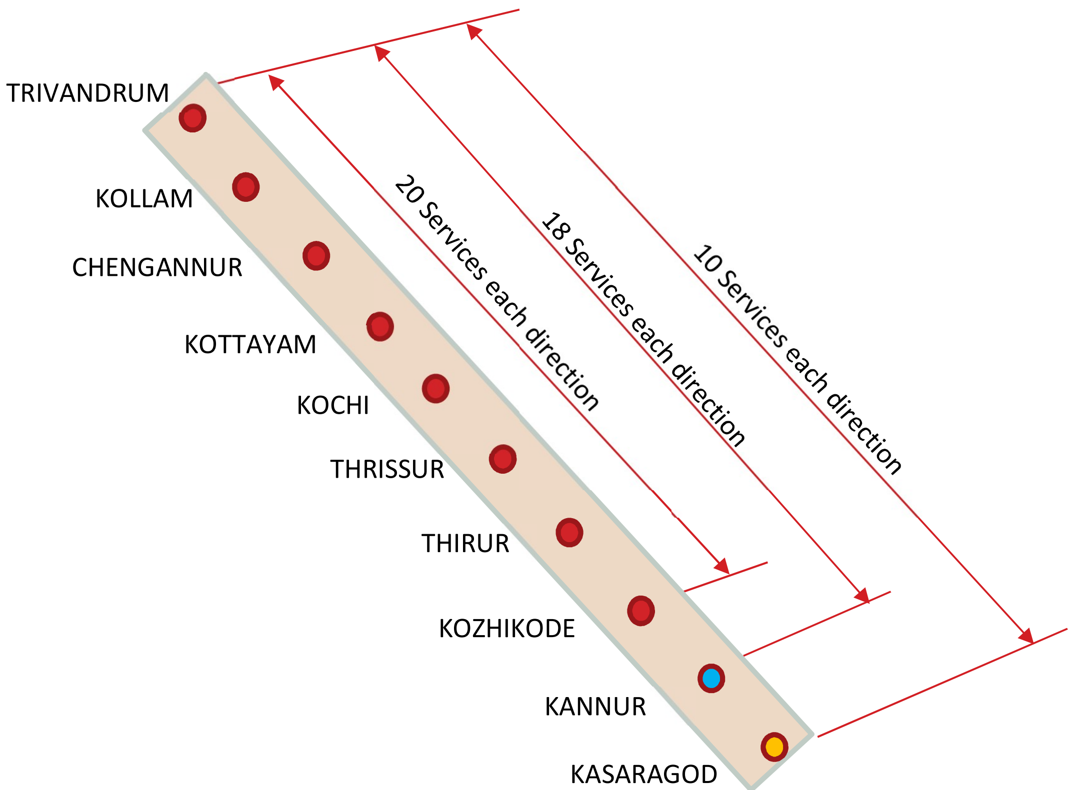


Figure 67: Year 2040 Service Plan -- Daily Train Service Density

This service plan concept estimates that 10 services will run from Trivandrum-Kasaragod per direction each day. Similarly, 18 services each will run between Trivandrum and Kannur, and 20 services will run between Trivandrum and Kozhikode each direction per day. Effective no. of daily services per direction between Trivandrum and Kozhikode, Kozhikode and Kannur, and Kannur and Kasaragod will be 48, 38 and 10 respectively.
However, Hourly Trip distribution can be adapted as per traffic demand peak and lean periods. Peak hour minimum headway required is estimated to be 17 minutes for year 2040.

8.3.4 Horizon Year (2051)

In year 2051, minimum 61 services each direction per day are planned with a bare minimum requirement of 40 trains of 12-car each.

Figure below presents the estimated level of train service along various SHSR sections that is required to deliver the appropriate choices of train stopping patterns to riders at all stations and satisfy the projected daily ridership demand in the horizon year of 2051.

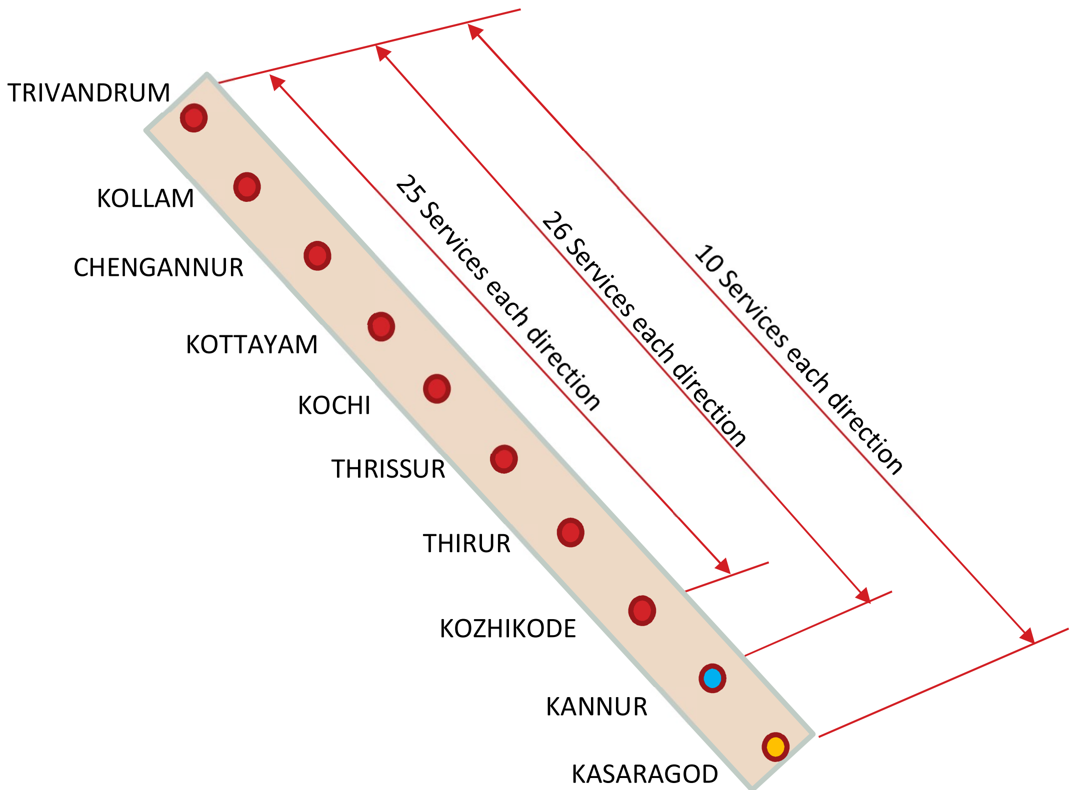


Figure 68: Year 2051 Service Plan – Daily Train Service Density

This service plan concept estimates that 10 services will run from Trivandrum-Kasaragod per direction each day. Similarly, 26 services each will run between Trivandrum and Kannur, and 25 services will run between Trivandrum and Kozhikode each direction per day. Effective no. of daily services per direction between Trivandrum and Kozhikode, Kozhikode and Kannur, and Kannur and Kasaragod will be 61, 36 and 10 respectively.

However, Hourly Trip distribution can be adapted as per traffic demand peak and lean periods. Peak hour minimum headway required is estimated to be 13 minutes for year 2051.

8.4 Passenger Station Operations

The service plan encompasses 10 passenger stations. Along with main Terminal stations Trivandrum and Kasaragod at each end of the SHSR corridor, Kochi, Kozhikode and Kannur are also planned as intermediate Terminal stations. Rest of the stations may be considered as intermediate stations.

Station platforms are assumed to be long enough to accommodate trains with 12 -car length which can be augmented up to 15 car train length. While 12-car platform length is enough till 2051 as per traffic demand estimates, platforms may be made up to 15-car length for future requirements.

8.4.1 Intermediate Stations and Platform Tracks

All the intermediate stations in the exclusive, dedicated sections of the semi high speed system incorporate platform tracks for stopping trains.

High volume stations such as Kochi, Thrissur, Tirur, Kozhikode and Kannur stations are to be designed both as terminal station and intermediate station with special layout that incorporates intermediate and terminal station features.

8.4.2 Terminal Stations

Terminal stations are envisioned to have island platforms serving tracks on both sides and be able to accommodate train cleaning, restocking with on board food service, mandatory train inspection and as-needed maintenance and repair of trainset components – along with the alighting and boarding of passengers. The track and platform configurations at terminal stations vary based on the level of projected train service, local physical constraints, and requirements for other (non-SHSR) train services that would be located adjacent to the SHSR facilities, if such plan is confirmed.

8.4.2.1 Passenger Boarding

There are several different ways in which passenger boarding could be managed at SHSR terminal stations. The SHSR project has not finalized the preferred methods for passenger-handling system wide, and the SHSR sponsors and operator likely will want consistent passenger handling practices across the entire system. Passenger-handling requirements affect the design and configuration of the physical facilities used for passenger-processing, waiting, queuing and horizontal and vertical circulation.

Examples of potential variations in passenger-handling procedures and required facilities encompass the following:

Advance staging of boarding passengers

- Retain all boarding passengers at concourse level until cleaning/servicing is substantially complete and the train is ready for boarding

- Permit boarding passengers to descend to platform level as soon as the load of detraining passengers has cleared the platform (passengers and service personnel and equipment would occupy the platform level simultaneously)

Reserved seat policy

- Open seating, where passengers select the car that they will board
- Reserved seating (similar to most European and Asian high-speed rail systems), where passengers are assigned to a seat in a particular car, and where the time required to board the train can be minimized by pre-positioning passengers either on the platform or at concourse level close to where their seat will be located.

These options have differing implications in terms of required facilities, the configuration of concourse and vertical circulation elements, and the station operating costs associated with managing the boarding process.

8.4.2.2 Train Cleaning and Servicing

At terminal stations, train servicing would be done using the passenger platforms or dedicated sidings as per requirement. To maximize passenger safety, servicing operations efficiency, and achieve predictable layover (train parking) times, normal operating procedures would plan for providing temporal separation between the passenger unloading and loading processes and train servicing activities at the terminal platforms.

To attract and keep a dedicated passenger clientele it is important to establish and maintain a cleanliness standard aboard the train consists. This service is accomplished by cleaning techniques implemented at selected times in a service day. Two types of cleaning are envisaged.

- "Normal" (Lay-up) Cleaning – This service is performed at a train storage and maintenance facility, and is generally done when a train is parked for a sufficient time to receive a thorough interior cleaning of the passenger areas to include seats and bathrooms. It is usually scheduled daily and is completed prior to a train entering revenue service in the morning. All trash is removed, seats and floors cleaned, and bathrooms sanitized.
- "Light" (Pick-up) Cleaning – When a train turns around (i.e. the rear end of the train arriving at the station becomes the front end of the train departing) in a terminal station or on a storage track with insufficient opportunity for a full normal cleaning, this service is performed to return the interior to an acceptable condition.

Cleaning toilets (and emptying the "holding" tanks) would occur during the overnight layup period at maintenance facilities or sidings and would not be done in the terminals during the turnaround time.

8.4.2.3 Train Layover Times at Terminal

Because the terminals are stub-ended, all SHSR trains will change directions (turnaround with rear end of the arriving train becoming the front end of the departing train) at terminal stations. Three types of train turnaround will occur in terminal stations:

- Revenue to Non-Revenue: Revenue trains (with passengers) arrive, with the equipment turning around and going to the rail depot for storage or servicing, without passengers
- Non-Revenue to Revenue: Trains enter the terminal from the rail depot (without passengers), departing passengers board (the train), and the train departs as a revenue train (with passengers)
- Revenue to Revenue: Revenue trains (with passengers) arrive and passengers unload, the train would park at the platform while it is inspected, cleaned and restocked with bathroom and food service supplies, departing passengers board the train, and the train departs as a revenue train (with passengers).

Estimating the time required to carry out the various terminal turnaround train servicing and passenger processing functions, and identifying which functions can proceed in parallel with each other and which depend upon the prior completion of other activities, allows definition of a "critical path" of activities that governs the minimum time necessary between an inbound train arrival and the subsequent outbound train departure. The required sequence of steps that must be followed for four basic processes that occur during the turnaround layover period are as follows:

- Passenger alighting and boarding
- Re-stocking of food and beverage service items
- Coach cleaning and re-stocking of bathroom supplies (critical path item)
- Train safety system pre-departure preparation
- In addition, minor equipment repairs that can be accomplished during the layover (parking) period will be addressed.

Facilities would need to be provided at the terminals to support the food service provisioning (commissary), coach cleaning and railroad mechanical department (equipment maintenance and repair). These facilities would need to be located in proximity to the SHSR platforms, to minimize the time required to access a train when it arrives at the terminal. Dedicated access would be required between these facilities and the SHSR platforms, separate from the elevators and access points used by passengers.

The SHSR scheduled terminal station turnaround time is composed of four primary "critical path" factors: Passenger alighting, interior cleaning, passenger boarding, and a "Recovery Time Factor."

The following table summarizes SHSR assumptions for the minimum exception and minimum standard scheduled turnaround times.

Table 87: Time Required for Terminal Layover Activities (SHSR Planning Assumptions, Revenue Train to Revenue Train)

CRITICAL PATH ACTIVITY	MINIMUM EXCEPTION	MINIMUM STANDARD
Passenger Alighting	5 minutes	5 minutes
Cleaning, Restocking, Servicing, Provisioning	10 minutes	15 minutes
Passenger Boarding Window (Includes up to 5 min. 'Recovery Time' Factor	10 minutes	10 minutes
Total Scheduled Turnaround Time Assumption	25 minutes	30 minutes

Note: Train safety system preparations can be accommodated within time windows available for alighting, cleaning and boarding.

Providing a scheduled 10-minute "window" for passenger boarding would permit train cleaning and servicing functions to be concluded prior to the start of the boarding process and minimizes the time spent queuing by departing passengers while also providing for a necessary allowance of up to five minutes of "recovery time" for trains arriving later than scheduled in the timetable.

8.5 Rolling Stock Storage and Maintenance

8.5.1 Fleet Requirements

Fleet requirement is estimated based on the operation planning described in above sections. Table 88 lists the required fleet for horizon years.

Table 88: Horizon Year 2024-2051 Service Plan Revenue Train Sets Required at Each Terminal to Start Weekday Morning Train Service

TERMINAL	2024	2028	2040	2051
Train Consist	9-Car	9-Car	12-Car	12-Car
Bare Minimum Trains	21	26	28	35
Maintenance Reserve	2	3	3	4
Operation reserve	1	1	1	1
Bare Minimum Cars required	**189**	**234**	**336**	**420**
Total Cars required	**216**	**270**	**384**	**480**

The Horizon Year 2051 operations and service plan envisions the need for 35 trains in revenue service. The estimated requirement is indicated in the Table above along with an allowance for spare train sets, resulting in an overall fleet estimate of 40 no. of 12-car trains. The 10% spares is the mid-range of spare ratios for international intercity and high-speed rail fleets. The estimated fleet requirement numbers will be modified as the operating plan, demand projections, and maintenance plans are refined.

8.5.2 Running KM

Given the number of trips planned to provide service at SHSR, the train running kilometres are projected in the table hereunder.

Table 89: Train Running Kilometres

Section	2024			2028			2040			2051		
	No. of Trips	Daily Train KM ($x10^3$)	Daily Car KM ($x10^6$)	No. of Trips	Daily Train KM ($x10^3$)	Daily Car KM ($x10^6$)	No. of Trips	Daily Train KM ($x10^3$)	Daily Car KM ($x10^6$)	No. of Trips	Daily Train KM ($x10^3$)	Daily Car KM ($x10^6$)
Trivandrum-Kozhikode	28	10.0	0.12	34	12.2	0.15	40	14.3	0.17	50.0	17.9	0.21
Trivandrum-Kannur	24	10.8	0.13	36	16.1	0.19	36	16.1	0.19	52.0	23.3	0.28
Trivandrum-Kasaragod	20	10.6	0.10	20	10.6	0.10	20	10.6	0.10	20.0	10.6	0.10
Total/ year	**26280**	**11450**	**125.78**	**32850**	**14195**	**158.7**	**35040**	**14978**	**168.1**	**44530**	**18900**	**215.2**

8.5.3 Train Storage and Maintenance Facilities

Train storage depot facilities are generally preferred to be located as close as physically possible to the terminal stations.

The overnight layup facilities are the basic facility at each of the terminal locations that provide overnight storage (parking) for the trainsets and daily inspections and cleaning. Layup facilities would be located close to the intermediate terminals in Kochi, Thrissur, Tirur and Kozhikode. Depots including a periodic inspection facility (shop) would be located in Kasaragod but without shop facility. One heavy maintenance facility will be located in Trivandrum to provide all of the overhauls and component refurbishment capability.

The storage capacity of each facility is based on the number of trains estimated in design year Operations and Service Plan and is summarized in Table below.

Table 90: Storage/ Layup Track (Sidings) Requirements at stations

LOCATION	NUMBER OF TRACKS (15-CAR STORAGE)	TRACKS FOR RORO SERVICE
Trivandrum	4 nos.	Yes
Kochi	2 nos.	Yes
Thrissur	4 nos.	
Tirur	2 nos.	
Kozhikode	2 nos.	
Kasaragod	4 nos.	Yes

Table 91: Storage/ Layup Track (Sidings) Requirements at Depot

LOCATION	NUMBER OF TRACKS (15-CAR STORAGE)		
	STABLING	INSPECTION	WORKSHOP
Trivandrum Depot	10 nos.	4 nos.	6 nos.
Kasaragod Depot	15 nos.	4 nos.	0 nos.

8.5.4 Rolling Stock Maintenance Program

Consistent with international methods, the Semi high-speed train system is planned to provide 5 different levels of train maintenance activity:

- Level 1 – In-Service Monitoring: daily testing and diagnostics of certain safety sensitive apparatus on the train in addition to automatic on-board and on-ground monitoring devices.
- Level 2 – In-Service Examinations: inspections, tests, verifications and “quick” replacement of certain components on the train. Examples include inspection and maintenance tasks associated with the train’s running gear, bogies, underbody elements and pantographs.
- Level 3 – Periodic Inspections: part of a planned preventive maintenance program requiring specialized equipment and facilities. Examples include: a) examination of interior fittings and all parts of the train in the immediate environment of the passengers, b) in depth inspection of axles and underbody components, critical to train safety by identifying and repairing any condition in

the running gear and connecting components, c) wheel condition diagnostics and re-profiling (wheel truing).

- Level 4 – Overhauls (HMF only): part of the planned life cycle maintenance program requiring a specialized heavy maintenance shop with specific heavy duty equipment. Activities include the complete overhaul of train components replaced during Level I, II and III. In addition, a full complement of heavy maintenance is completed on each trainset every 7 to 10 years (30 days per trainset) as well as mid-life overhauls which are performed on each trainset every 15 to 20 years (45 days per train-set).
- Level 5 – Rolling Stock Modifications & Accident Repair (HMF only): Activities to support installation of a major modification to the design of the trainset for purposes of improving safety, reliability and passenger comfort. In addition, this category includes repair to a trainset which has "suffered" significant damage.

The frequency with which these maintenance procedures are performed varies by level. To minimize cost, maximize flexibility and to address all of the levels of maintenance and inspections, these maintenance functions will be undertaken at Trivandrum Depot facility. The locations at which maintenance will occur can be broken into three groups:

- Overnight Layup Facility – Provides Levels 1 and 2 maintenance and inspections
- Periodic Inspection Facility – Provides Levels 1 to 3 maintenance and inspections
- Heavy Maintenance Facility – Provides Levels 1 to 5 maintenance and inspection, including overhauls and component refurbishment.

8.5.5 Commissioning of Rolling Stock

In addition to the in-service maintenance regimen, the HMF is assumed to be used during the pre-revenue service period (from 2023) for the assembly, testing, acceptance, and commissioning of the SHSR System new rolling stock fleet. Implementation of the testing, acceptance and commissioning activity would also require a main line test track between 100 and 150 kilometres in length connected directly to the HMF. The HMF would also be used for decommissioning or retirement of equipment from the system to make way for the next generation of rolling stock.

8.6 Train Dispatching and Control

8.6.1 Operations Control Centre

A train operations control centre has been planned within the HMF "compound" at Trivandrum Depot. Space for employee parking, pedestrian access/egress and other appropriate facilities is accounted for. The location of OCC may be planned over maintenance facility to avoid additional space in the depot.

8.6.2 Communications with SHSR Stations

SHSR trains will be dispatched and controlled from a central control facility remote from the individual stations and terminals. A direct communications link will exist between the central control facility and the Terminal Operations Centre or SHSR Passenger Services office at each SHSR station and terminal, to enable station staff of the SHSR System Operator (and the Terminal Operator, at facilities where the terminal is managed by a third party) to monitor the status of train operations on the rail network and respond to any unusual conditions that may arise.

8.7 O&M organization

The most important consideration for deciding the Operation and maintenance management structure for SHSR should be safety from day one. Management organization therefore should be firm and solid to prioritise safety and other aspect.
Railways being a complex system, it is extremely important to establish an organization to enable cooperation and cohesion among different sections of the organization
An independent SHSR management organization shall directly control the services at including work-site organizations, with train operation and infrastructure maintenance that are inseparable therefrom, shall never be separated but be controlled and executed under the same umbrella.

8.8 Organization for Safety and Disaster Measures

In a SHSR, Safety organization shall (1) comprehensively plan and implement safety measures from day one and (2) be independent of other divisions and positioned close to the top in order to facilitate smooth coordination between different divisions.

Initially, services shall be executed in principle by the organization itself, though there may be some to be outsourced after critical examination of the safety aspects of train operation and safety of passengers and staff. Later on, outsourcing of services may be planned and executed with a safety system established inhouse as well as outsourced service operators.

8.9 Organization for Operations & Maintenance

The Railway Operations & Maintenance department consists of (1) operation, (2) rolling stock, (3) civil engineering and (4) electrical engineering. These four divisions are thought to be an inseparable and closely-linked organization with OCC at the center including support of logistics services thereof.

8.9.1 Marketing Division

A marketing division shall be set up to secure non-fare box income and to advise on fare structure and service promotions.

8.9.2 Other Divisions

- Organization of training and education
- Materials procurement division
- Operation control centre (OCC)
- IT system
- Security measures
- Vigilance organization

8.10 Maintenance management

8.10.1 Introduction

To maintain the assets of the SHSR a maintenance organization has to be set up and facilities for maintenance have to be created. Having said this, an overall strategy for maintenance of assets is to be developed. The strategy will depend to a large extent on the maintenance needs specified by the supplier of the equipment that is purchased and the contractual terms of the purchase – whether maintenance by the supplier will be a part of the contract, what will be the free warranty replacement period etc. it will also depend on the plan for outsourcing some of the maintenance work. Therefore a detailed maintenance plan cannot be made at this stage. However the key issues and the broad principles for maintenance can be decided and these are discussed in the following sections.

The key aspects of maintenance management are described in the following sections.

8.10.2 Maintenance Strategy

The SHSR is expected to be operated heavily leaving very little time for maintenance. Most of the maintenance work has to be done at night when there is no train service or only slow trains are running. Therefore a strategy has to be adopted that will fulfil the maintenance and safety needs of the system and its assets.

8.10.2.1 Key Trends

Certain key aspects are noteworthy in the maintenance of a modern, Semi-High Speed railway system. These include:

- Preventative approach rather than a reactive approach leading to intensive asset monitoring including comprehensive asset condition data and fault recording.
- Emphasis upon mechanized maintenance to increase productivity and efficiency.
- Holistic approach considering rail assets as an integrated system over the life of the assets.
- Coordinated operation and maintenance of the infrastructure with train operations to optimize infrastructure capacity and efficiency.

In view of above aspects, operations and maintenance plan for SHSR shall:

- Emphasise mechanized maintenance as compared to traditional manual labour based maintenance.
- Emphasise on asset condition monitoring.
- Deploy higher proportion of skilled staff and less of unskilled staff.
- Deploy multi-skilled staff.
- May use road vehicles for maintenance work to avoid disruption to train movements.
- Maintenance for crucial and safety related items–P Way, OHLE, Rolling Stock and Signal equipment recommended to be in-house. Some of ancillary items may be outsourced.

8.10.3 Maintenance Philosophy

The maintenance practices for the SHSR must follow the best international practices, suitably modified for Indian local conditions and constraints of the SHSR. The methodology of maintenance procedures and processes will very much be dependent on the item of equipment. It is envisaged that several differing styles will be employed, such as;

• Time / periodic based or sequenced

• Condition monitored / appraised / assessed

• Reactive or corrective

The type of maintenance activity will vary from visual, detailed inspection, instrument measuring, lubrication, cleaning out, adjustment, servicing, component replacement to equipment renewal, these activities could be categorized into either light maintenance or heavy maintenance activities and the responsibility for carrying them out could be assigned to differing groups of people. Some activities may be undertaken by the user, such as visually checking for, damage, correct assembly and even the replacement of certain items such as defective lamps. Other activities could be undertaken by general staff members such as cleaners or station personnel such as visual inspection for abnormalities or the observation of warning lights or alarm messages, some cleaning out activities could also be undertaken by these less skilled persons. A large proportion of the maintenance activities will need to be undertaken by skilled, trained personnel. These could be in house employees or else contracted service engineers.

8.10.4 Asset Management Plan

An Asset Management Plan for the SHSR will be prepared. This is a plan to maintain, operate and upgrade if required, the physical assets of the SHSR cost-effectively. Asset policies form the cornerstone of an effective strategy, providing the pivotal link between strategy for meeting stake holder's or statutory requirements and manage asset base. Assets are designed, constructed, inspected, maintained and replaced in accordance with these policies. Asset management plan is a systematic goal and performance-driven management and decision-making process of operating, maintaining and upgrading transportation assets cost effectively.

8.10.5 Asset Management Policy

Asset management policy, along with the asset policies for sub systems, should be framed by the SHSR to cover the full life cycle management of physical assets from design, construction, operation, inspection and maintenance to take decision for renewal, alteration or replacement.

Asset management policies shall be cantered on a risk-based methodology. This methodology shall be used to identify the risks to the delivery of objectives, and to manage these risks by:

- An initial fit-for-purpose asset or system design;
- An inspection regime to monitor asset condition and identify actual or potential defects that could compromise the performance of the asset;

- Maintenance activities to address degradation identified at the time of inspection or to address predictable asset degradation; and
- Renewal criteria that identify when the current asset or system should be replaced as ongoing maintenance is considered to be uneconomic.

8.10.5.1 Asset Management Principles

- Asset management regime shall adopt following principles that reflect objectives and values of asset management:
- Asset investment plans shall balance maintenance and renewal work with the aim of minimizing whole life costs for the whole network;
- Prevent increase in the risk to passengers and workers by degradation or failure of infrastructure and reduce it where reasonably practicable;
- Develop technology and methods to support fact based decisions on maintaining and renewing the infrastructure improving capability for predicting and preventing failures;
- Use a risk management process to identify and reduce threats to meet objectives
- Develop asset policies, standards and plans through consensus, to improve their practicality, to encourage consistency and to help long-term maintainability;
- Asset Management System

Efficient Asset management system shall be established using suitable modern computer based solutions to maintain huge database and modern tools for asset management. AMS should also incorporate environmental and hazard management and emergency response systems. Once integrated, an AMS should serve the needs of all the parties that are in any-way connected to the railway system, such as the infrastructure owners, outsourced maintenance or operating agencies etc. They all should make use of the AMS, extract the data needed for their everyday or long-term strategic purposes, and also feed the appropriate data back to the system. AMS shall be able to handle following activities:

- Keeping record of information & location of all assets constituting Railway infrastructure i.e. keeping record of what the assets are and where they are located
- Monitoring and storing information about condition of all assets
- Infrastructure life cycle management
- List other assets and their condition, including, but not limited to, construction and maintenance equipment, vehicles, real estate, materials, corporate data and information
- Include deterioration rates for infrastructure assets; and
- Determine funds (short-term as well as long-term) necessary to fund infrastructure maintenance at the recommended performance level.

8.10.5.2 Asset Management Plans

All core maintenance activities shall be done in-house and not outsourced. Certain minor and non-safety related works may be outsourced under strict supervision of SHSR. In addition there

may be annual maintenance contracts for all sophisticated equipment which includes computers, S&T control equipment consoles, SCADA equipment, Substation transformers etc.
Integrated annual maintenance plan shall be prepared after coordinating and interfacing all sub systems along with traffic planners. Majority of the maintenance tasks shall be carried out on a pre-planned basis. Scheduled maintenance must be incorporated into the operational planning process. This means that the train plan must include defined maintenance periods, which in this case will be mostly during non-operational hours or off peak traffic hours.
Maintenance plan for the SHSR should satisfy the following objectives:

- Regularly review and optimize maintenance performance and efficiency
- Minimize disruption to operations
- Safety risk to be managed to be ALARP
- Meet Key Performance Indicators
- Ensure compliance with relevant Indian Railways standards, industry standards and Statutory Requirements
- Prevent premature degradation of assets and provide assured asset condition through effective asset stewardship
- Manage the infrastructure for economic and efficient service delivery
- Ensure maintenance activities have minimal impact on the environment

8.10.5.3 Maintenance Philosophy

The maintenance philosophy for the SHSR should be based on:

- Combination of some mechanized maintenance practices with traditional labour-intensive methods.
- More stress on mechanized maintenance as compared to traditional manual maintenance
- All sectors participate in the use of possession time on a planned basis,
- Higher proportion of skilled staff compared to unskilled staff. Staff need to be multi-skilled
- Use of road vehicles for maintenance work as far as feasible, to avoid disruption to train movements
- Equipment to detect wheel flats and hot axles in the rolling stock
- Maintenance to be performed in house for the crucial and safety related items – P Way, OHE and Signal equipment. Some items may be outsourced

Emergency repairs are invariably likely to be disruptive to normal operations but there must be capability to deal with such incidents. The regime established for infrastructure maintenance on SHSR should have the effect of minimizing the requirement to carry out emergency repairs because defects in the course of condition monitoring can be dealt with on a planned basis before they become an emergency. The main exception to this will be damage to track caused by rolling stock defects, and derailments.

8.10.6 MAINTENACE PLAN

Summarizing the above factors, a broad plan for maintenance of the SHSR assets has been proposed as below.

- There will be a maintenance organization set up in the SHSR which will be responsible for the repair and maintenance of all assets of the SHSR. The organization will consist of engineers, skilled staff and managerial personnel. Some unskilled staff will also be there for manual labour intensive work.
- Maintenance of different assets will be done on a preventive maintenance principle which includes directed maintenance. This means that the condition of assets will be monitored intensively through periodic inspections, on board computerized monitoring systems and from feedback of operating staff like train operators, station staff etc. This requires a high degree of computerization on the SHSR where asset condition data will be continuously fed into the computer and reports generated will be available to all maintenance staff. Computerized Maintenance Management Systems (MMS) are now available or can be developed for the SHSR.
- Minor attention to lineside and station equipment will be done at site during night or off peak service hours. For any major repairs or scheduled maintenance, the item will be brought to the maintenance depot. For attention to fixed assets, this work will be done during non-train operating hours or by taking a block.
- An integrated maintenance depot will be set up at Trivandrum to undertake maintenance of Rolling Stock as well as S&T, Electrical and Civil engineering equipment. A sub depot at Kasaragod will also be set up, mainly for stabling trains but also for carrying out petty repairs or emergency repairs.
- All departments must coordinate their working during traffic block hours so that the possession is effectively utilized.
- All crucial safety related maintenance work must be done in house with trained staff of the SHSR. Some non-core activities like building maintenance, electric substation maintenance, road transport, housekeeping work etc. can be outsourced to private parties. Any
- Maintenance of certain assets like the signalling system, rolling stock etc can be given to the supplier of the system, but this must be covered by strict contractual obligations and responsibilities in case of accidents.
- Annual maintenance contract must be given for sophisticated sub systems like computer network, S&T equipment modules, POH of track machines and locomotives etc. The work done by the private parties must be strictly monitored by the SHSR staff.
- Renewal of assets must be done after their economic life is over. The time of renewal will depend on the condition, the stated life of the asset as per the manufacturer, intensity of use etc. The Indian Railway Finance Code which lays down the codal life of Railway Assets can be a guide to determine replacement.

8.11 SAFETY Management in SHSR

8.11.1 Concept

In semi high-speed railways, to run trains near a speed of 200 km/h, mechanism to ensure train safety is critical. The safety mechanism to ensure safety is broadly based on following concept:

- Selection of facilities and rolling stock to cope with high-speed operation and establish a comprehensively harmonized modern mechanism.
- Elimination or minimization of the human intervention on safety critical elements by technological means or fool-proofing.
- Adoption of highly redundant systems for important safety equipment/ facilities to improve reliability and ensure fail-safe principle is applied comprehensively and followed strictly.
- Take measures to avoid the effect of windstorms, floods, earthquakes and other damages caused by natural phenomena as far as possible.
- Introduce equipment/facilities to minimize accidents due to obstacles falling on track (e.g. automobiles) and other troubles and institute legal/regulatory measures against deeds to compromise the safety of train operation.

8.11.2 Safety Measures

8.11.2.1 Train Safety measures

8.11.2.1.1 Prevention of derailment and collision between trains

In view of their long braking distance, it is not possible to protect high-speed railway trains by using conventional railway signals. Therefore, SHSR system requires signalling system with Automatic Train Control mechanism.

8.11.2.1.2 Prevention of the invasion of obstacles

In view of their long braking distance, it is not possible to for a driver to stop trains to avert obstacles within visual range. Therefore, to prevent people and other obstacles from entering the right of way, high speed railway system is designed as a completely segregated system with grade-separated crossings.

8.11.2.1.3 Segregation of operation and maintenance work hours

As Trains on SHSR are running at very high speed, maintenance on right of way and other safety critical systems should be planned when no trains are running. Therefore, dedicated maintenance hours (24:00-05:00Hrs.) are recommended accordingly.

Alternatively, only slow trains can be allowed to run during maintenance hours (24:00-05:00Hrs.) while maintenance is carried out with all safety measures to ensure safety during maintenance activities.

System shall be verified as safe after completion of maintenance works by running a pilot train.

8.11.2.1.4 Prevention of accidents on platforms

Platform shall be designed with adequate width to avoid passenger falling on track or contacting trains. Trains shall not pass the platform tracks at high speed to prevent passengers from falling onto the track pushed by the train draft. Through trains shall pass stations via tracks away from platforms unless special provisions are made and safety is assessed and ensured otherwise.

8.11.2.1.5 Rescue Operation

Assurance of safety, during normal operation as well as during accidents or disasters, is of paramount importance. Therefore, rescue operation during accidents and disasters shall be planned with adequate arrangements and method to ensure safety.

Following method is adopted for rescue in case of accidents or disasters :

- If the rescue train can come to the accident site, passengers shall be transferred to the rescue train.
- If the rescue train cannot come to the site, passengers shall get off the train and are rescued from maintenance slopes or emergency stairs*.

8.11.2.1.6 Prevention and Mitigation of Disasters

The SHSR is envisioned as Safe and reliable transport system to transform lives of its beneficiaries. However, given the nature ground conditions along the corridor between Trivandrum to Kasaragod which include unfavourable soil condition, sea-shore related risks, high temperature, heavy rains in the monsoon and uneven terrain, it requires robust foundations and special structures. In structure designing, it is important not only to guarantee stability of track even during earthquake and strength against rains but also to make arrangements to quickly catch meteorological information to prevent occurrence of disaster or minimize damage therefrom, thereby protecting running trains against damage due to natural phenomena. Therefore, introducing a disaster preventing system into this project to automatically collect disaster preventive data is recommended. Terminals of the disaster preventing system will be installed at the operation center and each maintenance depot aiming at establishing a communication system that makes it possible to renew data at a stretch from the operation control center in charge of train operation to field organizations. About rainfall, wind speed & rail temperature, OCC dispatchers check the situation from Disaster Detection and Warning System (DWS), order restriction speed to train drivers and directly send command to high-speed trains. About earthquake, OHE is tripped automatically based on information from distributed seismometers.

8.11.2.1.7 Other safety provisions

The interaction between system wide works and the works of other in close proximity to the railway system shall be given due consideration to identify potential safety issues. Following shall be analysed and understood from safety perspective:

- The intended use of the system and the mode of operation
- Maintenance activities

- The relationship between persons, infrastructure and systems e.g. Human factor considerations, disability provisions.
- The wilful act of persons to vandalize
- The interactions between the railway and its neighbours – noise, vibration, EMC and visual impact
- Degraded operating conditions
- Environmental conditions
- Fire prevention and life safety systems in Emergency scenarios

8.11.2.1.8 The objectives of safety provisions

While broad concept and safety measures for SHSR are detailed in previous sections, general objectives of safety provisions for railway systems are listed hereunder:

- There should be adequate clearances for public, trains, infrastructure, and maintenance, both in normal and emergency conditions
- The railway system should be protected against unwanted intrusion and unauthorized access.
- Tunnels and other enclosed structures should provide for the safe evacuation or protection of persons under all emergency conditions.
- Elevated railway routes should provide for the safe evacuation of persons away from danger.
- Any person should be able to identify their whereabouts on the railway system using location identify markers.
- The track and its supporting structure should provide for the safe guidance and support of the train.
- The signalling system should provide for the safe routing, spacing and control of trains, even in degraded conditions.
- Station platforms and access ways shall be appropriately sized for the volume of people using them, including during degraded and emergency conditions.
- The safety of people whilst moving around the stations including allowance for luggage, wheel chairs, buggies, cycles and the like.
- A means should be provided for the monitoring and controlling the persons using the railway.
- The implementation of Fire and Life safety systems must be ensured.
- The choice of materials shall be appropriate to the location and not give rise to danger in a fire situation.
- During an emergency there should be coordinated control between the railway, the emergency services and neighbouring communities.
- The interaction between road, rail, river/canal, and air and sea traffic should be avoided. Where this is unavoidable then special control measures should be implemented.
- The railway should provide for the safe and secure stabling, marshalling and maintenance of the trains.
- Railway depots, marshalling yards and sidings should have safe walking routes which minimize the possible contact between trains and persons.
- Railway workers should be provided with high visibility clothing so they can be seen both during the days and at night.

- Railway workers shall be provided with a means of communication with the railway controllers.
- The structural integrity of the trains should be maintained in normal operations and provide protection to persons on the train during an accident.
- The interiors of trains should provide a safe environment for people and their possessions. Trains shall have a safe means of entry and exit including during a train evacuation to trackside situation.
- The train should be provided with an effective means of communication between the driver, train attendant or central controller and the passengers
- The systems used for the guidance, control and communication interface of a train shall be compatible and not give rise to danger.
- The railway system shall have a safety management system which details the arrangements for providing safe systems of work and safe working environments.
- Each railway operator should undertake a thorough risk assessment and identify how each risk will be controlled.
- Safety targets and safety monitoring and audit will aim to continuously improve the safety systems and procedures.
- The provision of safety related training to staff, maintainers and operators with appropriate competence assessment should be implemented.
- Those persons who fulfil key safety critical roles such as signallers and track inspectors shall be regularly assessed, refreshed and provided with update training.

9. DETAILED PROJECT COST ESTIMATE

9.1 Introduction

Preliminary cost estimates have been prepared covering civil, electrical, signalling and telecommunications works, rolling stock, etc. at May, 2019 price level and escalated @5% PA.

While preparing the capital cost estimates, various items have generally been grouped under three major heads on the basis of (i) route km length of alignment, (ii) number of units of that item, and (iii) item being an independent entity. All items related to main line and maintenance depot related to alignment including traction power supply, signalling, viaduct, ballastless track have been estimated at rate per route Km. Cost of station structures, telecommunication other electrical services at these stations including Lifts & Escalators and Automatic Fare Collection (AFC) installations at all stations have been assessed in terms of each station as a unit. Similarly, rolling stock costs have been estimated in terms of number of units required. In remaining items, viz. Land, utility diversions, rehabilitation, EIA, R&R etc. the costs are assessed on the basis of each item, taken as an independent entity.

In order to arrive at realistic cost of various items, costs of the project have been derived from similar executed project in similar scenario.

The overall capital cost for Semi high speed rail corridor between Thiruvananthapuram and Kasaragod at 2019 price levels is 50289 Crores including land cost, design and PMC charges, EIA and R&R cost, contingency @3% of basic value excluding land cost, design and PMC charges, EIA and R&R.

Table 92 : Capital cost summary of Semi high speed rail corridor between Thiruvananthapuram and Kasaragod

Sr. No.	Corridor Name	Capital cost	Taxes & Duties	Total (@2019 price levels)	Completion Cost
1	Thiruvananthapuram and Kasaragod	50289 Cr.	5476 Cr.	55765 Cr.	66079 Cr.

The cost estimate has been prepared for this pre-feasibility report based on the following unit rates. The basis of the rates is also mentioned briefly against each item. The overall capital cost excluding taxes and duties at 2019 price is as given as below:

9.1.1 Capital cost estimate – Semi high speed rail corridor between Thiruvananthapuram and Kasaragod

The overall capital cost excluding taxes and duties for Semi high speed rail corridor between Thiruvananthapuram and Kasaragod at 2019 price is as given as below:

S. NO	Item	Unit	Rate as per March 2019 (in Cr)	Qty	Amount (in Cr)
1	**Alignment and Formation**				
1.1	**Tunnelling: Cut and cover**				
	Upto 17 depth normal/weak ground	R. Km	127.72	6.91	881.88
	Upto 17 depth strong ground	R. Km	94.21	16.51	1,555.48
	Tunneling: TBM method	R. Km	200.00	2.43	486.00
1.2	**Viaduct**				
	8 m high viaduct	R. Km	60.02	13.03	781.95
	10 m high viaduct	R. Km	75.03	25.24	1,893.44
	15 m high viaduct	R. Km	110.54	8.94	988.25
	20 m high viaduct	R. Km	114.58	9.83	1,125.76
1.3	**Embankment**				
1.3 a	On all terrain (2 m high)	R. Km	7.67	18.76	143.99
	On all terrain (2 m high) sand column	R. Km	10.38	7.80	80.94
	On all terrain (2 m high) stone column	R. Km	18.93	7.80	147.68
	On all terrain (2.5 m high)	R. Km	15.61	12.19	190.34
	On all terrain (2.5 m high) sand column	R. Km	18.32	5.30	97.07
	On all terrain (2.5 m high) stone column	R. Km	26.87	5.22	140.27
	On all terrain (3.6 m high)	R. Km	17.58	40.18	706.55

S. NO	Item	Unit	Rate as per March 2019 (in Cr)	Qty	Amount (in Cr)
	On all terrain (3.6 m high) sand column	R. Km	20.29	13.82	280.30
	On all terrain (3.6 m high) stone column	R. Km	28.84	12.55	361.84
	On all terrain (6 m high)	R. Km	29.31	61.53	1,803.05
	On all terrain (6 m high) sand column	R. Km	33.81	26.73	903.89
	On all terrain (6 m high) stone column	R. Km	48.07	24.45	1,175.35
1.3 b	Cutting in all soils 2 m	R. Km	2.89	57.70	166.79
	Cutting in all soils 4 m	R. Km	5.78	32.83	189.80
	Cutting in all soils 5.2 m	R. Km	7.52	65.93	495.47
	Cutting in all soils 8 m	R. Km	11.56	43.76	505.89
1.4	Bridges	R. Km	60.38	12.05	727.23
1.5	ROBs (mostly in cuttings one span)	Each	8.00	718.00	5,744.00
				Sub total (2)	**21,573.22**
2	**Stations**				
2.1	Type A 12 m wide platform at ground (incl lifts and escalators)		70.27	5.00	351.34
	Type A 12 m wide platform elevated (incl lifts and escalators)		106.05	1.00	106.05
	Type B 10 m wide platform at ground (incl lifts and escalators)		64.42	3.00	193.26
	Type B 10 m wide platform elevated (incl lifts and escalators)		100.12	1.00	100.12

S. NO	Item	Unit	Rate as per March 2019 (in Cr)	Qty	Amount (in Cr)
2.2	OCC and administrative buildingg	LS			100.00
2.3	ASS and MEP arrangements	LS	5.00	10.00	50.00
				Sub Total (3)	900.77
3	**All Depots & miscellaneous**				
3.1	Depot at Kochuveli (Thiruvananthapuram) including work shop and siding track and other infra, MEP and ASS	LS	200.00		200.00
3.2	Depot at Kasargod including work shop, system and siding track and other infra, MEP and ASS	LS	200.00		200.00
3.3	Track recording car, USFD rail testing car, Rail grinding machine, Catenary installation car etc	LS	125.00		125.00
3.4	Accident relief Train and other equipments	LS	175.00		175.00
3.5	Track machines & track depot including sidings	LS	200.00		200.00
3.6	safety & rescue and relief in tunnels and viaducts, including tunnel ventilation	LS	135.00		135.00
3.7	Automatic River water level monitoring system, rain fall monitoring system and wind speed monitoring system	LS	25.00		25.00
3.8	Track machine and track depots	LS	50		50.00
				Sub Total (4)	1,110.00
4	**Permanent way**				
4.1	Ballasted track for embankments, viaduct and yards	R. Km	8.90	500.40	4,453.56
4.2	Ballastless	R Km	10.00	46.3	463.00

S. NO	Item	Unit	Rate as per March 2019 (in Cr)	Qty	Amount (in Cr)
				Sub Total (5)	4,916.56
5	**Traction and power supply incl. OHE , ASS etc**				
5.1	Elevated Section/ At Grade Section	R KM	3.50	524.00	1,834.00
5.2	Underground Section - Tunnel	R KM	4.00	4.00	16.00
5.3	Depot - OHE	T KM	3.00	20.00	60.00
5.4	RSS/ TSS (including Cabling Extra High Tension from source to RSS)	Number	60.00	8.00	480.00
				Sub Total (6)	2,390.00
6	**Signalling and Telecom**				
6.1	Signalling GSMR / LTE & OCC Main line incl. OCC/BCC including Station and Depot including safety equipment	R.Km	3.39	528.00	1,789.92
6.2	On Board Equipment	LS	1.0	25.00	25.00
6.3	Telecom - Main Line, Station and Depot	R.Km	0.68	528.00	359.04
6.4	Ticketing & fare collection	Each	8.00	10.00	80.00
6.5	Other safety equipment	LS	10.00	1.00	10.00
				Sub Total (7)	2,263.96
7	**Rolling Stock & RORO Civil Cost**				
7.1	Rolling stock (SG) - Passenger	Set	15.00	234.00	3,510.00

S. NO	Item	Unit	Rate as per March 2019 (in Cr)	Qty	Amount (in Cr)
7.2	Rolling Stock - RORO	Per Train of 20 wagons	70.00	6.00	420.00
7.3	RORO - including parking for 40 trucks and ramp and ancillary facilities	LS	150.00	4.00	600.00
				Sub Total (8)	4,530.00
8	**Staff quarters and Barracks**				
8.1	Staff quarters for O&M	LS		50.00	50.00
				Sub Total (9)	50.00
9	**Others**				
9.1	Shifting of Utilities	LS	6.67	50.00	333.50
9.2	Multi modal Integration	Per Station	3.00	15.00	45.00
9.3	Security	Per Station	0.50	15.00	7.50
				Sub Total (10)	386.00
10	**Training Facilities & Machine in training centre including Overseas training**	LS	75.00		75.00
				Sub Total (11)	75.00
11	**Total for all items except land**				38,195.51

9.2 Engineering Works

9.2.1 Land Price

Land Price adopted for this FR is the FINAL AWARD for the land as per the LA act 13, in which half the final award is the Solatium.This makes land expensive, especially in a state like Kerala, where the land market price is high. For the final award for the land, the imporatant base data is the Mraket price of the land, which cannot be ascertained accurately at this point of time since the survey Nos of the affected land are not available. In this context, the average LA 13 cost of land for different types of land were obtained form the NH authorities and LA Deputy Tehsildhar and used in this report for arriving at the final award.

The procedure adopted for arriving at the Final award is given below.

- One of the major cost considerations for any infrastructure project in Kerala is the land price and the Rehabilitation prices. The Land and R&R cost is determined by "THE RIGHT TO FAIR COMPENSATION AND TRANSPARENCY IN LAND ACQUISTION., REHABILITATION and RESETTLEMENT ACT 2013, herein referred to as LA Act 13. The LA Act 13 compensates the landowners for Land, buildings, trees, livestock and crops as per THE FIRST and SECOND schedule and the THIRD schedule (provision for infrastructural amenities).
- As per the LA act 13, the **Final Award** = **[{Compensation} + {Solatium (100% of the calculated compensation)}]**

  The Compensation = [{Market Value (determined as per the section 26)} * {Multiplication factor (1.00 to 2.00 for rural areas depending upon the distance from urban areas and 1.00 for urban areas)} + {Value of assets (to be determined as per the section 29)}]. Here, Solatium means a gift or added compensation.

  The basis of the compensation amount is to arrive at the "**market price"** of the land and is done as per Clause 26 of the act at the district level, chaired by the District collector. Then this is confirmed at the state level by a committee under the chairmanship of the Chief secretary.

  Gist of Clause 26 is that the collector shall adopt the higher of (1) the market value specified in the **Indian Stamp act, 1899** (2) **average sale price of similar type of land** situated in the nearest village and (3) the **consenting amount of compensation as agreed upon under sub section (2) of section 2 in case of acquisition of lands for private companies or for public private partnership projects.**

- For the land costing, the land prices for the different categories of land along the alignment are compiled in the table below.

1 SL No	2 Type of land	3 Unit	4 Rate in Crores per Hectares	5 Qty of land required Hectares	6 Land cost (Col.4 x col. 5) Crores	7 Remarks (LA cost per Cents for easy understanding)
1	**Land**					
1.1	Private land					
a	Wet land/ land interior with no road	Ha.	7.41	665.84	4,933.87	3 Lakhs / Cent LA13 cost
b	Dry land with road connectivity	Ha.	14.82	152.52	2,260.35	6 Lakh/ Cent LA13 cost
c	Small town	Ha.	22.23	50.84	1,130.17	9 Lakh/ Cent LA 13 cost
d	Mid - Large town	Ha.t.	44.46	15.58	692.69	18 Lakh/Cent LA 13 cost
e	Bridges, Backwaters and *Poramboku*	Ha.	0.00	62.88	0.00	
1.2	Government land	Ha.	2.22	45.10	100.26	
1.3	Railway land	Ha.	6.67	44.28	295.30	
1.4	Station land	Ha.	Different rates at different locations	88.92	1,250.22	
1.5	workshops & depots	Ha.	7.41	100.49	744.63	
					11,407.49	
1.6	Cost of land for Rehabilitation (to be identified)	LS @ 15%			1,711.12	
			Total land cost		**13,118.61**	

The land costs could be brought down to this level due to the alignment which passes through the cheapest land for most of the alignment.

- The land costs / final award as per LA 13 shall be approximate at the feasibility study stage. A fair assessment can be made at the DPR stage. The actual market price which is the basis of the LA final award may vary from place to place. However, for this study, enquiries were made at NHAI office and Dy. Tehsildar (LA) offices and the rates are adopted based on their input as they have indicated that "In Kerala, no land is available less than 3 Lakhs per cent under LA 13, as half of that is SOLATIUM amount of 100%)".

So, the consultants checked out the probable market price for the most utilized land/ the cheapest land price by reverse method.

a. Final award as per LA 13 = Rs 3 lakhs /Cent
b. Solatium amount= 1.5 lakhs/ cent (100% solatium)
c. Considering the Assets attached to land at 10%, the structures and assets price et=1.5* 0.1= 15,000.00
d. Therefor the price before the multiplication factor of 1.4= 1,50,000-15,000= Rs 1,35,000.00 /cent
e. Market value of the land after deducting the 1.4 multiplication factor= 1,42,500/1.4= Rs 96,428.00 / cent.

This is the least market price fixed considered for the project, which the LA officials feel is really conservative, if we consider the actual market prices fixed in their LA cases and the arbitration, after the final award. R&R costs at 15% of the LA Costs have been considered, which is also the subjective norm for similar projects since in a place like Kerala, the R&R prices is normally considered high due to the uniform spread of the population.

- In view of the above facts, the land cost estimate given above is expected to be on the lower side. Therefore, a more thorough estimate of land cost should be prepared at the DPR stage. In discussions with MD and other officers of KRDCL, it was apparent that to contain total cost of land, which is a major component of the project cost, good liaison shall have to be maintained with the land acquisition officers and state authorities to ensure that payments are made by fair and realistic assessment of cost and liberal compensation are avoided
- As said earlier, the land cost needs to be kept to the minimum to make this project viable on completion. To achieve this, apart from reducing the ROW to the barest minimum by adopting good engineering practices, sharing the land cost with other agencies / stake holders by providing two lane roads on either side of the corridor (which could be used for construction) shall also be explored durting the DPR.

9.2.2 Alignment

Total length of alignment works out to 531.45 km, 25.85 km out of which is underground section, 23.42 km which is proposed to be constructed by Cut and Cover method. Cost of cut and cover tunnelling is taken as 127.72 cr for weak/normal ground and 94.21 Cr./km for strong ground. Remaining 2.43 km is proposed to be constructed using TBM tunelling method, cost of which is taken as 200 Cr./km. 57.03 km of alignment will be elevated. Cost of viaduct works out to 60.02 Cr./km for 8m high viaduct and 75.03 Cr./km for 10 m high viaduct, 110.54 Cr./km for 15 m high viaduct and 114.58 Cr./km for 20 m high viaduct. Cost of at grade alignment on all terrain and for cutting in all soil condition is given in table below:

S. NO	item	Unit	Rate as per March 2019 (in Cr)	Quantity	Total Cost
2	**Alignment and Formation**				
2.1	**Tunneling: Cut and cover**				
	Up to 17 depth normal/weak ground	R. Km	127.72	6.91	881.88
	Up to 17 depth strong ground	R. Km	94.21	16.51	1,555.48
	Tunneling: TBM method	R. Km	200.00	2.43	486.00
2.2	**Viaduct**				
	8 m high viaduct	R. Km	60.02	13.03	781.95
	10 m high viaduct	R. Km	75.03	25.24	1,893.44
	15 m high viaduct	R. Km	110.54	8.94	988.25
	20 m high viaduct	R. Km	114.58	9.83	1,125.76
2.3	**Embankment**				
2.3 a	On all terrain (2 m high)	R. Km	7.67	18.76	143.99
	On all terrain (2 m high) sand column	R. Km	10.38	7.80	80.94
	On all terrain (2 m high) stone column	R. Km	18.93	7.80	147.68
	On all terrain (2.5 m high)	R. Km	15.61	12.19	190.34
	On all terrain (2.5 m high) sand column	R. Km	18.32	5.30	97.07
	On all terrain (2.5 m high) stone column	R. Km	26.87	5.22	140.27
	On all terrain (3.6 m high)	R. Km	17.58	40.18	706.55
	On all terrain (3.6 m high) sand column	R. Km	20.29	13.82	280.30
	On all terrain (3.6 m high) stone column	R. Km	28.84	12.55	361.84
	On all terrain (6 m high)	R. Km	29.31	61.53	1,803.05
	On all terrain (6 m high) sand column	R. Km	33.81	26.73	903.89
	On all terrain (6 m high) stone column	R. Km	48.07	24.45	1,175.35
2.3 b	Cutting in all soils 2 m	R. Km	2.89	57.70	166.79
	Cutting in all soils 4 m	R. Km	5.78	32.83	189.80
	Cutting in all soils 5.2 m	R. Km	7.52	65.93	495.47
	Cutting in all soils 8 m	R. Km	11.56	43.76	505.89
2.4	Bridges	R. Km	60.38	12.05	727.23

S. NO	item	Unit	Rate as per March 2019 (in Cr)	Quantity	Total Cost
2.5	ROBs (mostly in cuttings one span)	Each	8.00	718.00	5,744.00
				Subtotal (2)	**21,573.22**

***these are base rates to which additional amount to be added for higher stabilization requirements at 200- 250 Kmph (see item 1.e above) which shall be done during the DPR stage when the soil exploration reasults are made available.**

9.2.3 Station Building

The cost includes general services at the stations but excludes the cost of tunnel, lifts & escalators, which have been considered separately under, respective items. Cost per station approximately works out to 70,27 Cr. for Type A at grade stations and 64.42 Cr. for Type B at grade stations and 106.05 Cr. for type A elevated stations and 100.12 Cr. For Type B elevated station. Cost of OCC and administrative buildings works out to 100 Cr. Cost of ASS & MEP arrangements has been taken seperately as 5 Cr./km.

9.2.4 Permanent Way

For underground section, ballastless track has been planned. However, for at grade section, ballasted tracks have been proposed. Rates are adopted based on Kochi Metro rates+ Additional rate required for high speeds of 200 to 250 Kmph.

S. NO	item	Unit	Rate (in Cr)	Basis of rates
2	**Permanent way**			
a	Ballast less track for tunnel	R. Km	8.9	Rate worked out based on Kochi Metro rates+ Additional rate required for high speeds of 200 to 250 Kmph
b	Ballasted track for embankments, viaduct	R. Km	10.00	worked out rates based on Kochi Metro rates+ Additional rate required for high speeds of 200 to 250 Kmph

9.2.5 Utility Diversion

The provision of utility diversion has been taken as 6.67 Cr. per running km, which works out to 333.50 Cr. for the affected length of 50 km.

9.2.6 Environmental and Social Impact Assessment

Detailed R &R and EIA study shall be taken up at DPR stage. For now we have taken 100 Cr. as Lump sum for Environment & Social Management Plan and 15% of project cost as R&R cost. Thus ESMP and R&R cost for the project works out to 1811 Cr.

9.3 Traction and Power supply

The Cost of Traction & Power supply has worked out to 3.5 Cr. Per km for both elevated & at grade section. For underground section cost has been taken as 4 Cr./km. Cost of OHE in Depot works out to 60Cr. for 20km of track length. Cost of RSS/TSS has been taken as 60 Cr. per RSS/TSS, including cable cost.

9.4 Rolling Stock

Cost of Rolling stock works out to 4530 Cr. including passenger, RORO and infrastructure facilities for RORO.

9.5 Depot

2 Depots have been proposed for the corridor i.e. one Depot at Kochuveli (Tiruvananthpuram) and another one at Kasargod. Cost of both the depots works out to 1110 Cr. This cost includes Track recording car, USFD rail testing car, Rail grinding machine, Cantenary installation car, Accident relief Train and other equipments, Track machines & track depot including sidings, safety & rescue and relief in tunnels and viaducts, including tunnel ventilation, Automatic River water level monitoring system, rain fall monitoring system and wind speed monitoring system and Track machine and track depots.

9.6 Taxes and Duties

It is estimated that taxes and duties for Semi high speed rail corridor between Thiruvananthapuram and Kasaragod will work out to 5476 Cr.

9.6.1 Custom Duty, Central GST, state GST have been taken under assessment for Taxes and Duties

Weighted average of custom duty has been taken as 24.07 %. The Quantity of each item on which custom duty is charged have been based on other similar projects in the country such as Delhi Metro Phase IV. The rate of central GST and state GST have been taken as per table below:

1	GST on construction, erection, commissioning, or installation of original Metro/ Monorail Works - IGST only	12.00%

2	***Tax Leviable on Import***	***Duty***
A	Assessable Value	100.00
B	Basic Custom Duty (BCD) (assumed @5.14%)	5.14
C	Total (A+B)	105.14
D	IGST (assumed to be levied @ 18.93 % on 'C')	18.93
E	***Effective rate of Custom Duties on Assessable Value***	24.07%

3	GST on Design, PMC	18.00%

9.6.2 Taxes and Duties on Project Cost Estimate

Taxes on duties for the project including civil works, other works, Design, PMC and contigencies works out to 5467 Cr. At FY 19 price levels. Item wise tax and duties have been given in the table below:

Table 93 : Item wise tax and duties

	Basic Value	Taxes	Total
Land - Considering JDA and removing 40% of the cost	6,844	0	6,844
R&R and ESMP	1811	0	1,811
Design @18% GST	764	138	901
PMC @18% GST	1528	275	1,803
Contingency	1146	138	1,283
Civil	27791	3361	31152
Others	10405	1565	11970

Taxes and Duties on only Civil and others work out to 5128.73 Cr, details of which is given below:

Table 94 : Item wise detailed tax component on Civil and Other cost component

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
Alignment and Formation										
Tunnelling: Cut and cover										
Upto 17 depth normal/weak ground	0%	0	-	0	0	882	53	53		106
Upto 17 depth strong ground	0%	0	-	0	0	1,555	93	93		187
Tunneling: TBM method	0%	0	-	0	0	486	29	29		58
Viaduct	0%	0	-	0	0	0	0	0		0
8 m high viaduct	10%	78.20	4.02	7.40	7.40	704	42	42		103
10 m high viaduct	10%	189.34	9.73	17.92	17.92	1,704	102	102		250
15 m high viaduct	10%	98.83	5.08	9.35	9.35	889	53	53		131

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
20 m high viaduct	10%	112.58	5.79	10.65	10.65	1,013	61	61		149
Embankment		0.00	0.00	0.00	0.00	0	0	0		0
On all terrain (2 m high)	10%	14.40	0.74	1.36	1.36	130	8	8		19
On all terrain (2 m high) sand column	10%	8.09	0.42	0.77	0.77	73	4	4		11
On all terrain (2 m high) stone column	10%	14.77	0.76	1.40	1.40	133	8	8		20
On all terrain (2.5 m high)	10%	19.03	0.98	1.80	1.80	171	10	10		25
On all terrain (2.5 m high) sand column	10%	9.71	0.50	0.92	0.92	87	5	5		13
On all terrain (2.5 m high) stone column	10%	14.03	0.72	1.33	1.33	126	8	8		19
On all terrain (3.6 m high)	10%	70.66	3.63	6.69	6.69	636	38	38		93
On all terrain (3.6 m high) sand column	10%	28.03	1.44	2.65	2.65	252	15	15		37
On all terrain (3.6 m high) stone column	10%	36.18	1.86	3.42	3.42	326	20	20		48
On all terrain (6 m high)	10%	180.31	9.27	17.06	17.06	1,623	97	97		238
On all terrain (6 m high) sand column	10%	90.39	4.65	8.55	8.55	814	49	49		119
On all terrain (6 m high) stone column	10%	117.54	6.04	11.12	11.12	1,058	63	63		155
		0	-	0	0	0	0	0		0
Cutting in all soils 2 m	0%	0	-	0	0	167	10	10		20
Cutting in all soils 4 m	0%	0	-	0	0	190	11	11		23
Cutting in all soils 5.2 m	0%	0	-	0	0	495	30	30		59

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
Cutting in all soils 8 m	0%	0	-	0	0	506	30	30		61
Bridges	0%	0	-	0	0	727	44	44		87
ROBs (mostly in cuttings one span)	0%	0	-	0	0	5,744	345	345		689
Stations										
Type A 12 m wide platform at ground (incl lifts and escalators)	0%	0	-	0	0	351	21	21		42
Type A 12 m wide platform elevated(incl lifts and escalators)	0%	0	-	0	0	106	6	6		13
Type B 10 m wide platform at ground (incl lifts and escalators)	0%	0	-	0	0	193	12	12		23
Type B 10 m wide platform elevated (incl lifts and escalators)	0%	0	-	0	0	100	6	6		12
OCC and administrative bldg.	0%	0	-	0	0	100	6	6		12
ASS and MEP arrangements	0%	0	-	0	0	50	3	3		6
All Depots & miscellaneous										
Depot at Kochuveli (Thiruvananthapuram) including work shop and siding track and other infra, MEP and ASS	0%	0	-	0.00	0.00	200	12	12		24

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
Depot at Kasargod including work shop, system and siding track and other infra, MEP and ASS	0%	0	-	0.00	0.00	200	12	12		24
Track recording car, USFD rail testing car, Rail grinding machine, Cantenary installation car etc	100%	125	6.43	11.83	11.83	0	0	0		30
Accident relief Train and other equipments	0%	0	-	0.00	0.00	175	11	11		21
Track machines & track depot including sidings	10%	20	1.03	1.89	1.89	180	11	11		26
safety & rescue and relief in tunnels and viaducts, including tunnel ventilation	30%	40.5	2.08	3.83	3.83	95	6	6		21
Automatic River water level monitoring system, rain fall monitoring system and wind speed monitoring system	0%	0	-	0.00	0.00	25	2	2		3
Track machine and track depots	0%	0	-	0.00	0.00	50	3	3		6
Permanent way										
Ballasted track for embankments, viaduct and yards	15%	668.034	34.34	63.21	63.21	3,786	227	227		615
Ballastless	15%	69.45	3.57	6.57	6.57	394	24	24		64
Traction and power supply incl. OHE , ASS etc										

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
Elevated Section/ At Grade Section	0%	0	-	0	0	1,834	110	110		220
Underground Section - Tunnel	0%	0	-	0	0	16	1	1		2
Depot - OHE	0%	0	-	0	0	60	4	4		7
RSS/ TSS (including Cabling Extra High Tension from source to RSS)	0%	0	-	0	0	480	29	29		58
Signaling and Telecom										
Signaling GSMR / LTE & OCC Main line incl. OCC/BCC including Station and Depot including safety equipment	60%	1074.0	55.2	101.6	101.6	716	43	43		344
On Board Equipment	100%	25.0	1.3	2.4	2.4	0	0	0		6
Telecom - Main Line, Station and Depot	70%	251.3	12.9	23.8	23.8	108	6	6		73
Ticketing & fare collection	60%	48.0	2.5	4.5	4.5	32	2	2		15
Other safety equipment	0%	0.0	0.0	0.0	0.0	10	1	1		1
Rolling Stock & RORO Civil Cost										
Rolling stock (SG) - Passenger	30%	1053.0	54.1	99.6	99.6	2,457	147	147		548
Rolling Stock - RORO	15%	63.0	3.2	6.0	6.0	357	21	21		58
RORO - including parking for 40 trucks and ramp and ancillary facilities	0%	0.0	0.0	0.0	0.0	600	36	36		72

Item	Import %	Import	Taxes - Import Component			Domestic	Taxes - Domestic Component			Total Tax
			BCD	CGST	SGST		CGST	SGST	Stamp Duty & Registration	
Staff quarters and Barracks										
Staff quarters for O&M	0%	0	-	0	0	50	3	3		6
Others										
Shifting of Utilities	0%	0	-	0	0	334	20	20		40
Multi modal Integration	0%	0	-	0	0	45	2.7	2.7		5.4
Security	0%	0	-	0	0	8	.5	.5		1
Training Facilities & Machine in training center including Overseas training										
	0%	0	-	0	0	75	4.5	4.5		9
TOTAL Tax		4519.3	232.3	427.6	427.6	46794.8	2020.6	2020.6	0.0	5128.7

ABSTRACT COST ESTIMATE
(May 2019 level)

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
1	**Land**					
1.1	Private land					
	Wet land/ no road	Hect.	7.41	665.84	4,933.87	
	Dry land	Hect.	14.82	152.52	2,260.35	
	Small town	Hect.	22.23	50.84	1,130.17	
	Mid - Large town	Hect.	44.46	15.58	692.69	
	Bridges, Backwaters and Poramboke	Hect.	0.00	62.88	0.00	
1.2	Government land	Hect.	2.22	45.10	100.26	
1.3	Railway land	Hect.	6.67	44.28	295.30	
1.4	Station land	Hect.	Different rates at different locations	88.92	1,250.22	
1.5	workshops & depots	Hect.	7.41	100.49	744.63	
					11,407.49	
1.6	Cost of land for Rehabilitation (to be identified)	LS @ 15%			1,711.12	
				Sub Total (1)	**13,118.61**	0
2	**Alignment and Formation**					
2.1	**Tunnelling: Cut and cover**					
	Upto 17 depth normal/weak ground	R. Km	127.72	6.91	881.88	106

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
	Upto 17 depth strong ground	R. Km	94.21	16.51	1,555.48	187
	Tunnelling: TBM method	R. Km	200.00	2.43	486.00	58
2.2	**Viaduct**					0
	8 m high viaduct	R. Km	60.02	13.03	781.95	103
	10 m high viaduct	R. Km	75.03	25.24	1,893.44	250
	15 m high viaduct	R. Km	110.54	8.94	988.25	131
	20 m high viaduct	R. Km	114.58	9.83	1,125.76	149
2.3	**Embankment**					0
2.3 a	On all terrain (2 m high)	R. Km	7.67	18.76	143.99	19
	On all terrain (2 m high) sand column	R. Km	10.38	7.80	80.94	11
	On all terrain (2 m high) stone column	R. Km	18.93	7.80	147.68	20
	On all terrain (2.5 m high)	R. Km	15.61	12.19	190.34	25
	On all terrain (2.5 m high) sand column	R. Km	18.32	5.30	97.07	13
	On all terrain (2.5 m high) stone column	R. Km	26.87	5.22	140.27	19
	On all terrain (3.6 m high)	R. Km	17.58	40.18	706.55	93
	On all terrain (3.6 m high) sand column	R. Km	20.29	13.82	280.30	37
	On all terrain (3.6 m high) stone column	R. Km	28.84	12.55	361.84	48
	On all terrain (6 m high)	R. Km	29.31	61.53	1,803.05	238
	On all terrain (6 m high) sand column	R. Km	33.81	26.73	903.89	119
	On all terrain (6 m high) stone column	R. Km	48.07	24.45	1,175.35	155

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
						0
2.3 b	Cutting in all soils 2 m	R. Km	2.89	57.70	166.79	20
	Cutting in all soils 4 m	R. Km	5.78	32.83	189.80	23
	Cutting in all soils 5.2 m	R. Km	7.52	65.93	495.47	59
	Cutting in all soils 8 m	R. Km	11.56	43.76	505.89	61
2.4	Bridges	R. Km	60.38	12.05	727.23	87
2.5	ROBs (mostly in cuttings one span)	Each	8.00	718.00	5,744.00	689
				Sub total (2)	**21,573.22**	
3	**Stations**					
3.1	Type A 12 m wide platform at ground (incl lifts and escalators)		70.27	5.00	351.34	42
	Type A 12 m wide platform elevated(incl lifts and escalators)		106.05	1.00	106.05	13
	Type B 10 m wide platform at ground (incl lifts and escalators)		64.42	3.00	193.26	23
	Type B 10 m wide platform elevated (incl lifts and escalators)		100.12	1.00	100.12	12
3.2	OCC and administrative bldg.	LS			100.00	12
3.3	ASS and MEP arrangements	LS	5.00	10.00	50.00	6
				Sub Total (3)	900.77	0
4	**All Depots & miscellaneous**					

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
4.1	Depot at Kochuveli (Thiruvananthapuram) including workshop and siding track and other infra, MEP and ASS	LS	200.00		200.00	24
4.2	Depot at Kasargod including work shop, system and siding track and other infra, MEP and ASS	LS	200.00		200.00	24
4.3	Track recording car, USFD rail testing car, Rail grinding machine, Cantenary installation car etc	LS	125.00		125.00	30
4.4	Accident relief Train and other equipments	LS	175.00		175.00	21
4.5	Track machines & track depot including sidings	LS	200.00		200.00	26
4.6	safety & rescue and relief in tunnels and viaducts, including tunnel ventilation	LS	135.00		135.00	21
4.7	Automatic River water level monitoring system, rain fall monitoring system and wind speed monitoring system	LS	25.00		25.00	3
4.8	Track machine and track depots	LS	50		50.00	6
				Sub Total (4)	1,110.00	
5	**Permanent way**					
5.1	Ballasted track for embankments, viaduct and yards	R. Km	8.90	500.40	4,453.56	615
5.2	Ballastless	R Km	10.00	46.3	463.00	64
				Sub Total (5)	4,916.56	
6	**Traction and power supply incl. OHE , ASS etc**					
6.1	Elevated Section/ At Grade Section	R KM	3.50	524.00	1,834.00	220

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
6.2	Underground Section - Tunnel	R KM	4.00	4.00	16.00	2
6.3	Depot - OHE	T KM	3.00	20.00	60.00	7
6.4	RSS/ TSS (including Cabling Extra High Tension from source to RSS)	Number	60.00	8.00	480.00	58
				Sub Total (6)	2,390.00	
7	**Signalling and Telecom**					
7.1	Signalling GSMR / LTE & OCC Main line incl. OCC/BCC including Station and Depot including safety equipment	R.Km	3.39	528.00	1,789.92	344
7.2	On Board Equipment	LS	1.0	25.00	25.00	6
7.3	Telecom - Main Line, Station and Depot	R.Km	0.68	528.00	359.04	73
7.4	Ticketing & fare collection	Each	8.00	10.00	80.00	15
7.5	Other safety equipment	LS	10.00	1.00	10.00	1
				Sub Total (7)	2,263.96	
8	**Rolling Stock & RORO Civil Cost**					
8.1	Rolling stock (SG) - Passenger	Set	15.00	234.00	3,510.00	548
8.2	Rolling Stock – RORO	Per Train of 20 wagons	70.00	6.00	420.00	58
8.3	RORO - including parking for 40 trucks and ramp and ancillary facilities	LS	150.00	4.00	600.00	72
				Sub Total (8)	4,530.00	
9	**Staff quarters and Barracks**					

S. NO	Item	Unit	Rate (in Cr)	Qty	Amount (in Cr)	Total Tax
9.1	Staff quarters for O&M	LS		50.00	50.00	6
				Sub Total (9)	50.00	
10	**Others**					
10.1	Shifting of Utilities	LS	6.67	50.00	333.50	40
10.2	Multi modal Integration	Per Station	3.00	15.00	45.00	5.4
10.3	Security	Per Station	0.50	15.00	7.50	1
				Sub Total (10)	386.00	
11	**Training Facilities & Machine in training centre including Overseas training**	LS	75.00		75.00	
				Sub Total (11)	75.00	9
12	**Total for all items except land**				38,195.51	
13	**Land**				13,118.61	
14	**Taxes**				5,128.73	
	Total capital cost				56,442.85	

10. ECONOMIC AND FINANCIAL ANALYSIS

10.1 Introduction

1. The current service delivery is not commensurate with the existing traffic scenario in general in Kerala. Kerala comprises several small settlements coupled with large urban centers like Trivandrum, Kochi etc. There is a problem of very poor soil conditions and difficulty in land acquisition making a transportation corridor dedicated to connecting the northern most and southern most districts very difficult. The existing National highway from Kasargod to Trivandrum is only 12 m wide in many places. A 590 km road is proposed to be widened for meeting this challenge, 3567 Ha of land need to be acquired for the same. Current land acquisition stands at 1400 Ha. Portions of land for this project have been acquired over the last two decades. This is a major transport corridor and although central government approval has been received for executing the project under HAM model, the execution remains a challenge. Additionally, this would result in widening of the road to 45m which would provide very temporary releif.
2. As a public transport system, proposed Semi high speed rail corridor between Thiruvananthapuram and Kasaragod will supplement the above infrastructure, which is need to service the growing inter-city travel demand, especially in the selected heavy traffic corridors. Spending public money in the construction of SHSR line has been defended as a socially desirable public investment which produces several types of benefits such as:
   - Passenger time savings,
   - Increase in comfort,
   - Generation of new trips,
   - Reduction in congestion and delays in roads,
   - Reduction in accidents, reduction in environmental externalities,
   - Wider economic benefits including the development of the less developed regions
3. Many factors influence the market shares between the other modes of public transport and SHSR. According to the literature, travel time is the most important one. The SHSR has a clear advantage over the traditional inter city bus services, Rail and the fast growing costly car modes due to very high tourist traffic in Kerala. Other factors that contribute to the relative position of SHSR are the quick travel times, reduction in establishment of uran infrastructure requirements in cities, preserving the semi urban set up natural to Kerala, frequency of the service, the integration of networks, accessibility , reliability and punctuality of the services and government policy.
4. The findings of this Feasibility Study will determine this inter-urban transport service through SHSR to improve accessibility so that residents of the state of Kerala will have better access to economic and social activities.

10.2 Scope and Objectives

1. The objective of this feasibility study (FS) to evaluate the potential for the identified SHSR services in the state of Kerala and to assess strategically the overall need and potential for development.
2. The scope of the study is divided into two stages, further divided into several phases:
3. Stage 1

- Phase 0 – Inception
- Phase 1 – Transport demand assessment
- Phase 2 – Corridor definition and Techno-economic feasibility

4. Stage 2
   - Phase 3 – Detailed Project Report

5. Based on the identified study area, a Semi high speed rail corridor between Thiruvananthapuram and Kasaragod is identified. The present section assessed the economic feasibility for the identified SHSR corridor and to provide recommendations for project implementation. The key success will hinge on the selection of the most viable route, the introduction of reliable systems, sufficient budget allocation and of course smooth land acquisition.

6. The objective of the economic analysis in the FS is to identify and quantify the benefits and costs associated with the investment proposal in order to select the optimum solution along with the economic viability in terms of its likely investment return potential. This is carried out in order to assess the economic feasibility and prioritize the identified transport investment proposal and assist the governments in Kerala State in making the right decision.

10.3 Approach and Methodology for the Analysis

The economic analysis contained in this chapter has been undertaken in accordance with the available guidelines including '*Manual on Economic Evaluation of Highway Projects in India*' IRC-SP30, 2009 by the Indian Roads Congress, '*Guidelines for the Economic Analysis of Projects, and Framework for the Economic and Financial Appraisal of Urban Development Sector Projects'1994* by Asian Development Bank (ADB) and '*Appraisal Guidelines for Metro Rail Projects Proposals*' (2017) and '*Metro Rail Policy 2017*' by the Ministry of Housing & Urban Affairs, Govt. of India. Economic analysis involve comparing 'with project' and 'without project' alternatives. By comparing the above alternatives, the net agency costs and net user costs and finally net project benefits associated with the project during its analysis period were calculated for the proposed improvement options separately in order to arrive at their internal rate of return (IRR) and net present value (NPV) both for economic and financial analysis.

10.3.1 Methodolody for Economic Analysis

1. In accordance with the guidelines, economic feasibility analysis was carried out for 30 years analysis period for Life Cycle Cost Analysis (LCCA):
   - Base Year (FY 19)
   - Construction period (FY 21 – FY 24)
   - Project opening for traffic (FY 25)
   - Project operating period (FY 25-FY 55)
   - End of the analysis period (FY55)

2. Thus a period of 30 years of operation is considered for the evaluation. All the cost were at FY 19 (Base Year) level and also the results including NPV, IRR were estimated for the base year level. In the Financial analysis, concession period is evaluated both for 30 years as well as 50

years. However, in economic analysis, due to the tremendous economic benefits to the people of the state, economic returns reach the desired value in 30 years only.

3. Considering the component wise opportunity cost (estimated for Kerala State conditions), the financial cost was converted into economic cost in accordance with the available guidelines from international funding agencies like Asian Development Bank (ADB).
4. The conventional economic model like HDM (which is used for highway improvement project analysis) may not be relevant for most of the rapid urban transport projects etc. Hence appropriate excel based models are developed, to quantify the relevant project benefits; life cycle costing; project net benefits and finally economic feasibility criteria like EIRR and ENPV.
5. Updated inputs available from the guidelines explained above, with suitable updates pertaining to the unit rates of VOC and travel time for different vehicle categories etc were used for the excel based models developed for this study.
   The cost – benefit analysis was carried out by using the discounted cash flow (DCF) technique to obtain the economic internal rate of return (EIRR) and economic net present value (ENPV) for the proposed investments and the likely quantified project benefits linked with the project during the project analysis period
6. Economic Opportunity Cost of Capital (EOCC): Given the complexity of estimating country-specific economic opportunity cost of capital (EOCC), a discount rate of 14% in constant economic prices is used. The EIRR must be compared with the EOCC, for interpretation purpose of project feasibility.

10.4 Estimation of Economic Project Cost of SHSR

10.4.1 Capital Cost

For economic analysis, only the cost estimates of the SHSR (excluding the cost of property development[7]) estimated in the cost section is adopted. Adding the preoperative expenses, physical contingency, applicable taxes, price contingency etc, the total financial cost for all the proposed corridor was estimated for the base year (FY 19).

The economic costs of capital works and annual operation and maintenance are calculated from the financial cost estimates on the following basis:

- Price contingencies are excluded but physical contingencies are included because they represent real consumption of resources;
- Import duties and taxes are excluded because they represent transfer payments. For this the shadow exchange rate factor (SERF) worked out below (1.03)[8] was used;
- The existence of unemployment and under-employment for unskilled workers within the Indian economy means that the opportunity cost of unskilled labour can be lower than its

Property development being a commercial activity, it is not considered for economic analysis.

8

Shadow Exchange Rate Factor (SERF) — INR in Billion

Details	2015-16	2014-15	2013-14	2012-13	2011-12	Average
Exports (INR Billion)	17,146	18,963	18,942	16,353	14,660	17,213
Imports (INR Billion)	24,880	27,371	27,142	26,732	23,455	25,916
Customs Duties (INR Billion)	2,083	1,887	1,231	1,155	1,056	1,482
Shadow Conversion Factor (SCF)	0.953	0.961	0.974	0.974	0.973	0.967
Shadow Exchange Rate Factor (SERF)	**1.05**	**1.04**	**1.03**	**1.03**	**1.03**	**1.03**

Source: Hand Book of Statistics on Indian Economy, 2015-16, 2014-15 & 2013-14, Reserve Bank of India

Note: Calculation Method based on ERD Technical Note Series No. 11, February 2004, 'Shadow Exchange Rate for Project Economic Analy wage rate – a conversion factor (SWRF) of 0.76[9] of the market wage rate for construction labour is used to estimate the shadow wage rate;

- The market wage rate for skilled labour and the acquisition cost of land are considered to represent opportunity costs, as both factors are in demand;
- Land cost is excluded for estimation of economic cost;
- All costs are valued using the domestic price numeraire, to enable an easier comparison with the information used to measure benefits (e.g. a significant component of benefit is the savings in resources, which would be used in the without project situation).

Table 95 : Details of project cost

Details	Total
Length Km	**531.45**
Project Cost Rs Million	6,21,117.3
Project Cost Rs Million/Km	1169
Economic Cost Rs Million	5,77,436.5
Economic Cost Rs Million/Km	1087

Note: The above are derived based on the methodology indicated in this para.

10.4.2 Capital Replacement

25% of electrical and mechanical equipments, 50% of signalling and telecommonucation equipment need replacement in 15 years, Rolling stock will be added in 20 years.

Table 96 : Estimated Replacement Cost Rs Million

Financial Year	Capital/ Replacement and augmentation Cost
FY 21	7,304.2
FY 22	16,478.4
FY 23	15,819.1
FY 24	12,129.5
FY 25	6,012.4
FY 26	-
FY 27	-
FY 28	-
FY 29	-
FY 30	-
FY 31	-
FY 32	-
FY 33	-
FY 34	-
FY 35	-

9

Shadow Wage-rate Factor (Y)	
Unskilled labor cost (Rs. per day)* (L)	400
Minimum Wages in Maharastra w.e.f January 1, 2018 (Rs. per day	495
Shadow Wage-rate Factor (Y); Y = L/M	0.81

*Wages practiced in Maharastra state in the construction industry in 2018.

** Minimum Wage in Maharastra w.e.f January 1, 2018 to March 31, 2018; https://www.labourlawreporter.com/wp-content/uploads/2017/04/Minimum-wages-maharashtra-01-01-18-a.pdf

Note: Calculated using the 'Guidelines for the Economic Analysis of Projects, 1997, ADB

Financial Year	Capital/ Replacement and augmentation Cost
FY 36	-
FY 37	369.5
FY 38	1,293.3
FY 39	679.9
FY 40	1,733.1
FY 41	247.6
FY 42	-
FY 43	-
FY 44	-
FY 45	-
FY 46	-
FY 47	-
FY 48	-
FY 49	-
FY 50	-
FY 51	-
FY 52	-
FY 53	-
FY 54	-
FY 55	-

Source: Consultant Estimate

10.4.3 O&M Cost

Annual operating costs of this investment proposal at constant prices has been broken down into different items of this investment proposal and used for analysis purposes. This annual operation and maintenance (O&M) for the proposed project include staff cost, maintenance cost and power charges as estimated in the financial analysis chapter, is considered for analysis.

Table 97 : Maintenance Cost

1. Staff cost - Rs Million	2904
2. Maintenance cost - Rs Million	1738
3. Power charges - Rs Million	962
Total - Rs Million	**5604**

Source: Consultant Estimate

10.5 Economic Benefits of SHSR

Proposed SHSR is expected to divert passengers from the existing modes like car, bus, rail and other modes with better comfort and improved speed. These improvements will benefit the users in terms of better speed with service quality and reduced travel time. In addition, the proposed SHSR will reduce the carbon emission from the diverted traffic and also will reduce stress on the existing road corridors. Reduction in the congestion on the existing road corridors will result in reduction of road accidents. Accordingly, the economic benefits considered in the present analysis for the subprojects in transport component in this investment proposal include:

1. Value of Travel Time Savings
- For the diverted passengers by using the proposed SHSR system;
- For the non-diverted passengers in the form of reduced congestion due to the diverted SHSR traffic
2. Value of vehicle operating cost (VOC) savings
- For the diverted passengers by using the proposed SHSR system;
- For the non-diverted passengers in the form of reduced congestion due to the diverted SHSR traffic
3. Savings in Reduction of Accidents
4. Pollution Reduction Benefits in terms of reduction in carbon emission from the vehicles due to the diversion to SHSR
5. Reduced Road Infrstructure Costs
- Reduction in annual maintenance cost
- Reduction in the road capacity improvement cost

Above project economic benefits are estimated on annual basis for the selected alignment corridors proposed in the technical section. Projected SHSR traffic for the selected option, in terms of daily passengers and passenger km, upon which the benefits are estimated is presented below in Table 98. Average trip length by SHSR is estimated to be 200 Km. Considering the assigned traffic to SHSR, its trip length, the modes from which these SHSR trips were diverted etc., the travel scenario under (i) without project and (ii) with project scenario including distribution by different modes were developed. This was used as the inputs for estimating all the project benefits discussed above.

Table 98 : Projected SHSR Daily Traffic Diverted from Different Modes

Year	Kasargod to Trivandrum	
	No. of daily passengers	Daily Passenger km (Million)
FY 25	67740	15.94
FY 26	71372	16.79
FY 27	75003	17.65
FY 28	78635	18.50
FY 29	82266	19.35
FY 30	84913	19.98
FY 31	87561	20.60
FY 32	90208	21.22
FY 33	92855	21.85
FY 34	95503	22.47
FY 35	98150	23.09
FY 36	100797	23.71
FY 37	103444	24.34
FY 38	106092	24.96
FY 39	108739	25.58
FY 40	111386	26.21
FY 41	114034	26.83

Year	Kasargod to Trivandrum	
	No. of daily passengers	Daily Passenger km (Million)
FY 42	116681	27.45
FY 43	119725	28.17
FY 44	122769	28.88
FY 45	125813	29.60
FY 46	128857	30.32
FY 47	131901	31.03
FY 48	134944	31.75
FY 49	137988	32.46
FY 50	141032	33.18
FY 51	144076	33.90
FY 52	147120	34.61
FY 53	150570	35.42
FY 54	154101	36.26

6. Additional assumptions followed for estimating the project benefits are given below.

Table 99 : Details of Road User Cost adopted for the Study

Vehicle Category	VOC (Rs. / Vehicle Km)	
	2008 [1,3]	2018 [2]
Car - New Technology (Maruti 800)	4.07	8.87
Bus	16.37	23.25
Indian Railways [4]		1821
Others		7.98

1 Approach for Economic and Operation Assessment for Identified Urban Roads and Transportation Sub-projects, Working Paper No. : WP-05, Comprehensive Transportation Study for Chennai Metropolitan Area, May 2008.

2. Escalated to 2019 with annual growth based on inflation.

3. Includes fuel cost

4. Vehicle operating cost for Indian Railways:

Table 100 : Vehicle operating cost for Indian Railways

Operating Expenditure Indian Railways in FY 17	160,4700	Million
Expenditure on Passenger	70%	
Operating Expenditure on Passenger traffic Indian Railways in FY 17	112,3290	Million
Total Passenger Km	1,004,418	Million Km
Train Operating Cost Per Km/ passenger	1.12	INR
No of Passengers Carried in 1 coach	74	No
No of Coaches per Train	22	No
Capacity of a train	1628	No
Train Operating Cost	1821	INR/ Km

Table 101 : Vehicle Category wise Passenger Travel Time (2018) - Urban Condition

Vehicle Type	Time value (Rs / Hour), 2019
Bus	117
Car	167
Indian Railways	117
Others	117

Note:

1. Approach for Economic and Operation Assessment for Identified Urban Roads and Transportation Sub-projects, Working Paper No.: WP-05, Comprehensive Transportation Study for Chennai Metropolitan Area, May 2008
2. Escalated to 2018 with 10% annual growth.

Table 102 : Assumptions for Carbon Emission Estimation

Treatment cost of CO2 Rs/Ton	500

Source: Appraisal Guidelines for Metro Rail Projects Proposals, 2017, MOH&UA, GOI

Carbon (CO_2) Emission - Ton /litre	0.0023

Source: *GHG Analysis Road Improvement, Guidance Note, World Bank Group, February 2016*)

Table 103 : : Unit Cost of Accidents

Details	Rs. 2004	Rs. 2019
Cost of Fatal Accident	437342	9,01,194
Cost of person injury	64256	1,32,407
Cost of damage to vehicles	29,911	61,636

Source: Appraisal Guidelines for Metro Rail Projects Proposals, 2017, MOH&UA, GOI

Note: 2004 costs are updated using average inflation rate

Table 104 : Estimation of Savings in Road Stress Reduction

Reduction in Maint. Cost Rs Million/Year

Major impacted roads length - Km	1180
Average annual maintenance Rs Million/Km	0.93
Total annual maintenance Rs Million	1101
Reduction in Maint. Cost Rs Million/Year	**110**

Reduction in Widening Cost Rs Million/Year

Major impacted roads length - Km	590
Average widening cost Rs Million/Km	320
Total widening cost Rs Million	188800
Reduction in widening Cost Rs Million/Year	**47200**

10.6 Economic Analysis – EIRR & NPV for 30 Years

As part of the economic feasibility analysis, the feasibility parameters developed are shown in Table 105. A more detailed economic feasibility analysis is given in Table 105.

- Economic Internal Rate of Return (EIRR)
- Economic Net Present Value (ENPV)

Table 105 : Economic Cost-Benefit Analysis

Details	Present Value (Rs. Million) a/, b/
Costs	
Capital costs	404290
O&M costs	50454
Total costs	454744
Benefits	
Savings in Travel Time Cost	92190
Savings in VOC	312067
Savings in Reduction of Accidents	75
Pollution Reduction Benefits	887
Reduced Road Infrstructure Costs	105303
Total benefits	510523
Economic Return Measures	
Net present value (Rs. Million)	55780
EIRR (%)	16.08 %

a/ In 2019 prices.

b/ Discounted at 14% EOCC

10.7 Sensitivity Analysis

Sensitivity analysis was carried out to their economic feasibility results for the following scenarios is presented in Table 106:

- Capital cost increase by 20%
- O&M costs increased by 20%
- Target beneficiaries reduced by 20%
- Delay in accrual of benefit by 1 year
- Combined adverse condition

Table 106 : Results of Sensitivity Analysis

Details	EIRR (%)	ENPV @14% (Rs Million)	MIRR (%)	SV
Main Evaluation (Base Case)	16.08%	55,780	12.49%	
20% Capital Cost Overrun	13.22%	(25,078)	11.70%	13.8%
20% O&M Cost Overrun	15.73%	45,689	12.38%	110.6%
20% Decrease in Project Benefits	12.23%	(46,325)	11.39%	10.9%
One Year Delay in Implementation	16.10%	49,383	12.50%	
All Four Tests Combined	9.52%	(1,20,053)	10.49%	

SV = Switching Value; MIRR = Modified Internal Rate of Return; ENPV = Economic Net Present Value; EIRR = Economic Internal Rate of Return

Note:

1. Calculated as the percentage change in a variable required for EIRR to reduce to 14%.
2. Discounted at 14% of EOCC.
3. MIRR, is the internal rate of return of an investment that is modified to account for the difference between re-investment rate and investment return.

10.8 Outcome on Economic Viability

1. The evaluation has indicated that the proposed SHSR corridor in the state of Kerela with a length of 531.45 km**,** considered under the investment proposals is found to be economically viable, with the calculated **EIRR value exceeding the economic opportunity cost of capital. With the EIRR of 16.08 % and ENPV of Rs. 55780 million @ 14% discount rate,** the proposed SHSR is found to be economically viable for concession period of 30 years. In some of the sensitivity analysis scenarios, EIRRs were found to be marginally lesser to the minimum required rate. This has identified the areas of risk which need to be focussed during implementation. **Additionally, if concession period is increased to 50 years as in case of Financial Analysis, then the benefits accrued will exceed 17% to 18% for the base case and will be postive for all sensitivity cases. Therefore, in light of the tremendous economic benefit, this corridor is highly recommended.**

2. Furthermore, for this investment proposed, the calculated EIRR value is considered minimum estimates of economic return, as there are a number of economic benefits like travel comfort, tourism benefits, employment generation and environment improvement that have not been quantified.

Exhibit 1 : Economic Analysis of Pune SHSR

Base Case	Phase 1		Vijaya wada Metro							(Rs.in Million)		20%	20%	20%		Rs Million
Year	Economic Cost			Economic Project Benefits						Net Benefit	Base Case	Construction Cost (20% Cost Increase Scenario)	O&M Cost (20% O&M Cost Increase Scenario)	Net Benefits (20% Benefits Reduction Scenario)	One year Delay	Combined Effect (Worst Scenario)
	Capital Cost	O&M Cost	Total	VOC Savings	Time savings	Savings in Reduction of Accidents	Pollution Reduction Benefits	Reduced Road Infrstructure Costs	Total							
2,019	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-
FY 21	73,042	-	73,042	-	-	-	-	-	-	(73,042)	-73042	-87,650.87	(73,042)	-73,042.39	-	-
FY 22	1,64,784	-	1,64,784	-	-	-	-	41,064	41,064	(1,23,720)	-123720	-1,56,676.84	(1,23,720)	-1,31,932.83	(73,042)	(87,651)
FY 23	1,58,191	-	1,58,191	-	-	-	-	41,064	41,064	(1,17,127)	-117127	-1,48,764.91	(1,17,127)	-1,25,339.56	(1,23,720)	(1,64,890)
FY 24	1,21,295	-	1,21,295	-	-	-	-	41,064	41,064	(80,231)	-80231	-1,04,490.28	(80,231)	-88,444.03	(1,17,127)	(1,56,978)
FY 25	60,124	6,974	67,098	18,127	57898	16	165	41,064	1,17,269	50,172	50172	38,146.71	48,777	26,717.67	(80,231)	(1,12,703)
FY 26	-	7,511	7,511	18,869	61,002	16	173	96	80,156	72,646	72646	72,645.55	71,143	56,614.29	50,172	13,298
FY 27	-	7,906	7,906	19,763	64,106	16	182	96	84,164	76,258	76258	76,258.07	74,677	59,425.28	72,646	55,112
FY 28	-	8,327	8,327	20,658	67,210	17	191	96	88,172	79,845	79845	79,844.59	78,179	62,210.26	76,258	57,844
FY 29	-	8,967	8,967	21,553	70,314	17	200	96	92,179	83,212	83212	83,212.11	81,419	64,776.24	79,845	60,545
FY 30	-	9,446	9,446	21,867	72,577	17	206	96	94,763	85,317	85317	85,317.13	83,428	66,364.54	83,212	62,983
FY 31	-	10,300	10,300	22,181	74,839	18	213	96	97,347	87,046	87046	87,046.45	84,986	67,577.12	85,317	64,475
FY 32	-	11,116	11,116	21,580	77,102	18	219	96	99,015	87,899	87899	87,899.29	85,676	68,096.25	87,046	65,517
FY 33	-	11,696	11,696	22,250	79,365	19	226	96	1,01,955	90,258	90258	90,258.47	87,919	69,867.53	87,899	65,873
FY 34	-	12,315	12,315	22,920	81,627	19	232	96	1,04,894	92,579	92579	92,579.00	90,116	71,600.14	90,258	67,528
FY 35	-	14,772	14,772	23,590	83,890	19	239	96	1,07,834	93,062	93062	93,062.32	90,108	71,495.55	92,579	69,137
FY 36	-	15,550	15,550	24,260	86,153	20	245	96	1,10,773	95,223	95223	95,223.19	92,113	73,068.51	93,062	68,541
FY 37	3,695	16,380	20,075	24,930	88,415	20	251	96	1,13,713	93,638	93638	92,898.95	90,362	70,895.38	95,223	69,958
FY 38	12,933	17,623	30,556	25,600	90,678	20	258	96	1,16,653	86,097	86097	83,509.98	82,572	62,766.08	93,638	66,880
FY 39	6,799	18,565	25,364	26,271	92,941	21	264	96	1,19,592	94,228	94228	92,867.97	90,515	70,309.41	86,097	56,655
FY 40	17,331	19,569	36,900	26,941	95,203	21	271	96	1,22,532	85,632	85632	82,165.29	81,718	61,125.19	94,228	65,237
FY 41	2,476	21,922	24,398	27,611	97,466	22	277	96	1,25,471	1,01,073	101073	1,00,577.98	96,689	75,978.89	85,632	53,745
FY 42	-	23,063	23,063	28,281	99,729	22	284	96	1,28,411	1,05,348	105348	1,05,347.70	1,00,735	79,665.51	1,01,073	71,099
FY 43	-	24,280	24,280	29,389	1,02,330	23	291	96	1,32,129	1,07,849	107849	1,07,849.42	1,02,993	81,423.58	1,05,348	75,053
FY 44	-	26,182	26,182	30,498	1,04,932	23	298	96	1,35,847	1,09,665	109665	1,09,665.04	1,04,429	82,495.55	1,07,849	76,568
FY 45	-	27,566	27,566	31,607	1,07,534	23	306	96	1,39,566	1,12,000	112000	1,11,999.83	1,06,487	84,086.68	1,09,665	77,259
FY 46	-	29,042	29,042	32,716	1,10,135	24	313	96	1,43,284	1,14,242	114242	1,14,242.47	1,08,434	85,585.67	1,12,000	78,574
FY 47	-	31,312	31,312	33,824	1,12,737	24	321	96	1,47,002	1,15,690	115690	1,15,690.43	1,09,428	86,289.97	1,14,242	79,777
FY 48	-	32,991	32,991	34,933	1,15,339	25	328	96	1,50,721	1,17,729	117729	1,17,729.34	1,11,131	87,585.23	1,15,690	80,028
FY 49	-	34,783	34,783	36,042	1,17,940	25	335	96	1,54,439	1,19,656	119656	1,19,655.74	1,12,699	88,767.97	1,17,729	80,987
FY 50	-	37,496	37,496	37,151	1,20,542	26	343	96	1,58,157	1,20,661	120661	1,20,661.23	1,13,162	89,029.80	1,19,656	81,811
FY 51	-	40,677	40,677	38,259	1,23,144	26	350	96	1,61,875	1,21,198	121198	1,21,198.40	1,13,063	88,823.32	1,20,661	81,531
FY 52	-	42,855	42,855	39,368	1,25,745	27	358	96	1,65,594	1,22,738	122738	1,22,738.45	1,14,167	89,619.70	1,21,198	80,688
FY 53	-	46,272	46,272	40,291	1,28,694	27	366	96	1,69,475	1,23,202	123202	1,23,202.38	1,13,948	89,307.42	1,22,738	81,049
FY 54	-	48,755	48,755	41,236	1,31,712	28	374	96	1,73,447	1,24,692	124692	1,24,691.86	1,14,941	90,002.49	1,23,202	80,053
FY 55	-	-	-	(50,814)	-	29	-	96	(50,689)	(50,689)	-50689	-50,689.49	(50,689)	-40,551.59	1,24,692	80,251
									Total	25,24,047	25,24,047	23,99,913	23,91,205	17,62,261	25,74,737	15,45,835
									ENPV	55,780	55,780	-25,078	45,689	-46,325	49,383	-1,20,053
									EIRR	16.08%	16.08%	13.22%	15.73%	12.23%	16.10%	9.52%
									MIRR	12.49%	12.49%	11.70%	12.38%	11.39%	12.50%	10.49%
									SV			13.8%	110.6%	10.9%		
ENPV @14%	4,04,290	50,454	4,54,744	92,190	3,12,067	75	887	1,05,303	5,10,523							

10.9 FINANCIAL ANALYSIS and non fare BOX revenue assessment

10.9.1 Introduction

The chapter seeks to examine the financial viability of the proposal of Semi high speed rail corridor between Thiruvananthapuram and Kasaragod. Based on the optimum routes discussed with KRDCL and covered in the previous chapters, a new line is proposed connecting the Northern most and southern most districts of Kerela namely Thiruvananthapuram and Kasaragod. On account of the poor soil conditions and inadequate road infrastructure, the line promises to change both passenger and freight traffic movement in the state of Kerela.

This chapter evaluates the financial feasibility of Semi high speed rail corridor between Thiruvananthapuram and Kasaragod. The proposed corridor would be constructed at an approximate cost of 55765 Crores at FY 19 prices. This includes all central and state taxes. The total cost of land acquisition works out to 11407 Crores. However, a Joint Development agreement is proposed with the land owners due to which the upfront cash out for land works out to 6844 Crores. The total cost of EIA and R &R works out to 1811 crores at FY 19 price levels.

Table 107 : Project Cost Details

Sr. No	Swargate to Katraj Corridor	Distance (KMs)	FY 19 Prices	Completion Cost basis (Escalated Cost @ FY 25 Levels)
1	Basic Cost - Without Land EIA and R&R and taxes	531.45	47110	59234
2	Cost Including Land, EIA, R&R and Taxes	531.45	55765	66079

Design cost of 2% and PMC costs of 4% are assumed as a percentage of the basic project costs excluding Land, EIA & R&R cost.

Construction period start is assumed in FY 21 and period of construction is assumed as 4 years. Start of operations is assumed FY 25. The investment of 55765 Crores broken down by year is presented in the table below. An escalation of 5% is assumed during the construction period. The total initial investment required to be done including escalation during construction works out to 66079 Crores (without imposition of Capital structure).

Table 108 : Project Cost Phasing

Financial Year	Estimated Cost with Land cost and with all taxes at FY 19 Price Level (Crore)	Completion Cost including cost of land cost taxes & duties (Crore)
FY 21	7984	8359
FY 22	16879	18857
FY 23	14893	18102
FY 24	10876	13880
FY 25 – Year of Opération	5134	6880
TOTAL	55765	66079

As per notification released by the press information bureau, Government of India, Ministry of Finance on 18th January 2018, GST rate on construction of metro and monorail projects (construction, erection, commissioning or installation of original works) has been reduced from 18% to 12%. The same has been considered for calculation of taxes.

Imports form a major part of the initial investment. KRDCL SHSR is eligible for availing concessional project import duty. Therefore Basic Custom Duty is taken at concessional rate of 5.14%. IGST is assumed to be levied at 18 % on the above giving us an effective rate of custom duty of 24.07%.

Although construction is expected to get over by March 2024, the cash flow will spill over to March 2025, on account of payment normally required to be made to various contractors upto that period necessitated by contractual obligations.

10.9.2 Investment towards Rolling Stock

Total investment provided in the FIRR calculation towards requirement of additional rolling stock duly escalated @ 5% per annum to cater increased ridership is placed in table as follows:

Year	2024	2030	2040	2051
Rolling Stock Requirement	189	228	314	400
Rolling Stock Procurement Plan	228		172	

10.9.3 O&M Costs

Energy Charges – Energy consumption figures for traction and auxiliary power over a 30 year period has been detailed below:

	Consumption (Million Units)	Energy Rate per Unit	Energy Cost (Cr.)
FY 25 - Start of Phase 1	277	5	127
FY 26	277	5	147
FY 27	277	5	147
FY 28	277	5	147
FY 29	277	6	169
FY 30	277	6	169
FY 31	342	6	208
FY 32	342	7	239
FY 33	342	7	239
FY 34	342	7	239
FY 35	342	8	275
FY 36	342	8	275
FY 37	342	8	275
FY 38	342	9	316
FY 39	342	9	316
FY 40	342	9	316
FY 41	436	11	464
FY 42	436	11	464
FY 43	436	11	464
FY 44	436	12	533
FY 45	436	12	533
FY 46	436	12	533
FY 47	436	14	614
FY 48	436	14	614

FY 49	436	14	614
FY 50	436	16	706
FY 51	436	16	837
FY 52	517	16	837
FY 53	517	19	962
FY 54	517	19	962

Grid electricity charges are taken as 6.62 INR per KWH. 75% is assumed to be drawn from the grid and 25% from solar as per RESCO model. Solar charges are taken as 4 INR/KWH.

10.9.4 Employee Costs

The O&M staff is assumed to be provided @ 5.6 persons per kilometer (Mumbai Ahmedabad HSR Feasibility Estimates staff per km@ 8 persons. However, taking a sensitivity for labor and outsourced staff, the same has been rationalized). As per the experience of DMRC and BMRCL metros, the average annual salary of Rs. 7.77 lakh per annum is considered. Further, the average salary is increased by 15% to account for the impact of Pay commission. Thus, the average annual staff salary considered for the corridors is Rs. 8.94 Lakhs in the year 2018. The escalation factor used for staff costs is 5 % per annum till FY 25 and 8% post FY 25 to provide for growth in salaries.

10.9.5 Maintenance Costs

Maintenance costs have been arrived at basis the table below. It works out to 0.51 Cr/km/year. Basis for the same is as per the table below:

Table 109 : Per unit cost of repairs and Maintainance

Maintenance Cost	0.45	Cr/ km/ year
Rolling Stock including POH	2%	of Capital Expenditure
P-Way and System	2.5	Cr/10 Km

Summary of O & M expenditure is as follows:

Table 110 : Year wise summary of Operation and Maintainance expenses

Financial Year	Energy Expense (Cr.)	Employee benefit expense (Cr.)	O & M Expenditure (Cr.)	Total(Cr.)
FY 25 - Start of Phase 1	127	357	318	802
FY 26	147	383	334	863
FY 27	147	412	350	909
FY 28	147	443	368	957
FY 29	169	476	386	1031
FY 30	169	512	405	1086
FY 31	208	550	426	1184
FY 32	239	591	447	1278
FY 33	239	636	469	1344
FY 34	239	684	493	1416

FY 35	275	735	688	1698
FY 36	275	790	722	1787
FY 37	275	849	758	1883
FY 38	316	913	796	2026
FY 39	316	981	836	2134
FY 40	316	1055	878	2249
FY 41	464	1134	922	2520
FY 42	464	1219	968	2651
FY 43	464	1311	1016	2791
FY 44	533	1409	1067	3009
FY 45	533	1514	1121	3168
FY 46	533	1628	1177	3338
FY 47	614	1750	1235	3599
FY 48	614	1881	1297	3792
FY 49	614	2023	1362	3998
FY 50	706	2174	1430	4310
FY 51	837	2337	1502	4676
FY 52	837	2513	1577	4926
FY 53	962	2701	1656	5319
FY 54	962	2904	1738	5604

10.9.6 Depreciation

Depreciation has been calculated both as per Companies Act and Income tax Act in order to account for:

- Benefit from the depreciation tax shield
- Calculate unabsoarbed depreciation and pass on benefit to tax payable

However, deferred tax asset/ deferred tax liability is not routed through the balance sheet as it is a non cash item.
Salvage value is considered as zero for ease of calculation.

10.9.7 Replacement Cost

The replacement cost are provided for meeting the cost on account of replacement of equipment due to wear and tear. With the nature of equipment proposed to be provided, it is expected that only 50% of signalling and telecom and 25% of electrical works would require replacement after 15 years.

10.10 Revenue

The revenue streams for the project are detailed as under:

- Fare Box Revenue
- Non Fare Box Revenue
- Premium levy from property development along the development corridor
- Sharing of Cess on stamp duty with PMC
- Property Development on available Government Land
- Advertising Revenue
- ATMs/ Kiosks on Stations

10.10.1 Fare Box Revenue

Fare box revenue sources are identified as follows:

1. Fare box revenues from passenger traffic.
2. Fare box revenues from Roll On Roll Off freight vehicles

Passenger Fare box revenue have been calculated by adopting fare structure of 2.75 INR/km/passenger. A Sensitivity of revenue collection vs Fare is covered in the table below.

Table 111 : Fare sensitivity analysis

Fare of SHSR (Rs/Km)	Annual Fare revenue (Rs Cr)	Dailly Rider Ship
1.00	886	121,300
1.50	1152	105,200
2.00	1300	89,000
2.75	1362	67,800
3.00	1364	62,300
3.50	1339	52,400
4.00	1294	44,300
5.00	1179	32,300
6.00	1069	24,400
8.00	870	14,900

As can be seen above, Fare box revenue is maximised at 2.75 INR/km/passenger. The above table comprises non-escalated rates. Therefore, the above rate is chosen for maximisation of passenger fare box collection. Average trip length is considered as 200 km and average number of working days per year is considered as 360 days. Yearly escalation of 7.5% is taken in the fare rates. Ridership figures taken in calculating fare box passenger revenue is listed in table below:

Table 112 : Ridership over horizon years

Horizon Year	Daily Ridership
2024	67740
2028	82266
2040	116681
2051	147120

Roll On Roll Off Freight traffic is another revenue segment planned for maximisation operation during lean hours i.e. from 22:00 to 6:00 Hours. The basis for arriving at revenue per truck (non escalated) can be seen in table below:

Table 113 : RORO Operation Plan

Hours of Operation	22:00 - 6:00 Hours	
No of Trains Up & Down	8	
No of Wagons	31	
Total no of Wagons	248	
Total No of Trucks	496	

Revenue	10000	for 531.45 km
Average Trip Length	531.45	
Revenue for average trip length	10000	
Revenue per truck	178.56	

Yearly escalation for RORO fares taken as 5%.

10.10.2 Minimisation of Cash Outflow for Land

Total cost of land is 11407 Crores. In order to minimise the cash outflow of the state government while ensuring stable returns and monetisation of ill-liquid asset for the landowner, it is proposed:

1. Land owner be paid 60% of the cost upfront
2. Balance 40% be paid such that 8.4% annualised returns can be ensured to the land owners.

FY 25 onwards, this amount would be promised as tax exempt annuity payment over a period of 30 years.

Table 114 : Cash Flow for Landowner tax exempt

	Cash Flow for Land Owner tax exempt (Cr.)
FY 21	-2624
FY 22	-2624
FY 23	0
FY 24	0
FY 25	135
FY 26	149
FY 27	166
FY 28	183
FY 29	203
FY 30	425
FY 31	465
FY 32	510
FY 33	558
FY 34	612
FY 35	1228
FY 36	1345
FY 37	1472
FY 38	1612
FY 39	1764
FY 40	1931
FY 41	2112
FY 42	2311
FY 43	2535
FY 44	2781
FY 45	3049
FY 46	3343
FY 47	3663

FY 48	4014
FY 49	4396
FY 50	4814
FY 51	5270
FY 52	5768
FY 53	6328
FY 54	6943

10.10.3 Non- Fare box source of Revenue

Non-fare box revenue sources are detailed as below:
1. Revenue from Levy of additional stamp duty by Government of Kerala.
2. Property Development on land at station
3. Revenue from application of TOD Policy along the corridor.

While 1 & 2 are covered in detail below along with assumptions, a Preliminary analysis reveals that FAR of 4 is already allowable in Kerala. Therefore, additional revenue from premium on Property Development due to enhanced FAR can be perused at DPR stage. With regard to 1 & 2, various assumptions are listed in table below:

Table 115 : Revenue from additional stamp duty

Revenue from Stamp Duty to Government of Kerala	2800.00	Crores
Stamp Duty Rate	8%	
Property Registration Volume	35000.00	Crores
1% Additional Stamp Duty	350.00	Crores
Escalation Rate for Above Non Fare Box Income	3%	

Table 116 : Revenue from Property Development

Area for PD at Station	2	Acre
FAR	4	
Area per station	348480.00	Sft
Total Area	5227200.00	
Leasing Rate	15.00	Per Sft/ Month
Income from Leasing	94.09	Cr
Escalation for leasing	3%	

Table 117 : Summary of Fare box & Non farebox revenue

Financial Year	Revenue Fare Box - Net of outflow for JDA for land	Revenue Non-Fare Box (Cr.)			Total Income (CR.)
		Inflow from Advertising, train wrapping etc	Other Income		
			Leasing of PD at Station	LBT share of Registration	
FY 25 - Start of Phase 1	2045	195	106	350	2697
FY 26	2301	221	109	359	2990
FY 27	2584	250	112	368	3313
FY 28	2896	282	115	377	3669
FY 29	3240	317	118	386	4061
FY 30	3379	351	120	396	4247
FY 31	3735	389	123	406	4653
FY 32	4124	431	127	416	5098
FY 33	4551	477	130	426	5584
FY 34	5019	528	133	437	6117
FY 35	4973	583	136	448	6140
FY 36	5481	644	140	459	6724
FY 37	6038	710	143	471	7362
FY 38	6647	783	147	482	8059
FY 39	7313	863	150	495	8821
FY 40	8042	950	154	507	9653
FY 41	8839	1045	158	520	10562
FY 42	9710	1150	162	533	11554
FY 43	10696	1268	166	546	12677
FY 44	11776	1398	170	560	13904
FY 45	12958	1540	174	574	15246
FY 46	14251	1696	179	588	16713
FY 47	15664	1866	183	603	18316
FY 48	17210	2052	188	618	20068
FY 49	18899	2256	193	633	21981
FY 50	20745	2479	197	649	24070
FY 51	22761	2722	202	665	26351
FY 52	24964	2988	207	682	28841
FY 53	27441	3288	213	699	31640
FY 54	30165	3617	218	716	34716

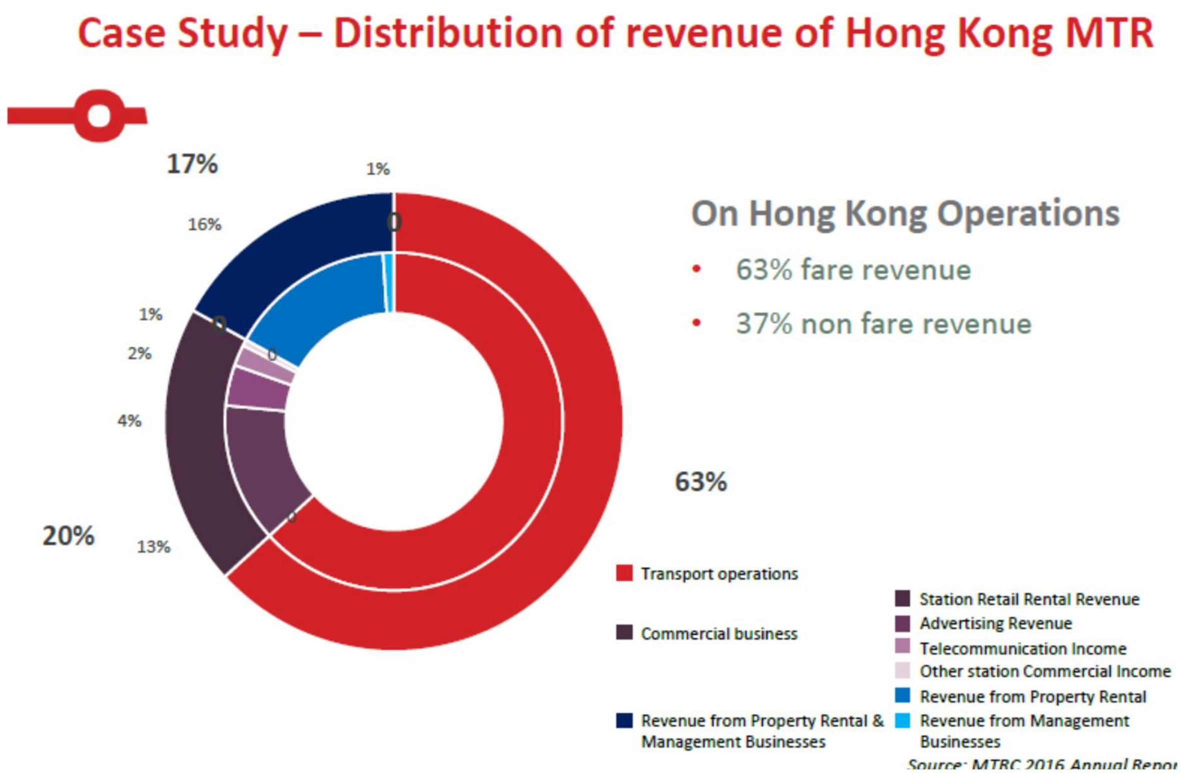
10.10.4 Financial Internal Rate of Return

The Financial Internal rate of return has been calculated in two scenarios – With concession period of 30 years and concession period of 50 years. The **financial internal rate of return** at completion cost basis with farebox and non fare box revenue with additional revenue sources (Other Income) from improved FSI along the development corridor (TOD) and cess from stamp duty works out to **5.6 %** with concession period of 30 years and **8.1 %** concession period of 50 years. **This is the project IRR without imposition of the capital structure.** The detail is given in the Exhibit 1 at the end of chapter.

The profit and loss statement and cash flow statement are attached in the exhibit. While unabsorbed depreciation is considered while calculating tax pay-out, since deferred tax is a non cash item, we have not routed it through the balance sheet.
Additionally there is a monetary grant from Government of Kerala and KRDCL generated by granting a 50 year capital lease on the owned land. From an accounting treatment perspective, monetary grant is treated as other equity in the balance sheet and not as Other Income. The other equity can be treated as deferred revenue year on year and phased out from the balance sheet. However in this model, the other equity item is not phased out.
Also, Salvage value is considered as zero for ease of calculation

10.10.5 Funding Options

The objective of the exercise is not just financial closure but to achieve financial closure while ensuring availability of lowest cost of funds while procuring and creating sustainable systems to achieve optimal project costs. It, being a public utility service, analysis of life cycle costs – low maintenance cost and longer life spans; must be done to ensure optimal project costs. Fares must be set which minimize dependence on subsidies. Returns must accrue to both direct and indirect beneficiaries. Additionally, one must draw on experience of metro projects the world over with regard to funding patterns. Experience from successful metro projects Singapore, Hong Kong suggests between 60% to 100% government capital contribution as metro projects typically yield high economic benefits reflected in the substantially better economic IRRs of the project.
Hong Kong has one of the highest non fare box revenue collections in the world at 37% and yet 66% of the capital contribution comes from the government. This underlines the fact that government funding is required despite exploring non fare box revenue sources well.



10.10.6 Financing Options

The operational metro services in India have adopted a similar capital structure. This DMRC/ BMRC/ CMRL pattern of financing is discussed in detail below. Another method of financing is through a public private partnership. **However PPP mode will present several challenges the most major being:**

- **Access to low cost fund – 1% interest rate from multilateral funding agencies.**
- **Mode of sharing of monetary and non monetary grants by PMC will have the lowest cost in case the asset is owned by a GoI and state controlled SPV structure**
- **This is an extension of an existing asset. The rolling stock however being added is for the entire section and not just the extended portion. Therefore, there will be sharing of both capital revenue which will prove challenging of the extended portion is hived off to a private party.**

10.10.7 DMRC/BMRC/CMRL pattern of Financing

A special purpose vehicle is set up for project implementation and subsequent operation and maintenance. Equity contributions are made by:

- Government of India
- State Government
- Urban Local Bodies.

Typically Government of India makes up to 20% equity contributions at the maximum. The project cost taken for equity contribution excludes cost of land acquisition and R&R. A portion of the above will be in the form of subordinated debt which would include taxes, land etc. 20% is funded by either local bodies or state Governemnt again in the form of equity or grants. Balance 60% constitutes loans from multilateral funding agencies.
Bi-lateral funded loan @ 1.4 % per annum

Table 118 : JICA ODA Loan terms

S.n.	Parameter	Value
1	Annual Interest rate for loan (As per JICA Funding)	1.40%
2	Front end fee	0.1%
3	Repayment Period	30 Years
4	Moratorium Period	10 Years
5	Payment Schedule	Yearly

In this case, the Government of Kerala and Government of India are major contributors with cash equity contribution about 7720 Cr. each.
Equity IRR works out to 8.9% for 30 year concession period and 11% for 50 year concession period. Refer exhibit 2 for detail.

Table 119 : Project Capital structure – SPV Mode loan @1.4%

Capital Structure		
Debt	**34454**	**52%**
IDC	**727**	**1%**
Equity		
Ministry of Railways	7720	12%
Government of Kerala	7720	12%
GoK / Urban Local Body- Land EIA and R&R	8656	13%
SubOrdinated Debt		
GoI	3564	5%
GoM	3564	5%
Total	**66405**	
Other Equity - Deferred Revenue (Real Estate for PD)	3485	

The phasing of the equity and term loan contributions are detailed as follows:

Table 120 : Phasing of equity and loan term – SPV Mode loan @1.4%

PARTICULARS	Year wise contribution					
	FY 21	FY 22	FY 23	FY 24	FY 25	TOTAL
State Government						
State Taxes (SGST)	474	1031	959	735	365	3564
Construction Cost	281	1844	2593	1974	1011	7703
Front End/ Commitment Fee	17.2				0	17
Sub Total (State Government)	772	2875	3552	2709	1376	11285
State Government						
Land, EIA and R&R	4328	4328	0	0	0	8656
Sub Total (GoK)	4328	4328	0	0	0	8656
Central Government						
Central Taxes (CGST)	474	1031	959	735	365	3564
Construction Cost	281	1844	2593	1974	1011	7703
Front End/ Commitment Fee	16.7				0	17
Sub Total (Central Government)	772	2875	3552	2709	1376	11284
JICA						
Construction Cost	2452	8812	11093	8694	4128	35181
Sub Total (JICA)	2452	8812	11093	8694	4128	35181
TOTAL	8324	18891	18197	14112	6880	66405
State Government						
Other Equity - Deferred Revenue (Real Estate for PD)					3485	3485

10.10.8 Conclusion and Recommendation

Government backed SPV model is most suitable. Equity contribution will be required to the tune of about 7720 Crores to be committed both by Government of Kerala and Ministry of Railways. Joint Development aggreements is to explored with land owners for bringing down the land cost from ~15000 to ~6000 Crores. Following topics will need to be covered in detail at the DPR stage:

- Assessment of Land Bank and Monetisation by Government of Kerala
- Assessment of Land Bank and Monetisation by Ministry of Railways
- Additional Revenue sources from application of TOD Policy

EXHIBIT 1 – Project IRR

	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25 - Star	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35	FY 36
Revenue Fare Box							2045	2301	2584	2896	3240	3379	3735	4124	4551	5019	4973	5481
Revenue Non Fare Box																		
Inflow from Advertising, train wrapping etc							195.2	221.1	249.8	281.5	316.6	351.3	389.5	431.3	477.3	527.7	583.0	643.6
Other Income																		
Leasing of PD at Station							106.5	109.1	111.8	114.6	117.5	120.4	123.5	126.5	129.7	132.9	136.3	139.7
LBT share of Registration							350.0	358.8	367.7	376.9	386.3	396.0	405.9	416.0	426.4	437.1	448.0	459.2
Total Income							**2697**	**2990**	**3313**	**3669**	**4061**	**4247**	**4653**	**5098**	**5584**	**6117**	**6140**	**6724**
Energy Expense							127.4	146.5	146.5	146.5	168.5	168.5	208.1	239.3	239.3	239.3	275.2	275.2
Employee Benefit Expense							356.5	383.3	412.0	442.9	476.1	511.8	550.2	591.5	635.9	683.5	734.8	789.9
O&M Expediture							317.6	333.5	350.2	367.7	386.1	405.4	425.6	446.9	469.3	492.7	687.9	722.3
Total Expenses							**802**	**863**	**909**	**957**	**1031**	**1086**	**1184**	**1278**	**1344**	**1416**	**1698**	**1787**
Depreciation							2030	2030	2030	2030	2030	2030	2030	2030	2030	2030	1573	1573
Finance costs																		
Profit/ Loss Before Tax							**-135**	**96**	**374**	**681**	**1000**	**1131**	**1439**	**1790**	**2210**	**2671**	**2870**	**3364**
Income Tax Payable							0	21	81	147	215	244	310	386	486	903	986	1132
Profit/ Loss for the Year							**-135**	**76**	**293**	**535**	**784**	**887**	**1129**	**1404**	**1724**	**1768**	**1883**	**2232**
Cash Flow Statement																		
Cash Outflow																		
Capital Expenditure			-8359	-18857	-18102	-13880	-6880	0	0	0	0	0	0	0	0	0	0	0
Principal Repayment																		
Cash Inflow																		
PAT							-135	76	293	535	784	887	1129	1404	1724	1768	1883	2232
Depreciation							2030	2030	2030	2030	2030	2030	2030	2030	2030	2030	1573	1573
Interest During Construction																		
Debt Drawdown																		
Equity - Cash Flow from Property Development - Deferred Revenue							1742	1742										
Balancing Equity																		
Net Cash Flow to Equity		0	-8359	-18857	-18102	-13880	-3242	3848	2324	2565	2815	2918	3159	3435	3754	3798	3456	3805
Project IRR with Concession period of 30 years		**5.6%**																
Project IRR with Concession period of 50 years		**8.1%**																
Balance Sheet																		
Uses of Fund																		
Cash							-3242	606	2930	5494	8309	11227	14386	17821	21575	25373	28829	32634
Fixed Asset - Gross Block							66079	66079	66079	66079	66079	66079	66079	66079	66079	66079	66079	66079
Accumulated Depreciation*							2030	4061	6091	8121	10151	12182	14212	16242	18272	20303	21876	23449
CWIP		0	8359	27216	45318	59198												
Net Block							64048	62018	59988	57958	55927	53897	51867	49836	47806	45776	44203	42630
Total Asset		**0**	**8359**	**27216**	**45318**	**59198**	**60806**	**62624**	**62917**	**63452**	**64236**	**65124**	**66253**	**67657**	**69381**	**71149**	**73032**	**75264**
Sources of Fund																		
Equity																		
Shareholder's Fund		0	8359	27216	45318	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198
Retained Earning							-135	-59	234	769	1553	2441	3570	4974	6698	8466	10349	12581
Other Equity							1742	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485
Non Current Liabilities																		
Term Loan		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities		**0**	**8359**	**27216**	**45318**	**59198**	**60806**	**62624**	**62917**	**63452**	**64236**	**65124**	**66253**	**67657**	**69381**	**71149**	**73032**	**75264**

	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42	FY 43	FY 44	FY 45	FY 46	FY 47	FY 48	FY 49	FY 50	FY 51	FY 52	FY 53	FY 54
Revenue Fare Box	6038	6647	7313	8042	8839	9710	10696	11776	12958	14251	15664	17210	18899	20745	22761	24964	27441	30165
Revenue Non Fare Box																		
Inflow from Advertising, train wrapping etc	710.1	782.9	862.6	949.9	1045.4	1149.9	1268.3	1398.1	1540.3	1695.8	1866.1	2052.3	2256.0	2478.7	2722.1	2988.1	3287.6	3617.0
Other Income																		
Leasing of PD at Station	143.2	146.7	150.4	154.2	158.0	162.0	166.0	170.2	174.4	178.8	183.3	187.8	192.5	197.4	202.3	207.4	212.5	217.8
LBT share of Registration	470.7	482.5	494.5	506.9	519.6	532.6	545.9	559.5	573.5	587.9	602.5	617.6	633.1	648.9	665.1	681.7	698.8	716.2
Total Income	**7362**	**8059**	**8821**	**9653**	**10562**	**11554**	**12677**	**13904**	**15246**	**16713**	**18316**	**20068**	**21981**	**24070**	**26351**	**28841**	**31640**	**34716**
Energy Expense	275.2	316.4	316.4	316.4	463.9	463.9	463.9	533.5	533.5	533.5	613.5	613.5	613.5	705.5	836.6	836.6	962.1	962.1
Employee Benefit Expense	849.2	912.9	981.3	1054.9	1134.0	1219.1	1310.5	1408.8	1514.5	1628.0	1750.2	1881.4	2022.5	2174.2	2337.3	2512.6	2701.0	2903.6
O&M Expediture	758.4	796.3	836.2	878.0	921.9	968.0	1016.4	1067.2	1120.5	1176.6	1235.4	1297.2	1362.0	1430.1	1501.6	1576.7	1655.5	1738.3
Total Expenses	**1883**	**2026**	**2134**	**2249**	**2520**	**2651**	**2791**	**3009**	**3168**	**3338**	**3599**	**3792**	**3998**	**4310**	**4676**	**4926**	**5319**	**5604**
Depreciation	1573	1384	1892	1892	2389	2389	2389	2389	2389	2389	2389	2389	2158	2158	2158	1882	1882	1882
Finance costs																		
Profit/ Loss Before Tax	**3906**	**4649**	**4795**	**5512**	**5653**	**6514**	**7497**	**8505**	**9688**	**10986**	**12328**	**13886**	**15825**	**17602**	**19518**	**22034**	**24440**	**27230**
Income Tax Payable	1348	1627	1683	1938	1991	2295	2642	2987	3380	3828	4322	4874	5558	6185	6859	7742	8586	9552
Profit/ Loss for the Year	**2558**	**3022**	**3112**	**3574**	**3662**	**4219**	**4855**	**5518**	**6308**	**7158**	**8006**	**9012**	**10267**	**11418**	**12659**	**14292**	**15853**	**17678**
Cash Flow Statement																		
Cash Outflow																		
Capital Expenditure	-1181	-4134	-3575	-10447	-1492	0	0	0	0	0	0	0	0	0	0	0	0	0
Principal Repayment																		
Cash Inflow																		
PAT	2558	3022	3112	3574	3662	4219	4855	5518	6308	7158	8006	9012	10267	11418	12659	14292	15853	17678
Depreciation	1573	1384	1892	1892	2389	2389	2389	2389	2389	2389	2389	2389	2158	2158	2158	1882	1882	1882
Interest During Construction																		
Debt Drawdown																		
Equity - Cash Flow from Property Development - Deferred Revenue																		
Balancing Equity																		
Net Cash Flow to Equity	2950	272	1428	-4982	4559	6608	7244	7908	8698	9547	10396	11402	12425	13576	14817	16173	17735	19560
Project IRR with Concession period of 30 years																		
Project IRR with Concession period of 50 years																		
Balance Sheet																		
Uses of Fund																		
Cash	35584	35856	37284	32302	36861	43469	50714	58621	67319	76866	87261	98663	111088	124663	139480	155654	173389	192948
Fixed Asset - Gross Block	66079	66170	66508	66558	66558	66558	66683	67143	67211	67211	67211	67211	67211	67211	67211	67211	67211	67211
Accumulated Depreciation*	25022	26406	28297	30189	32579	34968	37357	39747	42136	44525	46915	49304	51462	53619	55777	57658	59540	61421
CWIP																		
Net Block	41057	39765	38210	36369	33980	31590	29326	27396	25075	22686	20297	17907	15750	13592	11435	9553	7672	5790
Total Asset	**76641**	**75621**	**75494**	**68672**	**70841**	**75060**	**80040**	**86017**	**92394**	**99552**	**107558**	**116570**	**126838**	**138256**	**150915**	**165207**	**181060**	**198738**
Sources of Fund																		
Equity																		
Shareholder's Fund	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198	59198
Retained Earning	15139	18161	21273	24846	28508	32727	37582	43100	49408	56566	64572	73585	83852	95270	107929	122221	138074	155753
Other Equity	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485
Non Current Liabilities																		
Term Loan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Liabilities	**77823**	**80844**	**83956**	**87529**	**91191**	**95410**	**100265**	**105783**	**112091**	**119249**	**127255**	**136268**	**146535**	**157953**	**170612**	**184904**	**200757**	**218436**

* Salvage Value considered as 0 for ease of calculation

** Deferred tax Asset/ DTL not routed through B/S s it is a non cash item and impact on B/S is 0

*** Working Capital Requirement not worked out

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EXHIBIT 2 – SPV Mode Loan @1.4%

P&L Statement	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25 - Sta	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	FY 32	FY 33	FY 34	FY 35
Revenue Fare Box							2045	2301	2584	2896	3240	3379	3735	4124	4551	5019	4973
Revenue Non Fare Box																	
Inflow from Advertising, train wrapping etc							195	221	250	282	317	351	389	431	477	528	583
Other Income							0	0	0	0	0	0	0	0	0	0	0
Leasing of PD at Station							106	109	112	115	118	120	123	127	130	133	136
LBT share of Registration							350	359	368	377	386	396	406	416	426	437	448
PCNTDA Dev Fee							0	0	0	0	0	0	0	0	0	0	0
Total Income							**2697**	**2990**	**3313**	**3669**	**4061**	**4247**	**4653**	**5098**	**5584**	**6117**	**6140**
Energy Expense							127	147	147	147	169	169	208	239	239	239	275
Employee Benefit Expense							357	383	412	443	476	512	550	591	636	684	735
O&M Expediture							318	334	350	368	386	405	426	447	469	493	688
Total Expenses							**802**	**863**	**909**	**957**	**1031**	**1086**	**1184**	**1278**	**1344**	**1416**	**1698**
Depreciation							2079	2079	2079	2079	2079	2079	2079	2079	2079	2079	1611
Finance costs							453.5	482.4	482.4	482.4	482.4	482.4	482.4	482.4	482.4	482.4	474.3
Profit/ Loss Before Tax							**-637**	**-435**	**-157**	**150**	**469**	**600**	**908**	**1259**	**1679**	**2140**	**2358**
Income Tax Payable							0	0	0	32	101	129	196	271	1125	1153	964
Profit/ Loss for the Year							**-637**	**-435**	**-157**	**118**	**368**	**471**	**712**	**988**	**554**	**987**	**1393**
Cash Flow Statement																	
Cash Outflow																	
Upfront/ Commitment Fee			34.5														
Capital Expenditure			-8359	-18891	-18197	-14112	-6880	0	0	0	0	0	0	0	0	0	0
Principal Repayment							0	0	0	0	0	0	0	0	0	0	-1148
Cash Inflow																	
PAT							-637	-435	-157	118	368	471	712	988	554	987	1393
Depreciation							2079	2079	2079	2079	2079	2079	2079	2079	2079	2079	1611
Interest During Construction			34	95	232	366											
Debt Drawdown			2418	8718	10861	8328	4128	0	0	0	0	0	0	0	0	0	0
Equity - Cash Flow from Property Development - Deferred Revenue							1742	1742									
Balancing Equity from GoK/ GoI							2752	0									
Net Cash Flow to Equity		0.0	-5871.8	-10078.5	-7103.9	-5417.8	3184.4	3386.7	1921.9	2197.0	2446.7	2549.8	2791.4	3066.7	2633.2	3066.2	1855.5
		0	-5872	-10078	-7104	-5418	432	3387	1922	2197	2447	2550	2791	3067	2633	3066	1855
Equity IRR with period as 30 years		**8.9%**															
Equity IRR with concession period = 50 years																	
Balance Sheet																	
Uses of Fund																	
Cash							3184	6571	8493	10690	13137	15686	18478	21545	24178	27244	29099
Fixed Asset - Gross Block							66405	66405	66405	66405	66405	66405	66405	66405	66405	66405	66405
Accumulated Depreciation ***							2079	4158	6237	8316	10395	12474	14553	16632	18712	20791	22401
CWIP			8324	27215	45412	59525											
Net Block							64326	62247	60168	58089	56010	53931	51851	49772	47693	45614	44004
Total Asset		**0**	**8324**	**27215**	**45412**	**59525**	**67510**	**68818**	**68661**	**68779**	**69146**	**69617**	**70329**	**71317**	**71871**	**72858**	**73103**
Sources of Fund																	
Equity																	
Shareholder's Fund			5872	15950	23054	28472	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224
Retained Earning							-637	-1072	-1229	-1111	-743	-273	440	1427	1982	2969	4362
Other Equity							1742	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485
Non Current Liabilities																	
Term Loan			2452	11265	22358	31053	35181	35181	35181	35181	35181	35181	35181	35181	35181	35181	34032
Total Liabilities		**0**	**8324**	**27215**	**45412**	**59525**	**67510**	**68818**	**68661**	**68779**	**69146**	**69617**	**70329**	**71317**	**71871**	**72858**	**73103**
* Salvage Value considered as 0 for ease of calculation																	
** Deferred tax Asset/ DTL not routes through B/S s it is a non cash item and impact on B/S is 0																	
*** Working Capital Requirement not worked out										602							

P&L Statement	FY 36	FY 37	FY 38	FY 39	FY 40	FY 41	FY 42	FY 43	FY 44	FY 45	FY 46	FY 47	FY 48	FY 49	FY 50	FY 51	FY 52	FY 53	FY 54
Revenue Fare Box	5481	6038	6647	7313	8042	8839	9710	10696	11776	12958	14251	15664	17210	18899	20745	22761	24964	27441	30165
Revenue Non Fare Box																			
Inflow from Advertising, train wrapping etc	644	710	783	863	950	1045	1150	1268	1398	1540	1696	1866	2052	2256	2479	2722	2988	3288	3617
Other Income	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leasing of PD at Station	140	143	147	150	154	158	162	166	170	174	179	183	188	193	197	202	207	213	218
LBT share of Registration	459	471	482	495	507	520	533	546	560	574	588	603	618	633	649	665	682	699	716
PCNTDA Dev Fee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Income	**6724**	**7362**	**8059**	**8821**	**9653**	**10562**	**11554**	**12677**	**13904**	**15246**	**16713**	**18316**	**20068**	**21981**	**24070**	**26351**	**28841**	**31640**	**34716**
Energy Expense	275	275	316	316	316	464	464	464	533	533	533	614	614	614	706	837	837	962	962
Employee Benefit Expense	790	849	913	981	1055	1134	1219	1311	1409	1514	1628	1750	1881	2023	2174	2337	2513	2701	2904
O&M Expediture	722	758	796	836	878	922	968	1016	1067	1121	1177	1235	1297	1362	1430	1502	1577	1656	1738
Total Expenses	**1787**	**1883**	**2026**	**2134**	**2249**	**2520**	**2651**	**2791**	**3009**	**3168**	**3338**	**3599**	**3792**	**3998**	**4310**	**4676**	**4926**	**5319**	**5604**
Depreciation	1611	1611	1417	1925	1925	2423	2423	2423	2423	2423	2423	2423	2423	2191	2191	2191	1915	1915	1915
Finance costs	458.2	442.2	426.1	410.0	393.9	377.8	361.8	345.7	329.6	313.5	297.5	281.4	265.3	249.2	233.1	217.1	201.0	184.9	168.8
Profit/ Loss Before Tax	**2868**	**3426**	**4190**	**4351**	**5084**	**5241**	**6119**	**7118**	**8142**	**9342**	**10655**	**12013**	**13588**	**15543**	**17336**	**19268**	**21799**	**24221**	**27028**
Income Tax Payable	957	1179	1467	1528	1789	1848	2158	2510	2861	3259	3714	4212	4770	5460	6092	6772	7661	8511	9482
Profit/ Loss for the Year	**1910**	**2247**	**2723**	**2823**	**3296**	**3394**	**3961**	**4608**	**5282**	**6082**	**6940**	**7801**	**8818**	**10083**	**11244**	**12496**	**14139**	**15711**	**17546**
Cash Flow Statement																			
Cash Outflow																			
Upfront/ Commitment Fee																			
Capital Expenditure	0	-1181	-4134	-3575	-10447	-1492	0	0	0	0	0	0	0	0	0	0	0	0	0
Principal Repayment	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148	-1148
Cash Inflow																			
PAT	1910	2247	2723	2823	3296	3394	3961	4608	5282	6082	6940	7801	8818	10083	11244	12496	14139	15711	17546
Depreciation	1611	1611	1417	1925	1925	2423	2423	2423	2423	2423	2423	2423	2423	2191	2191	2191	1915	1915	1915
Interest During Construction																			
Debt Drawdown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equity - Cash Flow from Property Development - Deferred Revenue																			
Balancing Equity from GoK/ GoI																			
Net Cash Flow to Equity	2372.3	1527.7	-1142.3	24.2	-6374.9	3175.6	5235.6	5882.3	6555.7	7356.3	8214.6	9075.0	10091.7	11125.2	12286.3	13538.1	14904.9	16477.1	18312.4
	2372	1528	-1142	24	-6375	3176	5236	5882	6556	7356	8215	9075	10092	11125	12286	13538	14905	16477	18312
Equity IRR with period as 30 years																			
Equity IRR with concession period = 50 years																			
Balance Sheet																			
Uses of Fund																			
Cash	31472	32999	31857	31881	25506	28682	33918	39800	46356	53712	61926	71002	81093	92218	104505	118043	132948	149425	167737
Fixed Asset - Gross Block	66405	67586	71720	75295	85742	87235	87235	87235	87235	87235	87235	87235	87235	87235	87235	87235	87235	87235	87235
Accumulated Depreciation ***	24012	25623	27040	28965	30890	33313	35736	38158	40581	43003	45426	47849	50271	52462	54653	56844	58758	60673	62588
CWIP																			
Net Block	42393	41963	44680	46330	54852	53922	51499	49077	46654	44232	41809	39386	36964	34773	32582	30391	28477	26562	24647
Total Asset	**73865**	**74963**	**76537**	**78212**	**80359**	**82604**	**85417**	**88877**	**93010**	**97944**	**103735**	**110388**	**118057**	**126991**	**137087**	**148434**	**161424**	**175987**	**192384**
Sources of Fund																			
Equity																			
Shareholder's Fund	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224	31224
Retained Earning	6272	8518	11241	14064	17360	20754	24715	29323	34605	40687	47627	55428	64246	74329	85573	98068	112207	127918	145464
Other Equity	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485	3485
Non Current Liabilities																			
Term Loan	32884	31735	30587	29438	28290	27142	25993	24845	23696	22548	21399	20251	19102	17954	16805	15657	14508	13360	12212
Total Liabilities	**73865**	**74963**	**76537**	**78212**	**80359**	**82604**	**85417**	**88877**	**93010**	**97944**	**103735**	**110388**	**118057**	**126991**	**137087**	**148434**	**161424**	**175987**	**192384**

11. ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

11.1 GENERAL PHYSICAL ENVIRONMENT

Kerala is considered the "Gateway of South India". This is one of the States of India attracting large number of tourists and having the highest literacy rate. Kerala State lies between Latitude 8° 18' & 12° 48'N and Longitudes 74° 52' & 72° 22'E. This land of eternal beauty encompasses 1.18% of the country.

Kerala is located in the south western part of India with Arabian Sea coastline on the west. It is bordered by Karnataka on the North and by Tamil Nadu on the South and East. Kerala extends over an area of 38,863 sq. km. It has a total coastline of 590 km. Its width varies from 120 km at its maximum and just 30 km at its minimum.

11.1.1 Climate

The climate of Kerala is tropical monsoon with seasonally excessive rainfall and hot summer. The Western Ghats plays a major role in the climatic conditions that prevail all along the state. The period of March to the end of May is the hot season which is the summer. This is followed by South West Monsoon season that continues till the beginning of October. From October to December is the North East Monsoon season and two months, January and February, are the winter. The climate is pleasant from September to February. Classification of Seasons are presented in below Table.

Table 121: Classification of Seasons of Kerala

S. No.	Seasons	Duration
1	Wet Season a. Kalavarsha (South West Monsoon) b. Thulavarsha (North East Monsoon)	 June to September October to December
2	Dry Season (Winter)	January to February
3	Hot Season (Summer)	March to May

11.1.2 Rainfall

The average annual rainfall of the state is 3000mm, the bulk of which (70%) is received during the South-West monsoon which sets in by June and extends up to September. Approx. 90% of the total annual rainfall is received during the southwest and Northeast monsoon period. The actual rainfall received during Southwest monsoon last year (from 1st June 2018 to 30th September 2018) was 2515.7mm as against the normal total rainfall of 2923.4 mm during the years. Annual rainfall and month wise breakup for the 2012 to 2017 is given in below Table.

Table 122: Kerala Monthly and Annual Rainfall (in mm): 2012 - 2017

Source: IMD

Year	Month												Total for the year
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2012	7.4	9.1	29.6	197.5	83.8	444.6	360.6	502.6	240.0	189.3	113.4	9.7	**2187.6**
2013	3.9	40.1	49.9	49.3	119.3	1042.7	830.2	369.7	318.6	259.9	154.9	17.0	**3255.5**
2014	4.6	10.3	17.9	95.7	251.0	454.4	677.8	733.9	298.8	355.5	99.5	47.2	**3046.6**
2015	3.1	5.8	50.1	214.0	201.8	563.8	406.2	252.2	293.4	309.9	223.2	79.5	**2603.0**
2016	3.0	16.4	22.4	33.3	258.4	595.7	441.5	231.0	84.1	105.1	57.9	22.0	**1870.8**
2017	12.7	0.3	87.8	52.8	213.3	579.8	378.5	462.6	435.5	228.0	152.1	61.4	**2664.8**
Monthly Average	**5.7**	**13.7**	**42.9**	**107.1**	**187.9**	**613.5**	**515.8**	**425.3**	**278.4**	**241.3**	**133.5**	**39.5**	**2604.7**

11.1.3 Soil

Kerala, being situated in the humid tropical zone with heavy precipitation and high temperatures has given rise to widely varying soil groups from similar parent materials. They are forest soil, laterite soil, red soil, alluvial soil, peat soil, sandy soil, and black soil. Though the main geological formation of the state belongs to the Archean period consisting of crystalline and metamorphic rocks, climate and topography seem to be the dominant soil forming factors. The soil types and its characterizes are given in the below Table.

Table 123: Soil and its characteristics

S.No.	Soil Groups	Physiographic Division	Elevation Above MSL (metre)	Period	Parent Material	Relief	Vegetation
1	Laterite	Midland /dry	70	Tertiary	Detrial	Hilly	Orchard Trees
2	Forest Soil	Highland /dry	1000	Archean	Residual Gneissic	Rolling	Monsoon Forest
3	Alluvial soil	Coastal water logged	Sea level	Quaternary	Alluvial clay	Flat	Rice
4	Sandy soil	Coastal dry	6	Quaternary	Alluvial Sand	Flat	Rice
5	Red soil	Coastal dry	15	Coastak Dry	Aeoliean red earth	Undulating	Cocoanut
6	Black soil	Highland dry	100	Dharwar	Residual basaltic	Undulating	Rice
7	Peaty soil	Midland water logged	Sea level	Cenozoic	Alluvial Peat	Flat	Rice

11.1.4 Water Resources

In case of the water resources, Kerala is having both abundance and scarcity. The average annual rainfall of the state is 3000mm, the bulk of which (70%) is received during the South-West monsoon which sets in by June and extends up to September.

The rapidly falling terrain, heavy precipitation and the narrow width of the state have given rise to numerous rivers. Kerala has got 41 west-flowing and 3 east-flowing rivers, most of them originating from the Western Ghats and draining into the Arabian Sea. The total annual yield of all these rivers together is 78.041 Million Cubic Meters (MCM) of which 70,323 MCM is in Kerala.

The important rivers from north to south are; Valapattanam river (110 km), Chaliar (69 km), Kadalundipuzha (130 km), Bharathapuzha (209 km), Chalakudy river (130 km), Periyar (244 km), Pamba (176 km), Achancoil (128 km) and Kalladayar (121 km). Other than these, there are 35 more small rivers and rivulets flowing down from the Ghats.

11.1.5 Forest

Forest cover of Kerala is largely spread over the Western Ghats which border the state. The recorded forest area is 11524.411 sq. km. The percentage of forest cover in Kerala is 29.65% which is higher than the national coverage of 23.24%. This includes 9339.186 sq. km reserve forests, 284.218 sq. km is proposed and 1837.79 sq. km vested forest. The total plantation area accounts approx. 13.46% of the total forest area. Forest Types in Kerala are enumerated in below Table.

Table 124: Classification of Forest Area

S. No.	Type	Area (KM^2)	% of total
1	Reserve Forest	9339.186	81.04
2	Proposed Reserved	284.218	02.47
3	Vested Forest	1763.757	15.30
4	Ecologically Fragile Land	137.222	01.19
	Total	11524.411	

Source: Administrative Report 2016-17, Kerala Forest & Wildlife Department

11.1.6 Biodiversity

Kerala, hailed as the biodiversity paradise of India, accommodates the culture of over two hundred plant species in its wet, garden and dry lands making it an evergreen tract of unique ecological significance. Kerala having land areas of only about 1.12 percent of the country, houses about 25% of the biodiversity of the county. This when viewed against the fact that India, a mega- diversity country with 2.4% of the land area of the world, accounts for only 7-8% of the recorded species of the world, highlights the richness of the biodiversity of the state. Details of the biodiversity of the state is given in the below Tables.

Table 125: Flora Diversity Statistics

S.NO.	FLORA	INDIA	KERALA	% to the Indian Flora
1	Flowering Plants	17500	4500	25.71
2	Gymnosperms	64	4	6.25
3	Pteridophytes	1100	236	21.45
4	Bryophytes	2850	350	12.28
5	Lichens	2000	520	26.00
6	Algae	6500	325	5.00
7	Fungi	14500	4800	33.10

Table 126: Fauna Statistics

S.NO.	FAUNA	WORLD	INDIA	KERALA
1	Fishes	31,000	2439	196
2	Amphibians	6184	277	117
3	Reptiles	8734	408	159
4	Birds	9782	1179	484
5	Mammals	5416	410	145

11.2 KEY ENVIRONMENTAL LAWS AND REGULATIONS

The Government of India has issued Environmental Impact Assessment Notification in 1994, as a part of Environmental (Protection) Act, 1986 and amendments in September 2006. Railway projects do not fall under any category requiring an environmental clearance from MoEFCC. Only 'No Objection Certificate' (NOC) is required from SPCB under the Air and Water Acts for operating various equipment during construction works.

The environmental Acts, Rules and Norms which are generally relevant to Semi High Speed Rail Projects are listed below:

- Environment Protection Act- 1986
- Environmental Impact Assessment Notification -14th September 2006 and its amendment
- Air (Prevention and Control of Pollution) Act, 1981
- Water (Prevention and Control of Pollution) Act,1974
- Noise Pollution (Regulation and Control Act), 2000
- Forests (Conservation) Act, 1980 and its amendments
- The Forest (Conservation) Rules, 1981
- The State Forest Acts
- The Wild Life (Protection) Act, 1972 and its amendments
- National Green Tribunal Act, 2010
- National Green Tribunal (Prevention and Protection) Rules, 2011
- The Biological Diversity Act 2002
- Coastal Regulation Zones Rules 2011 with amendment dated 18th January 2019
- Wetlands (Conservation and Management) Rules, 2010
- Solid Waste (Handling and Management) Rules 2016
- Construction and Demolition (C&D) Waste Management Rules, 2016
- Hazardous and Other Wastes (Management and Transboundary Movement) Rules 2016

11.3 NATURAL HAZARD AND VULNERABILITY ASSESSMENT

The state of Kerala is vulnerable to a multitude of hazards and is categorized as a multiple-hazard prone state. The state experiences various kinds of disasters of recurrent nature that results in loss of life, livelihood and property, and disruption of economic activity, besides causing immense hardship to the affected population.

11.3.1 Floods

In Kerala, riverine flooding is a recurring event consequent to heavy or continuous rainfall exceeding the absorptive capacity of soil and flow capacity of streams and rivers. This causes the water course to overflow its banks onto flood plains. These flood plain by definition is a relatively flat land adjacent to a natural water course, composed primarily of unconsolidated depositional material derived from sediments transported by the related stream and subjected to periodic flooding. Reclamation and settlement in floodplain areas is a major cause of damage due to floods in Kerala.

The most affected areas in last flood 2018 were Aluva and Paravoor in Ernakulam district, Ranni and Pandalam in Pathanamthitta district, Kuttanad and Chengannur in Alappuzha district, Mananthavady and Panamaram in Wayanad district, and Munnar and Cheruthoni in Idukki district. The District level flood prone area in sq.km and in percentage are presented in below Table

Table 127: Flood prone area in each district

District	Area km²	Area%	District	Area km²	Area%
Thiruvananthapuram	268.09	12.23	Idukki	38.78	0.89
Kollam	283.62	11.41	Thrissur	688.44	22.65
Alappuzha	762.57	53.77	Malappuram	601.67	16.93
Pathanamthitta	212.76	8.00	Palakkad	567.16	12.66
Kottayam	461.33	20.95	Kozhikkode	288.83	12.30
Ernakulam	718.94	23.50	Wayanad	215.39	10.11
Kannur	339.18	11.45	Kasaragod	198.79	9.99

Source: CESS, 2010. Plan Project 249 for taluk wise area

11.3.2 Landslides

The term landslide includes a broad range of different types of motion whereby earth material is dislodged by falling, sliding and flowing under the influence of gravity. In fact, mass movements such as landslides are natural phenomenon that causes landscape changes, threat to life and destruction of property. The most common type of landslides in Kerala is debris flows. Landslides in Kerala commonly occur in localised areas of the Western Ghats region where the slope is steep and the soil is over saturated as a result of prolonged rainfall. The slope in the Western Ghats region is generally steep to very steep with plateau edges highly indented having >25° slope. The study reveals that 1848 km² or 4.75% of the state is under high and 3759 km² or 9.67% under low hazard category. Devikulam, Vythiri, Nilambur, Mannarkad and Ranni are the most landslide prone taluks in the state.

11.3.3 Tsunami

A tsunami is a series of ocean waves that sends surges of water, sometimes reaching heights of over 100 feet (30.5 meters), onto land. These walls of water can cause widespread destruction when they crash ashore.

The Kerala coast located in the shadow zone with respect to the direction of propagation of the tsunami, encountered unexpected devastation on 26th December 2004. Although tsunami affected parts of Kerala coast, maximum devastation was reported in the low coastal land of Kollam, Alleppey and Ernakulam districts, particularly a strip of 10 km in Azhikkal, Kollam district. The tsunami waves attained heights of 3m to 5m and inundated the coastal areas at different times. Figure 69 shows the time of maximum inundation at different locations, Kerala coast.

This varying effect along the coast could be attributed to local amplification of tsunami waves in certain regions. About 176 people were killed and 1600 injured in the coastal belt. Further, the tsunami reached 187 villages affecting nearly 25 lakh persons in Kerala. As many as 6280 dwelling units were uprooted, 11175 were partially damaged and nearly 84773 persons were evacuated from the coastal areas and accommodated in 142 relief camps after tsunami.

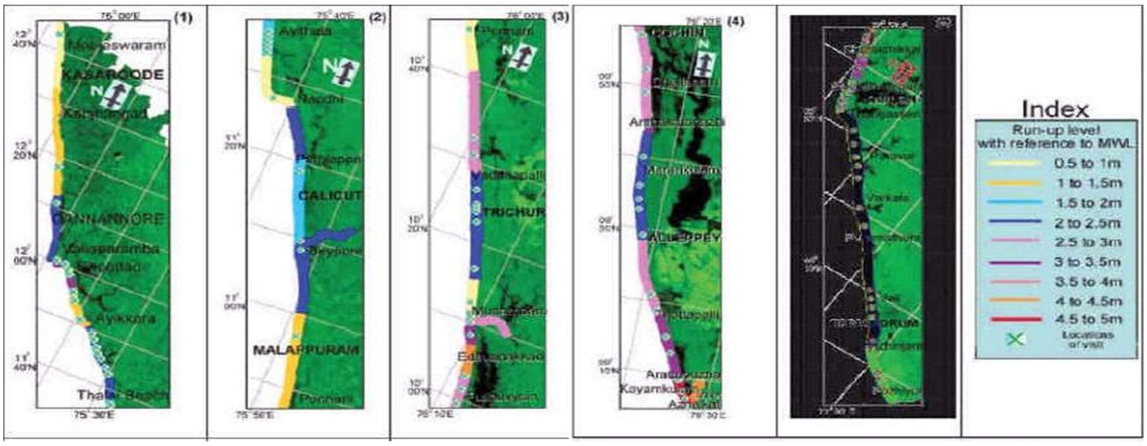

Figure 69: Tsunami run-up level along the Kerala

11.3.4 Coastal hazards

In Kerala, out of the total 14 districts, 9 districts are bordering the sea coasts which are too vulnerable to floods, cyclones and coastal erosion etc. Eroding sectors along the coast in each District, Taluk and whole State is presented in below Table.

Table 128: Eroding sectors along the coast in each District, Taluk and whole State

S. No.	District	Length		Length		Length	
		km	%	Km	%	km	%
		High (without sea wall)		High (with Sea wall)		Low	
1	Thiruvananthapuram	11.9	15.86	15.66	20.88	30.84	41.11
2	Kollam	1.14	2.34	37.77	77.58	0.91	1.86
3	Alappuzha			29.98	37.84	3.7	4.67
4	Ernakulam			33.39	69.02		
5	Thrissur	2.58	3.43	17.37	23.16	0.98	1.3
6	Malappuram			15.4	31.63	6.44	13.23
7	Kozhikode			35.4	44.68	8.47	10.69
8	Kannur			9.33	14.27	17.38	26.58
9	Kasaragod	1.3	1.47	4.34	4.93	28.31	32.15
	Total	**16.91**	**3.02**	**198.63**	**35.47**	**97.02**	**17.33**

Source: CESS, 2010. Plan Project 249 for taluk wise area

11.4 BASELINE ENVIRONMENT AND SOCIAL STATUS

Generation of environmental and social baseline of a project area is an important phase of any Environmental and Social Assessment process. Baseline data provide vital information on the existing environmental and social quality in which development program is planned.

In this study, the environmental and social characteristics of the project area were established through extensive literature search, secondary data available with various Govt. Departments, Research/Academic Institutes and published documents/ research papers.

The proposed Semi High-Speed Rail (SHSR) line project is expected to bring changes that are more positive to the residents along the corridor location and surrounding towns in terms of improving level of modern transportation within the Kerala region with other parts of the country, ease of conducting business, access to markets, medical facilities, schools and other social facilities.

Semi High-Speed Rail offers tangible advantages over other transport modes such as air, conventional rail and private vehicles for medium to long distance journeys. Considering the evaluation of complete life cycle of transportation systems in terms of sustainability, SHSR is one of the most efficient mode of transport. At the same time it combines many of the attributes that we most desire while travelling such as speed, reliability, comfort and safety.

11.4.1 Environmental Baseline Conditions

Physical environment includes air, meteorology, noise, water, soil, land, biological environment includes aquatic and terrestrial flora & fauna while social environment includes demographic details, civic infrastructure, public services, surrounding monuments, commercial facilities, employment levels, sources and levels of income, economic base of the area, land values, land ownership, etc.

Knowledge of the quality of baseline bio-physical surroundings of the impact zone is useful for impact assessment (assessing and predicting the environmental consequences of the significant actions). Hence baseline status of the project corridor area is to be studied in detail during detailed project report.

11.4.2 Air Environment

Ambient Air Quality

Air quality in India is governed by the National Ambient Air Quality Standards (NAAQS) formulated under the Air (Prevention and Control of Pollution) Act, 1981 by Central Pollution Control Board (CPCB). Pollutants that have established national standards are referred to as “criteria pollutants.” Pollutants considered for the proposed Semi High Speed Rail Corridor project are Respirable Suspended Particulate Matter (RSPM), Oxides of Nitrogen (NOx) and Sulphur Dioxide (SO_2).

Ambient air quality is being monitored by Kerala Pollution Control Board for Respirable Suspended Particulate Matter (PM10) Sulphur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) at various industrial and residential locations in different districts along the corridors, this has been analysed for the period 2017. The RSPM (PM10), Sulphur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) levels at all monitoring locations in the project corridor areas were well within the prescribed National Ambient Air Quality Standards for Industrial and Residential areas except one maximum value of RSPM at Kottayam. The summary of Ambient Air Quality results is presented in below Table.

Table 129: Ambient Air Quality Monitoring Data (24-hour average) Year 2017

S. No.	District / City	RSPM (PM10) in µg/m³			Sulphur Dioxide (SO_2) in µg/m³			Nitrogen Dioxide (NO_2) in µg/m³		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	**Thiruvananthapuram**									
	Filatex, Veli (Industrial)	44	57	51	14.70	17.64	16.70	24.04	29.66	26.72
	Pettah (Residential)	45	52	49	6.94	8.85	7.70	24.30	26.96	26.12
2	**Kollam**									
	KMML Chavara (Industrial)	41	64	47	2.0	6.21	3.39	4.50	9.25	6.62
	Kadapakkada (Residential)	24	46	39	2.0	3.61	2.33	4.50	4.50	4.50
3	**Pathanamthitta**									
	Industrial	--	--	--	--	--	--	--	--	--
	Makkamkunnu (Residential)	26	30	28	2.0	2.0	2.0	14.91	16.50	15.94
4	**Alappuzha**									
	D.C.Mills, Pathirapally (Industrial)	42	74	63	2.0	2.0	2.0	4.50	4.50	4.50
	Residential	--	--	--	--	--	--	--	--	--
5	**Kottayam**									
	Vadavathoor (Industrial)	40	101	59	4.53	5.21	4.84	14.23	17.03	14.94
	Nagampadom (Residential)	29	70	41	4.25	4.72	4.42	13.65	15.08	14.19
6	**Idukki**									
	Industrial	--	--	--	--	--	--	--	--	--
	Thodupuzha (Residential)	13	54	34	2.0	2.0	2.0	4.5	4.5	4.5
7	**Ernakulam**									
	TCC Eloor (Industrial)	42	87	56	2.0	2.0	2.0	25.6	42.20	31.97
	South Over bridge (Residential)	26	94	49	2.0	3.51	2.42	6.80	17.37	12.52
8	**Thrissur**									
	Industrial	--	--	--	--	--	--	--	--	--
	Poonkunnam (Residential)	50	70	58	2.0	2.0	2.0	4.50	6.03	5.12

S. No.	District / City	RSPM (PM10) in µg/m³			Sulphur Dioxide (SO_2) in µg/m³			Nitrogen Dioxide (NO_2) in µg/m³		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
9	**Palakkad**									
	Kanjikode (Industrial)	37	55	44	2.0	2.0	2.0	8.48	9.28	8.95
	Residential	--	--	--	--	--	--	--	--	--
10	**Malappuram**									
	Kakkanchery (Industrial)	22	48	32	2.0	2.0	2.0	13.64	27.58	21.24
	Residential	--	--	--	--	--	--	--	--	--
11	**Kozhikode**									
	Nallalam (Industrial)	27	66	48	2.0	2.0	2.0	14.02	21.57	16.77
	KSRTC Bus stand (Residential)	32	63	45	2.0	2.0	2.0	15.40	23.90	18.58
12	**Kannur**									
	Industrial	--	--	--	--	--	--	--	--	--
	Kannur-SAMP (Residential)	44	90	64	2.0	2.0	2.0	4.5	4.5	4.5
13	**Kasaragod**									
	Industrial	--	--	--	--	--	--	--	--	--
	Kasaragod-SAMP (Residential)	23	55	36	2.0	2.24	2.04	4.50	6.25	4.92

11.4.3 Noise Environment

Noise, in general, is sound that is composed of many frequency components of various loudness distributed over the audible frequency range. Various noise scales have been introduced to describe, in a single number, the response of an average human to a complex sound made up of various frequencies at different loudness levels. The most common and universally accepted scale is the 'A' weighted scale which is measured as dB (decibel). This is more suitable for audible range of 20-20,000 Hz and has been designed to weigh various components of noise according to the response of the human ear.

Noise after a certain level can have a very disturbing effect on both the people and animals exposed to it. Hence, it is important to assess the present noise quality of the area in order to predict the potential impact of future noise levels due to the Semi High-Speed Rail Line project.

11.4.4 Water Environment

Water environment consists of water resources and its quality. Its study is important from the point of view to assess the sufficiency of water resources for the needs of the project in its various stages of the project cycle and also to assess the impact of the project on water environment.

11.4.5 Seismicity of Project Area

Based on tectonic features and records of past earthquakes, a seismic zoning map of India has been prepared by a committee of experts under the auspices of Bureau of Indian Standard (BIS Code: IS: 1893: Part I 2002. According to the seismic-zoning map of India, the project area falls in Zone III of seismicity signifying moderate-risk of earthquake. List of historical earthquakes took place in Kerala are presented in Annexure 1. The seismicity map of study area is shown in Figure 70.

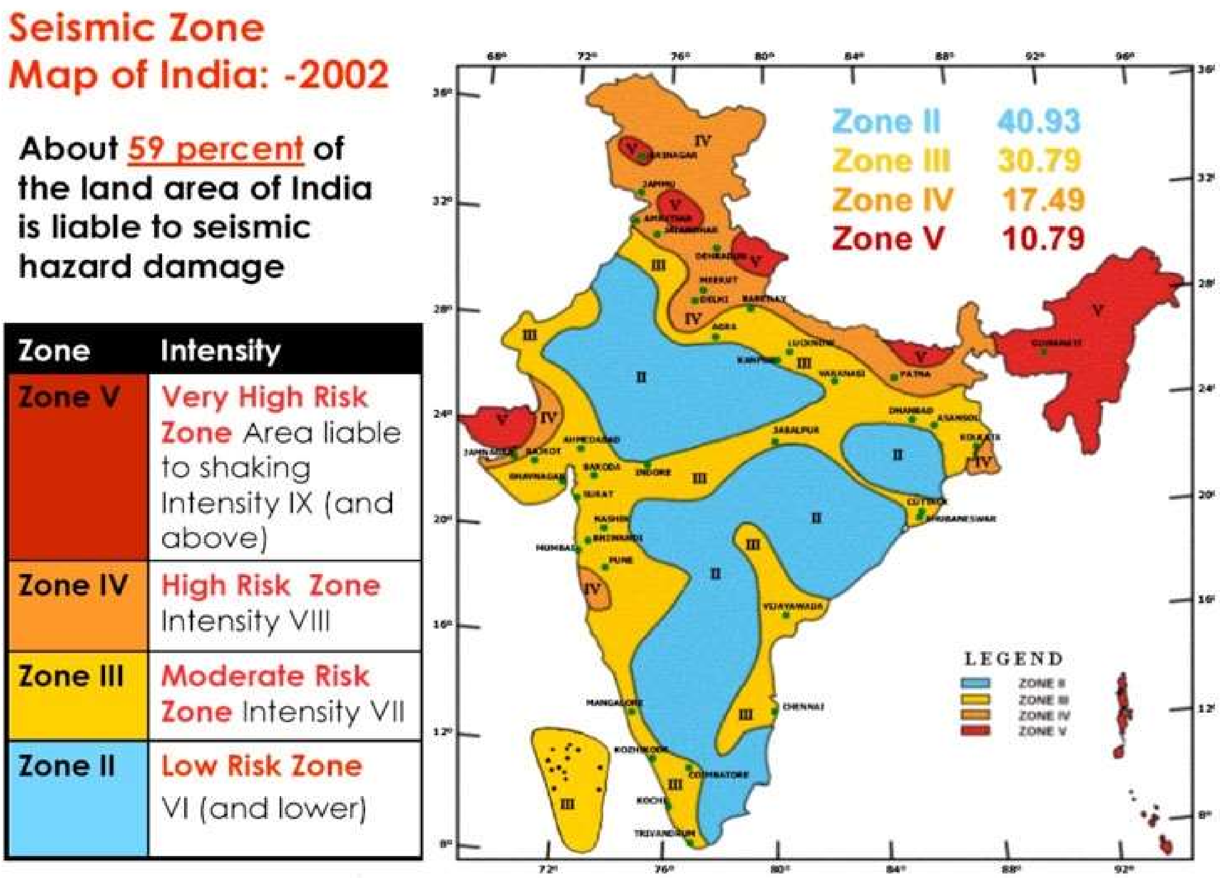

Figure 70: Seismic Zonation and Intensity Map of India

11.4.6 Land Use Pattern

Land use pattern of Kerala reveals that out of a total geographical area of 38.86 lakh hectare is classified according to thirteen different uses of land as given in Table and Figure. The cultivated area of the state comes to around 66.6% of the total geographical area. Within this, the Net Sown Area accounts for 52% and 16.83% of the cultivated area is sown more than once. Area under forest cover consist 28% and 11.37% of the area is put to non- agricultural use. Land Use Pattern in Kerala is shown in below Table and Figure 71.

Table 130: Land Use Pattern in Kerala

S. No.	Classification of Land	Area (Hectare)	Percentage of Geographical areas
1.	Forest	1081509	27.829
2.	Land put to non-agricultural uses	441934	11.371
3.	Barren and uncultivated land	11780	0.303
4.	Permanent Pastures and Grazing land	0	0
5.	Land under miscellaneous tree crops	2450	0.063

S. No.	Classification of Land	Area (Hectare)	Percentage of Geographical areas
6.	Cultivable waste	101379	2.609
7.	Fallow other than current Fallow	55530	1.429
8.	Current Fallow	72008	1.853
9.	Marshy Land	106	0.003
10.	Still Water	98343	2.530
11.	Water Logged Area	3210	0.083
12.	Social Forestry	2556	0.066
13.	Net Area Sown	2015482	51.861
Total		**3886287**	**100**

Source: Directorate of Economics and Statistics, Kerala

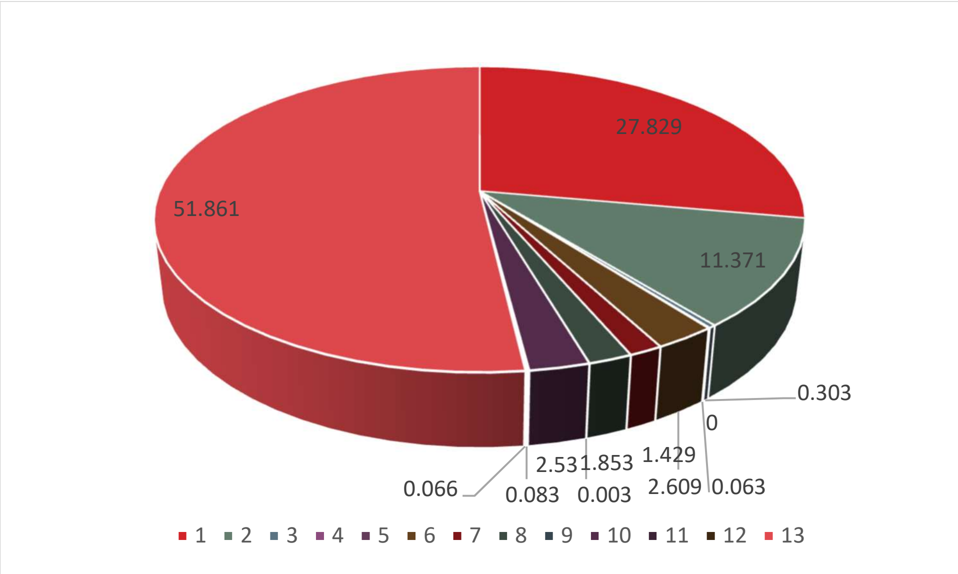

Figure 71: Land Use Pattern of Kerala

11.4.7 Ecological Environment

Ecosystem has self-sustaining capability and control the number of organisms at any level. The objectives of the present study are as follows:

- Understand baseline ecological status including important floristic elements, faunal elements, sensitive habitats and rare species.
- Understand the impact of proposed project on ecological structure of the study area
- Suggest recommendations for maintaining and improvement of the ecosystem

The present study on ecological status of the proposed project is based on secondary data from various governmental and nongovernmental sources. The biodiversity of the state is presented in the table 139 and 140.

11.4.8 Socio-Economic Environment

The proposed planned development of Semi High-Speed Rail Corridor has expected the rapid future growth of the area, subsequently will reduce road traffic and traffic congestions. The proposed rail corridor shall reduce the traffic in addition to contribution in managing better city life. The proposed rail corridor construction and operation needs to be studied from social environment perspectives.

11.4.9 Demographic Profile of Project Area

Demography is one of the important indicators of environmental health of an area. It includes population, sex ratio, number of households, literacy, population density, etc. The socio-economic data used in the section are derived from various sources, including the published data of Census of India, District Census Handbook, electronic media and published reports/journals.

Kerala consists of 14 districts spread over an area of 38863 sq. km. As per the census records 2011, the total population was 33,406,061. Out of this 48% were men and 52% were women. The decadal growth rate of Kerala's population is estimated at 4.9%. The sex ratio (females per 1000 males) of Kerala is 1084 and population density is 860 persons/sq. km. The distribution of population, demographic profile and employment pattern of Kerala is outlined in Annexure 2.

11.5 ENVIRONMENTAL AND SOCIAL IMPACTS

This chapter provides an analysis of the potential impacts likely to emerge from implementation of project activities, they can be positive or negative, direct or indirect. Significant positive impacts are usually associated with improved access, which is the prime objective of the Greenfield Semi High-Speed Rail Corridor project. Rail transport has environmental advantages with respect to both road and air transport modes, due to reduced energy consumption, lower emissions of greenhouse gases and less occupation of land. The total private land required is approximately 87.58% of the total land requirement . The proposed greenfield Semi High-Speed Rail (SHSR), is an important means which contribute to sustainable mobility development.

11.5.1 POSITIVE ENVIRONMENTAL & SOCIAL IMPACTS

Construction Phase

During the construction period, there is a likelihood of having the following impacts:

11.5.1.1 Creation of employment opportunities

Many job opportunities will be available for construction workers during the construction phase of the project. Employment opportunities are a benefit both in economic and social sense. For the construction development un-skilled labour, from the local community, will be hired. Although only during the duration of the project, several workers including casual labourers, masons, carpenters, joiners, electricians and plumbers are expected to work on the site during the construction. Thus, as a result the project would provide substantial direct employment. In addition to these, more people would be indirectly employed for allied activities.

11.5.1.2 Increased trade with construction workers

The construction workers required for the project will provide ready market for various goods and services, leading to several business opportunities for small-scale traders such as shop owners, accommodation providers, and food vendors near the project site.

11.5.1.3 Business opportunities in supply of materials and utilities

This project will require large quantities of construction materials, which will increase revenue for local businesses at project corridor area, such as cement, steel, and other miscellaneous materials required for construction that can be sourced locally.

11.5.1.4 Less Land Requirement

The land requirement for a double track rail corridor is 25m wide RoW which is 3 times less than the requirement for construction of 6 lane highway to cater same amount of traffic. The total estimated corridor length is about 531.45 km. Wherever the corridor is crossing the backwaters or rivers, it will cross through viaduct. Adequate clearance shall be provided under viaduct for passage of boats and ferries.

A preliminary alignment has been prepared which shows that about 1226.45 ha (Hectare) of total land shall be needed for the project as follows:

- Government land : 107.98 ha
- Railways land : 44.28 ha
- Private land : 1074.19 ha

Operational Phase

During the operation phase the following positive impacts are foreseen:

11.5.1.5 Improved transport efficiency for people

The operation of rail corridor (SHSR) and railway stations will improve efficiency of transportation of people, it will also improve connectivity within the major towns of Kerala state. The project will result in direct benefits to users in terms of reduction in vehicle operating costs, savings in travel time, improvement in quality of life, reduction in loss of productivity due to health disorders resulting from pollution and last but not the least substantial reduction in road accidents.

In the present context, the project will streamline and facilitate movement of public from different parts of Kerala. Average speed of travel (Thiruvananthapuram – Kasaragod) is expected to be 130 kmph approximate depending on the type of service (slow, express and very fast) compared to 40 kmph to 60 kmph on the existing main line Railway. The average speed of travel on the existing highway (NH-66) is also at 30 kmph to 40 kmph. So, the SHSR line has the potential to greatly improve transportation and benefit the economy and social life of the people of Kerala. It will greatly improve the opportunity for education and employment, by improving travel to the major universities, colleges and industrial hubs. Stations shall be provided at the following places: Thiruvananthapuram, Kollam, Chengannur, Kottayam, Ernakulam, Thrissur, Tirur, Kozhikode, Kannur and Kasaragod. This corridor will yield benefits in terms of growth in economic activity due to better accessibility, savings in fuel consumption, corresponding reduction in cost of road construction and maintenance, reduction in vehicle operating costs, savings in travel time, improvement in quality of life and reduction in loss of productivity due to health disorders resulting from pollution.

11.5.1.6 Benefits to Economy and Socio – Economic Status

The Semi High Speed Rail will connect ten major towns and cities of Kerala including six most populated cities of the state i.e. Thiruvananthapuram, Kollam, Ernakulam, Thrissur, Kozhikode and Kannur. The operation of rail corridor will lead to easy accessibility for all major towns, thereby attracting new investors and traders in the area. This will translate to economic growth in the area. Additionally, increased presence of investors will have the potential to increase land value for property owners near the railway stations area.

During construction, the project will have clear benefits with regard to local employment opportunities. The project will additionally require various skills and services which may not be available on the local level but certainly on the regional level, e.g. pipe fitters, plumbers, etc. for which appropriate personnel will be contracted.

The increase in employment will temporarily lead to an overall increase of income directly and indirectly (through increased demand of other local services). New businesses will grow such as food vending to construction workers.

11.5.1.7 Improved trade

The trade from and to the city will be improved and this will also give an opportunity for opening up the area around the project site to trade. In addition to opening up the trade centres, the delivery of farm produce, like vegetables, fruits livestock to market centres will be more efficient. Livestock and crop trade are expected to increase because of the ease of transportation coupled with the reduced cost and time of travel.

11.5.1.8 Enhanced delivery of services

This is a long-term impact due to the opening of the Semi High-Speed Rail Corridor, resulting in improved access to social services e.g. health facilities, education opportunities, etc.

11.5.1.9 Reduction of congestion and accidents on Road

One of the key aims of this project is to decongest the highways and decrease the bus and car circulation between Thiruvananthapuram to Kasaragod through an efficient rail transport. The basis of reduction of vehicle is shift of ridership from road vehicle to the Semi High-Speed Rail. The reduction in number of vehicles gives benefits to economy by reduction in Vehicle Operating Cost (VOC), Fuel Consumption, Pollution Load, Accidents and Travel Time etc. On implementation of the project, the consumption of petrol and diesel will get reduced. Summary of daily ridership on the SHSR, considering the probability of shift from the respective mode of transport (i.e. bus, car and train) is shown in below Table.

Table 131: Summary of Ridership

Horizon Year	Daily Ridership
2024	67740
2028	82266
2040	116681
2051	147120

11.5.1.10 Reduction in air pollution from vehicle emissions

Reduction and decongestions of vehicles on the highways translate to reduction of air pollution brought about by emissions from vehicles. The major vehicular air pollutants are Particulate Matter, Nitrogen oxides, Carbon monoxide, Hydro Carbons and Carbon dioxide. In addition, un-burnt products like aldehydes, formaldehydes, acrolein, acetaldehyde and smoke are by-products of vehicular emissions.

Deaths per 1,00,000 people from ambient PM 2.5 in South Asia (Bangladesh, India, Nepal and Pakistan) in year 2013 was 51. Welfare losses from ambient PM2.5 in South Asia in year 2013 was estimated at USD 256 billion or 3.1% of GDP; respective labour output foregone was estimated at USD 31.4 billion or 0.39% of GDP.

Welfare losses from air pollution in India in year 2013 was estimated at USD 505 billion and labour output foregone was estimated at USD 55 billion (The cost of air pollution - Strengthening the Economic Case for Action, World Bank IHME 2016).

11.5.1.11 Impact on Green House Gas (GHG) Emission

Road transport, the dominant mode of transport in India, emits 87% of total CO_2e emissions from the transport sector. The rail transport in comparison to all mode of transport emits only 5% of the total CO_2e emissions. As per the traffic survey conducted by IMaCS in 2017 at 11 locations along the project corridor

between Thiruvananthapuram to Kasaragod , the GHG emission has been estimated to be 3120328 Tonnes CO_2e in 2019 and it will be 4584786 Tonnes CO_2e in year 2024, without SHSR operation.
The Semi High-Speed Rail will reduce GHG emissions in the state by giving travellers a more efficient option for mid- to long-range trips. Every kilometre travelled on semi high-speed rail is a kilometre not travelled by automobile. The emissions associated with these less-efficient forms of travel will be significantly reduced. The GHG emission reductions is associated with the mode shift from conventional rail, cars, buses and trucks. The Semi High-Speed Rail corridor will reduce emissions from 2024 onwards, the first year of operation, as passengers switch over from conventional rail, cars and buses to SHSR. The annual GHG emission reductions forecasted for the horizon years 2024, 2028, 2040, and 2051 are presented in below Table. GHG savings are worked out as per the projected ridership. GHG savings are directly related to ridership. Higher the ridership, greater the GHG emission savings.

Table 132: GHG Emission Reduction

Horizon Year	Greenhouse Gas Reduction (Tonnes CO_2e/Year)
2024	213897
2028	237664
2040	293175
2051	381898

11.5.1.12 Aesthetic quality

The new rail corridor as well as new railway station, with its associated access road and other amenities will improve the aesthetics of the area, leading to improvement from its current situation.

11.5.1.13 Revenue to national and local governments

Through payment of relevant taxes, rates and fees to the government and the local authority, the project will contribute towards the national and local revenue earnings from those using the improved facilities, and any resultant increase from economic activities brought about by the improved situation.

11.5.1.14 Improved Drainage

One of the key enhancements of the railway station is the drainage system. It will integrate the existing infrastructure and topography such that it efficiently manages the surface runoff and avoid flooding at the station during heavy rains.

11.5.1.15 Improved Security

The access road to the railway station and its amenities such as pedestrian footpaths, street and flood lights will enhance the security in the area, which is currently lacking for commuters. This will encourage more commuters served by the station and the surrounding areas to use the railway transport.

11.5.1.16 Tourism

By providing faster intercity travel along the coastal belt which is known for endless beaches, famous backwaters of Kollam, Thiruvananthapuram, Varkala, Alleppey, Kochi, Thrissur, Kozhikode, Kannur, Bekal and Kasaragod, the SHSR will boost tourism. Access to the major religious places such as Sree Padmanabha Swami temple at Thiruvananthapuram, Vadakkunnathan Temple at Thrissur, and Guruvayoor Lord Krishna Temple near Thrissur will also attract tourism with SHSR line. Travel on SHSR line itself is likely to become a tourist attraction.

11.5.2 NEGATIVE ENVIRONMENTAL IMPACTS

Anticipated negative impacts due to various activities envisaged for each of the following environmental components:

11.5.2.1 Air Quality

The impact on air quality during the construction phase is envisaged due to fugitive dust emission from construction activities and gaseous emissions from construction equipments, vehicles and generator set. Implementation of adequate mitigation measures such as regular water sprinkling on construction sites and providing cover over the dust generating construction materials during transportation would improve the air quality of the area. All vehicles, equipments and machineries used for construction will be regularly maintained to ensure that the emission level conform to the stipulated norms and "Pollution under Control" certificate will be kept up-to-date and checked. Hence, overall impacts on the ambient air quality during construction phase will be temporary & only for a short duration during construction and reversible in nature.

During operation phase the impacts on the ambient air quality shall be insignificant. SHSR Line is an eco-friendly project and will help to reduce dependency on road transportation, thus reducing cause for Green House effect or GHG emission.

11.5.2.2 Noise and Vibration

Some noise will be generated due to operation of construction machines. Modern technologies producing low noise may be used during construction. Periodical inspection and effective maintenance of vehicle and equipment shall be ensured. The construction yards located near sensitive receptors should be provided with noise barriers. Protective devices like ear muff, ear plugs to be provided to the workers at construction site.

The vibrations should be reduced considerably by ensuring and keeping correct track geometry by advanced measurement. However, these noise and vibration sources will be of temporary nature and were operated mostly during day-time and for short duration.

11.5.2.3 Impacts on Flora

The major impact in this project on flora involves the removal of trees on both private and public lands to permit construction and to provide clear zone for safety of the users. Trees growing within the ROW need to be removed for efficient construction workmanship and more importantly to prevent collision with the trees, in case of accident. The removal of trees could adversely affect vegetation cover and local landscape and may lead to habitat fragmentation and loss.

Appropriate compensatory plantation using suitable native species or pollution tolerant species will be initiated as per the applicable state level tree felling and preservation acts to compensate for the vegetation loss due to felling of trees during site clearing for construction activities. Joint field verification should be conducted with State Forest Department to agree and mark trees to be cut. This will avoid uncontrolled and indiscriminate tree felling. The rate of replacement shall be decided by the State Forest Department.

11.5.2.4 Seismicity of Project Area

According to the seismic-zoning map of India, the project area falls in Zone III of seismicity signifying moderate-risk of earthquake. Adequate measures will be taken in the design of tunnels, bridges, viaducts, cuttings and embankment for the long-term stability of the double track section as well as station building, depot in the event of an earthquake.

11.6 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

The purpose of the Environmental and Social Management Plan (ESMP) is to initiate a mechanism for implementing mitigation measures for the potential negative environmental and social impacts and monitor the efficiency of these mitigation measures based on relevant environmental indicators. An environmental and social management strategy would be developed based on a hierarchy of impact avoidance, minimization, mitigation and control of residual impacts, for planning, construction and operation phases for all the relevant environmental and social attributes. ESMP describes administrative aspects of ensuring that mitigatory measures shall be implemented and their effectiveness is monitored over the entire life cycle of the project. The ESMP should address the following:

- To provide evidence of practical and achievable plans for the management of the proposed project.
- To provide the Proponent and the relevant Lead Agencies with a framework to confirm compliance with relevant laws and regulations.
- To provide community with evidence of the management of the project in an environmentally acceptable manner.

The ESMP will address the identified potential negative impacts and mitigation measures in the following project stages:

- During planning phase ESMP
- During construction phase ESMP and
- During operational phase ESMP

11.7 ENVIRONMENTAL AND SOCIAL MONITORING PLAN

Environmental and social monitoring is essential to track and sustain the effectiveness of the mitigation measures proposed for the project. An environmental and social monitoring plan shall be prepared as part of the ESMP, to be used during the implementation of the proposed project. The focus areas of monitoring cover air quality, noise, vibration, water quality, solid waste management and energy resources, occupational health and safety as well as local employment and economy.

Annexure – 1

Table 133: showing Earthquakes reported in Kerala (1950-2001): Revised from GSI (2000) and based on data from IMD, Broadband Station at Peechi, Kerala

Sl. No.	Date	Location		Intensity	Magnitude (Approx.) on Richter Scale
		Latitude	Longitude		
1*	31/10/1952	09.59	76.86	IV	3.7
2*	25/02/1953	09.58	76.83	V	4.8
3*	21/03/1953	09.56	76.76	V	4.8
4	26/07/1953	09.90	76.30		4.5
5	21/07/1959	11.50	75.25		4.0
6	27/07/1959	11.80	75.50	IV	4.0
7	27/07/1959	11.50	75.25		4.0
8	—/09/1964	11.30	75.80	IV	4.0
9	—/10/1964	11.30	75.80	V	4.0
10	19/01/1970	12.60	77.10		

11	17/01/1971	12.40	77.00		4.2
12	06/03/1971	12.40	77.00		4.2
13	27/03/1971	12.40	77.00		4.3
14	24/04/1972	12.40	77.00		3.7
15	16/05/1972	12.40	77.00		4.6
16	17/05/1972	12.40	77.00		4.5
17	29/07/1972	11.00	77.00		<4.0
18	01/03/1978	10.98	75.37		3.0
19	16/02/1979	10.50	77.00		3.7
20	09/06/1979	12.40	77.94		3.2
21	21/09/1979	12.60	77.30		3.1
22	03/05/1980	12.74	77.33		4.0
23	03/05/1980	12.87	77.36		3.1
24	25/12/1980	12.40	77.50		3.2
25	11/01/1981	09.92	76.61		3.0
26	17/02/1981	09.95	76.80		3.3
27	11/07/1981	09.92	76.61		3.0
28	22/04/1983	12.63	77.18		3.0
29	20/03/1984	12.55	77.77		4.4
30	27/06/1984	11.30	75.80	Micro tremors	
31	22/01/1986	10.20	76.70	III	3.0
32	23/01/1986	09.94	76.36		3.0
33	09/06/1988	09.8	77.20	VI	4.5
34	07/06/1988	09.8	77.20		4.1
35	08/06/1988	09.80	77.20		3.4
36	02/09/1988	08.70	76.90	IV	3.0
37	15/03/1989	10.60	76.30	III	3.0
38	25/02/1993	10.60	76.00	IV	3.6
39	02/12/1993	10.60	76.20	IV	3.6
40	17/09/1993	09.0	76.90	IV	3.6
41	14/11/1993	08.90	77.00	IV	3.6
42	09/04/1994	08.70	76.80	IV	3.6
43*	02/12/1994	10.75	76.25	V	4.3
44*	06/09/1996	10.52	76.22		2.8
45**	12/12/2000	09.69	76.80	VII	5.0
46**	07/01/2001	09.70	76.80	VI	4.8
47**	25/08/2001	10.76	76.25		2.8
48**	28/10/2001	07.20	76.00		4.5

* Epicenters determined through felt reports; **Locations from Peechi Station based on single station determinations; other epicenters based on GSI 2000 and IMD data

Table 134: Table showing Local events recorded at Peechi Station from December 2000-December 2008

S. No.	Date	Location		Probable location* (as also determined by the felt reports, excluding offshore events)	Magnitude (Approx.) on Richter Scale
		Latitude	Longitude		
1	12/12/2000	09.69	76.80	Erattupettah	5.0
2	12/12/2000	09.70	76.80	Near Pala	2.2
3	12/12/2000	09.62	76.39	Near Pala	2.0
4	12/12/2000	09.64	76.87	Near Pala	3.6
5	14/12/2000	09.57	76.47	Near Pala	1.5

S. No.	Date	Location		Probable location* (as also determined by the felt reports, excluding offshore events)	Magnitude (Approx.) on Richter Scale
		Latitude	Longitude		
6	15/12/2000	09.67	76.74	Near Pala	3.9
7	07/01/2001	09.70	76.80	Near Pala	4.8
8	07/01/2001	09.31	76.62	Near Pala	3.4
9	07/01/2001	09.63	76.38	Near Kottayam	2.7
10	25/08/2001	10.76	76.25	Desamangalam, Thrissur	2.8
11**	28/10/2001	07.15	76.32	Near Thiruvananthapuram	4.5
12	01/08/2002	10.76	76.24	Desamangalam, Thrissur	2.8
13	12/01/2003	11.83	75.65	Kannur-Wayanad	2.6
14	22/03/2003	10.22	76.24	Near Idukki Reservoir	1.9
15	07/09/2003	10.27	76.63	Near Edamalayar Reservoir	2.8
16	04/11/2003	11.95	76.88	Kannur-Wayanad	2.8
17	08/11/2003	11.72	75.55	Thalasseri, Kannur	3.2
18	08/11/2003	11.95	76.11	Kannur-Wayanad	2.5
19	27/11/2003	09.80	76.76	Near Pala	2.5
20	08/12/2003	10.57	76.20	Mangalam Dam, 17 km from Peechi	1.0
21	17/04/2004	10.81	76.13	Thrithala	1.6
22	18/04/2004	10.69	76.66	Palakkad-Coimbatore border	1.5
23	22/07/2004	10.76	76.30	Desamangalam, Thrissur	1.5
24	28/12/2004	11.42	76.55	Sultan Bathery, Near Wayanad	2.0
25	16/01/2005	09.97	76.59	Near Muvattupuzha	1.2
26	13/02/2005	10.61	76.42	Mangalam Dam, 12 km from Peechi	1.1
27	23/07/2005			Too mild to locate	<1.0
28	25/07/2005	10.00	74.81	South coast of Kerala	3.7
29	26/08/2005	11:61	76.18	Quilandi, Kozhikode	2.5
30	12/09/2005	09.50	75.09	Central coast of Kerala	2.7
31	27/02/2006	10.80	76.57	SW of Palakkad	1.0
32	01/03/2006	10.86	76.32	Near Pattambi	2.0
33	25/03/2006	10.76	76.34	Near Vaniyamkulam, Ottapalam	1.6
34	30/03/2006	10.19	77.75	Kerala-Tamil Nadu Border	2.5
35	21/05/2006	10.74	76.23	Near Desamangalam	1.0
36	03/06/2006	10.79	76.38	Near Ottapalam	1.6
37	17/06/2006	10.74	76.23	Near Desamagalam	0.8
38	04/07/2006	10.43	76.45	Ponmudi, Thrissur District	0.8
39	20/07/2006	10.61	76.42	12 km NE from Peechi	1.1
40	27/07/2006	12.25	75.85	Near Cherupuzha, Udayagiri, Kannur	1.3
41	08/08/2006	08.81	76.51	NW of Kilimanur, Thiruvananthapuram	2.6
42	09/08/2006	09.69	76.80	Near Erattupettah	1.5
43	18/08/2006	09.46	77.25	Vellimala, Thanikuddi	2.1
44	22/08/2006	10.35	76.02	141 km SW of Peechi Station in Lakshadweep Sea	1.3
45	07/09/2006	10.46	76.57	25 km SE of Peechi	1.2
46	03/10/2006	09.55	76.61	136 SW of Peechi in Lakshadweep Sea	2.1
47	19/10/2006	10.32	76.68	Near Edamalayar Dam	2.2
48	24/10/2006	10.32	75.67	78 km SW of Peechi in Lakshadweep Sea	1.6
49	29/11/2006	10.62	76.22	Athani, Thrissur (17 km NW of	0.8

S. No.	Date	Location		Probable location* (as also determined by the felt reports, excluding offshore events)	Magnitude (Approx.) on Richter Scale
		Latitude	Longitude		
				Peechi)	
50	11/12/2006	10.75	76.20	Near Vellore, Thrissur,29 km NW of Peechi Station	1.9
51**	17/12/2006	09.69	76.80	Nedumkandam	<1.0
52	20/12/2006	10.70	76.14	Wadakkanchery-Desamangalam	2.8
53	20/12/2006	10.70	76.14	Wadakkanchery-Desamangalam	1.5
54	21/12/2006	10.70	76.14	Wadakkanchery-Desamangalam	2.3
55	22/12/2006	10.78	76.32	Wadakkanchery-Desamangalam	1.6
56	22/12/2006	10.69	76.13	Wadakkanchery-Desamangalam	1.7
57	23/12/2006	10.69	76.14	Wadakkanchery-Desamangalam	1.9
58	27/12/2006	10.69	76.14	Wadakkanchery-Desamangalam	3.0
59	01/02/2007	10.69	76.14	Wadakkanchery-Desamangalam	2.7
60	02/02/2007	09.36	76.43	Pathanamthitta District	2.8
61**	07/02/2007	09.69	76.80	Near Kanjirapally	<1.0
62	13/02/2007	10.26	76.27	~7.5 km NW Chalakudy	2.0
63	30/04/2007	10.83	76.47	Srikrishnapuram, Palakkad	0.9
64**	04/05/2007	10.83	76.47	Srikrishnapuram, Palakkad	<1.0
65	06/08/2007	10.49	76.40	8 km SE Peechi Station (~1-2 km south of Peechi Dam)	1.8
66	14/08/2007	10.64	76.23	Mudathikode ,Thalappily Taluk,Thrissur	2.6
67	18/09/2007	10.30	76.34	22.5 km south of Peechi Station near Chalakudy.	1.3
68	02/10/2007	10.73	76.21	Desamangalam, Thrissur	2.4
69	03/10/2007	10.69	76.14	Desamangalam, Thrissur	1.0
70	03/10/2007	10.71	76.20	Desamangalam, Thrissur	2.4
71	03/10/2007	10.72	76.20	Desamangalam, Thrissur	1.5
72	05/10/2007	10.63	76.08	3.8 km SE of Kunnamkulam	1.9
73	06/10/2007	10.72	76.21	Desamangalam area, Thrissur	2.0
74	10/10/2007	10.71	76.21	Varavur-Thrissur	1.7
75	12/10/2007	10.71	76.19	Varavur-Thrissur	1.4
76	16/10/2007	09.44	75.29	Lakshadweep Sea,168 km SW of Peechi	3.0
77	02/11/2007	10.73	76.23	5 km NW of Cheruthuruthi, 5.5 km SW of Shoranur	1.2
78	16/12/2007	10.49	76.40	8 km SE of Peechi Station, 1.3 km South of Peechi Dam	1.4
79	11/01/2008	08.80	76.82	Near Attingal (199 km south of Peechi)	2.5
80	22/01/2008	10.36	76.69	Near Edamalayar Reservoir	1.8
81	30/01/2008	09.77	77.12	Near Nedukandam, Idukki, Kerala	2.5
82	11/02/2008	10.66	75.89	Lakshadweep Sea, 19.5 km west of Kunnamkulam	2.2
83	12/02/2008	12.03	75.76	10.5 km NE of Irutti	1.9
84	05/03/2008	10.36	76.68	Near Edamalayar Dam	2.0

S. No.	Date	Location		Probable location* (as also determined by the felt reports, excluding offshore events)	Magnitude (Approx.) on Richter Scale
		Latitude	Longitude		
85	24/03/2008	10.42	76.45	17 km SE of Peechi, near Vengapara	1.5
86	19/05/2008	07.93	77.24	Off Kanyakumari, 70 km south of Thiruvananthapuram	3.4
87	01/12/2008	10.69	76.52	NW Alathur (Palakkad)	2.3

Locations from Peechi Station are based on single station determinations

** Tremors not recorded at Peechi due to system shut down and/or they are very small magnitude events from distant places but felt by people and reported by newspapers. A source at Alathur (Palakkad) is known historically

Annexure – 2

Table 135: Distribution of Population, Demographic Profile and Occupational Pattern of Kerala

S. No.	Description	Units		Number
1	Geographical Area			
	Total	Sq. km.		38,863
	Rural	Sq. km.		31264
	Urban	Sq. km.		7599
2	Districts	No.		14
3	Taluks	No.		75
4	Villages	No.		1664
5	Towns	No.		520
6	Density			
	Total	Per sq. km.		860
	Rural	Per sq. km.		559
	Urban	Per sq. km.		2097
7	**Household**			
	Total	No.		7853754
	Rural	No.		4149641
	Urban	No.		3704113
8	**Population**	**Total**	**Male**	**Female**
	Total	33406061	16027412	17378649
	Rural	17471135	8408054	9063081
	Urban	15934926	7619358	8315568
9	**(0-6) Child Population**			
	Total	3472955	1768244	1704711
	Rural	1823664	927888	895776
	Urban	1649291	840356	808935
10	**SC Population**			
	Total	3039573	1477808	1561765
	Rural	1818281	883819	934462
	Urban	1221292	593989	627303
11	**ST Population**			
	Total	484839	238203	246636
	Rural	433092	213208	219884
	Urban	51747	24995	26752
12	**Literate**			

	Total	28135824	13704903	14430921
	Rural	14549320	7132430	7416890
	Urban	13586504	6572473	7014031
13	**Illiterate**			
	Total	5270237	2322509	2947728
	Rural	2921815	1275624	1646191
	Urban	2348422	1046885	1301537
	Status	**Total**	**Rural**	**Urban**
14	Family Size	4.25	4.21	4.30
15	Sex Ratio	1084	1078	1091
16	Total SC Population	9.10%	10.41%	7.66%
17	Total ST Population	1.45%	2.48%	0.68%
18	**Workers Pattern**	**Total**	**Male**	**Female**
	Total	11619063	8451569	3167494
	Rural	6341957	4507501	1834456
	Urban	5277106	3944068	1333038
19	**Type of Workers**	**Main**	**Marginal**	**Non**
	Total	9329747	2289316	21786998
	Rural	4930191	1411766	11129178
	Urban	4399556	877550	10657820
20	**Employment Pattern**	**Total**	**Rural**	**Urban**
	Cultivators	544932	481651	63281
	Agriculture	919136	760632	158504
	Industrials Household	198281	104642	93639
	Others	7667398	3583266	4084132

12. FINAL RECOMMENDATIONS

The following are the main findings of this feasibility study for the semi High-Speed Rail corridor from Thiruvananthapuram to Kasaragod:

1. The unique terrain and landforms in the coastal region and the Mid-Highlands which lie between the Western Ghats in the east and the Arabian Sea in the west have resulted in a very dispersed population in these two landform regions of Kerala where about 90% of the state's population lives.
2. The terrain and landforms of the region is also responsible for the slow speed of travel by surface transport (road and rail). The average speed of travel by road and rail is among the lowest of all regions of the country at about 30 to 40% lower than in the neighbouring states.
3. The total cost of project of 531 Km length is Rs 56,442.85 Crore including land cost and taxes. The project FIRR works out to be approx. 5.6% & 8.1% with the concession period of 30 years & 50 years respectively. The Equity IRR works out as 8.9% & 11% with the concession period of 30 years and 50 years respectively *and Economic IRR works out to 16.08%.*
4. There is possibility of an important indirect benefit of building this SHS line in the state. Since the beginning of railways more than 150 years ago the railways have led to the growth of large cities and shift of rural population from villages to towns and cities and formation of the mega cities of today that are driving the economic growth of the countries. This trend continues today. This also raises the possibility that by providing faster and efficient inter-city travel, the SHR Line can lead to a gradual shift of population from the smaller cities and towns to the larger cities. This would result in more urban population in the larger cities of the state that is essential for higher economic growth in a modern economy.
5. The SHSR line is expected to reduce journey time from Thiruvananthapuram to Kasaragod from 12 to 14 hours by road and rail to 3 hour 30 minutes to 4 hours depending on the type of service. The journey time may be further reduced when faster tilting trains are introduced in future.
6. The line will reduce pollution on the roads, safety on roads would also improve with reduced congestion, and dependence on oil which is import dependent commodity would also reduce.
7. For meeting the long-term transport needs of the state, construction of a SHSR line is expected to be more practical, as it requires much less land acquisition and could be less costly to build than a six-lane segregated expressway
8. The SHSR line is expected to boost tourism in the state by providing speedy comfortable daytime travel across the state which is full of tourist attractions like beaches, backwaters, and places of historical interest and religious importance.
9. Planned urban development of the cities along the corridor, and development of new cities along the SHSR line can be used to drive benefits for the socio-economic development in the regions served by the line. Planned urban development can be in the form of vertical development in the central part of the city and other parts by providing shorter access time to the SHSR stations. The indirect socioeconomic benefit of people moving from the smaller towns and cities to living in the larger.

Based on this exhausted examination of technical feasibility of a semi High-Speed line from Thiruvananthapuram and Kasaragod, **it has been concluded that construction of the line is technically feasible *and financially viable* and it is recommended to construct the semi high speed corridor** to have higher mobility, meet the traffic growth and economic development of the State.

13. SALIENT FEATURES

1.	Railway	- Thiruvananthapuram- Kasaragod Semi High Speed Corridor
2.	Route Length	- 531.450 Km
3.	Gauge	- Standard Gauge 1435 mm
4.	Maximum Permissible Speed	- 200 KMPH
5.	Stations	- Thiruvananthapuram at Kochuveli, Kollam, Chenganur, Kottayam, Ernakulam, Thrissur, Tirur, Kozhikode, Kannur and Kasaragod.
6.	Type of Structures	-Tunnel-2.430km(0.5%), Bridges-12.045km(2.27%), Viaduct- 57.030km(10.74%), Embankment-236.330km(44.48%), Cutting-200.220km(37.69%), Cut & cover-23.415km(4.40%)
7.	Track Structure	- Ballasted and ballast-less in combination.
8.	Maintenance Depots	- Workshop at Thiruvananthapuram and Inspection Depot at Kasaragod.
9.	Train type	- EMU type.
10.	Car body Width	- 3400mm(max).
11.	Seating	- 2+2(business), 3+2(standard), 3+3(low fare)
12.	Passenger capacity per Train	- 675 (9 car set)
13.	Traction	- 2x25kV Overhead simple catenary type
14.	Power Supply	- Kerala State Electricity Board supply supplemented by renewable energy supplies.
15.	Signaling &Train control	- ERTMS level 2 system(ETS 2 and GSM-R/LTE)
16.	Communication	- GSM-R/LTE
17.	Daily Ridership	- 67740 in 2024 increasing to 147120 in 2051
18.	Train Set	- 9 cars extendable to 12/15
19.	Train operation	- 44 services in 2024 with peak headway of 22.5 minutes, increasing to 61 in 2051 with peak headway of 13 minutes.
20.	Cars requirement	- 216 in 2024 increasing to 480 in 2051.
21.	Fare Collection	- Automatic Fare collection system with Centralized Computer and other supporting systems.
22.	Completion time	- 5 years
23.	Capital cost (Rs)	- 55765 crores
24.	Completion cost (Rs)	- 66079 crores
25.	Financing	- Debt Rs.34454cr (52%), Equity-MOR-Rs.7720cr(12%), GOK-Rs.7720cr(12%), GOK(land, EIA and R&R)-8656(13%), Subordinated debt-GOI-Rs.3564cr(5%), GOK-Rs.3564cr(5%) and balance in IDC, and other equities(PD).

26. Financial Internal Rate of Return - 5.6% with 30 years concession period and 8.1% with 50 years.
27. Equity Internal Rate of Return - 8.9% (30 years) and 11%(50years).
28. Economic Internal Rate of Return - 16.08%

Appendix