Jamica Highway, West Indies

PEER REVIEW/CONCURRENT EVALUATION OF DPR AND BID PROCESS MANAGEMENT FOR THE MUMBAI COASTAL ROAD PROJECT

PHASE 1 REPORT

February 2016

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Municipal Corporation of Greater Mumbai

Peer Review/ Concurrent Evaluation of Detailed Project Report & Bid Process Management for Mumbai Coastal Road Project

Phase I Report

February 2016

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INTRODUCTION

1 INTRODUCTION

1.1 Project Background

Comprehensive Traffic Studies (CTS) carried out for Mumbai city identified requirement of new arterial road along the Western Coast as part of transportation networks. Govt. of Maharashtra constituted a Joint Technical Committee under the Chairmanship of Municipal Commissioner, MCGM on 30 June 2011 to study and make recommendations on the subject of coastal roads in Mumbai. The Committee recommended a 35.6 km. coastal road comprising a combination of road based on reclamation, bridges, elevated roads and tunnels on western side of Mumbai. The proposed location is shown in Figure 1-1.

MCGM has appointed consortium of M/S STUP Consultants Pvt. Ltd and M/s. Ernst & Young Pvt. Ltd for Preparation of Feasibility Report, DPR Preparation and Bid process management for the proposed Mumbai Coastal Road Project. The Draft DPR has suggested a length of 34.56 km for the coastal road.

Frischmann Prabhu India Pvt. Ltd. has been appointed as Consultant for Peer Review/ Concurrent Evaluation of Draft DPR.

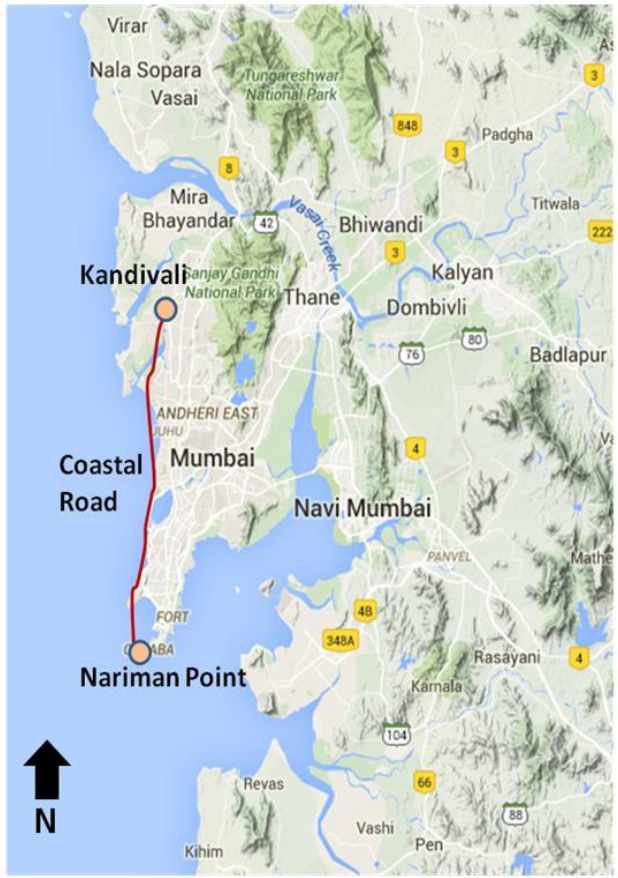

Figure 1-1 Location of Mumbai Coastal Road

1.2 Scope of Consultancy Work

Scope of work is clearly defined in TOR. The implementation of proposed consultancy work is as under but not limited to this. Scope of services shall include Peer Review/ concurrent evaluation of the Draft DPR and Bid Process Management including bid document for its correctness and to suggest, improvement, and alternatives if any especially on points mentioned below:

1. Draft Detailed Project Report (DPR).
2. The alignment/ capacity of roads from point of view of traffic study by carrying out fresh traffic survey, estimate traffic on Coastal road & dispersal system and nuisance to the public during construction of Coastal road.
3. The design from the point of view of safety, smoothness of traffic & economical aspects.
4. The environment impact assessment as done under the DPR including assessment of erosion/ flooding of coastal areas.
5. The reclamation methods as suggested under DPR.
6. The BRTS system proposed under Coastal road DPR.
7. Structural designs, specification from the point of view of safety, Environment Impact and cost effectiveness.
8. Effect of Draft DP 2034, other road networks & proposed land use on the Coastal road.
9. Effect of ongoing/proposed infrastructural projects (including Metros) by MMRDA, MSRDC, and Railway Projects etc.
10. Traffic adequacy of existing Bandra-Worli Sea Link as a part of Mumbai Coastal Road Project and check feasibility of avoiding the sea link toll plaza.
11. Design, construction methodology & risk analysis for all structures in Coastal Road.
12. Engineering survey & geotechnical investigation & any additional tests/ changes etc. The geotechnical investigation to be confirmed by taking 10 % stratified Random sampling.
13. Suggestion & objections received from Public, on the available DPR data.
14. Bid process management including tender/ contract document.
15. To propose phasing of work initially from the point of view of traffic priority, technical feasibility & homogenization with whole project.

1.3 Phases of Development

As per the discussion held with Client, the alignment has been divided in to three phases of development as detailed below:

Phase I

Section 2 : Priya Darshini Park to Mahalaxmi

Section 3 : Mahalaxmi to Baroda Palace

Section 4 : Baroda Palace to Worli End of Sea Link

Section 5 : Bandra End of Sea Link to Khar Danda (Carter Road)

Phase II

Section 1 : Jagannath Bhosale Road to Priya Darshini Park including Tambe Chowk connectivity

Section 6 : Khar Danda (Carter Road) to Ritumbhara College (Versova)

Phase III

Section 7A : Ritumbhara College(Versova) to Institute of Fisheries (Madh Island connectivity)

Section 7B Institute of Fisheries to Kandivali Junction

1.4 About this report

This report presents comments and suggestions based on the draft DPR for Phase -1 in order to facilitate further action by the DPR Consultant/Client. Aspects related to Traffic & Transportation, Environmental Impact Assessment and Tunnel Design are covered for the project as a whole.

The estimation of traffic demand on any new facility is a crucial step since the requirement and extent of the same form the base for further studies such as alignment studies. After evaluating possible alignment options the methods of developing the facility are to be examined and finalized in such manner as to be viable from the point of view of ease of construction, environmental and economic considerations. In view of this the review is broadly classified but not limited to the following:

1. Traffic & Transportation - Chapter 2
2. Alignment Studies - Chapter 3
3. Reclamation - Chapter 4
4. Tunnel Design - Chapter 5
5. Environmental Impact Assessment - Chapter 6
6. Construction Cost Estimate – Chapter 7

The above Chapters present the correctness of the Draft DPR and subsequent documents/drawings made available. Further, the comments, suggestions and improvements for each of the issues identified are enumerated.

However, the key issues are summarized and presented below:

1.5 Summary of Key Issues - Peer Review

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
1	**Lane Capacity and Configuration**	4+4 and 2+2 lane configuration suggested	The estimation of traffic and provision of the lanes is not substantiated on scientific methods. In the light of fresh traffic surveys, analysis and results the traffic demand and lane requirement has been reassessed under different scenarios.	Based on the studies the minimum lane requirement of coastal road is 4+4 lanes. However, provision for 5+5 lanes be made in the reclamation portions as warranted under Scenario 1.
2	**Relaxation or Departure from Standards**	Very limited or no information available	Relaxation or Departure are essential prior to freezing the alignment and need to be approved by Client	Approved List of relaxation / Departure from standard shall be produced and included in tender document.
3	**Adequacy of Reclamation/ Tunnelling/ Geotechnical/ Bathymetric Surveys**	Various Surveys have been identified in the DPR.	Limited number of surveys carried out to date	Additional surveys will be required to ensure that the contract is devised and executed with the minimum of uncertainties and the minimum of programme and cost impacts.
4	**Choice of type of design for each section-Tunnel/ Reclamation/ Bridge/ Bridge on stilts/ Elevated road**	The DPR is proposing specific methodologies, techniques and routes	The tunnelling methods are prescriptive and reclamation proposals are simplistic and probably not applicable to this situation.	Methodologies/ techniques need to be rigorously justified based on available evidence, clearly stated preferences, or based on facts obtained in the study to date.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
5	**Materials Investigation – Concrete/Bulk Fill Material**	Investigations are very limited.	There are significant shortfall in material volumes identified in excess of any other use of spoil arising from MML3 and/or CR Tunnelling etc.	As a matter of urgency, identify suitable resources conforming to appropriate specifications
6	**Logistics**	Not identified as a significant constraint	Logistics is a highly significant constraint given restrictions of land transportation and difficulties of marine operations. No fabrication areas have been identified by the DPR.	Logistics is highly influential factor on the construction methodology and the logistical constraints/ limitations need to be investigated as soon as possible by a Project Master Plan. Consideration of an enabling contracts to front load the works.
7	**Tunnelling Methodology**	Prescriptive Methodology without geotechnical basis.	Alternative methodologies should not be excluded by the tender process.	Execute detailed geotechnical investigations to ensure selection of optimal methodology.
8	**Reclamation**	The DPR includes various design options for reclamation. Hydraulic Modelling (NIO, GoI) is limited. The contract packages include both reclamation, bridges and road	Design options inappropriate and potentially costly No design criteria has been specified for reclamation and extreme environmental conditions The contract packages could be simplified to suit contractor's specialist capabilities.	Additional modelling to be carried out to consider extreme environmental conditions for an appropriate return period. Review contract packaging through the Master plan.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
9	**Programme/Critical Path**	Not discussed in sufficient detail	Need to consider overall contract programme (irrespective of different construction packages)	Consider optimum selection of single or multiple package options and identify critical path
10	**Safety and Security**	Not discussed in sufficient detail	The safety and security of the coastal road facility is paramount.	Safety and security related documents and plans required.

TRAFFIC & TRANSPORTATION

2 TRAFFIC & TRANSPORTATION

2.1 Background

The need for implementation of the Mumbai Coastal road project is established through various transportation studies for the Mumbai Metropolitan Region (MMR) and Greater Mumbai in the past and reiterated in recent studies. [1]

Vital Transportation infrastructure projects such as the Mumbai Metro, expected to bring a sea change in the travel pattern of the city are in various phases of implementation. With this background, the peer review studied the related work carried out during draft DPR stage through worksheets and reports submitted. The gaps identified were conveyed to MCGM and the draft DPR consultant through meetings.

Traffic surveys were carried out afresh to study the current travel characteristics. Traffic Demand Assessment for the base year and forecasts for the horizon year of 2034 are prepared to address the following:

1. **Alignment suitability** from traffic point of view
2. **Capacity requirements** for various sections of the proposed road. This includes the existing Bandra Worli Sea Link that connects the North and South sections of the coastal road.
3. **Traffic Dispersal** requirements

BRTS report submitted gives a conceptual overview of the system proposed. Details of the same are not available for review. Some suggestions on the same are included as part of this review.

[1] Draft DP for Greater Mumbai – 2034, CTS for MMR -2008, CMP for Greater Mumbai-Draft Final report- 2016

The aspect of avoiding nuisance to public due to the construction activities needs to be dealt with in a comprehensive logistics plan for the whole project including traffic diversion plans and safety measures for road users.

The various points are broadly discussed under the following heads:

1. Traffic Surveys and Analysis
2. Traffic Demand Forecast
3. Alignment Suitability
4. Sufficiency of Capacity
5. Traffic Dispersal and smoothness of design
6. Comments on BRTS

2.2 Traffic Surveys and Analysis

IRC SP:19-2001, Manual for Surveys, Investigation & preparation of Road projects provides guidelines for various studies to be undertaken during various stages of preparation of a road project.

The traffic count stations for CTVC need to be selected such that the results capture the likely traffic that may shift to the coastal road. Seven days continuous traffic counts are undertaken at each location and Average Daily Traffic (ADT) is calculated. Seasonal factors are incorporated to arrive at the Average Annual Daily Traffic (AADT).

OD locations should be taken on points where maximum through traffic can be captured. Through traffic in the context of Mumbai coastal road is the traffic that may use the total length of the North South Corridor between Kandivali (North) and Nariman Point/ Tambe Chowk (South) or other such stretches along the corridor. The OD locations should also capture traffic that is likely to use part of the coastal road.

2.2.1 Comments on Traffic Surveys of DPR

As part of the DPR, Traffic surveys were undertaken on the major arterial roads of the North South corridor of Mumbai.

1. Classified Traffic Volume Counts (CTVC)
2. Origin - Destination Survey (OD)
3. Speed and Delay Survey.

17 locations were chosen for CTVC and OD in the DPR study. OD included 8 nodes of inner cordons taken in the Mumbai CTS study-TRANSFORM. These locations capture the traffic on the North South corridor adequately.

However, a location on Eastern expressway would have been desirable to capture the traffic that may shift due to better East West connectivity in the future years. Juhu-Tara road serves traffic between Kandivali and Bandra. A location on this road would have captured the possible contributions from this sub-arterial. Fresh traffic surveys undertaken by the peer review consultant include the above two locations.

2.2.2 Traffic Surveys of Peer Review Study

Traffic volume surveys were carried out at 17 locations continuously for 7 days using video recording. Origin Destination surveys were carried out for 24 hours by Road Side Interviews at signalised junctions. The locations for traffic survey are shown in Figure 2-1 Traffic Survey Locations - Island city

Speed and delay surveys were conducted on the major arterials by moving car observer method.

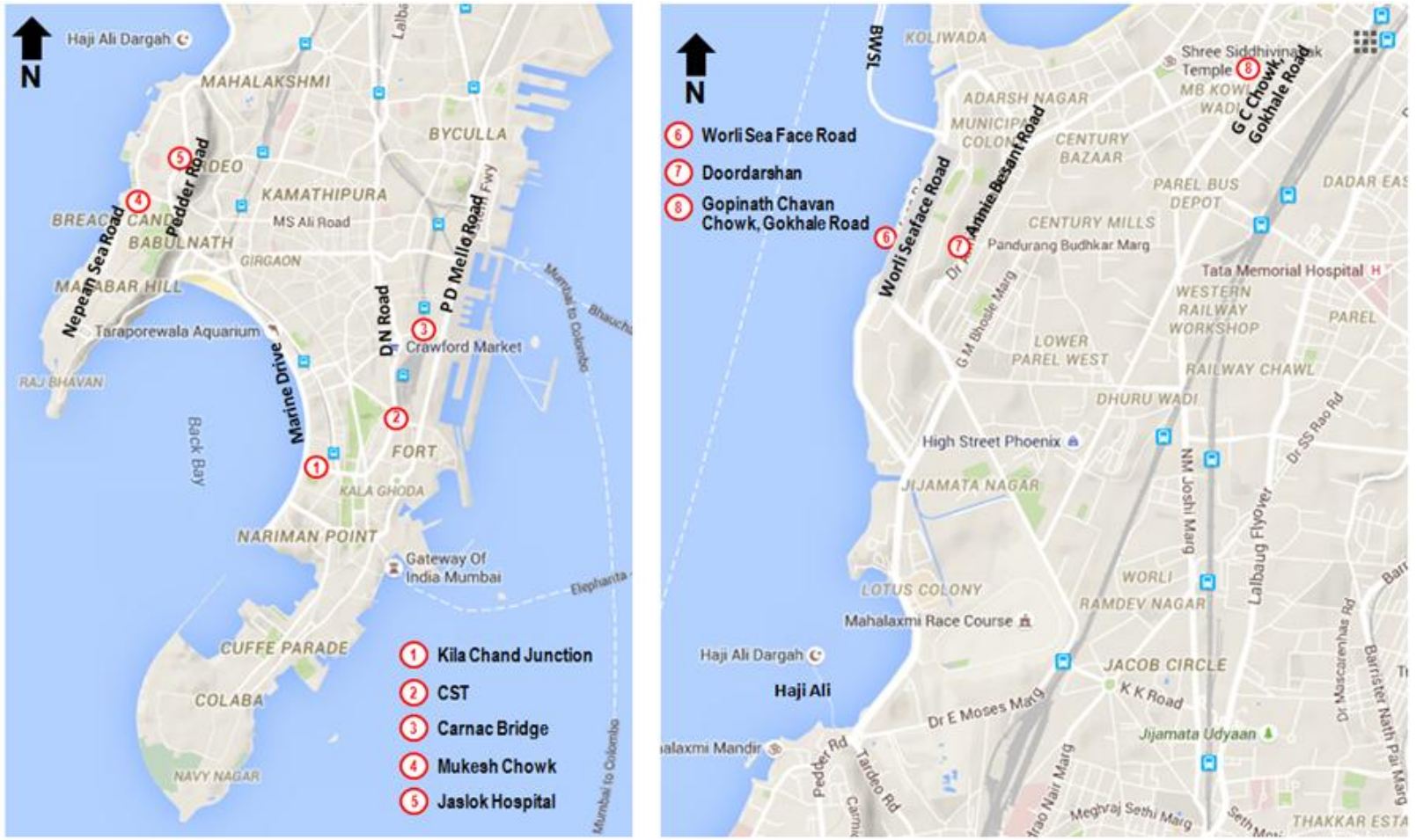

Figure 2-1 Traffic Survey Locations - Island city

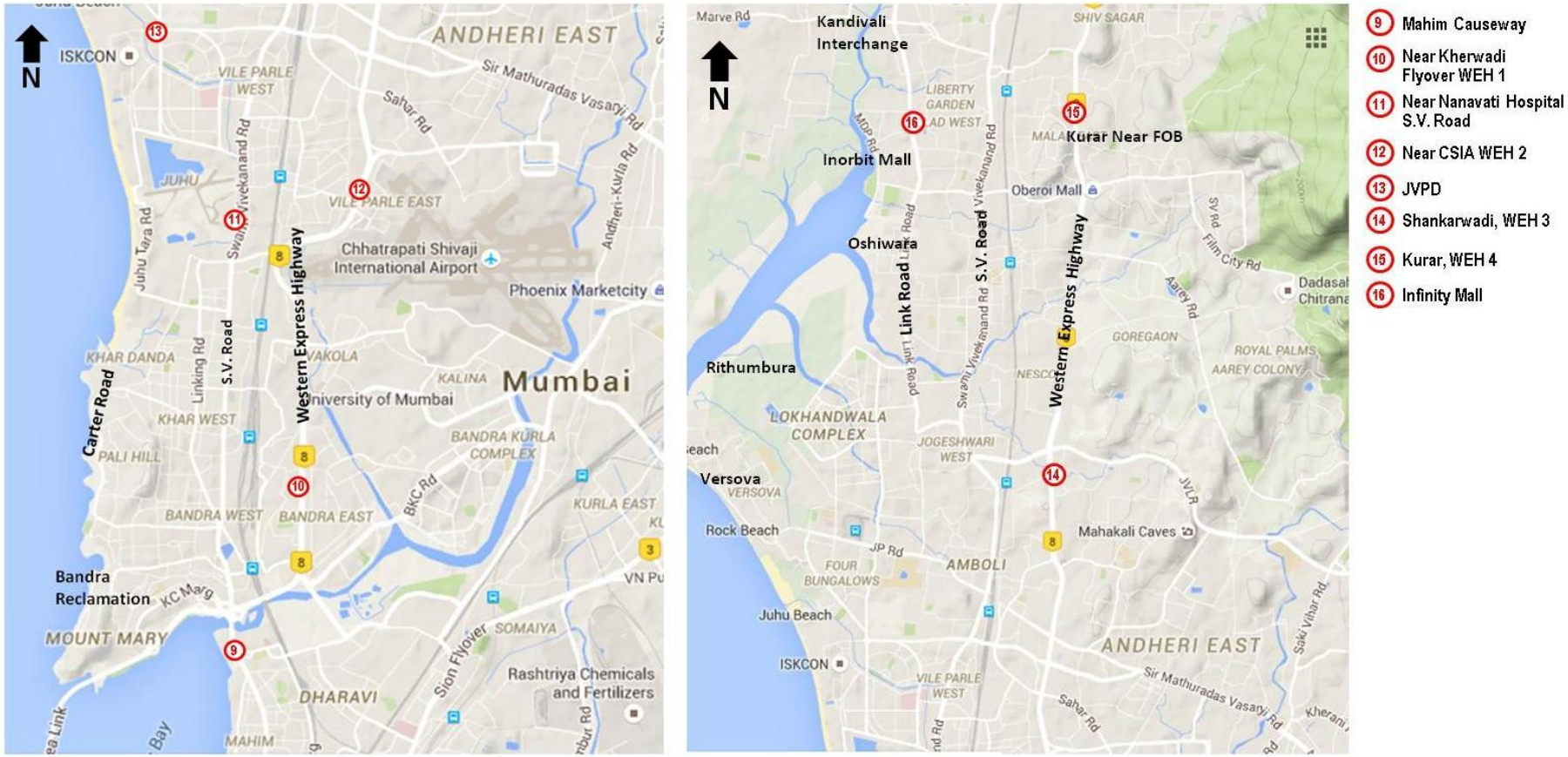

Figure 2-2 Traffic Survey Locations - Suburbs[2]

[2] 17th location is at the junction of NH8 & Godbunder Road

2.2.3 Traffic Volume on the North South Corridor

Analysis of volume count data shows a distinct variation in total traffic and peaking characteristics along the corridor. Average Daily traffic volume varies from 29,000 vehicles at Gopinath Chavan Chowk, Gokhale road to 2, 92,000 vehicles near Kherwadi flyover on Western Express Highway (WEH).

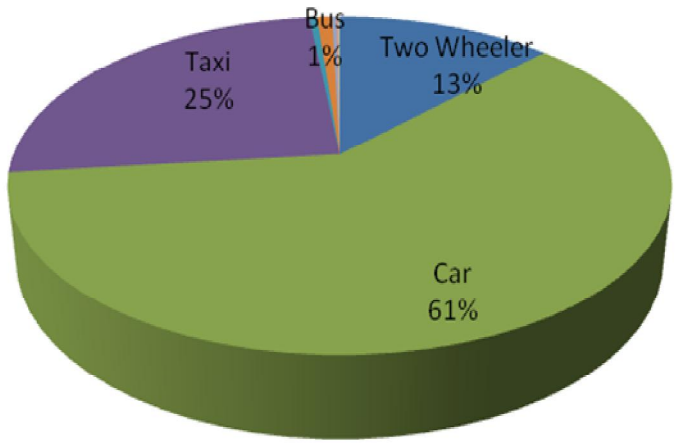

Figure 2-3 Traffic Composition - Marine Drive

Traffic composition of major arterials (Marine Drive, PD Mello Road, Peddar Road) in the island city has Cars and taxis up to 80-90%. Other locations in the island city such as Doordarshan on Annie Besant Road and Mahim Causeway have comparatively lower share of car traffic of 55 to 60%. In the western suburbs, the share of Cars drops down to 45-60% on various points on the Western Express Highway and 30-40% on SV Road and Link Road where more localised traffic interactions are present. Presence of auto rickshaws in the traffic stream is about 15-20% on the Western Express Highway. Other roads in the Western suburbs have high share of auto rickshaws in the traffic stream which is about (35-40%).

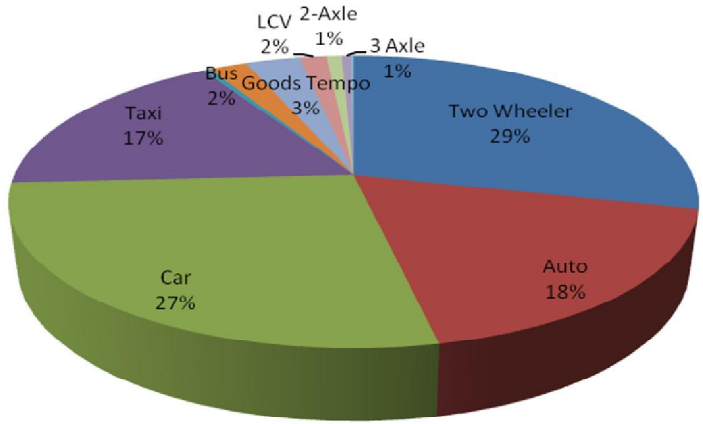

Figure 2-4 Traffic Composition - WEH

Peak periods of traffic in the morning and evening are between 7 AM -12 PM and 5PM- 9PM. The peak period begins earlier in the morning and persists later into the evening in suburban locations as compared to the island city.

Peak traffic varies between a minimum of 2400 vehicles to a maximum of 23000 vehicles/hour. Marine Drive, CST and PD Mello road each have peak traffic in the range of 6000-6500 vehicles/hour. Same range of traffic is observed on each location surveyed in the island city. Towards the suburbs, the peak traffic climbs to a higher level of 18000-20000 vehicles/hour on the WEH. On other locations in the suburbs the peak traffic values are in the range of 5500- 8000 vehicles/hour with localised peaks in locations such as the infinity mall up to 9000 vehicles/hour.

Morning peaks are more intense at most of the locations. Highest Morning Peak hour is observed between 9 AM and 11 AM. Highest Evening peak hours are observed between 5 PM and 7 PM. Network wide peak is observed on Monday between 10AM and 11 AM. Peak

is most intense in the North section in the Western suburbs. A range of 20,000- 25000 vehicles is observed here during the morning tapering to around 10,000 -12000 vehicles at Mahim causeway and Worli. At Worli the BWSL and Annie Besant road share the volume of traffic. At locations where evening peak is higher the difference is in the range of about 1%- 3%. Mondays and Tuesdays show highest traffic at many locations. WEH near the international airport shows highest peak on Friday morning. The details of the classified traffic volume studies are presented in a separate report entitled Traffic Demand Estimation.

2.2.4 Travel characteristics - OD Analysis

The study area is divided into 41 zones. The zones are divided keeping in mind the project influence area and its applicability for further use in transportation modelling. Zone nos. 1-19 are within MCGM area. Zone nos. 20- 26 are special transport zones such as the Airport zone and railway termini. Zone nos. 27- 34 are located outside the MCGM area, within the MMR. Zones 35 to 41 are outside MMR encompassing Maharashtra and rest of India. OD samples from each location are analysed separately and then combined to represent the OD pattern for the whole corridor.

Desire line diagram shown in Figure 2-5 represents the travel patterns for the study area. Ward A is the terminal point for desire lines radiating to distant zones within and outside MMR as well as zones within the MCGM area.

High interactions are observed between Ward A consisting of the Fort area and Ward D (Nepean Sea) as well as Ward A and Ward GS Worli, Lower Pare) within the island city (Figure 2-6). In the suburbs, highest flows are observed between KW (Andheri West, Versova) and R Wards (RN, RC, RS consisting of Borivali, Kandivali) in the north.

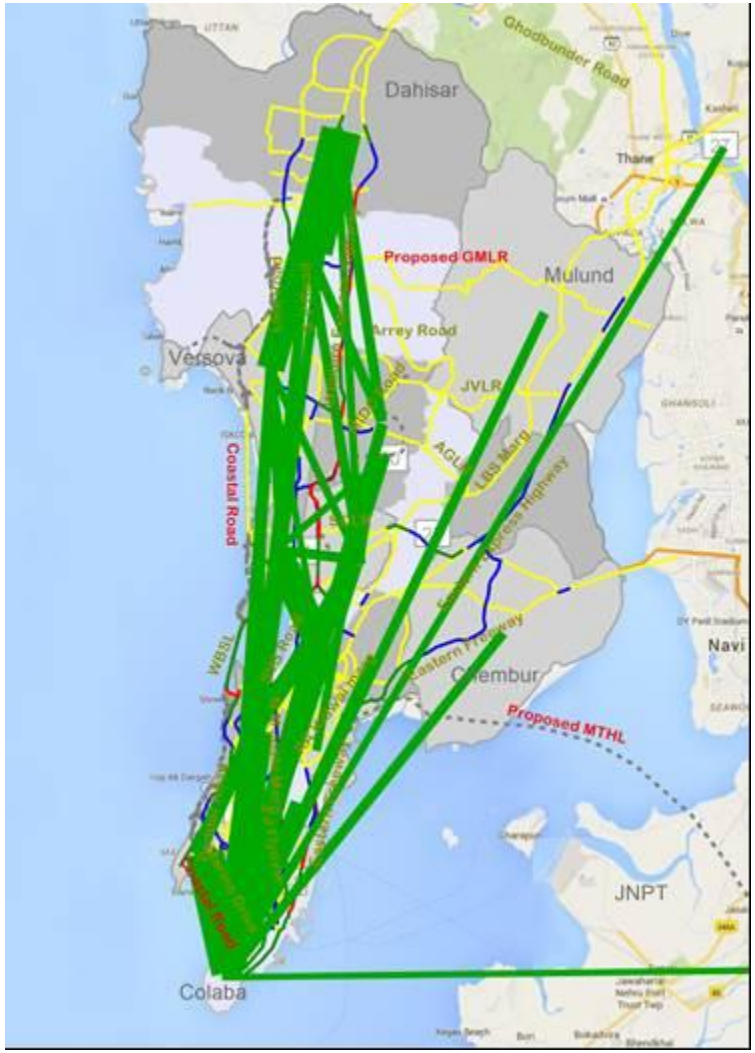

Figure 2-5 Desire Lines for Travel

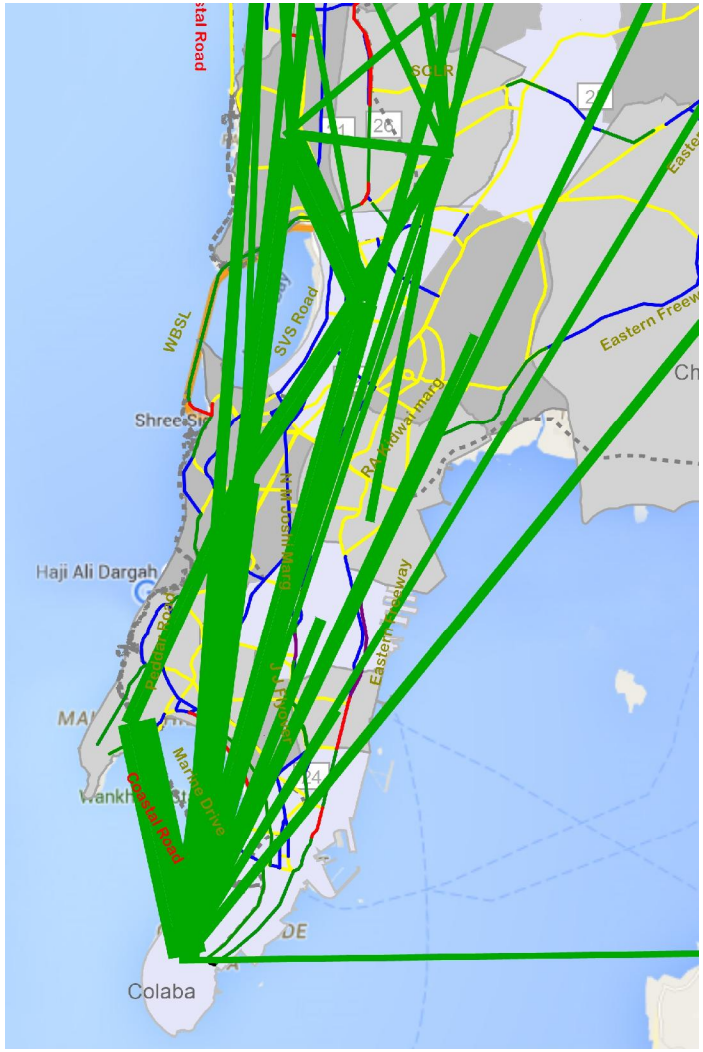

Figure 2-6 Desire Lines generated from Island City

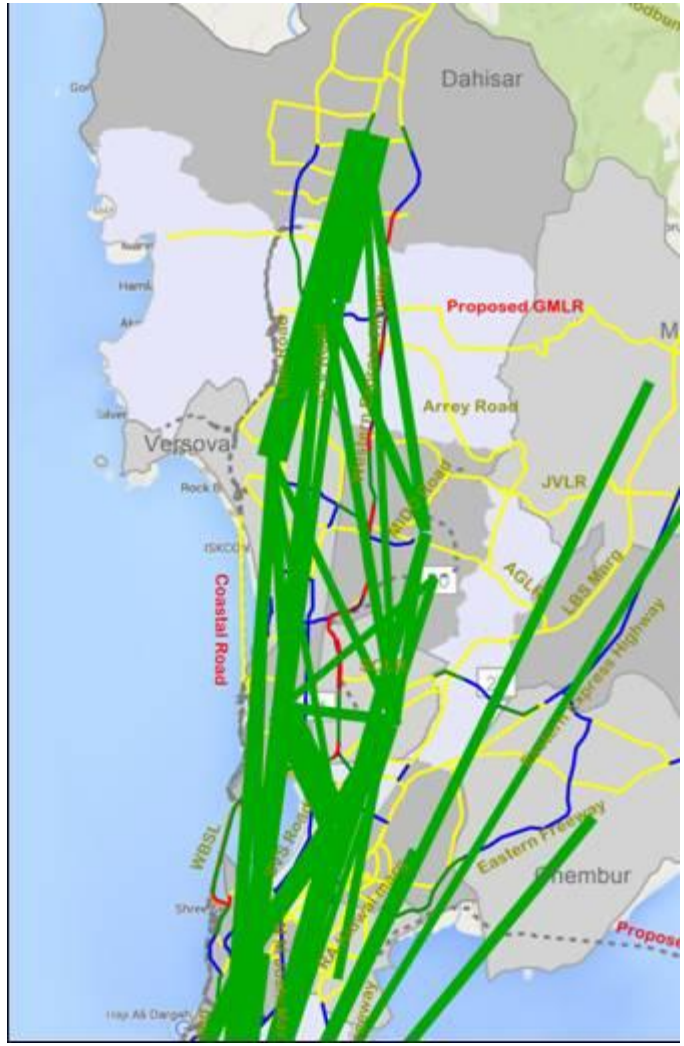

Figure 2-7 Desire Lines - Suburbs

2.2.5 OD Matrices

For the purpose of estimation of traffic on coastal road mode wise OD matrices were developed. OD matrices are derived separately for Cars and Taxis and goods vehicles as these are the user categories of vehicles on the coastal road. Two wheelers, autorickshaws and slow moving vehicles are assumed to be on coastal road keeping safety and other traffic management measures in vogue. Buses will be part of the BRTS system. The OD Matrices from the primary data collected are analysed to obtain four categories of peaks as given below:

1. Network Peak Matrices- Considering the total traffic volume on the road network surveyed, peak traffic was observed during 10AM-11AM on Monday. Matrices derived for this hour termed as Network Peak Matrices are used to assign and validate base traffic scenario on the state of the art VISUM network model.
2. Morning Peak Matrices- The highest peak volume observed during the morning peak period for each location surveyed is used in deriving the morning peak matrices. As mentioned earlier, morning peaks are more intense in most locations.
3. Evening Peak Matrices - The highest peak volume observed during the evening peak period for each location surveyed is used in deriving the evening peak matrices.
4. Average Peak Matrices-The average of peaks observed during the seven days at each location is used to obtain the average peak matrices.

The OD analysis shows that about 85-90% trips during the peak hours are produced and attracted to zones within Greater Mumbai. About 25% trips begin and end within the island city. Further, about 35% trips interact within the western suburbs and around 35% trips represent interaction between the island city and western suburbs.

Ward A consisting of the Fort area is the highest attractor of trips followed by GN and GS wards which have Dadar, Lower Parel and Worli which are major commercial centres. In the suburbs, wards PN, 11 and 12 have high OD shares represented by Goregaon, Malad, Kandivali and BKC.

2.2.6 Speed and Delay surveys

Average speed during peak periods on links varied between 7 kmph to 15 kmph. Results of speed and delay surveys were used to build the network model in transportation planning software VISUM.

2.3 Traffic Demand Forecast

Observations on Traffic Demand Forecast carried out in the draft DPR are given in this section followed by discussions on the traffic forecast prepared by the peer review study.

2.3.1 Comments on Traffic Demand Forecast

In the DPR study, Traffic demand for the coastal road is arrived in the following steps:

1. Vehicle categories that are not allowed on the coastal road are removed from the ADT.
2. Diversion shares are assigned to the ADT through empirical methods using OD matrices to derive the base traffic on the coastal road.
3. Growth rates are applied to the base traffic ADT (2%) to obtain future ADT.
4. Peak hour traffic is derived from ADT by applying a uniform peak hour factor of 8%.

In the draft DPR, the methodology of assigning diversion percentages to the ADT is not clear. Traffic forecasts need to be undertaken for a range of scenarios which foresee different combinations of population, employment and availability of transport infrastructure for the horizon years in order to capture the range of traffic risk. Further, the diversion of traffic takes place based on the generalized cost of using a particular facility and these need to be captured in order to minimize the error.

Effect of ongoing and planned transport infrastructure projects also need to be taken into consideration. Evidences of such considerations are not explicitly seen in the DPR study.

Lane Configurations obtained from analysis in DPR study do not take cognizance of the provision of a separate BRT lane in each direction. Therefore, these need to be re-visited.

2.3.2 Approach to Traffic Demand Forecast

Traffic Demand forecast undertaken in the peer review derives the base year demand from the observed Origin Destination pattern of the current traffic flows on the road network (Refer 2.2.5). Traffic demand Forecasts are made for the horizon year (2034) under different scenarios of land use planning parameters and transport infrastructure levels which are consistent with the Draft DP for Greater Mumbai 2034 and Comprehensive Mobility Plan (CMP) for Greater Mumbai (Draft Final Report, January 2016).

Transportation network is modelled using state of the art transportation planning software, VISUM in order to simulate travel patterns.

The scenarios developed for traffic demand estimation, forecasts for horizon year and network assignments with coastal road and other networks are explained in ensuing sections.

2.3.3 Scenarios for Traffic Demand Forecast

Scenarios are proposed to visualize the range of future traffic on the Mumbai coastal road and thus provide the decision maker with the range of traffic risk.

The Mumbai coastal road is envisaged as part of an urban system where traffic is primarily generated by the interaction between residences and activity centres through the transportation network/ modes of transport. Thus, future land use plans and planned transport infrastructure are essential inputs required for traffic forecast.

In CTS-2008 for MMR, detailed travel demand analysis has been carried out for the horizon year 2031 (Long Term), 2021 (Medium Term) and 2016 (Short Term). Alternative population and employment scenarios have been evaluated and shortlisted three growth scenarios as combination of population and employment of Greater Mumbai for the year 2031 as below:

Table 2-1 Growth Scenarios for Greater Mumbai in CTS study

CTS	Growth Scenarios		
Planning Parameters	**P2E2**	**P3E3**	**P3E4**
Population 2031	18 Million	16 Million	16 Million
Employment 2031	9.7 Million	7.35 Million	5.1 Million

In subsequent planning studies for assessment of ridership for metro corridors, road infrastructure, etc., MMRDA adopted/ suggested for using P3E3 scenario as it represents a balanced scenario in terms of population and employment distribution.

Major changes in population distribution in MMR have been observed from 2011 Census for example, reduction in Island city population and rapid growth in Navi Mumbai. Similarly changes in employment in MMR also have been observed based on preliminary results of 2014 economic census. As part of Draft Development Plan preparation and ongoing efforts of MMRDA on revision of Regional Plan, Planning parameters for the horizon period up to 2034 for Greater Mumbai and Rest of the Region have been assessed using 2011 census database and various methods of forecast. For Greater Mumbai, the population and employment forecasted for the horizon year 2034 are 14.0 million and 8.0 million respectively and the same have been considered in the present study.

Table 2-2 Horizon year Planning Parameters for Greater Mumbai

	Horizon Year Planning parameters
Population 2034	14 Million
Employment 2034	8 Million

The Comprehensive Mobility Plan (CMP) for Greater Mumbai has assessed Planning parameters at disaggregate level based on the land use and transport network considerations keeping the overall growth scenario in line with the Draft DP-2034. The zone level planning parameters for the peer review study aligns with the CMP.

Population projections as per Draft DP show negative growth in the island city. Population growth is highest in the five wards (PN, PS, RN, RC, RS) consisting of Malad, Goregaon, Borivali and Kandivali areas which would be high production zones for traffic on the coastal road. Wards HE and KE (Bandra(E), Andheri(E) also have significant population growth.

Employment Growth projected is highest in A ward with more than 4 lakh new jobs followed by GN ward with an increase of 1.79 lakh jobs. In the suburbs HE ward that includes BKC area has highest growth in employment, followed by KE ward.

Capacity enhancements in the suburban rail network, development of new corridors (Suburban, metro and monorail) and growth of private vehicles would play a major role in the choice available to travellers in Mumbai in the horizon year. Hence, these factors have been considered as part of CMP/Draft DP and the same are adopted while development of alternative scenarios.

Alternative scenarios have been considered for combinations of three parameters:

1. Base Traffic Level (B)
2. Transportation Network availability (T)
3. Private vehicle usage (P)

Table 2-3 Parameters for Traffic scenario development

Parameter	**Levels considered**
Base Traffic Levels (B)	B1 -Morning Peak B2- Evening Peak B3- Average Peak
Transportation Network availability (T)	T1-Limited Transportation Network availability T2-Fully developed Multimodal Transportation Network

Parameter	Levels considered
Car usage (C)	C1-High Growth in Car usage C2- Medium Growth in Car usage C3 – Low growth in Car usage

Base Traffic Levels are derived from matrices for different peaks obtained from traffic surveys (Refer 2.2.5)

Transportation Network availability (T) refers to the available road & rail network in the horizon year.

Limited Transportation Network availability (T1) includes the Base year transport network + on-going construction and committed projects. New road links worth special mention in this network scenario are:

1. East West Connectivity to the Coastal Road through GMLR near Malad interchange
2. East West Connectivity between the Coastal Road and Western Express way at Kandivali
3. Ongoing road works and flyovers
4. Ongoing and committed suburban rail works
5. Ongoing and committed monorail works

Fully developed Multimodal Transportation Network (T2) includes the following:

Base year transport network + Draft Development Plan proposed road network + On-going construction and committed projects (Monorail, Metro line II and III) + proposed potential Metro corridors based on Mumbai Master Plan study and CTS for MMR study. New links worth special mention in this network scenario are:

1. MTHL
2. Sewri Worli link (Road & Metro)
3. Metro line II & III

Car usage (C)

Past trend in Car growth has been high. However, in the future, implementation of proposed transit corridors (Suburban, metro, monorail etc.) will encourage travellers to use public transport depending on the accessibility, efficiency and reliability of the network available in the horizon year. Considering this, three car growth scenarios are envisaged i.e. High Car usage, Medium Car usage and Low Car usage.

Critical combinations of the above three parameters are presented in scenarios given below:

Scenario 1- Base Traffic corresponding to Maximum Peak of each location during the morning peak hour is used. All network links are fully developed.

Higher car usage levels are taken considering factors such as high past trends and the propensity of two wheeler users becoming future car users, especially due to the availability of better road network. This represents the most traffic intense scenario.

Scenario 2- Base Traffic corresponding to Average of Peak of each location during the morning peak hour is used. All network links are fully developed.

Lower car usage levels are taken considering higher public transport patronage. This represents a more likely scenario on the future network as compared to scenario 1.

2.3.4 Estimation of Traffic on the Coastal Road- VISUM Modeling

Based on the various characteristics of the network and traffic as discussed above, state of the art Transportation planning softwarel, VISUM was used for model development. Various network parameters were modelled as Links, Nodes and Zones. Individual Links, Intersection and Zonal Characteristics were fed into the model in the form of link attributes such as Link Flows, Speeds, Impedances; Nodal Capacities, Turn Capacities, Turn Penalties; Zonal Characteristics, etc. Using these base attributes, the skim matrices were derived. The horizon year Fully developed road Network is shown in Figure 2-8.

The model was validated using the Network peak observations of flow as well as Origin Destination matrix. The matrices were corrected using the tool TFlowFuzzy, which is used to validate the CTVC counts on specific links with flows estimated by the VISUM Model. Once the Matrices were validated, the growth factors were applied (under the scenarios mentioned in section 2.3.3) in order to arrive at the horizon year Productions and Attractions for individual zones. The future Productions and Attractions so derived were then distributed to get the future year matrix. This matrix was assigned on the network scenarios to estimate the flow on the proposed coastal road using user equilibrium method. The traffic assignment for Scenario 1 is shown in Figure 2-9.

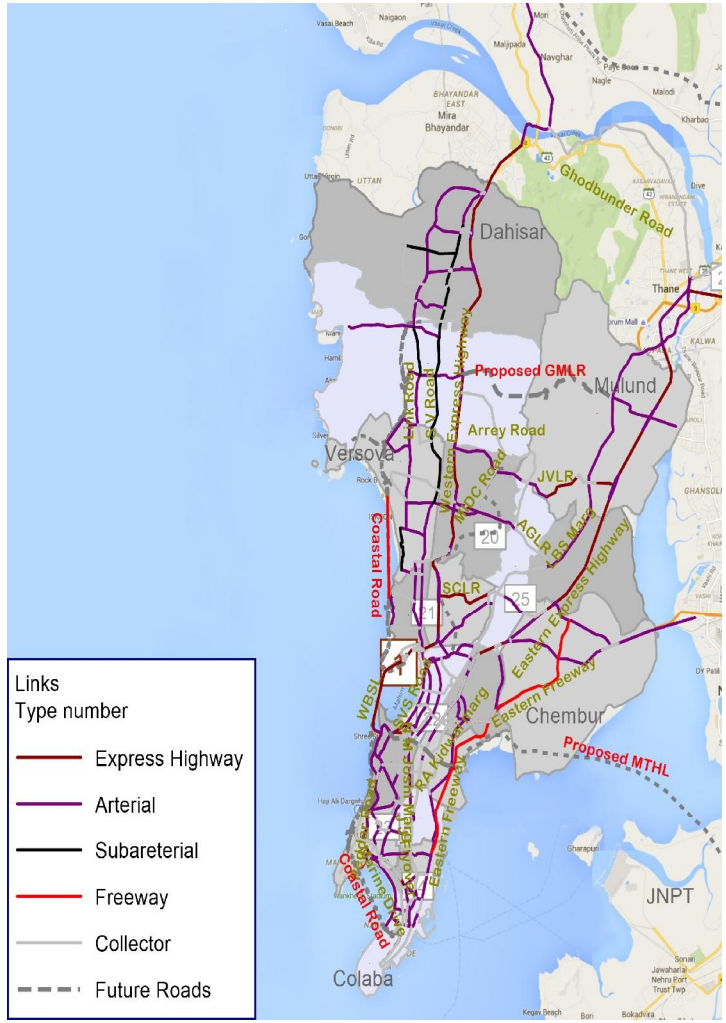

Figure 2-8 Horizon year fully developed Road Network

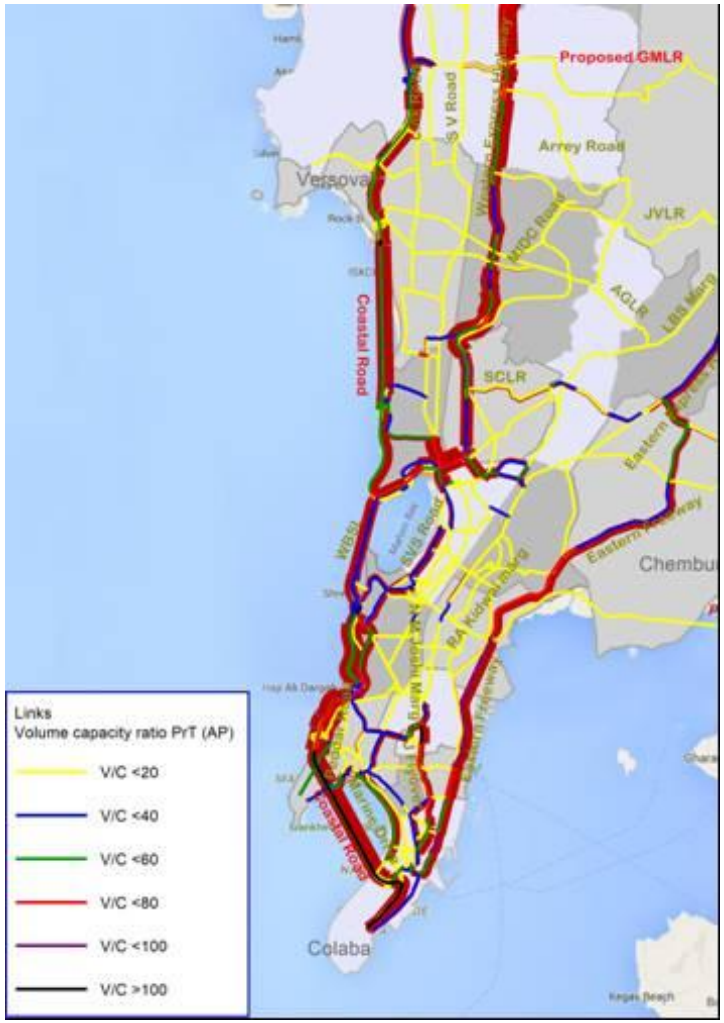

Figure 2-9 Traffic Assignment Scenario 1

It is observed that significant diversions are observed from the current arterials in the island city portion such as the Marine drive and Peddar road. The level of service on these arterials have improved due to the coastal road. Moving further northward towards the sections in the suburbs, the diversions to the coastal road are comparatively lower. The suburban productions and attractions are spread over a wider area on either side of the current major arterial road, i.e. Western Express Highway. Longer Travel distances (east west distances) are involved in travelling from these activity centres to the coastal road than in the island city. As already observed in the section describing future planning parameters growth nodes in the North West will be the major beneficiaries of the coastal road.

Similarly traffic assignment for Scenario 2 is carried out.

2.3.5 Lane Requirement & suggestions on Alignment

Based on the assignments the requirement for number of lanes is worked out as follows:

Sr. No.	Section	Peak Hour Traffic (in PCU)		No. of Lanes required	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
1	Nariman Point to Amarson Garden	6600	6010	3+3 Lanes	3+3 Lanes
2	Amarson Garden to Haji Ali	5580	3280	3+3 Lanes	2+2 Lanes
3	Haji Ali to BWSL	12540	7790	6+ 6 Lanes	4+ 4 Lanes
4	BWSL	10760	8360	5+5 Lanes	4+ 4 Lanes
5	BWSL to Carter Road	7770	5110	4+ 4 Lanes	3+3 Lanes
6	Carter Road to Seven Bunglows	11280	8040	5+5 Lanes	4+ 4 Lanes
7	Seven Bunglows to Madh Island Interchange	10960	7650	5+5 Lanes	4+ 4 Lanes
8	Madh Island Interchange to Lokhandwala Interchange	11630	8580	5+5 Lanes	4+ 4 Lanes
9	Lokhandwala Interchange to Malad Interchange	14060	10160	6+ 6 Lanes	5+5 Lanes
10	Malad Interchange to Kandivali Interchange	8690	6300	4+ 4 Lanes	3+3 Lanes

In Scenario 2 which is the more likely traffic scenario for the horizon year, most sections of the coastal road warrant 4+4 Lanes.

Nariman point to Amarson garden section requires 3+3 Lanes in both scenarios. Variation between Maximum and average peaks in this section are low. The lane requirements observed above are the minimum requirement based on traffic assignment. Considering the provision of one Exclusive Bus Lane (EBL) for BRTS additional requirement of at least one more lane in each direction is suggested. Therefore at least a 4+4 Lanes coastal road is suggested.

The section between Amarson garden to Haji Ali is proposed on reclamation. As Reclamation is proposed for a ROW of 80-100m, it is prudent to provide 5+5 lanes for such sections as warranted under scenario 1. In the elevated sections, considering the cost of construction and other aspects such as availability of land, 4+4 lanes is suggested.

2.3.6 Comments on Alignment based on Lane Requirement

In the draft DPR, alignment from Jagannath Bhosale Chowk to Amarson Garden is planned as a 2+2 lane underwater tunnel. This alignment will need augmentation to 4+4 configuration, from traffic point of view.

Traffic assignment shows significant traffic volume joining the Coastal road at Amarson garden interchange. Connectivity from Tambe Chowk to Amarson Garden is recommended as a 2+2 Lane configuration in order to relieve the feeder roads to the interchange.

The traffic demand on BWSL warrants a minimum of 4+4 configuration whilst under scenario 1 the same requires 5+5 configuration. As the existing BWSL is of 4+4 configuration the same may be reviewed at a later date depending on the implementation of the committed/ proposed developments within MCGM/ MMR.

2.4 Traffic Dispersal

Traffic Dispersal is planned through 12 numbers of interchanges on the proposed alignment. In the draft DPR report, Traffic Volume on the interchange arms is derived from empirical assumptions and presented as Average Daily Traffic (ADT) for the base year and horizon year.

2.4.1 Comments on Traffic Dispersal

Interchange Traffic Volume

Lane requirement of interchange arms should be decided based on the peak hour volume forecasts for the horizon year.

Suggestions for City level Roads Connecting to Interchanges

- Traffic Volume on connecting city level roads to the interchange locations need to be forecast and sufficiency of these to cater to the demand needs to be brought out.
- Wherever feasible, capacity augmentation needs to be suggested along with alternative local area traffic management schemes as applicable.

The details of Traffic Demand Assessment, Lane Capacity and Traffic Dispersal shall be dealt with as part of a separate technical report.

2.5 Bus Rapid Transport System (BRTS)

Bus Rapid Transit System is proposed on outer lane of the coastal road with the objective of bringing in public transport related benefits. Notable points regarding BRT system from traffic engineering/ transportation planning point of view are:

- Outer lane shall be bus only. However, buses are allowed to move on all lanes
- Boarding/Alighting points are offline and do not interrupt flow of bus lane traffic
- Stopping time of one minute is assumed with frequency of 20 seconds for station
- GPS equipped, Low floor Articulated buses with capacities in the range of 190 to 250 passengers are assumed.
- Fleet size - 600 buses
- Routes to be derived based on operational demand
- Multilevel Car Parking, IPT (Auto/Taxi) stands and basic public amenities at stations
- Elevators/ ramps for Universal accessibility

2.5.1 Comments on BRTs

Demand for BRT

Scale of Demand for BRT is not established in the study. Given the fact that public transport facilities available are grossly short of capacity to cater to the huge demand for the same, BRT will find regular customers provided that the system is well connected to the bus system in mainland.

The coastal road alignment is intercepted with several interchanges. The effective length available for operation and implementation of BRTS needs to be studied in sufficient detail. The availability of sufficient weaving length within interchange as well as between two interchange is the essence of successful BRTS scheme. This shall be followed with more detailed road user information in terms of directional signs, road markings for smooth and safe weaving. The detail planning of BRTS is absent in DPR which shall be further explored. Further, the details of last mile travelled need to be integrated and planned.

2.6 Traffic Logistics, Diversion and safety measures during Construction

A well conceived Construction Logistics plan (CLP) is a primary requirement for the project. Traffic Logistics, diversions and safety should be part of this CLP. It will provide a framework to better manage all types of freight vehicle movement to and from construction sites. Having a management plan will improve the safety and reliability of deliveries to a site, reduce congestion and minimise the environmental impact. The CLP should be part of the contract document

Construction of the Coastal road requires transport of millions of tonnes of material. Although a high share of transport may take place through the sea route, trucks and other heavy construction vehicles will play a key role in the project, by transporting equipment, delivering materials and removing waste. The issues related to this aspect are detailed out under Reclamation section.

2.6.1 Traffic Route Plans

Route plans form the core of a CLP. Traffic Route shall be planned taking into account factors such as

- Capacity constraints on Local roads
- Safety considerations
- Likely site access and unloading points

2.6.2 Work Zone Traffic Management Plan

Work zones shall be demarcated and a Work Zone Traffic Management Plan shall be prepared in consultation with and approval of Mumbai Traffic Police/ MCGM. The guidelines given in IRC SP 55-Guidelines for traffic management in work zones should be part of the contract document.

2.6.3 Protection of Vulnerable Road Users

Adequate measures for Vulnerable Road Users (VRU) such as guidance systems and barriers needs to be incorporated.

2.6.4 Role and responsibilities

Clearly defining the roles and responsibilities of who must do what and when in ensuring that important safety issues are not overlooked at any time.

2.6.5 Public Involvement

Informing and involving the community through public hearings and in the planning of Work zones and detours.

2.7 Summary of Key Issues - Traffic and Transportation

The key issues related to traffic and transportation are summarised below:

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
1	Lane Capacity and Configuration	4+4 and 2+2 lane configuration suggested	The estimation of traffic and provision of the lanes is not substantiated on scientific methods. In the light of fresh traffic surveys, analysis and results the traffic demand and lane requirement has been reassessed under different scenarios.	Based on the studies the minimum lane requirement of coastal road is 4+4 lanes. However, provision for 5+5 lanes be made in the reclamation portions as warranted under Scenario 1.
2	Traffic Dispersal	Traffic Dispersal is planned through 12 numbers of interchanges on the proposed alignment. In the draft DPR report, Traffic Volume on the interchange arms is derived from empirical assumptions and presented as Average Daily Traffic (ADT) for the base year and horizon year.	Traffic Volume on the interchange arms needs to be derived from peak hour traffic assignments.	Traffic Volume on connecting city level roads to the interchange locations need to be forecast and sufficiency of these to cater to the demand needs to be brought out. Wherever feasible, capacity augmentation needs to be suggested along with alternative local area traffic management schemes as applicable. The pedestrian circulation at bus stops and locations where promenades are proposed need to be segregated and properly planned to enhance safety.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
3	BRTS	Bus Rapid Transit System is proposed on outer lane of the coastal road with the objective of bringing in public transport related benefits	Evidences of a detailed study on the BRTS recommended in the DPR are not	Success of such a facility depends on well planned pedestrian facilities integrating multilevel car parks, IPT stands and bus stops of buses plying on mainland. The details of the same may be provided for further review
4	Traffic Logistics, Diversion and safety measures during Construction	This aspect is not dealt with in the DPR	A well conceived Construction Logistics plan (CLP) is a primary requirement for the project. Traffic Logistics, diversions and safety should be part of this CLP.	Traffic route Plans and Work Zone Traffic Management Plan should be prepared in consultation with and approval of Mumbai Traffic Police.

ALIGNMENT STUDIES

3 ALIGNMENT STUDIES

3.1 General

Mumbai is surrounded by Arabian Sea on the East, South and west side. Mumbai being an island has no room to expand. To have a better connectivity between Island city to main land, sea links are planned on the Western side and Trans harbour link on the East. During the meeting held in Mumbai on 15th April 2011 by Hon. Minister MOEF, GOI, the proposal of reclamation based Coastal road encircling Mumbai was presented to Hon Minister. The proposal envisioned a coastal road on reclamation which not only provided a speedy connectivity but also enhanced the quality of the city environment through the reduction in pollution and respiratory diseases and provision of excellent green space adjoining the road on either side and thus providing a much needed recreational space in addition to the road that connects the various parts of the city. Hon. Union Minister (MOEF) suggested that the proposal needed a closer examination through a committee whose recommendations could be made available to the Government for taking up further action in the matter. Accordingly, the Govt. of Maharashtra formed a committee under its Resolution dated 30th June 2011 with following Terms of Reference.

a. To examine the various options in the construction of a coastal road including road on stilt or sea link in Mumbai.

b. To evaluate options on the basis of technical feasibility and environmental impact and impact on the neighbourhoods.

c. To recommend the best option which provides improved mobility, enhances environment and leads to sustainable development of open spaces/ greenery.

3.2 Peer Review Methodology

3.2.1 Alignment / Interchange Review

The Alignment review is divided under following sections,

1. Surveys
2. Typical Cross Section
3. Alignment of road
4. Interchanges / Junctions

The review methodology for Alignment and Interchange broadly remains same, with only change of applicable design parameters in accordance with the relevant IRC codes. Where IRC codes fall short, relevant references to international standards like Design Manual for Road and Bridges (DMRB), AASHTO, or any other relevant code etc. has been taken into account. The review has been carried out as per best industry practice.

3.2.2 Design Standards

The review has been undertaken based on IRC SP: 99 2013-Manual of Specifications and Standards for Expressways. The same has been adopted by DPR consultant for design of project road. The other relevant IRC code as applicable and mentioned in Manual has also been referred. The peer review has taken into account all such similar codes applicable for undertaking a comprehensive review. The reference has been made to various relevant International standards wherever applicable.

3.2.3 Typical Cross sections

The typical cross sections proposed by the DPR consultant are reviewed in terms of lane capacity and the overall capacity of the road with due consideration of the future growth. Lane drop or Lane gain requirement shall be explored in view of the projected peak hour traffic.

3.2.4 Geometric Design Standards

The main road alignment has been reviewed based on the provisions of IRC SP: 99-2013 as proposed by the DPR consultant. The design speed proposed by DPR consultant is 100 or 80 kmph. The geometric parameters are reviewed to conform to the relevant design standard. Any improvement or shortfalls have been highlighted and reported accordingly.

3.2.5 Interchanges / Junction Review

Total 12 nos. of Interchanges have been proposed by DPR consultant at following locations:

Phase I

- Amarson Garden Interchange (Bhulabhai Desai Road)
- Haji Ali Junction Interchange (Lala Lajpat Rai Road)
- Bandra Worli Sea link Interchange (Worli End)
- Bandra Worli Sea Link - Toll Plaza Interchange (Bandra End)
- Carter Road Interchange (Dana Village)

Phase II

- Jagannath Bhosale Marg Interchange
- Tambe Chowk Interchange (Walkeshwar Road)

Phase III

- Ritumbhara College Interchange
- Madh Island Interchange (Institute of Fisheries Education)
- Oshiwara Interchange
- Malad Interchange
- Kandivali Interchange

The proposal of the interchanges has been reviewed in terms of capacity, traffic movement, and location. DPR consultant has proposed interchanges without any conflict of traffic.

The outcome of the feasibility review shall be adoption of alignment proposed in the DPR or an alternative suggestion which can be further explored by the DPR consultant.

3.2.6 Cross sections

The typical cross sections proposed by the DPR consultant has been reviewed in terms of lane capacity and the overall capacity of the road with due consideration of the future growth. The requirement shall be explored in view of the projected peak hour traffic.

3.2.7 Geometric Design Standards

The ramps and loops of interchange have been reviewed based on the provisions of IRC SP:99-2013 as proposed by the DPR consultant. The provisions of IRC 99 are also taken into consideration. The design

speed proposed by DPR consultant is 40 kmph for Interchange loops and ramps. The design speed and other geometric parameters have been reviewed to conform to the relevant design standard. Any improvement or shortfalls are highlighted and reported for further improvement in designs.

3.3 Alignment

It is observed that the DPR consultant has developed various options for each of the sections above. DPR consultant has also given due consideration to the options proposed by the Joint Technical Committee (JTC) report of December 2011.

It is aimed to review all the various options with their pros and cons including the options proposed by JTC. Our initial approach is to review the feasibility of the alignment before going into details of the geometry proposed.

The review has aimed to recommend the best possible alignment under given constraint(s). All issues like heritage values, proximity to high rise buildings, religious importance, health and safety, constructability, sustainability, recreational value, environment and social assessment, design for maintenance etc has been taken into account.

Based on the outcome of the review of alignment, the suitability of alignment proposed in the DPR shall be confirmed or an alternative suggestion shall be given for further study.

3.4 Surveys

3.4.1 Topographic Survey

The basic objective of the topographic survey would be to capture the essential ground features along the alignment in order to consider improvements and for working out improvements, bypass, green field alignment, rehabilitation and upgrading costs.

Collection of details for all features such as structures (bridges, culverts etc.) utilities, HFL, HTL, existing roads, electric and telephone installations (both O/H as well as underground), huts, buildings, fencing and oil and gas lines etc. falling within the extent of survey or property boundary is important.

The topographic survey was carried out by DPR Consultant between November 2014 to January 2015 and details have been provided by the DPR Consultant in Volume IV - Topographic Survey Report.

Our observations on the topographic survey report and drawings are given in table below:

TOPOGRAPHIC SURVEY REPORT AND DRAWINGS				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 201 (R0) to 213 (R0) and 251 (R0) to 270 (R0) Note: 8098/E/DN-6	Topographic Survey	The survey appears to be insufficient at following locations **South End** The bed levels at tunnel locations are not shown on topographic drawings. The location of existing Walkeshwar road is not captured near Km 4+300 The location of Napean Sea Road is not captured near Km 5+100. The survey corridor at following locations is inadequate, Km 6+000 to Km 7+600, Km 9+200 to 12+500 **North End** The survey corridor at following locations is inadequate, Km 1+500 to Km 2+200, Km 11+900 to Km 12+200, Km 14+000 to Km 16+500 The bed levels at tunnel locations are not shown on topographic drawings.	The deficient survey location shall be surveyed to capture details required for proper design works. In addition sufficient information needs to be provided to bidder to ensure competitive prices are received.

TOPOGRAPHIC SURVEY REPORT AND DRAWINGS				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
			Existing Sea Link is not captured in topographic survey. This is required for proper tie-in design. Existing Sea link at Bandra end, toll plaza not sufficiently captured. The topographic survey limit shall be extended sufficiently to design the Kandivali Interchange. There is High Tension Line Crossing at proposed Interchange location near Km 16+000. The same is not captured in topographic survey.	

3.5 Project Alignment

Joint Technical Committee, Government of Maharashtra has recommended 2 nos. of alignment options in their Report dated December 2011. The project alignment starts from Jagannath Bhosale Marg and terminates at Kandivali Junction. Further, DPR Consultants have developed another 4 nos. of options and presented in their Draft Detailed Project Report dated February 2015. Based on Lane capacity evaluations, DPR Consultant has proposed the project alignment as Expressway with eight lane road except the section from Nariman point to Tambe Chowk which is having four lanes. The review of lane capacity has been described in Chapter 2.

The various options have been developed by DPR consultant based on Satellite imageries and levels extracted from Google Earth Pro Software, assisted by site visits/ reconnaissance survey.

The review of alignment options has been carried out by peer review consultant by considering parameters mentioned below:

1. Topography of the project area
2. Conformation with Design Standards
3. Storm water and sewage discharge locations
4. Connectivity at important locations along the alignment through Interchanges
5. Suitability for siting of structures
6. Availability of Construction Material and Ease of construction
7. Cost of construction, maintenance and operation.
8. Shifting of Utilities
9. User Safety aspect
10. Requirement of various environment, CRZ and forest clearances etc.
11. Aesthetics of project road
12. Rehabilitation and resettlement of project affected people
13. Location of Religious, Heritage and Archaeological structures along the alignment.
14. Social aspects

The review of alignment options has been carried out by peer review consultant by considering above mentioned parameters.

3.6 Project Sections

The project alignment is divided in 7 nos. of project sections based on traffic pattern and construction aspects. There are various alignment options developed by Joint Technical Committee and DPR Consultants for each of the sections. The merits and demerits have been identified for each options. The same has been reviewed and accordingly conclusions and recommendations have been presented. The project sections are presented in the figure below:

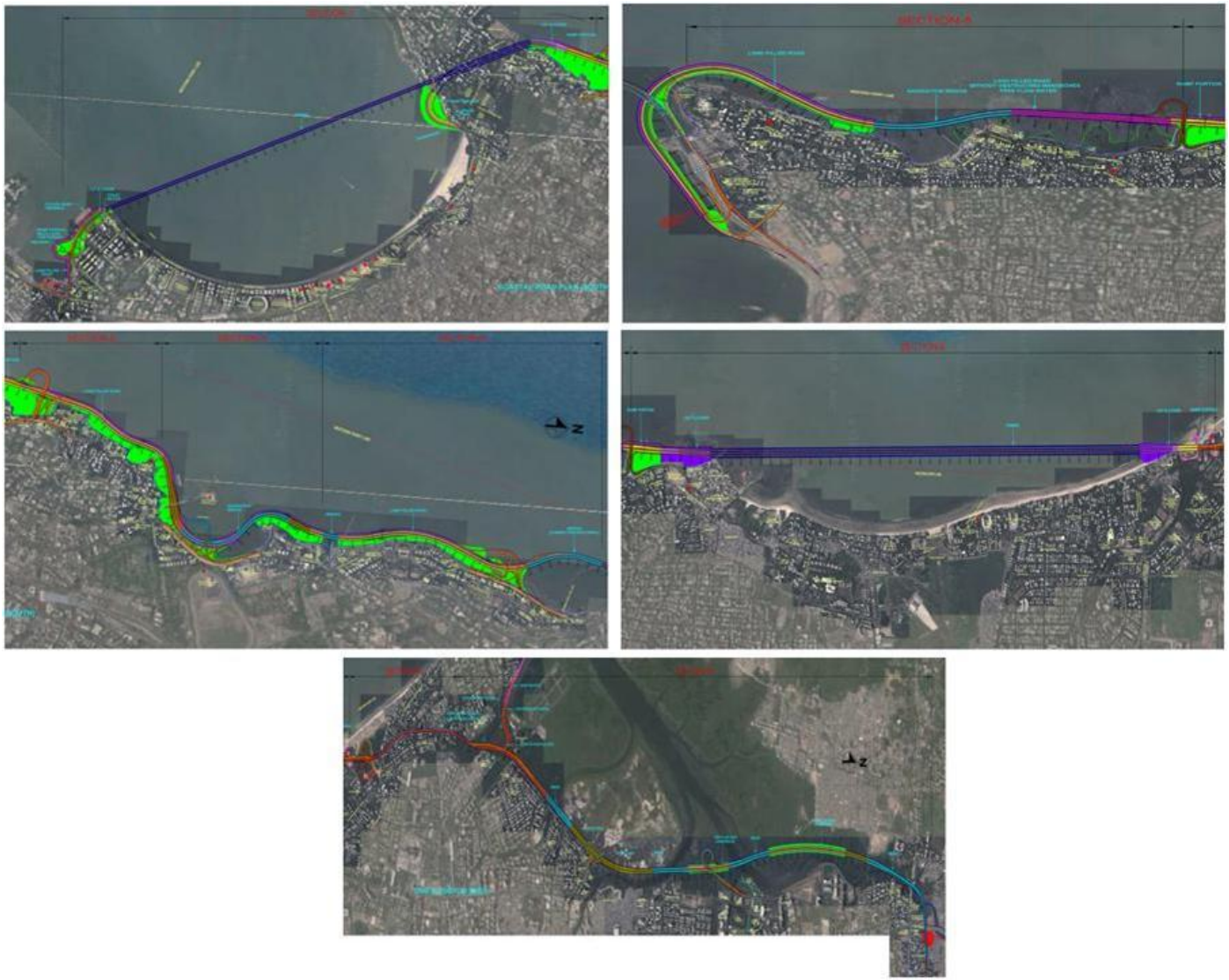

Figure 3-1 Project Alignment Sections

The various project sections as shown in figure above are listed as below:

Part A: South (Jagannath Bhosale Road to Worli end of Sea Link)

Section 1 : Jagannath Bhosale Road to Priya Darshini Park

Section 2 : Priya Darshini Park to Mahalaxmi

Section 3 : Mahalaxmi to Baroda Palace

Section 4 : Baroda Palace to Worli End of Sea Link

Part B: North (Bandra end of Sea Link to Kandivali Junction)

Section 5 : Bandra End of Sea Link to Juhu Sea Side Garden

Section 6 : Juhu Sea Side Garden to Ritumbhara College

Section 7 Ritumbhara College to Kandivali Junction and Central Institute of Fisheries, Versova to Madh Island

The sections falling in Phase- I have been discussed below and accordingly our observations and recommendations are given therein.

3.6.1 Section 2 : PriyaDarshini Park to Mahalaxmi

The Alignment Options in Section 2 as proposed by JTC and DPR Consultants have been presented as below:

Figure 3-2 Section 2 - Option 1 & 2

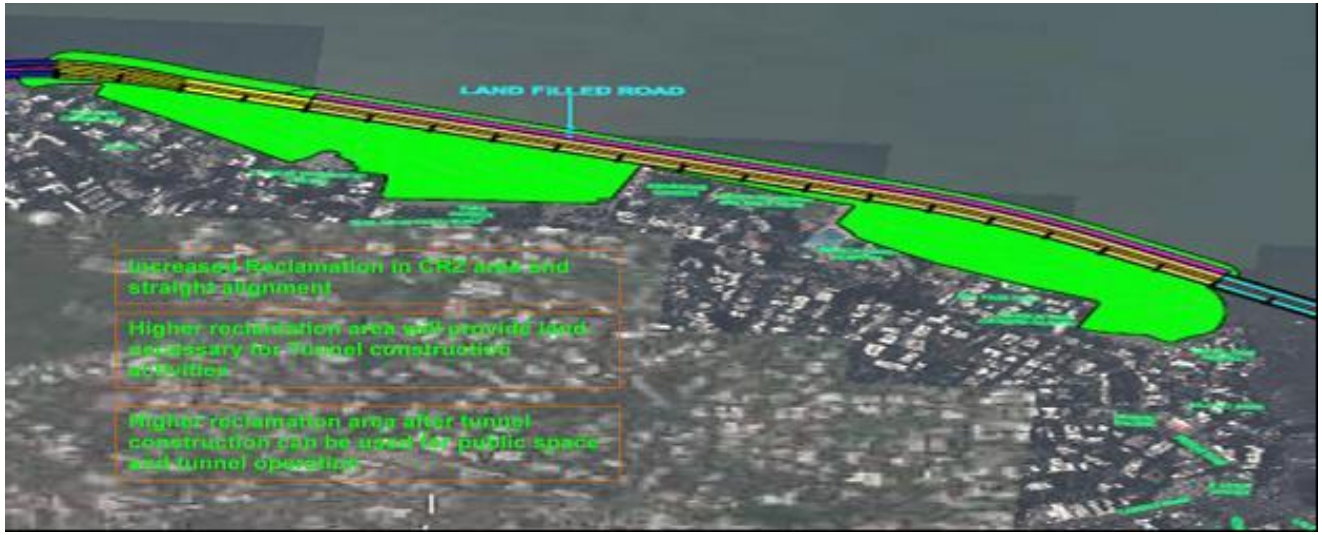

Figure 3-3 Section 2 - Option 3 & 4

Figure 3-4 Section 2 - Option 5 & 6

The summary of salient features of all the alignment options including the JTC report as provided by DPR consultant is presented below:

Option No.	Type of Road/ Structure	Start of Road/Structure	End of Road/ Structure	Length of Alignment (m)	Reclamation Area (Hectare)	No. of Heritage Structure
Option 1 & 2	Land Filled Road	Priya Darshini Park	Mahalaxmi Temple	2400	35.77	2
Option 3 & 4	Land Filled Road	Clinical Diagnostic Centre	Mahalaxmi Temple	1500	38.42	2
Option 5 & 6	Land Filled Road	Clinical Diagnostic Centre	Mahalaxmi Temple	1490	36.64	1

DPR consultant has recommended Alignment Option no. 5 & 6 as preferred Option.

Conclusions and Recommendations:

The alignment of section 2 starts from the End of tunnel in Section 1 at Priyadarshini Park and runs up to Mahalaxmi temple. It is seen that in all 6 nos. of options, alignment in this section is proposed as Land filled Road. The key features of alignment options identified by DPR consultant have been mentioned on the figures itself.

The alignment geometry in Option 1 & 2 traverses close to the shore line due to which the area of reclamation is minimized. However, it results in substandard geometry of the alignment which may compromise safety of road user for the intended design speed.

The alignment in geometry Option 3 & 4 is almost straight alignment. It results in reduction in length of alignment, though area of reclamation increases. This option has an advantage of availability of additional land for development of public facilities and landscaping along the alignment. The visibility and road safety is also enhanced in this option. Also, additional area of reclamation along the alignment can be used for catering to tunnel activities during tunnel construction as proposed in section 1.

Option 5 & 6 have been developed by further refining Option 3 & 4. The initial part is retained same as that of option 3 & 4 and later part of alignment is brought closer to shore line keeping the geometry conforming to standards thereby reducing the area of reclamation. This option is an improvement with better visibility and conforming to design standard for intended design speed. There is further scope to improve the geometry around the Mahalaxmi temple with better radius though it will slightly reduce the reclamation area. The DPR consultant may explore this possibility.

It is also to be noted that if the alignment geometry in option 3 & 4 is chosen for later part, then it will compel to pass behind Haji Ali structure in section 3. The combined effect of alignment geometry of section 2 and section 3 in particular to Haji Ali Structure is discussed under section 4.3.2 below.

In view of merits and demerits described above, it is recommended to adopt Alignment Option 5 & 6. This option is also economical in construction since entire alignment in this option is proposed on land filled.

3.6.2 Section 3: Mahalaxmi to Baroda Palace

The Alignment Options in Section 3 as proposed by JTC and DPR Consultants have been presented as below:

Figure 3-5 Section 3 - Option 1 & 2

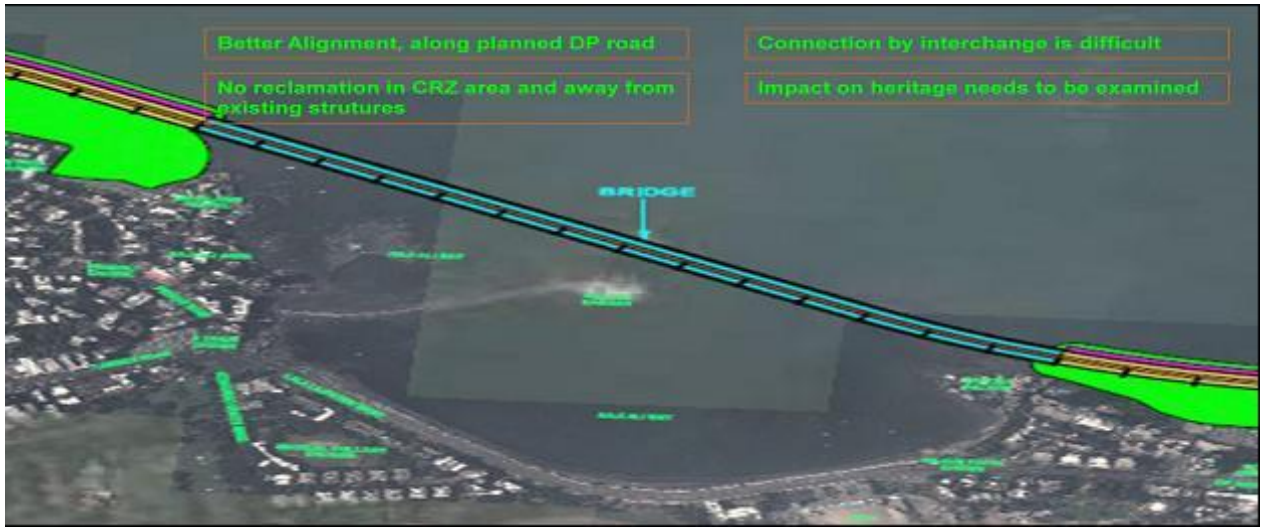

Figure 3-6 Section 3 - Option 3 & 4

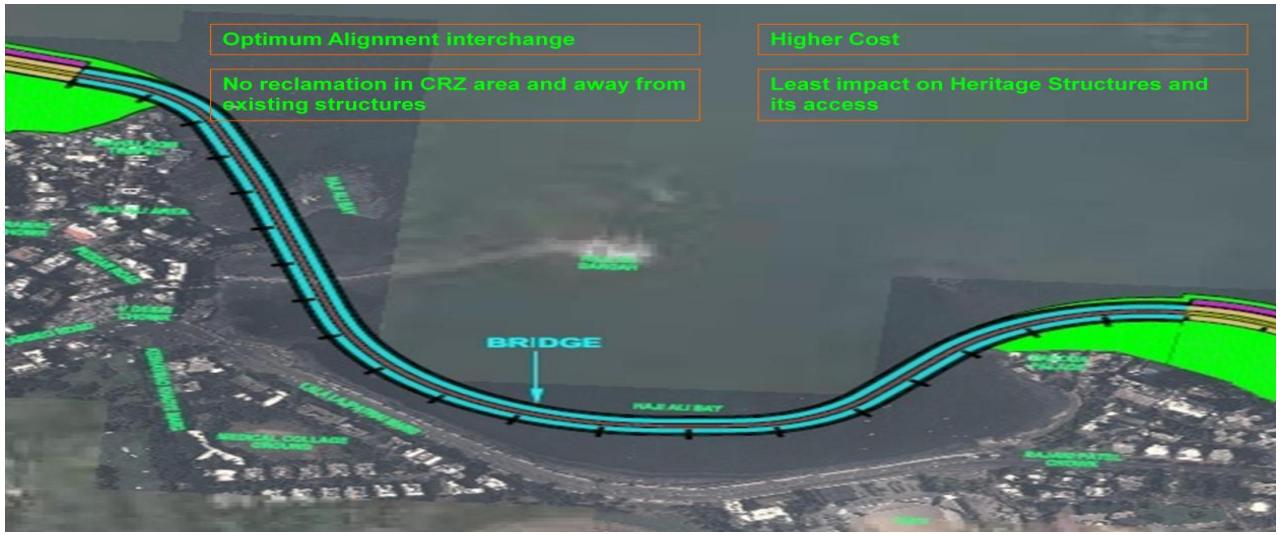

Figure 3-7 Section 3 - Option 5 & 6

The summary of salient features of all the alignment options including the JTC report as provided by DPR consultant is presented below:

Option No.	Type of Road/ Structure	Start of Road/ Structure	End of Road/ Structure	Length of Alignment (m)	Reclamation Area (Hectare)	No. of Heritage Structure
Option 1 & 2	Land Filled Road	Mahalaxmi	NSCI	1350	19.90	1
	Bridge on Sea	NSCI	Baroda Palace	450	8	
Option 3 & 4	Bridge on Sea	Mahalaxmi Temple	Baroda Palace	1400	Nil	1
Option 5 & 6	Bridge on Sea	Mahalaxmi Temple	Baroda Palace	2000	Nil	2

DPR consultant has recommended Alignment Option no. 1 & 2 as preferred Option.

Conclusions and Recommendations:

The alignment in this section, starts from the Mahalaxmi temple and runs up to Baroda Palace There are 2 nos. of religious structures falling along this section, i.e. Mahalaxmi Temple and Haji Ali. These religious places attract huge crowd. The key features of alignment options identified by DPR consultant have been mentioned on the figures itself.

In Option 1 & 2, the alignment geometry traverses on land filled area for the length of 1350 m along the shore line and remaining part of alignment in this section is proposed on Bridge. The geometry of alignment conforms to design standards of intended design speed. The bridge has been proposed to facilitate balancing of water and navigation. This also creates additional recreational spaces and public facilities at this location which are very much desirable here. There is scope to improve the geometry around the Baroda Palace with better radius though it will slightly reduce the reclamation area.

The DPR consultant may explore this possibility.

Alignment geometry in Option 3 & 4 proposes straight alignment on Bridge in the sea behind the Haji Ali Structure. This geometry would be the continuation of option 3 & 4 of section 2 above.. It results in reduction in length of alignment with enhanced visibility and safety to road user. It also nullifies requirement of reclamation in sea. However, the cost of construction is high. The DPR mentions that if the alignment is taken from back of Haji Ali structure, there will be impact on religious value of this structure. However, the DPR is silent on the evaluation of heritage / religious value of the said structure. In addition to above the construction of interchange at Haji Ali will be expensive as it has to be constructed in sea and will need longer connector to existing road.

Option 5 & 6 has been developed by further amending Option 1 & 2. The alignment is proposed as elevated structure along the shore line in this option. It will not impact religious structures. However, cost will be higher and also it nullifies the opportunity of creating additional space for public facilities at such important religious structure.

After evaluating the options provided by DPR consultant it is seen that Option 1 & 2 is more suitable and cost effective. This option has an advantage of creating spacious recreational and public facilities catering to the requirements of the users at Haji Ali and Mahalaxmi. It also facilitates ease of construction of Interchange necessary for dispersal of traffic at Haji Ali. Moreover, this option is the most economical though it will warrant CRZ clearance for reclamation.

3.6.3 Section 4: Baroda Palace to Worli End of Sea Link

The Alignment Options in Section 4 as proposed by JTC (Option 1 & 2) and DPR Consultants (Option 3 to 6) have been presented as below:

Figure 3-8 Section 4 - Option 1 & 2

Figure 3-9 Section 4 - Option 3 & 4

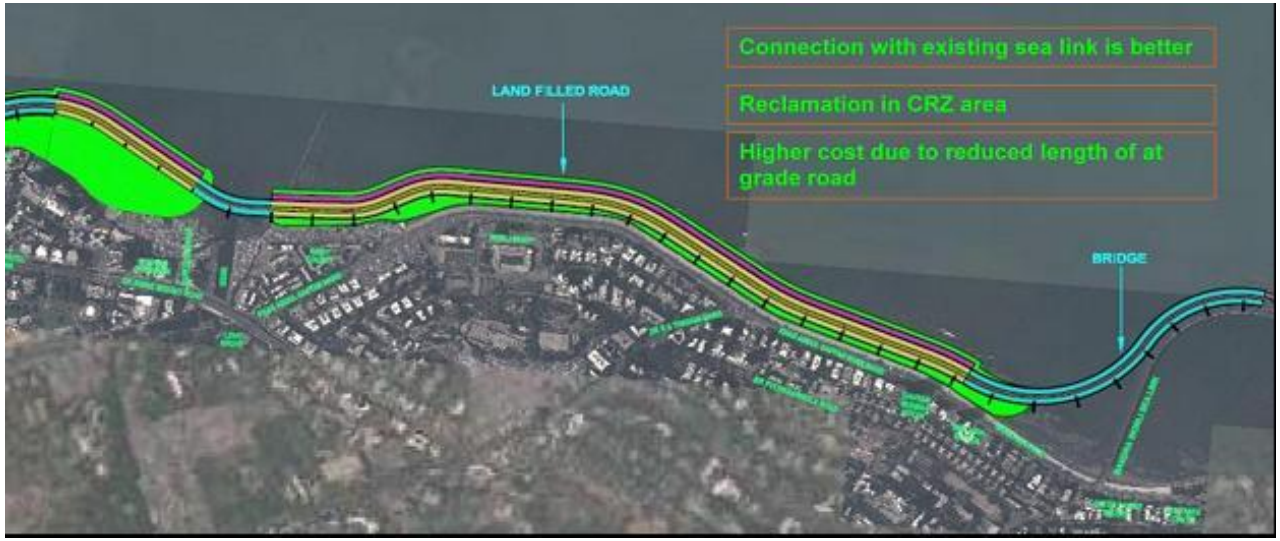

Figure 3-10 Section 4 - Option 5 & 6

The summary of salient features of all the alignment options including the JTC report as provided by DPR consultant is presented below:

Option No.	Type of Road / Structure	Start of Road / Structure	End of Road / Structure	Length of Alignment (m)	Reclamation Area (Hectare)	No. of Heritage Structure
Option 1 & 2	Land Filled Road	Baroda Palace	Markandeshwar Temple	550	37.00	
	Bridge on Sea	Markandeshwar Temple	Dairy Colony	200		
	Land Filled Road	Dairy Colony	Near BWSL	2050		
	merging with BWSL	Near BWSL	merging with BWSL	200		
Option 3 & 4	Land Filled Road	Baroda Palace	Markandeshwar Temple	400	30.07	
	Bridge on Sea	Markandeshwar Temple	Dairy Colony	200		
	Land Filled Road	Dairy Colony	Near BWSL	2100		
	merging with BWSL	Near BWSL	merging with BWSL	250		
Option 5 & 6	Land Filled Road	Baroda Palace	Markandeshwar Temple	400		
	Bridge on Sea	Markandeshwar Temple	Dairy Colony	200		
	Land Filled Road	Dairy Colony	Near BWSL	1830	10.30	
	merging with BWSL	Near BWSL	merging with BWSL	250		

DPR consultant has recommended Alignment Option no. 5 & 6 as preferred Option.

Conclusions and Recommendations:

The alignment geometry continues from the Baroda Palace and connects to Bandra-Worli Sea Link. As can be seen from all 6 nos. of options, alignment in this section is proposed as Land filled Road with provision of bridges in sea at Worli Outfall location and at connection with existing Bandra Worli Sea Link Bridge. Since all options are developed with reclamation, the development of public space, facilities of public transport and landscaping along the alignment is possible by space management. The salient features of alignment options identified by the DPR consultant have been mentioned on the figures itself.

The alignment geometry in Option 1, & 2 traverses along the shore line. The connection with existing BWSL has been achieved with bridge with sharp curve followed almost parallel and close to the existing entry/exit ramp of sea link. However, it results in substandard geometry of the alignment at connection with BWSL with reduced visibility for the intended design speed.

The alignment geometry in Option 3 & 4 is similar to option 1 & 2 with more tight and sharp radius followed almost parallel and close to the existing entry/exit ramp of the sea link..

The option 5 & 6 is similar to earlier options except for the provision of bridge at connection with existing BWSL. The bridge length has been increased to achieve desired smooth geometry of alignment conforming to design standards. Therefore, it is recommended to adopt Option 5 & 6, though the cost may be is higher in comparison as compared to other options.

3.6.4 Section 5: Bandra End of Sea Link to Juhu Sea Side Garden

The alignment between section 4 and 5 is connected via existing Bandra Worli Sea Link. TOR envisages checking the feasibility of avoiding the alignment of coastal road through sea link toll plaza. This is feasible partially by an interchange and the alternative options have been suggested under Interchange Section 4.6. However, completely avoiding toll plaza or sea link is not possible without a parallel sea link bridge or any underground tunnel.

The Alignment Options in Section 5 as proposed by JTC (Option 1 & 2) and DPR Consultants (Option 3 to 6) have been presented as below:

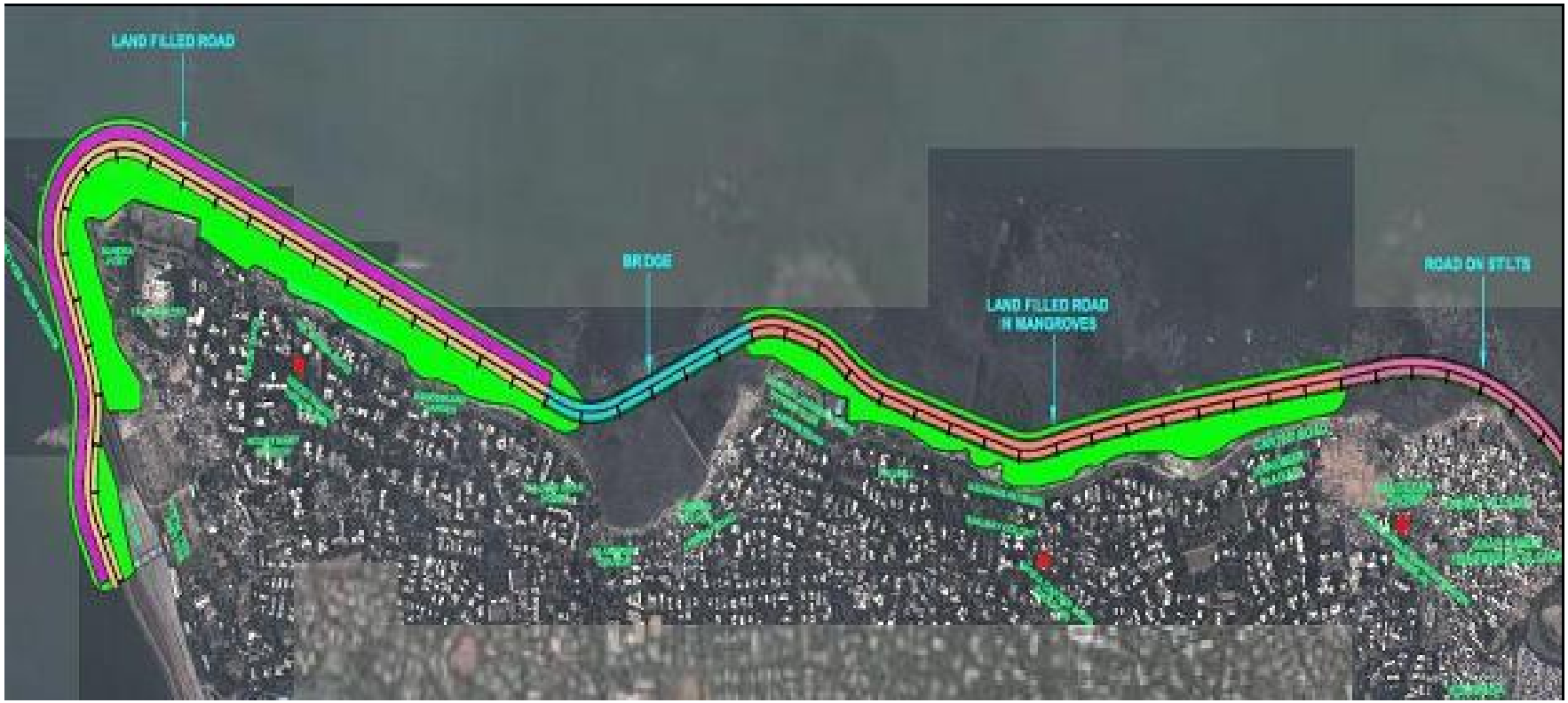

Figure 3-11 Section 5 - Option 1

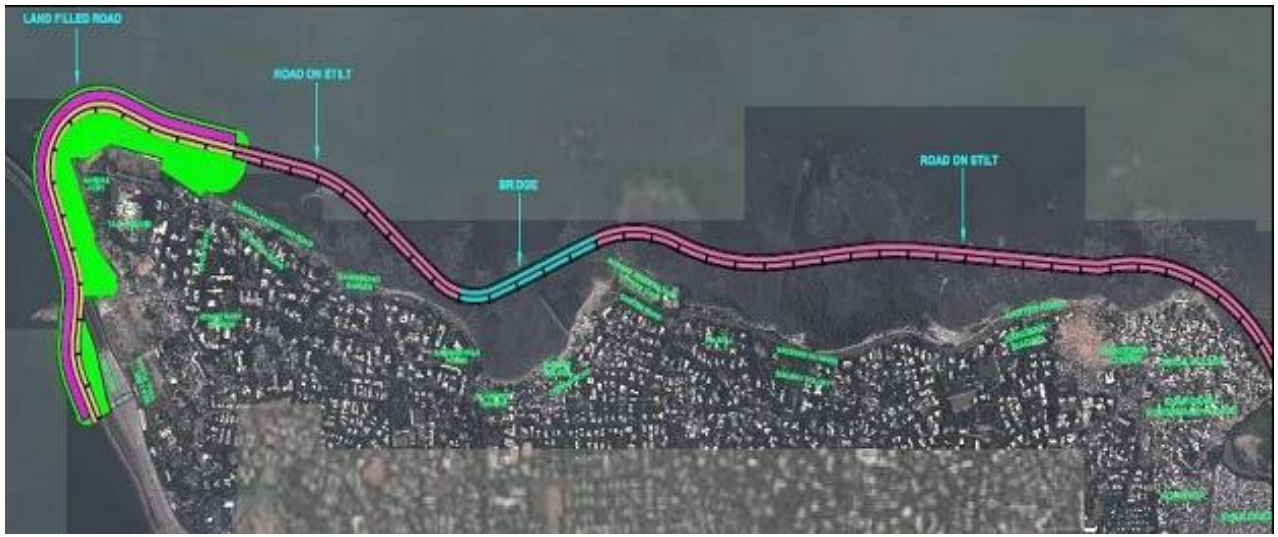

Figure 3-12 Section 5 - Option 2

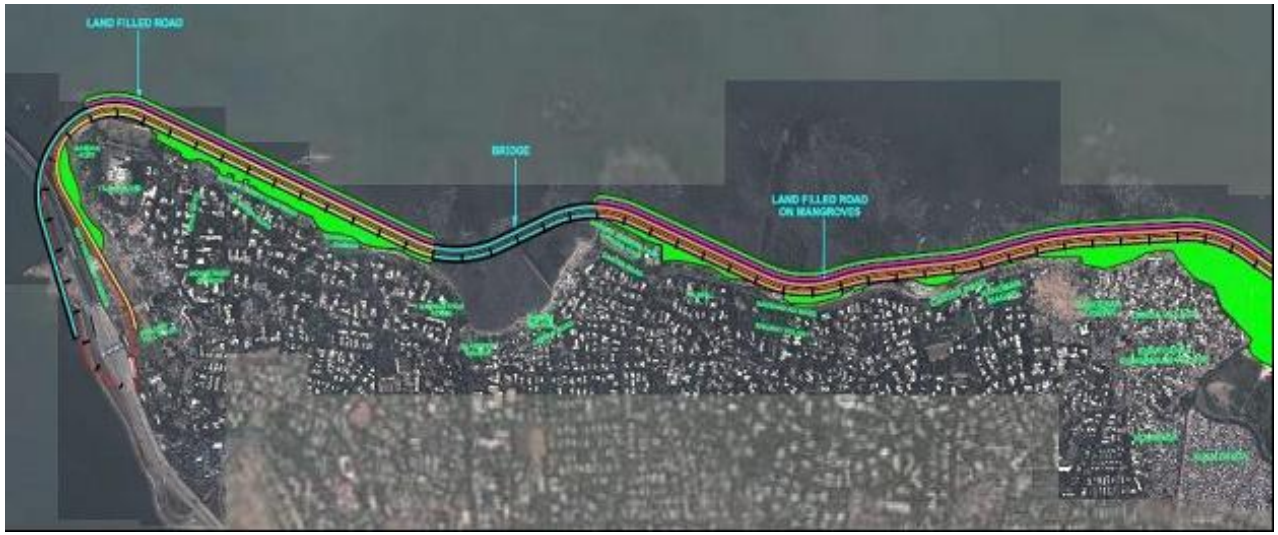

Figure 3-13 Section 5 - Option 3 & 4

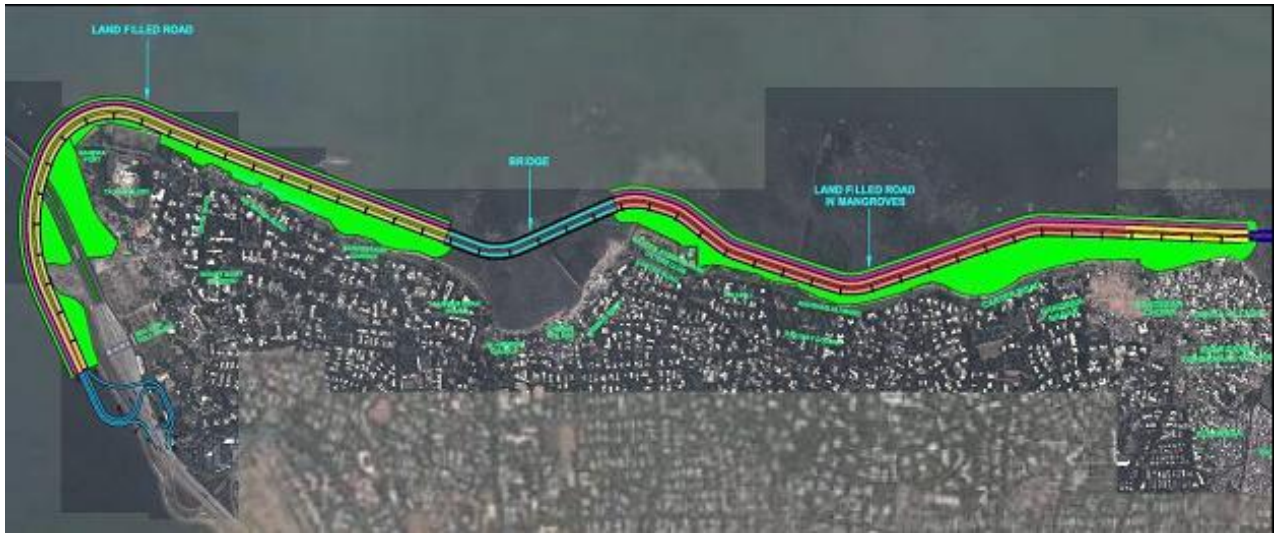

Figure 3-14 Section 5 - Option 5 & 6

Figure 3-15 Section 5 - Option 7

The summary of salient features of all the alignment options including the JTC report as provided by DPR consultant is presented below:

Option No.	Type of Road/ Structure	Start of Road/ Structure	End of Road/ Structure	Length of Alignment (m)	Reclamation Area (Hectare)	No. of Heritage Structure
Option 1	Land Filled Road	merging with BWSL	St Andrew Church	2300	52.66	3
	Bridge on Sea	St Andrew Church	Bandra Joggers Park	600		
	Land Filled Road on Mangroves	Bandra Joggers Park	Dandekar Chowk	1700	10.20	
	Road on Stilt	Dandekar Chowk	Khar Danda	1025		
	Land Filled Road on Mangroves	Khar Danda	Juhu Sea side garden	200	1.20	
Option 2	Land Filled Road	BWSL toll plaza	Band Stand	1500	22.88	3
	Road on Stilt	Band Stand	St Andrew Church	900		
	Land Filled Road on Mangroves	St Andrew Church	Bandra Joggers Park	500		
	Road on Stilt	Bandra Joggers Park	Khar Danda	2700		
	Land Filled Road on Mangroves	Khar Danda	Juhu Sea side garden	200	1.20	
Option 3 & 4	Bridge on Sea	Merging with BWSL	Bandra Fort	775		3
	Land Filled Road	Bandra Fort	St Andrew Church	2075		

Option No.	Type of Road/ Structure	Start of Road/ Structure	End of Road/ Structure	Length of Alignment (m)	Reclamation Area (Hectare)	No. of Heritage Structure
	Bridge on Sea	St Andrew Church	Bandra Joggers Park	600		
	Land Filled Road on Mangroves	Bandra Joggers Park	Khar Danda	2400		
Option 5 & 6	Land Filled Road	<erging with BWSL	St Andrew Church	2180		2
	Bridge on Sea	St Andrew Church	Bandra Joggers Park	600		
	Land Filled Road on Mangroves	Bandra Joggers Park	Dandekar Chowk	1810	10.86	
Option 7	Land Filled Road	merging with BWSL	St Andrew Church	2500		2
	Bridge on Sea	St Andrew Church	Bandra Joggers Park	800		
	Land Filled Road on Mangroves	Bandra Joggers Park	Khar danda	1000		

DPR consultant has recommended Alignment Option no. 7 as preferred Option.

Conclusions and Recommendations:

The alignment geometry continues from the Bandra end of Bandra-Worli Sea Link through the existing sea link toll plaza and continues up to Khar Danda. There are several fisherman communities (Chimbai Village) and dense mangrove forest in this section. The bridge with navigation facility at Chimbai village is common and mandatory provision in all alignment options in this section. The salient features of alignment options have been mentioned on the figures itself.

The alignment geometry in Option 1 traverses along the shore line. The filling has been proposed on mangroves. In Option 2, the entire alignment after Band stand is proposed on stilt. Also the, alignment is shifted away from shore avoiding mangrove area. The alignment option 3 & 4 is similar to Option 1 with improvement in geometry. However, it proposes bridge section in initial portion near toll plaza and stilt (as proposed in Option 1) towards Khardanda has been replaced with land filling. Alignment option 5 & 6 is proposed with entire alignment on land filling on mangroves except for bridge against Chimbai village.

Further to 6 nos. of options in this section alignment option 7 has been developed. In this Option land filled road with smooth geometry is proposed in the initial section followed by the navigation bridge. The bridge length is increased compared to other options to achieve smooth geometry. The remaining section has been proposed with land filled road avoiding mangrove area with provision for free flow of water. It also provides space for facilities at reclamation areas along the alignment. Moreover the road safety and visibility is enhanced with better geometry though the initial bend around Bandra Fort appears to be tight in geometry.

It is therefore believed that alignment option no. 7 to be most preferred one.

3.7 DPR Overall Preferred Option - Option 7

DPR Consultants have proposed various alignment options for each of the sections as described above. Also, they have indicated the preferred alignment option for each of the alignment sections. Accordingly, Option no. 7 has been developed for overall alignment by adopting preferred alignment in each section with more fine tuning in the geometric element of the alignment.

After review of all alignment options and describing suitability / feasibility of each option in aforementioned sections,. It is found that alignment Option no. 7 is most preferred one for Phase I, i.e. from Section 2 (Priya Darshini Park) to section 5 (Khardanda) of project road This alignment may be taken further for detailed studies and formulation of proposal.

The complete Alignment plan for preferred alignment Option 7 is presented below:

Figure 3-16 Preferred Alignment - Option 7 (Section 2 to Section 5)

3.8 Review of Plan Alignment Drawings of Preferred Alignment

We have reviewed Typical Cross section drawings and Plan and Profile drawings as received from DPR Consultants under Volume VII: Drawings dated February 2015. It is noted that these drawings are developed for preferred Alignment Option, i.e. Option no. 7. This review is limited to Alignment Phase I - Section 2 to 5, i.e. Priya Darshini Park to Khar danda. In addition to the comments and observations made under conclusion and recommendation section of each alignment section following comments shall be taken into account for the preferred alignment.

Sr. No.	Report / Drawing Reference	Element	Observation / Comments	Recommendation
1	8098/E/DD-407 (R1)	Typical Cross Section at Tunnel	Emergency lay by or cross passage is required in case of any emergency arising in tunnel	Provide emergency lay by or cross passage to other tunnel and include emergency exit / disaster management plan.
2	-	Road Capacity	Presently under phase I, four lane dual carriageway has been proposed by DPR Consultant which is in accordance with the projected traffic for the horizon year 2044.	As described in chapter 2 the lane capacity for Phase I is five lane dual carriageway.
3	All drawings	SSD/DSD	SSD Visibility report and envelops considering all hazards as application to the design section, e. g. kerbs, safety barrier, parapets etc. to be developed to ensure correctness of geometry. Separate report on Decision sight Distance (DSD) to be developed for review for all Interchanges/ Toll Plaza and Change of cross section in accordance with IRC SP:99 Cl.2.9.3.2	Recommended for compliance.
4	All Profile Drawings	L Section (all)	Show the Sea Level (HTL or HRT) considered in design as minimum. The Proposed road level shall be in accordance with the requirement of shore protection and reclamation with due consideration to climate change. The present proposed level of +8.5m CD or +6.0m above MSL is likely to be on the lower side with respect to the design water level (see comments in section 4)	The vertical alignment of the highway should ensure that there is sufficient construction depth to accommodate drainage infrastructure. Please indicate

Sr. No.	Report / Drawing Reference	Element	Observation / Comments	Recommendation
			The proposed structures like culvers, Bridges, Foot Over Bridges, Interchange arms are not shown along profile Show the crossing of Western Ferry Line in Profile	the details for better understanding, correctness, sufficiency and clarity.
5	8098/E/DD-501A (R0)	Horizontal Curve & Transition length	Transition length provided to radius 500m and 625m is more than required. This will lead to much flatter rate of change of elevation and will cause flat spot issues. Transition length shall be provided in accordance with IRC 73 Cl 9.5 subject to minimum length in accordance with IRC SP:99 Cl 2.9.2.4 as applicable Flat spots are undesirable as they have potential to cause accidents. Designer to confirm and provide flat spot analysis.	Consider revising transition length. Designer shall check and confirm this for all such similar locations
6	8098/E/DD-508A (R0)	Horizontal geometry and Super elevation	Space appears to be available to fit the horizontal radius to minimum of 400m. Calculated transition in accordance with IRC 73 Cl 9.5, considering design speed of 80 kmph, SE-limit 7%, radius of 260m and rate of change 1 in 150 works out to be 178 (say 180m) for rotation width of 17m. The provided transition of 130m appears to be low. Super elevation shall be limited to 7% as per clause 2.9.2.2 of IRC SP 99	Consider revising the horizontal geometry and amend other design parameter accordingly
7	8098/E/DD-509A (R0)	Horizontal geometry and Super elevation	Consider revising radius to desirable minimum of 400m Super elevation shall be limited to 7% as per clause 2.9.2.2 of IRC SP 99	Recommended for compliance.

3.9 Interchanges

DPR consultant has proposed five number of interchange along coastal road under Phase I.

The proposed Five Interchanges in Phase I are listed below:

Phase I

- Amarson Garden Interchange (Bhulabhai Desai Road)
- Haji Ali Junction Interchange (Lala Lajpat Rai Road)
- Bandra Worli Sea link Interchange (Worli End)
- Bandra Worli Sea Link-Toll Plaza Interchange (Bandra End)
- Carter Road Interchange (DandaVillage)

Amarson Garden Interchange (Bhulabhai Desai Road):

The Interchange layout proposed by DPR consultant is shown below:

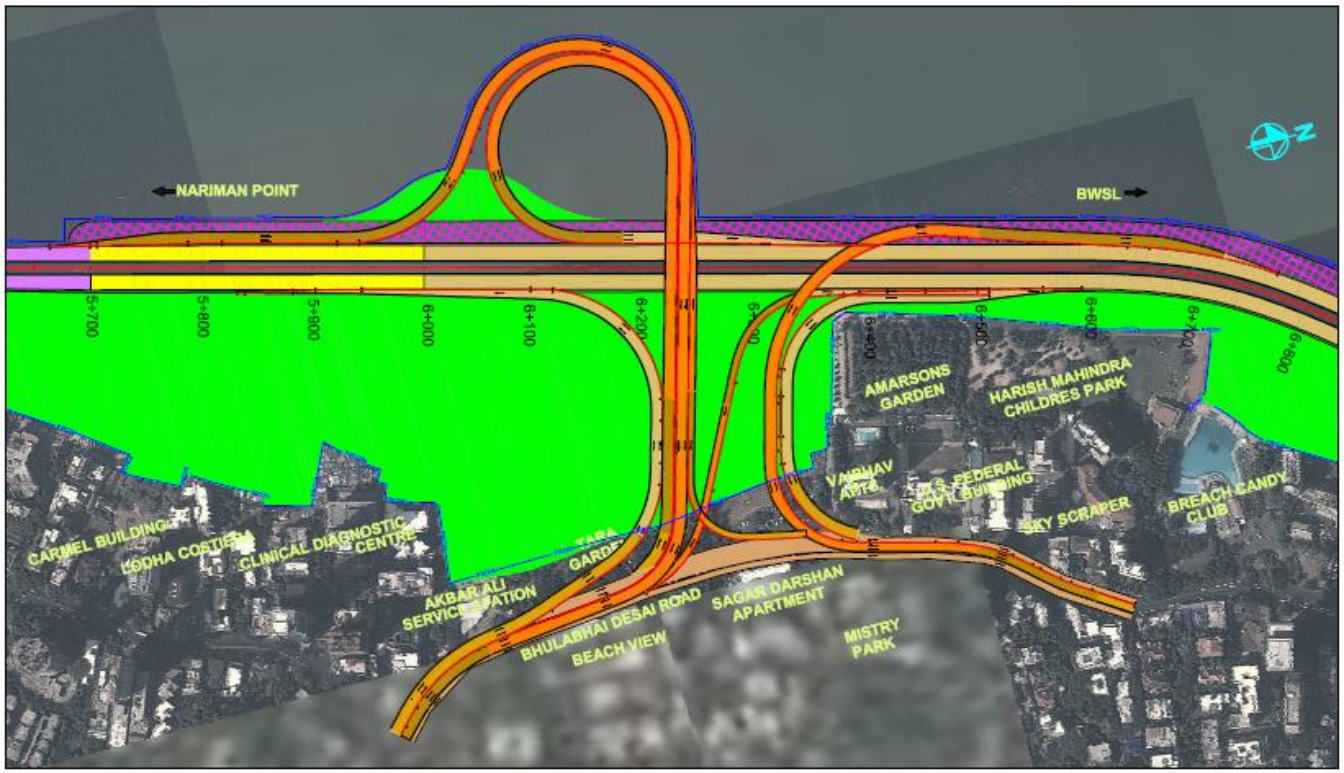

Figure 3-17 Amarson Garden Interchange (Bhulabhai Desai Road)

Our observation and finding on the above interchange are tabulated below:

AMARSON GARDEN INTERCHANGE (BHULABHAI DESAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Location	The ideal minimum spacing between interchanges shall be 3 km in accordance with clause 3.3.5 of IRC SP 99. However, the location of this interchange is in order in view of the traffic dispersal.	
2	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Traffic Dispersal	The provision has been made for traffic dispersal to and fro from Coastal road except the entry to coastal road from US Federal Govt. building towards Nariman point not provided. The requirement of this arm should be arrived at based peak hour traffic. The DPR report provides turning ADT.	Peak hour turning movement should be used to arrive at the requirement of different arms and their capacities of Interchange.
3	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Design Speed	The Design speed adopted for interchange ramp and loop is 40 kmph which is not as per Table 3.1 of IRC SP 99.	The main road design speed is 80 kmph. The recommended design speed as given in table 3.1 of IRC SP 99 shall be followed. The geometry should be designed with respect to the design speed.
4	8098/E/DD- 1110 (R0) to 1117A (R0) and	Acceleration and Deceleration Lane	Insufficient lengths are provided for acceleration and Deceleration lanes. For e.g. Arm 5, 6 & 7 – it appears acceleration length provided is less than required	In the interest of road safety acceleration and deceleration length shall be provided as per standard along with appropriate nose lengths. Taper length shall be indicated on

AMARSON GARDEN INTERCHANGE (BHULABHAI DESAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7		(table 3.2 IRC SP 99), Arm 4 – Deceleration length is less than required (table 3.3 IRS SP 99)	drawings for better clarity.
5	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Tie-in with Bhulabhai Desai Road	It is not clear from layout if the interchange ramps are properly tie-in to Bhulabhai Desai road. The existing space availability for landing the elevated ramp may create constraint and congestion on existing road space.	DPR consultant to clarify if sufficient space is available for tie-in. Provide 2-3 cross section at critical locations showing existing road and other feature with constraints if any.
6	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	All Tie-ins	Tie-in shall be matched properly. The tie-in shall be in same design plane as per main carriageway sufficiently covering the acceleration and deceleration lengths. Design contours shall be made available for further review.	DPR consultant to confirm.
7	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Visibility	Visibility report / envelops not available for review. SSD and Decision sight distance (DSD) (as per table 2.7 and 2.8 of IRC SP 99) shall be available.	DPR consultant to provide visibility report and confirm availability of SSD/DSD considering all the hazards e.g. kerb, parapets etc. Widening shall be incorporated wherever necessary or appropriate mitigation measures shall be suggested and incorporated in design.

AMARSON GARDEN INTERCHANGE (BHULABHAI DESAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
8	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Turning movement	Width of loops and ramps on curves needs to be checked for manoeuvring of large vehicles.	DPR consultant shall confirm conflict free manoeuvring based on Auto Turn layout considering the highest possible rigid vehicle length likely to use the interchange. Deficient bends shall be widened appropriately.
9	8098/E/DD- 1110 (R0) to 1117A (R0) and Note: 8098/E/DN-7	Crossfall/ Superelevation	The location of tie-in and application of super elevation are likely to cause flat spot issues which are undesirable as they have potential to cause accidents.	Flat spot shall be avoided. DPR consultant shall provide flat spot report and confirm there are no flat spot when checked for desirable gradient of 0.5%.

Haji Ali Interchange (Lala Lajpat Rai Road):

The Interchange layout proposed by DPR consultant is shown below:

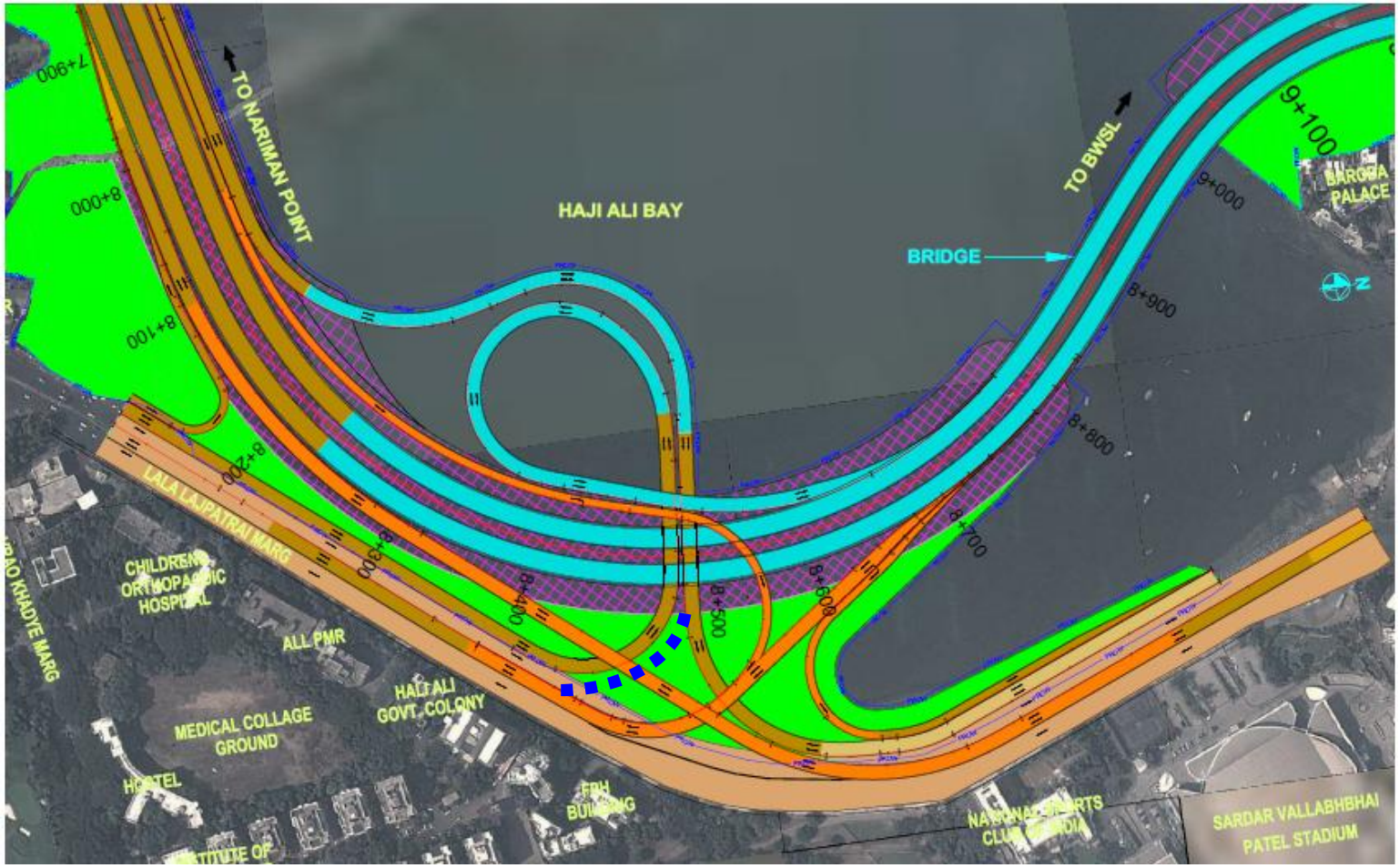

Figure 3-18 Haji Ali Interchange (Lala Lajpat Rai Road)

Our observation and finding on the above interchange are tabulated below:

HAJI ALI INTERCHANGE (LALA LAJPAT RAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Location	The ideal minimum spacing between interchanges shall be 3 km in accordance with clause 3.3.5 of IRC SP 99. However, the location of this interchange is in order in view of the traffic dispersal.	
2	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Traffic Dispersal	The provision has been made for traffic dispersal to and fro from Coastal road except entry to coastal road from North end towards Bandra not provided. The requirement of this arm should be arrived at based peak hour traffic. The DPR report provides turning ADT.	Peak hour turning movement should be used to arrive at the requirement of different arms and their capacities of Interchange.
3	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Design Speed	The Design speed adopted for interchange ramp and loop is 40 kmph which is not as per Table 3.1 of IRC SP 99.	The main road design speed is 80 kmph. The recommended design speed as given in table 3.1 of IRC SP 99 shall be followed. The geometry should be designed with respect to the design speed.

HAJI ALI INTERCHANGE (LALA LAJPAT RAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
4	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Arm No.5	It is seen that separate elevated ramp has been proposed for traffic exiting coastal road from south end and travelling towards Haji Ali junction	It is suggested to explore the possibility of connecting loop from arm 1 to arm 4 as shown in blue dotted line for exit towards Haji Ali Junction (refer figure above). This will eliminate the requirement of arm 5 thereby considerable saving can be achieved.
5	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Acceleration and Deceleration Lane	Insufficient lengths are provided for acceleration and deceleration lanes. For e.g. Arm 2, 6- it appears acceleration provided is less than required (table 3.2 IRC SP 99), Arm 4, 7 - Deceleration length less than required (table 3.3 IRC SP 99)	In the interest of road safety, sufficient acceleration and deceleration length shall be provided as per standard along with appropriate nose lengths. Taper length shall be indicated on drawings for better clarity.
6	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Tie-in with Lala Lajpat Rai Road	It is not clear from layout if the interchange ramps are properly tie-in to existing Lala Lajpat Rai Road. The existing space availability for landing the elevated ramp may create constraint and congestion on existing road space.	DPR consultant to clarify if sufficient space is available for tie-in. Provide 2-3 cross section at critical locations showing existing road and other feature or constraints.
7	8098/E/DD- 1120 (R0) to 1127A (R0) and	All Tie-ins	Tie-in shall be matched properly. The tie-in shall be in same design plane as	DPR consultant to confirm.

HAJI ALI INTERCHANGE (LALA LAJPAT RAI ROAD)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7		per main carriageway sufficiently covering the acceleration and deceleration lengths. Design contours shall be made available for further review.	
8	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Visibility	Visibility report / envelops not available for review. SSD and Decision sight distance (DSD) (as per table 2.7 and 2.8 of IRC SP 99) shall be available.	DPR consultant to provide visibility report and confirm availability of SSD/DSD considering all the hazards e.g kerb, parapets etc. Widening shall be incorporated wherever necessary or appropriate mitigation measures shall be suggested and incorporated in design.
9	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Turning movement	Width of loops and ramps on curves needs to be checked for manoeuvring of large vehicles.	DPR consultant shall confirm conflict free manoeuvring based on Auto Turn layout considering the highest possible rigid vehicle length likely to use the interchange. Deficient bends shall be widened appropriately.
10	8098/E/DD- 1120 (R0) to 1127A (R0) and Note: 8098/E/DN-7	Crossfall / Superelevation	The location of tie-in and application of super elevation are likely to cause flat spot issues which are undesirable as they have potential to cause accidents.	Flat spot shall be avoided. DPR consultant shall provide flat spot report and confirm there are no flat spot when checked for desirable gradient of 0.5%.

Bandra Worli Sea Link Interchange (Worli End):

The Interchange layout proposed by DPR consultant is shown below:

Figure 3-19 Bandra Worli Sea Link Interchange (Worli End)

Our observation and finding on the above interchange are tabulated below

BANDRA WORLI SEA LINK INTERCHANGE (WORLI END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Location	The location of this interchange is in order in view of the traffic dispersal.	
2	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Traffic Dispersal	The provision has been made for traffic dispersal to and fro from Coastal road except exit from coastal road from North end towards South side. Presently this provision is made through existing exit ramp of sea link and then travel through existing road.	Peak hour turning movement should be used to arrive at the requirement of different arms and their capacities of Interchange.
3	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Design Speed	The Design speed adopted for interchange ramp and loop is 40 kmph which is not as per Table 3.1 of IRC SP 99.	The main road design speed is 80 kmph. The recommended design speed as given in table 3.1 of IRC SP 99 shall be followed. The geometry should be designed with respect to the design speed.
4	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Acceleration and Deceleration Lane	Insufficient lengths are provided for acceleration and Deceleration lanes. For e.g. Arm 2, 3, 5, 6-it appears acceleration provided is less than required (table 3.2 IRC SP 99), Arm 4, 5 – Deceleration length less than required (table 3.3 IRC SP 99)	In the interest of road safety, sufficient acceleration and deceleration length shall be provided along with appropriate nose lengths. Taper length shall be indicated on drawings for better clarity.

BANDRA WORLI SEA LINK INTERCHANGE (WORLI END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
5	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Tie-in with Khan Abdul Gafar Khan Road	It is not clear from layout if the interchange ramps are properly tie-in to existing Khan Abdul Gafar Khan Road. The existing space availability for landing the elevated ramp may create constraint and congestion on existing road space.	DPR consultant to clarify if sufficient space is available for tie-in. Provide 2-3 cross section at critical locations showing existing road and other feature or constraints.
6	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	All Tie-ins	Tie-in shall be matched properly. The tie-in shall be in same plane as per main carriageway sufficiently covering the acceleration and deceleration lengths. Design contours shall be made available for further review.	DPR consultant to confirm.
7	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Visibility	Visibility report / envelops not available for review. SSD and Decision sight distance (DSD) (as per table 2.7 and 2.8 of IRC SP 99) shall be available.	DPR consultant to provide visibility report and confirm availability of SSD/DSD considering all the hazards e.g. kerb, parapets etc. Widening shall be incorporated wherever necessary or appropriate mitigation measures shall be suggested and incorporated in design.
8	8098/E/DD- 1130 (R0) to 1136A (R0) and	Turning movement	Width of loops and ramps on curves needs to be checked for manoeuvring of large vehicles.	DPR consultant shall confirm conflict free manoeuvring based on Auto Turn layout considering the highest possible rigid

BANDRA WORLI SEA LINK INTERCHANGE (WORLI END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7			vehicle length likely to use the interchange. Deficient bends shall be widened appropriately.
9	8098/E/DD- 1130 (R0) to 1136A (R0) and Note: 8098/E/DN-7	Crossfall / Superelevation	The location of tie-in and application of super elevation are likely to cause flat spot issues which are undesirable as they have potential to cause accidents.	Flat spot shall be avoided. DPR consultant shall provide flat spot report and confirm there are no flat spot when checked for desirable gradient of 0.5%.

Bandra Worli Sea Link Interchange (Bandra End):

The Interchange layout proposed by DPR consultant is shown below:

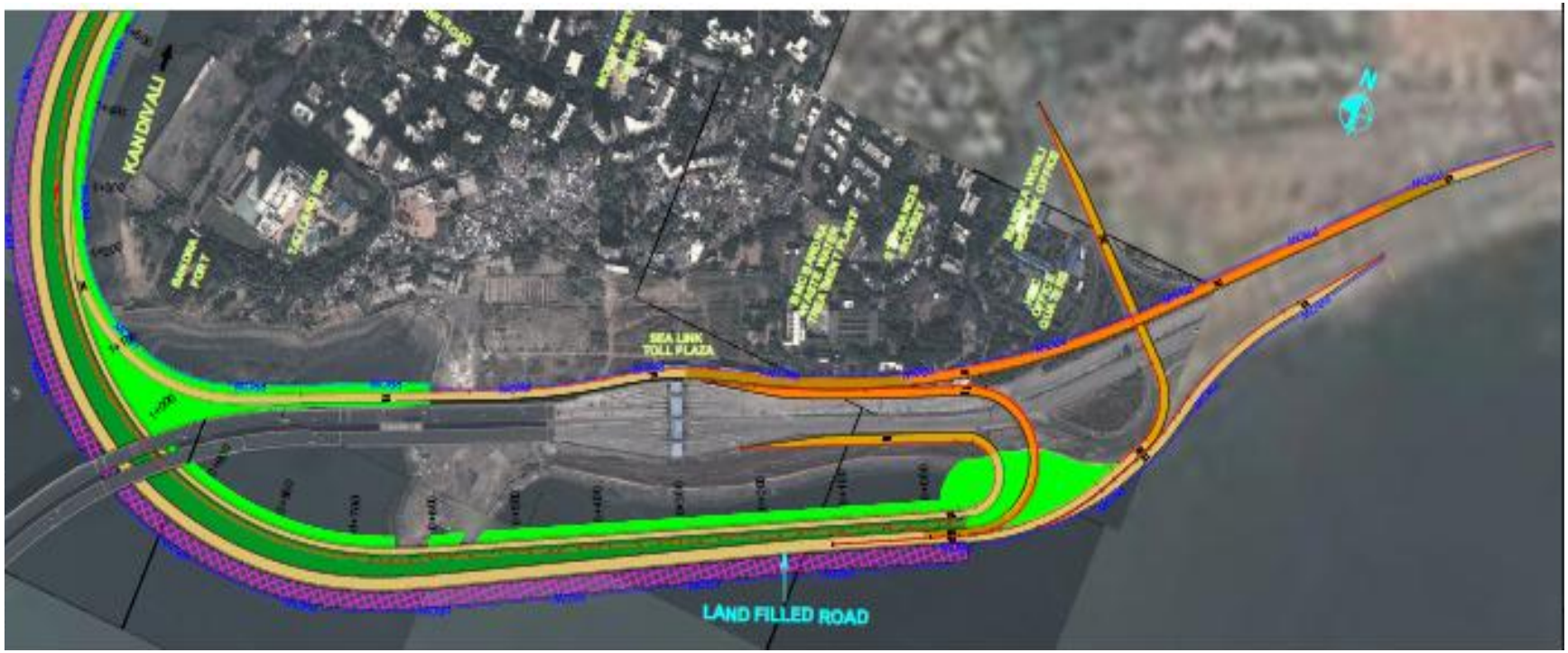

Figure 3-20 Bandra Worli Sea Link Interchange (Bandra End)

Our observation and finding on the above interchange are tabulated below

BANDRA WORLI SEA LINK INTERCHANGE (BANDRA END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Location	The location of this interchange is in order in view of the traffic dispersal. The DPR report provides turning ADT.	Peak hour turning movement should be used to arrive at the requirement of different arms and their capacities of Interchange.
2	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Traffic Dispersal	The provision has been made for traffic dispersal to and fro from Coastal road.	
3	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Improvement at Interchange	TOR envisage to check the feasibility of avoiding the alignment of coastal road through sea link toll plaza.	Three numbers of alternative Interchange layouts are suggested by avoiding the alignment through toll plaza for North-South traffic. Each of the alternatives has been described along with merits and demerits in sub-sections below. It is however to be noted that avoiding the present sea link is unlikely without a separate parallel sea link or an underground tunnel.
4	8098/E/DD- 1140 (R0) to 1145A (R0) and	Design Speed	The Design speed adopted for interchange ramp and loop is 40 kmph which is not as per Table 3.1 of IRC SP 99.	The main road design speed is 80 kmph. The recommended design speed as given in table 3.1 of IRC SP 99 shall be

BANDRA WORLI SEA LINK INTERCHANGE (BANDRA END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7			followed. The geometry should be designed with respect to the design speed.
5	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Acceleration and Deceleration Lane	Insufficient lengths are provided for acceleration and Deceleration lanes. For e.g Arm 4, 5,– it appears acceleration provided is less than required (table 3.2 IRC SP 99)	In the interest of road safety, sufficient acceleration and deceleration length shall be provided along with appropriate nose lengths. Taper length shall be indicated on drawings for better clarity.
6	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Tie-in with existing Road	It is not clear from layout if the interchange ramps are properly tie-in to existing Road. The existing space availability for landing the elevated ramp may create constraint and congestion on existing road space.	DPR consultant to clarify if sufficient space is available for tie-in. Provide 2-3 cross section at critical locations showing existing road and other feature or constraints.
7	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	All Tie-ins	Tie-in shall be matched properly. The tie-in shall be in same plane as per main carriageway sufficiently covering the acceleration and deceleration lengths. Design contours shall be made available for further review.	DPR consultant to confirm.
8	8098/E/DD- 1140 (R0) to 1145A (R0) and	Visibility	Visibility report / envelops not available for review. SSD and Decision sight distance (DSD) (as per table 2.7 and 2.8 of	DPR consultant to provide visibility report and confirm availability of SSD/DSD considering all the hazards e.g

BANDRA WORLI SEA LINK INTERCHANGE (BANDRA END)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7		IRC SP 99) shall be available.	kerb, parapets etc. Widening shall be incorporated wherever necessary or appropriate mitigation measures shall be suggested and incorporated in design.
9	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Turning movement	Width of loops and ramps on curves needs to be checked for manoeuvring of large vehicles.	DPR consultant shall confirm conflict free manoeuvring based on Auto Turn layout considering the highest possible rigid vehicle length likely to use the interchange. Deficient bends shall be widened appropriately.
10	8098/E/DD- 1140 (R0) to 1145A (R0) and Note: 8098/E/DN-7	Crossfall / Superelevation	The location of tie-in and application of super elevation are likely to cause flat spot issues which are undesirable as they have potential to cause accidents.	Flat spot shall be avoided. DPR consultant shall provide flat spot report and confirm there are no flat spot when checked for desirable gradient of 0.5%.

3.10 Alternatives Developed to Avoid toll Plaza

Alternative - I

The Alternative - I is shown below:

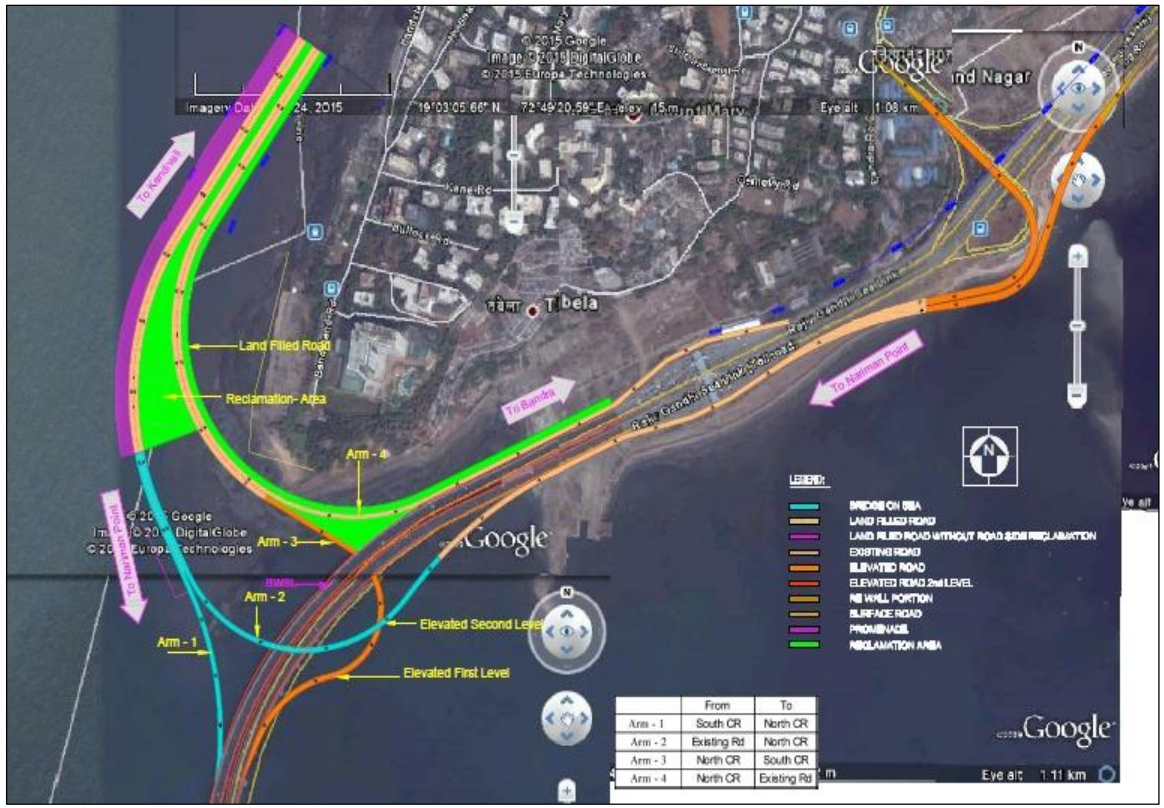

Figure 3-21 Bandra Worli Sea Link Interchange (Bandra End Alternative - I)

The Alternative - I proposed is a three level service interchange. The traffic coming from north will partially exit at Bandra with two lane exit ramp arm no. 4, while the other two lane (arm no. 3) will be carried under the existing sea link and will join sea link bridge before the cable stayed span. The traffic coming from south will continue towards north via two lane ramp (arm no 1). Also two lane ramp coming from east (Bandra end - arm no. 2) will join arm no. 1. The arm no. 2 coming from east will climb over the existing sea link before joining. The rest of the proposal on east of toll plaza is kept same as proposed by DPR consultant.

The interchange is conceptualized based on the presumption that existing tolling scenario shall be met with. Based on this presumption the road users who wish to travel in north-south direction through coastal road shall not require to pay any toll. The road users who wish to exit to Bandra or Western Express highway from south as well as road user entering from Bandra or Western Express highway for travel to south will require to pay toll. This is as per the current toll pattern which has not been altered.

The Alternative-II is shown in Figure 3-22 below:

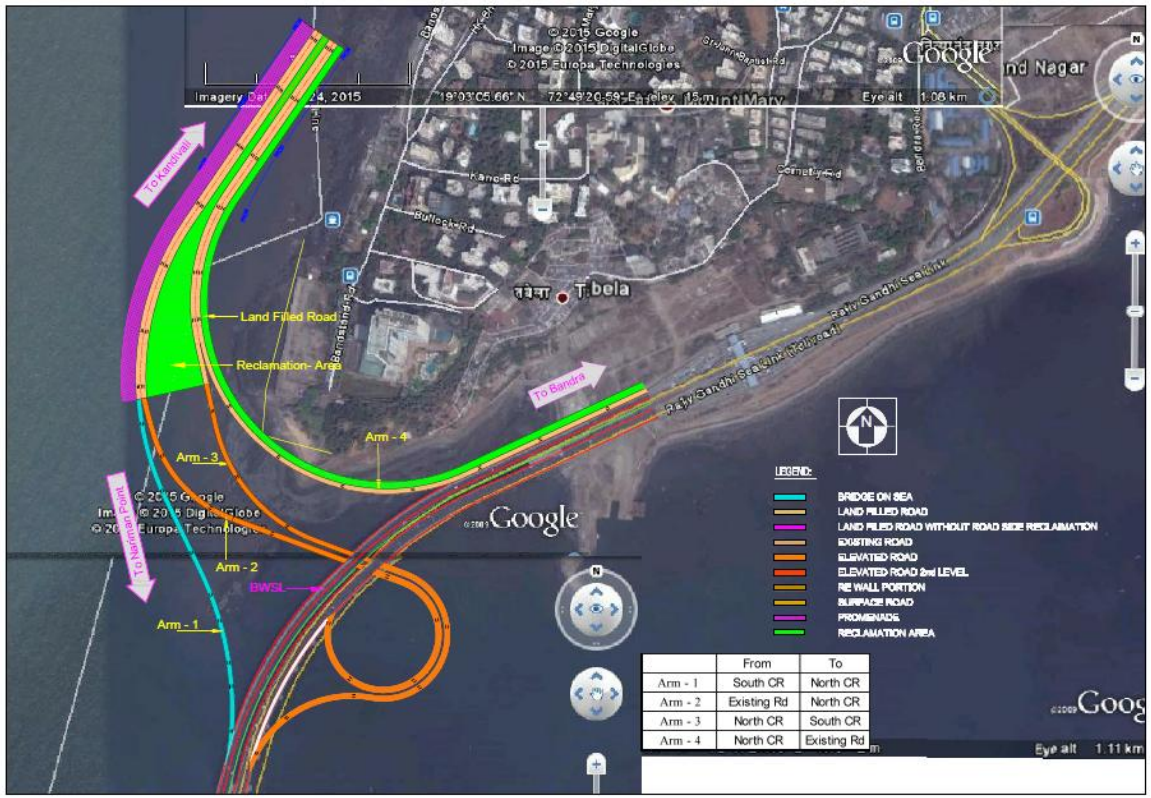

Figure 3-22 Bandra Worli Sea Link Interchange (Bandra End Alternative - II)

Alternative - II

The interchange is conceptualized based on the presumption that existing toll plaza will be withdrawn by the authority. This alternative II also aims to eliminate the interchange arrangement proposed by DPR consultant on east of toll plaza.

The Alternative - II proposed is a two level trumpet service interchange. The traffic coming from north will partially exit at Bandra with two lane exit ramp arm no. 4, while the other two lanes (arm no. 3) will be carried under the existing sea link and will join sea Link Bridge before the cable stayed span via a semi directional ramp. The traffic coming from south will continue towards north via two lane ramp (arm no. 1).Also two lane ramp coming from east (Bandra end – arm no. 2) will join arm no 1. The arm no. 2 coming from east will exit from sea link via loop and will pass under the existing sea link before joining arm no. 1.

The Alternative-III is shown in Figure 3-23 below:

Figure 3-23 Bandra Worli Sea Link Interchange (Bandra End Alternative - III)

Alternative – III

The interchange is conceptualized based on the presumption that existing toll plaza will be withdrawn by the authority. This alternative III also aims to eliminate the interchange arrangement proposed by DPR consultant on east of toll plaza.

The Alternative - III proposed is a two level trumpet service interchange. The traffic coming from north will partially exit at Bandra with two lane exit ramp arm no. 4, while the other two lanes (arm no. 3) will be carried under the existing sea link and will join sea Link Bridge via a loop. The traffic coming from south will continue towards north via two lane ramp (arm no. 1).Also two lane semi directional ramp coming from east (Bandra end – arm no. 2) will join arm no. The arm no. 2 coming from east will pass under the existing sea link and joins arm no. 1.

Comparison of Alternatives

The above proposed alternatives for Bandra Worli Sea Link Interchange (Bandra End) has been compared for parameters like, ease of traffic flow, block cost, constructability etc. The comparison has been presented in Table 3-1 below.

Table 3-1 Comparison of Alternative (Bandra Worli Sea Link Interchange - Bandra End)

Bandra Worli Sea link Interchange (Bandra End)						
Sr. No.	**Parameters**	**Alternative - I**	**Alternative - II**	**Alternative - III**	**DPR Consultant (Alignment)**	**Remarks**
1	Design Speed	40	40	40	40	Deviation from Standard
2	Geometry	Complied to Design Speed	Complied to Design Speed	Complied to Design Speed	Not Complied to Design Speed E.g Arm no 3	
3	Acceleration and Deceleration lane	Design Standard achieved	Arm 2 - Short Deceleration length Arm 3 - Short Acceleration Length	Arm 2 - Short Deceleration length Arm 3 - Short Acceleration Length	Arm 4, 5 Short Acceleration Length	It is proposed to mitigate the short fall in deceleration and acceleration length by hatch road marking as shown on the sketches. The existing Bandra Worli Sea Link is having 4 lanes in each direction. Out of this one lane will not be used by through traffic in between the diverge and merge sections of interchange ramps. Thus eliminating the risk due to weaving. The proposal is like lane drop for diverge and lane gain after merge. Three lanes are available for through travel traffic.
4	Traffic Dispersal	Free Flow	Free Flow	Free Flow	Free Flow	
5	No of Arms.	6	4	4	5	

Bandra Worli Sea link Interchange (Bandra End)						
Sr. No.	**Parameters**	**Alternative - I**	**Alternative - II**	**Alternative - III**	**DPR Consultant (Alignment)**	**Remarks**
6	No of Levels	3	2	2	2	
7	Length of Bridge on Sea (in m)	1111	530	530	-	
8	Elevated Road Length	1336	1447	1294	3004	
9	Block Cost (approx)	275.29	222.41	205.20	212.00	
10	Ranking	3	2	1	-	Based on geometric parameter and cost, Alternative III is recommended for detailed study under which it is presumed that the toll plaza will be withdrawn. However if toll plaza is to be continued then Alternative I shall be preferred.

Note: *Block cost is based on DPR unit cost*

Recommendation

Based on geometric parameter and cost, Alternative III is recommended for detailed study under which it is presumed that the toll plaza will be withdrawn. However if toll plaza is to be continued then Alternative I shall be preferred.

Carter Road Interchange (Danda Village):

The Interchange layout proposed by DPR consultant is shown below:

Figure 3-24 Carter Road Interchange (Danda Village)

Our observation and finding on the above interchange are tabulated below:

CARTER ROAD INTERCHANGE (DANDA VILLAGE)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
1	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Location	The drawings provided shows two separate interchange at Otters Club and Carter Road. The final Interchange layout given for review is the combination of both layout. The comments are based on the final layout. The location of this interchange is in order in view of the traffic dispersal.	
2	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Traffic Dispersal	The provision has been made for traffic dispersal to and fro from Coastal road except for the following: • The entry to the coastal road from north end of Carter Road towards Nariman Point and Kandivali. • The exit from south end of coastal road towards Otters Club. The requirement should be arrived at based on peak hour traffic. The DPR report provides turning ADT.	The distance between this interchange and the previous interchange is about 3.5 Km. If the exit from coastal road and entry towards Otters Club is not provided then the road users between interchange and Otters club has to exit at Bandra Interchange which is not advisable. Also the road users who wish to travel to south and north from North of Carter Road will have to enter from Madh Interchange or Bandra Worli Sea Link Interchange (Bandra End) which is not advisable.

CARTER ROAD INTERCHANGE (DANDA VILLAGE)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
				Therefore it is recommended to explore the provisions as said above. Peak hour turning movement should be used to arrive at the requirement of different arms and their capacities of Interchange.
3	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Design Speed	The Design speed adopted for interchange ramp and loop is 40 kmph which is not as per Table 3.1 of IRC SP 99.	The main road design speed is 80 kmph. The recommended design speed as given in table 3.1 of IRC SP 99 shall be followed. The geometry should be designed with respect to the design speed.
4	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Acceleration and Deceleration Lane	Insufficient lengths are provided for acceleration and Deceleration lanes. For e.g Arm 1, 2, – it appears acceleration provided is less than required (table 3.2 IRC SP 99). Deceleration length provided is less than required (table 3.3 IRC SP 99) – arm 1.	In the interest of road safety, sufficient acceleration and deceleration length shall be provided along with appropriate nose lengths. Taper length shall be indicated on drawings for better clarity.
5	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and	Tie-in with existing Road	It is not clear from layout if the interchange ramps are properly tie-in to existing Road. The existing space availability for landing the elevated ramp may create constraint and congestion on existing road space.	DPR consultant to clarify if sufficient space is available for tie-in. Provide 2-3 cross section at critical locations showing existing road and other feature or constraints.

CARTER ROAD INTERCHANGE (DANDA VILLAGE)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7		There appears to be conflict of merging traffic joining the carter road towards Dandekar Chowk due to space restrictions. There appears to be conflict of diverging traffic requiring to join the coastal road from Otters club side onto coastal road.	
6	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	All Tie-ins	Tie-in shall be matched properly. The tie-in shall be in same design plane as per main carriageway sufficiently covering the acceleration and deceleration lengths. Design contours shall be made available for further review.	DPR consultant to confirm.
7	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Visibility	Visibility report / envelops not available for review. SSD and Decision sight distance (DSD) (as per table 2.7 and 2.8 of IRC SP 99) shall be available.	DPR consultant to provide visibility report and confirm availability of SSD/DSD considering all the hazards e.g. kerb, parapets etc. Widening shall be incorporated wherever necessary or appropriate mitigation measures shall be suggested and incorporated in design.
8	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and	Turning movement	Width of loops and ramps on curves needs to be checked for manoeuvring of large vehicles.	DPR consultant shall confirm conflict free manoeuvring based on Auto Turn layout considering the highest possible rigid vehicle length likely to

CARTER ROAD INTERCHANGE (DANDA VILLAGE)				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion**
	Note: 8098/E/DN-7			use the interchange. Deficient bends shall be widened appropriately.
9	8098/E/DD- 1150 (R0) to 1152A (R0), 1156 (R0) to 1158A and Note: 8098/E/DN-7	Crossfall / Superelevation	The location of tie-in and application of super elevation are likely to cause flat spot issues which are undesirable as they have potential to cause accidents.	Flat spot shall be avoided. DPR consultant shall provide flat spot report and confirm there are no flat spot when checked for desirable gradient of 0.5%.

3.11 Pavement Design

The DPR consultant has presented the pavement design chapter in Volume II: Design Report (Part-1). The same has been reviewed in accordance with the latest codes. Our observations and comments are tabulated below:

PAVEMENT DESIGN				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion / Remark**
1	Pavement Design Section 2 (Volume II: Design Report)	Design Standard	IRC 37-2001 and IRC 58-2002 has been used for flexible and rigid pavement design respectively	The latest code IRC 37-2012 and IRC 58-2015 shall be used for pavement design. The design shall be revised accordingly.
2	Pavement Design Section 2 (Volume	Traffic	It is observed that initial traffic is taken 2000 buses only; This is based on assumptions and doesn't reflect the expected traffic based on	The AADT shall be in accordance with the traffic analysis and expected diversions

PAVEMENT DESIGN				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation / Suggestion / Remark**
	II: Design Report)		model analysis.	onto coastal road.
3	Pavement Design Section 2 (Volume II: Design Report)	Growth Rate	It is observed that 3% growth rate has been considered for all types of vehicles.	Please clarify the basis of 3% growth. In general minimum 5% growth has been recommended by IRC guidelines
4	Pavement Design Section 2 (Volume II: Design Report)	Vehicle Damage factor (VDF)	It is observed that VDF values for different vehicles are provided directly. It is presumed that axle load data may have been captured.	Please provide VDF calculation
5	Pavement Design Section 2 (Volume II: Design Report)	Design Traffic	It is observed that for given AADT calculated design traffic for 15 years is 8MSA & Pavement has been designed for 100MSA	There is an opportunity for optimizing the pavement design by way of stage construction.
6	Pavement Design Section 2 (Volume II: Design Report)	Rigid Pavement Design	Based on K value of subgrade the effective k value is 41.7 kg/cm2/cm. However lower effective k value has been taken in design which is 20.8 kg/cm2/cm.	Use of lower K value will reduce the fatigue life thus decreasing the number of allowable repetitions on pavement.

3.12 Land acquisition plans

The land acquisition plans are not made available for review at this stage. The same will be reviewed once the data is made available to us.

3.13 Structural Design

3.13.1 Interchanges

- The codes used, IRC6:2000, IRC 21-2000 have been superceded. Latest prevailing codes to be used.
- Working stress method is used. Limit state method should be adopted in the detailed design.
- Wind pressure to be checked with IS 875.
- No calculations have been given for curved girders. Pier design and foundation design for curved girders will also be required.
- Effect of continuous girders not considered in design
- Seismic arrestors to be added
- In design of superstructure, last page, calculation shows section is unsafe in ultimate shear.
- Wave pressure not considered in design of substructure and foundations. Wave pressure forces are also to be applied to the substructure and the foundations.
- Scouring effect not considered in design
- Spherical bearings to be adopted, as they have longer life and are more resistant to corrosion.
- Reinforcement bars with galvanising, to be used as project is located in a highly corrosive environment.
- Corrosion protection is required for saline environment.
- Sea Wall calculations are also required.

3.13.2 Bridges

- The points mentioned for Interchanges, also apply for the design of Bridges
- Considering the spans are not less than 30m neoprene bearings are to be avoided. Spherical bearings should be used.

3.13.3 Foot Over Bridges

- A more contemporary design should be adopted, considering the importance of the project and the city.
- For calculating wind loads, effect of hoardings to be considered.
- Wind loads to be as per IS 875.
- Working stress method has been used. This may be acceptable in preliminary design, in the final design, limit state method should be adopted.

3.14 Material Survey and Investigation

The DPR consultant has carried our material investigation for the project road and the report reference Note 8098/E/DN-07 title “Material Investigation Report” is made available for review.

The search for bulk raw materials need to identify type, quality and quantity. Careful study of project requirements and the careful measurement of existing resources will be needed. Further special investigations may be needed in some cases.

Provisions must be made to search for existing resources and potential new sites and identify:

- Existing quarries and pits

- Potential new sites (land)
- Potential marine sites (dredging potential)
- Consideration of appropriate access routes to main sites
- Intermediate logistical corridors outside and within site area
- Studies for design options concerning lightweight fills, reinforced earth, and other design changes might be investigated.

Source of Material

The DPR consultant has identified the source of various materials and have presented in Volume III - Material Investigation Report.

The identified sources appears to be the nearest to the project site. The availability of earth fill quantity required shall be verified at source and confirmed by the DPR Consultant.

Similarly the material report is silent on quality of reclamation fill available at various identified sources. It is also understood during discussion that the excavated muck from proposed tunnel as well as muck from metro line tunnel will be used for reclamation fill. At this stage this is very optimistic scenario. The execution of metro as well as coastal road needs to be planned accordingly to ensure fill material is available in time. Moreover the suitability of the material and logistics needs careful planning to avoid delays and cost overruns.

Alternative source shall be identified in case the work of both the project cannot be taken up simultaneously. This risk needs attention and monitoring to avoid cost overruns and project delay.

Observations and Comments:

Our observations on the Material Investigation report are given in table below:

MATERIAL INVESTIGATION REPORT				
Sr. No.	**Report / Drawing Reference**	**Description**	**Test Results**	**Observation / Comments**
1	Note:8098/E/DN-7	General Earth for construction	Maximum Dry Density (MDD) - 1.75 - 1.99 g/cc Optimum Moisture Content (OMC) - 12.00 – 15.00% Liquid Limit (LL) - 22 - 31% Plastic Limit (PL)NP/19 - 20% Plasticity Index (PI)NP/08 - 11% Free Swell Index - 15 - 20 % CBR - 10 - 19 % Angle of friction - 32 - 39 degs	The results of the earthwork /subgrade material are within the specified limit of MoRTH specifications
2	Note:8098/E/DN-7	Grading Aggregate for Granular Sub base and Base course	Only the general requirements are given.	The result of the tested aggregates needs to be included.

3.15 Road Safety

The safety of road user is paramount while designing the road facility. Any fault in design and subsequent execution, if not properly mitigated may lead to serious potential accidents. The various hazards that may pose serious risk to road user needs to be identified and appropriately mitigated to minimise and control the risk.

The mitigation measures can be in the form of,

a) Crash Barriers
b) Road Signs
c) Road Markings
d) Highway Traffic Management System (HTMS)
e) Education

Observations

Based on the available information from the DPR consultant and in the interest of safe traffic movement along the coastal road following suggestion / recommendation shall be taken into account along the coastal road and/or at all critical locations e.g. Interchanges etc.

1. HTMS Control System and continual monitoring (Variable Message Signs)
2. Traffic Safety Aid (ambulance and patrol vehicle)

Pedestrian Circulation

The coastal road scheme will generate recreational spaces along the project road which is currently under threat. This opens spaces shall attract public to enjoy the nature's beauty using the promenade facility provided along sea front.

The DPR consultant has proposed Bus bay/ Bus stops at Intermediate interval with Pedestrian bridges. However, the pedestrian circulation and segregation from the high speed facility is not provided in detail. The same shall be provided in the interest of ensuring safe movement of the pedestrian.

Road Signs and Marking

The proposed road sign and marking are reviewed based on the alignment scheme, traffic dispersal and safety of the road user. Our observations on the information provided by DPR consultant is tabulated below:

Table 3-2 Traffic Signs and Markings

Traffic Signs and Markings				
Sr. No.	**Report / Drawing Reference**	**Element**	**Observation / Comments**	**Recommendation/ Suggestion**
1	Road Signs and Marking Drawings	Layout	The layout plan for signs and marking is not available for review.	Provide Location plan for the same.
2	Traffic Road Signs & Markings	Traffic Sign details	It is observed that all signage's are designed as per IRC-67-2010	Latest IRC-67-2012 shall be followed.
3	Traffic Road Signs & Markings/FPI/SD/0100/039(RO)	Toll Plaza Layout	It is observed that Typical details of 6 lane Toll Plaza are shown for 4+2 Lane; The location of proposed toll plaza is not available .	Please confirm if toll plaza is required.

3.16 Security

The DPR provided is silent on the security of the coastal road.

The security of the coastal road facility needs to be given top most priority. The facility needs to be properly secured in curbing any untoward incident that may happen in near future. The plans and related documents of the same need to be provided so that the review can be made. These may comprise of the following but not limited to:

1. Variable Message Sign boards (VMS)
2. Ramp Metering systems, replete with Vehicle Detectors and linked to VMS system
3. Incident Detection and Management Systems
4. Communication System along with plan to deal with breakdown/ Disaster Management
5. Traffic Dispersal Management

3.17 Summary of Key Issues - Alignment Studies

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
1	**Topographic Surveys**	Topo survey information is limited	Key features required at important locations are missed out (e.g. Sea bed levels, existing roads etc.).	The deficiency shall be covered by capturing the key features at all such locations
2	**Typical Cross-section**	Limited details shown	The provision of space for utility ducts / services, cross passage for tunnels required	The details shall be included.
3	**Relaxation or Departure from Standards**	Very limited or no information available	Relaxation or Departure are essential prior to freezing the alignment and need to be approved by Client	Approved List of relaxation / Departure from standard shall be produced and included in tender document.
4	**Geometric Parameters (Main Alignment and Interchange)**	Geometric details provided.	At few locations the geometric features do not conform to adopted standards. There is opportunity for improvement in geometry.	The geometry shall be improved to the extent possible.
5	**Visibility (Main Alignment and Interchange)**	No information on available / achieved visibility	The facility is designed as high speed road and Visibility is of utmost importance for safe travel.	The achieved visibility shall be confirmed in view of safety of the road user
6	**Traffic Dispersal**	Substantial evaluation of Traffic movement not detailed out.	The requirement and capacity of the interchange ramps should be arrived at based on peak hour traffic. The DPR provides ADT information.	The DPR consultant shall substantiate the lane capacity and requirement based on peak hour flows
7	**Tie-ins with existing network**	Limited or no information provided.	Sufficient details are required at all tie-in locations with existing roads to ensure enough space is available for construction	Detailed cross sections shall be produced by DPR consultant at all such critical locations to

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
			and dispersal.	ensure there are no constraint and congestion.
8	**Road Signs and Markings**	Typical details available	The signs are designed using IRC 67-2010. Detailed layout plans not available	Latest Sign code IRC 67-2012 shall be followed. Detailed layout plans shall be developed
9	**Road Safety**	Not identified in detail	Traffic Safety aid or HTMS needs to be provided. The pedestrian circulation and segregation from the high speed facility is not provided in detail.	The safety plan and document shall be provided in the interest of ensuring safe movement of the vehicles and pedestrians.
10	**Security**	No information	Security of the coastal road is an important element and needs effective planning	Incident information and management systems/ plans, communication plans and disaster management system shall be developed
11	**Material Transportation**	Sources are identified within transportation plan	Very limited information on transportation/ logistics. Both marine material and Road transportation networks identified but the impact of road and marine transportation on existing Mumbai network is not evaluated in detail. This is an essential element to plan precisely the programme, logistics, delays, risks and cost	A detailed logistic master plan is needed with careful planning at micro level to avoid delays and cost overruns.

RECLAMATION

4 RECLAMATION

4.1 Introduction

The Mumbai Coastal Road project lies directly adjacent to the Indian Ocean and is exposed to wind and waves emanating from the west between Nariman Point in the south and Versova beach in the north. To the north of Versova Beach the road moves inland passing through a tidal creek finishing in Link Road.

Accordingly, the road passes through two distinctive and very different environments. Between Nariman Point and Versova Beach the design of reclamation features and coastal protection is dominated by consideration of the wave and tidal climate in conjunction with near shore bathymetry and geology. Within the tidal creek the major influences are tidal and fluvial flows together with the presence of soft estuarine soils and mangroves. The project comprises approximately 168.08 ha of reclamation, 9.40 km of coastal protection works and 10.86 km of land filled road. The general characteristics of the areas to be reclaimed are:

A wide rocky uneven foreshore which is exposed at low tide (Figure 4-2)

- A range of seawall types and shoreline protection (concrete walls / capping, rock armour and Tetrapods).

DPR Consultant has prepared a detailed project report (DPR) for the project and the objective of this section of the report is to summarise the findings of the Peer Review for the reclamation and coastal protection elements of the project. The activities within the peer review have included:

- Review of the DPR documents
- Site visits along the length of the project
- A gap analysis on the information supplied with the DPR
- Assessment of the technical options presented in the DPR
- Identification of potential risks to cost and programme
- Recommendations to mitigate the principal risks
- Assessment of the overall technical feasibility

4.2 General Definitions

Throughout this report, the term “Platform level” has been used to describe the final constructed level of the island. The “Platform level” will be the surface on which road will be constructed. The term “crest level” refers to the top of the bund protecting the periphery of the island. Both of these definitions are shown in Figure 4-1 below:

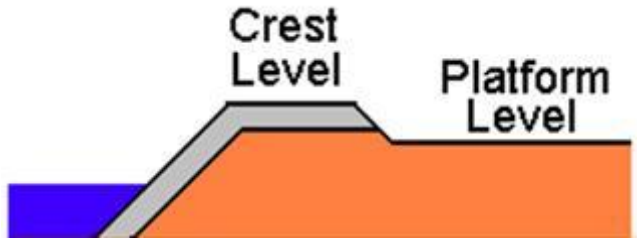

Figure 4-1 Definition of Levels

Figure 4-2 Rocky Foreshore

Figure 4-3 Rock Armour Protection

Figure 4-4 Tetrapod Protection with Concrete Capping Wall

4.3 Contract Definitions

For the purposes of this report the following definitions have been used in this report:

- **Contract Data** - Information supplied with the Contract Package for the use of the Tenderer to prepare his tender. For example, this would include: bathymetric survey data; site investigation information and data on sources of materials. It should be noted that the Contract Data should be issued on the basis that it is the responsibility of the Tenderer / Contractor to undertake his own investigations and that the Employer is not responsible for the accuracy or the interpretation of the information by the Contractor.
- Design Requirements - Information supplied with the Contract Package which specify the overall design requirements as a Design and Build Contract. For example, this would include: geometrical requirements such as: the vertical and horizontal alignment of the roads; horizontal alignment and minimum crest levels for the shore protection. The Design Requirements should also include details associated with appropriate codes of practice, wave heights, design water levels, design return periods etc.
- Performance Specification - Specification defining the performance of the works. For example, this could include density requirements for the reclamation,
- Materials Specification - Specification of materials used within the works to ensure that materials incorporated within the works are durable and fit for purpose.
- Employer's Requirements - The Contract Package which includes: Contract Data, Design Requirements, Performance and Materials Specifications

4.4 Marine Environment

4.4.1 General

Water level and wave climate are critical factors in the design of the shoreline protection works and reclamation. The reclamation platform and crest levels must be set at a sufficiently high enough elevation to minimise the risk of: wave overtopping, flooding and water damage to property. Under storm conditions the reclamation must also remain secure and stable at all times. All shore protection to the reclamation must be able to survive an extreme event and avoid catastrophic failure. Accordingly, the shoreline protection works must be designed to resist wave impact forces, lateral earth pressures and mitigate the risk of erosion to foundations.

Addressing shore protection and flooding issues is usually achieved by specifying a design return period (or Extreme Annual Probability) for water level and wave climate. In this respect it is noted that the DPR has adopted a design return period of 1 in 100 years which is considered to be generally acceptable. The standard of protection for tidal situations varies around the world. In the UK the design standard is 1 in 200 and in parts of the Middle East it is 1 in 50 years. It is recommended that the design standard is commensurate with Indian National Standards.

The four marine environmental components associated with the design of the shore protection works and reclamation are:

- Astronomical tides
- Storm surge
- Climate change (sea level rise)
- Inshore wave climate

Water level variations, which incorporate the effects of tidal variation, storm surge and climate change, occur over a comparatively long duration but variations due to waves occur in a matter of seconds. Nonetheless, these component must be appropriately combined to ensure that the objectives of ensuring stability and mitigating flooding.

> **EXPLANATORY NOTE**
> **Tidal variation** is dependent principally on the position of the Moon and Sun and tidal levels can be predicted with accuracy.
> **Storm Surge** is the combined effect of the effects on the sea surface of meteorological effects which includes wind set-up and barometric variation. During storms onshore winds tends to pile water up on the coast and this can influence water levels significantly. This is known as wind set-up. In addition, low pressure depressions can lead to an increase in water level.
> **Design Water Level** is the addition of tides, storm surge and climate change.

4.4.2 Water Level Fluctuation

Mumbai Tides are semi-diurnal with a diurnal asymmetry. Based on the information contained in the DPR and confirmed elsewhere, the tidal range at Mumbai between Mean High Water Spring (MHWS) and Mean Low Water Spring (MLWS) is approximately 3.66m (see Table 4-1).

The highest recorded water level quoted in the DPR is 5.04 m Chart Datum (CD) (Volume 1 Main Report (February 2015)). Mumbai Port Trust quotes a figure for the Highest High Water Recorded (HHWR) as 5.39m CD on their website and presumably includes the effect of storm surge. The return period of the surge event and the magnitude (height or surge residual) is not stated on the website.

Appendix V (Reclamation Report) elaborates further on design water levels stating that +4.00m CD is the most likely high level of sea water during the passage at a storm. This latter figure is clearly incorrect as MHWS tidal levels are 4.42m CD and well below the Highest High Water Recorded of 5.39m. It should also be noted that the design water level should include the effects of climate change which for 100 years of climate change are quoted as ranging from 0.22m to 0.5m. However, the source of this information or its applicability to Mumbai is not stated. It is considered that the adoption of 4.0m CD as the design water level would not be appropriate.

Table 4-1 Tidal Constants

Tidal Constants	m RL	m CD
Highest Astronomical Tide (HAT)	2.89	5.40
Highest High Water Recorded* (HHWR)	2.88	5.39
Mean High Water Spring (MHWS)	1.91	4.42
Mean High Water Neap (MHWN)	0.79	3.30
Mean Water Level (MWL)	0.00	2.51
Mean Low Water Neap (MLWN)	-0.65	1.86
Mean Low Water Spring (MLWS)	-1.75	0.76

*Mumbai Port Trust website

4.4.3 Wave Heights

Waves generated offshore by storms propagate through deep water before being affected by shallower depths where they undergo a series of changes which have an impact on the energy and height of the wave. Generally, this means that wave heights reduce as the wave approaches the shoreline. Transformational effects include:

- Wave Refraction
- Wave Shoaling
- Wave Diffraction
- Wave Breaking

The National Institute of 0ceanography (NIO) has undertaken hydro dynamic and wave modelling studies and their findings are given in their final report (January 2016). The objective of the modelling and reporting was to assess the impact at the reclamation on coastal processes and hydrodynamics. The modelling is based on the prevailing "day to day" wave climate and the report does not consider the extreme wave climate for the design of coastal protection works and the reclamation.

However, it should be noted that the wave model developed by NIO could be used to assess offshore to inshore wave transformation and better accuracy obtained by updating the model by including the bathymetric survey undertaken for the works.

The Volume 1 Main Report (February 2015) gives some basic information on the wave climate and states that the 1 in 100 year return period significant wave height for the Mumbai coast shall be taken as Hs= 4.5m. The report does not say whether this is an offshore or inshore estimate which takes account of the above transformation effects. It should also be noted that the data on which this estimate is based is now 25 years old and it is considered that the analysis should be based on more contemporary information and data. There is no reference to wave period within the Volume 1 Main Report document.

Appendix V does elaborate any further on the selection of Hs but does discuss proposed road level and wave overtopping. The analysis presented in paragraph 4 on page 3 is fundamentally incorrect. In addition, there is no reference to the need to use the design wave height for the design of the concrete or rock protection.

4.4.4 Conclusions and Recommendations

The analysis presented in the Volume 1 main report and Appendix V are, in places, incorrect, inconsistent and confusing and does not give any confidence that the process of assigning a design maximum still water level, significant wave height and wave period for design purposes has been understood. The assumptions made in Appendix V could potentially lead to a serious under design of the reclamation and coastal protection works. As a result, it is considered that the existing analysis is not fit for purpose and must either be substantiated with additional information or revised in accordance with best practice.

These issues must be rectified and details included with the contract package. The maximum still water level, significant wave height and wave period at the structure and combinations thereof, are key design parameters.

A review of the document prepared by NIO indicates that the wave modelling considered prevailing “day to day” conditions with comparatively low wave heights. It did not include an assessment of extreme inshore wave conditions which could be used for the design of armour units or assess overtopping to the reclamation onto the road.

Accordingly, it is recommended that:

- The offshore wave climate should be re-evaluated to determine an up-to-date estimate of the significant wave height (Hs). More contemporary research may be available within NIO as an alternative. This shall be presented for a range of return periods including 1:5, 1:25, 1:50 1:100 year return periods
- An extreme water level analysis of Maximum Annual Still Water Levels should be undertaken using available tide gauge data. Again this should be presented for a range of return periods including 1:5, 1:25, 1:50 and 1:100 year return periods and must incorporate climate change.
- A joint probability analysis to determine design combinations of wave height and water levels is carried out.
- A wave modelling study by NIO using the Existing MIKE model of Mumbai to transform the offshore wave climate inshore is undertaken. Various combinations of water level and wave height should be used to determine the design wave climate (Hs &Ts /Tp) adjacent to the reclamation.
- Undertake wave transformation modelling to assess inshore wave heights (Hs) throughout the project.
- Eurotopor a similar analytical technique to assess wave overtopping and determine: parapet crest levels, road levels and threshold levels for tunnel entrances as necessary.
- Derive minimum crest level for the sea protection works, minimum road level and threshold protection levels at the tunnel entrances.
- This wave analysis should be included in the contract package as Contract Data
- The minimum crest, road and tunnel threshold levels derived from the analysis should be included within the Employer's Requirements as Design Requirements.

The above work stream is shown in Figure 4-5 and should be undertaken by a competent organisation and individuals who have suitable experience in the above techniques. The benefits of implementing these recommendations would include:

- Removal of uncertainty associated with the design requirements for shoreline protection
- Significant reduction in uncertainty at tender stage allowing Contractors to prepare accurate pre-tender designs
- More competitive tendering with all tenderers using the same baseline information

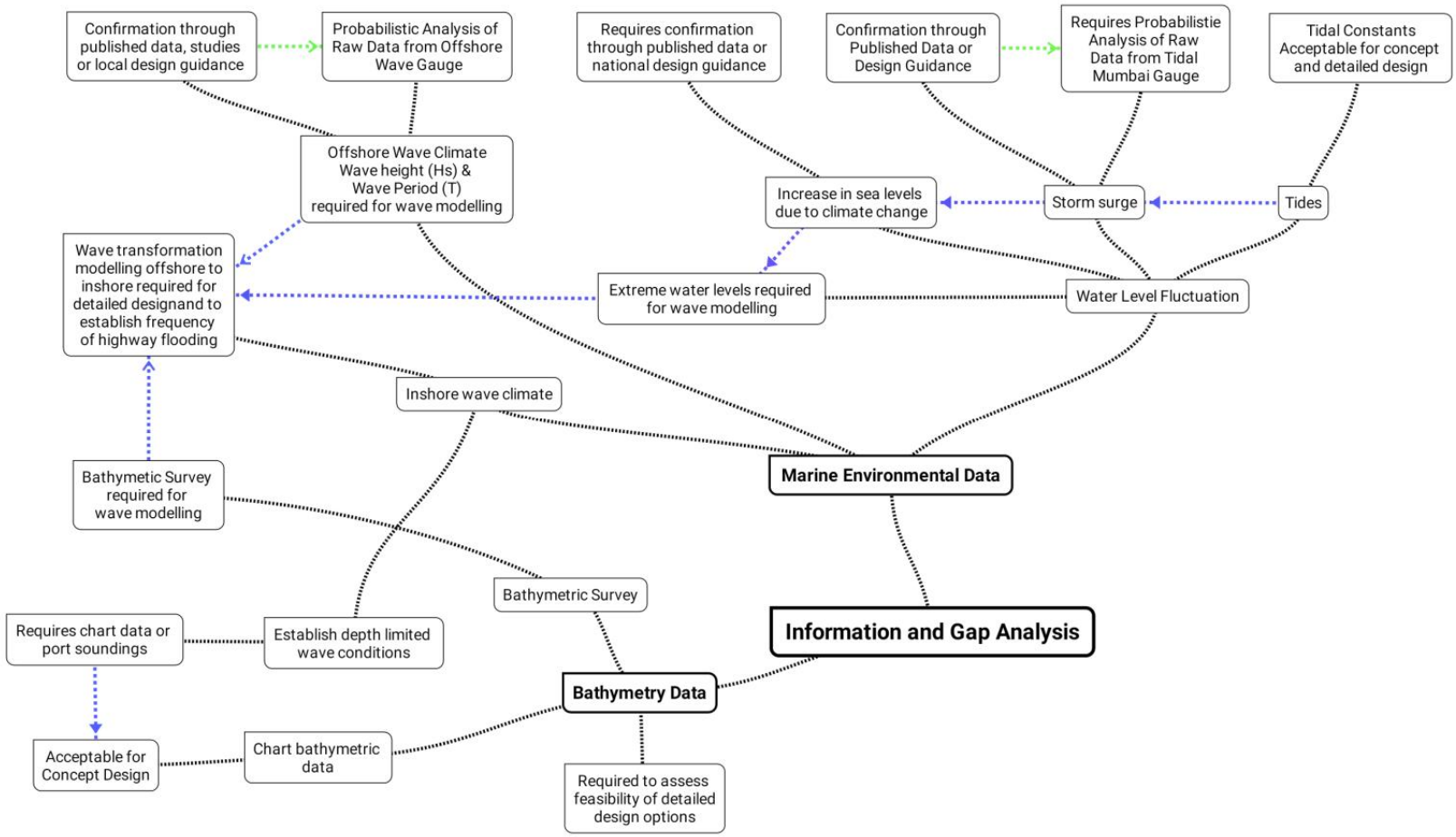

Figure 4-5 Wave and Water Level Analysis Flow of Work

4.5 Flood Risk

4.5.1 General

The potential sources of flood risk associated with the construction of the road are:

- Surface water flooding of the highway
- Reduced capacity of existing drainage outfalls as a result of the coastal road works
- Tidal and wave overtopping of the coastal protection works

In relation to the first of these bullet points it is assumed that the highway design will incorporate and specify drainage infrastructure and sea outfalls to manage the risk of surface water flooding on the highway. This section concentrates on flood risk from existing surface water drainage systems, tidal inundation and wave overtopping.

It is considered that the coastal road and reclamation infrastructure should facilitate and not impede the discharge of existing flows from the land to the sea. This includes all drainage ditches, tidal creeks and rivers which currently discharge directly into the Arabian Sea. The objective should be to ensure that there is no increase in the risk of flooding to existing communities. In addition, it is also considered that the risk of flooding to the road from rainfall and overtopping from the sea should be managed within the design of the works. This means that the shore protection crest levels and thresholds to tunnels should be rigorously assessed. These issues are discussed in more detail below.

4.5.2 Capacity of the existing surface water infrastructure, tidal creeks and rivers

A formal flood risk assessment (FRA) does not seem to have been developed as part of the DPR. It is considered that the preparation of an FRA would have been helpful given the problem of surface water flooding during periods of monsoon. It would also have assisted in the concept design of the shore protection and reclamation by identifying locations where drainage systems must be conveyed under the highway and through shoreline protection structures.

In lieu of a flood risk assessment, the DPR contains an evaluation of run-off from surface water catchments to the rear of coastal road and reclamation. The input to the calculations and the analysis has not been checked but it is noted that the methods used to evaluate run-off are generally appropriate albeit somewhat out of date. Whilst the analysis presented includes calculations of flow rates within existing drains it makes no reference on how these flows will be accommodated by the works. There is a danger that flood risk problems could be increased if existing drainage routes are compromised by the reclamation. This could occur either by the introduction of undersized structures or failures to identify existing drainage routes.

It is understood that provision will be made to ensure that bridge spans and outfalls will be accommodated by providing three times the width of the existing river, ditch or outfall. However, it has not been possible to find this statement in the DPR. It would be more helpful if the DPR could include further information specifically related to existing surface water drainage systems and ideally this would be in the form of a flood risk assessment which would concentrate on flood risk issues.

4.5.3 Tidal inundation and wave overtopping

Tidal inundation occurs when tidal and storm surge levels rise to a level which exceeds the crest level of the sea defence. This can result in extensive flooding which occurs very rapidly. Tidal inundation of this nature is of particular concern for the coastal road project as it could potentially flood tunnels causing significant loss of life and critical damage to infrastructure.

Wave overtopping occurs when wave conditions are sufficiently severe to allow waves to break over the sea defence or coastal protection structure. Generally, wave overtopping is not as severe as tidal overtopping. Figure 4-6 and Figure 4-7 shows an example of extreme wave overtopping in Porthcawl in South Wales and a less severe example at Dawlish in Southern England. Wave forces and undercutting of the sea wall /scour eventually led to collapse of the wall in 2014. Wave overtopping is dependent on a number of factors including the:

- Height of the incident wave
- Bathymetry and depth of water in front of the wall
- Reflective properties of the wall / sea protection infrastructure

Accordingly, the crest level of the coastal protection structure is a critical design parameter in the design of the coastal road and the tunnel but there is no reference to crest levels in the document. Moreover, and as noted in sections 4.4.2 and 4.4.3, the evaluation of the design still water level, inshore wave climate and wave overtopping in the DPR is not considered to be fit for purpose. It is considered essential that these key design parameters are established to allow the design to be developed particularly in relation to setting crest and threshold levels.

Figure 4-6 Wave Overtopping

Figure 4-7 Wave Overtopping Dawlish

4.5.4 Conclusions and Recommendations

The DPR contains very little meaningful information concerning the risk of flooding as a result of the construction of coastal road. A formal Flood Risk Assessment has not been prepared and there is little or no specific information or analysis within the DPR associated with:

- Maintaining existing flood discharge capacities from land to sea
- Highway drainage outfalls to the sea
- Crest and threshold levels for the coastal protection works

In relation to accommodating existing surface water infrastructure, tidal creeks and rivers it is recommended that the Employer's Requirements incorporates the following:

- The location of all existing outfalls, drainage ditches, tidal creeks and rivers which discharge into the sea. (Contract Data)
- The width, invert and soffit levels required for all of the above features so that flood water can be safely discharged through the reclamation in a 1 in 100 year or other agreed return period event. (Design Requirements)
- The vertical alignment of the highway to ensure that there is sufficient construction depth to accommodate drainage infrastructure and the highway (Design Requirements)

It should be noted that these requirements are more prescriptive than the 3 x width criterion mentioned above and would be more reliable in ensuring that existing drainage systems are not compromised.

As noted in Section 4.4.4 it is essential that the design water level and wave climate are included in as Design Requirements so that

crest and threshold levels can be used to inform the design of the coastal protection works by the Contractor. However, it is considered that there could also be benefits in:

- Undertaking hydrological analysis and hydraulic modelling to investigate changes to flood risk as a result of the construction of the Coastal Road.
- Designing outfalls to future proof existing drainage systems for higher flows within the drainage systems
- Assigning a minimum freeboard above the crest level and including this as a requirement in the Employer's Requirements.
- Placing limits to the rate of overtopping as a design requirement within the Employer's Requirements.
- Introducing secondary flood walls set back from the line of the reclamation to mitigate the risk of flooding as a result of wave overtopping.
- Ensuring that the Employer' Requirements contain requirements to include return discharge routes to the sea to ensure that flood water can be returned as quickly as possible

The above issues are not included in the DPR but the benefits of implementing these measures would include:

- Identification of all structures required to convey flood water through the reclamation and better identification of the scope of construction works
- Removal of uncertainty associated with the design requirements for shoreline protection
- Significant reduction in uncertainty at tender stage allowing Contractors to prepare accurate pre-tender designs

4.6 Bathymetric and Topographic Survey Data

As noted above the reclamation will be located on the rocky foreshore much of which is exposed at low tide. The DPR consultant has supplied details of the inshore bathymetric survey which is understood to be subject to confidentiality agreements with the Indian Navy. It is not clear whether this information can be used within the tender package. The above survey terminates at the 3m CD which in places is between 0.5km and 1 km from the existing shoreline and does not include the reclamation area.

Accordingly the situation with respect to bathymetric data is not ideal for the following reasons:

- There will be significant uncertainty in the volume of fill material required for the reclamation works. This will have a direct and inflationary impact on the tender prices.
- The wave climate at the structure is dependent on water depth and lack of bathymetric information could lead to uncertainty in the evaluation of crest levels.
- Information on operational depth for marine plant is uncertain. This means that decisions associated with the use of specialist plant and barges will be difficult at tender stage.

This third and last bullet point is discussed in more detail in the section on construction logistics (see section 4.10). In conclusion it is recommended that:

- The DPR consultant should procure a survey to fill gaps in the bathymetric survey data which should include shallow areas which could be used for barge access to the works and the reclamation area.

- The bathymetric survey data is supplied as part of the Contract Data within the Employer's Requirement.

There are a number of important benefits in undertaking a bathymetric survey including:

- Uncertainty in the evaluation of crest and threshold levels for the shore protection is reduced.
- The volume of fill material is better defined allowing Contractors greater certainty in the production of tender costs.
- The feasibility of different construction methodologies can be assessed and the use of particular types of specialist plant can be confirmed or rejected by tenderers.

4.7 Geotechnical Data

The majority of the reclamation will be located on the rocky basalt foreshore and it is not anticipated that there will be significant problems in founding the coastal protection and reclamation on the basalt outcrop. However, it should be noted that the extent of the basalt has not been proven either by topographical/ bathymetric survey or by geotechnical site investigation.

Accordingly, it is considered that geotechnical site investigation should be undertaken along the line of the sea protection structure. An average frequency at one borehole per 300m has been recommended and this is not considered unreasonable for a reclamation project of this size. However, the site investigation should be designed to be flexible so that borehole locations can be changed to allow particular locations to be explored in greater detail if required (e.g. soft spots).

In conclusions it is recommended that the:

- Results of the geotechnical site investigation is included in the Employer's Requirements as Contract Data

4.8 Materials

4.8.1 General

As noted above the design of the shore protection works and reclamation is likely to include the following materials:

- Precast concrete wall or coping units
- Rock fill materials to support precast concrete units
- Rock or pre-cast concrete armour units
- Reclamation fill materials
- Geotextiles

The Volume 3 Materials Investigation Report prepared by the DPR Consultant does not include reference to rock or reclamation fill materials in relation to quality or quantity and it is considered that this should be rectified as they are critically important materials. In relation to concrete products it has been assumed that sufficient volumes of cement and aggregate can be sourced within Mumbai and would be readily available for this project. More discussion of concrete products and fabrication is contained in Section 4.10.

4.8.2 Reclamation Fill

It is understood that the DPR consultant has calculated that approximately 8.1 million cubic metres of fill material is required for the reclamation. The expectation of the DPR consultant is that a substantial volume of this material will come from the Phase 3 Metro Site and from the tunnel construction. However, a review of the

volume of materials from tunnelling and the Metro indicates that there will still be a significant shortfall in fill materials even if the Metro works and tunnelling can be phased to supply the reclamation works.

The specification of fill materials is comparatively flexible and the primary requirement will be to produce a medium dense fill below MHWS which is compacted above this level to a density which is suitable for road construction. lt is recommended that the Performance Specification specifies the placed density requirements for the fill to ensure that it is fit for purpose. Reclamation materials placed below MHWS levels should be specified separately from embankment materials.

The Volume 3 Report includes potential sources of material within the Mumbai area but it does not evaluate the quantity or quality of the above materials. It should be noted that the suitability of materials for reclamation will be dependent on a range of issues including:

- **Compaction requirements** - Methods such as vibro-compaction require strict limits on the grading of sands to allow vibro-compaction to work.
- The inclusion of silts, clays and fines within the fill material can significantly affect settlement and consolidation of the reclamation. This can result in differential settlement across the fill and in some circumstances the presence of "waves" on the surface which reflect the "softness" of the underlying reclamation materials.
- The presence of silts and clays can also affect the methods used to densify the material and the time required for settlement and consolidation. With high percentages of silt or claypre-loading may be required and this would have a major impact on programme.

Whilst these investigations could be undertaken by the Tenderer, information on the quality and quantity of locally sourced reclamation fill would quickly demonstrate whether the project can be undertaken using material available in the Mumbai area.

It is also noted that there is no reference to dredging to win reclamation fill materials within the report. Whilst it is understood that it is unlikely that there is a source of suitable marine material in the Mumbai area it is considered that a study of marine sources within Indian waters up to 30m deep should be undertaken. The use of dredged material could potentially translate to significant costs savings for the project even if shipping distances are comparatively large.

4.9 Rock Materials

The Contractor's design of the shore protection works could include rock materials which could be for the:

- Foundations of pre-cast concrete units
- Containment of reclamation fill to MHWS tidal levels
- Primary armour to ensuring stability of the shore protection works
- Mitigating the risk of wave overtopping

Rock materials generally falls into two categories which are primary armour and core materials (see Figure 4-8). Typically, primary armour ranges from 3 tonnes to 7 tonnes depending on the incident wave conditions. Core materials are smaller forming the foundation to gravity structures, underlayers and core of structures. Typically, core and underlayer materials range from Dn50 = 100mm to 400mm.

Rock Core Materials

It is likely that rock materials will form the Containment Structure (to MHWS) for the reclamation and for the support of gravity walls or capping units. The advantage of using rock core materials to form the containment structure is that rock core materials are reasonably stable under “normal” or prevailing wave conditions where sand or fill would wash away. It is recognised that there could be good sources of basalt in Mumbai and it is assumed that local quarries would be able to deliver general rock products in appropriate gradings which would be suitable for core and underlayers. The availability of this category of materials has not been investigated in the DPR Materials Investigation Report.

Rock Armour

There are a number of examples along the length of the Mumbai coast where both rock and tetrapods have been used as primary armour. The inclusion of rock or concrete armour units will be dependent on the relative cost of obtaining and placing armour but it should be noted that concrete armour units are frequently more expensive than rock armour. If the Contractor is able to find an economic source of rock armour, then this could be a cost effective alternative option to the use of pre-cast concrete armour. It is likely that local quarries may not have the production methods to deliver large rock armour (say 3 tonnes) but it may be possible to economically source large rock products from further afield. This includes Ras al-Khaimah in the UAE which supplies rock products across the Middle East.

Sourcing Rock Materials and Specification for Durability

The Materials Investigation Report does not include information on the source or specification of rock materials. If the Contractor decides to use rock within the shore protection works, then the Contractor will determine the grading of rock materials (armour and core) to ensure that the shore protection works are stable in extreme wave conditions. This does mean that a Materials Specification would be required to ensure that rock products supplied to the site are durable.

The specification of rock materials for use as armourstone and core is complex requiring specific constraints on shape, mechanical properties, density, water absorption and defects and this should be addressed in the DPR Consultant's Materials Investigation Report. It is considered that durability requirements for armourstone should be included within the Employer’s Requirements as a Materials Specification. This could be based on the use of rock which is rated as Excellent or Good in accordance with The Micro Deval or AQD methods given in Section 3.6 of the Rock Manual (The Use of Rock in Hydraulic Engineering CIRIA Report 683) and:-

- BS EN 13383-1:202: Armourstone; Part 1 Specification
- BS EN 13383-2:202: Armourstone; Part 2 Test Methods

It may also be sensible to exclude certain rock types which are inherently less durable in a marine environment. The development of an appropriate and tight specification to ensure that rock materials are durable will require careful consideration. It is likely that locally sourced basalt would be rated as good or excellent and could be used as core materials but this does assume that grading requirements imposed by the design can be met.

Figure 4-8 One Tonne Rock Armour Revetment & Rock Core at Low Tide Pont Briwet Wales (Locally Delivered Basalt)

4.9.1 Conclusions and Recommendations

In summary, the availability of suitable reclamation materials within the immediate vicinity of Mumbai has not been conclusively proven within the Materials Investigation Report. It is considered that the DPR consultant should undertake further investigations as a matter of urgency including

- Identifying where material can be sourced and assess the available volumes. This includes sand fill (marine supply including dredging) and rock material (quarry sources) for the construction of the containment structure and include this information as part of the Contract Data
- Developing a Performance Specification for the reclamation which specified density and settlement requirements for the reclamation fill material.
- Developing Materials Specification for all materials which could be included in the works to ensure that durability is maintained throughout the life of the structure.

The benefits of implementing the above recommendations are that it:

- Removes the uncertainty that there are sufficient materials in the Mumbai area in order to undertake the works
- Ensures that the quality and durability of materials used in the reclamation and shore protection works of the reclamation materials are adequate.

4.10 Logistics

4.10.1 Constraints on Construction Methodology

As noted elsewhere the reclamation site is located on a wide foreshore which is exposed at low tide but covered at high tide. Inter-tidal working is an important constraint on the construction methodology. In addition, land access to the site is restricted by narrow roads and high volumes of traffic. This means that there are a

number of important constraints on the construction methodology which are discussed in more detail below.

Delivery of Materials to Site

The DPR consultant has calculated that approximately 8.1 million cubic metres of fill material is required for the reclamation. Essentially the site can be supplied by:-

- Overland transportation
- Marine transportation
- Transfer of materials from within the site (i.e. the tunnels)

The delivery of materials is a major issue associated with the construction of the works and it is recognised that there are significant constraints associated with both marine and overland transportation which must be addressed by the Contractor. The DPR does not consider these issues in any detail but it is important to recognise the constraints.

Overland Delivery

In relation to overland transportation the principal issues are as follows:-

- The large number of daily vehicle movements required to import fill material from the Metro site and elsewhere will lead to congestion on the road system leading to slow delivery of materials to the site.
- Excavation production rates from the Metro Site may be low by comparison to the production rates that can be achieved for reclamation filling.

Accordingly, the delivery of materials to site from the Metro site or elsewhere by road is likely to lead to slow production rates for the construction of the reclamation and a significantly extend the programme. Nevertheless, it is considered that options for the delivery of materials by road should be kept as an option and the DPR consultant should ensure that the necessary approvals are in place before the Contract is let.

Marine Delivery

Whilst the delivery of rock materials from the sea is normally less expensive than land transportation the delivery of materials to the Coastal Road site is not without problems. The rocky basalt foreshore extends some distance offshore but as noted in Section 4.6 the extent and level of the basalt and the location of deep water is unknown at present.

It is assumed that large bulk materials such as rock fill and rock armour units will be delivered and offloaded from shallow drafted barges from the marine side. The feasibility of barge operations at the site will be dictated by:-

- The depth of water and the draft of available barges and support vessels (tugs)
- The distance from deep water to the place of offloading
- The operational tidal window

The DPR consultant has developed a transport plan which focuses on the use of local materials including reclamation fill delivered by barge. The plan identifies a number of sources and loading points many of which require double or multiple handling. The transport plan does not include any information on the suitability of the loading facilities including:-

- The availability of mechanical handling facilities to load barges
- The availability and characteristics of barges and tugs
- The size of the available area for stockpiling

- Depth and length at berth
- Navigational depths between the source and the point of delivery

It is recognised that conveyor and crane systems to load barges are comparatively simple and inexpensive to install but depth at berth, navigational depths and length of berth will be important in demonstrating whether the facilities can be accessed by barge and the number of barges which can be accommodated at berth. It is recommended that the details of the source "ports" are investigated further and included in the Contract Data.

The plan has identified three barge types all of which have an unladen draft of 9 feet (2.74m).The carrying capacity of the barges ranges from 1,000 tonnes to 3,300 tonnes which is considered reasonable in terms of delivery packages. Assuming 8.1 M cubic metres of material is imported by barge then approximately 6,800 deliveries to complete the works.

However, it should be recognised that are significant restriction in relation to intertidal working at the source part and at the point of delivery. Figure 4-9 shows a typical period of tidal fluctuation in Mumbai. Assuming that:-

- The foreshore level at the point of delivery is at MLWS (0.76m CD ± 0.25 m)
- Under keel requirements for barges are 0.5m to take account of uncertainties in vessel trim and the variability in rock levels on the foreshore
- The laden draft of the barge is 3.0m

Then the minimum water level required to deliver material will be 4.51m CD (0.76+0.25+3.0+0.5). Accordingly barge access will be restricted by tidal fluctuation particularly at neap tides. Indeed Figure 4-9 suggests that tidal conditions would only be suitable for 3 of the 7 days shown on the figure. The same consideration should be given to the source "port".

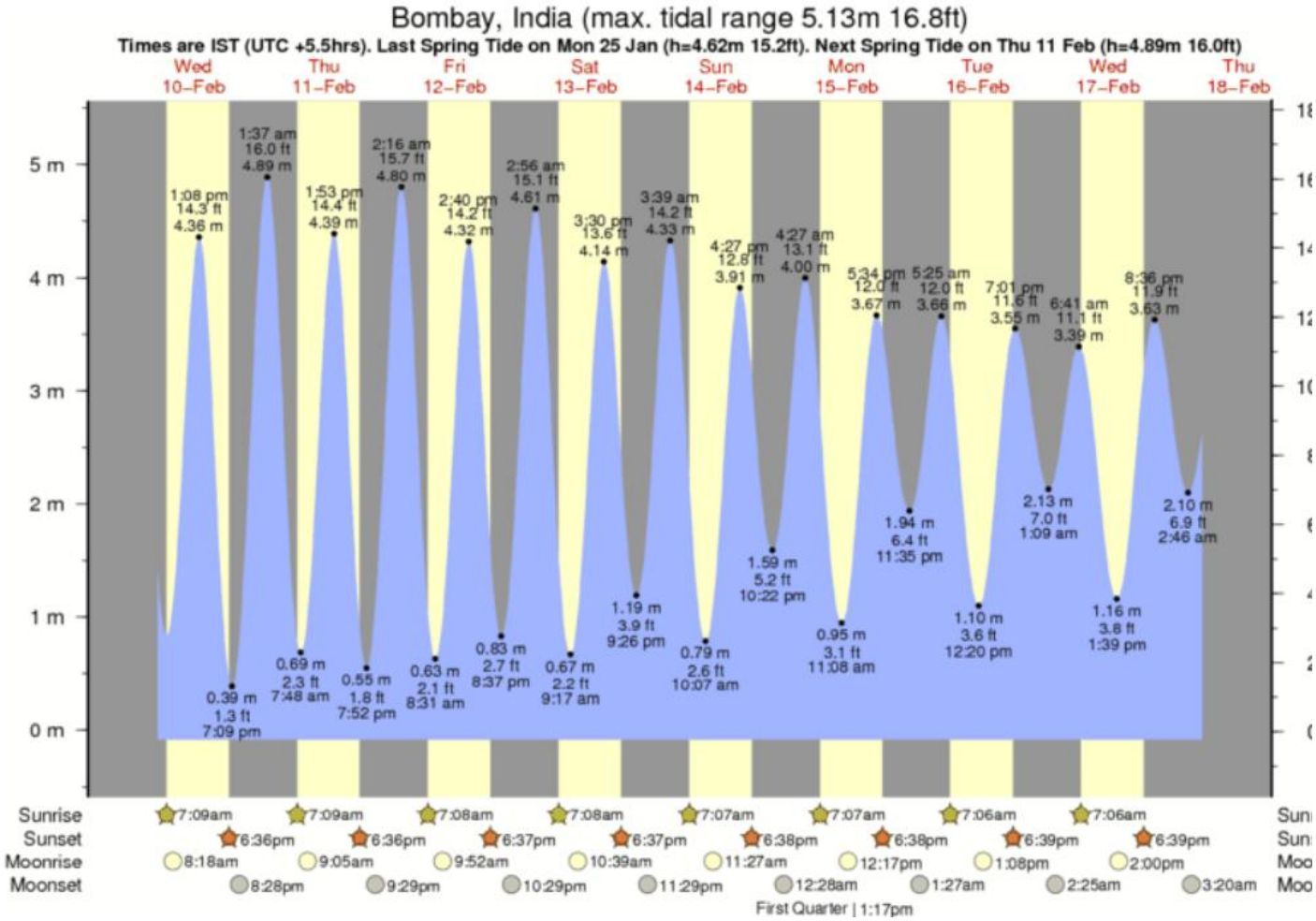

Figure 4-9 Typical Tidal Fluctuation Mumbai

The process described by the DPR consultant places a lot of dependence on the availability and suitability of barges for the delivery of all materials. As noted above there will also be significant tidal restrictions on delivery. Accordingly, barge handling of materials will require careful planning (Figure 4-10) to ensure that barges can access shallow water and this may also require:

- Double handling of materials associated with the transfer of rock materials from ship to barge.
- The construction of pads on the seabed so that barges can be "laid down" at low water without compromising the integrity of the hull to allow offloading of rock materials at low tide.

Figure 4-10 Delivery of Rock Products from Sweden to the UK & Motorised Barges Delivery of Reclamation Fill in Hong Kong

The Contractor could consider a number of alternative marine delivery methods to offset the dependency on barges and this could include:-

- The construction of a light jetty or causeway for offloading rock core and reclamation fill materials.
- Pump ashore methods using marine dredged hydraulic fill.

The construction of a light jetty may not be economically viable for a Reclamation Contractor but the advantage of this approach is that the jetty could also be used the exportation of arisings from the tunnel if it is not possible to incorporate them within the works. However, it is recognised that the construction of a temporary jetty might require a separate enabling works contract.

Pump ashore alternatives may be a viable cost effective alternative but this would require a source of material to be found. Hopper capacities in the larger trailing suction dredgers typical range from 18,000m3 to 46,000m3 (Figure 4-11) implying that between 180 and 450 deliveries would be required to supply the works. The largest trailing suction dredgers draw approximately 15.2m of water whilst laden and are able to dredge to depths of 155m.Conversely the use of a typical barge carrying 1,500 m3 would require 5,400 deliveries to complete the reclamation filling. This would be equivalent of 5 deliveries per day over a 3 year period.

Figure 4-11 Jan De Null's Cristóbal Colón - Hopper capacity 46,000m^3

Transfer of materials within the site

The DPR Consultant has been encouraged to consider the use of materials from the tunnel excavation as reclamation fill. There are a number of potential problems with this approach which include:

- Phasing of the tunnel and reclamation works. The reclamation works is currently scheduled as the first phase of works. If this is the case, then materials from the tunnel may not be available.
- Materials excavated from the tunnel may be in the wrong position and require double handling to move them to the point of placing either by barge or land transportation.
- The quality of the excavated materials from the tunnel means that the material has to be re-worked to meeting the specification requirement for rock core or reclamation fill.

These issues may mean that the advantages of using material from the tunnel cannot be realised. Nevertheless, it is considered that the

option should be left open to allow the Tunnel Contractor to sell or give the materials to the Reclamation Contractor.

4.10.2 Plant

The use of marine plant including cranes and as previously discussed will be severely restricted by the available working tidal window. This issue is discussed in more detail in Section 4.12.2. It should also be recognised that the delivery of plant including large cranes, excavators and muck shifting plant will also be constrained by land access.

4.10.3 Concrete Fabrication

As noted above the Contractor's design of the shore protection works could include pre-cast concrete armour units (e.g. Tetrapods) and pre-cast concrete capping / wall units. In addition, there will be a requirement to produce pre-cast concrete elements and cast in-situ for the bridge works and provide concrete for the tunnels. Accordingly, there could be a significant demand for concrete across the project.

The DPR does not specifically consider concrete production within the document but it will form an important element of the construction process. Ideally concrete fabrication would be undertaken on the site to minimise transportation problems within Mumbai and delivery problems from the sea. However, it should be recognised that there is comparatively little space on the reclamation in the early phases of the work for the construction of a fabrication plant to supply the reclamation works.

This situation may change as the reclamation develops and there could be significant advantages in setting aside an area within the reclamation for concrete production. This aspect of the programming should be investigated through the project master plan and it is assumed that the construction of the fabrication facilities would be the responsibility of the reclamation contractor. An alternative would be to identify an area which could be used for concrete fabrication elsewhere in Mumbai.

4.10.4 Conclusions and Recommendations

There are significant constraints associated with the delivery of materials and plant to the site from land and sea. These constraints will influence the:

- Design of the shore protection works
- Sourcing of material used within the reclamation
- Programme of works
- Tendered cost of the works

It is considered that there could be opportunities to improve the Project Master Plan to benefit the wider aims of the scheme and have a positive impact on cost and programme. The DPR currently envisages that the reclamation works contracts are split linearly along the length of the project with the contracts including shore protection, reclamation, road and bridge construction but this may not be the most efficient contract strategy.

The logistical constraints imposed by the marine and land access may mean that it would be more efficient to split contract packages vertically and horizontally so that the reclamation/ coastal protection, roadworks and bridgeworks are undertaken as separate packages. This would allow contractors to work within their own specialist areas and minimise interface issues between package where different design methods were employed.

Importantly it may also address some of the logistical constraints. For example, a concrete fabrication areas and batching plant could be erected on the first phase of the reclamation. This could supply concrete products and in-situ concrete to the reclamation, bridge and tunnel works for the duration of the contract. This would reduce transportation problems associated with importing large and heavy concrete products via marine or land transportation routes. It would also concentrate concrete production for the scheme in one or two areas of the works rather than having several contractors supplying concrete individually.

It would also reduce potential logistical problems with the importation of concrete products from a number of different small suppliers in the Mumbai area and give better certainty on quality and production rates for wall, armour and bridge units. The incorporation of a concrete fabrication plant would need to be introduced to the Project Master Plan and the responsibility for the construction and operation of the plant assigned to a Fabrication Contractor who may not be the Reclamation Contractor. The relationship between the fabrication contractor and the reclamation / coastal protection, roadworks, bridgeworks and tunnelling contractor would have to be developed to ensure that the advantages of having fabrication unit on site were realised.

As noted above there are major logistical issues in relation to the importation of materials from the sea by barge particularly as there are major operational constraints imposed by tidal working which could have a serious impact on programme. Accordingly measures to reduce or remove operational restrictions should be evaluated. The DPR Consultant should assess the advantages and disadvantages of constructing of a jetty or jetties equipped with conveyors to facilitate the supply of: reclamation fill material; rock core materials; aggregate and cement. This would extend from the reclamation to a deep water location so that it can be accessed by dredgers and other vessels. The objective would be to allow material to be unloaded irrespective of the tide.

It is envisaged that the jetty or jetties would be located in an area close to the fabrication plant and near a tunnel entrance. It should also be noted that the jetty or jetties could also be used for exportation of tunnel spoil. The introduction of a jetty or jetties to the project could be undertaken prior to the reclamation contract as part of an enabling package or as part of the reclamation contract.

In relation to the logistical issues, it is recommended that the DPR should:

- Supply the bathymetric data as identified in Section 4.6 to allow the Tenderer understand the extent and level of the basalt and the location of deep water in order to be able to plan the logistics associated with the delivery of materials. This should be included as part of the Contract Data.
- Considers the advantages and disadvantages of creating fabrication yard and batching plant a separate contract for the fabrication of concrete products for the whole of the works.
- Ensure that all marine and navigational approvals are in place particularly in relation to permissions from the Indian Navy.
- Consider the advantages and disadvantages of building a jetty or jetties to supply reclamation materials, rock core, aggregates and cement to the site.

4.11 Shoreline Protection and Reclamation Design

4.11.1 Introduction

It is understood that the design of the Shoreline Protection and Reclamation will be undertaken through a Design and Build Contract

based on Contract Data, Design Requirements, Performance and Materials Specifications which describe the extent of the works and the requirements of the design and material used in the works. This information will be included in the Employer's Requirements which will be prepared by the DPR Consultant.

This section reviews the design options developed by the DPR consultant conjunction with other information presented in the DPR reports but ultimately these options are unimportant as the design will be developed by the Design & Build Contractor.

For the purposes of the peer review the following distinctions have been made:

- The shore protection works relates to the structure at the edge of the reclamation which supports reclamation fill. The shore protector works are also referred in the peer review as a Containment Structure.
- The reclamation refers to the area of fill between the shore protection and the existing shoreline.

The configuration of the shore protection and reclamation works will ultimately be the responsibility of the Design and Build Contractor who will take a range of factors into account including:

- Mobilisation of marine plant
- Availability of plant and materials
- Access to the site for marine and land based plant
- The cost of transporting and placing fill and rock materials
- The cost of fabricating and placing concrete wall and armour units

These issues are discussed elsewhere in the report under the general headings of Logistics and Materials Investigations. This section will include a review of options presented by the DPR consultant for the design of the shore protection works.

4.11.2 Shore Protection Works

The design objectives for the shore protection works are to ensure that the:

- Structure is buildable given the constraints associated with the use of plant in inter-tidal conditions
- Shore protection works are robust and stable under the design wave and water level conditions
- Shore protection works are geotechnically stable under the design lateral earth and surcharge loading conditions
- Crest levels to the shore protection works (incorporating freeboard) and secondary protection walls mitigates the risk of flooding to the road, promenade and tunnels
- The design mitigates the risk of erosion to the base of the structure
- Accommodates highway and land drainage and allows the return of water to the sea through the shore protection works

It is anticipated that the shore protection works will be constructed on the basalt outcrop which characterises the foreshore in the areas where the reclamation will be built. The basalt will provide a good foundation for the shore protection works but it should be recognised that:

- The basalt has not been proven along the full length of the shore protection works and there could be areas where there are soft materials which may require more detailed investigation with respect to the competency of the foundations. It has been

recommended that a bathymetric and geotechnical site investigation survey are undertaken to investigate this issue.

- The basalt foreshore is highly uneven and it will not be possible to found concrete structures directly on the foreshore. Concrete structures will have to rest on a pre-prepared bed of material (probably rock fill)

The Main Report and the Appendix V Reclamation Report considers a number of potential design options for the Shore Protection works which includes: rubble mound seawalls; sheet piled walls; gabions; geobags; counterfort retaining walls; Tetrapods; Caissons and Geotextile Tubes. Many of these structures have rightly been dismissed by the DPR Consultant and a summary of the methods and comments are included in Table 4-2 Interestingly the options do not include a mass concrete gravity retaining wall or composite options which are frequently used in these situations.

It is considered that there may be some advantage in composite structures which incorporate a rock core which provide a containment structure for fill materials below MHWS tidal levels and a flat surface on which to place precast concrete units. Figure 4-12 shows a cross section of a similar structure which was proposed for the National Assembly reclamation in Bahrain. Similar composite approaches have successfully been used in Mumbai (see Figure 4-13) where Tetrapods have been used to provide protection to the wall and foundation.

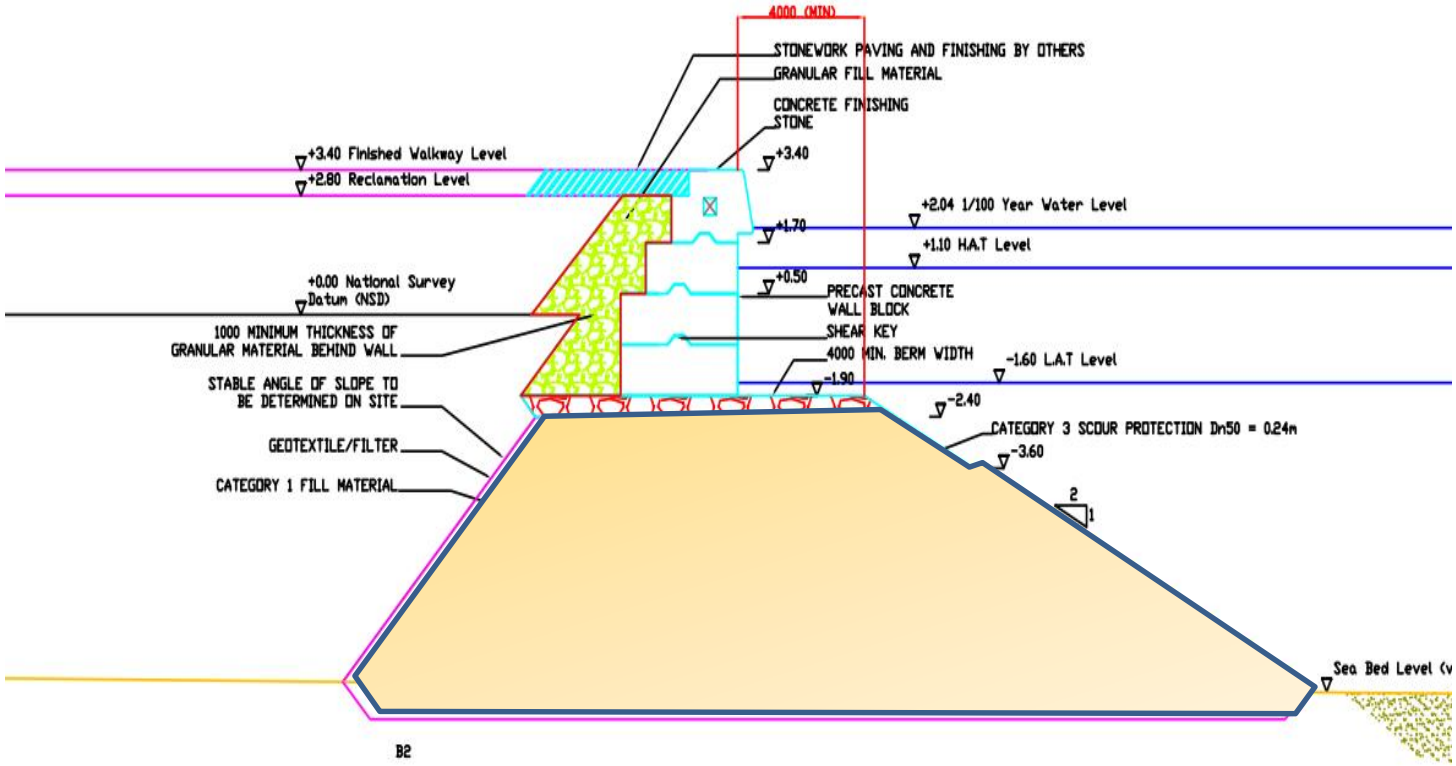

Figure 4-12 Composite Structure

Table 4-2 Summary of Shoreline Protection Options

Structure Type	Dismissed by DPR Consultant	Comments
Rubble mound seawalls	No	The DPR Consultant makes no comment on the viability of rubble mound structures but it is considered that a rubble mound structure protected by concrete or rock armour is a viable option given the logistical constraints. However, it is acknowledged that there are problems with the transportation of materials to the site.
Sheet piled walls	Yes	The DPR Consultant's view is correct. Driving sheet piled walls would not be economically viable
Gabions	Yes	The durability of gabions in the marine environment, particularly the splash zone would be a significant weakness in the sustainability of the structure.
Geobags	No	The use of geobags would not be economically viable
Counterfort retaining	Yes	The DPR's view is correct and the use of heavy pre-cast or in-situ concrete units is not a viable option
Tetrapods / Quarry Stone	No	The DPR's view is correct in that the construction of a shore protection structure protected by pre-cast concrete or rock armour could be viable. However, it is acknowledged that there are problems with the transportation of materials to the site.
Caissons	No	Rock filled caissons are recommended by the DPR Consultant as an effective method of providing shore protection. The use of the term Caisson in this context is probably incorrect as a Caisson is generally taken to mean a large concrete box structure which is floated into place. A more appropriate term would be rock filled concrete boxes which act as a gravity structure. However, the cost of rock filled concrete boxes can be high because of the requirement create a formwork void in the unit and reinforce the concrete. In addition, there is comparatively little advantage in using rock fill from a geotechnical perspective. This form of structure was considered and rejected for the Bahrain National Assembly Project on cost grounds

Figure 4-13 Nariman Point Mumbai

Figure 4-14 Failed Gabion Baskets, Poole, Southern England

4.11.3 Reclamation

As noted previously, the reclamation will be constructed on the rocky basalt foreshore and this is an ideal substrate on which to build reclamation. The complexity of a reclamation design increases substantially where there are: loose cohesionless soils; cohesive soils or soils with a high content of clay / silt present in the native substrate below the fill. If this is the case, then improvement / densification of the native material will probably be required to address settlement and / or consolidation of the finished reclamation. Settlement of these soil types frequently requires pre-loading or the introduction of band / wick drains which accelerates consolidation / settlement of these soil groups. Fortunately, the presence of the basalt horizon on the foreshore means that settlement / consolidation of the substrate is not an issue.

The design of the reclamation will be the responsibility of the Design and Build Contractor and it is likely that the Contractor will want to minimise the amount of improvement / densification works to the reclamation fill material placed on the foreshore. As such the Contractor will probably exclude the use of cohesive soils or soils with a high content of clay / silt. As noted above these soil groups are subject to long term consolidation and improvement require the use of more complex and expensive improvement techniques (e.g. pre-loading or band / wick drains). It should also be noted that these techniques can have a negative impact on programme due to the time required for consolidation.

It is highly probable that the Contractor will seek to use a granular material (sands, gravel etc.) for the reclamation fill. Granular material is also suitable for pumping (frequently known as hydraulic fill) and this can be a rapid and cost effective method of placing large volumes of fill using comparatively little land based plant. Whether

the material is placed as hydraulic fill or by back-tipping, the placed density of sands / gravel in water is normally "Very Loose".

Figure 4-15 Installation of Wick Drains (Central Area Reclamation Manila)

In the majority of circumstances there will be some improvement in density to the placed fill as a result of drainage and tidal action but the amount of densification is dependent on the overburden (weight), tidal range and porosity of the fill. In some cases, "natural" densification can improve in-situ densities from "Very Loose" to "Medium Dense". "Natural" densification is occasionally used in parts of the Middle East where conditions are appropriate. However, it should be recognised that where this is practiced the expectation is that the land developer is responsible for additional ground improvement and that buildings on the reclamation will be piled. Above MHWS tidal levels fill can be placed using conventional plant which is compacted in thin layers (say 250mm). Compaction of fill above MHWS is undertaken by conventional land based plant such as vibrating rollers.

The Main Report Appendix V makes reference to a number of improvement techniques including the use of wick / band drains, vibro-compaction, dynamic compaction and stone columns. The use of wick / band drains and stone columns is highly unlikely but it is considered that the use of dynamic compaction methods should be excluded due to potential impacts on the shore protection works and adjacent buildings.

The Main Report and Appendix V of the DPR makes no reference to specification requirements associated with density, settlement and

consolidation of road and this will be an important factor in the design. Accordingly, the development of a comprehensive Performance Specification taking into account the use of the reclamation as a highway is crucial. This should specify:

- Density requirements for fill above and below MHWS tidal levels
- Settlement/ consolidation requirements to ensure that settlements of the road are acceptable
- Monitoring requirements for density, settlement / consolidation

The density of fill materials below MHWS is usually monitored through the use of Cone Penetometer Testing (CPTs). Density above MHWS tides is normally monitored through Proctor Testing or Nuclear Densometers.

4.11.4 Conclusions and Recommendations

As noted in the introduction the Design and Build Contractor will be responsible for the design of the Shore Protection Works and the Reclamation. However, it is the duty of the DPR Consultant to prepare the Employer's Requirements which should include sufficient information to allow the design to be developed and the works to be built. As noted previously this includes the: Contract Data; Design Requirements; Performance and Materials Specifications. It is recommended that the DPR Consultant should include the following information into the Employer's Requirements:

Contract Data

- Bathymetric survey including: the reclamation strip, nearshore and offshore soundings
- Geotechnical site investigation to be undertaken on the foreshore by the DPR Consultant
- This extreme wave and water level analysis including consideration of extreme wave heights and overtopping to be undertaken by a competent organisation.
- The location of all existing outfalls, drainage ditches, tidal creeks and rivers which discharge into the sea.

Design Requirements

- The vertical and horizontal alignment of the highway to ensure that there is sufficient construction depth to accommodate drainage infrastructure and the highway
- The minimum shore protection crest, road and tunnel threshold levels derived from the extreme wave and water level analysis taking into account wave overtopping and freeboard.
- Minimum levels for the reclamation
- The width, invert and soffit levels required for all existing outfalls, drainage ditches, tidal creeks and rivers which discharge into the sea so that flood water can be safely discharged through the reclamation in a 1 in 100 year or other agreed return period event.

Performance Specification

- Density requirements for reclamation fill above and below MHWS tidal levels
- Settlement / consolidation requirements to ensure that settlements of the reclamation fill in relation to the design of the road are acceptable
- Monitoring requirements for density settlement / consolidation

Figure 4-16 Vibro-Compaction Lantau Island Hong Kong & Dynamic Compaction at Al Khiran in Kuwait

Materials Specifications

- Materials Specification for the materials which are likely to be included in the Contractor's design to ensure that materials used in the reclamation and shore protection are durable and fit for purpose. This includes rock for armour / core and reclamation fill.

It should be noted that this list is not exhaustive and should be carefully reviewed by the DPR Consultant. In addition, it is considered that the Employer and DPR Consultant should design and implement monitoring systems to:

- Independently check and verify the designs to ensure that they meet international standards and are in accordance with the Employer's Requirements
- Validates that the construction work conforms to the design and the Employer's Requirements.

4.12 Construction - Reclamation Methodology

4.12.1 General

The sections on Materials (Section 4.8), Logistics (Section 4.10) and Design of the Shoreline Protection and Reclamation (Section 4.11) has included discussion on the construction of the works primarily because the construction methodology cannot be separated from the availability of suitable materials, the logistical constraints which will also dictate the design of the works. In addition, it must also be recognised that the Design and Build Contractor will dictate the reclamation methodology based upon the particular skills of the Contractor and the availability of plant at the Contractor's disposal.

Another significant influence on the Construction Methodology was discussed in Section 4.10. At present the contracts are divided longitudinally along the length of the Coastal Road but there may be advantages in:

- Splitting the contract both horizontally and vertically so the reclamation contract is separated from the bridgeworks, tunnel and road contractors. As noted this allows each Contractor to concentrate on their own area of expertise rather than managing sub-contractors.
- Creating a Pre-Cast Concrete Fabrication Yard on the reclamation which would include a batching plant to provide concrete and concrete products to the whole of the development including the tunnels and bridges. This would overcome potential problems associated with the marine / land delivery of large concrete units to the site.
- The construction of a light materials handling jetty or causeway (probably including a conveyor) to deliver reclamation fill, rock core, aggregates, cement and other bulk products to the works. This would partially overcome problems of scheduling barge delivery of materials within short daily tidal windows. The facility would extend to deep water allowing the discharge of materials from marine vessels avoiding the need for double handling. It should also be noted that the jetty could be used by the tunnel contractor for the export of spoil.

It is recommended that these options are considered in the Master Plan for the Project so that the advantages and disadvantages of implementing these, and other, programming options can be understood.

Given the logistical issues and the large volumes of materials for the works it is likely that the Contractor or Contractors appointed to undertake the reclamation works will be Major International Dredging Contractors who have experience of similar works around the world. Accordingly, it is extremely important that the Employer's Requirements are robust containing the appropriate checks and balances on the construction of the works and that the Project

Master Plan is detailed and comprehensive to ensure that interfaces between Contractors are well defined.

4.12.2 Construction Methodology

The Contractor's programme will dictate the sequence of the supply of materials but it is highly likely that the first operation within the programme will be to form a Containment Structure to hold reclamation fill material. Whilst, it is likely that the Contractor will avoid intertidal working (particularly as the rocky foreshore means that there will be restrictions in the tracking of plant) the initial phases of the work will mean that land based plant will have to move the material along the foreshore from the barge delivery position to the point of placing.

It is likely that rock core material will be used to form the containment possibly up to MHWS tidal level. The grading of the material should be sufficiently large to ensure that it is not removed by the prevailing wave climate but this will be the responsibility of the Contractor. The material should be free of fines to mitigate the risk of pollution by fines in the water column. The DPR Main Report considers the use of Geotubes which have been used elsewhere to form containment structures. Geotubes are generally effective in situations where the foreshore or reef is exposed for a reasonably long time at low tide in order to fix and fill the tubes with hydraulic fill. This technique has been used successfully but is generally considered to be expensive.

The use of land based plant during this phase of work will mean the creation of safe plant refuges (high platforms) which are above MHWS tides. Again the likely solution would be the use of rock Material. The second phase of work would be the introduction of reclamation fill material in the void formed to the rear of the containment. As noted previously this material could be delivered by:

- Barge and moved to the point of placing by plant.
- Pump ashore methods using hydraulic fill
- Conveyor from a jetty or causeway

Due to restrictions in depth and manoeuvrability, it is unlikely that motorised or split hopper barges could be used to deliver material directly to the point of placing. The constraints associated with the use of barges was discussed in the Logistics section at this report and it is therefore considered that there could be significant advantages in the use of conveyors or pumped hydraulic fill material to form the reclamation.

Figure 4-17 Geotudes Amwaj Island Bahrain

Figure 4-18 Pollution Control Via Silt boxes Bahrain

Figure 4-19 Pump Line for Hydraulic Fill Bahrain

Figure 4-20 Hydraulic Filling Bahrain

The use of granular fill material will mitigate the risk of pollution through the suspension of fine sediments in the water column. However, the Contractor should make provision to mitigate the risk of sediment plumes forming during the filling process. This could be through the development of silt boxes or other measures. The DPR Main Report does not consider pollution and the Employer's Requirements should include a Water Quality Monitoring Strategy which is designed to monitor and evaluate water quality before, during and after construction. The water quality strategy should include water quality thresholds above which the Contractor should take action to mitigate pollution.

The formation of the containment structure and reclamation will probably progress in stages up the coast in a series of cells. Following the construction of the containment structure and the "first'' fill, land based plant will be able to track over the reclamation without tidal restrictions. Densification of material placed below MHWS tides could be undertaken by vibro-compaction or other appropriate methods.

It is envisaged that plant will place rock / precast concrete armour units “overhand” using machinery based on the fill thus avoiding problems with using plant on the foreshore and the attendant problems associated with inter-tidal working. Overhand placing of rock / precast concrete armour is not ideal but may be possible. It is then envisaged that the pre-cast capping / wall would be installed. Finally, the reclamation would be brought up to its final level in thin layers.

4.12.3 Conclusions and Recommendations

The construction of the reclamation is feasible and within the capability of a large International dredging Contractor but it should be noted that the design and construction cannot be separated from the availability of suitable materials, the logistical constraints. In addition, it must also be recognised that the Design and Build Contractor will dictate the design and construction of the reclamation based upon the particular skills of the Contractor and the availability of plant at the Contractor’s disposal.

As noted in the text the contracts for the reclamation are divided longitudinally along the length of the Coastal Road but it is recommended that the Project Master Plan is reviewed to consider the advantages and disadvantages of:

- Splitting the contract both horizontally and vertically so the reclamation contract is separated from the bridgeworks, tunnel and road contractors.
- Creating a Pre-Cast Concrete Fabrication Yard on the reclamation which would include a batching plant to provide concrete and concrete products to the whole of the development including the tunnels and bridges.
- The construction of a light materials handling jetty or causeway (probably including a conveyor) to deliver reclamation fill, rock core, aggregates, cement and other bulk products to the works.

In addition it is recommended that:

- A water monitoring strategy is developed to ensure that pollution due to the discharge of fines into the sea is controlled during construction. This should include thresholds above which action should be taken to mitigate pollution events.

4.13 Summary of Key Issues - Reclamation

The project is feasible but with many opportunities to significantly reduce the risks associated with large project. The key issues are tabulated below.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/suggestions
1	**Marine Environment** • **Water Level Fluctuation** • **Wave Climate**	The analysis are, in places, incorrect, inconsistent and confusing does not give any confidence that the process of assigning a design maximum still water level, significant wave height and wave period for design purposes has been understood. The NIO document considered prevailing "day to day" conditions. It did not include an assessment of extreme inshore wave conditions which could be used for the design of the shore protection works or assess overtopping to the reclamation onto the road	These deficiencies could potentially lead to a serious under design of the reclamation and coastal protection works. It is considered that the existing analysis is not fit for purpose and must either be substantiated with additional information or revised in accordance with best practice.	It is recommended that the assessment of wave climate and water level fluctuation should be undertaken by a competent organisation and individuals who have suitable experience and expertise. The benefits of implementing these recommendations would include: • Removal of uncertainty associated with the design requirements for shoreline protection • Significant reduction in uncertainty at tender stage allowing Contractors to prepare accurate pre-tender designs • More competitive tendering with all tenderers using the same baseline information.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/suggestions
	Flood Risk	There is little or no specific information or analysis within the DPR associated with: - • Maintaining existing flood discharges capacities from land to sea • Highway drainage outfalls to the sea • Crest and threshold levels for the coastal protection works	It is considered that the coastal road and reclamation infrastructure should facilitate and not impede the discharge of existing flows from the land to the sea. This includes all drainage ditches, sewers, tidal creeks and rivers which currently discharge directly into the Indian Ocean. The objective should be to ensure that there is no increase the risk of flooding to existing communities.	it is recommended that the Employer's Requirements incorporates the following details: - • The location of all existing outfalls, drainage ditches, tidal creeks and rivers which discharge into the sea. • The width, invert and soffit levels required for all of the above features • The vertical alignment of the highway
2	**Adequacy of** • **Bathymetric, Topographic Surveys** • **Geotechnical Data**	The bathymetric Surveys data does not include complete reclamation area. The extent of the basalt has not been proven either by topographical/ bathymetric survey or by geotechnical site investigation.	Limited number of surveys carried out to date and there will be significant uncertainty in the volume of fill material, evaluation of crest levels. Further, operational depth for marine plant is uncertain.	Additional surveys will be required to ensure that the contract is devised and executed with the minimum of uncertainties and the minimum of programme and cost impacts.
3	**Materials Investigation** • **Bulk Fill Material** • **Rock Products**	Investigations are very limited. The Materials Investigation Report does not include	There are significant shortfalls in material volumes identified in excess of any other use of spoil	As a matter of urgency, identify suitable resources conforming to appropriate material

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/suggestions
	• **Concrete**	information on the source or specification of rock materials.	arising from MML3 and/or CR Tunnelling etc. The availability of suitable reclamation materials within the immediate vicinity of Mumbai has not been conclusively proven within the Materials Investigation Report	specifications and develop materials and performance specifications to remove uncertainty and ensure quality and durability of different materials to be used in the project.
4	**Logistics** • **Overland Delivery** • **Marine Delivery** • **Transfer of materials within the site** • **Concrete Fabrication**	Not identified as a significant constraint.	Logistics is a highly significant constraint given restrictions of land transportation and difficulties of marine operations keeping in mind the operational tidal window, approvals required. The DPR currently envisages that the reclamation works contracts are split linearly along the length of the project with the contracts including shore protection, reclamation, road and bridge construction but this may not be the most efficient contract strategy.	Logistics is highly influential factor on the construction methodology and the logistical constraints/limitations need to be investigated as soon as possible by a Project Master Plan. It is considered that there could be opportunities to improve the Project Master Plan to benefit the wider aims of the scheme and have a positive impact on cost and programme. This could include revising the contract strategy, to include enabling works and concrete fabrication.

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/suggestions
5	**Choice of type of design for Reclamation and related structures**	The DPR is proposing specific methodologies and techniques which in some cases are inappropriate. The DPR makes no reference to the information and data to be supplied to the Contractor through the Employer's Requirements.	The Design and Build Contractor will be responsible for the design of the Shore Protection Works and the Reclamation. The Design and Build Contractor will take a range of factors into account including: - • Mobilisation of marine plant • Availably of plant / materials • Access for marine and land based plant • The cost of transportation • The cost of fabrication	In order to be able to prepare a competitive tender The Employer's Requirements should include sufficient information to allow the design to be developed and the works to be built. This includes: • Contract Data; • Design Requirements • Performance Specifications • Materials Specifications. it is considered that there the Employer implement monitoring systems to: - • Independently check and verify the designs to ensure the requirements specified. • Validate the construction work
6	**Construction** • **Shore Protection Works** • **Reclamation**	There is very little information in the DPR in relation to possible construction methodologies. There is no information on the controls to be placed on the Contractor during construction.	The construction of the reclamation is feasible and within the capability of a large International Dredging Contractor but it should be noted that the design and	it is recommended that the Project Master Plan is reviewed to consider the advantages and disadvantages of: - • Splitting the contract both horizontally and vertically

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/suggestions
		This includes: noise, water and air quality requirements.	construction cannot be separated from the availability of suitable materials and the logistical constraints. It must be recognised that the Design and Build Contractor will dictate the design and construction of the reclamation based upon the particular skills of the Contractor and the availability of plant at the Contractor's disposal.	to separate the reclamation from the bridgeworks, tunnel and road contractors. • Creating a Pre-Cast Concrete Fabrication Yard to provide concrete products to the whole of the works • The construction of a materials handling jetty/ causeway for the delivery of bulk products to the works. Water, air and noise pollution strategies should be developed for the works.
7	**Programme/Critical Path**	Not discussed in sufficient detail	Need to consider overall contract programme (irrespective of different construction packages)	Consider optimum selection of single or multiple package options and identify critical path

TUNNEL DESIGN

5 TUNNEL DESIGN

5.1 Introduction

The following notes refer to the DPR report for the Mumbai Coastal Road Project dated 18/2/15.

From the perspective of building roads, tunnels and more common infrastructure works which are largely driven by an appreciation of geotechnical and logistical considerations, it is vital to recognise the complexity of this project. The project will require work, at parallel and different stages, on & in: rock; soil; very soft ground; underground; over water; under water; in tidal zones; in flooded zones; and furthermore require the consideration of access, logistical and environmental concerns that will emerge for rural and very crowded urban sites; and, for new greenfield sites and old brownfield sites. So, given a relatively routine infrastructure requirement, the necessary range of field studies, of all possible forms, could not be greater, or, with more hurdles to be either overcome or to be avoided. This will demand close cooperation, careful planning and thoughtful execution to remain effective and efficient.

A thorough technical appraisal of the proposed works requires an overview of all conditions at site, including the actual (and/or potential) geological and engineering impacts of construction and maintenance whilst also recognising that it is necessary to work within local, national regulations and best practice requirements for public health and safety and for the potential and actual environmental impacts, as these too will affect the technical decisions made at this stage.

As from all major infrastructure developments, adverse impacts can arise dependent upon the method adopted to build: from noise, vibration, pollution (and dust), waste disposal, potential foundation disturbances, utility disruptions/changes and hydrological impacts, and they can extend over large areas. In the case of the Mumbai Coastal Road route, such issues are less likely to impact adjoining properties and infrastructure as the suggested route is attempting to avoid much of the existing infrastructure and to use open wetland, or, coastal strip, or, underground areas but severe problems can still emerge. And yet, despite, construction in 'clear' areas, the close proximity of urban sites will be influential as logistical capacity will be strained and as tunnels advance below urban areas. And yet, despite, construction in 'clear' areas, the close proximity of urban sites will be influential as logistical capacity will be strained and as tunnels advance below urban areas. Severe problems can still emerge. Sensitive areas and structures do exist within the current route corridor and the loss of amenity, even on a temporary basis, might still give rise to disputes. So, any attempt to move or to compensate these loses may require extensive proof of performance and high expectations of higher quality in their replacements.

These notes describes some of the issues which must be addressed in a manner which does not limit contractor options but does highlight factors which must be addressed.

5.2 Marine Environment and Tunnelling

Tunnelling in a marine environment, generally meaning to tunnel beneath the sea or open water, is not particularly different to that undertaken under land. Clearly, there is a greater perceived risk from flooding and this is true if tunnel portals are close to water but, if sufficient competent ground is between the open water and the tunnel crown, the difference is always going to be minimal.

Clearly, there are some additional risks and this relates to groundwater. Often the most difficult problems in tunnelling is in relation to the control of groundwater, which itself may lead to other

issues stability and other difficulties. If poor ground or a permeable zone is detected and is persistent between seabed and the tunnel, then the risk of flooding is immediately raised. Whereas, in typical tunnel flood scenarios the groundwater may surge and then ease as storage is depleted, the sea provides unlimited water storage and the only option for miners is to close off the supply whilst the inflow remains very high. There are many techniques to do this but these must be prepared, practiced and available at all times.

A further difference in land and marine sites may arise from the possible use of ancillary systems reaching from surface such as probing, investigation boreholes, grouting holes and ventilation shafts. These items may be costlier in the marine environment. The consequences of these limitations are various and many but they must not be ignored or avoided.

The marine or coastal environment can also provide opportunities for material supply and for spoil disposal should a tunnel heading be close to the sea.

Given the precise details of project which will involve considerable reclamation, a secondary use may be made of berthing and/or off-loading facilities in relation to tunneling works. Furthermore, opportunities might arise to export spoil as fill, reuse locally, or, to use it in some constructive marine endeavor.

5.3 Bathymetric and Topographic Survey Data including geophysical investigations

As well as routine layout and horizontal and vertical controls, it will be necessary to consider/provide additional or specific survey controls for marine operations (at a few kilometers) and for underground control near to tunnel portals.

Figure 5-1 Infrastructure at the Coast: Roads and Rail Links with Bridges, Piers, Embankments on Reclamation and Into Tunnels

Detailed bathymetric survey specifications must be issued (including with Sub-bottom profiling and side scan sonar) which are necessary to tunnel design in determining the elevation, thickness and cover of materials above the tunnel crown. Other surfaces and deeper levels will be related to ground surface during the course of geotechnical investigation (GI) studies, so confidence on reference ground level must be high. These same requirements, of course, relate to marine and land works. Seabed requires high definition taken from known tidal references (as well as, today, GPS direct elevation too). Accurately known control stations must be visible from sea and

abundant about the tunnel alignments. Bathymetric surveys are often conducted alongside marine geophysical surveys.

However, it must also be noted that shallow water marine surveys are often highly restricted by limited water depth, and near-shore, and tide related, sea conditions. Basic survey tools such as echo sounders, side scan and seismic systems need minimal water depths to work effectively. As a rule of thumb, a water depth equal to the depth of engineering interest below the seabed level at point of investigation is needed in shallow marine seismic studies. Other simpler systems may be employed to provide fuller data picture. Stereo photography, scanning, probing and line sounding is still highly valid when simple measurements are needed. Careful planning is needed and this needs to be specified.

Of course, detailed topographic surveys require also precise positioning and levelling to enable controls to be transferred underground during tunnel operations. In principal this should not prove too difficult. However it is necessary to understand and translate between several potential different schemes of survey control, which must be specified. There will also be a requirement to report, expressly, upon the survey controls used by all interested parties: MCGM; utilities; highways; private and commercial land ownership; admiralty (and tidal data); navy; coastguard; and others. Contractor shall be held responsible for any damage to any other properties unless adequate survey data is gathered from owners. And, in order to do this, it will be necessary to establish and utilise properly controlled (and translated) survey data.

Other surfaces and deeper levels will be related to ground surface during the course of GI studies, so confidence on ground level must be high to use later in reference to deeper features. Other systems such as laser scanning etc. are typically used when underground, so it is premature to apply this now, although other early uses may emerge in particular situations.

Survey control is not expected to be complete or universally tied throughout the route. Therefore, a project wide scheme must be set in-place and all construction and contractual survey and layout matters tied to that. It is essential that the scheme is complete and wide-ranging, sufficient for most imagined eventuality of dispute or construction need and to be independent of contractor or land-owner, both readily accessible and freely available to all. This needs an unambiguous statement within the DPR.

5.4 Land and Marine Geotechnical Data

The need for a serial, staged, survey phases, concerning general survey matters (e.g. traffic related surveys and topographic works can go on separately) is largely unnecessary except for specific issues and for the broad topographic picture covering the main route, which is likely to be sufficiently defined as per previous studies. However, it is necessary to find a common base plan and although new phases and parts will emerge in planning, of course it is important to ensure that they finally coalesce in a controlled way prior to final design and ultimately for construction. It is necessary to make early progress on utilities as these may affect many other aspects of routine working.

Ground investigations will need to use defined survey controls on a local basis, and in rare cases a specific site study may require early survey checking. Control points do therefore need to be established early and this process must be specified and detailed. These need to address both land and marine needs, either as line-of-sight or to use radio, GPS or other electronic systems.

In future works there are a number of key issues which require attention. A few key statements/key issues to assist this work are

necessary. In general, they are covered by national or international standards. These need to be stated as appropriate:

- **Ground Investigations for Roads:** General area coverage appears sufficient, however, rock should always be proven (as per international standards) and this is generally 3m into, to prove, rock head. A number of specific issues must be addressed in specifications.
- **Ground Investigations for Structures:** Structures require investigation at every principal point of ground loading. Spacing at 200m is likely to be insufficient. Furthermore, they must be investigated and studied not less than 3D depth below (D being a principal dimension, usually footing width) and generally 3m into, to prove, rock head, whichever is greatest. For other matters see below - Ground Investigations for Tunnels. Nevertheless, on the basis that confidence is high for good geological interpretation the spacing may be relaxed so long as adjacent holes do show the anticipated geology.
- **Ground Investigations for Tunnels**: Both rock (and soil) materials and masses must be assessed in rigorous and internationally accepted logging schemes supplemented by necessary laboratory and field tests and further by characterizations for rock mass assessments and for tunnel design schemes. In all cases, as qualitative and semi-quantifiable systems, it is common practice to apply multiple schemes and then to compare and contrast the results of each one. Considerable boring and coring to provide samples for inspection and testing will be required both from land and overwater locations.
- Spacing of holes should be as close as possible since the least risk (cost) is associated with knowledge; and underwater the knowledge is essential. However practical limits may allow engineers to widen separations in areas where the geology is seen to be regular and known. Again, on the basis that confidence is high for good geological interpretation the spacing may be relaxed so long as adjacent holes do show the anticipated geology.

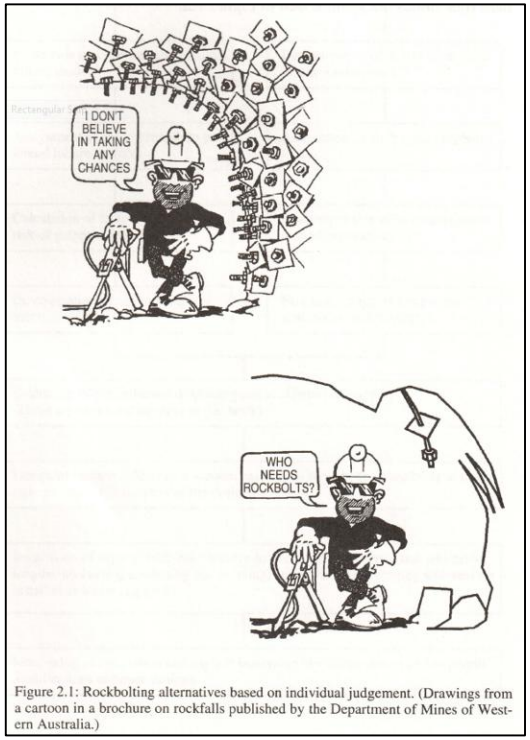

Figure 2.1: Rockbolting alternatives based on individual judgement. (Drawings from a cartoon in a brochure on rockfalls published by the Department of Mines of Western Australia.)

These investigations too should follow the basic parameters of scale, namely a reach of several diameters away from the structures; above, below and sideways. These stated guides will influence survey control needs.

A number of options may be applied to tunnel excavation selection. The choice is largely one of preference and a convincing argument from contractors to excavate as required.

The attached Table 5-1 shows some challenges that must be met by any selection. A default TBM should not be applied.

Once selection is made, or even in the making of a selection, for tunnels then:

- The collection and sufficiency of geotechnical data, including, the position and level of top surface, rock head, water bodies, tides and a full characterisation of overlying soils.
- Rock volume components (including weathering, strength, deformation characteristics) expressly as:
    - Rock material descriptions
    - Rock mass characterisation
    - Rock joint description and characterisation
    - Rock mass structure (disposition of natural discontinuity sets and faulting)
- Assessing strength and deformation of material and masses at engineering scales.
- Hydrological conditions including mass and joint permeability and transmissivity.
- Sufficient modeling and monitoring options to cover all design approaches.
- An assessment of in situ stress.
- Full appraisal of support types, by agreed codes, including protection, mesh, ribs, dowels, bolts, cast-concrete, shotcrete and FRS.
- Specialist testing needs wide range of excavation methodologies.
- Hydraulic / Hydrological studies
- Monitoring may be required to prove water flows and extents of water bodies. In this case pumping tests may be required, particularly for reclamation areas. However, in tunnel and routine works, more localised well tests and packer testing may provide sufficient data.

Utilities surveys are critical survey and should be made early. The detail of this process should be highlighted. It is clearly an issue which requires MCGM planning. The consequences of damage to utilities can be severe and it is important to have risk and procedures in-place to avoid inadvertent damage or disturbance or disruption. These include, power, oil, gas, telephone, water, sewerage, special services and other access lines such as line-of-sight services (microwave). All sighted, overhead, surface and underground (and submarine) services must be identified prior to any works. Legal and illegal services should be noted on plans, if possible. If plans are not accessible, then special care must be taken to advance carefully past likely services sites.

Land acquisition surveys is another aspect to be commenced as soon as possible, although much of the work is office based and should be in advance of field works, proof will be measured on site. Ownership plans should be made available to all interested parties working on the project to avoid issues.

Bulk natural materials surveys (various) is the search for bulk raw materials and the need to identify type, quality and quantity. Careful study of project requirements and the careful measurement of existing resources will be needed. Further special investigations may be needed in some cases.

Provisions must be made to search for existing resources and potential new sites and identify:

- Existing quarries and pits
- Potential new sites (land)
- Potential marine sites (dredging potential)
- Consideration of appropriate access routes to main sites
- Intermediate logistical corridors outside and within site area
- Studies for design options concerning lightweight fills, reinforced earth, and other design changes might be investigated.

5.5 Materials Investigation

A full scale materials investigation is recommended for the scale of filling is considerable. There is no doubt that marine sources and marine transport routes will dominate.

A materials investigation requires consideration of the engineering needs of the site to be filled. Generally, it is a flowing material, but clean and free draining materials allow rapid construction and avoiding settlement and consolidation issues and become and can be made stable very quickly or with minimum effort. Uniform sands are frequently used, when available, although any materials might be applied, they will usually be less attractive for a whole range of practical and financial reasons.

Materials are required for a whole range of purposes in even basic schemes the same is detail under Reclamation chapter.

And for other purposes of general and flexible pavement constructions, sub grade, road base, even asphalt supplies if the contractor wishes to bring his own asphalt plant as well as concrete plant and construction yard.

Depending upon the success of this search and potential for exploitation, it may be necessary to improve the performance of the available choice of materials with reinforcement systems such as geomembranes. Indeed, a further possibility is to employ light-weight fills beneath roadways, if reclamation capacity is limited. Obviously cost will balance the proportional use of natural materials and reinforcement systems.

Sub Grade surveys (SGS) will largely be part of GI surveys in general. Equipment for excavation and testing will be used simultaneously. Normally, SGS studies would not be limited to 1 meter. They would progress and investigate a range of values over depth.

5.6 Logistics

Logistics will define this project. The project is only feasible when the logistics can solve the movement of materials for reclamation filling; shoreline protection construction; road construction; and, tunnel disposal.

Given the crowded streets of Mumbai already at capacity, road access is not considered a feasible option except in emergency situations when traffic may have to be disrupted.

The entire design of the project will come from marine operations and will therefore require associated priming works. Jetties, harbour and quay walls may be necessary to facilitate the contractors operational plans and for the execution options of other road parts.

Great play made for use of tunnel spoil as fill material. However, the reality is that tunnels will unlikely provide much material since filling will largely take place before tunnelling and the production rate and reliability is unlikely to be high enough for major filling operations which are supplied by sea. Although it may play a small localised part in the filling process, the estimation of tunnel arising are required for

estimation of spoil areas which are given in detail under Reclamation chapter.

5.7 Construction - Tunnel Methodology

As the DPR is proposing methodologies, techniques or routes, then these must be based upon available evidence, clearly stated preferences (perhaps as owner instructions), or, based on facts obtained in the study to date. Outside of this condition, the DPR should not yet be promoting specifics but enable future studies that may assist an appropriate method selection, at the appropriate time. There is no preference given, at this stage, towards any particular design approach or generic construction method.

The Table 5-1 below describes a series of options for construction. These challenges are entirely optional. A good deal depends upon the choice of the contractor and preferences of the client. It is obvious that options are available and each are workable but they are dependent upon several factors. The main criteria for selection refer to flexibility of use, the impact on design (Hz/Vt curvature for instance), the scale of essential working areas (which will have to be provided in advance) and the nature of construction process (segmental / non segmental lining). Although efficient, a TBM has huge demands on space and materials supply in the form of lining segments. Other systems have much reduced land take and lining is generally pumped (i.e. cast in situ shutters) or sprayed (i.e. shotcrete) alongside other flexible systems of rock support. This flexibility might allow, for instance, entrance portals to be placed between existing properties, a few hundred meters from the coast and hence a shorter route and less obtrusive to existing infrastructure. Although some properties may be affected, such a scheme would be cheaper and shorter.

Table 5-1 Challenge Issues relating to Chosen Tunnelling Technique

Site Specific issue/ Technical Aspect	TBM (Tunnel Boring Machine)	RH (Road-Header)	D&B (Drill and Blast)	Combined RH & DB	Associated techniques, Notes, Warnings
Coastal, inter-tidal Marine environment risk	VL complex track access and train configuration	L Portal protection 'gates'	L Portal protection 'gates'	L Portal protection 'gates'	± for all techniques Water levels (MHWL) anticipated at or close to invert level
Scale of Work Site Areas (outside of tunnel portal)	VL As long as TBM train; very long; erection (cavern) area; reduce after starting	S Sufficient for Road-Header, Haulers/ Loaders	S Sufficient for Jumbo, Haulers/ Loaders	S Sufficient for wheeled equipment	TBM train typically very long and requires all train systems of marshaling and loading, unloading. RH and D&B typically wheeled systems and mobile and flexible support and loading
Construction supplies; Rock Support; emergency systems; Power supplies	VL pre-cast segment requires construction yards; storage areas; Concrete supply areas; high power supply	M small yards; small maintenance areas; Concrete-shotcrete supply areas; diesel / electric	M small yards; small maintenance areas; Concrete-shotcrete supply areas explosive stores (offshore?) diesel / electric	M small yards; small maintenance areas; Concrete-shotcrete supply areas explosive stores (offshore?) diesel / electric	Large and aligned sites are required for TBM systems. Small and dispersed sites can be utilized in RH and D&B systems, flexible and pumped into casts or sprayed shotcrete

Site Specific issue/ Technical Aspect	TBM (Tunnel Boring Machine)	RH (Road-Header)	D&B (Drill and Blast)	Combined RH & DB	Associated techniques, Notes, Warnings
excavation related stress; support demands	M Low stress due to circular cut; some over-space	S Optimized stress; no over-space	S Optimized stress; no over-space	S Can be Optimized no over-space	TBM yields circular opening; good for stress distribution but may involve considerable over cut for need. Others can cut to optimum for stress or need as required.
Spoil handling and disposal	L	M	S	S	TBM is semi continuous system of spoil delivery requires secondary handling or continuous disposal to dump. Other systems are cyclic
Excavation, probing and support risks	VL	M	S	S	Experience and likelihood of ground failure, or, inability to probe or handle surprise conditions
Construction contractor experience	VL	M	VL	VL	Good experiences in civil infrastructure for TBM and D&B RH is typically more mining related experiences

Site Specific issue/ Technical Aspect	TBM (Tunnel Boring Machine)	RH (Road-Header)	D&B (Drill and Blast)	Combined RH & DB	Associated techniques, Notes, Warnings
Recovery Risk	VL	M	M	S	Ability to handle unforeseen conditions. Because of flexibility of systems all eventualities of emergency support or treatments are possible or can be handled
Emergency access risks	VL	M	VS	S	TBM provides closed and tight machinery; others have open spaces and relatively free access
Pre-construction surveys, and, vibration monitoring	M	M	VL	L	Pre-construction surveys needed in all options not under sea
NOTES:	*D&B likely required for portals and cross-tunnels		*Explosives require special permissions		VL – Very Large; Very High L– Large; High M– medium; moderate S– Small; Low VS– Very Small; Very Low

The information available at this stage is considered minimal and not necessarily representative of current knowledge and/or capabilities of the Client, contractors or designers but it is not known at this stage what other data may be available or easily gathered. Therefore, at inception stage, it is considered pertinent to start at a broad level of technical appraisal and rapidly close in on appropriate solutions under the guidance of technical, commercial and program constraints as they are made known to the reviewers.

Although visual impacts are typically low for a tunnel construction (since tunnels are underground) it is not unusual for tunnels and other large excavations to have potentially quite severe impacts in urban environments, or, work to avoid the higher risks in shallow and underwater environments. There are of course a whole range of generic issues to be addressed but in general terms the appraisal will follow a similar path, as:

- Assessing the proposed outline design and the anticipated route
- Local geological environment and potential impacts
- Understanding the necessary site requirements and planning constraints for any given proposed scheme
- The gathering, appraisal and sufficiency of data for geotechnical matters (particularly when it may require additional lead time)
- The sufficiency and robustness for alternative methods of construction, support installation, final linings, monitoring, maintenance and repairs
- Assessing the design in managing construction risks and achieving quality of construction
- Criteria for choosing designers and constructors
- Long term durability of the construction

However, as alluded to in the section 5.1, there are a number of issues that are raised by tunnelling in general, but still more raised by the particular nature of this work, namely: hard rock materials, a large size, shallow depth and underwater.

Lacking at this stage from the DPR is a thorough assessment of the materials to be excavated and how these might perform in various schemes of excavation. Clearly it is impossible at this stage to have the full geotechnical site investigation reports, but a range of material classes can already be studied, e.g. Basalt, Tuff, Breccia as three principle material. Such tables of information will provide a better picture of potential works and may influence alignment choices as well as excavation system. It should be noted that few of the items discussed below are currently available in an accessible form. Although some modeling has been done, the nature of the modeling provides no further insights to the selection and excavation process.

An indication of the sort of technical details that will be considered, checked, and verified, in the course of a review is given in the following sections. The lists are not exhaustive or yet fully detailed as the checking and consideration may be complex and involve further analysis to be undertaken or further collection of data, however, they do give a flavor of the necessary consideration that must be given to any proposals.

Figure 5-2 Road-Header Tunnel 'Square' Efficient Shape in Competent, Homogeneous Rocks

Both rock (and soil) materials and masses must be assessed in rigorous and internationally accepted logging schemes supplemented by necessary laboratory and field tests and further by characterisations for rock mass assessments and for tunnel design schemes. In all cases, as qualitative and semi-quantifiable systems, it is common practice to apply multiple schemes (e.g. NGI-Q and RMR and others) and then to compare and contrast the results of each one. Considerable sampling and testing may therefore be required both from land and overwater locations as mentioned in section 5.4.

In summary, as a large public infrastructure construction, risks must be low and designs must be robust and durable. A few key considerations are brought to mind at this stage.

Each of the lists below represent only key aspects of design, some of which are addressed (highways for instance), others not (shallow depth for instance), in the DPR. Each of these items must be carefully considered against each of the excavation options and each of the route options.

Highways

- Size – increased scale and capacity of support requirements
- Public access site - robust and low risk design options
- Ventilation; lighting; fire risks - high design priorities
- Deep portals and long ramps
- Vertical and horizontal grade limits

Shallow depth

- Low stress, however, consequence can be high support loads as little stress redistribution might arise in 'loose and weathered' surface rocks. At deep levels, natural rock arching reduces load on support to a nominal level in the shadow of the rock-arch. At shallow levels in loose or weathered rock, the entire rock mass, from crown to surface, may be carried by supports.
- Cover (soil/seabed) above the crown must be well defined as this provides the effective roof cover and a short-term impermeable or semi-permeable barrier to the ingress of water from the sea above.
- Weathered rock and soil is generally less strong, more variable, less reliable and is more likely close to surface than fresh rocks. Local variations can lead to narrow zones and irregular levels which may not be detected but can be intercepted during tunnelling. These may give rise to loose, weak sections requiring difficult support systems but also may frequently be conduits for heavy and persistent flood water.

- The consequence of many of the above may lead to loose blocks, key-block and largely kinematic controls on rock block failures.

Figure 5-3 Twin TBM Bores Opening into Cavern

Submarine

- water ingress potential is high if a direct or free-flow route exists between the sea and tunnel level
- inaccessible to surface/rock head unless plant is available to work over water, either floating or jack-up, to provide additional access to problem areas or for remote repair.
- Finally, on the technical review lists, there are a few issues already known for the particular and route proposals which may lead first considerations in the review.

Local Knowledge of Site

- urban environment
- crowded environment; public will never be far from site possibly to be considered in several different activities, safety is a concern.
- road access will undoubtedly be strained and transport of goods, and disposal issues will be considerable, this must be avoided by primary selections of construction and logistic systems.
- water access may be a huge benefit in this scheme. However, specific construction schemes may be required to create the project infrastructure.

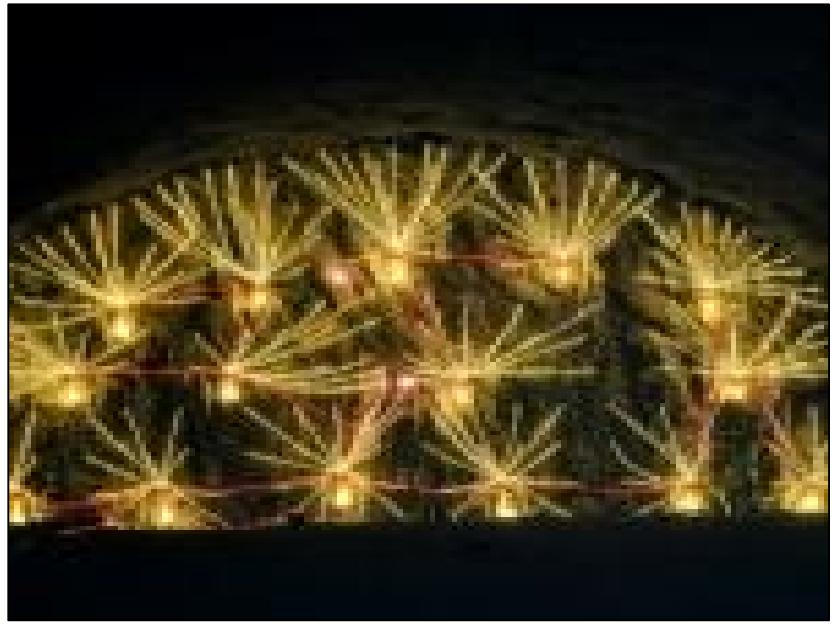

Figure 5-4 Lighting Up the Face as D&B Tunnel Shot-Fires

Geology

- Deccan Traps is well documented although locally may need confirmation
- Much of tunnelling will be along-strike so features such as bedding planes and flow-surfaces will be running along the length of the excavation.
- It may be feasible to select and follow the natural geology along or within preferred rock types which are easier to tunnel.
- local coastline is accessible to investigate conditions to provide hints at depth
- seabed conditions; A veneer of impermeable clay will exist in some parts and must be investigated. A veneer of impermeable clay does exist in some parts and must be investigated

5.8 Flood Risk

Flood risks are real for the tunnel. Both from internal water break through but also from sea at the entrance, due to storm surge or other exceptional conditions. Clearly methods will be considered for the former during tunnelling operations. The latter case will require other ad hoc protections, possible of a form that can be temporarily placed and removed again. Such barriers will protect the works from significant water ingress although would be prudent not to continue working during exception high water events if they pose a risk to working underground.

The scale of protection measures and ease of evacuation are considerations in excavation method selection.

5.9 Conclusions and Recommendations

The DPR for tunnels should provide sufficient details for designer and contractor to demonstrate their abilities to complete the work as planned. It will also be able to test their ingenuity, design skills, technical knowledge and management skills to ensure that the contract is devised and executed with the minimum of surprises and minimum of program or cost changes. It is hoped that a close engagement can be achieved between reviewers and contractors/ designers which results in a mutually beneficial and smooth progression into the execution phase.

Great play made for use of tunnel spoil as fill material. However, the reality is that tunnels will unlikely provide much material since filling will largely take place before tunnelling and the production rate and reliability is unlikely to be high enough for major filling operations which are supplied by sea. Although it may play a small localised part in the filling process, the estimation of tunnel spoil is required for the predicted scale of spoil areas and perhaps to imagining enhancements to reclamation facilities.

5.10 Summary of Key issues - Tunnelling

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
1	**Adequacy of Tunnelling Surveys**	Various Surveys have been identified in the DPR.	Limited number of surveys carried out to date	Additional surveys will be required to ensure that the contract is devised and executed with the minimum of uncertainties and the minimum of programme and cost impacts.
2	**Choice of type of design for each section-Tunnel**	The DPR is proposing specific methodologies, techniques	The tunnelling methods are prescriptive.	Methodologies/techniques need to be rigorously justified based on available evidence, clearly stated preferences, or based on facts obtained in the study to date.
3	**Materials Investigation**	Investigations are very limited.	There are significant shortfall in material volumes identified in excess of any other use of spoil arising from MML3 and/or CR Tunnelling etc.	As a matter of urgency, identify suitable resources conforming to appropriate specifications
4	**Logistics**	Not identified as a significant constraint	Logistic will define this project. Logistics is a highly significant constraint given restrictions of land transportation and tunnel disposals.	Logistics is highly influential factor on the construction methodology and the logistical constraints/limitations need to be investigated as soon as possible by a Project Master Plan Consideration of an enabling contracts to front load the works
5	**Tunnelling Methodology**	Prescriptive Methodology without geotechnical basis	Alternative methodologies should not be excluded by the tender process	Execute detailed geotechnical investigations to ensure selection of optimal methodology

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
6	**Programme/Critical Path**	Not discussed in sufficient detail	Need to consider overall contract programme (irrespective of different construction packages). Lack of sufficient information for bidding purpose.	Consider optimum selection of single or multiple package options and identify critical path Sufficient details for designer and contractor shall be included to warrant competitive pricings.
7	**Safety and Security**	Not discussed in sufficient detail	The safety and security of the coastal road including tunnel facility is paramount.	Safety and security related documents and plans required.

ENVIRONMENTAL IMPACT ASSESSMENT

6 ENVIRONMENTAL IMPACT ASSESSMENT

6.1 Introduction

The Mumbai Coastal Road project is proposed to be constructed on a combination of road based on reclamation, bridges, elevated roads and tunnels on western side of Mumbai and has largely been debated because of its impact on the cultural heritage in the project area, along with environmental impacts due to the reclamation of land along the coast.

This section is divided in seven main areas:

- Methodology adopted for review of EIA and SIA Reports
- Adequacy of reported Baseline Environmental data
- Sufficiency of Regulatory and Institutional Regime
- Identification of Impacts
- Impact mitigation and enhancement measures
- Adequacy of Environmental Management Action Plan
- Continuous public consultation and participation

Each area is discussed in the following sub-headings:

6.2 Methodology Adopted for Review of EIA and SIA Reports

6.2.1 Environmental Impact Assessment

The Environmental review verifies the natural setting of the project zone, the appropriateness of the collected baseline data, proper identification of the anticipated environmental impact and adequacy of mitigation measures to minimize the adverse impacts. The prevailing institutional and legislative setup of the Government of India (GOI) has been followed. The review also takes into account the mechanism for ensuring effective implementation of the environmental safeguard measures at different stages of the project.

Institutional responsibilities for the implementation of the suggested management plan have also been identified as part of this task.

The EIA Notification 2006 and its subsequent amendments issued in 2009, 2011 and 2013, IRC: 104-1988, “Guidelines for Environmental Impact Assessment of Highway projects, MoEF & CC publication 2010 “Environmental Impact Assessment Guidance Manual for Highways and Guidelines on preparation and implementation of Environment Management plan (IRC:SP:108-2015) had been referred.

6.2.2 Social Impact Assessment

The Social Impact assessment will be reviewed in the light of RFCTLARRA. The Government of India has brought in to force a new Act viz., the "Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013" (RFCTLARRA) with effect from 1-1-2014. Section 103 of the said Act provides that it shall be in addition to and not in derogation of any other law for time being in force and that Section 107 provides that the Act shall not prevent any State from enacting any law to enhance or add to the entitlements enumerated under the said Act which confers higher compensation than payable: and made provisions for R&R which is more beneficial than benefits under the RFCTLARRA Act-2013.

It will be also review that through the public consultation the project ensures that the affected population and other stakeholders are Informed, consulted, and allowed to participate actively in the development process. Consultation has been carried out in ways appropriate for gender-based and other differences among the stakeholders. The findings of consultations have been incorporated

in the design of the proposed alignment of the project section and were included in the mitigation measures suggested.

That during implementation and monitoring stage, information will be disseminated to project affected persons and other key stakeholders in appropriate ways. This information will be prepared in Hindi and Marathi/local languages as required, describing the main project features including the entitlement framework. It will ensure the following:

a. That the vulnerable groups, (disabled, elderly persons, women and children, indigenous peoples) have been identified and shall be given additional support and assistance under the project;

b. All common property resources (CPR) lost due to the project will be reconstructed or compensated by the project;

c. Information related to the preparation and implementation of resettlement plan will be disclosed to all stakeholders and people's participation will be ensured in planning and implementation;

d. Appropriate grievance Redressal mechanism will be established at project and state levels to ensure speedy resolution of disputes;

e. An effective monitoring and evaluation mechanism will be established to ensure consistent implementation of resettlement activities planned under the project including third party monitoring.

6.3 Adequacy of Reported Baseline Environmental and Social Data

The base line description /data collection should take into account the existing and proposed developments in the area so that cumulative impacts can be assessed.

A Land use map of the study area drawn to a scale of 1: 25,000 based on recent satellite imagery delineating the crop lands (both single and double crop), agricultural plantations, fallow lands, waste lands, water bodies, built-up areas, forest area and other surface features such as railway tracks, ports, airports, roads, and major industries etc. have not been incorporated in the report(also a requirement of EIA report as per Standard TOR issued by ministry in April-2015), followed by ground truthing and also through secondary data sources.

A detailed ground surveyed map on 1:2000 scale showing the existing features falling within the right of way namely trees, structures including archeological & religious, monuments etc. if any should be attached in the EIA Report along with the NOC from the Archeological Department (if the structure falls between 100m to 300m from the edge of the road).

The nearest IMD meteorological station from which climatological data have been obtained has not been mentioned.

Water resources discussed under climatic conditions needs to be discussed elsewhere.

For EIA studies the monitoring period is generally for a season in this report monitoring has been conducted for a month only. As per TOR air quality monitoring should be carried out as per the new notification issued on 16th November, 2009.

The Social demography has other components like, scheduled castes, scheduled tribes, religion, literacy rate, languages spoken etc., which has not been mentioned in the report.

6.4 Sufficiency of Regulatory and Institutional Regime

The proposed project does not completely fulfill either of the criterions described for Category A or B, i.e. the proposed alignment

is a coastal road which is 34.56 km (less than 100km) and it is not a national/state highway (As per the EIA Notification of MoEF & CC issued on 14th September, 2006, and its subsequent amendments (2009, 2013) a National or State highway development or expansion projects fall in either Category A or B of the schedule of the notification). Hence, there is no need of obtaining Environment Clearance from Ministry of Environment and Forests (MoEF) for which an EIA/EMP study is a primary requirement. However, the proposed alignment passes through coastal regulation zone (CRZ) as per the Coastal Zone Management Plans (hereafter referred to as the CZMPs) of Mumbai and Navi Mumbai. Hence application for approval from Maharashtra Coastal Regulation Zone Management Authority (MCZMA) and MoEF was put with a request for amendment to Coastal Regulation Zone (CRZ) notification, 2011.

The Union Ministry of Environment and Forests (MoEF) issued a final notification to allow reclamation for a coastal road. On 30th December 2015 the project has been granted clearance for constructing coastal road on 150 ha of reclaimed land and also diversifying the mangroves forest for non-forestry purposes.

6.4.1 Additional Applicable Regulations

Some of the Environmental Legislation Applicable and not mentioned in the EIA document of DPR consultant are mentioned below:

a. Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013;

b. Central Motor Vehicle Act,1988;

c. The Right to Information Act,2005;

d. The Flyash Notification, 2008 as Trombay Tata Power plant is 12km away from project site;

e. Hazardous Wastes (Management and Handling) Rules, 1989;

f. Public liability and Insurance Act ,1991;

g. Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996;

h. Mines and minerals(Regulation and Development) Act 1957 as amended in 1972;

i. The Building and Other Construction Workers (Regulation of Employment and conditions of Service) Act 1996;

During the construction stage, some of the key statutory requirements that need to be obtained by the Contractor as part of mobilization (pre-construction) have been listed in the table given below, needs to be mentioned in the EIA Report.

Table 6-1 Statutory Clearances to be obtained by the Contractor

Sr. No.	Clearance Required for	Statute under which clearance is required	Statutory Authority
1	Hot mix plants, Crushers and Batch Mix Plants	Air (Prevention and Control of Pollution) Act, 1981 and Noise Pollution (Regulation and Control) Rules, 2000	State Pollution Control Board
2	Storage, handling and transport of hazardous materials	Hazardous Waste (Management and Handling) Rules, 1989 and Manufacturing, Storage and Import of Hazardous Chemicals Rules, 1989	State Pollution Control Board
3	Location/ layout of workers camp, equipment and storage yards	Environment Protection Act, 1986 and Manufacturing, Storage and Import of Hazardous Chemicals Rules, 1989	State Pollution Control Board
4	Quarries (in case of opening of new quarries)	Environment Protection Act, 1986	Dept. of Mining; Concerned District Administration
5	Discharges from Labor Camp	Water (Prevention and Control of Pollution) Act, 1974	State Pollution Control Board
6	Permission for withdrawal of groundwater for construction	Environment Protection Act, 1986	State Ground Water Board
7	Permission for sand mining from river bed	Environment Protection Act, 1986	Irrigation Department; Concerned District Administration
8	Disposal of bituminous wastes	Hazardous Waste (Management and Handling) Rules, 1989	As per state norm/Local Civic Body
9	Tree felling permission	Indian Forest (Conservation) Act, 1980	Maharashtra State Forest Department, MoEF & CC
10	Permission to store Hazardous Materials	Waste Management and Handling Act 1989	State Pollution Control Board

Sr. No.	Clearance Required for	Statute under which clearance is required	Statutory Authority
11	Storage of Explosive Materials	The Explosive Act (& Rules) 1884, 1983	Chief Controller of explosives, Petroleum & Explosive Safety Organization

6.4.2 Other Applicable Laws

Environmental issues during road construction stage generally involve equity, safety and public health issues. The road construction agencies require complying with laws of the land, which include inter alia, the following:

a. Workmen's Compensation Act 1923: The Act provides for compensation in case of injury by accident arising out of and during the course of employment;

b. Contract Labour (Regulation and Abolition) Act, 1970: The Act provides for certain welfare measures to be provided by the contractor to contract labour;

c. Minimum Wages Act, 1948: The employer is supposed to pay not less than the Minimum Wages fixed by appropriate Government as per provisions of the Act;

d. Payment of Wages Act, 1936: It lays down as to by what date the wages are to be paid, when it will' be paid and what deductions can be made from the wages of the workers;

e. Equal Remuneration Act, 1979: The Act provides for payment of equal wages for work of equal nature to Male and Female workers and not for making discrimination against Female employees;

f. Child Labour (Prohibition and Regulation) Act, 1986: The Act prohibits employment of children below 14 years of age in certain occupations and processes and provides for regulation of employment of children in all other occupations and processes. Employment of child labour is prohibited in Building and Construction Industry;

g. Inter-State Migrant Workmen's (Regulation of Employment and Conditions of Service) Act, 1979: The inter-state migrant workers, in an establishment to which this Act becomes applicable, are required to be provided certain facilities such as housing, medical aid, travelling expenses from home to the establishment and back, etc.;

h. The Factories Act, 1948: The Act lays down the procedure for approval of plans before setting up a factory, health and safety provisions, welfare provisions, working hours and rendering information-regarding accidents or dangerous occurrences to designated authorities;

i. Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996: The Rules provide for mandatory preparation of On-Site Emergency Plans by the industry and Off-Site Plans by the district collector and the constitution of four tier crisis groups at the centre, district, and local levels for the management of chemical disaster.

In addition, the methods of measuring air pollution should be in conformance with IS: 5182-1977 and in case of noise pollution, IS: 3028-1980 for measurement of noise emitted by moving road vehicles; IS: 4758-1968 for measurement of noise emitted by machines; IS: 10399-1982 for measurement of noise emitted by stationary road vehicles are to be followed. As regards Highway aesthetics, use of provisions made in IRC: SP: 21-1979 - Manual on Landscaping of roads and its subsequent revised versions are to be followed. Some other references include the Indian Roads Congress (IRC) Guidance note on Highways, May 2011 and Guidelines on preparation and implementation of Environment management plan (IRC:SP:108-2015) are to be referred.

6.5 Identification of Impacts

6.5.1 Impact on Biodiversity

The project is located within 10km of the Sanjay Gandhi National Park (Borivali National Park) for which a map duly authenticated by Chief Wildlife Warden showing these features vis-à-vis the project location and the recommendations or comments of the Chief Wildlife Warden thereon should be attached in the EIA Report.

The possibilities of relocating the existing trees which are impacted by the project have not been explored.

6.5.2 Impact on Coast Line

As per the standard TOR uploaded on website by MOEF & CC, if the proposed route involves tunneling, the details of the tunnel and locations of tunneling with geological structural fraction should be provided. In case the road passes through a flood plain of the river, the details of micro drainage, flood passages and information on high levels flood periodicity at least of last 50 years in the area should be examined and included in the EIA report.

The study which is going on Coastal Protection needs an inclusion in the EIA Report.

State of Maharashtra has embarked on a nine-year program (2010-2019 Executing Agency: Maharashtra Maritime Board) to develop and implement sustainable methods to manage its shoreline and also meeting the needs of stakeholders and the environment. The expected outcomes are:

1. Develop a sustainable management structure and management plans for shorelines i.e., Promote natural protection measures - Develop and vegetate dunes, plant mangrove or other trees for protection or shelter.
2. Reduced coastal erosion and instability- Key areas of intervention include navigation inlets and training of river and creek mouths.
3. Enhanced in-state capacity for shoreline planning and development - like water quality improvement, dredging, reclamation, etc.

6.5.3 Impact on Physical Environment

Details of sand quarry, borrow area and their rehabilitation is not included in the EIA report prepared by DPR consultant.

Prediction of noise levels should be done by using mathematical modeling at different representative locations and especially within the two tunnels. Points of resonance and heightened vibrations should be studied for underground tunnels so that adequate mitigation can be done of the same.

Prediction of impact on ambient air quality using appropriate mathematical model, description of model, input requirement and

reference of derivation, distribution of major pollutants and presentation in tabular form for easy interpretation shall be carried out within the tunnels and all along the coastal roads as wind flow reversal in day and night time may support the air pollutant accumulation at critical locations.

If the proposed route is passing through low lying areas, details of fill materials and initial and final levels after filling above MSL should be given in the report.

Details of water quantity required and source of water including water requirement during the construction stage with supporting data and also categorization of ground water based on the CGWB classification is not given in the report.

Provision has not been made for oil and grease removal from surface runoff in the report.

Mean sea-level-rise trends along the Indian coasts are about 1.30 mm/yr. During construction deforestation of mangrove for land clearance will generate greenhouse gasses such as CO_2. At the same time, operation of construction machines and construction activities generate the CO_2. Post construction greenhouse gas may increase by the increase in traffic. Hence all the components participating climatic change need severe mitigative measures.

6.5.4 Impact on Social Environment

The Social Impact assessment is missing in the report.

The final alignment has been frozen based on technical and environmental feasibility only, social impact assessment report on different alternatives and its comparative cost benefit analysis (based upon number of persons displaced, affected, Community property relocated) is lacking.

6.6 Impact Mitigation and Enhancement Measures

Specific impact mitigation measures have been proposed in the EIA report. The environmental enhancement measures are intended to provide value addition to the proposed project.

6.7 Adequacy of Environmental Management Action Plan

The Environmental Management plan outlines existing and potential problems that may adversely impact the environment and recommends corrective measures where required. Also, the plan outlines roles and responsibility of the key personnel and contractors who are charged with the responsibility to manage the proposed project site.

Management plan for reclamation area, coastal protection and soil erosion and sediment management should be formulated.

Guidelines on preparation and implementation of Environment management plan (IRC:SP:108-2015) should be referred for a fool proof EMP.

Management plan for follow-up environmental monitoring, environmental recovery plan for closedown or abandonment shall be prepared.

Risk analysis and contingency planning shall be included.

6.8 Continuous Public Consultation and Participation

The public consultation is not included in the report. The social impact assessment due to the proposed construction of road, details of the properties, houses, businesses religious and social places etc. activities likely to be affected by land acquisition and their financial loses annually, are not given.

Detailed R&R plan with data on the existing socio-economic status of the population in the study area and broad plan for resettlement of the displaced population, site for the resettlement colony, alternative livelihood concerns/employment and rehabilitation of the displaced people, civil and housing amenities being offered, etc and the schedule of the implementation of the project specific R&R plan are not given.

The EMP implementation cost is not included in the report.

6.9 Conclusions and Recommendations

The Draft EIA report is in accordance with the generic structure as given by MoEF & CC.

The public consultation needs to be carried out and included in the report. The social impact assessment due to the proposed construction of road, details of the properties, houses, businesses religious and social places etc. activities likely to be affected by land acquisition and their financial loses annually, are to be covered in the report.

Detailed R&R plan and the EMP implementation cost shall be included in the report.

Anticipated environment impact and forecasting of air and noise pollution using mathematical models shall be included. Guidelines on preparation and implementation of Environment management plan (IRC:SP:108-2015) should be referred for a fool proof EMP.

Table 6-2 Key Issues of EIA & SIA

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
1.	Erosion and Sedimentation	Very little is discussed in DPR	Land Reclamation may increase erosion and sedimentation	Mitigation measures are to be incorporated for both aspects
2.	Topography Flood plains/ coastal belt	Not discussed	Topography of Flood plains & coastal belt will change	Impacts due to change in topography needs inclusion in report
3.	Vulnerability to subsidence, in Reclaimed zone	Not discussed	Information based on secondary source may be furnished	Mitigation measures are to be incorporated
4.	Materials Availability	Inadequate	Quantity of Natural resources required for the project should be detailed out	Carbon Foot prints are to be calculated from the same
Climate, Air Quality and Noise				
5.	Micro-climate Change, Global Warming, accelerated sea level rise (due to potential global warming climate effects), seawater intrusion, flooding, lithoral transport	Not discussed	Mitigation measures are to be suggested for the same	Impacts of construction on climate change need to be incorporated
6.	Air Dispersion Model, Noise Impact from Traffic	Not discussed	Ground level Contours of CO, HC and PM_{10} and $PM_{2.5}$ are to be studied	Mathematical modelling is Suggested

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
Coastal Hydrodynamics				
7.	Hydrodynamic simulations	Not discussed	The same can be reviewed from secondary sources/simulation studies	Mitigation measures are to be suggested for the same
8.	Impacts on current flow trends and velocities	Not discussed	The same can be reviewed from secondary sources/ simulation studies	Mitigation measures are to be suggested for the same
9.	Impact on long term shoreline changes	Not discussed	The same can be reviewed from secondary sources/ simulation studies	Mitigation measures are to be suggested for the same
Hydrology				
10.	River sediment spreading and settlement	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
11.	Tidal Flushing	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
Biological System				
12.	Habitat Damage	Not discussed	The same can be included in biodiversity report	Mitigation measures are to be suggested for the same
13.	Drainage interceptor (Drainage and streams for biological communities)	Not discussed	The same can be included in biodiversity report	Mitigation measures are to be suggested for the same

Sr. No.	Issue	DPR	Peer Review observation	Recommendations/ Suggestions
14.	Migratory route/crossing of wild animals and birds (outside designated protected areas)	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
Socio- Economic Systems				
15.	Land use Change/ Settlements	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
16.	Drinking water sources	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
17.	Demographic change	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same
18.	Livelihood of those who are dependent on the sea resources (fishermen and tourism operators)	Not discussed	The same can be reviewed from secondary sources	Mitigation measures are to be suggested for the same

CONSTRUCTION COST ESTIMATES

7 CONSTRUCTION COST ESTIMATES

The DPR consultant has submitted Draft Project Report Volume-V, Vol-V Cost Estimate & Rate Analysis (South & North) Note No. 8098/E/DN-09 Rev. No. (R1) dated 24/02/2015 for Mumbai Coastal Road Project. The document has been reviewed and the comments are presented as below:

Table 7-1 Observations on Rate Analysis, Cost Estimate & BOQ (South)

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
1.	Abstract / General	Other ancillary costs are not added.	It is suggested to allow cost provision for following heads over Civil cost, • Contingencies • Agency charges • Quality control charges • Road Safety audit charges • Supervision Charges • Escalation Charges • Utility & Environment Charges • R & R cost • Forest Clearance • Land acquisition Cost

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
2.	Rate Analysis	It is observed that rates are used from following SOR's. MCGM SOR – 2013 Chembur SOR – 2012-13 Thane DSR – 2013-14 Jaipur PWD SOR MMRDA ongoing works	SOR's of current year may be used or appropriate escalation may be applied for the available SOR. For items not available in SOR separate Rate Analysis shall be carried out.
3.	Rate Analysis	Item description not found in Rate Analysis of Typical Land Filled Road for item code New & BW-4.53.	Please include item description.
4.	Rate Analysis	It is observed that Rate Analysis is provided for each and every section (i.e. Reclamation of Land, Road on Land Filled, Structure, etc.)	It is suggested that single Rate Analysis should be provided for the entire project covering all the items of the project as a different volume.
5.	BOQ for Reclamation of Land – South	It is observed that for Item Code 12a &12b, reclamation area mentioned under Item Description has not been used for quantity calculations. Also, depth of fill taken for Item code 12b is 0.050 m.	This may be reviewed/ included/ amended as necessary.
6.	BOQ for Reclamation of Land – South	It is observed that earthwork for reclamation of land is calculated considering average depth of fill for entire reclamation area. However the basis of arriving at average depth is not clear.	The calculation of depth need to be carried out carefully, since it has great impact on the quantity.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
7.	BOQ for Reclamation of Land – South	It is presumed that DPR Consultant has ensured that required quantity & quality of fill is available at identified borrow areas.	This may please be ensured Logistics needs to be carefully planned supplement by overall project Master Plan to avoid delays & overruns. This will also help in getting a competitive pricing from bidders.
8.	Road Furniture	It is observed that Quantity for road side furniture, sign boards, etc are calculated for each items individually. (Eg.: Land Filled Road, Bridges, Interchanges, etc.)	Comprehensive location plan of Road Furniture shall be made available to avoid any omission and duplication of road furniture.
9.	Bituminous work	It is observed that extra cost for compacting bituminous course with Pneumatic Roller is considered for bituminous concrete; however the rate for bituminous concrete in rate analysis is inclusive of rolling with Pneumatic Roller.	This may be reviewed/ included/ amended as necessary.
10.	BOQ for Structures	It is observed that depth of piles considered for estimation is same for all the structures i.e. 25m. However the basis of this constant depth used is not clear	This may be reviewed/ included/ amended as necessary.
11.	BOQ for Structures	It is observed that the composition for wearing coat considered is 6 mm Mastic Ashpalt + 50 mm Dense Bituminous Macadam + 25 mm Bituminous Concrete which does not match with any of the Bituminous Wear Coat Type given in section 2702.1 of MoRT&H (Fifth Revision)	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
12.	BOQ for Tunnel at NCPA – South Side Quantity Estimation	It is observed that for Sr. No. 9 (c) rate and amount are missing.	This may be reviewed/ included/ amended as necessary.
13.	BOQ for Tunnel at NCPA – South Side Quantity Estimation	It is observed that measurements for this BOQ are missing.	This may be reviewed/ included/ amended as necessary.
14.	Description of Items for Structure Works – Bridge in Sea – South Side	It is observed that over and above total cost of bridge, 20% extra is considered as Overheads for Major Bridges and 30% extra for working in tidal zone. The source of these additional overhead charges is not clear.	This may be reviewed/ included/ amended as necessary.
15.	BOQ for Bridge 7+970 km to 9+030 km	It is observed that quantity for each item is calculated considering only 22 piers in place of 25 piers. Ref: Drawing No. 8098/E/DD/5111 (R0), 5112 (R0), 5113 (R0) & 5514 (R0).	This may be reviewed/ included/ amended as necessary.
16.	BOQ for Bridge 7+970 km to 9+030 km	It is observed that for calculation of quantities (such as Mastic Asphalt, DBM, BC, Tack Coat, Crash Barrier) length of Bridge considered is 900m whereas as per drawing it should be 1250m Ref: Drawing No. 8098/E/DD/5111 (R0), 5112 (R0) & 5113 (R0)	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
17.	BOQ for Bridge 7+970 km to 9+030 km	It is observed that for Item Code 12 (Earthwork in Embankment and Median Filling), the width has not been considered for calculating the quantity.	This may be reviewed/ included/ amended as necessary.
18.	BOQ for Bridge 7+970 km to 9+030 km	It is observed that quantity for pavement crust (Bituminous & Non Bituminous) is taken in bridge approach which has also been considered under estimation of Typical Land Fill Road BOQ.	This may be reviewed/ included/ amended as necessary.
19.	BOQ for Bridge 9+723 km to 9+873 km	It is observed that measurements of pier caps does not match with that of drawing.	This may be reviewed/ included/ amended as necessary.
20.	BOQ for Bridge 9+723 km to 9+873 km	It is observed that measurements of POT-PTFE bearing does not match with that of drawing.	This may be reviewed/ included/ amended as necessary.
21.	BOQ for Bridge 11+670 km to 12+420 km	It is observed that quantity for pavement crust (Bituminous & Non Bituminous) is taken in bridge approach which has also been considered under estimation of Typical Land Fill Road BOQ.	This may be reviewed/ included/ amended as necessary.
22.	BOQ for Bridge 11+670 km to 12+420 km	It is observed that for Item Code 12 (Earthwork in Embankment and Median Filling), the width has not been considered for calculating the quantity.	Please verify and amend.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
23.	BOQ for Bridges	It is observed that road signs such as Stop, Facility Information etc are considered in BOQ for bridges.	These signs are generally not required for bridge section. This may be reviewed.
24.	BOQ for Interchanges	It is observed that details such as no. of piles, size of pile and pile caps, dimension of pier, pier caps etc. are not mentioned in drawings.	These details are required for review of quantity estimation.
25.	BOQ for Interchanges	It is observed that measurements of Strip Seal Expansion Joint does not match with that of drawing.	This may be reviewed/ included/ amended as necessary.
26.	BOQ for Interchanges	It is observed that road signs such as Stop, Facility Information etc are considered in BOQ for interchanges.	These signs are generally not required for interchanges section. This may be reviewed.
27.	BOQ for Interchanges	It is observed that for Item Code 12 (Earthwork in Embankment and Median Filling), the width has not been considered for calculating the quantity.	Please verify and amend.
28.	BOQ for Interchanges	It is observed that length of approach of interchange arms does not match with that of drawing.	This may be reviewed/ included/ amended as necessary.
29.	BOQ for Interchanges	It is observed that quantity of concrete crash barrier is not considered in interchange approaches.	This may be reviewed/ included/ amended as necessary.
30.	BOQ for Interchanges	It is observed that quantity for item code BW-5.6-i (Pile Load Test) is considered in estimation for at grade roads.	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
31.	BOQ for Interchanges	It is observed that quantity for road marking with thermoplastic paint item code BW-5-7-i is not considered in estimation for interchange approaches.	This may be reviewed/ included/ amended as necessary.
32.	BOQ for Bridges and Interchanges	It is observed that the width considered for estimation of wearing cost is inclusive of crash barrier.	This may be reviewed/ included/ amended as necessary.
33.	BOQ for FOB	It is observed that rate analysis for structural steel in not available.	This may be reviewed/ included/ amended as necessary.
34.	BOQ for FOB	It is observed that cost towards lift is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
35.	BOQ for FOB	It is observed that cost towards painting of structural steel is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
36.	BOQ for FOB	It is observed that cost towards roof of ramp and staircase is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
37.	BOQ for FOB	It is observed that quantity for Column P2, concrete of staircase and ramp, etc. are not as per drawing.	This may be reviewed/ included/ amended as necessary.
38.	Cost Estimate & Rate Analysis	Page numbers are not mentioned in the entire volume.	This will help in giving references and identifying missing data if any.

Table 7-2 Observations on Rate Analysis, Cost Estimate & BOQ (North)

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
1.	Abstract / General	Other ancillary costs are not added.	It is suggested to allow cost provision for following heads over Civil cost, • Contingencies • Agency charges • Quality control charges • Road Safety audit charges • Supervision Charges • Escalation Charges • Utility & Environment Charges • R & R cost • Forest Clearance • Land acquisition Cost
2.	Rate Analysis	It is observed that rates are used from following SOR's. MCGM SOR – 2013 Chembur SOR – 2012-13 Thane DSR – 2013-14 Jaipur PWD SOR MMRDA ongoing works	SOR's of current year may be used or appropriate escalation may be applied for the available SOR. For items not available in SOR separate Rate Analysis shall be carried out.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
3.	Rate Analysis	Item description not found in Rate Analysis of Typical Land Filled Road for item code New & BW-4.53.	Please include item description.
4.	Rate Analysis	It is observed that Rate Analysis is provided for each and every section (i.e. Reclamation of Land, Road on Land Filled, Structure, etc.)	It is suggested that single Rate Analysis should be provided for the entire project covering all the items of the project as a different volume.
5.	BOQ for Reclamation of Land – South	It is presumed that DPR Consultant has ensured that required quantity & quality of fill is available at identified borrow areas.	This may please be ensured Logistics needs to be carefully planned supplement by overall project Master Plan to avoid delays & overruns. This will also help in getting a competitive pricing from bidders.
6.	Road Furniture	It is observed that Quantity for road side furniture, sign boards, etc are calculated for each items individually. (Eg.: Land Filled Road, Bridges, Interchanges, etc.)	Comprehensive location plan of Road Furniture shall be made available to avoid any omission and duplication of road furniture.
7.	Bituminous work	It is observed that extra cost for compacting bituminous course with Pneumatic Roller is considered for bituminous concrete; however the rate for bituminous concrete in rate analysis is inclusive of rolling with Pneumatic Roller.	This may be reviewed/ included/ amended as necessary.
8.	BOQ for Structures	It is observed that depth of piles considered for estimation is same for all the structures i.e. 25m. However the basis of this constant depth used is not clear	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
9.	BOQ for Structures	It is observed that the composition for wearing coat considered is 6 mm Mastic Ashpalt + 50 mm Dense Bituminous Macadam + 25 mm Bituminous Concrete which does not match with any of the Bituminous Wear Coat Type given in section 2702.1 of MoRT&H (Fifth Revision)	This may be reviewed/ included/ amended as necessary.
10.	km 3+800 to km 4+400	It is observed that cost estimate for section km 3+800 to 4+400 is not available.	This may be reviewed/ included/ amended as necessary.
11.	BOQ for Typical Land Filled Road on Mangroves.	It is observed that quantity for Pedestrian Guard Rail is considered in estimate. However Typical Cross Section shows provision of Safety Barrier.	This may be reviewed/ included/ amended as necessary.
12.	BOQ for Typical Land Filled Road on Mangroves.	It is observed that quantity for built-up drain is considered in estimate. However Typical Cross Section does not show provision of built-up drains.	This may be reviewed/ included/ amended as necessary.
13.	BOQ for Typical Land Filled Road on Mangroves.	It is noted that provision of noise and visual barrier is made in the cost estimate. However drawings and specification are not available.	Drawings and specifications shall be included
14.	BOQ for Typical Land Filled Road on Mangroves	It is observed that quantity for Metal Crash Barrier is not in accordance with mangroves cross section.	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
15.	BOQ for Typical Land Filled Road on Mangroves	It is observed that additional length of 1335m is considered in cost estimation of Filled Road on Mangroves.	Please check and review.
16.	BOQ for Surface Road.	It is observed that quantity for Pedestrian Guard Rail is considered in estimate. However Typical Cross Section shows provision of Safety Barrier.	This may be reviewed/ included/ amended as necessary.
17.	BOQ for Surface Road.	It is noted that provision of noise and visual barrier is made in the cost estimate, however drawings and specification are not available.	Drawings and specifications shall be included.
18.	BOQ for Surface Road.	It is observed that quantity for Metal Crash Barrier is not in accordance with mangroves cross section.	This may be reviewed/ included/ amended as necessary.
19.	BOQ for Tunnel at NCPA – North Side Quantity Estimation	It is observed that for Sr. No. 9 (c) rate and amount are missing.	This may be reviewed/ included/ amended as necessary.
20.	BOQ for Tunnel at NCPA – North Side Quantity Estimation	It is observed that measurements for this BOQ are missing.	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
21.	Description of Items for Structure Works - Bridge in Sea – North Side	It is observed that over and above total cost of bridge, 20% extra is considered as Overheads for Major Bridges and 30% extra for working in tidal zone. The source of these additional overhead charges is not clear.	This may be reviewed/ included/ amended as necessary.
22.	BOQ for Bridge 15+100 km to 15+700 km & 16+200 km to 16+800 km	It is observed that measurements of POT-PTFE bearing do not match with that of drawing.	This may be reviewed/ included/ amended as necessary.
23.	Elevated Road (North Side Bridge)	It is observed that cost estimate for section km 10+000 to 10+300 LHS is not available.	This may be reviewed/ included/ amended as necessary.
24.	Road on Stilt (km 18+350 to 19+400)	Structural drawings for road on stilt from km 18+350 to 19+400 are not available in drawing volume.	These details are required for review of quantity estimation.
25.	BOQ for Bridges	It is observed that road signs such as Stop, Facility Information etc are considered in BOQ for bridges.	These signs are generally not required for bridge section. This may be reviewed.
26.	BOQ for Interchanges	It is observed that details such as no. of piles, size of pile and pile caps, dimension of pier, pier caps etc. are not mentioned in drawings.	These details are required for review of quantity estimation.
27.	BOQ for Interchanges	It is observed that measurements of Strip Seal Expansion Joint do not match with that of drawing.	This may be reviewed/ included/ amended as necessary.

Sr. No.	Element	Observation / Comments	Recommendation / Suggestion / Remark
28.	BOQ for Interchanges	It is observed that road signs such as Stop, Facility Information etc are considered in BOQ for interchanges.	These signs are generally not required for interchanges section. This may be reviewed.
29.	Bridges and Interchanges	It is observed that quantity of concrete crash barrier is not considered in interchange approaches.	This may be reviewed/ included/ amended as necessary.
30.	BOQ for FOB	It is observed that rate analysis for structural steel in not available.	This may be reviewed/ included/ amended as necessary.
31.	BOQ for FOB	It is observed that cost towards lift is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
32.	BOQ for FOB	It is observed that cost towards painting of structural steel is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
33.	BOQ for FOB	It is observed that cost towards roof of ramp and staircase is not considered in cost estimate.	This may be reviewed/ included/ amended as necessary.
34.	BOQ for FOB	It is observed that quantity for Column P2, concrete of staircase and ramp, etc. are not as per drawing.	This may be reviewed/ included/ amended as necessary.
35.	Cost Estimate & Rate Analysis	Page numbers are not mentioned in the entire volume.	This will help in giving references and identifying missing data if any.