15 -ാം കേരള നിയമസഭ

14 -ാം സമ്മേളനം

നക്ഷത്ര ചിഹ്നം ഇല്ലാത്ത ചോദ്യം നം. 1274 **19-09-2025 - ൽ മറുപടിയ്ക്ക്**

ഫോർട്ട് കൊച്ചിയേയും വൈപ്പിനേയും ബന്ധിപ്പിക്കുന്നതിന് ഭൂഗർഭ ടണൽ

ചോദ്യം		ഉത്തരം	
ശ്രീ. കെ.എൻ. ഉണ്ണികൃഷ്ണൻ		**ശ്രീ. പി.എ.മുഹമ്മദ് റിയാസ്** **(പൊതുമരാമത്ത്-വിനോദസഞ്ചാര വകുപ്പ് മന്ത്രി)**	
(എ)	തീരദേശ ഹൈവേയിൽ ഫോർട്ട് കൊച്ചിയെയും വൈപ്പിനേയും ബന്ധിപ്പിക്കുന്നതിന് ഭൂഗർഭ ടണൽ അല്ലെങ്കിൽ എലിവേറ്റഡ് ഹൈവേ നിർമ്മിക്കുന്നത് സംബന്ധിച്ച് കെ-റെയിൽ സാധ്യതാ പഠനം നടത്തി സമർപ്പിച്ച റിപ്പോർട്ടിന്മേൽ നടപടി സ്വീകരിച്ചിട്ടുണ്ടോ; എങ്കിൽ സ്വീകരിച്ചിട്ടുള്ള നടപടി വ്യക്തമാക്കാമോ;	(എ)	തീരദേശ ഹൈവേയിൽ ഫോർട്ട് കൊച്ചിയെയും വൈപ്പിനേയും ബന്ധിപ്പിക്കുന്നതിന് ഭൂഗർഭ ടണൽ നിർമ്മിക്കുന്നത് സംബന്ധിച്ച് കെ-റെയിൽ സാധ്യതാ പഠനം നടത്തി തയ്യാറാക്കിയ റിപ്പോർട്ട് ഗതാഗത വകുപ്പിനും പൊതുമരാമത്ത് വകുപ്പിനും ലഭ്യമാക്കിയിരുന്നു. സ്വകാര്യ പങ്കാളിത്തത്തോടെ Design-Build-Finance-Operate-Transfer (DBFOT) മോഡൽ പ്രകാരം പ്രസ്തുത പദ്ധതി നടപ്പാക്കുന്നതിന് Expression of Interest (EOI) ക്ഷണിക്കുവാൻ KRDCL-നു ഗതാഗത വകുപ്പിൽ നിന്നും നിർദ്ദേശം നൽകിയിട്ടുണ്ട്.
(ബി)	പ്രസ്തുത സാധ്യതാ പഠന റിപ്പോർട്ടിന്റെ പകർപ്പ് ലഭ്യമാക്കാമോ?	(ബി)	തീരദേശ ഹൈവേയിൽ ഫോർട്ട് കൊച്ചിയെയും വൈപ്പിനേയും ബന്ധിപ്പിക്കുന്നതിന് ഭൂഗർഭ ടണൽ നിർമ്മിക്കുന്നത് സംബന്ധിച്ച് കെ-റെയിൽ സാധ്യതാ പഠനം നടത്തി സമർപ്പിച്ച റിപ്പോർട്ട് അനുബന്ധമായി ചേർക്കുന്നു.

സെക്ഷൻ ഓഫീസർ

FEASIBILITY REPORT

FORT KOCHI - VYPIN UNDER WATER TUNNEL

JULY 2023

FEASIBILITY REPORT

CONSTRUCTION OF A TUNNEL LINKING FORT KOCHI WITH VYPIN UNDER THE SHIPPING CHANNEL OF COCHIN PORT FOR LINKAGE IN COASTAL HIGHWAY PROJECT

IDENTIFICATION TABLE	
Client/Project owner	Kerala Rail Development Corporation Limited (K-RAIL)
Project	Construction of a tunnel linking Fort Kochi with Vypin under the shipping channel of Cochin Port for linkage in Coastal Highway Project
Type of document	Feasibility Report
Date	11-07-2023
File name	KRDCL/BD/01/2023
Framework	General
Confidentiality	External
Language	English
Number of pages	126

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CONSTRUCTION OF A TUNNEL LINKING FORT KOCHI WITH VYPIN UNDER THE SHIPPING CHANNEL OF COCHIN PORT FOR LINKAGE IN COASTAL HIGHWAY PROJECT

0 EXECUTIVE SUMMARY

0.1 Kerala's Coastal Highway Project:

A highway along the coastal belt of Kerala extending from Thiruvananthapuram in the south to Kasaragod in the North were discussed for the last few decades. The planning of the project began with a study conducted by the National Transportation Planning and Research Centre (NATPAC) in 1993. The proposed corridor's main objective is to reduce the traffic congestion along the National Highways and to develop the corridor along the west coast for developing the coastal parts of the state and for increasing their tourism potential. The coastal highway shall also facilitate container and other goods movement from the international container transhipment terminal at Vallarpadom and the proposed transhipment terminal at Vizhinjam apart from improving the connectivity of several minor ports in the area. The project intends to enhance transportation connectivity, boost tourism, and facilitate economic development in the coastal region and in the entire state. The project holds immense potential to uplift Kerala's coastal areas, bridging communities and unlocking new opportunities.

Coastal Highway passes through nine districts in Kerala state. In Ernakulam district, the project alignment comprises of 48 km (approximately) from South Chellanam to Munambam. The proposed alignment routes are as follows:- South Chellanam- Kandakkakadavu Mundamveli- Fort Kochi- Fort Vypin- Puthuvype Beach Njarakkal Fish Farm- Aniyal beach- Cherai beach- Munambam.

0.2 Need for a Tunnel Road Link at Fort Cochin-Vypeen:

In the proposed corridor in Ernakulam district, 3 sections are identified with missing links via land.

a. Fort Kochi (also known as Cochin) to Vypin (also known as Vypeen)
b. Near Matsyafed Tourist office
c. Munnambam – Azhikode

While discontinuities at b and c are proposed to be closed by bridge construction, discontinuity from Fort Kochi to Vypin has been proposed to be connected through water transport (ferry services as existing) in the coastal high project reports (Feasibility as well as DPR made by NATPAC). Water connectivity is retained on the coastal highway project as this channel is serving as the Shipping Approach Channel of the Cochin Port and has been considered as non-bridgeble in the study reports.

This discontinuity is turning out to be a major bottleneck and critical for the project as other available road systems in the area are totally inadequate and not capable of handling traffic arising in the area. If a suitable bridging solution is not found, this may hamper the

traffic and developments in the area as a permanent measure affecting the growth of the area for centuries to come. Therefore it has become necessary to find a viable technical solution to bridge the waters by a bridge or tunnel or any other means, hence this study. Location details are given in figure below.

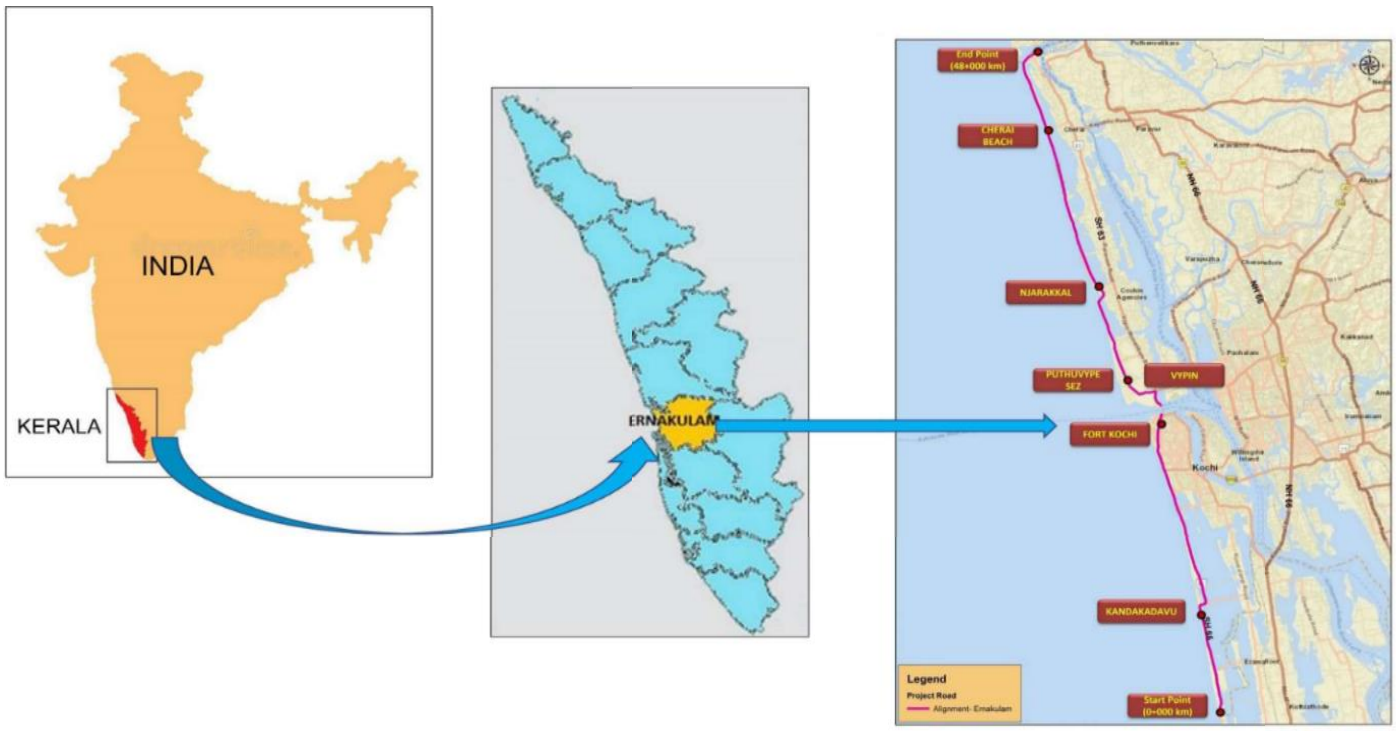


Figure 0-1: Location Details of Proposed Project

0.3 Objective of the Study:

Various alternatives for bridging the channel has been considered and based on initial studies, an under-water tunnel appears to be a feasible option. Objective of this report is to assess the feasibility of providing the coastal highway connectivity in the discontinuity at Fort Kochi-Vypin by means of a Tunnel Road system under the shipping channel of Cochin Port.

0.4 Location of the linking site:

Cochin is a port city dissected and interlinked by backwaters and canals and has two busy ports, one at Wellington Island and the other at Vallarpadam. The shipping channel of Cochin Port, with a draught of fifteen meters, is across two land formations and the channel goes between the heritage town of Fort Kochi and island Vypin. The exact location of the crossing should be ideally of least distance with good draught and reliable undersea soil

profiles and will depend on available roads or land for the development of approaches for the road. Plan below shows the area under discussion.

Figure 0-2: Location of the Tunnel Link Road site

0.5 Shipping channel of Cochin Port:

A view of the Cochin Port shipping Channel is given in the plan above. The main inward shipping channel of the Cochin port divides in to the Ernakulam and Mattancherry channels. The entrance to the harbour is by a 16500m long and 260 m wide 15.95 m deep outer approach channel marked with eight sets of buoys numbered from 1 to 16. Inner harbour is divided into two navigational channels - Ernakulam Channel of 2800m long and 300 - 500 m wide with depths from 9.75 to 13.5 m and Mattancheri Channel of 2200 m long and 180 - 250 m wide with a depth of 9.75 m.Mattancheri Channel has the berths Q1 to Q4, North and South Coal berths and B.T.P.Ernakulam Channel has berths Q5 to Q10, North and South Tanker Berths and Cochin Oil Terminal.

0.6 Possible options for crossing the Channel:

The road between Fort Cochin and Vypeen/Puthuvypee, along the shore via Mattancherry, wellington island, Ernakulam, Goshree is about 16 km long. The Bridge or Tunnel across the channel, through an optimum alignment in terms of least distance and reliable soil profiles, would be about 2.5 km to 3.0 km including its approaches.

Any road link between Fort Cochin and Vypeen/other islands has to cross the Shipping Channel which is about of 500-600 m in width near Vypeen and about 1000 m near Vallarpadam, with the least width of about 470 m. Depth of channel varies and is 15-20 m deep generally. Possible options for crossing the shipping channel, apart from taking the circuitous and torturous shore land/Goshree route, are:-

- ✓ A Fly-Over bridge
- ✓ An Underwater Tunnel

Bridging the channel by an overbridge is technically difficult and financially not viable due to vertical clearance requirements for ships and soil characteristics for foundations. Failure of such bridges over shipping channels, available at a few locations have been catastrophic. Tunnels are safer, can be designed and constructed and are sustainable under all weather conditions.

0.7 Existing Under-Water International/National tunnels:

There are a large number of under-sea/underwater road and rail tunnels existing in various parts of the world. There exists an underwater tunnel under the Thames River in London, UK and another one under the Mass river in Rotterdam, Netherlands. The Channel Tunnel (Chunnel) between UK and France under the English Channel is very popular. Two major undersea tunnels have been built in recent times, in the Port of Busan in South Korea and Santos Highway in Brazil. In India also tunnel roads and railways exist for a long time though underwater tunnels have come up only very recently. Indian Railways have commissioned an under-water tunnel below the Hoogly River in 2022, as part of the Kolkatta Metro Project, which is 600 m long and located at depths of 30-35 m below the bed level. These tunnels are serving roads/rails very efficiently without any disturbance even under heavy water current/severe earthquake conditions. At present two such major under-sea tunnels are in progress in Mumbai area, one in Mumbai-Ahmedabad High Speed Rail project and the other in the Borivalli-Thane sector of Mumbai Coastal Road project.

0.8 Traffic studies:

As part of the Feasibility Study for the Tunnel Link Road project between Fort Cochin and Vypeen, preliminary estimate of likely traffic expected to pass through the proposed Fort Cochin – Vypeen tunnel is estimated for the base year and projected for future years. The estimation and projection of traffic are based on secondary data and the draft report on 'DPR for Integrated Development of Coastal Highway in Ernakulam District', prepared by L & T Infra Engineering, during September 2022. The DPR study is based on extensive primary traffic surveys including Classified Traffic Volume Count, Origin-Destination Survey and Speed & Delay Survey at carefully selected survey stations and road sections in and around Cochin City. The proposed Fort Cochin – Vypeen tunnel when completed would be a part of the Coastal Highway and the data available in the DPR is systematically analysed to form the traffic data base for the present study.

Break-up of Projected Daily Traffic on the Proposed Tunnel System for Different Horizon Years under 'No Toll' and 'Alternative Toll Scenarios":

		Total traffic - No toll				Total traffic - Kumbalam Toll			
		2025	2030	2035	2040	2025	2030	2035	2040
		No toll scenario				Toll as per Kumbalam plaze			
1	Bus	174	198	223	248	144	164	185	206
2	Mini Bus	128	146	163	180	59	67	74	81
3	Car/ Jeep/ Van	3,138	4,100	5,241	6,571	1,891	2,440	3,092	3,854
4	Auto Rickshaw	923	1,128	1,359	1,614	606	733	876	1,034
5	Two Wheelers	14,994	18,741	23,018	27,852	10,823	13,418	16,384	19,741
6	Multi Axle truck	141	190	249	319	35	46	59	75
7	Truck 2&3 axle	127	165	207	256	34	44	54	66
8	LCV 4,6,ace	759	977	1,230	1,518	303	383	476	583
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	313	334	353	371	313	334	353	371
11	Others	7	7	7	7	7	7	7	7
Total Vehicles (No.)		**20,703**	**25,983**	**32,051**	**38,935**	**14,215**	**17,633**	**21,561**	**26,017**
Total Vehicles (PCU)		**14,606**	**18,417**	**22,815**	**27,816**	**9,325**	**11,578**	**14,174**	**17,119**

Total traffic - 1.5times Kumbalam				Total traffic - 2times Kumbalam			
2025	2030	2035	2040	2025	2030	2035	2040
1.5 time of Toll at Kumbalam plaze				2 time of Toll at Kumbalam plaze			
143	163	183	204	142	162	182	203
54	62	68	74	52	58	64	70
1,752	2,255	2,853	3,552	1,670	2,146	2,712	3,374
572	691	825	973	552	666	794	936
10,146	12,553	15,306	18,424	9,717	12,006	14,625	17,591
32	42	53	67	30	40	51	65
31	40	49	60	29	38	46	57
274	346	429	524	258	325	402	491
-	-	-	-	-	-	-	-
313	334	353	371	313	334	353	371
7	7	7	7	7	7	7	7
13,323	**16,490**	**20,127**	**24,255**	**12,770**	**15,779**	**19,237**	**23,164**
8,736	**10,823**	**13,217**	**15,938**	**8,378**	**10,360**	**12,637**	**15,230**

0.9 Recommended Tunnel Dimensions:

Decision on type/size of tunnel will depend on the road arrangement finally adopted and the construction scheme/machinery available. Twin tube tunnels with 4.5 m and 3.5 m lanes in each tunnel is recommended for this project with approaches transitioning in to a 4 lane road on both sides till joining the coastal highway as this will provide a smooth road arrangement which can cater to the traffic needs for another 50 years. Additional facilities such as Emergency Stop-Bays at every 250m and Emergency Exits for passengers with ventilation at every 500m will also be required. Service lines, Gas/Fuel pipe lines, drainages with pumping arrangements are also to be provided suitably using the median/footpath space available. This will require an internal dimension of 11.25 m and external dia of 12.50 m for the tunnel. The twin tunnel arrangement proposed is currently a favoured arrangement in such proposals in the country for road and rail projects based on aspects such as available machinery for providing such tunnels (TBM) and safety requirements such as emergency escape arrangements.

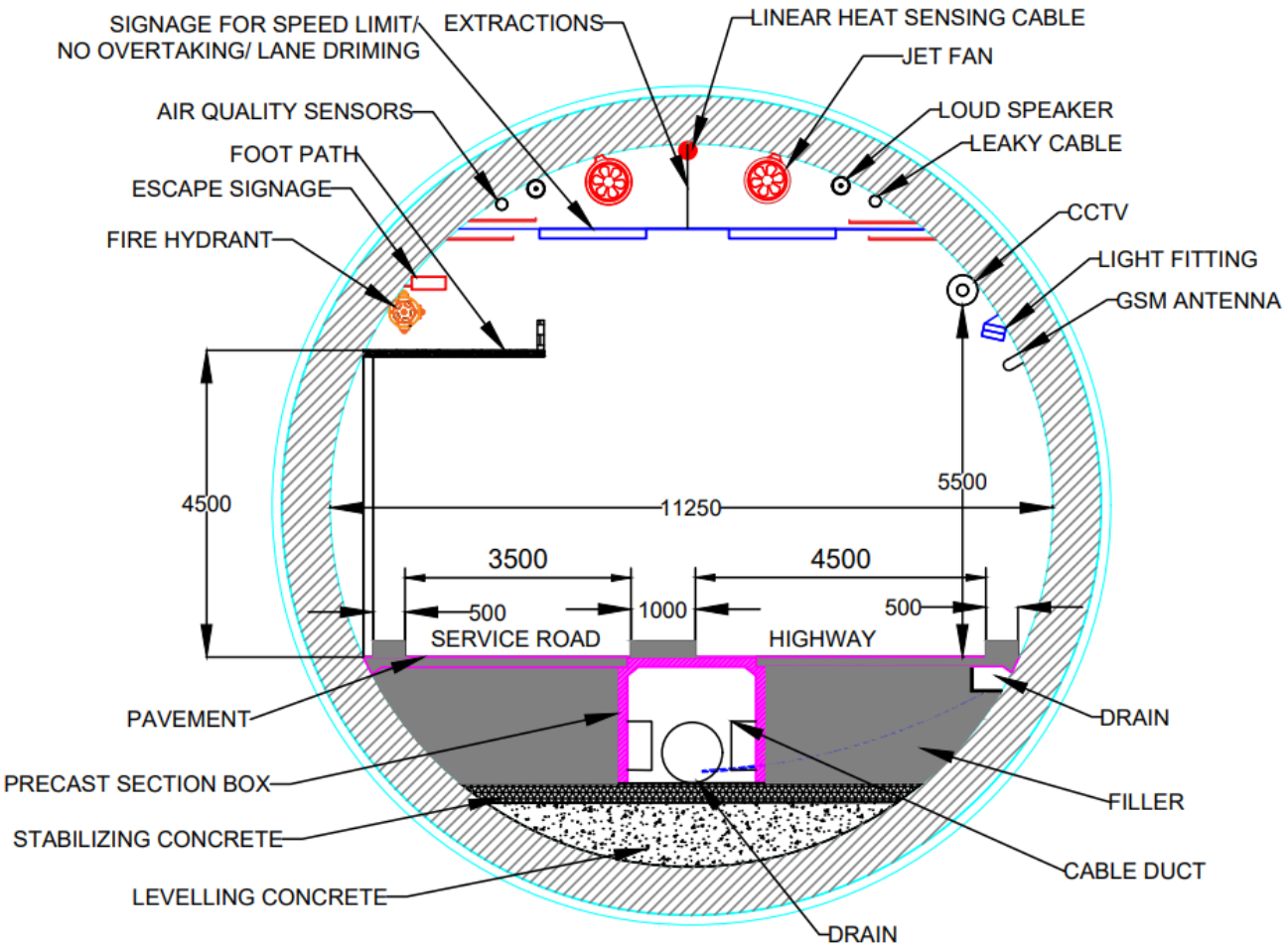


Figure 0-3: Recommended Tunnel Dimensions

0.10 Suitability of soil for Tunnelling:

The soil profiles indicate that at higher levels available soils are not very suitable for tunnelling by normal/TBM methods because of loose nature of the alluvial deposits. At deeper depths, 40-45 m below the sea bed levels, stiff marine clay exists and TBM tunnelling might be possible. However, special tools/steps will be necessary as the marine clays may have varying material properties across the profile in single layers. This will also require relevant expertise at design and construction stages.

0.11 Alignment:

Horizontal: Detailed topographical studies are required to arrive at the most suitable and feasible alignment for the tunnel and approach roads. The area on Fort Cochin side is well developed with large number of big and small residential, commercial and religious structures. Land value in the area is also high. Development will affect at least 1200 to 1500 m length of developments in the area, if not more. Similar is the case with the approach on Vypeen island, though the density of construction is relatively less. While the costal highway proposes to join and pass through the Goshree road, with the tunnel arrangement, it is not possible due to level of roads and hence a subway under the Goshree road with service roads may become necessary. A possible green field approach alignment over the marshy lands on the western part of the island may slightly increase the length but will have less acquisition and construction problems. This road will join the existing Goshree road in a circle.

There are two clear possibilities in aligning the tunnel across the shipping channel as shown below. In the first option, the tunnel of about 545m (reducible to 500 m) can connect the existing KV Jacob road on Fort Cochin side near the RO-RO Jetty and the coastal highway road on Vypeen side to be developed after acquisition. Second option will be a longer tunnel of about 700 m connecting the same road on Fort Cochin side and a new road on the western side in Vypeen through marshy lands. However, there will be a difficulty as the marshy area in Vypeen has significant mangrove population. The choice of alignment will have an effect on the connecting road junctions and in turn the available gradients for the approach roads. Tendative coordinates are indicated in the plans.

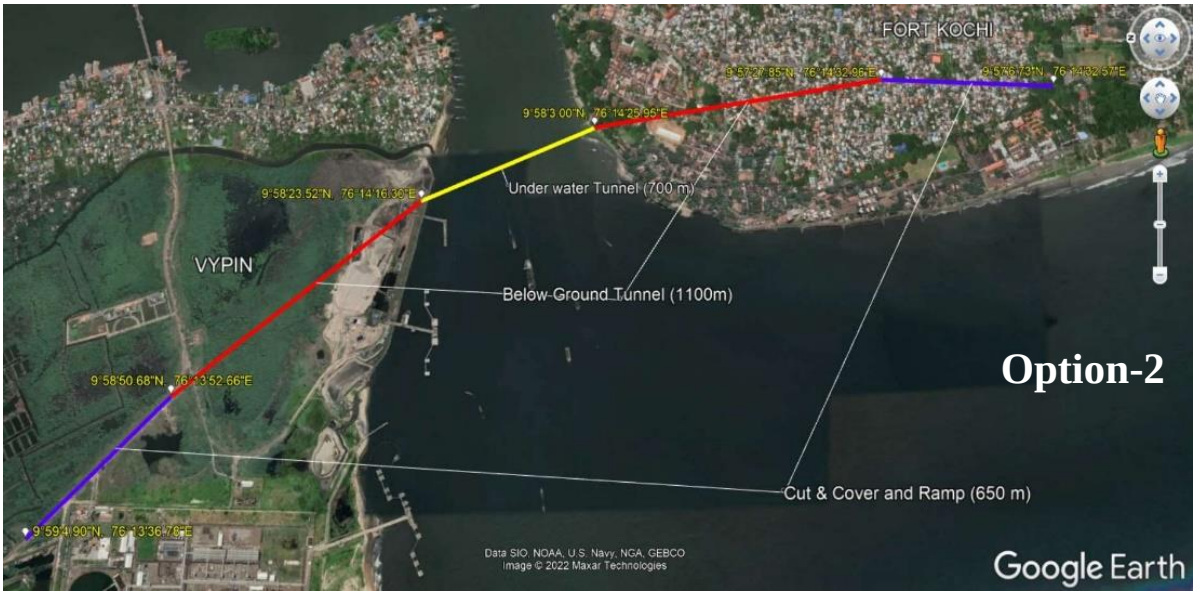


Figure 0-4: Proposed Crossing Alignments Option 1 and 2

Longitudinal Profile of Tunnel: The tunnel has to pass through partly under land and partly under sea on either side of Vypeen and Fort Cochin islands. The main tunnel will be at a depth of 35 m from sea level (low sea level) depending on the type, size and design of the tunnel bores, giving around 20m draught for the shipping path and 15 m soil cushion above the tunnel required for TBM tunneling. Sagarmala project scheme has already considered a draught depth of 18m for future. Figure below shows the details schematically.

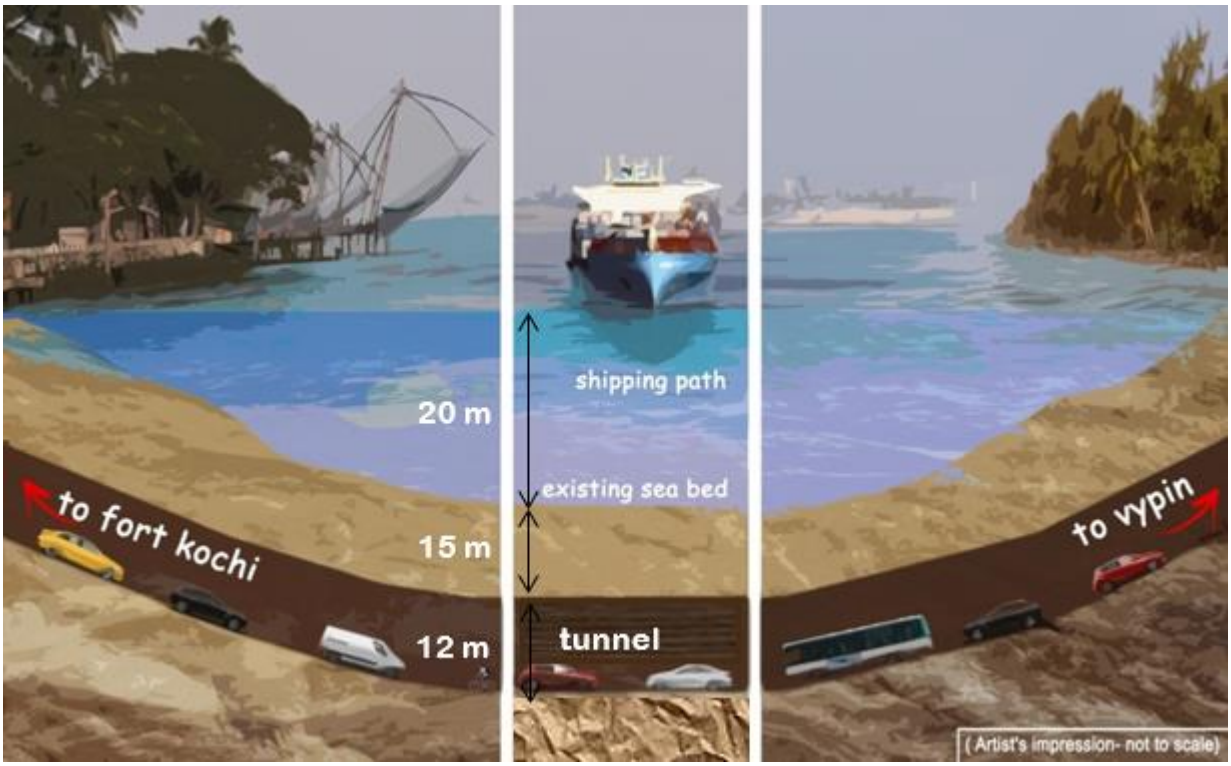


Figure 0-5: Schematic Longitudinal Profile of Tunnel

A tendative longitudinal profile for the proposed tunnel as per Option-1 is shown below. While the gradients may be decided based on the availability of roads on either side, a maximum gradient of 1 in 25 (4%) can only be allowed keeping the type and nature of traffic in view. A slope of 1 in 33 (3.0%) or even 1 in 40 (2.5%) may be preferable in view of likely future developments.

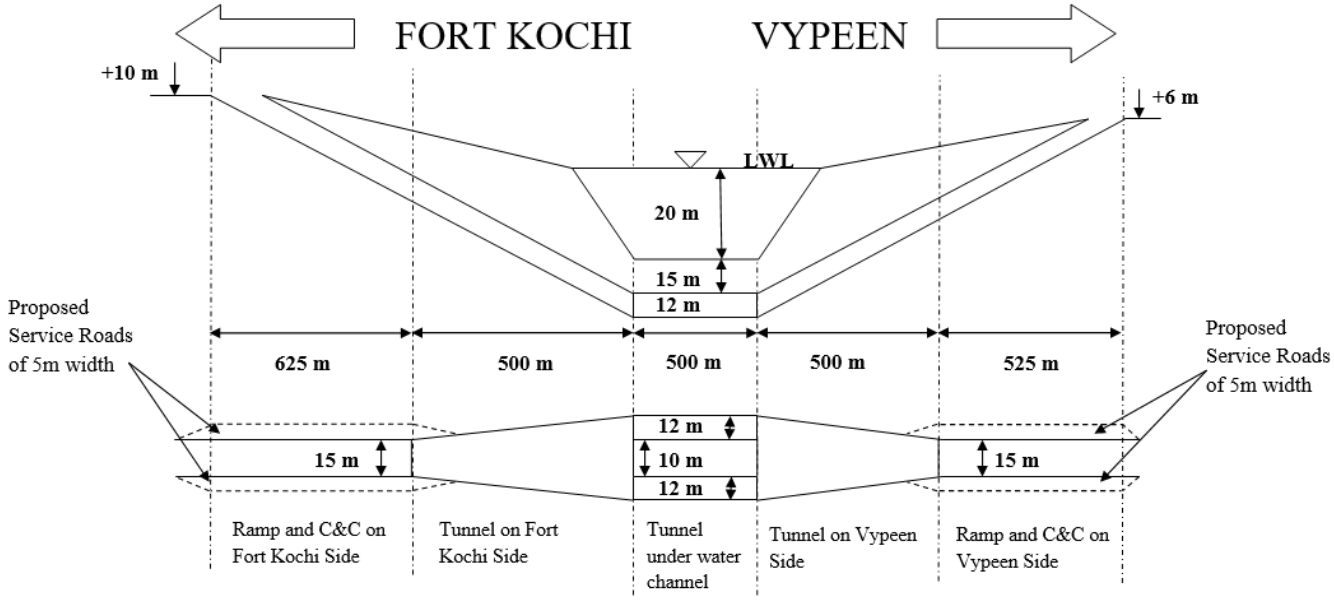


Figure 0-6: Longitudinal Profile and Plan of Proposed Tunnel

(Skematic- Not To Scale)

Notes:

1. Levels indicated on the sides are as per Google Map.
2. Gradient for approach is taken as 1 in 25 (4%).
3. Road connection at ends not decided. Cut&Connection/Open cutting will be suitably designed to meet the road connections as approved.

Land Acuisition: An assessment of land and buildings acquisition for the project is given below.

Assessment of Land and Buildings required to be acquired

ACQUISITION OF LAND AND BUILDINGS			
Item	**Vypin end**	**Fort Kochi end**	**Total**
Land (Ha)	**1.4**	**1.39**	**2.79**

0.12 Construction:

Construction methodology and in consequence the cost will depend on the detailed designs adopted. As the soil in the sea bed is expected to be clay mostly, a scheme using

Tunnel Boring Machine can be followed in this project as being done in the Mumbai Coastal Road Project currently. TBMs of 10 to 12 m dia are now freely available in large numbers in the country, hence the scheme will be viable. Being underwater tunnelling , suitable strengthening/freezing steps may also be necessary. If underground soil profile consists of full or partial rock structure, Shield TBM will be used. If the profile has high porosity with loose water bearing, as could be expected here, Slurry Face TBM will be used. Tunnels can also be constructed by other methods such as NATM (New Austrian Tunnelling). TBM method of construction, which is generally faster, may take about 2 to 2.5 years whereas other methods may take longer. However exact method of tunnelling can be decided after thorough soil and other investigations and based on the availability of suitable machinery.

Other aspects of the project construction may involve reclaiming some land from the backwaters on the eastern side of the Vypeen island where one of the alignment options proposed go close to the waters, managing the dumping of construction debris, etc. In this project, most of the debris being under sea clay materials, reclaiming adjoining lands using this material may be an advantageous and cheaper option.

Timeline: Overall construction period for the project might be about 2 1/2 years apart from the time taken for land acquisition. The base year is assumed as April 2025 (when the construction is expected to start) and the date of likely completion and commissioning is September 2027.

0.13 Essential Studies for Detailed Project Report:

- Traffic study and IRR/EIRR evaluation,
- Topographical and Alignment studies using Drone or other methods incl assessment of structures and properties affected and heritage/ecological features involved,
- EIA and SIA studies,
- Hydrological/oceanic studies involving bathymetry, channel characteristics, tidal effects, channel bed profile, bed history, dredging history, channel currents incl velocity of flows, etc,
- Geological survey of the channel bed and approach areas,
- Geotechnical survey of the channel bed and approach areas,
- Location survey for land pockets for erection/launching of machinery, dumping and disposal of soil/waste materials, and
- Routes for movement of machinery, material, etc, incl waste management.

0.14 Project Estimate:

Project Cost Estimate

Sl No.	Description of Work	Amount Rs (In Crores)
1	Preliminary Works (Establishment, Mobilisation, Preliminary design, etc)	10.00
2	Carrying out detailed studies at site by Contractor	10.00
3	Land and Property Acquisition	500.00
4	Ground Development for Tunneling including reclamation	200.00
5	Bored Twin Tube Tunnels 1750 m long (@ Rs.350 cr/km for each tube)	1225.00
6	Cut & Cover/Open at the approaches where cushion is less, total 1000 m(@150 cr/km)	150.00
7	Tunnel Safety systems(TVS, Emergency Exit arrangements, etc)	150.00
8	Junction arrangements at both ends incl. signals, E&M, Scada, etc	150.00
9	Muck disposal	50.00
10	Environment protection, Utility shifting, Retaining structures, etc	100.00
11	Detailed Designs, PMC cost (@ 5%)	117.25
	Total Estimated Cost	**2672.25**

0.15 Financial and Economic Returns of the Project and Recommendation:

The economic analysis entails comparing project costs and benefits in economic terms and calculating the project's Economic Internal Rate of Return (EIRR) as per the guidelines in IRC SP:30-2019. Financial IRR is not calculated at this stage as the mode of financing and other terms are not decided.

Economic Returns of the project (EIRR) based on the traffic and other details presently available works out to 9.63%, which is reasonable and can be considered favourably for further consideration of the project.

Based on the details furnished and the EIRR anticipated, the project looks viable and implementable and will be of great benefit to the local areas and the coastal districts of the state in their economic growth via effiecient traffic movement and developments in tourism and related fields.EIRR is expected to increase substantially when all factors affecting the influence zone areas are considered in detail such as growth in tourism potential, value additions to all walks of life and increase in land value in the area.

1 INTRODUCTION

1.1 Greater Cochin Area:

Kochi, also known as Cochin, is a major port city on the Malabar Coast of India on the Arabian Sea. It is part of the district of Ernakulam in the state of Kerala and is commonly referred to as Ernakulam. Kochi is the most densely populated city in Kerala. As of 2011, it has a corporation limit population of 677,381 within an area of 94.88 km^2 and a total urban population of more than 2.1 million within an area of 440 km^2, making it the largest and the most populous metropolitan area in Kerala. Kochi city is also part of the Greater Cochin region and is classified as a Tier-II city by the Government of India. The current metropolitan limits of Kochi include the mainland Ernakulam, Fort Kochi, the suburbs of Edapally, Kalamassery, Aluva and Kakkanad to the northeast; Tripunithura to the southeast; and a group of islands closely scattered in the Vembanad Lake.

Called the "Queen of the Arabian Sea", Kochi was an important spice trading centre on the west coast of India from the 14th century onwards. Kochi was one of the 28 Indian cities among the emerging 440 global cities that will contribute 50% of the world GDP by 2025, in a 2011 study done by the McKinsey Global Institute. Kochi is the only city in the country to have water metro system along with the metro rail. Kochi is known as the financial, commercial and industrial capital of Kerala. It has the highest GDP as well as the highest GDP per capita in the state.

The city is home to the Southern Naval Command of the Indian Navy and is the state headquarters of the Indian Coast Guard with an attached air squadron, named Air Squadron 747. Commercial maritime facilities of the city include the Port of Kochi, an International Container Transhipment Terminal, the Cochin Shipyard, offshore SPM of the BPCL Kochi Refinery and the Kochi Marina. Kochi is home for the International Pepper Exchange, Marine Products Export Development Authority, Coconut Development Board, companies like HMT, Apollo Tyres, FACT, IREL, Petronet LNG, Kochi Refineries, V-Guard and industrial parks like the Cochin Special Economic Zone, Smart City, Infopark and Kinfra Hi-Tech Park. Kochi is home for the High Court of Kerala and Lakshadweep, Naval Physical and Oceanographic Laboratory, Indian Maritime University, Sree Sankaracharya Sanskrit University and the Cochin University of Science and Technology, and National University of Advanced Legal Studies. Kochi was earlier home to Cochin Stock Exchange (CSE).

1.2 Kerala's Coastal Highway Project:

A highway along the coastal belt of Kerala extending from Thiruvananthapuram in the south to Kasaragod in the North, were discussed for the last few decades. The project began with a study conducted by the National Transportation Planning and Research Centre (NATPAC) in 1993. The proposed corridor's main objective is to reduce the traffic congestion along the national highways and to develop the corridor along the west coast for developing the coastal parts of the state and for increasing their tourism potential. The coastal highway shall also facilitate container and other goods movement from the international container transhipment terminal at Vallarpadom and the proposed transhipment terminal at Vizhinjam apart from improving the connectivity of several minor ports in the area. The project intends to enhance transportation connectivity, boost tourism, and facilitate economic development in the coastal region and in the entire state. The project holds immense potential to uplift Kerala's coastal areas, bridging communities and unlocking new opportunities.

The feasibility study for this proposal has been carried out by the NATPAC for developing the coastal highway from Thiruvananthapuram to Kasaragod with minimum impact on the existing eco-system. The proposed alignment is passing through nine districts such as Thiruvananthapuram, Kollam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod. The proposed length of the highway is about 590 Km. The detailed study includes that of the Ernakulam district, which is around 48 Km. NATPAC has suggested an alignment option on their feasibility study proposal.

The project road comprises 48 km (approximately) from South Chellanam to Munambam. The proposed alignment routes are as follows:- South Chellanam- Kandakkakadavu Mundamveli- Fort Kochi; Fort Vypin- Puthuvype Beach -Njarakkal Fish Farm- Aniyal beach- Cherai beach- Munambam.

The project involves the construction of a four-lane highway through nine districts along the coastal belt of Kerala. The Kerala Road Fund Board (KRFB) Project Management Unit will construct 468 km and the remaining work will be taken up by National Highways Authority of India under the Bharat Mala Pariyojana Scheme as per the present planning. The project is estimated to cost about Rs.6500 cr. The Route Map of Coastal Highway Project is given in **Figure 1-1**.

Figure 1-1: Route Map of Coastal Highway Project

1.3 Purpose of the coastal highway project:

- ✓ ***Enhanced Connectivity:*** The construction of the Kerala Coastal Highway will significantly enhance transportation connectivity along the entire coastline. Currently, travel along the coast can be challenging due to inadequate road infrastructure. The highway will provide a smooth and efficient route, reducing travel time and improving accessibility to various towns, villages, and tourist destinations. It will enable seamless movement of people and goods, fostering better social integration and economic exchange between different regions.
- ✓ ***Promoting Tourism:*** Kerala is renowned for its captivating backwaters, pristine beaches, and rich cultural heritage. However, limited connectivity has often hindered the full potential of its tourism sector. The coastal highway project aims to change this by linking popular tourist destinations, such as beach towns and historical sites, with a well-connected road network. Improved access to these attractions will attract more visitors, both domestic and international, and contribute to the growth of the tourism industry. Additionally, the project will create opportunities for local communities to engage in tourism-related businesses, generating employment and income.
- ✓ ***Economic Development:*** The Kerala Coastal Highway project holds immense promise for stimulating economic development in the coastal areas. The improved transportation infrastructure will facilitate the movement of goods and services, enabling easier trade and commerce. It will open up avenues for businesses to expand their reach and establish connections with a broader market. Moreover, the project will attract investments in hospitality, tourism-related infrastructure, and other sectors, fostering entrepreneurial opportunities and economic growth. By increasing the local mobility, commercial activities will grow many fold in the presently water-locked islands with increased aqua-commercial activities. The multiplier effect of increased economic activity along the coast can lead to improved living standards for the local population.

1.4 Need for a Tunnel Road Link at Fort Cochin-Vypeen:

The proposed coastal highway in Ernakulam district is majorly a brownfield alignment (except 2.76 km greenfield alignment) starting from Chellanam in the South and ending at Munambam in the North. However, in the proposed corridor, 3 sections are identified with missing links via land.

a. Fort Kochi to Vypeen
b. Near Matsyafed Tourist office
c. Munnambam – Azhikode

While discontinuities at b and c are proposed to be closed by bridge construction, discontinuity from Fort Kochi to Vypeen has been proposed to be connected through water transport (ferry services as existing) in the coastal high project reports (Feasibility as well as DPR made by NATPAC.) Water connectivity is retained on the coastal highway project as this channel is serving as the Shipping Approach Channel of the Cochin Port and has been considered as non-bridgeble in the study reports.

This discontinuity is turning out to be a major bottleneck and critical for the project as other available road systems in the area are totally inadequate and not capable of handling traffic arising in the area. If a suitable bridging solution is not found, this may hamper the traffic and developments in the area as a permanent measure affecting the growth of the area for centuries to come. Therefore it has become necessary to find a viable technical solution to bridge the waters by a bridge or tunnel or any other means, hence this study. Location details of Kerala's Coastal Highway Project are given in **Figure 1-2**.

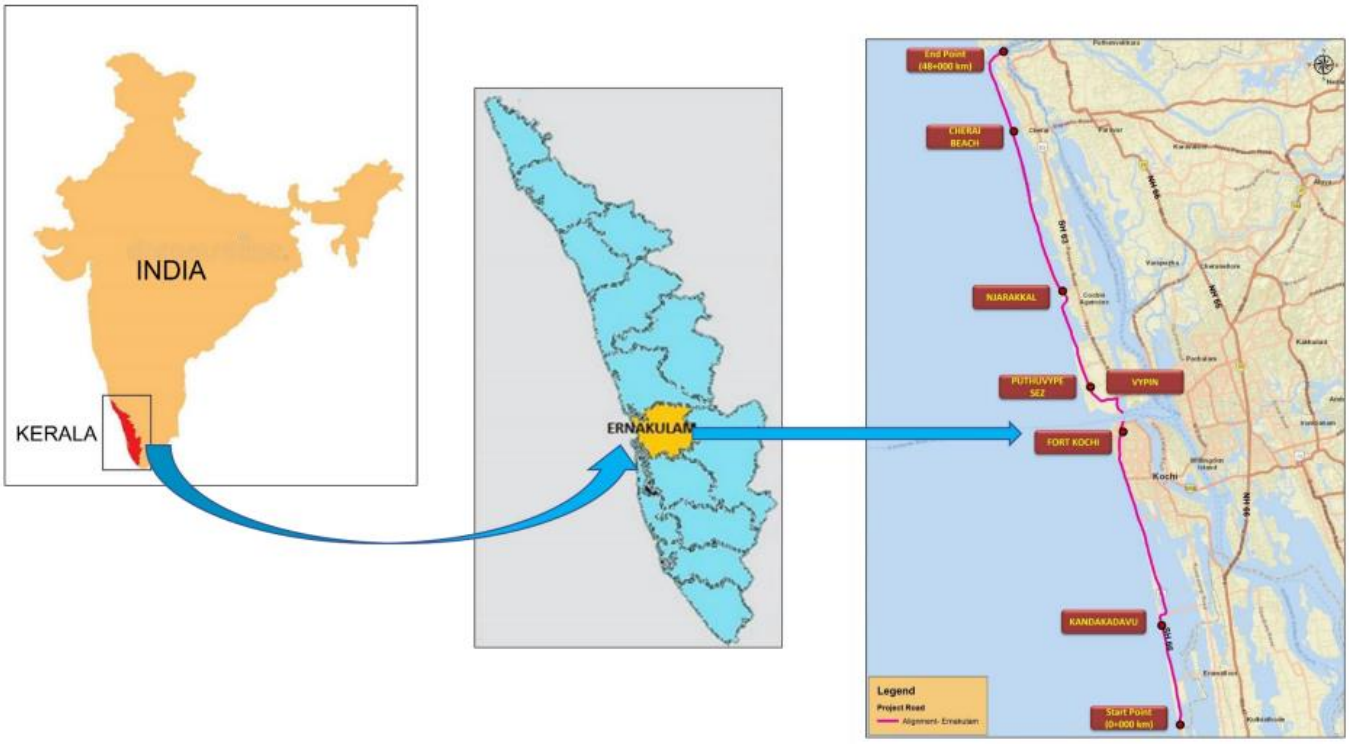


Figure 1-2: Location Details of Proposed Project

2 OBJECTIVE AND SCOPE OF THE REPORT

2.1 Objective of the Study:

Objective of this report is to assess the feasibility of providing coastal highway connectivity in the discontinuity at Fort Kochi-Vypeen by means of a Tunnel Road system under the shipping channel of Cochin Port.

2.2 Scope of Study:

- ✓ The scope of this study will be limited to studying the feasibility of providing the missing connectivity to the coastal highway across the Cochin Port shipping channel to make the highway directly through to benefit the traffic to flow smoothly and efficiently.
- ✓ The study shall identify the possible means of crossing the channel with least disturbance and damages to the shipping channel.
- ✓ The study shall indicate the rough proposal of works involved and the cost of providing the connectivity and possible ways of funding.
- ✓ The study shall indicate a way forward for taking up the project including further studies required for the preparation of a Detailed Project Report which should provide clear scope and design for the project, detailed cost estimates, details on viability and benefits of the project and likely disturbances to the eco-system of the area suggesting remedial measures and steps to obtain necessary approvals.

3 FORT COCHIN-VYPEEN TUNNEL ROAD PROJECT BACKGROUND

3.1 Location of the linking site:

Cochin is a port city dissected and interlinked by back waters and canals and has two busy ports, one at Wellington Island and other at Vallarpadam. The shipping channel of Cochin Port, with a draught of fifteen meters, is across two land formations and the channel goes between the heritage town of Fort Cochin and island Vypeen. The exact location of the crossing should be ideally of least distance with good draught and reliable undersea soil profiles and will depend on available roads or land for development of approaches for the road.

Figure 3-1: Location of the Tunnel Link Road site

Fort Cochin is a historical port city with a high level of development and human settlements. It has high population density and residence density. It also has a number of heritage and religious structures in the area. Roads are generally narrow and Railway has not reached here. On the other hand, the islands on the opposite side are Vypeen, Vallarpadam and Bolghati, which are relatively less occupied. Vypeen consists of old coastal settlements and Vallarpadam has a Container Terminal. These islands also have narrow roads only. A major road 'Goshree' has recently come up connecting these islands with the Ernakulam mainland near the High Court area. Generally, connectivity is poor and traffic crawls most of the time. Ferry services transport passengers, goods and even trucks across the channel and has jetties at Fort Cochin and Vypeen.

3.2 Shipping channel of Cochin Port:

A view of the Cochin Port shipping Channel is given in **Figure 3.2.** The main inward shipping channel of the Cochin port divides into the Ernakulam and Mattancherry channels. The entrance to the harbour is by a 16500m long and 260 m wide 15.95 m deep outer approach channel marked with eight sets of buoys numbered from 1 to 16. The inner harbour is divided into two navigational channels - Ernakulam Channel 2800m long and 300 - 500 m wide with depths ranging from 9.75 to 13.5 m and Mattancheri Channel 2200 m long and 180 - 250 m wide with a depth of 9.75 m. Mattancheri Channel has the berths Q1 to Q4, North and South Coal berths and B.T.P.Ernakulam Channel has berths Q5 to Q10, North and South Tanker Berths and Cochin Oil Terminal.

Basin for the International Container Transhipment Terminal (ICTT) lies just north of the shipping channel along the south face of Vallarpadam island. The basin for the LNG terminal of Petronet LNG Ltd. is located north of the approach channel between buoys 14 & 16 with the jetty along the south end of Puthuvypin Island. All ships approaching Cochin are to contact Cochin Port Control on VHF Channel 15 / 16 and report their E.T.A. to receive instructions on Pilot boarding / anchoring. Cochin Port Control is equipped with Radar / A.I.S. based V.T.M.S. and monitors the approach of vessels towards the fairway buoy. Open anchorage is South of the Channel with clay and sand bottom offering good holding ground. Pilots board ships in the vicinity of the Buoys no. 3 & 4 (Deep drafted vessels - about 0.5 n.m. West of buoys 1 & 2). Pilot ladders are to be rigged on the lee side 1.5 m above the water line. The Pilots embark from Pilot boats with white superstructure / red hull with 'PILOTS' marked on the sides.

3.3 Future Development of the Channel:

Any development in the channel should take care of the Port's future requirements. Any Over-Bridge crossing should give adequate clearance for the ships/liners to pass under it freely under all weather conditions. If a tunnel under the water is to be considered, such a tunnel should provide adequate draught (draft) for the shipping channel of the port as this is one of the major ports in the country serving the west coast. There exists the Vallarpadam Container Terminal which is also served by the same shipping channel. The present draught of the channel is about 14 m and considering future requirements, a minimum draught of 20 m may have to be ensured in the planning. The width of the channel is highly varying. A channel width of about 500 m may be adequate for all futuristic requirements. These details, however, need confirmation from the Port authorities.

Figure 3-2 shows the existing shipping channel with its berthing connections.

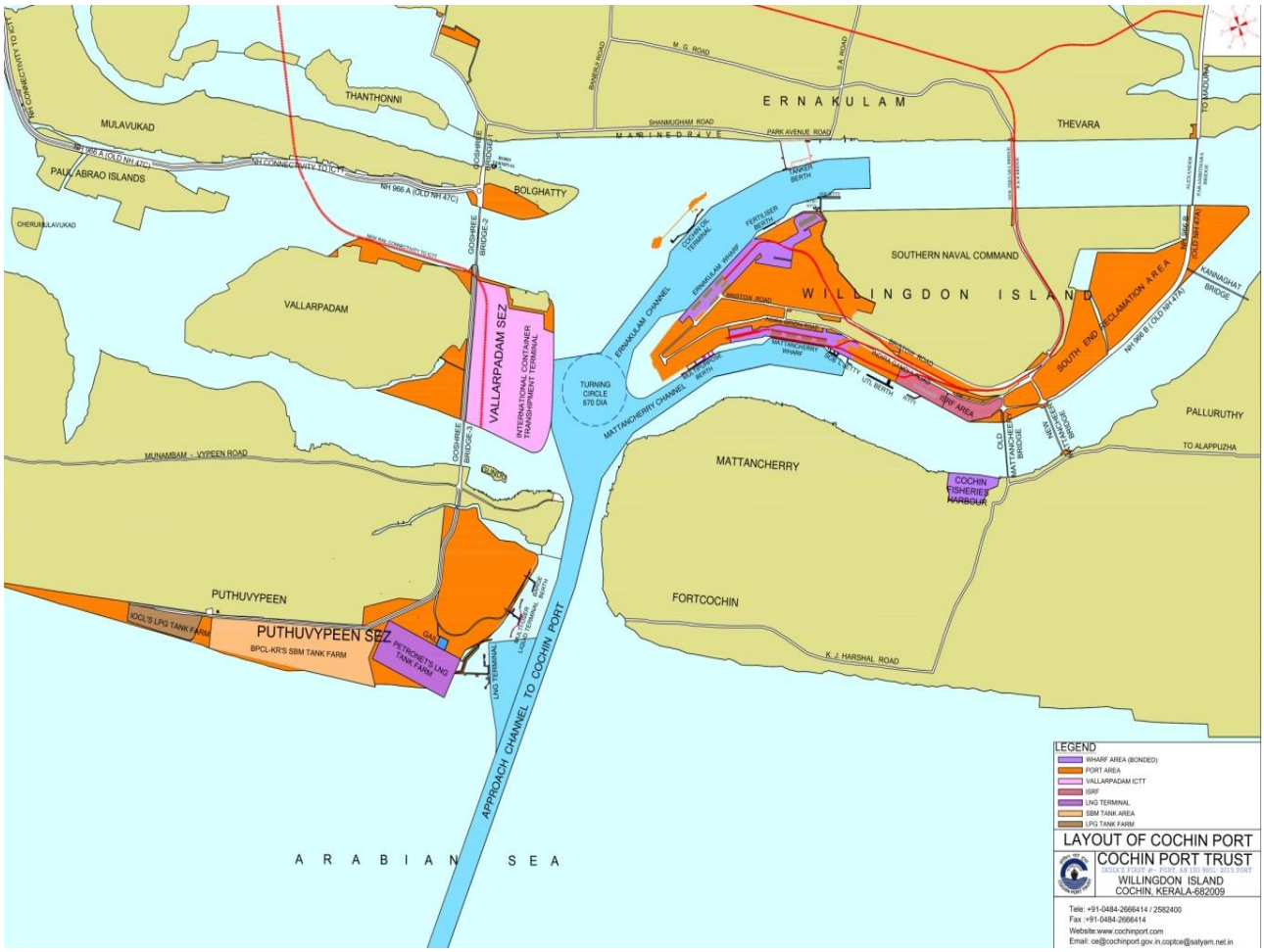


Figure 3-2: Shipping Channel in Fort Cochin

3.4 Possible options for crossing the Channel:

The road between Fort Cochin and Vypeen/Puthuvypee, along the shore via Mattancherry, wellington island, Ernakulam and Goshree is about 16 km long. The Bridge or Tunnel across the channel, through an optimum alignment in terms of least distance and reliable soil profiles, would be about 2.5 km to 3.0 km including its approaches.

Any road link between Fort Cochin and Vypeen/other islands has to cross the Shipping Channel which is about 500-600 m in width near Vypeen and about 1000 m near Vallarpadam, with the least width of about 470 m. The depth of channel varies and

is 15-20 m deep generally. Possible options for crossing the shipping channel, apart from taking the circuitous and torturous Shore land/Goshree route, are:-

- ✓ A Fly-Over bridge
- ✓ An Underwater Tunnel

3.4.1 Over-Bridge Crossing:

Bridging the channel by an over-bridge, though may be an ideal proposal, is technically difficult and financially not viable as the vertical clearance requirements of the shipping channel (above high sea level) might be a constraint, at about 50-60 m, based on the information of clearance requirements of ships and liners likely to berth in the Port. Such high construction close to the open sea is difficult. The clear span requirement of 500 m without supports in between is not practical. Spanning the whole channel by a long span cable-stayed or suspension bridge is also not possible as the sea bed in the area may not meet the structural (foundation) requirements for such bridges as seen from the available data. Similar bridges have faced serious problems in the past. A Cable Stayed bridge of this proportion may cost anything about Rs.1600-2000 cr.

3.4.1.1 Failure of Bridges:

It is important to note that catastrophic failures of bridges over shipping channels, are rare due to rigorous engineering standards and regular maintenance. However, there are serious possibilities and number of instances which range from catastrophic to minor failures in records. Examples of notable incidents involving bridges over shipping channels are:

- **Sidney Sherman Bridge (Houston, Texas):** The bridge clearance is 135 feet (41 m), which some officials have deemed too low for ships to navigate. By the time the V-struts supporting the mainspan were put in place, the Port of Houston claimed the struts were an even more dangerous hazard to ships that must veer from the middle of the waterway. By some accounts, port officials protested, but TxDoT did not listen to their pleas. The bridge had cost $19 million in its current configuration; a higher clearance would have cost more, and the agency went on to investigate that ships did not need 120 feet (37 m). This decision proved to be a mistake. Several ships have collided with the bridge over 27 years, but despite this, the bridge only suffered minor damage and was still intact. That all changed in December 2000, when a cargo crane struck the bridge, knocking a hole in the concrete deck and damaging a steel beam. The damage took six weeks to repair, forcing several lanes to be closed in the process. The worst accident, though, happened in May 2001, when a freighter's cargo boom caused severe damage to a girder and put another

gaping hole in the span. Several lanes of the bridge were closed for two months while repairs were completed.

- **Morandi Bridge (Genoa, Italy):** The Morandi Bridge, also known as the Polcevera Viaduct, was a cable-stayed bridge that collapsed on August 14, 2018. Although it did not directly cross a shipping channel, it connected the A10 motorway and its failure impacted the nearby port. The collapse resulted in the loss of 43 lives and significant disruptions to transportation.
- **Skagit River Bridge (Washington, United States):** The Skagit River Bridge, located on Interstate 5 in Washington, experienced a partial collapse on May 23, 2013. While it didn't cross a shipping channel, it is relevant as it carried vehicles over a waterway. An oversize truck struck several overhead beams, leading to the collapse of a section of the bridge. Fortunately, there were no fatalities, but it highlighted the vulnerability of bridges to vehicle collisions.

3.4.2 Underwater tunnels:

Underwater tunnels are preferred over bridges in certain situations due to factors like-

- ***Navigational Constraints:*** In shipping channels or areas with heavy maritime traffic, building a bridge may pose navigational challenges. Ships require sufficient clearance to pass safely, and constructing a bridge with a high enough vertical clearance can be costly and technically complex. In such cases, an underwater tunnel allows unobstructed navigation for ships above.
- ***Environmental Considerations:*** Bridges can have an impact on the natural environment, especially in sensitive areas such as ecologically rich water bodies or habitats. By opting for an underwater tunnel, the ecological impact can be minimized as it avoids disturbing the water surface, marine life, and shoreline aesthetics.
- ***Weather Conditions:*** Bridges can be susceptible to extreme weather conditions, such as high winds, storms, or icing, which can affect their structural integrity and safety. An underwater tunnel is protected from these weather-related factors and provides a more stable transportation route, ensuring an uninterrupted flow of traffic.
- ***Aesthetics and Urban Planning:*** In urban areas or scenic locations, there may be a preference for preserving the visual appeal of the landscape. An underwater tunnel remains hidden from view, preserving the natural or architectural beauty of the surroundings, whereas a bridge might alter the visual aesthetics of the area.
- ***Security and Safety:*** Underwater tunnels are inherently more secure than bridges. They are less accessible and less vulnerable to unauthorized access or potential

threats. Additionally, tunnels provide a controlled environment that is protected from external hazards, reducing the risk of accidents or incidents.

3.4.2.1 Existing Under-Water International/National tunnels:

There are a large number of under-sea/underwater road and rail tunnels existing in various parts of the world. There exists an underwater tunnel under the Thames River in London, UK and another one under the Mass river in Rotterdam, Netherlands. The Channel Tunnel (Chunnel) between UK and France under the English Channel is very popular. Two major undersea tunnels have been built in recent times, in the Port of Busan in South Korea and Santos Highway in Brazil. In India also tunnel roads and railways exist for a long time though underwater tunnels have come up only very recently. Indian Railways commissioned an underwater tunnel below the Hoogly River in 2022, as part of the Kolkatta Metro Project, which is 600 m long and located at depths of 30-35 m below the bed level. These tunnels are serving roads/rails very efficiently without any disturbance even under heavy water currents/severe earthquake conditions. At present two such major under-sea tunnels are in progress in Mumbai area, one in Mumbai-Ahmedabad High Speed Rail project and the other in the Borivalli-Thane sector of Mumbai Coastal Road project.

The Mumbai Coastal Road project provides a Twin Tube tunnel arrangement of 11.85 m internal dia for a length of 11200 m (being executed in two packages). The Mumbai Coastal Road project's alignment and tunnel details are shown in **Figure 3.3.**

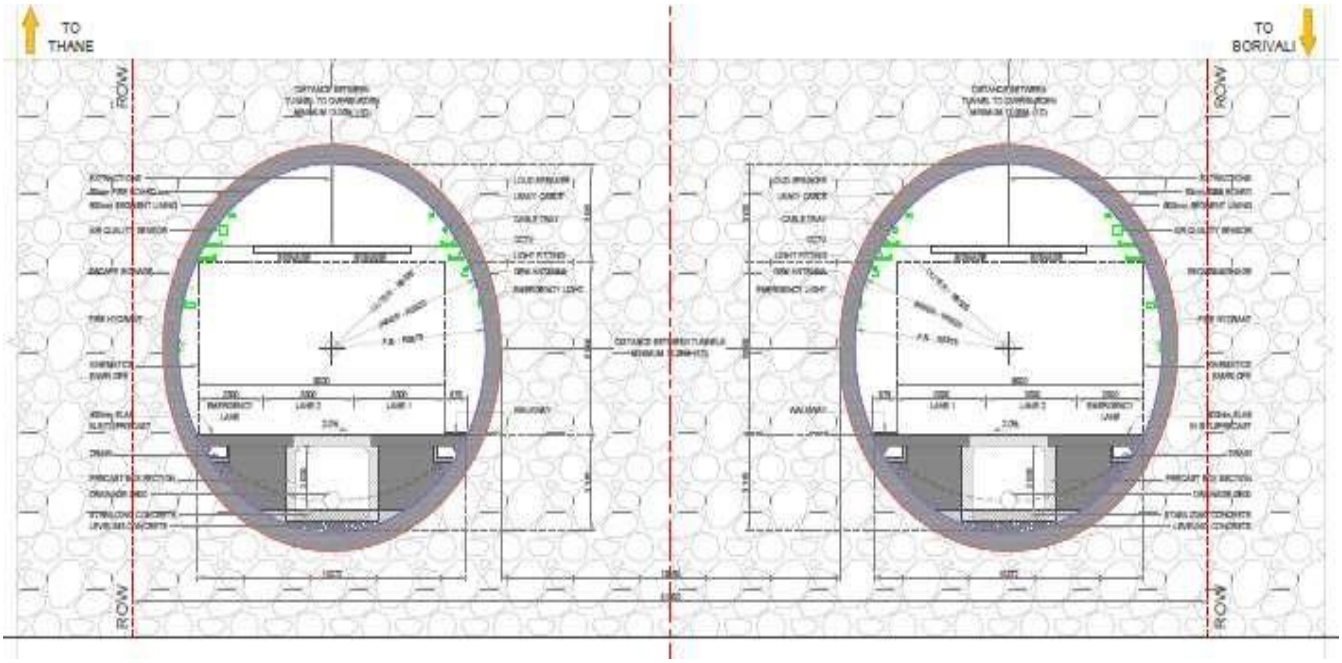
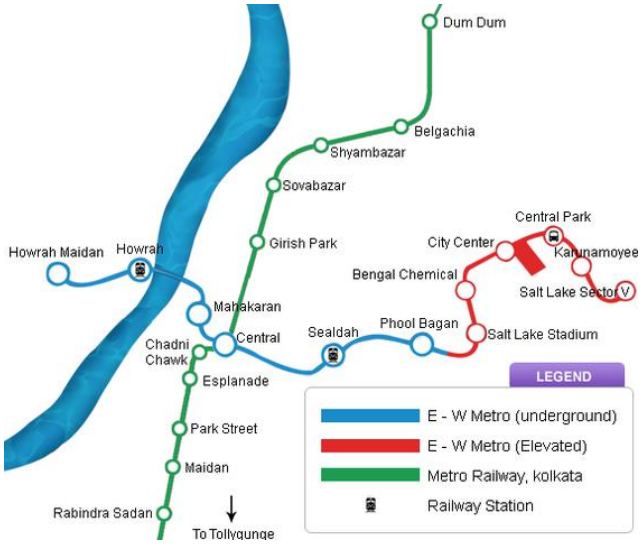


Figure 3-3: The Mumbai Coastal Road project's alignment and tunnel details.

Details of a few under-water tunnels are presented below:

- **East-West Metro Tunnel**

East West Metro Tunnel is a constructed underwater river tunnel of Kolkata Metro in Kolkata, West Bengal. The river tunnel is constructed underneath the Hooghly River. It is the biggest underwater river tunnel of South Asia and as well as India, which is made for metro rail service. The East-West Metro Tunnel's length is 10.8 km and width is 5.55 metres. A 520 m stretch of the tracks will go through a tunnel under the Hooghly River. The roof of the tunnel is about 30 metres from the ground level and 13 m from river bed level. The tunnel is used by East-West Metro Line for metro rail service and was constructed by Kolkata Metro Rail Corporation.



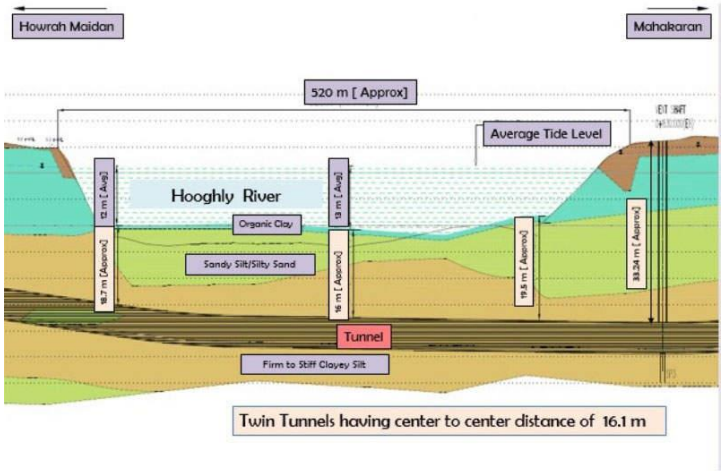


Figure 3-4: East-West Metro Tunnel

- **Thames Tunnel**

The Thames Tunnel is a tunnel beneath the River Thames in London. It connects Rotherhithe and Wapping. It measures 11 m wide by 6.1 m high and is 400 m long, running at a depth of 23 m below the river surface measured at high tide. It is the first tunnel known to have been constructed successfully underneath a navigable river.

Figure 3-5: Thames Tunnel

- **Maastunnel**

The Maastunnel is a tunnel in Rotterdam, the Netherlands, connecting the banks of the Nieuwe Maas. About 75,000 motor vehicles and a large number of cyclists and pedestrians use the tunnel daily, making the Maastunnel an important part of Rotterdam's road network. The building commenced in 1937 and finished in 1942.

The Maastunnel was built using the sunken tube or immersed tube method. Separate parts of the Maastunnel were built elsewhere in a dry dock, and then floated into place and sunk into a trench dug in the river bottom, a technique used in many other Dutch tunnels after the Maastunnel. The Maastunnel was the world's first rectangular shaped underwater tunnel built in this way. Earlier tunnels were all of a circular design. Each of the nine parts of the tunnel has a length of over 60 metres, a height of 9 metres and a width of 25 metres. They contain two adjacent tubes for motorised traffic, and two piled tubes for mopeds, cyclists and pedestrians next to it (accessible by escalator). At one time there was a laboratory in one of the ventilation buildings to examine the air quality in the tunnel.

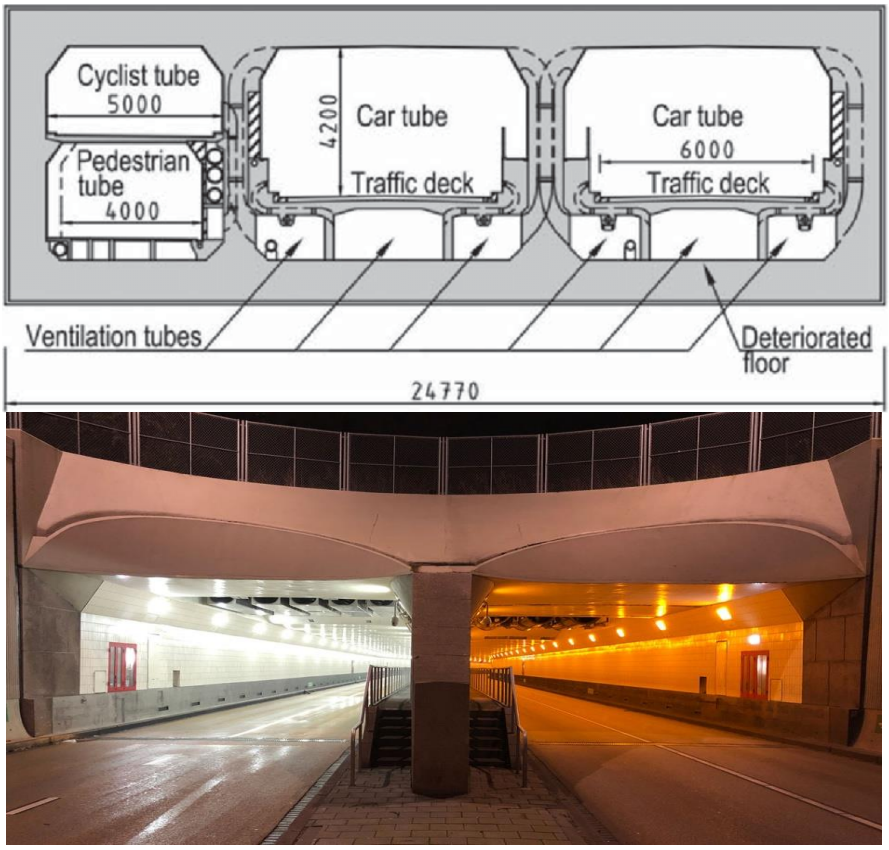


Figure 3-6: Cross Section of Maastunnel

- **Channel Tunnel**

The Channel Tunnel , also known as the Chunnel, is a 50.46 km underwater railway tunnel that connects Folkestone (Kent, England) with Coquelles beneath the English Channel at the Strait of Dover. It is the only fixed link between the island of Great Britain and the European mainland. At its lowest point, it is 75 metres deep below the sea bed and 115 metres below sea level. At 37.9 kilometres, it has the longest underwater section of any tunnel in the world and is the third longest railway tunnel in the world.

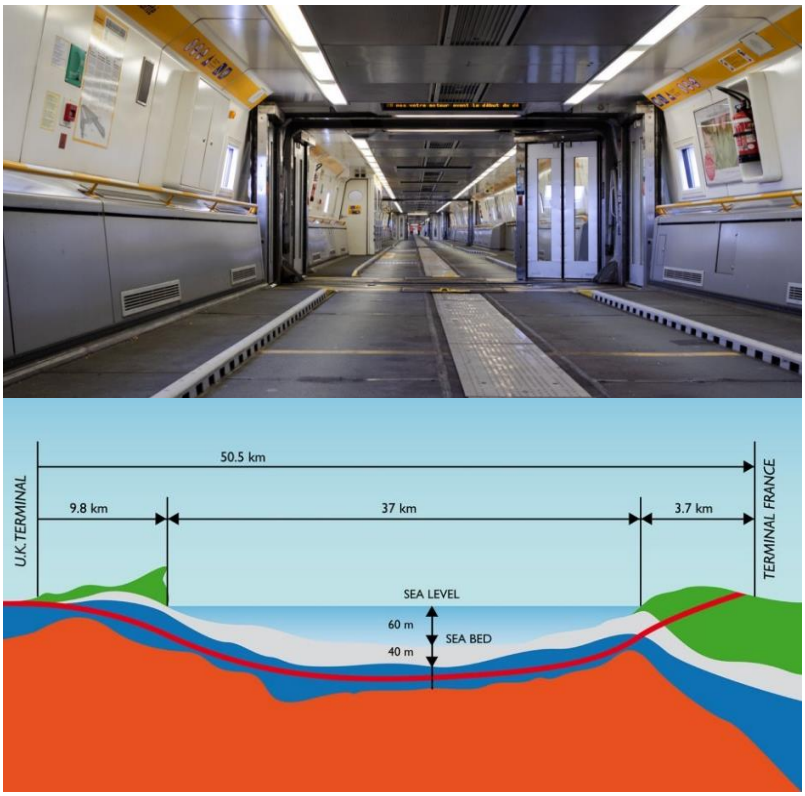


Figure 3-7: Cross section and longitudinal profile of Channel Tunnel

From discussions above, it can be concluded that tunnels are generally reliable structurally and can be designed with ideal and economical profiles and are sustainable structures. Adequate knowledge and experience are also available currently for sustainable maintenance and operation in underwater tunnels. Hence an Under-sea Tunnel road of appropriate dimensions appears to be the most reliable and sustainable option. An Expert's opinion on the idea of tunnel crossing reported sometime back is given in **Annexure –1** for information.

4 PRELIMINARY TRAFFIC STUDY

4.1 Basis for the study:

As part of the Feasibility Study for the Tunnel Link Road project between Fort Cochin and Vypeen, a preliminary estimate of likely traffic expected to pass through the proposed Fort Cochin – Vypeen tunnel is estimated for the base year and projected for future years. The estimation and projection of traffic are based on secondary data and the draft report on 'DPR for Integrated Development of Coastal Highway in Ernakulam District', draft prepared by L & T Infra Engineering, in September 2022. The DPR study is based on extensive primary traffic surveys including Classified Traffic Volume Count, Origin-Destination Survey and Speed & Delay Survey at carefully selected survey stations and road sections in and around Cochin City. The proposed Fort Cochin – Vypeen tunnel when completed would form part of the Coastal Highway and the data available in the DPR is systematically analysed to form the traffic database for the present study.

4.2 Base Year Traffic Estimation:

Traffic likely to ply through the proposed tunnel system is worked out by considering the following components of traffic viz.

(i) Normal traffic – Normal traffic is defined as the traffic currently plying on the existing road.

(ii) Generated traffic – Generated traffic considered consists of diverted traffic and induced traffic.

(a) Diverted Traffic*:* Diverted traffic is defined as the component of traffic that will get diverted from the existing road network to the project road considering reduced travel distance, travel time and Vehicle Operating Cost (VOC), as well as better accessibility and improved riding quality.

(b) Induced Traffic*:* Investment in new or upgraded roads raises the level of service and alters the pattern of accessibility over the whole area served by the road system. Vehicle users will perceive the opportunities of this increased accessibility and respond in various ways, most of which can lead to more travel on the system. To the extent that travel increases overall, it can be said to have been induced by road improvement.

(iii) Development Traffic: It is the future traffic volume component that is due to developments on land in the influence area of a new road or infrastructural facility. It can arise due to tourism and industrial developments in and around the project site.

❖ **Normal Traffic:**

In the absence of direct road connectivity between Fort Cochin and Vypeen, vehicles are transported through RORO/ Ferry Junker services. The volume of vehicles carried through the RORO services is taken as the base year normal traffic for the proposed tunnel system. Secondary data collected from Kerala Shipping & Inland Navigation Corporation (KSINC) revealed that a total of 5,531 vehicles per day were carried in two ferry services with 140 round trips in 2022 (**Table 1**).

Table 1: Estimated Normal Traffic between Fort Kochi and Vypeen in 2022

Sl. No.	Type of vehicle	No. of vehicles
1	Bus	6
2	Mini Bus	24
3	Car/ Jeep/ Van	714
4	Auto Rickshaw	260
5	Two Wheelers	4,207
6	Multi Axle truck	13
7	Truck 2&3 axle	13
8	LCV 4,6,ace	108
9	Goods Auto	-
10	Cycles	182
11	Cycle riksha	-
12	Tractor	-
13	Others	4
	Total Vehicles	**5,531**
	Total vehicles (PCU)	**3,498**

❖ **Generated Traffic:**

Generated traffic includes ***diverted traffic*** from other roads as well as ***induced traffic*** generated within the influence area of the proposed tunnel.

a) Diverted traffic-

Diverted traffic is estimated as per methodology adopted in DPR for Integrated Development of Coastal Highway in Ernakulam District, as presented in **Attachment: 2.1 of Annexure-2**. It is estimated that 2,478 vehicles will get diverted to the Ferry system between Fort Cochin and Vypeen in the year 2025 when the coastal road is fully operational as per **Table 2**.

Table 2: Estimated Diverted Traffic in 2025 with RORO Services

Sl. No.	Type of vehicle	Divertible traffic in 2025
		As per Diversion analysis with RORO Services
1	Bus	3
2	Mini Bus	11
3	Car/ Jeep/ Van	320
4	Auto Rickshaw	116
5	Two Wheelers	1,885
6	Multi Axle truck	6
7	Truck 2&3 axle	6
8	LCV 4,6,ace	48
9	Goods Auto	-
10	Cycles	82
11	Others	2
	Total Vehicles (No.)	**2,478**
	Total Vehicles (PCU)	**1,567**

However, the Diverted Traffic estimation reported in the DPR has not considered the proposed tunnel system for the diversion analysis. In view of the same, **a new cost ratio model is worked out to estimate the diverted traffic to the tunnel system**, taking into consideration the generalized cost of travel, consisting of vehicle operating cost, value of time and provision for toll sensitivity analysis for the tunnel system.

Based on information collected from KSINC, the transport charges collected for RORO services between Fort Cochin and Vypeen vary according to the type, carrying capacity and dimension of vehicles. Accordingly, average transport fare for RORO services for different categories of vehicles are considered for working out the cost ratios. In the case of the proposed tunnel system, the costs are worked out based on zero tolls as well as assuming the existing toll rate at Kumbalam toll plaza on NH 66. The existing transportation rates of Fort Cochin – Vypeen RORO Service and Toll rates at Kumbalam Toll plaza are presented in **Table 3.**

Table 3: Existing Transportation Rates of Fort Kochi-Vypeen RORO Services and Toll Rates at Kumbalam Toll Plaza

Sl. No.	Type of vehicle	Average rates for RORO Service (Rs)	Toll rates at Kumbalam (Rs)
1	Bus	200	125
2	Mini Bus	100	60
3	Car/ Jeep/ Van	50	35
4	Auto Rickshaw	20	35
5	Two Wheelers	10	10
6	Multi Axle truck	350	195
7	Truck 2&3 axle	250	125
8	LCV 4,6,ace	150	60
9	Goods Auto	50	35

For working out the new cost ratios, Vehicle Operating Costs obtained from Road User Cost Study are updated to 2022 prices, estimated based on Consumer Price Index. The Value of Time and Commodity Holding Cost are adopted from the report of DPR for Integrated Development of Coastal Highway in Ernakulam District.

Average time to cross the ferry through RORO services is taken as 15 minutes, consisting of 5 minutes of travel time and 10 minutes of time for waiting plus boarding and alighting the RORO service. In the case of tunnel, 5 minutes of travel time is considered to cross the channel.

Diversion Multiplier Factor (DMF) is worked for various categories of vehicles as below:

DMF = GC of Travel through Ferry / GC of Travel through Tunnel

The DMF is worked out under different toll scenarios for the proposed tunnel system, viz.

(i) Zero tolls

(ii) Based on toll rates presently charged at Kumbalam on NH 66

(iii) 1.5 times of toll rates at Kumbalam and

(iv) 2 times of toll rate at Kumbalam toll plaza.

The Diversion Multiplier Factor (DMF) for different vehicle types under alternative toll scenarios are presented in **Table 4.**

Table 4: Diversion Multiplier Factor (DMF) under Different Toll Scenarios

Sl. No.	Type of vehicle	Diversion Multiplier Factor (DMF)			
		No Toll	Same as Kumbalam Toll Rate	1.5 times Kumbalam Toll Rate	2 times Kumbalam Toll Rate
1	Bus	12.45	1.56	1.08	0.83
2	Mini Bus	8.02	1.62	1.16	0.90
3	Car/ Jeep/ Van	5.57	1.68	1.24	0.99
4	Auto Rickshaw	3.82	1.10	0.81	0.64
5	Two Wheelers	3.81	1.60	1.24	1.01
6	Multi Axle truck	19.86	1.65	1.13	0.86
7	Truck 2&3 axle	17.73	1.80	1.24	0.95
8	LCV 4,6,ace	11.49	2.05	1.46	1.13
9	Goods Auto	7.66	1.20	0.85	0.65

DMF worked out for different vehicle types are applied to the diverted traffic estimated with RORO service, to get the estimated diverted traffic to the proposed tunnel system in the base year.

In the case of bus services, since rerouting is a policy decision based on demand and accessibility, it is assumed that a proportion of buses presently operated within Fort Cochin and Vypeen will be extended to ply through the proposed tunnel system. A conservative estimate of 15% of buses plying through Fort Cochin and Vypeen is considered for diversion through the proposed tunnel system to cater to the demands of tourism, industry and local residents. The total divertible traffic expected to pass through the tunnel in 2025 under different toll rates is presented in **Table 5.**

Table 5: Daily Divertible Traffic to the Proposed Tunnel System in 2025 under Alternative Toll Scenarios

Sl. No.	Type of Vehicle	Divertible Traffic in 2025									
		As per Diversion Analysis with RORO	As per Diversion Analysis with Tunnel				Proposed bus schedules	Total			
			No Toll	Toll as per Kumbalam	1.5 times Toll as per Kumbalam	2,0 times Toll as per Kumbalam		No Toll	Toll as per Kumbalam	1.5 times Toll as per Kumbalam	2,0 times Toll as per Kumbalam
1	Bus	3	36	7	6	5	129	165	136	135	134
2	Mini Bus	11	97	28	23	20		97	28	23	20
3	Car/ Jeep/ Van	320	2,103	856	717	636		2,103	856	717	636
4	Auto Rickshaw	116	561	244	211	191		561	244	211	191
5	Two Wheelers	1,885	9,066	4,895	4,218	3,789		9,066	4,895	4,218	3,789
6	Multi Axle truck	6	121	15	12	11		121	15	12	11
7	Truck 2&3 axle	6	109	16	13	11		109	16	13	11
8	LCV 4,6,ace	48	604	148	119	103		604	148	119	103
9	Goods Auto	-	-	-	-	-		-	-	-	-
10	Cycles	82	82	82	82	82		82	82	82	82
11	Others	2	2	2	2	2		2	2	2	2
Total Vehicles (No.)		2,478	12,782	6,294	5,402	4,850	129	12,911	6,423	5,531	4,979
Total Vehicles (PCU)		1,567	9,280	3,999	3,410	3,052	387	9,667	4,386	3,797	3,439

b) Induced Traffic-

Induced traffic arises due to an increase in transport infrastructure or improvement in riding quality of developed roads, new and improved Road side developments, shifting of road users from public transport mode to private mode, etc. Induced traffic is that component of traffic in which people forgo or restrict their travel due to unavailability or reduced availability of infrastructural facilities.

For the present study, Induced Traffic is estimated as 10% of normal traffic in the base year, considering the fact that the proposed tunnel would facilitate easy access to hitherto unconnected settlements in the region and also features a unique undersea infrastructure development. The base year induced traffic works out to 649 vehicles per day in the year 2025. The induced traffic growth rate is assumed to reduce by 2% in the subsequent five-year blocks.

Development Traffic:

Development traffic has been assessed based on the secondary data collected with respect to tourist potential and industrial developments.

(a) Tourism oriented development traffic-

The influence area of the proposed tunnel has a number of national and international level tourist centres, like Fort Kochi, Mattancherry, Puthuvype beach, Cherai Beach, Munambam Beach etc. In addition, a Mega Oceanarium is coming up at Puthu Vyppin, at an area of 65 acres with an investment of Rs.300 crores. This is the first Oceanarium of the country and will be the largest in Asia. All these existing and proposed tourism prospects will result in increased demand for travel.

In concurrence with these tourism potential, as per details provided in **Attachment: 2.2 of Annexure-2**, it is seen that Ernakulam District tourism is growing at an average growth rate of 8.2% over the previous years. Accordingly, 8% of normal traffic is considered as growth rate for tourism related development traffic from 2025, when the coastal highway and tunnel system will be fully operational.

(b) Industry oriented development traffic-

Large scale industrial developments are taking place or in pipeline at Puthu Vyppin mainly related to natural regasification project and petroleum projects. They include:

(i) ***LNG Terminal:*** The Kochi LNG Terminal of Petronet LNG Ltd is the first LNG terminal in southern India and the fourth LNG terminal of the country. The Project is a Greenfield LNG Re-gasification terminal at Puthu Vyppin Special Economic Zone (SEZ) on land allotted by the Kochi Port Trust. The terminal has a capacity of 5 million tonnes per year.

(ii) ***Single Buoy Mooring:*** It is a loading buoy anchored offshore that serves as a mooring point and interconnect for tankers loading or offloading petroleum products. It is operated by Kochi Refineries Ltd (KRL), a subsidiary of BPCL.

(iii) ***Bunkering Terminal:*** An international bunkering terminal to supply fuel for vessels is planned by Cochin Port Trust. The bunkering industry points out that major transhipment trade has shifted to Kochi from Colombo with the commissioning of the ICTT. This will in turn attract a higher volume of vessel traffic including a greater number of coastal feeder vessels. Besides, the port's strategic location given its close proximity to the international sea route will attract mother vessels to Kochi.

(iv) ***Ship Repair Complex:*** Cochin Port Trust also plans to build a Ship Repair Complex at Puthuvypeen.

All these industrial developments are expected to bring in development traffic. A conservative growth rate of 2% of normal traffic is assumed to forecast the increase in traffic triggered by industrial developments from 2025 onward.

(c) Overall Development Traffic-

Overall development traffic is thus expected to be 10% of normal traffic in 2025 when the coastal road and tunnel system is fully operational and it is assumed to decrease by 0.5% for every five-year block thereafter.

4.3 Traffic Projection:

Traffic forecasting is the attempt of estimating the number of vehicles that will use a specific transportation facility in the future years. It may estimate the number of vehicles on a planned road or bridge or tunnel, the ridership on a railway line, the number of passengers visiting an airport, or the number of ships calling on a seaport etc. It estimates the current as well as future demand supply gap and assesses the adequacy or inadequacy of given facilities. The traffic forecast for each horizon year was estimated considering three components:

(i) Normal traffic

(ii) Generated traffic and

(iii) Developmental traffic.

❖ **Method Adopted for Traffic Projection:**

Forecasting of traffic involves understanding the past trend in traffic growth using different direct and indirect methods, which should account for making realistic assessments of the traffic growth and envisaged economic growth in the PIA. The Growth Rate method is adopted for traffic projection as discussed in **Attachment: 2.3 of Annexure-2**. It can be seen that growth rates are estimated separately for urban and rural

areas. For the rural sections, growth rates have been worked out for both passenger and goods vehicles and in the case of the urban section growth rate of only passenger vehicles have been considered. As the proposed tunnel system, although lying in an urban section, is likely to attract a large number of goods vehicles due to reduced travel distance and time, growth rates of rural sections have been adopted for the traffic projection as presented in **Table 6.**

Table 6: Adopted Growth Rates for Traffic Projection

Sl. No	Vehicle Type	2022-25	2026-30	2031-35	2036-40	2041-45
1	Bus	3%	3%	2%	2%	2%
2	Mini Bus	3%	3%	2%	2%	2%
3	Car	7%	6%	5%	5%	4%
4	Auto	5%	5%	4%	4%	3%
5	Two Wheeler	6%	5%	5%	4%	4%
6	MAV	7%	6%	6%	5%	4%
7	3 Axle	6%	5%	5%	4%	4%
8	2 Axle	5%	5%	4%	4%	3%
9	LCV	6%	5%	5%	4%	4%
10	Tata Ace	5%	5%	4%	4%	3%
11	Goods Auto	5%	5%	4%	4%	3%
12	Others	2%	2%	2%	1%	1%

❖ **Projection of Normal and Diverted Traffic:**

Traffic projection is carried out separately for normal traffic and diverted traffic using the above growth rates**. Table 7** gives the Daily Normal Traffic projected for different horizon years.

Table 7: Daily Normal Traffic Projected for Different Horizon Years

Sl. No.	Type of Vehicle	Normal Traffic			
		2025	2030	2035	2040
1	Bus	7	8	9	10
2	Mini Bus	26	30	34	38
3	Car/ Jeep/ Van	862	1,148	1,486	1,879
4	Auto Rickshaw	301	375	458	549
5	Two Wheelers	4,940	6,305	7,857	9,605
6	Multi Axle truck	16	22	29	37
7	Truck 2&3 axle	15	20	25	31
8	LCV 4,6,ace	129	168	213	264
9	Goods Auto	-	-	-	-
10	Cycles	193	211	228	244
11	Others	4	4	4	4
	Total Vehicles (No.)	**6,493**	**8,291**	**10,343**	**12,661**
	Total Vehicles(PCU)	**4,116**	**5,277**	**6,606**	**8,111**

Traffic projection of divertible traffic for different horizon years have been carried out for 'No Toll' scenario and assuming toll rates presently charged at the Kumbalam Toll Plaza on NH 66.

Table 8 gives the daily divertible traffic projected for different horizon years, under 'no toll' and toll rates presently charged at Kumbalam toll plaza, scenarios.

Daily divertible traffic projected for different horizon years assuming 1.5 times and 2 times the toll rates of Kumbalam toll plaza is presented in **Appendix-A**

Table 8: Daily Divertible Traffic Projected for Different Horizon Years under 'No Toll' and 'Toll Rates at Kumbalam Toll Plaza' Scenarios

Sl. No.	Type of Vehicle	Divertible Traffic							
		'No Toll' Scenario				Toll as per Kumbalam Plaza			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	165	189	213	237	136	155	175	195
2	Mini Bus	97	111	125	139	28	32	36	40
3	Car/ Jeep/ Van	2,103	2,801	3,626	4,584	856	1,141	1,477	1,867
4	Auto Rickshaw	561	700	856	1,027	244	305	373	447
5	Two Wheelers	9,066	11,571	14,420	17,629	4,895	6,248	7,786	9,518
6	Multi Axle truck	121	165	218	280	15	21	28	36
7	Truck 2&3 axle	109	142	180	223	16	21	27	33
8	LCV 4,6,ace	604	786	998	1,238	148	192	244	303
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	82	89	96	103	82	89	96	103
11	Others	2	2	2	2	2	2	2	2
Total Vehicles (No.)		**12,911**	**16,556**	**20,734**	**25,462**	**6,423**	**8,206**	**10,244**	**12,544**
Total Vehicles (PCU)		**9,667**	**12,420**	**15,593**	**19,191**	**4,386**	**5,581**	**6,951**	**8,493**

❖ **Projection of Induced and Development Traffic:**

In the case of induced traffic, as discussed earlier, 10% of normal traffic is treated as induced traffic which is visualized to decrease by 2% every five-year block. As far as development traffic is concerned, 10 percent of normal traffic is considered as development traffic in the year 2025, with 0.5% decrease in the subsequent five year blocks. Induced and Development traffic projected for different horizon years are presented in **Table 9.**

Table 9: Projected Induced and Development Traffic for Different Horizon Years

Sl.No.	Type of vehicle	Induced traffic				Development traffic			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	1	1	0	0	1	1	1	1
2	Mini Bus	3	2	2	1	3	2	2	2
3	Car/ Jeep/ Van	86	69	52	34	86	82	78	73
4	Auto Rickshaw	30	24	18	12	30	29	27	26
5	Two Wheelers	494	395	296	198	494	469	445	420
6	Multi Axle truck	2	1	1	1	2	2	1	1
7	Truck 2&3 axle	2	1	1	1	2	1	1	1
8	LCV 4,6,ace	13	10	8	5	13	12	12	11
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	19	15	12	8	19	18	17	16
11	Others	0	0	0	0	0	0	0	0
	Total Vehicles (No.)	**649**	**519**	**390**	**260**	**649**	**617**	**584**	**552**
	Total Vehicles(PCU)	**412**	**329**	**247**	**165**	**412**	**391**	**370**	**350**

❖ **Projection of Overall Traffic:**

Combined daily traffic on the proposed tunnel system projected for different horizon years under alternative toll scenarios is given in **Table 10**. It could be observed that the proposed tunnel system will have a total of 14,606 PCU of vehicles plying through it in the year 2025 under 'no toll' scenario and will increase to 27,816 PCU in 2040. In the case of collecting toll as per Kumbalam toll plaza, the vehicle load shall be 9,325 PCU in 2025 and 17,119 PCU in 2040. In the case of 1.5 times of toll rate, the traffic load shall increase from 8,736 PCU to 15,938 PCU in 2040. With 2.0 times of toll rate, the traffic loading shall be 8,378 PCU in 2025 with an increase to 15,230 PCU in 2040. Appendix-B gives the break-up of Projected Daily Traffic on the proposed tunnel system for different horizon years.

Table 10: Projected Total Daily Traffic (in PCU) on the Proposed Tunnel System under Alternative Toll Scenarios

Sl. No.	Scenario	Total Daily Traffic (No.)				Total Daily Traffic (PCU)			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Scenario 1: 'No toll'	20,703	25,983	32,051	38,935	14,606	18,417	22,815	27,816
2	Scenario 2: 'Kumbalam toll rate'	14,215	17,633	21,561	26,017	9,325	11,578	14,174	17,119
3	Scenario 3: '1.5 times Kumbalam toll rate'	13,323	16,490	20,127	24,255	8,736	10,823	13,217	15,938
4	Scenario 4: '2 times Kumbalam toll rate'	12,770	15,779	19,237	23,164	8,378	10,360	12,637	15,230

Appendix-A

Projected daily divertible traffic for different horizon years under 1.5 times and 2 times the toll rates at Kumbalam toll plaza:-

Sl. No.	Type of vehicle	Divertible traffic*							
		1.5 times of Toll rate at Kumbalam plaza				2 time of Toll rate at Kumbalam plaza			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	135	154	173	193	134	153	172	192
2	Mini Bus	23	27	30	33	20	23	26	29
3	Car/ Jeep/ Van	717	956	1,238	1,565	636	847	1,097	1,387
4	Auto Rickshaw	211	263	322	386	191	238	291	349
5	Two Wheelers	4,218	5,383	6,708	8,201	3,789	4,836	6,027	7,368
6	Multi Axle truck	12	17	22	28	11	15	20	26
7	Truck 2&3 axle	13	17	22	27	11	15	19	24
8	LCV 4,6,ace	119	155	197	244	103	134	170	211
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	82	89	96	103	82	89	96	103
11	Others	2	2	2	2	2	2	2	2
Total Vehicles (No.)		5,531	7,063	8,810	10,782	4,979	6,352	7,920	9,691
Total Vehicles (PCU)		3,797	4,826	5,995	7,313	3,439	4,363	5,415	6,605

Appendix-B

Break-up of Projected Daily Traffic on the Proposed Tunnel System for Different Horizon Years under 'No Toll' and 'Alternative Toll Scenarios":

		Total traffic - No toll				Total traffic - Kumbalam Toll			
		2025	2030	2035	2040	2025	2030	2035	2040
		No toll scenario				Toll as per Kumbalam plaze			
1	Bus	174	198	223	248	144	164	185	206
2	Mini Bus	128	146	163	180	59	67	74	81
3	Car/ Jeep/ Van	3,138	4,100	5,241	6,571	1,891	2,440	3,092	3,854
4	Auto Rickshaw	923	1,128	1,359	1,614	606	733	876	1,034
5	Two Wheelers	14,994	18,741	23,018	27,852	10,823	13,418	16,384	19,741
6	Multi Axle truck	141	190	249	319	35	46	59	75
7	Truck 2&3 axle	127	165	207	256	34	44	54	66
8	LCV 4,6,ace	759	977	1,230	1,518	303	383	476	583
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	313	334	353	371	313	334	353	371
11	Others	7	7	7	7	7	7	7	7
Total Vehicles (No.)		**20,703**	**25,983**	**32,051**	**38,935**	**14,215**	**17,633**	**21,561**	**26,017**
Total Vehicles (PCU)		**14,606**	**18,417**	**22,815**	**27,816**	**9,325**	**11,578**	**14,174**	**17,119**

Total traffic - 1.5times Kumbalam				Total traffic - 2times Kumbalam			
2025	2030	2035	2040	2025	2030	2035	2040
1.5 time of Toll at Kumbalam plaze				2 time of Toll at Kumbalam plaze			
143	163	183	204	142	162	182	203
54	62	68	74	52	58	64	70
1,752	2,255	2,853	3,552	1,670	2,146	2,712	3,374
572	691	825	973	552	666	794	936
10,146	12,553	15,306	18,424	9,717	12,006	14,625	17,591
32	42	53	67	30	40	51	65
31	40	49	60	29	38	46	57
274	346	429	524	258	325	402	491
-	-	-	-	-	-	-	-
313	334	353	371	313	334	353	371
7	7	7	7	7	7	7	7
13,323	**16,490**	**20,127**	**24,255**	**12,770**	**15,779**	**19,237**	**23,164**
8,736	**10,823**	**13,217**	**15,938**	**8,378**	**10,360**	**12,637**	**15,230**

4.4 Economic Studies:

While the above preliminary traffic study focuses on the road traffic projections, the benefits or effects likely to arise in the area have not been covered there. A detailed study covering aspects like developments on account of population migration, tourism, commercial, port related and strategic applications needs to be carried out which only can bring out the massive economic benefits anticipated in the project.

4.5 Other advantages of the Tunnel Road Link:

A few key developments/benefits anticipated are listed herein for ready reference.

- ✓ Under-Sea tunnel will be a better eco-friendly solution as the area involved is not an eco-sensitive location containing corals, etc and being the shipping channel in constant use undergoes regular dredging of soil for channel maintenance.
- ✓ This tunnel road will provide an important link in seamless transportation along the proposed coastal highway and will reduce traffic congestion on the existing NH-47 and NH 66 and will provide an effective alternative to our national transportation network.
- ✓ An average traveller takes about 2½ hours to go from Fort Cochin to the High Court junction in Ernakulam and back and he has to spend about Rs.300/- as auto fare. Through the channel tunnel, he will spend just Rs. 50 or 100/- and half an hour for the journey. A daily commuter in a month can save a minimum of Rs. 1500/- per month and his valuable 60 hours. Similar savings will accrue to trucks and other traffic using the tunnel.
- ✓ Construction of an undersea tunnel will produce a very huge quantity of good sand. The excavated sand itself could be a good source of revenue.
- ✓ Cochin Port has proposed a development plan to construct an Outer Harbor which will lead to significant developments in the Vypeen and neighboring regions. A channel tunnel will ensure speedy transportation of men and materials and will help promote maritime trade and commerce.
- ✓ A channel tunnel will provide seamless land connectivity between Vypeen and Fort Kochi. The entire Island of Vypeen extending upto 20 km will receive a great boost. Many tourist resorts and other associated infrastructure will come up along the entire stretch of the island from Vypeen to Palliport where there is great scope for developing beach tourism, water sports, etc, which, in turn, will help in improving the life of locals and enhancing the state's finances.

- ✓ Indian Navy has a plan to associate itself with Cochin Port's outer harbor project as they will need a significant portion of land in the reclaimed area of the proposed outer harbour. Naval establishments in Cochin will find the channel tunnel very useful from a strategic and logistic angle which will help India in defence preparedness.
- ✓ Major industrial establishments like the GAIL, IOC, BPCL, etc, have a significant presence in the Puthu Vypin area and a strategic undersea channel tunnel will help them reduce transportation costs significantly.
- ✓ The existence of an undersea channel tunnel itself could lead to developing centers of tourist attractions. Many innovative projects could be planned and developed to improve revenue realisation for the State.

5 ROAD PROFILES AND DIMENSIONS

5.1 Existing Roads in the area:

Existing roads in both Fort Cochin and Vypeen areas are narrow and do not provide adequate lanes and utilities. Bigger roads have a width of 10 to 14m, but smaller roads and lanes have only 6-7m width. The approach road to the Boat Jetty in Fort Cochin is 14 m wide.

5.2 Coastal Highway road profile:

Coastal Highway's recommended road profile is given below. The proposal is based on the typical cross-section arrangements proposed in the feasibility stage of the coastal highway project. Further based on the functional requirements, a cycle track is also proposed on both sides of the carriageway. The PROW recommended is 16.5m.

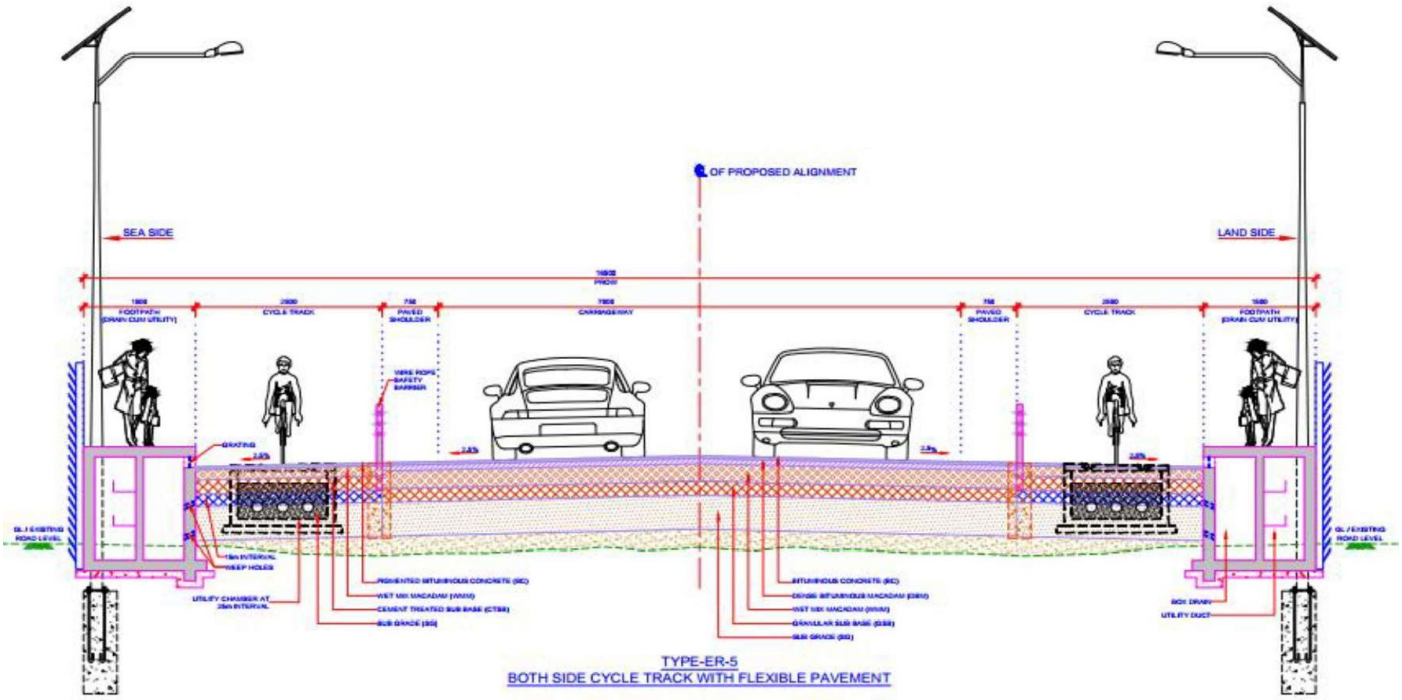


Figure 5-1: Coastal Highway road profile

5.3 Profile alternatives for road in tunnel:

The tunnel can be with the following options:

- ✓ Single Tube tunnel providing two 5.5m lanes (providing a car lane and two-wheeler lane) together with footpaths on both sides - Tunnel 14.4m dia.
- ✓ Twin Tube tunnels (each providing one car lane of 5.5m) with footpaths- 9m dia.
- ✓ Single Tube tunnel (providing two 7.5m main lanes and two 3.5m service roads with footpaths above the service roads)- 25.8 m dia.
- ✓ Single Tube tunnel (providing two 4.5m main lanes and two 3.5m service roads) with footpaths above service roads- 15.8 m dia.
- ✓ Twin Tube tunnels (each providing one car lane of 4.5m and 3.5m service roads) with footpaths above service roads- 11.25 m dia.

5.4 Recommended Tunnel Dimensions:

Decision on the type/size of the tunnel will depend on the road arrangement finally adopted and the construction scheme/machinery available. Twin tube tunnels with 4.5 m and 3.5 m lanes in each tunnel is recommended for this project with approaches transitioning into a 4-lane road on both sides till joining the coastal highway as this will provide a smooth road arrangement which can cater to the traffic needs for another 50 years. Twin tunnels are recommended as the available machinery(TBM) in the country currently are only up to 11-12 m diameter and most of the projects in India have gone for twin tunnel arrangement. Twin tunnel has an additional favourable point in that it provides an emergency escape arrangement automatically and improved serviceability of the road.

Additional facilities such as Emergency Stop-Bays at every 250m and Emergency exits for passengers with ventilation at every 500m will also be required. Service lines, Gas/Fuel pipe lines and drainages with pumping arrangements are also to be provided suitably using the median/footpath space available. This will require an internal dimension of 11.25 m and an external dia of 12.50 m for the tunnel.

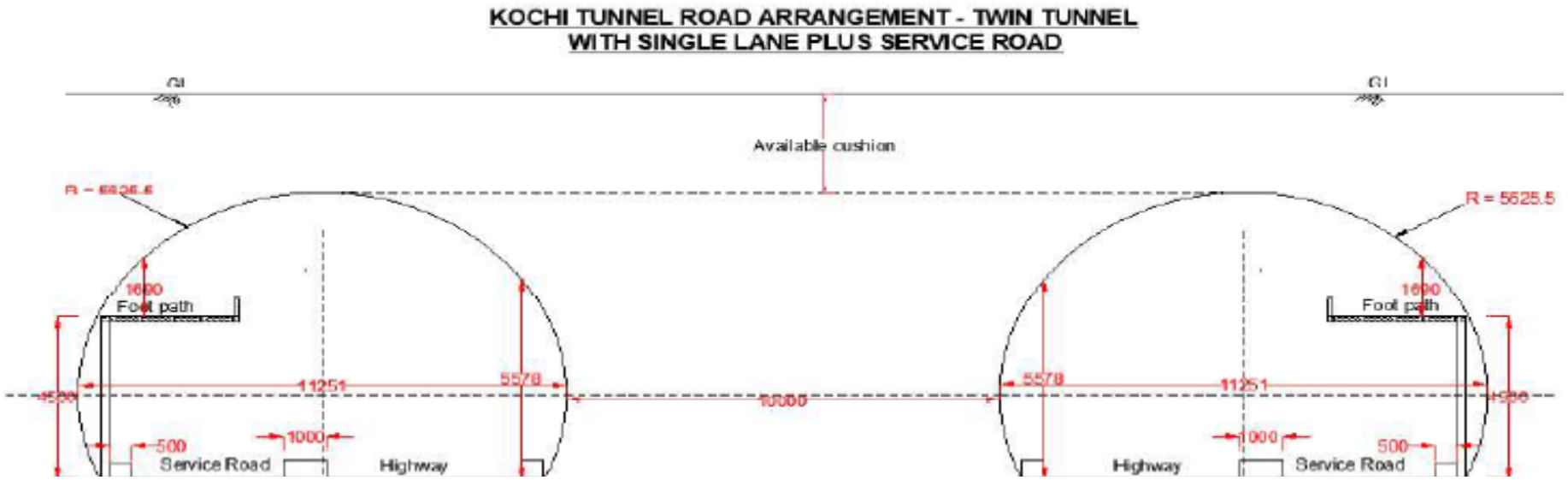
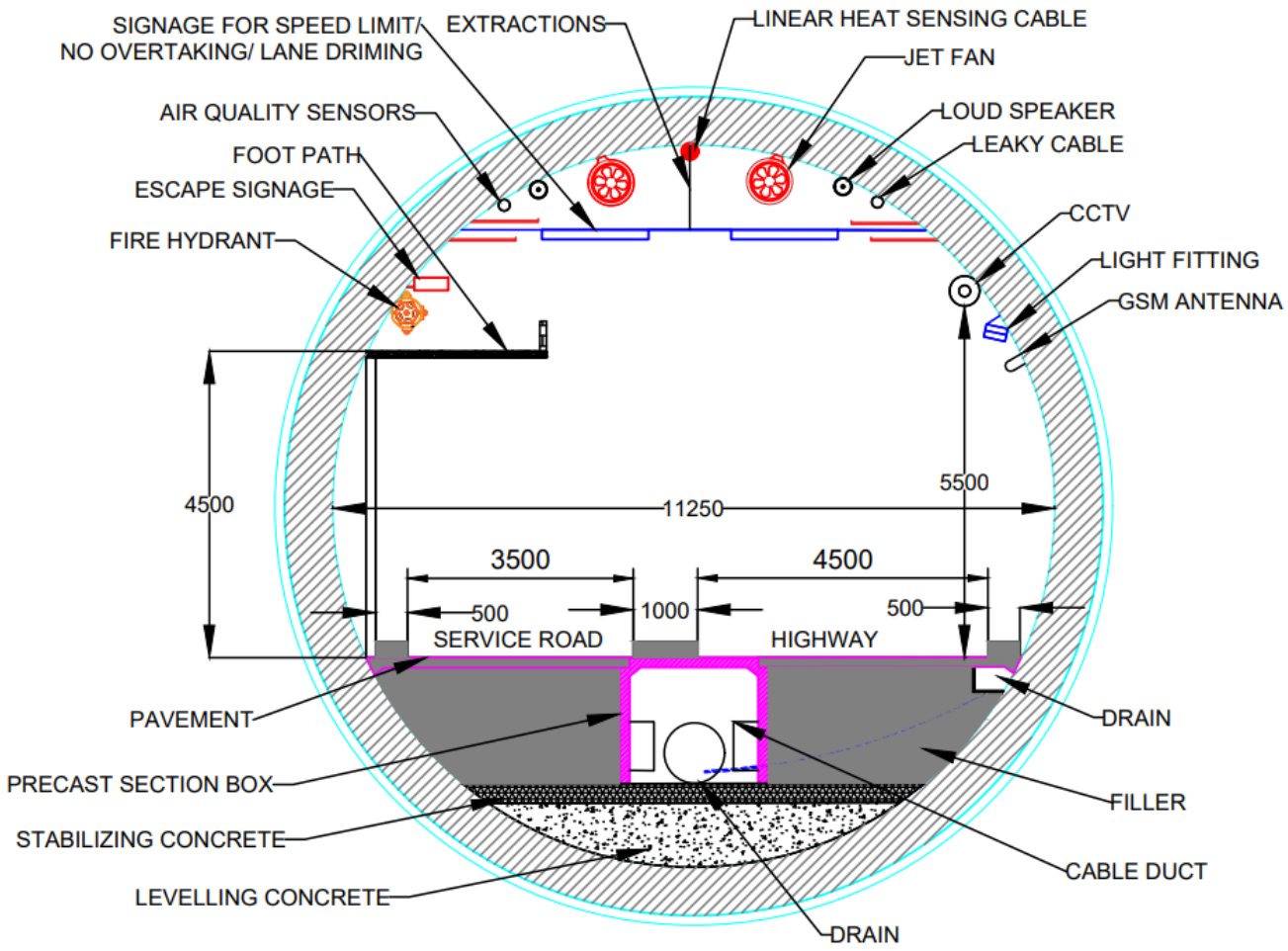


Figure 5-2: Recommended Tunnel Road Arrangement



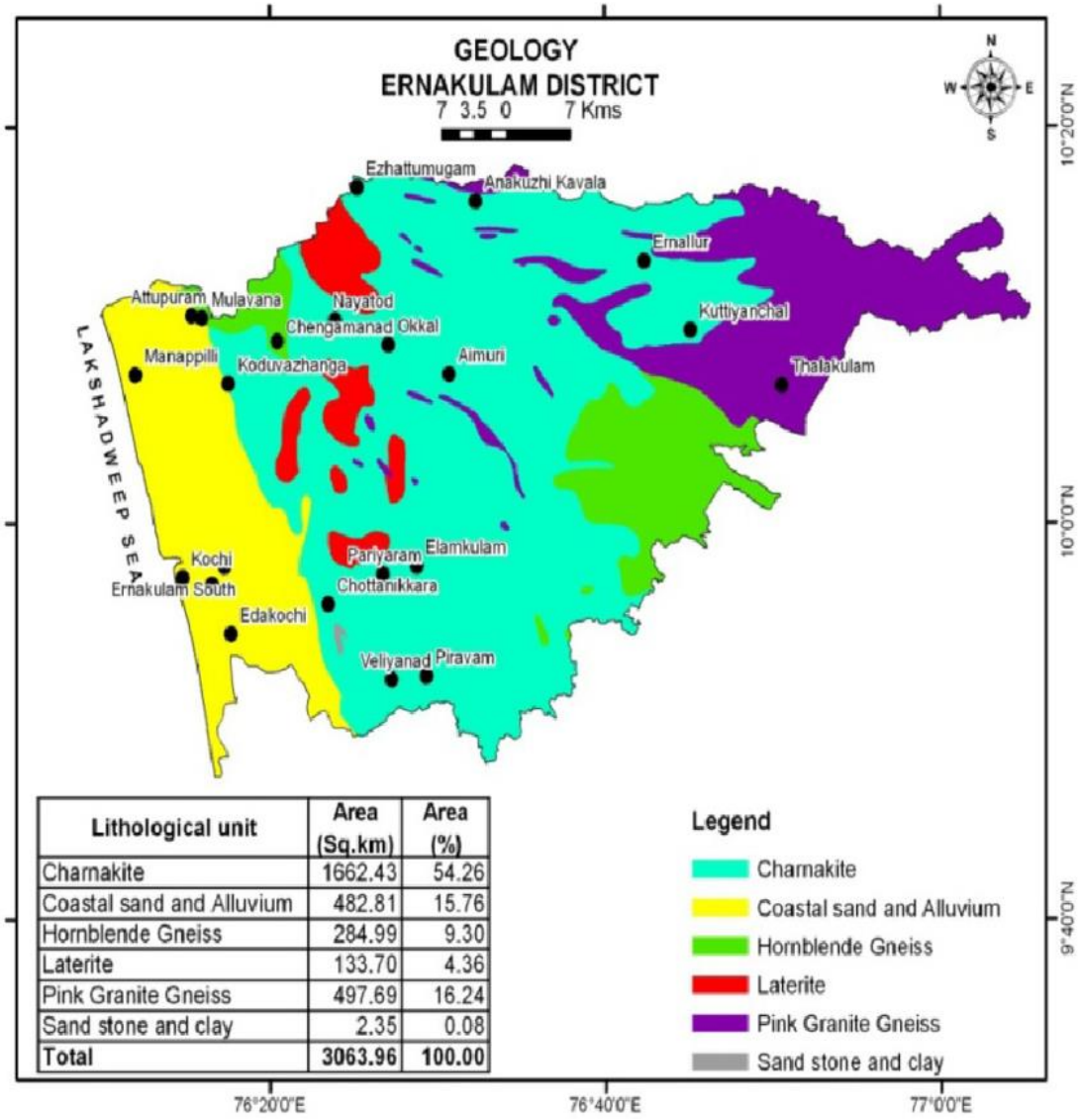
ALL DIMENSIONS ARE IN mm

Figure 5-3: Recommended Tunnel Dimensions

6 GEOLOGY AND SOIL PROFILES IN THE AREA

6.1 Geology of the area:

Geology and soil profiles along the final alignment chosen will be critical for the design and construction of the tunnel. This information will be required to be collected through a professional agency before final designs are made.



Lithological unit	Area (Sq.km)	Area (%)
Charnakite	1662.43	54.26
Coastal sand and Alluvium	482.81	15.76
Hornblende Gneiss	284.99	9.30
Laterite	133.70	4.36
Pink Granite Gneiss	497.69	16.24
Sand stone and clay	2.35	0.08
Total	**3063.96**	**100.00**

Figure 6-1: Geological Profile

6.2 Sample Soil profiles from near by areas:

Cochin Port Trust has recently surveyed the soil profiles in the south Coal Berth area and the same are furnished below. This, at best, can give some idea of the soils likely to be encountered, but a decision on the type/size of tunnels and the method of its construction can be decided only after the exact details are available.

Table 11: Soil Profile (Bore Hole details) of CPT area

Depth below E G.L (m)	Soil Profile Encountered
ESBL to 6.0	Very loose silty clay with sea shells
6.0 to 16.5	Blackish silty clay with sea shells
16.5 to 22.5	Greyish silty clay with fine particles of whitish yellow colour
22.5 to 25.5	Greyish silty clay with fine particles of whitish yellow colour
25.5 to 28.5	Silty clay in whitist grey colour
28.25 to 33.0	Greyish silty clay with shells and kankar
33.0 to 36.0	Silty clay in greenish grey colour
36.0 to 45.0	Blackish silty clay
45.0 to 46.5	Blackish silty clay with decayed coal particles
46.5 to 51.0	Blackish silty clay with decayed coal particles
51.0 to 58.5	Greyish silty clay with mica
58.5 to 61.5	Blackish sandy silty clay with mica
61.5 to 64.5	Blackish silty clay with decayed coal particles
64.5 to 70.0	

6.3 Suitability for Tunnelling:

The soil profiles indicate at higher levels available soils are not very suitable for tunnelling by normal/TBM methods because of the loose nature of the alluvial deposits. At deeper depths, 40-45 m below the sea bed levels, stiff clay exists and TBM tunnelling might be possible. However, special tools/steps will be necessary as the marine clays may have varying material properties across the profile in single layers. A detailed note on the feasibility based on available soil details is given in **Annexure-3.**

7 ALIGNMENT OF LONGITUDINAL PROFILE OF THE TUNNEL LINK ROAD

7.1 Discussion on Alignment:

Detailed topographical studies are required to arrive at the most suitable and feasible alignment for the tunnel and approach roads. The area on Fort Cochin side is well developed with a large number of big and small residential, commercial and religious structures. Land value in the area is also high. The development will affect at least 1200 to 1500 m length of developments in the area if not more. Similar is the case with the approach on Vypeen island, though the density of construction is relatively less. A possible green field approach alignment over the marshy lands on the western part of the island may slightly increase the length but will have lesser acquisition and construction problems. This road will join the existing Goshree road in a circle. Alignment plans showing the connection arrangements and land acquisition boundaries are given in **Annexure-4**, which needs to be developed further in consultation with Municipal and Road authorities.

There are two clear possibilities in aligning the tunnel across the shipping channel as shown below. In the first option, the tunnel of about 545m (reducible to 500 m) can connect the existing KV Jacob road on Fort Cochin side near the RO-RO Jetty and the coastal highway road on Vypeen side to be developed after acquisition. The second option will be a longer tunnel of about 700 m connecting the same road on Fort Cochin side and a new road on the western side in Vypeen through marshy lands. However, there will be a difficulty as the marshy area in Vypeen has a significant mangrove population. The choice of alignment will have an effect on the connecting road junctions and in turn the available gradients for the approach roads. Tentative coordinates are indicated in the plans.

Figure 7-1: Option 1- Proposed Crossing Alignment 1

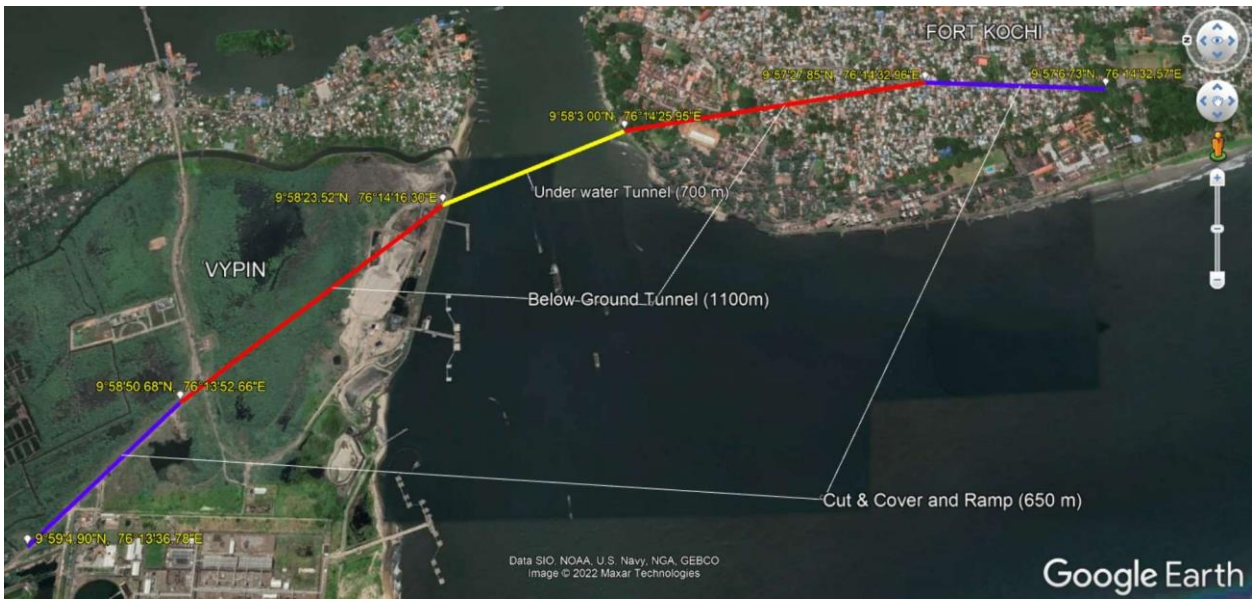


Figure 7-2: Option 2- Proposed Crossing Alignment 2

7.2 Longitudinal Profile of Tunnel:

The tunnel has to pass through partly under land and partly under sea on either side of Vypeen and Fort Cochin islands. The main tunnel will be at a depth of 35 m from sea level (low sea level) depending on the type, size and design of the tunnel bores, giving around 20m draught for the shipping path and 15 m soil cushion above the tunnel required for TBM tunneling. Sagarmala project scheme has already considered a draught depth of 18m for future. Figure below shows the details schematically.

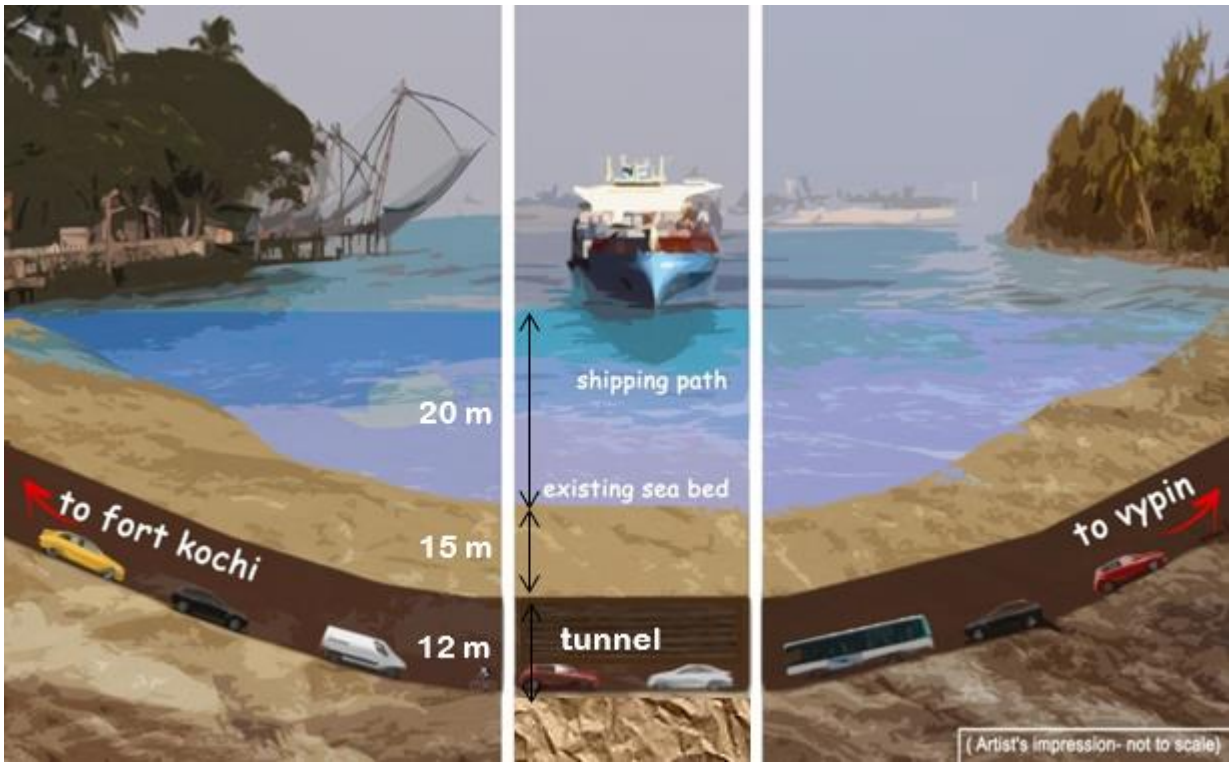


Figure 7-3: Schematic Longitudinal Profile of Tunnel

A tendative longitudinal profile for the proposed tunnel as per Option-1 is shown in **Figure 7-4**. While the gradients may be decided based on the roads availability either side, a maximum gradient of 1 in 25 (4%) can only be allowed keeping the type and nature of traffic in view. A slope of 1 in 33 (3.0%) or even 1 in 40 (2.5%) may be preferable in view of likely future developments.

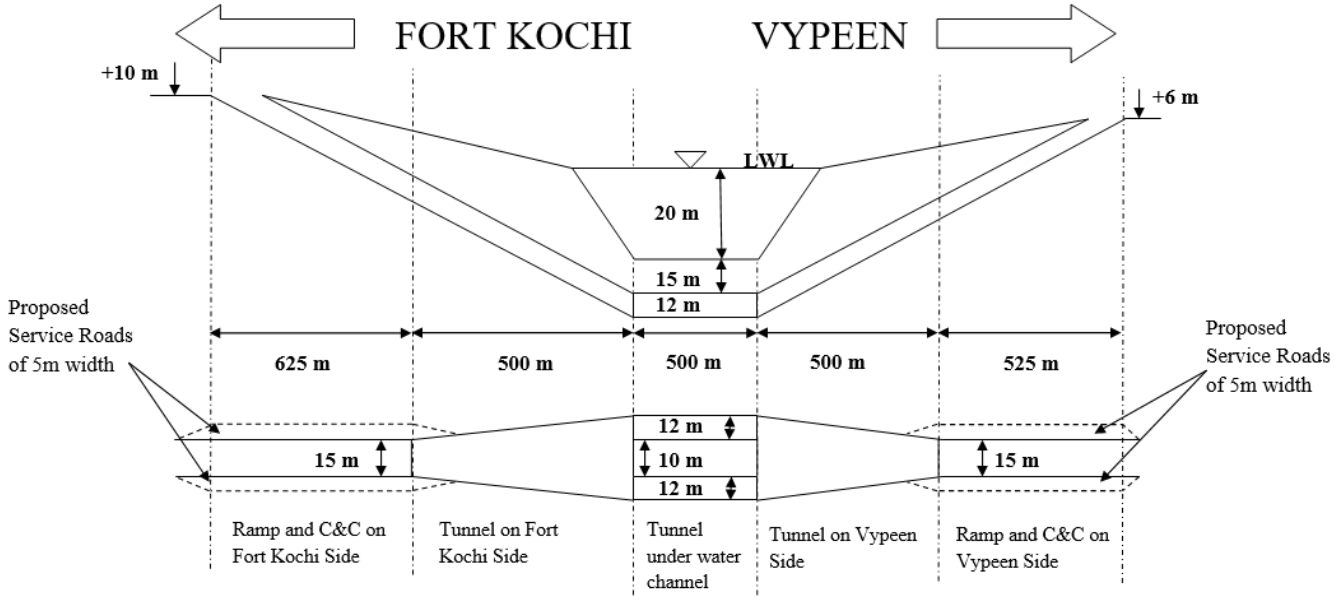


Figure 7-4: Longitudinal Profile and Plan of Proposed Tunnel
(Skematic- Not To Scale)

Notes:

1. Levels indicated on the sides are as per Google Map.
2. Gradient for approach is taken as 1 in 25 (4%).
3. Road connection at ends not decided. Cut & Connection/Open cutting will be suitably designed to meet the road connections as approved.

Detailed alignment plans for the two options, made on a reconnaissance survey covering the roads and other assets in the area, are shown in **Annexure-4.** This includes a tendative vertical profile and also a rough assessmsnt of land and properties involved. The plans and details shown in **Annexure-4** are slightly at variance from the discussions above. However actual details are possible only after detailed topographic surveys are made.

8 LAND AND PROPERTY ACQUISITION

Land acquisition for the project will depend on the final arrangements for the tunnel and the roads involved and detailed plans finalised. Road widening or new roads in Fort Cochin area and Vypeen area will be required to the extent connections are required. Twin-Tube tunnel may involve about 34 m width underwater and 45-50 m at the approaches for cut&cover which may require additional land for service roads and transitioning. Overall about 3-4 Ha of land may be required for the 2500 m tunnel stretch, which only includes the requirements of cut&cover tunnel and cuttings. It involves about 300 buildings and structures to be acquired and removed. Additional land may be required for the extension of approach roads depending on the connectivity to the coastal highway, which is not included in the estimate. Additionally, about 1 Ha of land may be required for handling TBM. The exact amount of land and structures affected will be assessed by a survey.

The table below indicates the rough assessment of land and buildings required to be acquired in Fort Cochin and Vypeen for Option-1 alignment. Option-2 is not assessed.

Table 12: Assessment of Land and Buildings required to be acquired for Option-1

ACQUISITION OF LAND AND BUILDINGS			
Item	**Vypin end**	**Fort Kochi end**	**Total**
Land (Ha)	**1.4**	**1.39**	**2.79+**
Buildings (NO)	**160**	**125**	**285+**

+ Indicates rough assessment for cut & cover tunnel and cutting only. Construction requirements to be added.

9 DESIGN AND CONSTRUCTION METHODOLOGY AND PROGRAMME

9.1 Design of Tunnel and Services:

The basic goal of the design criteria is to develop a safe, reliable, maintainable, energy efficient and economical Mechanical and Electrical system for tunnel.The design of tunnel services shall meet the following objectives:

- Provide the appropriate level of tunnel equipment and operation to contribute towards a safe tunnel environment for road users, local inhabitants, operators and maintenance staff.
- Addresses Tunnel Dilapidation Risks.
- Reduces Operational Risks.
- Increases Structural and Network resilience.
- Provide continuous control of internal air quality to meet the specified requirement;
- Provide adequate visibility levels in all conditions at all times of the day and night;
- Provide appropriate collection, treatment and disposal of ground water and surface wash waters;
- Provide mechanical ventilation and smoke control systems capable of fully functional continuous operation for a range of fire events;
- Provide emergency egress from all areas of tunnels; Provide emergency response facilities in accordance with operational standards required by the authority;
- Minimize whole life costs;
- Incorporate mitigation measures from risk analysis as per EU directive
- The strategy for design of tunnel services shall be to adopt minimum acceptable provisions, with due regard to international best practices.

The design of tunnel services shall achieve safe tunnel environment for following stake holders:

- ✓ Road users;
- ✓ Local residents;
- ✓ Tunnel owner and operator;
- ✓ Maintenance staff;
- ✓ Police and civil defence
- ✓ Fire Authority;
- ✓ Emergency services;
- ✓ Government control authorities;
- ✓ Basis of tunnel services design

The E&M Systems includes the following areas:

- Tunnel Ventilation System
- Power Supply System
- Tunnel Lighting System
- Water Supply and Drainage system
- Fire Protection System
- Communications and Traffic Control
- Tunnel Operation and Plant Control/ SCADA
- Buildings and Plant room facilities

One important aspect of the design process in this case will be the need to look at the nature and features of the ground an soil conditions thoroughly and more closely. It may be advisable to obtain design service/advisory support from experts with previous experience in similar conditions in the country and also abroad.

❖ TUNNEL SAFETY AND RISK ASSESSMENT:

Safety in tunnels requires a number of measures relating, amongst other things, to the geometry of the tunnel and its design, safety equipment, including road signs, traffic management, training of the emergency services, incident management, the provision of information to users on how best to behave in tunnels, and better communication between the authorities in charge and emergency services such as the police, fire-brigades and rescue teams.

❖ FIRE IN THE TUNNEL

Fires in the tunnel are a serious risk and the probability of such incidence is based on the likelihood of a serious accident occurring inside the proposed tunnel and the vehicle involved catching fire. Tunnel alignment for tunnels has to be maintained as straight alignment with a maximum grade of 2.5% allowing high visibility distance.

❖ ACCIDENTS

The probability of occurrence of an accident in a uni-directional tunnel is very unlikely. To reduce the probability of the same to an extremely unlikely event, the alignment of the tunnels has been designed as straights with maximum grade of 4%. This will ensure high visibility to stopping vehicle / debris on the road. It is also proposed to restrict the vehicle speeds to 80Kmph for the tunnels and enforce the same through speed detection cameras.

❖ **BREAKDOWN AND DEBRIS ON ROAD:**

The risk of occurrence of such an event is similar to accidents. An automatic incident detection system shall be implemented to reduce the impact of such event.

❖ **OVERSIZE VEHICLES**

It is proposed to restrict the entry of all oversized vehicles/ consignments to tunnels to eliminate such risk.

❖ **Animals in Tunnel**

It is proposed to provide guard rails along the entire road to restrict the entry of animals in the traffic lanes. Therefore, the risk of such event is unlikely.

❖ **VANDALISM**

Considering that this is an urban tunnel, it is necessary to provide for the securitisation of likely entry points to the tunnels by pedestrians. Such a vandalism event may have a very high impact on tunnel services. Therefore, the control room shall be provided with an automatic incident detection system to report the stoppage of vehicles and pedestrians inside tunnel. Control rooms shall be manned 24x7 to register and act on such incidence. However, to eliminate the risk of this high impact event, the SCADA software shall be capable of sending message to enforcement agencies automatically with details of location.

❖ **TERRORIST ATTACK**

The impact of such an event on tunnel operation would be disastrous and would require immediate action by local police. The method of reducing the risk of such an event shall be discussed with the authority at the time of execution.

❖ **TRAFFIC QUEUES**

The risk of occurrence of traffic queues is unlikely considering an adequate number of lanes have been proposed with adequate distances from tunnel entry/ exit points from proposed interchanges. However, the event of traffic queuing is unlikely to impact tunnel services. Environmental monitoring sensors are to be proposed to adjust the level of tunnel services such as lighting and ventilation.

Table 13: Essential norms as per NEPA and other guidelines:

Service	Condition	Suggested provision
Structural Measures	Twin tubes Mandatory where 15-year forecast shows that traffic > 10000 veh./lane.	Twin uni-directional tunnels
	Gradients less than 5% are mandatory	Gradients shall be restricted to 2.5%
	Emergency walkways are mandatory where no emergency lane is provided	Provision of exclusive walkway
	Emergency exits	Cross passages proposed at every 500m
	Drainage for flammable and toxic liquids is mandatory where such goods vehicles are allowed	Drainage provisions shall be made underneath the pavement
	Fire resistance of structures is mandatory where local collapse of structure may have disastrous effect	Provision to be made
Lighting	Normal Lighting	As per CIE 88,2004
	Safety lighting	As per CIE 88,2004
	Evacuation lighting	As per NFPA 502
Ventilation	Mechanical ventilation if tunnel length exceeds 1000 m	Longitudinal ventilation by providing axial fans and saccardo nozzles
Emergency Stations	Mandatory provision of emergency stations at 150m equipped with telephone and two fire extinguishers necessary	To be made
Fire Hydrant	At every 100m	Fire main attached to water tank to be provided with supply point to match location of emergency station.
Control Centre	Surveillance of several tunnels may be centralized into a single control centre.	Control centres shall be provided to respond to incident on entire stretch with provision of SCADA.
Monitoring Systems	Video	CCTV cameras shall be provided along tunnels
	Automatic incident detection and/or fire detection	SCADA system connected to CCTV equipped with automatic incident detection

Equipment toclose tunnel	Traffic signals before the entrances	Provision of boom gate, VMS, traffic signals before the portals controlled from Control centre
Communication System	Radio re-broadcasting for emergency services	Through SCADA system
	Emergency telephone for tunnel users	Connected to SCADA system
	Loudspeakers in shelters and exits	Connected to SCADA system
Emergency power supply	Mandatory	Control centre to have necessary capacity of stand by generators with necessary fuel storage.
Fire resistance of equipment	Mandatory	All tunnel fixtures and fitting shall be fire resistance compliant.
Additional Provisions	Drainage	Provision of sump and pumps to collect seepage/storm water at lowest point of tunnels and dispose the same to outside
	Leaky feeder cable	Provision of leaky feeder cable to enable use of mobile services within tunnels.
	Environmental monitoring censors	Provision of environmental monitoring censors to monitor visibility levels, air quality and smoke detection
	Linear Heat Detection	Linear heat detection through adoption of OFC cables cross looped to detect exact location offire.
	Variable Message signs	VMS system attached to SCADA at control centre to enable safe tunnel operation.

9.2 Construction:

Construction methodology and in consequence, the cost will depend on the detailed designs adopted. As the soil in the sea bed is expected to be clay mostly, a scheme using Tunnel Boring Machine can be followed in this project as being done in the Mumbai Coastal Road Project currently. TBMs of 10 to 12 m dia are now freely available in large numbers in the country, hence the scheme will be viable. Being underwater, suitable strengthening/freezing steps may also be necessary. If the underground soil profile consists of a full or partial rock structure, Shield TBM will be used. If the profile has high porosity with loose water bearing, as could be expected here, Slurry Face TBM will be used. One concern will be the cost of mobilisation of a special TBM for a one-time work of this nature involving a length of about 2 km. Given the site, it appears such mobilisation is very necessary for the project. Tunnels can also be constructed by other methods such as NATM (New Austrian Tunnelling). TBM method of construction, which is generally faster, may take about 2 to 2 1/2 years time whereas other methods may take longer. However the exact method of tunnelling can be decided after thorough soil and other investigations and based on availability of machinery.

Other aspects of the project construction may involve reclaiming some land from the backwaters on the eastern side of Vypeen island where one of the alignment options proposed go close to the waters, finding and managing dumping of construction debris, etc. In this project, most of the debris being under sea clay layers, reclaiming adjoining lands using this material may be an advantageous and cheaper option.

9.3 Project Timeline:

Over all construction period for the project might be about 2 1/2 years apart from the time taken for land acquisition. Base year is assumed as April, 2025 (when the construction is expected to start) and the date of likely completion and commissioning is September, 2027. **Figure 9-1** shows the timeline for construction of the project.

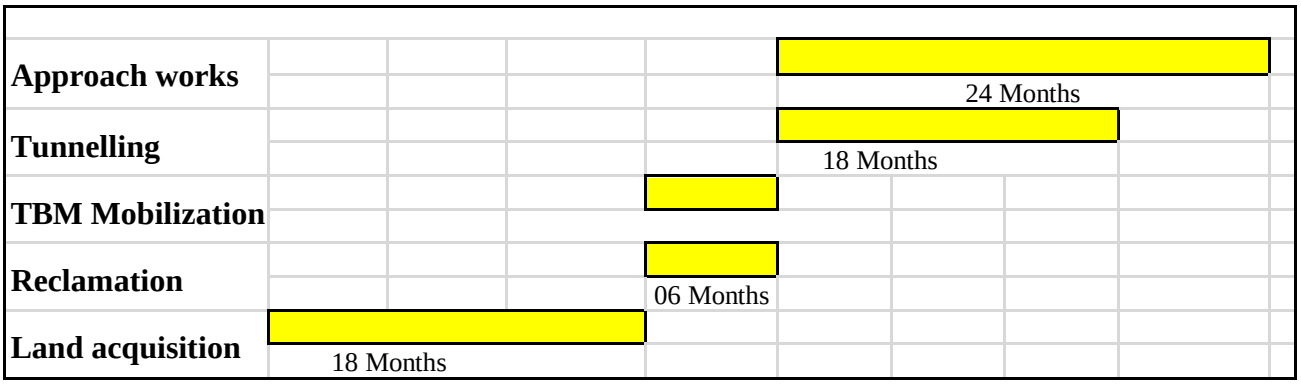


Figure 9-1: Time Line of the Vypeen- Fort Kochi Tunnel Project

10 ENVIRONMENTAL AND SOCIAL IMPACTS

An Environmental Impact Assessment (EIA) and Social Impact Assessment (SIA) study has to be carried out to study the potential environmental and social impacts of the Tunnel Link Road project and if agreeable to identify necessary remedial measures.

10.1 Environmental Impact Assessment (EIA):

The proposed development is not envisaged to alter the existing environment of the project area or create significant negative impacts. Impacts due to the proposed development are not envisaged to create adverse impacts which will be on a permanent basis. The project activities during construction and operational phase include various activities like levelling of the site, clearing of trees, construction of several structures, transportation of material, digging inside the sea/shipping channel, operation of transport services in the tunnel, tourism and other related commercial activities in the vicinity, etc.

All these activities contribute to different types of impacts. Potential environmental impacts due to proposed development on attributes like air quality, noise, water quality, soil, flora and fauna, etc. have to be assessed as part of this EIA study. The identified impacts are typically localized and can be mitigated with minor to negligible residual impacts. Appropriate mitigation measures to avoid/minimise the impacts due to the various activities that will be carried out during the construction and operation stages of the proposed project have to be assessed and recommended in this EIA study. Measures include avoidance measures, mitigation measures and environmental enhancement measures.

10.2 Social Impact Assessment (SIA):

The Social Impact Assessment to be carried out involves primary social profiling of the affected persons, stakeholder consultations, etc. The proposed development will involve land acquisition; design considerations are to be aimed to keep land acquisition to the minimum possible. This has to go through the applicable regulatory process for necessary land acquisition. LA will result in people losing their homes/commercial establishments, impact on religious structures, impacts existing lifelines, agriculture/fishing, etc.

Loss of land shall be compensated with appropriate monetary compensation as per applicable guidelines/framework for R&R. Squatters and encroachers have to be informed about their removal with prior information and they have to be shown alternate locations with regards to livelihood as applicable. Appropriate compensations as per

applicable rules shall be provided to all those who are impacted due to the land acquisition.

There shall be direct and indirect employment opportunities for the locals during the construction stage of the project. Local labourers need to be preferred for the construction work to the extent possible. Hence there will be positive impacts on the vicinity of the project site. In addition, it needs to be envisaged that the area would witness improvements in basic social infrastructure like schools, colleges, hospitals etc. in the vicinity due to the development of the road corridor.

10.3 Environmental and Social requirements:

The project will involve obtaining necessary **Environmental/CRZ Clearance from MoEF** and **Consent to Establish/NOC from KSPCD**. Disturbances to the marine life in the vicinity and likely damages to mangroves, if any, will need study and remedial measures need to be assessed. EIA has also to bring out the Carbon Emission benefits likely in the project as a significant reduction in fuel usage in the Greater Cochin area will be available. Similarly, detailed Social Impact assessment needs to be made and extant regulations connected to R&R requirements have to be observed. Likely land acquisition for the ROW on the residential houses and businesses and effects on existing services including Ferry Services in the area also should be covered. Resettlement plans for the people and properties affected need to be spelt out clearly. Important regulations connected to environmental requirements are listed below for ready reference.

10.4 Key Environmental and Land Acquisition Laws and Regulations:

The Government of India issued Environmental Impact Assessment Notification in 1994, as a part of Environmental (Protection) Act, 1986 and amendments in September 2006. The environmental Acts, Rules and Norms which are generally relevant to Tunnel 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
- ✓ Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act 2013.

11 ESSENTIAL STUDIES REQUIRED FOR PREPARATION OF DPR

Studies required for assessing the requirements of traffic, alignment, design and construction are as under:

- ✓ Traffic study and IRR/EIRR evaluation,
- ✓ Topographical and Alignment studies using Drone or other methods including assessment of structures and properties affected and heritage/ecological features involved,
- ✓ EIA and SIA studies,
- ✓ Hydrological/oceanic studies involving bathymetry, channel characteristics, tidal effects, channel bed profile, bed history, dredging history, channel currents including velocity of flows, etc,
- ✓ Geological survey of the channel bed and approach areas,
- ✓ Geotechnical survey of the channel bed and approach areas,
- ✓ Location survey for land pockets for erection/launching of machinery, dumping and disposal of soil/waste materials, and
- ✓ Routes for movement of machinery, material, etc, including waste management.

12 PROJECT COST ESTIMATE

For a Twin tunnel system with internal diameter 11.2 m for the tunnel link road, the cost estimate on rough basis is Rs.2672.25 cr, as follows:

Table 14: Project Cost Estimate

Sl No.	Description of Work	Amount Rs (In Crores)
1	Preliminary Works (Establishment, Mobilisation, Preliminary design, etc)	10.00
2	Carrying out studies at site by Contractor	10.00
3	Land and Property Acquisition	500.00
4	Ground Development for Tunneling including reclamation	200.00
5	Bored Twin Tube Tunnels 1750 m long (@ Rs.350 Cr/km for each tube)	1225.00
6	Cut & Cover/Open at the approaches where cushion is less, total 1000 m(@150 Cr/km)	150.00
7	Tunnel Safety systems(TVS, Emergency Exit arrangements, etc)	150.00
8	Junction arrangements at both ends including. signals, E&M, Scada, etc	150.00
9	Muck disposal	50.00
10	Environment protection, Utility shifting, Retaining structures, etc	100.00
11	Detailed Designs, PMC cost (@ 5%)	117.25
	Total Estimated Cost	**2672.25**

Notes:

1. Cost is based on current costs incurred in various projects and on considerations relevant to site. Tunneling cost in Mumbai Coastal Road project is about Rs.350 Cr/km. Special works such as ground improvement, reclamation, safety systems are also required.
2. Road connections to the Coastal Highway beyond the Tunnel (Cut & Cover) are not included, cost for the same may have to be added to the Coastal Highway Project estimate.
3. Cost of preparation of DPR including EIA and SIA and all other investigations/studies will be extra and may be in the order of about Rs.25 Cr.

13 FINANCIAL AND ECONOMIC ANALYSIS OF THE PROJECT

13.1 Basic Approach of Economic Analysis

The economic viability of the Fort Kochi-Vypeen Tunnel Project has been evaluated using the wide framework of "Cost-Benefit Analysis," which is commonly used to evaluate public investment projects. The basic criteria for evaluation in economic analysis are the socio-economic impacts on the economy, and the benefits are estimated for the economy as a whole.

The economic analysis entails comparing project costs and benefits in economic terms under "with" and "without" project conditions, as well as calculating the project's Economic Internal Rate of Return (EIRR) as per IRC SP: 30-2019. This demonstrates the potential return to society from the planned investment across the project's life cycle, i.e. the analysis period.

13.2 Approach and Methodology for Economic Analysis

The main steps followed are:

(i) Estimation of Capital and Operations & Maintenance costs at economic prices, along with the capital cost phasing.
(ii) Estimation of economic benefits including network effects
(iii) Comparison of annual streams of costs with benefits and computation of EIRR.

13.3 Quantification of Economic Costs and Economic Benefits

The quantification of economic costs and benefits is a crucial step in the calculation of the Economic Internal Rate of Return (EIRR). To calculate EIRR, both the costs and benefits associated with a project need to be identified, quantified, and discounted over time. Economic costs include all expenses incurred during the project's lifetime, such as initial investments, operational and maintenance costs. Economic benefits, on the other hand, encompass the positive impacts generated by the project, such as travel time savings, cost savings and societal benefits like job creation or environmental improvements.

13.4 Economic Cost

The Economic cost includes Capital Cost, operations & maintenance cost at economic prices, along with the capital cost phasing.

The Economic Capital Cost of the Project is detailed in **Table 15.**

Table 15 : Economic Cost of the Project

Particulars	Amount (INR in Crores)
Project Cost excluding taxes	2439.51
Conversion Factor	0.9
Economic Cost of Project	**2195.60**

The operation and maintenance cost is taken as under-

- Annual cost = 0.25% of Construction cost with an annual escalation of 5%
- Special maintenance cost once in 10 years = 0.5% of Construction cost

13.5 Economic Benefits

The benefits accruing to society from the proposed improvement are mainly reduced vehicle operating cost (VOC), reduced travel time cost for passengers and freight, reduced emission costs and employment generation benefits. The travel time savings and VOC are directly related to the journey speed which is a function of traffic levels and capacity. Time benefits depend upon the journey speed and value of time for various vehicle users or goods. VOC benefits depend upon the vehicle operating cost of the vehicles, which is the function of journey speed, vehicle type and the pavement surface condition.

13.5.1 Time Savings

To work out time savings, the speeds for different vehicles have been calculated from surveys. The time savings have been worked out as the difference of travel time under “with and “without” project situations. The average Value of Time per person is estimated based on the per capita income of the region obtained from State economic survey documents. The travel time savings is then calculated as the product of passenger time savings and value of passenger time.

In the case of commodities, shorter transit time equals lower inventory costs. Travelling faster reduces the set rates per kilometre that every operator must pay. Travelling faster saves time for the vehicle crew as well. The value of freight time savings is calculated as the product of freight time savings and commodity holding costs.

13.5.2 Value of Vehicle Operating Cost (VOC) Savings

Vehicle operating costs (VOCs) are the cost to the owner of operating a motor vehicle. The VOC cost varies based on vehicle type (2-wheelers, 3-wheelers, cars, buses or any other prevalent mode) and is calculated using the equations and guidelines given in the "Economic Evaluation of Highway Projects in India, IRC:SP:30-2019".

The vehicle operating costs adopted for different modes are provided in **Table 16.**

Table 16: VOC for existing modes

Mode	VOC/Km.*(INR)
Bus	52.39
Car	18.17
2 Wheeler	8.54
Auto	18.17
LCV	38.25
Truck (HCV)	38.15
Truck (MCV)	58.08

Source: Economic Evaluation of Highway Projects in India, IRC:SP:30-2019

Based on these, the savings were estimated.

13.5.3 Employment Generation

During the period of construction, manpower will be needed for various project activities. In post-construction phase, manpower will be employed for the operation and maintenance of the system. Thus, the project would provide substantial direct, employment. In addition to these, more people would be indirectly employed in allied activities.

Employment benefits	=	Capex (INR)	x	Employment cost as a % of Project Cost (INR)	x Share of Skilled v/s unskilled employment	X Direct / Indirect employment multiplier

13.5.4 Reduction in Emissions

The reduction in emissions is calculated based on the decrease in vehicle kilometres, volume of pollutants emitted from different modes and the cost of treatment per ton. The monetary value of these pollution loads is estimated using the estimates of prices of pollutants provided in 'Appraisal Guidelines for Metro Rail Projects Proposals, MoHUA, GOI 2017 and specified in **Table 17.**

Table 17: Volume of pollutants emitted (gram per km) for different modes

Vehicle Type/ Pollutant	CO	HC	NOX	PM	CO2
2-wheeler	1.4	0.7	0.3	0.05	28.58
Auto	2.45	0.75	0.12	0.08	77.89
Cars (incl. cabs)	1.39	0.15	0.12	0.02	139.52
Bus (incl. BRT)	3.72	0.16	6.53	0.24	787.72
Treatment Cost (Rs. /ton)	2,00,000	2,00,000	2,00,000	2,00,000	20,000

Source: Appraisal guidelines for Metro Rail Project Proposals MoHUA, GOI 2017

13.6 Economic Appraisal

The annual cost and benefit streams are used to derive the net cash flow for the project to compute EIRR. The EIRR arrived at based on the project costs and benefits in economic terms under "with" and "without" project conditions for the project is 9.52%.

Based on the details furnished and the EIRR anticipated, the project is viable and implementable and will be of great benefit to the local areas and the coastal districts of the state in their economic growth via effiecient traffic movement and developments in tourism and related fields. EIRR is expected to increase substantially when all factors affecting the influence zone areas are considered in detail such growth in tourism potential, value additions to all walks of life and increase in land value in the area.

14 CONCLUSIONS & RECOMMENDATIONS

The project details and justification are given above. Recommendations based on the Feasibility study are as under:

- ✓ The feasible solution for connecting the Coastal Highway ends through the Cochin islands is by providing an Under-Sea Tunnel between the Fort Cochin and Vypeen islands.
- ✓ The proposed tunnel will help in faster economic development of the area and the State. The total requirement of funds will be about Rs. 2672.25 cr and EIRR for the project works out to 9.52%.
- ✓ Innovative projects in the infrastructure sector capable of producing a revolutionary impact on a longterm basis on a country's economy and public welfare are supported by World bodies such as the Japanese Government and other International agencies. They make available highly concessional loans at less than 0.5% annual interest with a repayment period of about 35-50 years and a 10-15 year moratorium period. The Mumbai- Ahmedabad Bullet Train project involving 1 lakh crore investment is a shining example.
- ✓ In case it becomes necessary to fund the project locally, this can be brought under KIIFB as it would fit in the state’s development plans in view of its tourism potential. This may be funded through KIIFB as it is very part of the Coastal Highway which project is funded by KIIFB.
- ✓ Project can be considered under BOT schemes as there is potential for toll collections for tunnel usage and service charge collections from the tourism industry.
- ✓ This project can be pursued by studying the traffic requirements, assessing the likely returns closely and further studying the EIA/SIA, topographical, geological, geotechnical and hydrological features of the area using appropriate technologies for assessing more realistic cost and reliable method of construction by developing a Detailed Project Report. On approval of the DPR, construction and other developments can be planned.

****

ANNEXURE -1

EXPERT'S OPINION ON THE IDEA OF TUNNEL CROSSING

VYPIN –FORT KOCHI UNDER SEA TUNNEL

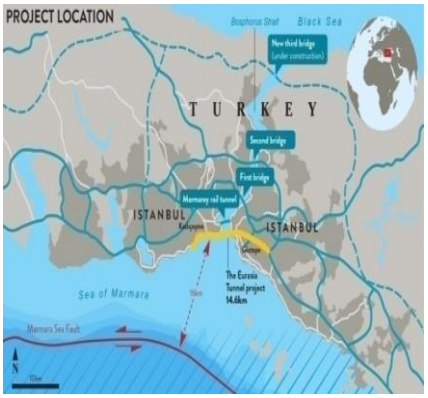
Dr. Jose Paul
MA, PhD (WaleS), FBIM, FCIT (London)
Former Acting Chairman, J N Port, New Mumbai Former Chairman, Mormugao Port Trust, Goa, and Adjunct Professor of Indian Maritime University, Chennai.

1.1 MODERN UNDERSEA TUNNELS

Tunnels are amazing displays of civil, mechanical and marine engineering.

- The Channel Tunnel (built 1994)
- Eurasia Tunnel (Istanbul, Turkey; built 2016)
- Busan-Geoje Bridge, South Korea (built 2010)
- Sydney Harbour tunnel (built 1992)
- Seikan tunnel, Japan

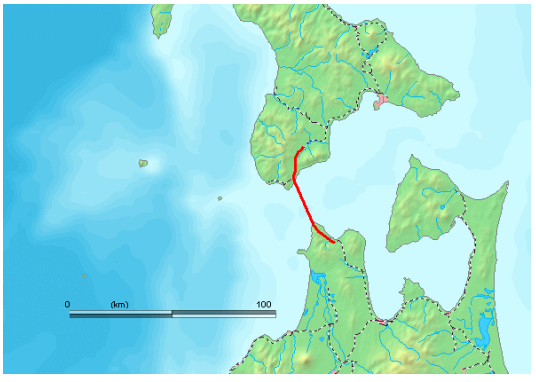
Channel Tunnel



Eurasia Tunnel

Busan-Geoje Bridge

Sydney Harbour tunnel

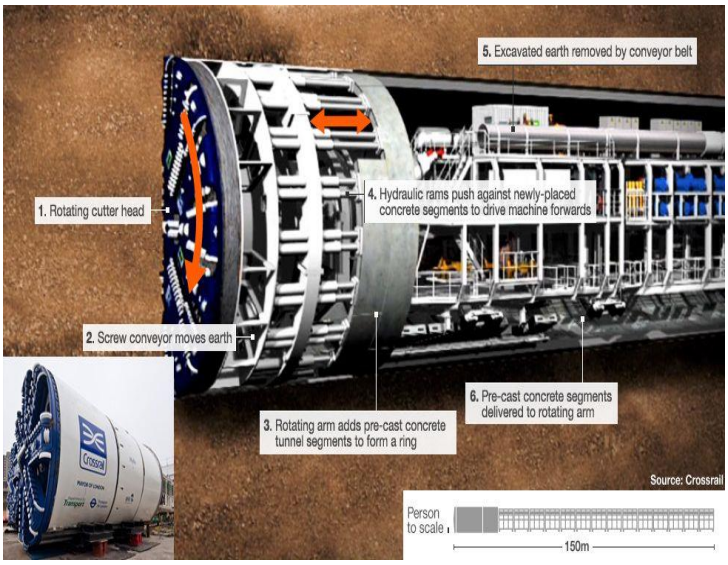


Seikan tunnel

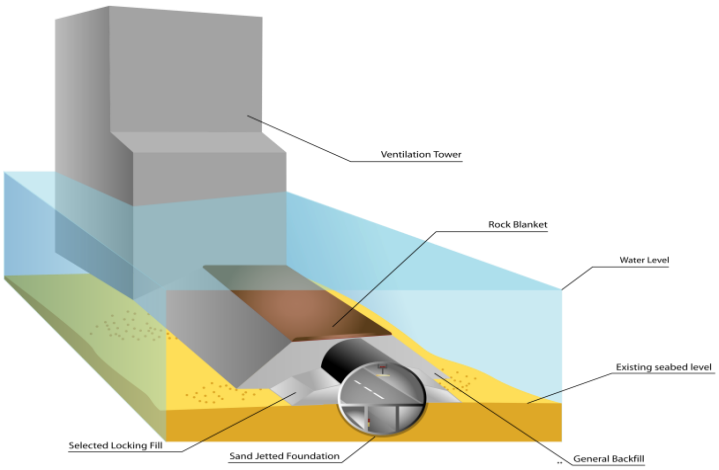
1.2 CONSTRUCTION METHODS

1.2.1 Tunnel boring machines

A TBM is a multistory-tall engine of destruction capable of chewing through solid rock. At its front spins a cutting head, a giant wheel that bristles with rock-breaking disks and incorporates a system of scoops to lift pummeled rock and drop it onto an outbound conveyor belt. Behind the cutting head swings an erector, a rotating assembly that builds the tunnel lining in the TBM's wake.



1.2.2 Immersed Tube Tunnel (ITT)



ITTs aren't bored through rock or soil; they are assembled on-site from football-field-sized, prefabricated pieces. First used to build the Detroit River railroad tunnel (1906-10) connecting Detroit, Mich., to Windsor, Ont., and they've been the go-to technique for vehicle tunnels ever since. Indeed, more than 100 such tunnels were built in the 20th century alone.

1.3 LAND ACQUISITION CHALLENGES

Land acquisition in Puthu-vypeen will not cause much of a problem because the entire accreted land in Puthuvypeen belongs to cochin port authority and there are no human settlements in the area.

But the channel tunnel will emerge on the Fort Kochi side likely to be near the lighthouse hotel and the Droncharya naval complex where some limited land acquisition will have to be undertaken.

1.4 ENVIRONMENTAL IMPACT

- The potential impacts which are typical for the immersed tunnel technique are mostly related to the marine environment.
- In particular, the disturbance and potential loss of habitat due to the dredging activities may require special attention and can temporarily affect marine life over a large distance.
- Immersed tunnel projects can be delivered in a sustainable manner and there are many good examples where creative solutions have been applied to create socio-economic and environmentalbenefits. Most dredged and excavated material is clean and options for beneficial use are numerous sites.
- Another option is to re-use the dredged material again as backfilling material. Alternatively, the backfill material can also be import surplus material from other projects.

1.5 ECONOMIC VIABILITY

- The proposed tunnel will change the face and fate of the under- developed Vypeen Island capable of enjoying the fruits of regional development and prosperity by the establishment of tourist resorts and associate infrastructure along the entire 27km long stretch of Vypeen Island.
- Informal discussions with experts on tunnel construction suggest the total costs may come around Rs. 1500 crore.
- The proposed undersea tunnel could start earning revenue immediately after commissioning by way of toll charges and users of the tunnel should be able to pay enhanced toll charges for a faster, safer and well-organized land transport system.
- This is because transport is an intermediate product and it facilitates faster and efficient transportation, the benefits of which will be reaped by the entire community living in such regions. Government participation at the state and central level will be needed for successful completion of the project.

1.6 PROJECT FINANCE

- As the proposed channel tunnel will become an integral part of the coastal highway transportation network, investment on it could be treated as the social overhead capital of the country to be collectively consumed by the population.

1.7 AGENCY FOR IMPLEMENTATION

- Innovative projects in the infrastructure sector capable of producing significant impact on a sustainable basis to a country's economy and public welfare are supported by the Japanese Government and some European agencies. They make available highly concessional long-term loans to developing countries at less than 0.5% interest rates with repayment period of 40 years and a moratorium period of 15 years.
- The Mumbai-Ahmadabad bullet train project, now under construction, is a good example.

1.8 HOW TO KICK START THE PROJECT

- As the proposed undersea tunnel is the first of its kind in India and the primary beneficiary of this project being the State of Kerala, the Government of Kerala will be the right agency to undertake a proper feasibility study.

1.9 SEAMLESS CONNECTIVITY

- The undersea tunnel will provide an important link in seamless transportation along the proposed coastal highway. When completed, this coastal highway will reduce traffic congestion and provide an effective alternative to the national transportation network. The proposed highway with the tunnel will help travelling public from northern districts of Kerala to reach southern districts through the shortest route, thereby saving time, energy and fuel resulting in less pollution and accidents.
- For the fast-growing Cochin Metropolis, this transport link will provide the much- needed fast transportation connectivity between north-south and east-west directions.

1.10 TOURISM POTENTIAL

- The existence of an undersea tunnel itself will be a tourist attraction and innovative projects in the infrastructure sector capable of producing revolutionary impact on Kerala's economy and public welfare needs to be taken up on priority.
- With the completion of the proposed tunnel, several beach resorts like those in Cherai can come up in Puthuvypeen, Malipuram, Njarakal, Kuzhupally and Munambam.

1.11 LIFE OF UNDERSEA TUNNELS

- The designed service life of undersea tunnels is assessed at least 100 years.
- Modern undersea tunnels are free from the adverse effects from climate change, and are even capable of withstanding earthquakes and could be viewed as a permanent infrastructure to be collectively used by the population of the country.

1.12 MINIMAL DISRUPTION

- Compared to building a large bridge across the main shipping channel of Cochin harbor, an undersea tunnel will have little or no disruption to the important shipping traffic that passes through Cochin port on a daily basis.
- The construction of a large sea bridge would undoubtedly create disruption to the shipping traffic in an already busy port in addition to causing serious navigational hazards.

1.13 REGIONAL ECONOMIC DEVELOPMENT

- One of the stated objectives of regional and national governments is to create equitable development in all regions.
- The 27km long Vypeen island is an underdeveloped area and the proposed connectivity and proximity to the mainstream activities of the city would help the region to attract medium and small enterprises generating considerable employment potential to the local population.

1.14 SAFER MODE OF TRANSPORT

- An undersea tunnel was constructed in Tsugaru straits in Japan following the sinking of ferries affected by typhoons.
- A number of human lives were lost, and the resultant public outcry forced the Japanese government to construct an undersea tunnel.
- A serious ferry accident took place in the main shipping channel of Cochin on 26th August 2015 killing 11 passengers.
- The proposed undersea tunnel will ensure a safer, faster and more efficient transportation system in the Cochin metropolis.

1.15 CARGO CONSOLIDATION & EVACUATION

- Efficiency of a major seaport depends not only on the efficiency of cargo handling and ship movements, but also on the efficiency of consolidation and evacuation of cargo in and out of the port.
- The proposed undersea tunnel will enhance the quality of the transport infrastructure which in turn would help promote faster and more efficient cargo movement from the hinterland.

ANNEXURE -2

TRAFFIC ANALYSIS REPORT

2. PRELIMINARY TRAFFIC STUDY

As part of the feasibility study, preliminary estimate of likely traffic expected to pass through the proposed Fort Cochin – Vypeen tunnel is estimated for the base year and projected for future years. The estimation and projection of traffic are based on secondary data and the study report on 'DPR for Integrated Development of Coastal Highway in Ernakulam District', prepared by L & T Infra Engineering, during September 2022. The above mentioned DPR prepared in 2022 was based on extensive primary traffic surveys including Classified Traffic Volume Count, Origin-Destination Survey and Speed & Delay Survey at carefully selected survey stations and road sections in and around Cochin City. The proposed Fort Cochin – Vypeen tunnel when completed would form part of the Coastal Highway and the data available in the DPR is systematically analysed to form the traffic data base for the present study.

2.1 Base Year Traffic Estimation

Traffic likely to ply through the proposed tunnel system is worked out by considering the following components of traffic viz.

(i) **Normal traffic** – Normal traffic is defined as the traffic currently plying on the existing road.

(ii) **Generated traffic** – Generated traffic consists of diverted traffic and induced traffic.

(a) ***Diverted Traffic:*** Diverted traffic is defined as the component of traffic that will get diverted from the existing road network to the project road considering reduced travel distance, travel time and Vehicle Operating Cost (VOC), as well as better accessibility and improved riding quality.

(b) ***Induced Traffic***: Investment in new or up-graded roads raises the level of service and alters the pattern of accessibility over the whole area served by the road system. Vehicle-users will perceive the opportunities of this increased accessibility and respond in various ways, most of which can lead to more travel on the system. To the extent that travel increases overall, it can be said to have been induced by the road improvement.

(iii) **Development Traffic:** It is the future traffic volume component that is due to developments of land in the influence area of a new road or infrastructural facility. It can arise due to tourism and industrial developments in and around the project site.

2.1.1 Normal Traffic

In the absence of direct road connectivity between Fort Cochin and Vypeen, vehicles are transported through RORO/ Ferry Junker services. The volume of vehicles carried through the RORO services is taken as the base year normal traffic for the proposed tunnel system. Secondary data collected from Kerala Shipping & Inland Navigation Corporation (KSINC) revealed that a total of 5,531 vehicles per day were carried in two ferry services with 140 round trips in 2022 (**Table 2.1**).

Table 2.1: Estimated Normal Traffic between Fort Kochi and Vypeen in 2022

Sl. No.	Type of vehicle	No. of vehicles
1	Bus	6
2	Mini Bus	24
3	Car/ Jeep/ Van	714
4	Auto Rickshaw	260
5	Two Wheelers	4,207
6	Multi Axle truck	13
7	Truck 2&3 axle	13
8	LCV 4,6,ace	108
9	Goods Auto	-
10	Cycles	182
11	Cycle riksha	-
12	Tractor	-
13	Others	4
	Total Vehicles	**5,531**
	Total vehicles (PCU)	**3,498**

Source: Table 9.41 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

2.1.2 Generated Traffic

Generated traffic includes ***diverted traffic*** from other roads as well as ***induced traffic*** generated within the influence area of the proposed tunnel.

(a) *Diverted traffic*

Diverted traffic is estimated as per methodology adopted in DPR for Integrated Development of Coastal Highway in Ernakulam District, as presented in **Attachment 2.1**. It is estimated that 2,478 vehicles will get diverted to the Ferry system between Fort Cochin and Vypeen in the year 2025, when the coastal road is fully operational as per **Table 2.2.**

Table 2.2: Estimated Diverted Traffic in 2025 with RORO Services

Sl. No.	Type of vehicle	Divertible traffic in 2025
		As per Diversion analysis with RORO Services
1	Bus	3
2	Mini Bus	11
3	Car/ Jeep/ Van	320
4	Auto Rickshaw	116
5	Two Wheelers	1,885
6	Multi Axle truck	6
7	Truck 2&3 axle	6
8	LCV 4,6,ace	48
9	Goods Auto	-
10	Cycles	82
11	Others	2
	Total Vehicles (No.)	**2,478**
	Total Vehicles (PCU)	**1,567**

Source: Table 9.63 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

However, the Diverted Traffic estimation reported in the DPR has not considered the proposed tunnel system for the diversion analysis. In view of the same, **a new cost ratio model is worked out to estimate the diverted traffic to the tunnel system,** taking into consideration the generalized cost of travel, consisting of vehicle operating cost, value of time and provision for toll sensitivity analysis for the tunnel system.

Based on information collected from KSINC, the transport charges collected for RORO services between Fort Cochin and Vypeen vary according to the type, carrying capacity and dimension of vehicles. Accordingly, average transport fare for RORO services for different categories of vehicles are considered for working out the cost ratios. In the case of proposed tunnel system, the costs are worked out based on zero tolls as well as assuming the existing toll rate at Kumbalam toll plaza on NH 66. The existing transportation rates of Fort Cochin – Vypeen RORO Service and Toll rates at Kumbalam Toll plaza are presented in **Table 2.3**.

Table 2.3: Existing Transportation Rates of Fort Kochi-Vypeen RORO Services and Toll Rates at Kumbalam Toll Plaza

Sl. No.	Type of vehicle	Average rates for RORO Service (Rs)	Toll rates at Kumbalam (Rs)
1	Bus	200	125
2	Mini Bus	100	60
3	Car/ Jeep/ Van	50	35
4	Auto Rickshaw	20	35
5	Two Wheelers	10	10
6	Multi Axle truck	350	195
7	Truck 2&3 axle	250	125
8	LCV 4,6,ace	150	60
9	Goods Auto	50	35

For working out the new cost ratios, Vehicle Operating Costs obtained from Road User Cost Study are updated to 2022 prices, estimated based on Consumer Price Index. The Value of Time and Commodity Holding Cost are adopted from the report of DPR for Integrated Development of Coastal Highway in Ernakulam District.

Average time to cross the ferry through RORO services is taken as 15 minutes, consisting of 5 minutes of travel time and 10 minutes of time for waiting plus boarding and alighting the RORO service. In the case of tunnel, 5 minutes of travel time is considered to cross the channel.

Diversion Multiplier Factor (DMF) is worked for various categories of vehicles as below:

DMF = GC of Travel through Ferry / GC of Travel through Tunnel

The DMF are worked out under different toll scenarios for the proposed tunnel system, viz.

(i) Zero tolls
(ii) Based on toll rates presently charged at Kumbalam on NH 66
(iii) 1.5 times of toll rates at Kumbalam and
(iv) 2 times of toll rate at Kumbalam toll plaza.

The Diversion Multiplier Factor (DMF) for different vehicle types under alternative toll scenarios are presented in **Table 2.4**.

Table 2.4: Diversion Multiplier Factor (DMF) under Different Toll Scenarios

Sl. No.	Type of vehicle	Diversion Multiplier Factor (DMF)			
		No Toll	Same as Kumbalam Toll Rate	1.5 times Kumbalam Toll Rate	2 times Kumbalam Toll Rate
1	Bus	12.45	1.56	1.08	0.83
2	Mini Bus	8.02	1.62	1.16	0.90
3	Car/ Jeep/ Van	5.57	1.68	1.24	0.99
4	Auto Rickshaw	3.82	1.10	0.81	0.64
5	Two Wheelers	3.81	1.60	1.24	1.01
6	Multi Axle truck	19.86	1.65	1.13	0.86
7	Truck 2&3 axle	17.73	1.80	1.24	0.95
8	LCV 4,6,ace	11.49	2.05	1.46	1.13
9	Goods Auto	7.66	1.20	0.85	0.65

DMF worked out for different vehicle types are applied to the diverted traffic estimated with RORO service, to get the estimated diverted traffic to the proposed tunnel system in the base year.

In the case of bus services, since the rerouting is a policy decision based on demand and accessibility, it is assumed that a proportion of buses presently operated within Fort Cochin and Vypeen will be extended to ply through the proposed tunnel system. A conservative estimate of 15% of buses plying through Fort Cochin and Vypeen is considered for diversion through the proposed tunnel system to cater to the demands of tourism, industry and local residents. The total divertible traffic expected to pass through the tunnel in 2025 under different toll rates are presented in **Table 2.5.**

Table 2.5: Daily Divertible Traffic to the Proposed Tunnel System in 2025 under Alternative Toll Scenarios

Sl. No.	Type of Vehicle	Divertible Traffic in 2025								
		As per Diversion Analysis with Tunnel				Proposed bus schedules	Total			
		As per Diversion Analysis with RORO	No Toll	Toll as per Kumbalam	1.5 times Toll as per Kumbalam	2,0 times Toll as per Kumbalam		No Toll	Toll as per Kumbalam	1.5 times Toll as per Kumbalam	2,0 times Toll as per Kumbalam
1	Bus	3	36	7	6	5	129	165	136	135	134
2	Mini Bus	11	97	28	23	20		97	28	23	20
3	Car/ Jeep/ Van	320	2,103	856	717	636		2,103	856	717	636
4	Auto Rickshaw	116	561	244	211	191		561	244	211	191
5	Two Wheelers	1,885	9,066	4,895	4,218	3,789		9,066	4,895	4,218	3,789
6	Multi Axle truck	6	121	15	12	11		121	15	12	11
7	Truck 2&3 axle	6	109	16	13	11		109	16	13	11
8	LCV 4,6,ace	48	604	148	119	103		604	148	119	103
9	Goods Auto	-	-	-	-	-		-	-	-	-
10	Cycles	82	82	82	82	82		82	82	82	82
11	Others	2	2	2	2	2		2	2	2	2
Total Vehicles (No.)		2,478	12,782	6,294	5,402	4,850	129	12,911	6,423	5,531	4,979
Total Vehicles (PCU)		1,567	9,280	3,999	3,410	3,052	387	9,667	4,386	3,797	3,439

(b) Induced Traffic

Induced traffic arises due to increase in transport infrastructure or improvement in riding quality of developed road, new and improved road side developments, shifting of road users from public transport mode to private mode, etc. Induced traffic is that component of traffic in which people forgo or restrict their travel due to unavailability or reduced availability of infrastructural facilities.

For the present study, Induced Traffic is estimated as 10% of normal traffic in the base year, considering the fact that the proposed tunnel would facilitate easy access to hitherto unconnected settlements in the region and also features a unique under sea infrastructure development. The base year induced traffic works out to 649 vehicles per day in the year 2025. The induced traffic growth rate is assumed to reduce by 2% in the subsequent five year blocks.

2.1.3 Development Traffic

Development traffic has been assessed based on the secondary data collected with respect to tourist potential and industrial developments.

(a) Tourism oriented development traffic:

The influence area of the proposed tunnel has a number of national and international level tourist centres, like Fort Kochi, Mattancherry, Puthuvype beach, Cherai Beach, Munambam Beach etc. In addition, a Mega Oceanarium is coming up at Puthu Vyppin, at an area of 65 acres with an investment of Rs.300 crores. This is the first Oceanarium of the country and will be the largest in Asia. All these existing and proposed tourism prospects will result in increased demand for travel.

In concurrence with these tourism potential, as per details provided in **Attachment 2.2,** it is seen that Ernakulam District tourism is growing at an average growth rate of 8.2% over the previous years. Accordingly, 8% of normal traffic is considered as growth rate for tourism related development traffic from 2025, when the coastal highway and tunnel system will be fully operational.

(b) Industry oriented development traffic:

Large scale industrial developments are taking place or in pipeline at Puthu Vyppin mainly related to natural regasification project and petroleum projects. They include:

(i) ***LNG Terminal:*** The Kochi LNG Terminal of Petronet LNG Ltd is the first LNG terminal in southern India and the fourth LNG terminal of country. The Project is a Greenfield LNG Re-gasification terminal at Puthu Vyppin Special Economic Zone (SEZ) on land allotted by the Kochi Port Trust. The terminal has a capacity of 5 million tonnes per year.

(ii) ***Single Buoy Mooring:*** It is a loading buoy anchored offshore that serves as a mooring point and interconnect for tankers loading or offloading petroleum products. It is operated by Kochi Refineries Ltd (KRL), a subsidiary of BPCL.

(iii) ***Bunkering Terminal***: An international bunkering terminal to supply fuel for vessels is planned by Cochin Port Trust. Bunkering industry point out that major transshipment trade has shifted to Kochi from Colombo with the commissioning of the ICTT. This will in turn attract a higher volume of vessel traffic including a greater number of coastal feeder vessels. Besides, the port's strategic location given its close proximity to international sea route will attract mother vessels to Kochi.

(iv) ***Ship Repair Complex***: Cochin Port Trust also plans to build a Ship Repair Complex at Puthuvypeen.

All these industrial developments are expected to bring in development traffic. A conservative growth rate of 2% of normal traffic is assumed to forecast the increase in traffic triggered by industrial developments from 2025 onward.

(c) Overall Development Traffic:

Overall development traffic is thus expected to be 10% of normal traffic in 2025 when the coastal road and tunnel system is fully operational and it is assumed to decrease by 0.5% for every five year block thereafter.

2.2 Traffic Projection

Traffic forecasting is the attempt of estimating the number of vehicles that will use a specific transportation facility in the future years. It may estimate the number of vehicles on a planned road or bridge or tunnel, the ridership on a railway line, the number of passengers visiting an airport, or the number of ships calling on a seaport etc. It estimates the current as well as future demand supply gap and assesses the adequacy or inadequacy of given facilities.

The traffic forecast for each horizon year was estimated considering three components:

(i) Normal traffic
(ii) Generated traffic and
(iii) Developmental traffic.

2.2.1 Method Adopted for Traffic Projection

Forecasting of traffic involves understanding the past trend in traffic growth using different direct and indirect methods, which should account for making realistic assessments of the traffic growth and envisaged economic growth in the PIA.

Growth rate method is adopted for traffic projection as discussed in **Attachment 2.3**. It can be seen that growth rates are estimated separately for urban and rural areas. For the rural sections, growth rates have been worked out for both passenger and goods vehicles and in the case of urban section growth rate of only passenger vehicles have been considered. As the proposed tunnel system, although lying in urban section, is likely to attract a large number of goods vehicles due to reduced travel distance and time, growth rates of rural sections have been adopted for the traffic projection as presented in **Table 2.6.**

Table 2.6: Adopted Growth Rates for Traffic Projection

Sl. No	Vehicle Type	2022-25	2026-30	2031-35	2036-40	2041-45
1	Bus	3%	3%	2%	2%	2%
2	Mini Bus	3%	3%	2%	2%	2%
3	Car	7%	6%	5%	5%	4%
4	Auto	5%	5%	4%	4%	3%
5	Two Wheeler	6%	5%	5%	4%	4%
6	MAV	7%	6%	6%	5%	4%
7	3 Axle	6%	5%	5%	4%	4%
8	2 Axle	5%	5%	4%	4%	3%
9	LCV	6%	5%	5%	4%	4%
10	Tata Ace	5%	5%	4%	4%	3%
11	Goods Auto	5%	5%	4%	4%	3%
12	Others	2%	2%	2%	1%	1%

Source: Table 9.75 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

2.2.2 Projection of Normal and Diverted Traffic

Traffic projection is carried out separately for normal traffic and diverted traffic using the above growth rates. Table 2.7 gives the Daily Normal Traffic projected for different horizon years.

Table 2.7: Daily Normal Traffic Projected for Different Horizon Years

Sl. No.	Type of Vehicle	Normal Traffic			
		2025	2030	2035	2040
1	Bus	7	8	9	10
2	Mini Bus	26	30	34	38
3	Car/ Jeep/ Van	862	1,148	1,486	1,879
4	Auto Rickshaw	301	375	458	549
5	Two Wheelers	4,940	6,305	7,857	9,605
6	Multi Axle truck	16	22	29	37
7	Truck 2&3 axle	15	20	25	31
8	LCV 4,6,ace	129	168	213	264
9	Goods Auto	-	-	-	-
10	Cycles	193	211	228	244
11	Others	4	4	4	4
	Total Vehicles (No.)	**6,493**	**8,291**	**10,343**	**12,661**
	Total Vehicles(PCU)	**4,116**	**5,277**	**6,606**	**8,111**

Traffic projection of divertible traffic for different horizon years have been carried out for 'No Toll' scenario and assuming toll rates presently charged at the Kumbalam Toll Plaza on NH 66.

Table 2.8 gives the daily divertible traffic projected for different horizon years, under 'no toll' and toll rates presently charged at Kumbalam toll plaza, scenarios.

Daily divertible traffic projected for different horizon years assuming 1.5 times and 2 times the toll rates of Kumbalam toll plaza is presented in **Appendix 2.1.**

Table 2.8: Daily Divertible Traffic Projected for Different Horizon Years under 'No Toll' and 'Toll Rates at Kumbalam Toll Plaza' Scenarios

Sl. No.	Type of Vehicle	Divertible Traffic							
		'No Toll' Scenario				Toll as per Kumbalam Plaza			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	165	189	213	237	136	155	175	195
2	Mini Bus	97	111	125	139	28	32	36	40
3	Car/ Jeep/ Van	2,103	2,801	3,626	4,584	856	1,141	1,477	1,867
4	Auto Rickshaw	561	700	856	1,027	244	305	373	447
5	Two Wheelers	9,066	11,571	14,420	17,629	4,895	6,248	7,786	9,518
6	Multi Axle truck	121	165	218	280	15	21	28	36
7	Truck 2&3 axle	109	142	180	223	16	21	27	33
8	LCV 4,6,ace	604	786	998	1,238	148	192	244	303
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	82	89	96	103	82	89	96	103
11	Others	2	2	2	2	2	2	2	2
Total Vehicles (No.)		**12,911**	**16,556**	**20,734**	**25,462**	**6,423**	**8,206**	**10,244**	**12,544**
Total Vehicles (PCU)		**9,667**	**12,420**	**15,593**	**19,191**	**4,386**	**5,581**	**6,951**	**8,493**

2.2.3 Projection of Induced and Development Traffic

In the case of induced traffic, as discussed earlier, 10% of normal traffic is treated as induced traffic which is visualized to decrease by 2% every five year block. As far as development traffic is concerned, 10 percent of normal traffic is considered as development traffic in the year 2025, with 0.5% decrease in the subsequent five year blocks. Induced and Development traffic projected for different horizon years are presented in **Table 2.9**.

Table 2.9: Projected Induced and Development Traffic for Different Horizon Years

Sl.No.	Type of vehicle	Induced traffic				Development traffic			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	1	1	0	0	1	1	1	1
2	Mini Bus	3	2	2	1	3	2	2	2
3	Car/ Jeep/ Van	86	69	52	34	86	82	78	73
4	Auto Rickshaw	30	24	18	12	30	29	27	26
5	Two Wheelers	494	395	296	198	494	469	445	420
6	Multi Axle truck	2	1	1	1	2	2	1	1
7	Truck 2&3 axle	2	1	1	1	2	1	1	1
8	LCV 4,6,ace	13	10	8	5	13	12	12	11
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	19	15	12	8	19	18	17	16
11	Others	0	0	0	0	0	0	0	0
	Total Vehicles (No.)	**649**	**519**	**390**	**260**	**649**	**617**	**584**	**552**
	Total Vehicles(PCU)	**412**	**329**	**247**	**165**	**412**	**391**	**370**	**350**

2.2.4 Projection of Overall Traffic

Combined daily traffic on the proposed tunnel system projected for different horizon years under alternative toll scenarios is given in **Table 2.10**. It could be observed that the proposed tunnel system will have a total of 14,606 PCU of vehicles plying through it in the year 2025 under 'no toll' scenario and will increase to 23,833 in 2040. In the case of collecting toll as per Kumbalam toll plaza, the vehicle load shall be 9,325 PCU in 2025 and 13,370 PCU in 2040. In the case of 1.5 times of toll rate, the traffic load shall increase from 8,736PCU to 12,005PCU in 2040. With 2.5times of toll rate, the traffic loading shall be 8,378PCU in 2025 with increase to 11,297 PCU in 2040.

Table 4.10: Projected Total Daily Traffic (in PCU) on the Proposed Tunnel System under Alternative Toll Scenarios

Sl. No.	Scenario	Total Daily Traffic (No.)				Total Daily Traffic (PCU)			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Scenario 1: 'No toll'	20,703	25,983	32,051	38,935	14,606	18,417	22,815	27,816
2	Scenario 2: 'Kumbalam toll rate'	14,215	17,633	21,561	26,017	9,325	11,578	14,174	17,119
3	Scenario 3: '1.5 times Kumbalam toll rate'	13,323	16,490	20,127	24,255	8,736	10,823	13,217	15,938
4	Scenario 4: '2 times Kumbalam toll rate'	12,770	15,779	19,237	23,164	8,378	10,360	12,637	15,230

Appendix 2.2 gives the break-up of Projected Daily Traffic on the proposed tunnel system for different horizon years.

Appendix 2.1

Projected daily divertible traffic for different horizon years under 1.5 times and 2 times the toll rates at Kumbalam toll plaza

Sl. No.	Type of vehicle	Divertible traffic*							
		1.5 times of Toll rate at Kumbalam plaza				2 time of Toll rate at Kumbalam plaza			
		2025	2030	2035	2040	2025	2030	2035	2040
1	Bus	135	154	173	193	134	153	172	192
2	Mini Bus	23	27	30	33	20	23	26	29
3	Car/ Jeep/ Van	717	956	1,238	1,565	636	847	1,097	1,387
4	Auto Rickshaw	211	263	322	386	191	238	291	349
5	Two Wheelers	4,218	5,383	6,708	8,201	3,789	4,836	6,027	7,368
6	Multi Axle truck	12	17	22	28	11	15	20	26
7	Truck 2&3 axle	13	17	22	27	11	15	19	24
8	LCV 4,6,ace	119	155	197	244	103	134	170	211
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	82	89	96	103	82	89	96	103
11	Others	2	2	2	2	2	2	2	2
Total Vehicles (No.)		5,531	7,063	8,810	10,782	4,979	6,352	7,920	9,691
Total Vehicles (PCU)		3,797	4,826	5,995	7,313	3,439	4,363	5,415	6,605

Appendix 2.2

Break-up of Projected Daily Traffic on the Proposed Tunnel System for Different Horizon Years under 'No Toll' and 'Alternative Toll Scenarios"

		Total traffic - No toll				Total traffic - Kumbalam Toll			
		2025	2030	2035	2040	2025	2030	2035	2040
		No toll scenario				Toll as per Kumbalam plaze			
1	Bus	174	198	223	248	144	164	185	206
2	Mini Bus	128	146	163	180	59	67	74	81
3	Car/ Jeep/ Van	3,138	4,100	5,241	6,571	1,891	2,440	3,092	3,854
4	Auto Rickshaw	923	1,128	1,359	1,614	606	733	876	1,034
5	Two Wheelers	14,994	18,741	23,018	27,852	10,823	13,418	16,384	19,741
6	Multi Axle truck	141	190	249	319	35	46	59	75
7	Truck 2&3 axle	127	165	207	256	34	44	54	66
8	LCV 4,6,ace	759	977	1,230	1,518	303	383	476	583
9	Goods Auto	-	-	-	-	-	-	-	-
10	Cycles	313	334	353	371	313	334	353	371
11	Others	7	7	7	7	7	7	7	7
Total Vehicles (No.)		**20,703**	**25,983**	**32,051**	**38,935**	**14,215**	**17,633**	**21,561**	**26,017**
Total Vehicles (PCU)		**14,606**	**18,417**	**22,815**	**27,816**	**9,325**	**11,578**	**14,174**	**17,119**

Total traffic - 1.5times Kumbalam				Total traffic - 2times Kumbalam			
2025	2030	2035	2040	2025	2030	2035	2040
1.5 time of Toll at Kumbalam plaze				2 time of Toll at Kumbalam plaze			
143	163	183	204	142	162	182	203
54	62	68	74	52	58	64	70
1,752	2,255	2,853	3,552	1,670	2,146	2,712	3,374
572	691	825	973	552	666	794	936
10,146	12,553	15,306	18,424	9,717	12,006	14,625	17,591
32	42	53	67	30	40	51	65
31	40	49	60	29	38	46	57
274	346	429	524	258	325	402	491
-	-	-	-	-	-	-	-
313	334	353	371	313	334	353	371
7	7	7	7	7	7	7	7
13,323	**16,490**	**20,127**	**24,255**	**12,770**	**15,779**	**19,237**	**23,164**
8,736	**10,823**	**13,217**	**15,938**	**8,378**	**10,360**	**12,637**	**15,230**

Attachment 2.1: Estimation of Diverted Traffic

Estimation of diverted traffic to the proposed tunnel system is based on methodology adopted for the study DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, September 2022. As per the methodology, diverted traffic from existing road network is estimated using traffic survey data conducted at various locations in the study area. Out of these locations, only those locations which have relevance to the present study have been considered in the analysis. Details of surveys conducted are presented in **Table 2.7** below:

Table 2.7: Details of survey locations

Survey Code	Name of the Location	Duration
	Classified Traffic Volume Count Survey (CVC)	
CVC 1	SH 66, Near Chellanam Village Office	7 Days
CVC 2	NH 66, Near Kannukulangara Sri MahavishnuTemple, Ezhupunna	7 Days
CVC 3	NH 66, Near Government School, Akalad	7 Days
CVC 4	SH 63, Kuzhupilly Thodu River Bridge	1 Day
CVC 5	NH 66, Chettuva Bridge, Near Rajah Island	7 Days
	Origin Destination Survey (O-D)	
OD 1	SH 66, Near Chellanam Village Office	24 hours
OD 2	NH 66, Near Kannukulangara Sri MahavishnuTemple, Ezhupunna	24 hours
OD 3	NH 66, Near Government School, Akalad	24 hours
OD 4	SH 63, Near Goshree Junction, Murikumpadam	12 hours

Figure 2.1 below provides outline of the study area along with locations of different traffic surveys.

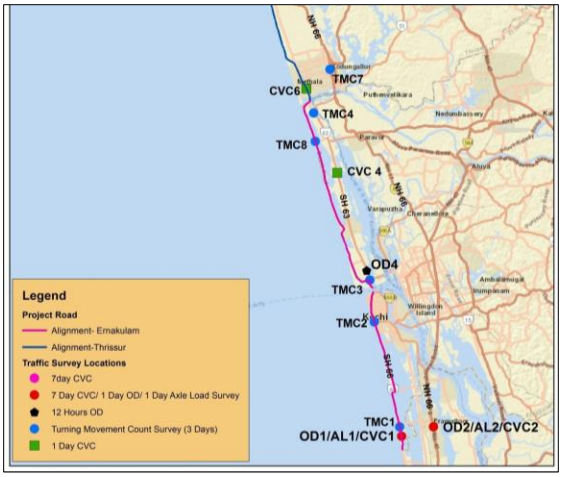


Figure 2.1: Map showing the project influence area and survey locations

Diverted traffic estimate is worked out considering O-D pairs which have potential to divert to the project road from the three alternate roads, namely

(i) NH 66
(ii) SH 66 South Chellanam – Fort Kochi road
(iii) SH 63 Vypeen – Munambam road

Average daily traffic volume observed on the above roads is presented in **Table 2.8.**

Table 2.8: Average Daily traffic volume at the survey locations

Sl. No.	Vehicle type	SH 66, Near Chellanam	NH 66, Near Ezhupunna	SH 63, Kuzhupilly Thodu River Bridge
1	Bus	208	905	652
2	Mini Bus	293	1,448	256
3	Car/ Jeep/ Van	856	22,278	3,892
4	Auto Rickshaw	633	2,205	1,495
5	Two Wheelers	6,485	28,251	17,001
6	Multi Axle Truck	2	909	37
7	Truck - 2/3 axle	20	2,140	86
8	LCV - 4/6/ace	317	5,666	1,199
9	Goods Auto	104	417	325
10	Cycles	755	756	618
11	Others*	17	44	35
	Total Vehicles	**9,690**	**65,019**	**25,596**
	Total PCUs	**6,963**	**74,822**	**19,871**

Source: Table 9.24 & 9.25 of DPR for Integrated Development of Coastal Highway in Ernakulam District, L&T Infra Engineering, Sep 2022

The identified number of trips on project corridor multiplied with diversion potential (diversion percentage) gives the diverted traffic on the project road. The procedure for estimating diversion potential is presented below:

- Project road is considered as two lane configuration. Lane configuration considered for alternative road of NH-66 is six lane divided toll road whereas SH-66 & SH 63 are considered as two lane road.
- Cost Ratio factors are derived for each type of vehicle considering the parameters such as travel distance, speed, mileage, fuel rate, existing and proposed toll rate and Value of travel time (VOT) i.e. comparison of generalized cost of travel on project road and alternate roads.
- Travel Speed of the project road and alternative roads are estimated based on Speed and Delay Survey conducted on existing roads and alternative roads

- These speeds are expanded based on Speed-Flow Equations for different type of vehicles and carriageway as per IRC: SP: 30-2019 (Manual on Economic Evaluation of Highway Projects in India) and the same is presented in **Table 2.9**.

Table 2.9: Speed of Project Road and Alternative Roads

Type of vehicle	Speed (kmph)		
	Project Road (2 lane)	NH-66 (6 lane road)	SH- 63 (2 lane road)
Bus	39	57	34
Car	49	74	37
Two wheeler	35	55	55
MCV	26	47	39
HCV	33	53	27
LCV	35	48	32

Source: Table 9.58 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

- Vehicle Operating Cost (VOC) is estimated based on travel distance, mileage and fuel cost
- Value of travel time (VOT) is considered as per IRC: SP: 30-2019 based on different type of road. VOT of passenger vehicle is estimated based on Travel Time Savings (Rs/hr) whereas VOT of Goods vehicle is estimated based on savings in Commodity holding cost (Rs/day).
- Travel time savings of 2 lane road and Multi-Lane Road for base year (2022) is estimated and the same is presented in **Table 2.10**. Based on this, Value of Travel Time (VOT) of Passenger vehicle is estimated.

Table 2.10: **Travel Time Savings of Passenger Vehicles for different type of Roads**

	VOT (Rs/hr)	
Type of Vehicle	**2 Lane Road**	**Multi-Lane Road**
Car	135.8	**206.6**
Two Wheeler	69.6	**70.0**
Bus	**88.6**	**101.3**

Source: Table 9.59 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

- Savings in Commodity Holding Cost of 2 lane roads and Multi-Lane Road for base year (2022) is estimated and the same is presented in **Table 2.11**. Based on this Value of Travel Time (VOT) of goods vehicles are estimated.

Table 2.11: Commodity Holding Cost Savings of Goods Vehicles for different type of Roads

Commodity Holding Cost (Rs/day)		
Type of Vehicle	**2 Lane Road**	**Multi-Lane Road**
LCV	126.8	**263.9**
HCV	386.2	**1,915.6**
MCV	**724.0**	**3,016.8**

Source: Table 9.60 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

- Diversion curves are empirically developed relationships for developing the logical estimates of the proportion of traffic that is likely to be diverted to the project road. The diversion potential for each type of vehicle from each of the alternate roads is estimated using the cost ratio factors and diversion curve equations.
- The diversion curve equations used for estimation of the diversion potential of the project road is given in **Table 2.12**.

Table 2.12: **Diversion Curve Equations used for Diversion Analysis**

Type of Vehicle	Cost Ratio Interval	Equations
Car	< 0.634	% Div = 98.75 – ((CR/0.634)*8.125)
	0.64 <= CR <= 1.465	% Div = 90.625 – ((CR - 0.634)/0.831)*84.375
	1.465 <= CR <= 2.00	% Div = 6.25 – ((CR - 1.465)/0.535))*5.25
Bus and Truck	**<=0.75**	% Div = 100 – (CR/0.75)*0.5
	0.75 <= CR <= 1.25	% Div = 95 – ((CR-0.75)/0.5)*90
	1.25 <= CR <= 2.00	% Div = ((2-CR)/0.75)*5

Source: Table 9.61 of DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022

Attachment 2.2: Development Traffic based on Tourism Developments

Generated Traffic for the Project road has considerable potential with respect to tourism related developments. In order to assess the generated traffic secondary data of tourist footfalls were compiled from District Tourism Promotion Council of Ernakulam.

- Year-wise and District-wise tourist statistics of Kerala
- Year-wise and Month-wise tourist statistics of Ernakulam
- Major tourist place-wise statistics of Ernakulam

The summary of the data collected with respect to tourist statistics of Kerala state and Ernakulam District is presented in **Table 2.1 & 2.2**.

Table 2.1: Year-wise Domestic and Foreign Tourist Statistics of Kerala

Year	Domestic Tourists	Foreign Tourists	Total Tourists	Annual Growth Rate		
				Domestic	Foreign	Total
2008	75,91,250	5,98,929	81,90,179	-	-	-
2009	79,13,537	5,57,258	84,70,795	4.2%	-7.0%	3.4%
2010	85,95,075	6,59,265	92,54,340	8.6%	18.3%	9.2%
2011	93,81,455	7,32,985	101,14,440	9.1%	11.2%	9.3%
2012	1,00,76,854	7,93,696	108,70,550	7.4%	8.3%	7.5%
2013	1,08,57,811	8,58,143	117,15,954	7.8%	8.1%	7.8%
2014	1,16,95,411	9,23,366	126,18,777	7.7%	7.6%	7.7%
2015	1,24,65,571	9,77,479	134,43,050	6.6%	5.9%	6.5%
2016	1,31,72,535	10,38,419	142,10,954	5.7%	6.2%	5.7%
2017	1,46,73,520	10,91,870	157,65,390	11.4%	5.1%	10.9%
2018	1,56,04,661	10,96,407	167,01,068	6.3%	0.4%	5.9%
2019	1,83,84,233	11,89,771	195,74,004	17.8%	8.5%	17.2%
Compound Annual Growth Rate (CAGR)				**8.4%**	**6.4%**	**8.2%**

Source: Kerala Tourism Statistics 2019

- The tourist arrivals to Kerala is growing at the rate of 8.2%
- Foreign tourist arrival to Kerala during the year 2019 is 11.89 lakhs, showing an increase of 8.5% over the previous year.
- Domestic tourist arrival to Kerala during the year 2019 is 1.83 crores showing an increase of 17.8% over the previous year.

Table 2.2: Year-wise Domestic and Foreign Tourist Statistics of Ernakulam District

Year	Domestic Tourists	Foreign Tourists	Total Tourists	Annual Growth Rate		
				Domestic	Foreign	Total
2010	19,87,743	2,77,675	22,65,418			
2011	21,69,426	3,08,674	24,78,100	9.1%	11.2%	9.4%
2012	23,51,631	3,30,390	26,82,021	8.4%	7.0%	8.2%
2013	25,45,573	3,52,314	28,97,887	8.2%	6.6%	8.0%
2014	27,24,718	3,72,997	30,97,715	7.0%	5.9%	6.9%
2015	28,97,894	3,83,643	32,81,537	6.4%	2.9%	5.9%
2016	30,73,159	4,07,653	34,80,812	6.0%	6.3%	6.1%
2017	32,85,088	4,53,973	37,39,061	6.9%	11.4%	7.4%
2018	34,46,889	4,88,175	39,35,064	4.9%	7.5%	5.2%
2019	40,60,134	5,22,232	45,82,366	17.8%	7.0%	16.4%
Compound Annual Growth Rate (CAGR)				**8.3%**	**7.3%**	**8.1%**

Source: Kerala Tourism Statistics 2019

- The tourist arrivals to Ernakulam district is growing at the rate of 8.1%
- Considering the district wise foreign tourist arrival, Ernakulam district shows the highest footfall of 5.22 lakhs.
- Considering the district wise Domestic tourist arrival, Ernakulam district shows the highest footfall of 40.6 lakhs in the year 2019 in all over Kerala.

Domestic and Foreign tourist arrivals to the major tourist attraction along the project road is presented in **Table 2.3** and **Table 2.4**.

Table 2.3: Domestic Tourist Arrivals to Major Tourist Attraction along the Project Road

Year	2017	2018	2019	Annual Growth Rate	
				2017-2018	2018-2019
Kochi City	23,05,627	25,10,623	27,95,880	8.9%	11.4%
Fort Kochi	2,02,535	2,25,092	2,61,570	11.1%	16.2%
Cherai Beach	81,257	89,225	1,20,286	9.8%	34.8%

Source: Kerala Tourism Statistics 2019

- Considering the destination wise Domestic tourist arrival, Kochi city shows the highest footfall of 27.96 Lakhs all over Kerala.

Table 2.4: Foreign Tourist Arrivals to Major Tourist Attraction along the Project Road

Year	2018	2019	GR
Kochi City	2,36,870	2,70,032	8.9%
Fort Kochi	1,15,482	1,35,219	11.1%
Cherai Beach	14,591	16,987	9.8%

Source: Kerala Tourism Statistics 2019

- Considering the destination wise foreign tourist arrival, Kochi city shows the highest footfall of 2.7 Lakhs all over Kerala.

Tourist arrivals to the major attraction places along project road for base year (2022) is estimated based on following growth rates and the same is presented below;

- Tourist attraction places along the project road and the tourist arrivals both foreign and domestic tourist for the year 2019 is collected from District Tourism Promotion Council (DTPC)
- Foreign tourist arrival is growing at an average growth rate of 7.3% in Ernakulam District
- Domestic tourist arrival is growing at an average growth rate of 8.3% in Ernakulam District

Generated traffic has been assessed based on the secondary data collected and with respect to following assumptions:

- Ernakulam District tourism is growing at an average growth rate of 8.2%
- Therefore 8% is considered as the generated traffic growth rate for the initial five year block in Ernakulam District. Growth rate will decrease for every five year block thereafter
- Tourist arrivals are further divided to North, West and South side based on distribution of Population growth for estimation of section wise tourist arrivals
- Based on the above assumptions, the generated traffic of the base year (2022) is estimated.

Attachment 2.3: Estimation of Traffic Growth Rate

For traffic projection, growth rate method is adopted. Growth rates are obtained as per methodology suggested in the report 'DPR for Integrated Development of Coastal Highway with Cycle Track in Ernakulam District, L&T Infra Engineering, Sep 2022.

Major factors that are considered in estimating the traffic growth rate are listed below:

(i) Economic Factors
- GDP of India
- NSDP/ NDDP of states
- Sector-wise NSDP/NDDP and GDP such as Agriculture, Industry and Services etc.

(ii) Demographic Factors
- Population
- Per Capita Income

The above factors have been duly considered for arriving at traffic growth rates. Accordingly, traffic Growth Rates has been estimated by Elasticity method which co-relates the growth of traffic on the road with economic parameters and the same is presented in this section.

Elasticity Values Considered: The elasticity values recommended by Ministry of Road Transport & Highways "Road Development Plan – Vision 2021 and IRC Paper "Road transport demand forecast for 2000 revisited and demand forecast for 2021" is adopted for the current Project. However, these values are lower in case of Kerala. Therefore, elasticity of traffic with respect to NSDP is assumed as 0.9 for commercial vehicle and 1.4 is considered for passenger vehicle.

Estimation of Growth Rates for goods vehicles: Based on the recommended elasticity values, the location-wise growth rates have been assessed for the project road using state-wise influence factors obtained from origin-destination survey analysis for different type of vehicles separately. Base year growth rates for goods vehicles are obtained using the following formula:

Traffic Growth of Goods Vehicles= (Influence of region X Combined Sector Growth of region) X Elasticity

In order to arrive at the growth rate of goods vehicles, the influence of each zone in terms of goods traffic is considered. Combined sector growth of Agriculture, Service and Industrial sectors are considered for estimating growth of commercial vehicles. The sample calculation of growth rates for MAV (base year- 2022) at NH 66 (Near Akalad) is presented in **Table 3.1**. Similarly growth rates are arrived for rest of the goods vehicles.

Table 3.1: Estimation of Growth Rates for MAV

Influence District/State	Influence Factor	Growth in NDDP/ NSDP
Ernakulam	34.1%	6.00%
Alappuzha	2.3%	6.10%
Thrissur	9.1%	6.53%
Malappuram	13.7%	6.08%
Palakkad	-	5.38%
Kottayam	0.8%	5.06%
Kozhikode	15.4%	6.88%
Kannur	3.9%	6.54%
Kollam	3.7%	7.65%
Thiruvananthapuram	0.5%	6.38%
Rest of Kerala	0.3%	8.97%
Tamil Nadu	0.3%	10.05%
Karnataka	12.2%	8.19%
Rest of India	3.7%	4.23%
Weighted NDDP/ NSDP		**6.49%**
Elasticity		**0.9**
Growth Rate **(Weighted NDDP/NSDP XElasticity)**		**5.85%**

Estimation of growth rates for passenger vehicles: For estimation of growth rates for Passenger traffic (Car & Bus), the population and per capita income (PCI) are taken as indicators instead of NSDP/ NDDP. To estimate Car growth rates 20% weightage is given to population and 80% weightage is given to per capita income and to estimate Bus growth rates, 70% weightage is given to Population growth trends and 30% weightage is given to Per Capita Income growth trends because the travel demand for public transportation is more influenced by Population growth. The sample calculation of growth rates for Car at NH 66 (Near Akalad) is presented in **Table 3.2.**

Table 3.2: Estimation of Growth Rates for Car

Influence District / State	Influence Factor	Growth Trend in Population	Growth Trend in Per capita Income	Combined Growth Trend of Indices (20:80)
Ernakulam	8.4%	0.55%	5.42%	0.37%
Alappuzha	0.7%	0.09%	6.00%	0.03%
Thrissur	53.0%	0.48%	6.02%	2.60%
Malappuram	24.7%	1.27%	4.77%	1.01%
Palakkad	0.1%	0.71%	4.65%	0.00%
Kottayam	1.4%	0.11%	4.95%	0.06%
Kozhikode	6.7%	0.70%	6.14%	0.34%
Kannur	3.0%	0.46%	6.05%	0.15%
Kollam	0.9%	0.19%	7.45%	0.05%
Thiruvananthapuram	-	0.21%	6.16%	-
Rest of Kerala	0.4%	0.55%	5.87%	0.02%
Tamil Nadu	0.1%	0.50%	5.89%	0.00%
Karnataka	0.4%	0.83%	5.99%	0.02%
Rest of India	0.2%	1.12%	2.95%	0.01%
Elasticity				1.4
Growth Rate **(Sum of Combined Growth Trend of Indices X Elasticity)**				6.53%

Similarly growth rates are arrived for rest of the passenger vehicles. Location-wise estimated growth rates and average growth rate of all the locations has been summarized in the below **Table 3.3.**

Table 3.3: Estimated Growth Rates

Type ofVehicle	SH-66, Near Chellanam	NH-66, Near Ezhupunna	NH-66, Near Akalad	SH-63, Near Goshree Jn	AverageGrowth Rate
Two Wheeler	5.63%	5.81%	5.90%	5.55%	5.73%
Auto	4.92%	5.05%	5.19%	4.87%	5.01%
Car	6.39%	6.58%	6.53%	6.26%	6.44%
Mini Bus	2.82%	2.73%	3.13%	2.84%	2.88%
Bus	2.81%	2.73%	3.10%	2.83%	2.87%
Goods Auto	5.40%	5.50%	5.63%	5.39%	5.48%
Tata Ace	5.41%	5.58%	5.65%	5.40%	5.51%
LCV	5.42%	5.73%	5.66%	5.42%	5.56%
2 Axle Truck	5.46%	5.75%	5.69%	5.45%	5.59%
3 Axle Truck	5.48%	5.95%	5.79%	5.40%	5.65%
MAV	-	5.63%	5.85%	5.40%	5.62%

Past Trends in Traffic on the Project Road: Past traffic data were compiled from on NH 66 and SH 63 from Mobility Plan (CMP) for Kochi- 2015 prepared by Kochi Metro Railway Limited (KMRL) and compared with present data as presented in **Table 3.4 and Table 3.5**.

Table 3.4: Past Growth Trend in Traffic at SH-63 (Vyppin-Munambam Road)

Vehicles	Near Goshree Junction			Maliyankara Bridge		
	Past Study-2015	PresentStudy-2022	GR (2015-2022)	PastStudy-2015	PresentStudy-2022	GR (2015-2022)
Mini Bus	145	140	-0.5%	51	40	-3.4%
Bus	1,036	521	-9.4%	112	99	-1.7%
Car	4,487	7,415	7.4%	1,146	1,918	7.6%
Two Wheeler	13,876	22,101	6.9%	6,646	10,068	6.1%
Auto	2,556	2,349	-1.2%	995	1513	6.2%
Goods Auto	372	360	-0.5%	-	-	-
LCV	483	766	6.8%	568	888	6.6%
2 AxleTruck	359	178	-9.5%	195	82	-11.6%
3 Axle Truck & MAV	75	157	11.1%	7	63	36.9%
Cycle	220	198	-1.5%	396	530	4.3%

Table 3.5: Past Growth Trend in Traffic at NH-66

Vehicles	Near Aroor			Near Ponnani		
	Past Study-2015	PresentStudy-2022	GR (2015-2022)	PastStudy-2019	PresentStudy-2022	GR (2019-2022)
Mini Bus	148	619	22.7%	77	122	16.6%
Bus	2,144	905	-11.6%	265	226	-5.2%
Car	19,218	22,278	2.1%	5,513	5,889	2.2%
Two Wheeler	34,490	28,251	-2.8%	18,003	6,992	-27.0%
Auto	4,786	3,034	-6.3%	3,498	1,026	-33.6%
Goods Auto	-	-	-	282	156	-17.9%
LCV	4,766	6,083	3.5%	956	1,456	15.1%
2 AxleTruck	5,560	1,430	-17.6%	317	556	20.6%
3 Axle Truck & MAV	1,170	1,619	4.7%	415	933	31.0%
Cycle	1,546	756	-9.7%	278	174	-14.5%

Recommended Growth Rates: Generally, the spread of economic development induces changes in the spatial distribution of activities and corresponding changes in transport demand elasticity. As regions become more and more self-sufficient, the need for long-distance transport diminishes. Therefore, it is generally assumed that transport demand elasticity, for both truck and passenger traffic would tend to decline over time despite growth in NDDP/ NSDP, population and per capita income. Hence a decline in elasticity has been assumed for the future period. ***In future years, the growth rate is expected to reduce gradually and therefore, the growth rate is assumed such that it will decrease for every five year block period***

Considering the above, criteria growth rate is estimated. Project road passes through rural areas as well as highly urbanized area. Therefore Growth rates are arrived separately for rural areas and urban area and the same is presented in this section.

Recommended Growth Rates for Rural Sections of the Project Road: Recommended growth rates for rural sections are presented in **Table 3.6.**

Table 3.6: Recommended Traffic Growth Rates of the Project Road (Rural Road)

Vehicle Type	2022-2025	2026-2030	2031-2035	2036-2040	2041-2045
Two Wheeler	5.5%	5.0%	4.5%	4.1%	3.5%
Auto	5.0%	4.5%	4.1%	3.7%	3.1%
Car	6.5%	5.9%	5.3%	4.8%	4.1%
Mini Bus	3.0%	2.7%	2.4%	2.2%	1.9%
Bus	3.0%	2.7%	2.4%	2.2%	1.9%
Goods Auto	5.0%	4.5%	4.1%	3.7%	3.1%
Tata Ace	5.0%	4.5%	4.1%	3.7%	3.1%
LCV	6.0%	5.4%	4.9%	4.4%	3.7%
2 Axle	5.0%	4.5%	4.1%	3.7%	3.1%
3 Axle	6.0%	5.4%	4.9%	4.4%	3.7%
MAV	7.0%	6.3%	5.7%	5.1%	4.3%
Others*	2.0%	1.8%	1.6%	1.4%	1.2%

- Cycle Rickshaw, Animal/Hand Drawn, Hand Cart, Other NMV, Agricultural Tractor/Trailer, Ambulance/ Fire Engines
- A minimum growth rate of 5% is considered for the purpose of pavement design.

Socio economic parameters used in the Elasticity method are Macro level whereas Past trends are the micro level indicator which represents the local site conditions. At present, Public Transport & IPT modes are showing declining trend due to COVID scenario. Therefore Past traffic growth trend is not considered in deriving the growth rates.

However, if we consider the ***recent growth trend of 2-Axle Truck, there is a decline in trend observed in all over the country***. The same trend is observed from the past traffic data of decline in trend for 2-Axle Truck. This is due to axle conversion of 2-Axle trucks to more efficiently operated LCVs and MAVs.

Hence, the potential for growth of 2-Axle trucks are tend to reduce in the same way as observed in the past decade and increase in growth rate of LCVs and MAVs.

Recommended Growth Rate of Passenger Vehicles for Urban Section of the Project Road: The project road is passing through highly urbanized area of Fort Kochi. Based on population and employment growth, growth rates of passenger vehicles are arrived for highly urbanized section. As per **Comprehensive Mobility Plan (CMP) for Kochi- 2015**, Population and Employment data is compiled and it shows that an average of population growth is 1.4% and average of growth of Employment is 1.9%. Based on this 2% growth rate is considered for passenger vehicles. In case of commercial vehicles growth rate of rural section of the project road is considered due to less numbers of goods vehicles observed in the urban road. Recommended growth rate of Passenger Vehicles for highly urbanized section are presented in **Table 3.7.**

Table 3.7: Recommended Traffic Growth Rate of Passenger Vehicles for Urban Road

Vehicle Type	2022-2025	2026-2030	2031-2035	2036-2040	2041-2045
Two Wheeler	2.0%	1.8%	1.6%	1.4%	1.2%
Auto	2.0%	1.8%	1.6%	1.4%	1.2%
Car	2.0%	1.8%	1.6%	1.4%	1.2%
Mini Bus	2.0%	1.8%	1.6%	1.4%	1.2%
Bus	2.0%	1.8%	1.6%	1.4%	1.2%

ANNEXURE -3

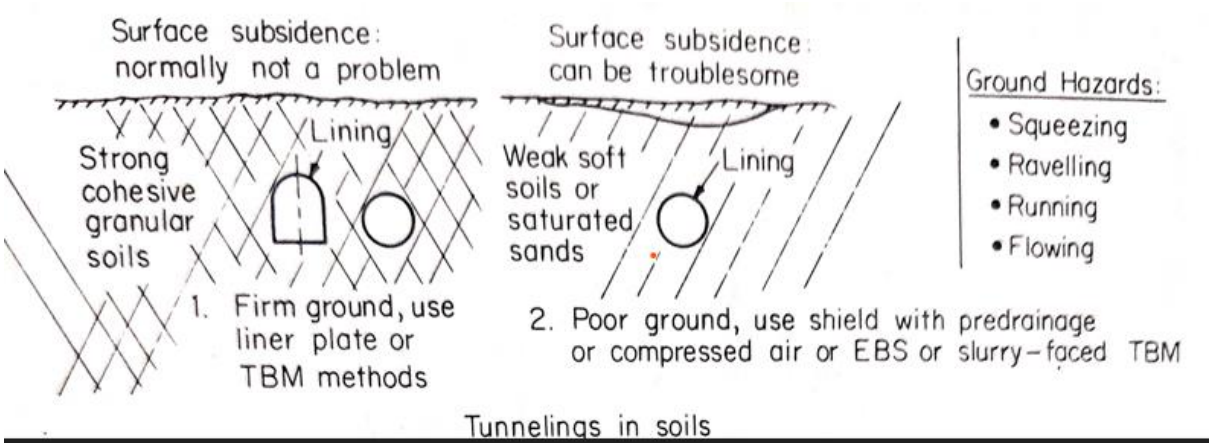
FEASIBILITY BASED ON AVAILABLE SOIL DETAILS

3.1 TUNNELING IN VYPIN – FEASIBILITY BASED ON AVAILABLE SOIL DETAILS

The basic study elements for any underground construction can be considered to be

- ***Excavation*:** The methods required for the removal of material, generally related to its hardness and strength.
- ***Retention of the opening*:** Support requirements to prevent closure during and after construction.
- ***Ground Improvement*:** Treatments required to improve unfavourable or hazardous conditions may endanger workers, cause delays and extra construction costs, affect construction performance, and cause surface subsidence.
- ***Geologic conditions*** are the controlling factors in underground construction, which for a given project can provide a range of variation to a much greater degree than other categories of construction. Adequate identification of all geologic conditions which may be encountered is usually a difficult and costly undertaking, and seldom will all significant conditions be known prior to construction.

Firm ground provides favourable conditions since a tunnel roof can be left unsupported for several days without inducing perceptible movement of the surrounding ground. Trouble some ground can ravel, run, flow, squeeze, or swell and without proper treatment can fill an opening immediately or gradually depending on various conditions as shown below.



Tunnelings in soils

The most serious problem encountered during excavation often is the sudden inflow of large quantities of water. Groundwater and seepage pressures are a major factor in raveling, flowing and squeezing ground. The possibility of high corrosive effects of water on linings also must be considered.

3.2 CLASSIFICATION OF GROUND CONDITIONS SUMMARIZED FOR SOIL

Condition	Associations	Performance
Firm Ground (Soil)	Strong cemented or cohesive granular soils, stiff to hard clays (non-swelling)	Opening can be left unsupported for several days without inducing perceptible ground movement.
Raveling Ground (Soil)	Slightly cohesive granular soils such as loess and residuals, or stiff fissured clays.	Material breaks into chunks, flakes and angular fragments which drop from the roof, enlarging the cavity.
Running Ground (Soil)	Dry, Cohesionless soil	Discharges immediately into opening to form a cone with sides about 34o
Flowing Ground (Soil)	Cohesionless soils or soils with low cohesion below GWL.	Invades tunnels as a stream extending for large distances.
Squeezing ground (Soil)	Soft to firm clays. Tendency is probable if (Pc-Pa)/Su >5	All exposed, unsupported faces advance into the opening slowly and continuously.

3.3 GROUND RESPONSE TO OPENINGS

Stress Field changes

Underground excavation results in stress relief which causes a redistribution of the natural stress fields about the opening and new strains and deformations in the surrounding materials. It may lead to high compressive forces in the vertical direction while the mass tends to expand under reduced compressive forces in the horizontal direction. It also depends very much on the shape, such as circular or slot, and the size of the opening.

Support requirements for underground excavations can be grouped into two categories: temporary support during construction and permanent support which may include a lining. During excavation in soils, support is required at the face of the opening and, depending upon ground conditions, may be provided by breasting boards, an excavating machine, a slurry wall, or air pressure. The arch and sides may be supported temporarily by liner plates or a shield. Permanent lining is required and is provided by cast-in-place concrete or by concrete or steel segments. Construction support methods for the roof arch in soils is given below.

Ground Conditions	Construction support of roof arch
Strong soils: residuals, stiff to hard clays and clayey sands, cemented dense sands	Shotcrete (10 to 20 cm) over mesh and metal arches or steel ribs and liners with cast concrete
Moderately strong soils: clayey sands (firm ground)	Steel ribs and liners with cast concrete or jacked in-place steel or concrete segments
Medium dense to loose sands, saturated, below GWL; loose fine sands (dry and running)	Stabilize with air pressure, dewatering, grouting or freezing, then support as given above, or use TBM and slurry-faced method
Soft soils; organic, clays, wilts below GWL (flowing and squeezing ground)	Use shield tunneling with air pressure or slurry-face methods and line with grouted steel or concrete segments.

3.4 CONSTRUCTION ASPECTS:

***Excavation methods*:** In soils, if liner plates and breasting boards are used, material at the face is removed by hand or by a machine such as a backhoe. Hydraulically advanced shields with either a closed face displace soft soils; with an open face the soil is removed by hand or machine as the shield advances. Tunnel boring machines with or without a slurry face or an earth pressure balanced (EPB) shield excavate material at the face, where it is removed by conveyor system.

***Ground Improvement*:** Various techniques are used to improve unfavourable ground with the result, for example, that flowing or running ground is changed to raveling ground or even firm ground. Air pressure is used in squeezing soil and soil with a tendency to flow. Dewatering with well points, deep wells, or water collectors is used in free-draining soils below GWL. Grouting is used in granular soils below GWL. Electroosmosis or freezing is used in fine grained saturated soils, the latter particularly where they are stratified, and dewatering or grouting is less effective than in homogeneous formations.

3.5 DESIGN FACTORS

Lining Stresses

Soil tunnels ae lined with concrete, steel, cast iron, or timber and designed to resist deformation under earth pressure. Ideally, performance depends on lining rigidity and soil type and deformation properties, as these factors influence the earth pressure to be supported. The disturbance that occurs during installation, however, substantially affects earth pressure and their distribution.

Flexible lining

In the ideal case, a circular, completely flexible lining inserted into the ground without disturbing the ground inside or out would be subjected to a vertical pressure Pz = γ.z and a horizontal pressure Ph = Ko Pz, causing an elliptical pressure distribution about the lining. Removal of soil from within the lining causes it to deflect to adjust to the pressures until it is slightly elliptical and support is provided by its ring stress capacity.

3.6 SOIL CONDITIONS, GENERAL EXCAVATION METHODS AND SUBSIDENCE

Soil conditions	Excavation Methods	Construction hazard	Treatment	Subsidence Potential
Strong cemented or cohesive granular soils	Liner plate, ribs and lagging, TBM	Usually none	None needed	Not a problem with good construction practice
Stiff to hard clays	Liner plate, ribs and lagging, shield, TBM	Possible squeezing	Careful excavation	Can be significant with liner plates, negligible with TBM
Slightly cohesive fine grained granular soils with relict structures (loess, residuals)	Liner plate, ribs and lagging, or TBM	Raveling ground	Provide support promptly, predrain, advance face in small size drifts	Small to negligible with proper construction, can result in sinkholes if uncontrolled
Cohesionless granular soil above GWL	Liner plate or TBM with slurry face	Running ground, dry flows	Chemical grout	Local surface effects and sinkholes, negligible with TBM and slurry face.
Cohesionless granular soil below GWL (loose to medium compact)	Shield or TBM with slurry face	Flowing ground	Air pressure, dewatering chemical grout, freezing	Local surface effects and sinkholes, negligible with TBM and slurry face
Very soft to medium clays and organic clays	Shield or TBM with slurry face	Squeezing ground	Air pressure	Large area surface effects difficult to prevent but reduced by TBM with slurry face

3.7 TYPICAL SOIL PROFILES IN VYPIN REGION

Soil profile at Karthedam near Malippuram, Karthedam Old Boat Jetty, Pukkad Boat Jetty near Elankunnappuzha, Nedungad Boat jetty, Ellathupady near Edavanakkad etc shows very soft silty clay with a medium stiff layer at 5 to 10 m depth. All these bore holes represent near backwater side. Towards Njarackal area, the ground condition changes to medium to dense sand with silt.

PROJECT : Proposed Kayalora Ring bound Road Vypin LAC
SITE : Pukkad Boat Jetty, Elankunnapuzha
BORE HOLE NO. : 3 (Ch : km 8/190)
TYPE OF BORING : Rotary drilling
1/1

DATE OF COMMENCE : 26-10-2018
DATE OF COMPLETION : 26-10-2018
GROUND WATER LEVEL: Aprox. 0.70m Below G/L

BORE LOG CHART & DATA SHEET

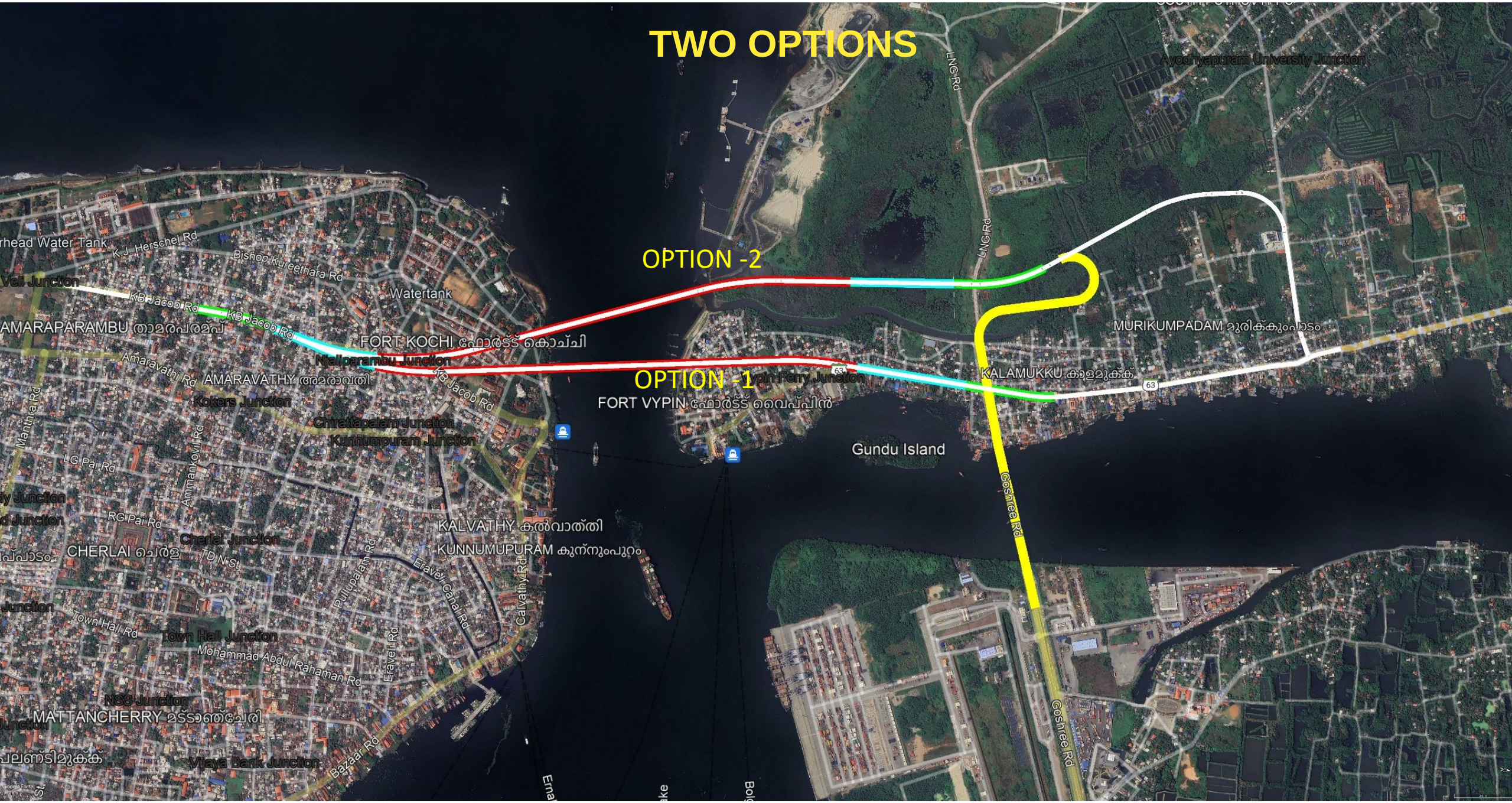
Depth in Meter	Soil Profile	Visual Description of Soil	Thickness of Layers (M)	Standard Penetration Test Data: Depth (m)	15	30	45	'N' Value	Graph of 'N' Value (10 20 30 40 50 >50)	Remarks
0.00										
		Silty fine sand (Grey)	1.80	1.00	1	1	1	2		
1.80				2.00	1	1	1	2		
		Silty clayey fine sand (Grey)	1.20	3.00	1	1	0	1		
3.00				4.50	1	2	1	3		
		Silty clay (D/grey)	2.80	6.00	1	2	1	3		
5.80				7.50	1	1	1	2		
		Silty fine sand with clay(Grey)	1.70	9.00	1	2	1	3		
7.50				10.50	1	1	1	2		
		Silty clayey fine sand (Grey)	2.50	12.00	1	1	1	2		
10.00				13.50	1	1	1	2		
				15.00	1	1	2	3		
		Silty clay (Grey)	10.00	17.00	1	2	2	4		
				19.00	2	3	2	5		
20.00				20.00	1	5	3	8		
		Bore Hole Terminated at 20.00m Depth								

3.8 RECOMMENDATION

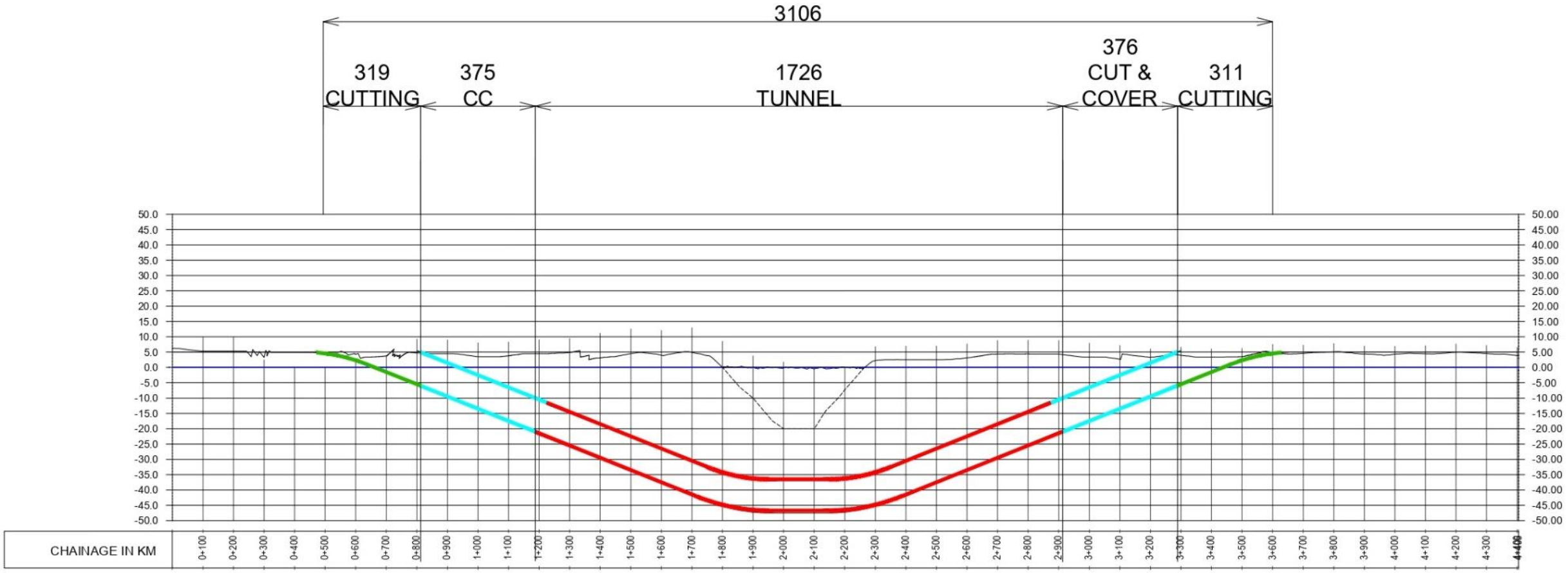
Hence the tunnelling in this area, consisting of soft clayey soil, is possible but with necessary precautions and ground supporting systems or TBM with slurry face must be adopted. However, wide variation in ground conditions has to be ascertained before taking up the proposal.

ANNEXURE -4

ALIGNMENT PLANS SHOWING THE CONNECTION ARRANGEMENTS AND LAND ACQUISITION BOUNDARIES


TWO OPTIONS
OPTION -2
OPTION -1
FORT KOCHI ഫോർട്ട് കൊച്ചി
FORT VYPIN ഫോർട്ട് വൈപ്പിൻ
AMARAPARAMBU താമരപറമ്പ്
AMARAVATHY അമരാവതി
KALVATHY കൽവാത്തി
KUNNUMUPURAM കുന്നുംപുറം
CHERLAI ചെർള
MATTANCHERRY മട്ടാഞ്ചേരി
MURIKUMPADAM മുരിക്കുംപാടം
KALAMUKKU കാളമുക്ക്
Gundu Island
Ayodhyapuram University Junction
Watertank
Njaliparambu Junction
Kokers Junction
Chiralapalam Junction
Kunhumpuram Junction
Cherlai Junction
Town Hall Junction
NSS Junction
Vijaya Bank Junction
Vypin Ferry Junction
LNG Rd
Goshree Rd
K.J. Herschel Rd
Bishop Kureethara Rd
KB Jacob Rd
Amaravathi Rd
Mantra Rd
LG Pai Rd
RG Pai Rd
Ammankovil Rd
Pullupalam Rd
Elavel Canal Rd
Calvathy Rd
Elavel Rd
Town Hall Rd
Mohammad Abdul Rahaman Rd
Bazaar Rd
63
Tunnel
Cut & Cover
Cutting

LONGITUDINAL PROFILE



KERALARAILDEVELOPMENTCORPORATION LTD.

☎ 0471 2326330 🖷 0471 2325330 ✉ krdclgok@gmail.com 🌐 www.keralarail.com

5th Floor, Trans Tower, Vazhuthacaud, Thuruvananthapuram, Kerala, Pin: 695014