MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY
THE REPUBLIC OF INDIA

THE PREPARATORY SURVEY ON THE PROJECT FOR CONSTRUCTION OF MUMBAI TRANS HARBOUR LINK IN THE REPUBLIC OF INDIA

FINAL REPORT

VOLUME 1: MAIN REPORT

JANUARY 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
EAST NIPPON EXPRESSWAY CO., LTD.
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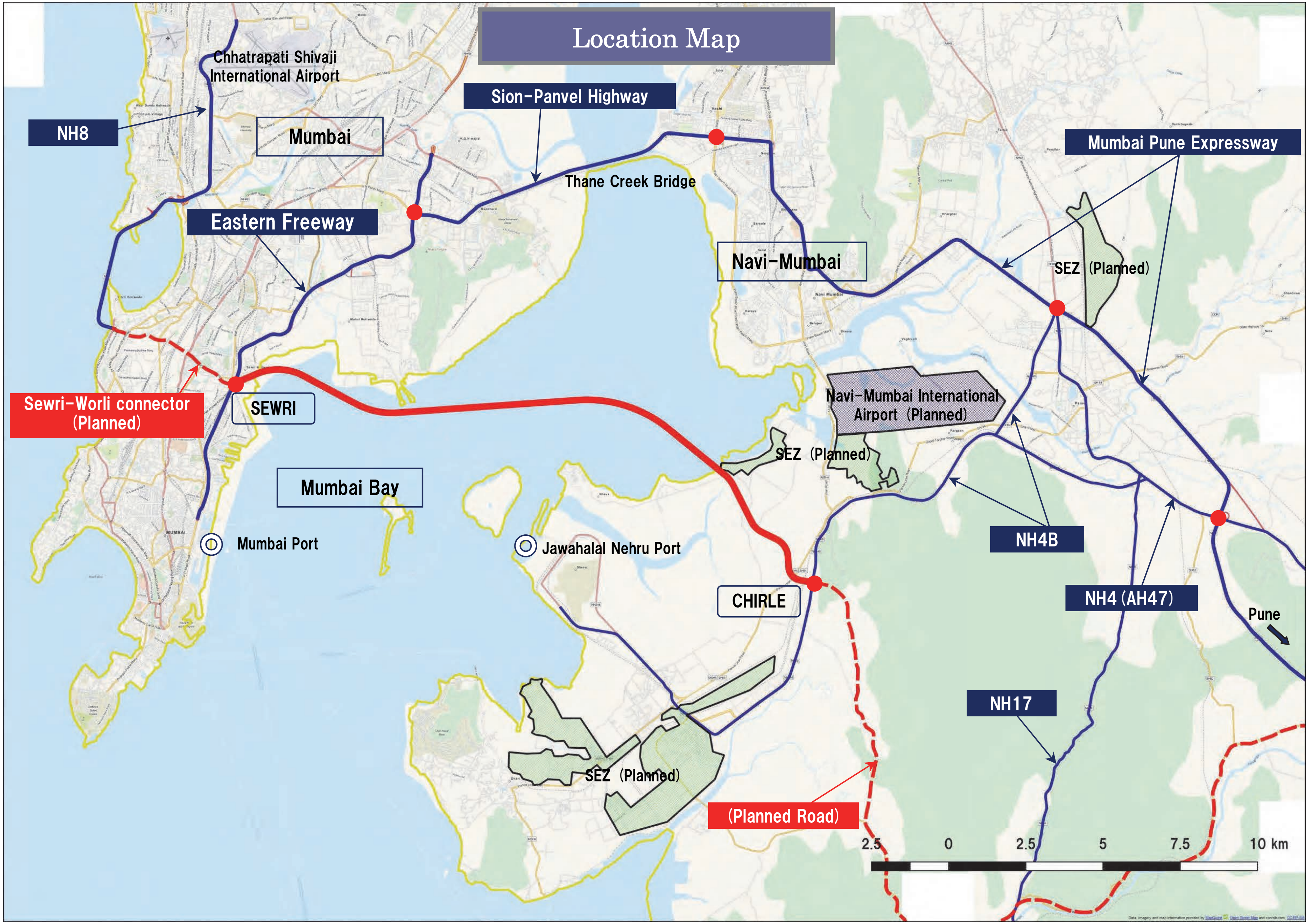
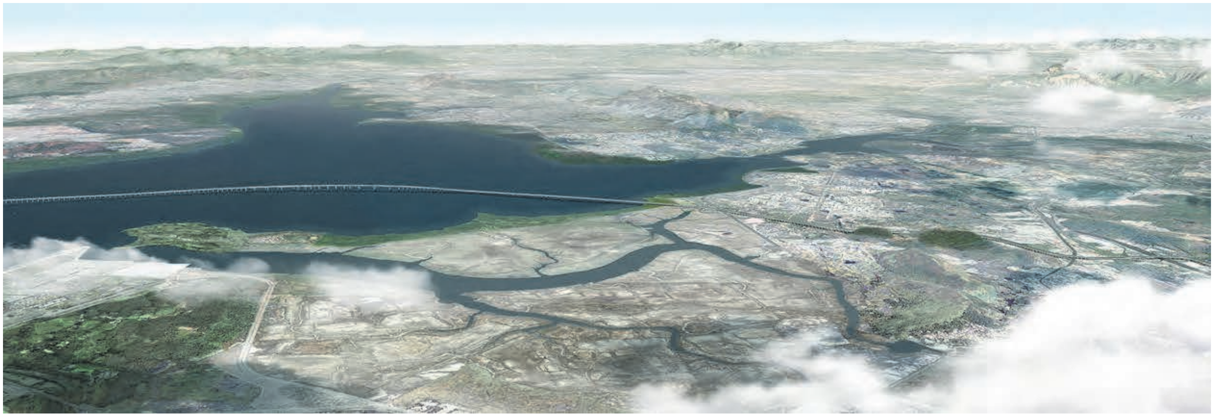

Location Map
Chhatrapati Shivaji International Airport
Sion-Panvel Highway
NH8
Mumbai
Mumbai Pune Expressway
Thane Creek Bridge
Eastern Freeway
Navi-Mumbai
SEZ (Planned)
Navi-Mumbai International Airport (Planned)
Sewri-Worli connector (Planned)
SEWRI
SEZ (Planned)
Mumbai Bay
Mumbai Port
Jawahalal Nehru Port
NH4B
CHIRLE
NH4 (AH47)
Pune
NH17
SEZ (Planned)
(Planned Road)
2.5 0 2.5 5 7.5 10 km

Computer Graphics of Steel Box Girder Bridge with Steel Deck

Computer Graphics of PC Box Girder Bridge

Bird’s-eye View at Mumbai Side



Bird’s-eye View at Navi-Mumbai Side

The Preparatory Survey on the Project for Construction of Mumbai Trans Harbour Link

In

The Republic of India

FINAL REPORT

Executive Summary

1. BACKGROUND, OBJECTIVES AND IMPLEMENTATION OF THE SURVEY

1.1 Background of the Project

Although the urbanization in the Republic of India (hereinafter called India) has been rapidly progressing, the speed of infrastructure development in the urban areas has not caught up to the speed of urbanization. Particularly, there is heavy traffic congestion in the urban areas due to a lack of road network and this hinders the economic development in the urban areas. Given this situation, the necessity of a comprehensive infrastructure development plan was given great importance for the growing economic developments.

Mumbai Metropolitan Region, which includes Greater Mumbai and Navi Mumbai, had a population of about 22.8 million people in 2011 and the population density reached 20,694 people per km^2 in the centre of Greater Mumbai, which makes it one of the most overpopulated cities in the world.

The Navi Mumbai is on the east side of Greater Mumbai, across the Mumbai Bay and it has large potential for development. The State Government of Maharashtra has been facilitating various infrastructure projects in Navi-Mumbai area, such as the Navi Mumbai International Airport, Special Economic Zone (SEZ), and expansion of Jawaharlal Nehru Port in order to secure the sustainable economic development in Mumbai Metropolitan Region. Furthermore, the State Government has also facilitated construction of National Highway 4B to Jawaharlal Nehru Port and Mumbai-Pune Expressway. Similarly, the Mumbai Trans Harbour Link (MTHL) would be an important infrastructure project to improve the connectivity between Greater Mumbai and Navi-Mumbai facilitating the economic development in Mumbai Metropolitan Region.

Mumbai Metropolitan Region Development Authority (MMRDA) invited bids in 2013 for implementation of the MTHL project on a Public-Private Partnership (PPP-DBFOT) basis. However, there was no response to the bid process. Subsequently MMRDA decided to implement the project on an EPC (Design-Build) basis with the assistance of an Official Development Loan (ODA) loan from Japan International Cooperation Agency (JICA).

1.2 Outline of the Project

The project involves construction of about 22 km of a full access-controlled link across the Mumbai bay between Sewri in Mumbai and Chirle in Navi Mumbai with four interchanges in Mumbai and Navi Mumbai (see Location Map).

2. GENERAL APPRECIATION AND DEVELOPMENT PLAN

2.1 Socio-Economic Conditions of the Project Area

The Mumbai Metropolitan Region is located on the western coast of Maharashtra State of India, and spreads over 4,355 km^2 with 22.8 million in population in 2011, which is one of the most densely populated areas in the world, comprising 8 Municipal Corporations and 9 Municipal Councils, along with more than 1,000 villages in Thane and Raigad Districts.

Although Mumbai Metropolitan Region is also a capital of Maharashtra State, it has been developed as a financial and commercial center of India and many headquarters of financial institutions are located there, particularly in Greater Mumbai. Furthermore, since the Mumbai Bay forms a natural harbour, namely Mumbai Port on the Greater Mumbai side and Jawahalal Nehre Port on the Navi Mumbai side, maritime trade of the two ports accounts for approximately 70% of the national maritime trade in India.

Source: Comprehensive Transportation Study, MMRDA, 2008

Figure 2.1.1 MMRDA Jurisdiction Area

2.2 Major Development Plan

The national development plan, the development plan in the road sector and Mumbai Metropolitan Region, are shown in Table 2.2.1.

Table 2.2.1 Major Development Plans

National Development Plan, Road Sector Development Plan	Major Development Plans in Mumbai Metropolitan Region
• National Transport Policy	• Regional Master Plan for Mumbai Metropolitan Region • Comprehensive Transportation Study (CTS) for Mumbai Metropolitan Region • Navi Mumbai International Airport • Special Economic Zone Development • Expansion of Jawahalal Neharu Port

Source: JICA Study Team

Mumbai Metropolitan Region (Greater Mumbai and Navi-Mumbai) has some development plans which are shown in Table 2.2.1. Hence, the Mumbai Trans Harbour Link (MTHL) would be an important infrastructure project to improve the connectivity between Greater Mumbai and Navi-Mumbai facilitating the economic development in Mumbai Metropolitan Region.

3. REVIEW OF PREVIOUS STUDIES ON MTHL

The latest project outline has been formulated on the basis of the "Final Feasibility Study Report: Detailed Feasibility Study and Bid Process Management for Selection of Developer for MTHL: Sewri to Nhava in MMR, Maharashtra State, India 2012" (hereinafter Final Feasibility Study Report, 2012) which is the latest feasibility study for the Project and conducted by Arup, CES and KPMG JV. In this chapter, the Final Feasibility Study Report, 2012 is mainly reviewed.

3.1 Review of Traffic Demand Forecast

The following reports shall be focused on during the review for the traffic demand forecast;

- Techno-Economic Feasibility Study for Mumbai Trans Harbour Link prepared by Consulting Engineering Services (CES), 2004;
- Comprehensive Transportation Study for Mumbai Metropolitan Region (CTS) prepared by Lea International, 2008;
- Mumbai Trans Harbour Link prepared by Arup et al, 2012 (Final Feasibility Study Report, 2012); and
- Study on the Mumbai Trans Harbour Link Road, Ministry of Economy, Trade and Industry (METI), Japan 2011.

The Earlier estimates of traffic on MTHL are shown in Table 3.1.1. The principal findings from the earlier studies review is that there is a need for the MTHL to proceed to construction in a timely manner.

Based on the review of the earlier studies, the forecast traffic volumes on MTHL were found significantly different against future assumptions such as future network, toll system and future development plan in the Region. In particular, several conditions have been rapidly changing as a result of rapid economic growth of the study area. Therefore, appropriate and realistic future assumptions of transport demand forecast needs to be decided on in-depth discussions with relevant authorities.

Table 3.1.1 Earlier Estimates of Traffic on MTHL

Project	Year of Project Undertaking	Reference Toll (Rs)	Estimated Volume in 2022 (pcu)
CES Study	2004	100	93,200
CTS	2008	100	73,200
MTHL: Final FS 2012	2012	150	94,000
MTHL Study by METI	2011	150	48,000

Source: JICA Study Team

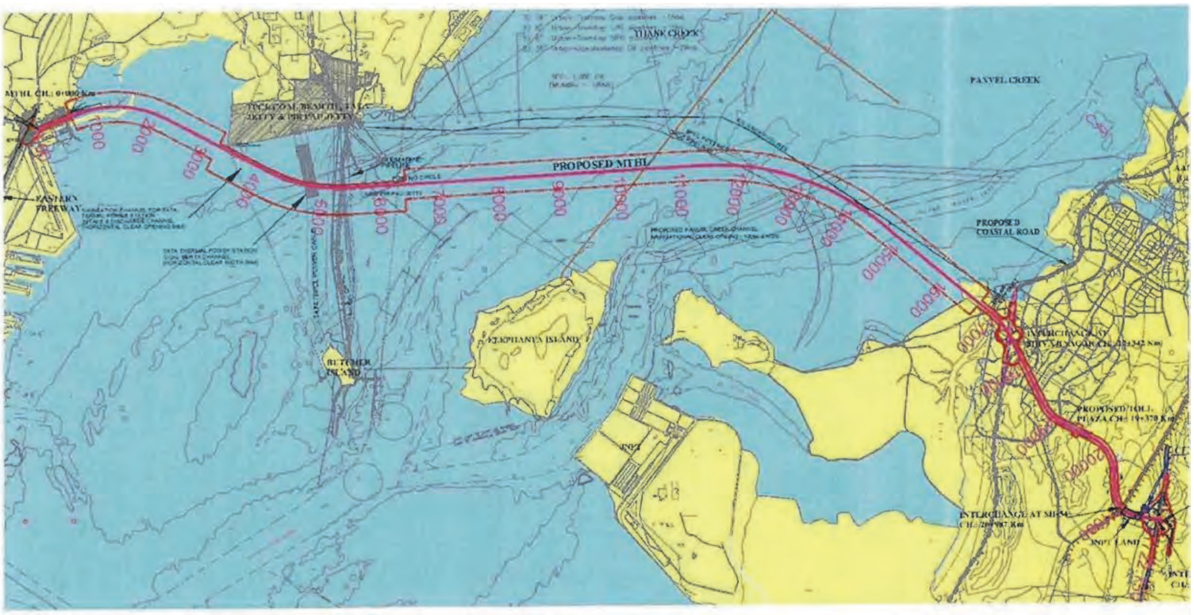
3.2 Review of Road Plan

(1) Road Alignment

The horizontal alignment and vertical alignment in the Final Feasibility Study Report, 2012 are shown in Figure 3.2.1 and Figure 3.2.2.

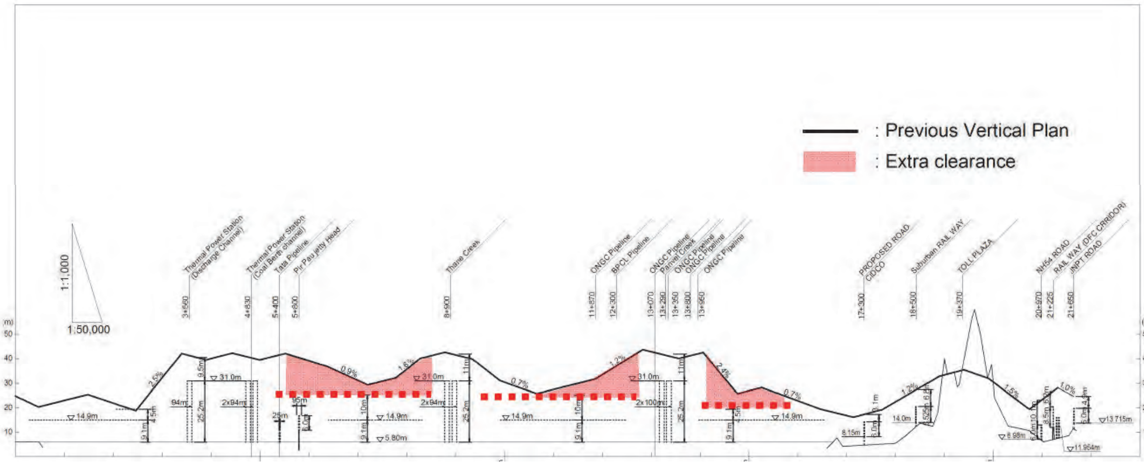
In terms of the horizontal alignment, the latest horizontal alignment fulfilled all control points required from the relevant authorities. Since the present route did not considered influence to mud flat are where is a feeding ground of Flamingos flying from 1995 on, additional route alignment option, which avoids mad flat at the maximum, is considered in this Study. As a result, it is judged that the original route option is superior than the new option because of a large number of residence resettlement and increase in the construction cost due to longer alignment length.

Regarding the vertical alignment, although all geometrical actors applied to main carriageway in the latest alignment fulfilled the IRC standards at 100km/h of the design speed, it was founded that there is extra clearance in some sections on the vertical alignment, which are indicated with red shadows.



Source: Final Feasibility Study Report, 2012

Figure 3.2.1 Horizontal Alignment



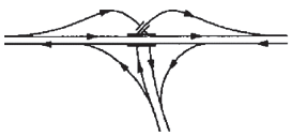
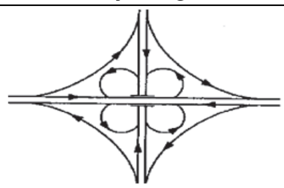
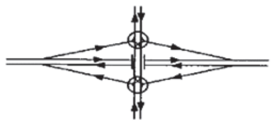
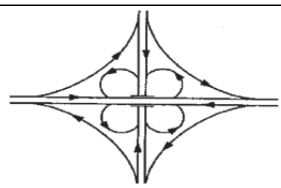
Source: JICA Study Team

Figure 3.2.2 Vertical Alignment

(2) Interchange Plan

There are four interchanges in this route and the interchange types are shown in Table 3.2.1. As a result of the review, it seems to have adopted the appropriate interchange type.

Table 3.2.1 Interchange Type

Sewri IC	Shivaji Nagar IC	SH54 IC	Chirle IC
 Y-Interchange	 Clover-Interchange	 Diamond Interchange (half)	 Clover-Interchange

Source: JICA Study Team

3.3 Review of Bridge Plan

(1) Control Points for Bridge Plan

All obstacles/utilities on the marine section, which should be considered in bridge plan, and span arrangements for such control points, are also shown in Table 3.3.1.

Table 3.3.1 Crossing Utilities and Required Span Arrangement on Marine Section

Crossing Utilities	Navigation Clearance		Span Arrangement
	Horizontal	Vertical above (C.D.)	
(General)	50m	14.72m	50m
Tata Thermal Power Station, Intake and Discharge Channel	1 x 94m	31.00m	85m+150m+85m
Tata Thermal Power Station, Coal Berth Channel	2 x 94m	31.00m	80m+2@150m+85m
Tata Pipeline	-	-	90m+3@150m+85m
Pir Pau Jetty Head	-	+6m above jetty level	
Thane Creek	2 x 94m	31.22m	100m+2@180m+100m
ONGC Pipeline BPCL Pipeline	-	-	100m+180m+110m
	-	-	110m+180m+100m
Panvel Creek	2 x 100m	31.22m	100m+2@180m+95m

Source: JICA Study Team

(2) Outline of Bridge Plan

The outline of the bridge plan for MTHL in the Final FS, 2012 is shown in Table 3.3.2 to Table 3.3.4. MTHL passes through the general sections on both land and above the water. Obstacles in the marine sections include mangrove forest areas, and on in the land sections there are flyover sections over railways and roads.

Table 3.3.2 Marine Bridge Properties (1/3)

	Chainage From	Chainage To	Bridge Type	Span Length	Pier	Substructure Type
General (Marine)	0+495	1+045	PSC box girder bridge (span by span method)	2@50m=100m	MP1 (0+495)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				3@50m=150m	MP3 (0+595)	
				2@50m=100m	MP6 (0+745)	
				2@50m=100m	MP8 (0+845)	
				2@50m=100m	MP10 (0+945)	
					MP12 (1+045)	
	1+045	2+795		5@50m=250m	MP13 (1+095)	Pile bent pier : φ2.4m - 2piers
				6@50m=300m	MP17 (1+295)	
				6@50m=300m	MP23 (1+595)	
				6@50m=300m	MP29 (1+895)	
				6@50m=300m	MP35 (2+195)	
				6@50m=300m	MP41 (2+495)	
					MP46 (2+745)	
	2+795	3+395		6@50m=300m	MP47 (2+795)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP53 (3+095)	
					MP59 (3+395)	
Special (Marine)	3+395	3+715	PSC box girder bridge (cantilever method)	85m+150m+85m =320m	MP60 (3+480)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
					MP61 (3+630)	
General (Marine)	3+715	4+595	PSC box girder bridge (span by span method)	6@50m=300m	MP62 (3+715)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP68 (4+015)	
				40m+4@50m+40m =280m	MP74 (4+315)	
					MP80 (4+595)	
Special (Marine)	4+595	5+060	PSC box girder bridge (cantilever method)	80m+2@150m+85m =465m	MP81 (4+675)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
					MP82 (4+825)	
					MP83 (4+975)	
General (Marine)	5+060	5+310	PSC box girder bridge (span by span method)	5@50m=250m	MP84 (5+060)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
					MP89 (5+310)	
Special (Marine)	5+310	5+935	PSC box girder bridge (cantilever method)	90m+3@150m+85m =625m	MP90 (5+400)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
					MP91 (5+550)	
					MP92 (5+700)	
					MP93 (5+850)	
General (Marine)	5+935	8+635	PSC box girder bridge (span by span method)	6@50m=300m	MP94 (5+935)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP100 (6+235)	
				6@50m=300m	MP106 (6+535)	
				6@50m=300m	MP112 (6+835)	
				6@50m=300m	MP118 (7+135)	
				6@50m=300m	MP124 (7+435)	
				6@50m=300m	MP130 (7+735)	
				6@50m=300m	MP136 (8+035)	
				6@50m=300m	MP142 (8+335)	
					MP148 (8+635)	
Special (Marine)	8+635	9+195	PSC box girder bridge (cantilever method)	100m+2@180m+100m =560m	MP149 (8+735)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
					MP150 (8+915)	
					MP151 (9+095)	
General (Marine)	9+195	10+395	PSC box girder bridge (span by span method)	6@50m=300m	MP152 (9+195)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP158 (9+495)	
				6@50m=300m	MP164 (9+795)	
				6@50m=300m	MP170 (10+095)	
					MP176 (10+395)	
	10+395	11+295		6@50m=300m	MP177 (10+435)	Pile bent pier : φ2.4m - 2piers
				6@50m=300m	MP182 (10+695)	
				6@50m=300m	MP188 (10+995)	
					MP193 (11+245)	
	11+295	11+635		6@50m+40m=340m	MP194 (11+295)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
					MP201 (11+635)	

Source: JICA Study Team

Table 3.3.3 Marine Bridge Properties (2/3)

	Chainage From	Chainage To	Bridge Type	Span Length	Pier	Substructure Type
Special (Marine)	11+635 (L)	12+075 (L)	PSC box girder bridge (cantilever method)	50m+100m+180m+110m =440m	MP201 (11+635 (L))	Pier : φ2.5m - 1piers
					MP202 (11+685 (L))	Pile : φ1.5m - 4piles
					MP203 (11+785 (L))	Pier : 6mx3m - 2piers
					MP204 (11+965 (L))	Pile : φ2.4m - 4piles
	12+075 (L)	12+515 (L)		110m+180m+100m+50m =440m	MP205 (12+075 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP206 (12+185 (L))	Pier : 6mx3m - 2piers
					MP207 (12+365 (L))	Pile : φ2.4m - 4piles
					MP208 (12+465 (L))	Pier : φ2.5m - 1piers
					MP209 (12+515 (L))	Pile : φ1.5m - 4piles
Special (Marine)	11+635 (R)	12+115 (R)	PSC box girder bridge (cantilever method)	40m+40m+100m+180m+120m=480m	MP201 (11+635 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP202 (11+675 (R))	
					MP203 (11+715 (R))	
					MP204 (11+815 (R))	Pier : 6mx3m - 2piers
					MP205 (11+995 (R))	Pile : φ2.4m - 4piles
	12+115 (R)	12+515 (R)		120m+180m+100m=400m	MP206 (12+115 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP207 (12+235 (R))	Pier : 6mx3m - 2piers
					MP208 (12+415 (R))	Pile : φ2.4m - 4piles
					MP209 (12+515 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
General (Marine)	12+515	12+715	PSC box girder bridge (span by span method)	4@50m=200m	MP209 (12+515)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
	12+715	12+955		4@50m+40m=240m	MP213 (12+715)	
					MP218 (12+955)	
Special (Marine)	12+955 (L)	13+600 (L)	PSC box girder bridge (cantilever method)	50m+100m+2@180m+95m+40m=645m	MP218 (12+955 (L))	Pier : φ2.5m - 1piers
					MP219 (13+005 (L))	Pile : φ1.5m - 4piles
					MP220 (13+105 (L))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP221 (13+285 (L))	
					MP222 (13+465 (L))	
					MP223 (13+560 (L))	Pier : φ2.5m - 1piers
					MP224 (13+600 (L))	Pile : φ1.5m - 4piles
Special (Marine)	12+955 (R)	13+600 (R)	PSC box girder bridge (cantilever method)	40m+100m+2@180m+95m+50m=645m	MP218 (12+955 (R))	Pier : φ2.5m - 1piers
					MP219 (12+995 (R))	Pile : φ1.5m - 4piles
					MP220 (13+095 (R))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP221 (13+275 (R))	
					MP222 (13+455 (R))	
					MP223 (13+550 (R))	Pier : φ2.5m - 1piers
					MP224 (13+600 (R))	Pile : φ1.5m - 4piles
General (Marine)	13+600	14+500	PSC box girder bridge (span by span method)	6@50m=300m	MP224 (13+600)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP230 (13+900)	
				6@50m=300m	MP236 (14+200)	
					MP242 (14+500)	
	14+500	16+000		6@50m=300m	MP243 (14+550)	Pile bent pier : φ2.4m - 2piers
					MP248 (14+800)	
				6@50m=300m	MP254 (15+100)	
				6@50m=300m	MP260 (15+400)	
				6@50m=300m	MP266 (15+700)	
				6@50m=300m	MP271 (15+950)	
Mangrove part	16+000	17+257		6@50m=300m	MP272 (16+000)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP278 (16+300)	
				3@53.333m=160m	MP284 (16+600)	
				47m	MP287 (16+760)	
				3@50m=150m	MP288 (16+807)	
				3@50m=150m	MP291 (16+957)	
				3@50m=150m	MP294 (17+107)	
					MP297 (17+257)	

Source: JICA Study Team

Table 3.3.4 Marine Bridge Properties (3/3)

	Chainage		Bridge Type	Span Length	Pier	Substructure Type
	From	To				
Road Overpass	17+257 (L)	17+452 (L)	PSC box girder bridge (span by span method)	35m+45m+40m+40m +35m=195m	MP297 (17+257 (L))	Pier : φ2.5m - 1piers
					MP302 (17+452 (L))	Pile : φ1.5m - 4piles
Road Overpass	17+257 (R)	17+452 (R)	PSC box girder bridge (span by span method)	45m+45m+40m+40m +25m=195m	MP297 (17+257 (R))	Pier : φ2.5m - 1piers
					MP302 (17+452 (R))	Pile : φ1.5m - 4piles
Mangrove part	17+452	18+022	PSC box girder bridge (precast whole span method)		MP302 (17+452)	
				4@30m=120m	MP303 (17+482)	
				5@30m=150m	MP306 (17+572)	
				5@30m=150m	MP311 (17+722)	
				5@30m=150m	MP316 (17+872)	Pier : φ2.5m - 2piers
Road Overpass	18+022	18+082		20m+40m=60m	MP321 (18+022)	Pile : φ1.2m - 12piles
Mangrove part	18+082	18+232		5@30m=150m	MP323 (18+082)	
Road Overpass	18+232	18+352		3@40m=120m	MP328 (18+232)	
General (Land)	18+352	18+388		36m	MP331 (18+352)	
Railway Overpass	18+388	18+458	Steel Truss Bridge	70m	MP332 (18+388)	Pier : φ3.25m - 3piers
					MP333 (18+458)	Piles : φ1.5m - 12piles
General (Land)	18+458	18+922	PSC box girder bridge (precast whole span method)	44m	MP334 (18+502)	
				5@30m=150m	MP339 (18+652)	Pier : φ2.5m - 2piers
				5@30m=150m	MP344 (18+802)	Pile : φ1.2m - 12piles
				3@40m=120m	MA2 (18+922)	
Embankment	18+922	20+092				
General (Land)	20+092	21+172	PSC box girder bridge (precast whole span method)	5@30m=150m	LA1 (20+092)	
				5@30m=150m	LP5 (20+242)	
				5@30m=150m	LP10 (20+392)	Pier : φ2.5m - 2piers
				5@30m=150m	LP15 (20+542)	Pile : φ1.2m - 12piles
				5@30m=150m	LP20 (20+692)	
				3@30m=90m	LP25 (20+842)	
				18m	LP28 (20+932)	
Road Overpass				35m	LP29 (20+950)	Pier : φ1.5m - 3piers
General (Land)				35m	LP30 (20+985)	Pile : φ1.2m - 10piles
				32m+4@30m=152m	LP31 (21+020)	
					LP32 (21+052)	Pier : φ2.5m - 2piers
					LP36 (21+172)	Pile : φ1.2m - 12piles
	21+172	21+184.533	PSC-I girder bridge	12.533m	LP37 (21+184.533)	Pier : φ3.25m - 3piers
Railway Overpass	21+184.533	21+379.533	Steel Truss Bridge	3@65m=195m	LP40 (21+379.533)	Piles : φ1.5m - 12piles
	21+379.533	21+412	PSC-I girder bridge	32.467m	LP41 (21+412)	
General (Land)	21+412	21+715.78	PSC box girder bridge (precast whole span method)	3@30m=90m	LP44 (21+502)	
				3@30m=90m	LP47 (21+592)	
				23.78m	LP48 (21+615.78)	Pier : φ2.5m - 2piers
Road Overpass				35m	LP49 (21+650.78)	Pile : φ1.2m - 12piles
				35m	LP50 (21+685.78)	
General (Land)				30m	LA2 (21+715.78)	

Source: JICA Study Team

(3) Outline of Bridge Structure

Superstructure in general marine section utilizes PC continuous box girders with a standard span of 50m to be erected by span-by-span method utilizing precast segments. For piers less than 20m high from the ground surface, a pile bent structure has been selected in order to mitigate environmental impact. For piers over 20m high, a pile cap structure has been selected, which was supported by cast-in-place bored piles with diameter of 1.5m. In the obstacle/Navigation channel sections, PC rigid frame box girder bridges of 150m and 180m in maximum span length are applied with cast-in-situ cantilever erection method.

Superstructures for the general sections lare PC simple box girder with a standard span of 30m, supported by pile cap structure with bored piles

3.4 Review of Construction Cost and Schedule

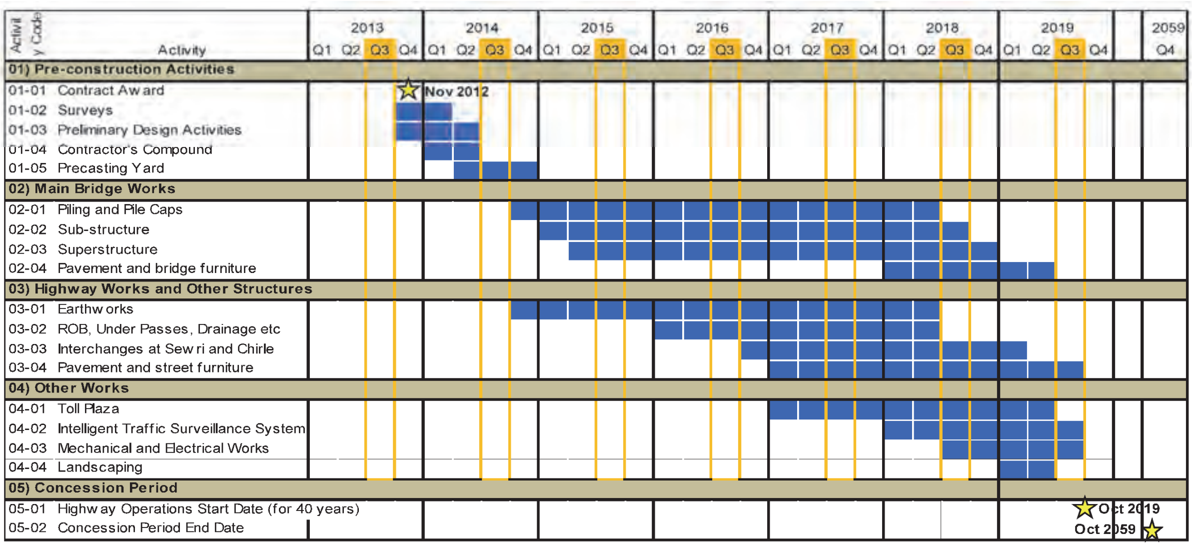
(1) Review of Construction Cost

The Final Feasibility Study Report, 2012 mentioned INR 76,969 million for the construction cost for MTHL and 5% is used as the inflation rate in the report. However this inflation rate is different from the one which IMF published. The construction cost which was recalculated using the inflation rate published by IMF became INR 95,788 million.

(2) Review of Construction Schedule

The Final Feasibility Study Report, 2012 estimated an implementation schedule of six years to complete the project as shown in Table 3.4.1. This includes the preparation period, survey, design and construction in the BOT scheme. In principle, the proposed schedule can be achievable if the contractor mobilizes sufficient work teams to the site.

Table 3.4.1 Construction Schedule in Previous Study



1) Actual phasing of works will vary depending on contractors own construction plan.
2) Orange highlight indicates monsoon period.

Source: Final FS Report for MTHL, 2012, MMRDA

3.5 Economic Analysis

(1) Financial analysis

In the Final Feasibility Study Report, 2012, the Financial Internal Rate of Return (Project IRR and Equity IRR) were calculated as shown in Table 3.5.1. Unless otherwise applied Viability Gap Fund (VGF), the project is not financially feasible.

Table 3.5.1 Financial Internal Rate of Return

	Without VGF and additional revenue	With 40% VGF (without additional revenue)	With 40% VGF and additional revenue)
Project IRR	12.90%	15.60%	15.90%
Equity IRR	12.90%	16.80%	17.20%

(2) Economic Analysis

In the Final Feasibility Study Report, 2012, Economic IRR for the Project is 14%. This exceeds the evaluation standards that specify 12% on infrastructure projects in India, which indicates that implementation of the project is relevant from the viewpoints of the national economy as well as from the regional economy.

4. TRANSPORT DEMAND FORECAST

4.1 Transport Survey

The understanding of the existing traffic situation in the vicinity of the MTHL was achieved through a series of classified vehicle count surveys (CVCS), railway passenger count surveys (RPCS) and vehicle occupancy surveys at some 18 sites as described in Table 4.1.1.

Table 4.1.1 Location of Traffic Count Sites

Site No	Survey Type	Survey Location	Duration
1	CVCS and Vehicle Occupancy Survey	NH-3 on Thane Creek	24 Hours
2		Kalwa Bridge	
3		Mulund-Airoli Bridge	
4		Vashi Bridge (on Thane Creek)	
5		NH-4 near Taloja	
6		Sion-Panvel Highway (Taloja Creek Bridge)	
7		Amra Marg near Kille (On Panvel Creek)	
8		BPT Road on Eastern Freeway near Sewri Rly Stn	
9		Rafi Ahmed Kidwai Marg	
10		G D Ambekar Marg near Parel Village	
11		Dr Ambedkar Road near Parel	
12		N.M. Joshi Marg	
13		Senapati Bapat Marg	
14		Dr Annie Besant Road	
15		Khan Abdul Gaffar Khan Road	
16		NH-4B JNPT Road, Near Wawal Bus Stn	
17	RPCS	Thane Creek Railway Bridge	24 Hours
18		Vashi-Mankhurd Rail Sea Link	

Source: JICA Study Team

4.2 Future Demand on MTHL

Based on the traffic survey results, the latest future transport network plan and development plans, the future traffic forecast on MTHL was updated with the model developed by the local consultant using the Cube Voyage software. The future traffic forecast on MTHL by vehicle class is shown in Table 4.2.1. Note that major assumptions for the forecast are the opening of MTHL in 2022 and toll fees for cars between Sewri IC and Shivaji Nagar, and Shivaji Nagar IC and Chilre IC are INR 130 and INR 40 respectively.

Table 4.2.1 Traffic Forecast Volume on the Main Bridge Link by Vehicle Class

(Unit: pcu)

Vehicle Type	Sewri IC - Shivaji Nagar IC			Shivaji Nagar IC – Chirle IC		
	2022	2032	2042	2022	2032	2042
Car	24,100	66,400	94,100	4,900	21,300	43,300
Taxi	2,700	14,100	20,200	100	400	2,300
Bus	2,700	3,700	3,700	2,700	3,700	3,700
LCV	2,200	4,100	5,600	700	1,300	1,800
HCV	3,000	6,500	8,100	1,000	2,000	2,200
MAV	4,600	9,100	13,800	400	900	1,700
Total	**39,300**	**103,900**	**145,500**	**9,800**	**29,600**	**55,000**

Source: JICA Study Team

5. NATURAL CONDITIONS ALONG MTHL

5.1 Topographic Survey

Objectives of the topographical survey are to obtain the base map for road and bridge design and to obtain the basic information in order to analyse the tidal levels and the ocean waves. Topographical survey items and quantities are shown in Table 5.1.1.

Table 5.1.1 Survey Items and Quantities

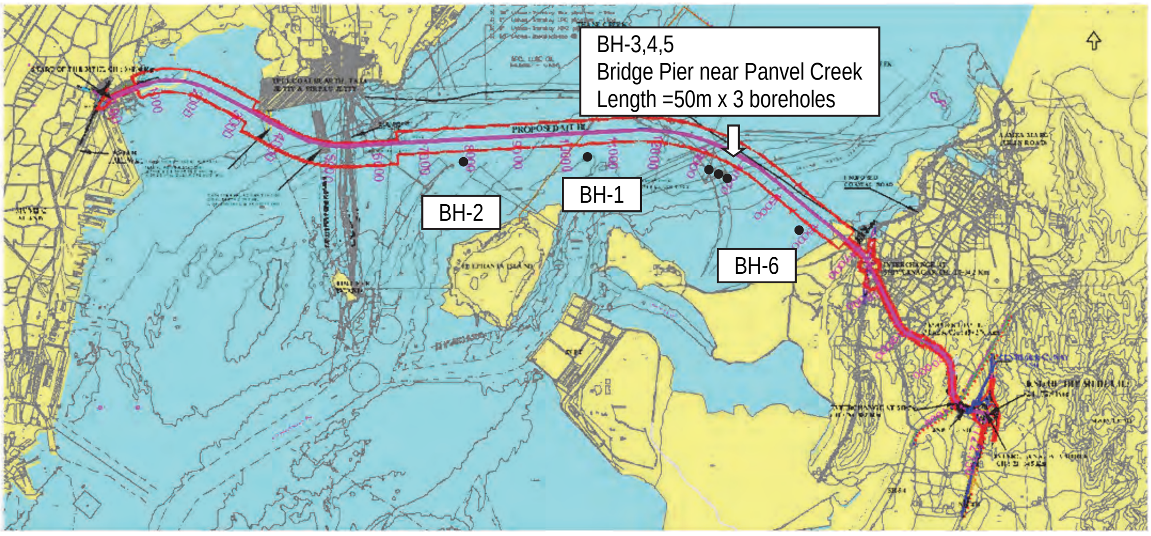
Item	Unit	Quantity	Note
Plane Survey by Total Station for Land	m^2	3,190,000	• Eastern Freeway Interchange: 450,000m^2 • Navi-Mumbai Side: 1,100,000m^2 (5,500m x 200m) • Shivajinagar Interchange: 600,000m^2 • Chirle Interchange: 1,040,000m^2
Plane Survey for Sea	m^2	825,000	• 16,500m x 50m
Centreline / Profile Levelling Survey for Land	m	6,500	• Mumbai Side: 1,000m • Navi-Mumbai Side: 5,500m
Cross Section Survey for Land	m	17,500	• Main Line: 17,500m (350 line x 50m)
Centreline / Profile Levelling Survey for the Cross Roads on Land	m	3,400	• Eastern Freeway: 1,500m • At Shivajinagar Interchange: 600m • At Chirle Interchange: 1,300m
Cross Section Survey for the Cross Roads on Land	m	8,500	• Eastern Freeway: 3,750m (75 line x 50m) • At Shivajinagar Interchange: 1,500m (30 line x 50m) • At Chirle Interchange: 3,250m (65 line x 50m)
Profile Levelling Survey for Land	m	1,200	• 800m + 400m (2 lines)
Profile Levelling Survey for Sea	m	16,540	• 8,380m + 8160m (2 lines)

Source: JICA Study Team

5.2 Geological Survey

(1) Location of Geological Survey

The Geological Survey was carried out to obtain geological and geotechnical information at bridge sites on MHTL. Location of geological survey is shown in Figure 5.2.1.

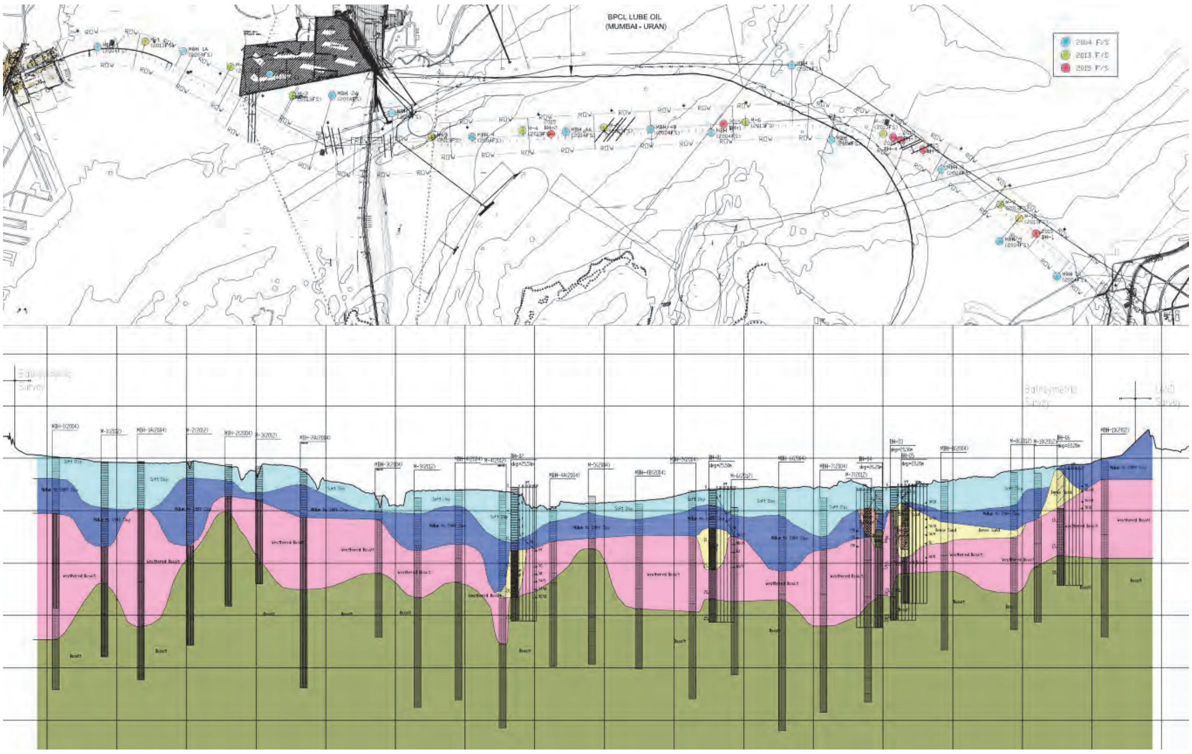


Source: JICA Study Team

Figure 5.2.1 Borehole Locations

(2) Geological Profile

The geological profile along MTHL was made with reference to the survey results in the past and the borehole survey results this time shown in Figure 5.2.2.



Source: JICA Study Team

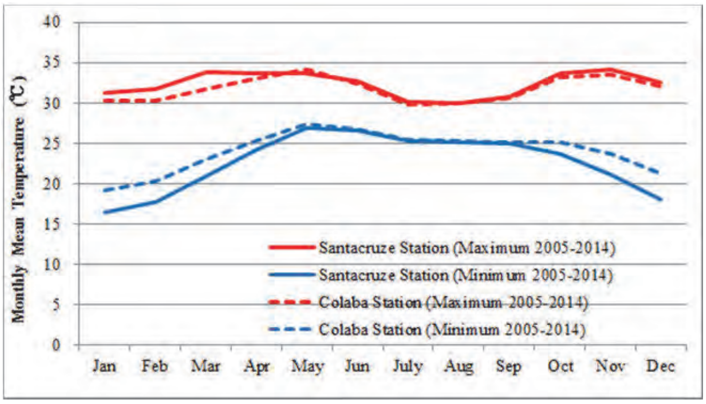
Figure 5.2.2 Geological Profile along MTHL

Weathered Basalt rock layers are confirmed in all boreholes and the depth of surface of the layer is from 10m to 35m from the seabed. The compression strength of Basalt rock ranges from 5.5 -112MPa, average 49MPa according to the laboratory test. From the results, it can be said that the Basalt rock has enough strength as the supporting layer for the pile foundation.

5.3 Meteorological and Hydrological Survey

(1) Temperature

The mean daily maximum temperatures range from 30°C to 34°C. During the winter period the minimum temperature may fall to about 17°C. The hotter months are March to June and October to November, as shown in Figure 5.3.1.



Source: JICA Study Team, IMD

Figure 5.3.1 Mean Monthly Maximum and Minimum Temperatures

(2) Wind Speed and Direction

The monthly maximum wind speed in the period 2005-2014 is shown in Table 5.3.1. Historical maximum wind speed was 28.9 m/s at Santacruz station in 2014 and 39.2 m/s at Colaba station in 2014. However, the design wind speeds to be used for the bridge superstructure design have been defined as 44m/s for Mumbai area (Zone 5) by IS-875 (Indian Standard).

Table 5.3.1 Monthly Maximum Wind Speed (2005-2014)

Monthly Maximum Wind Speed (m/s) at Santacruz Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	12.2	6.1	5.0	6.1	5.0	12.2	9.4	11.1	8.3	5.0	5.0	3.9
2006	4.4	4.7	6.1	7.2	5.6	6.1	8.9	6.1	6.1	4.4	3.9	3.9
2007	4.4	22.5	6.7	6.7	6.7	8.3	8.4	10.6	16.7	5.6	3.9	3.9
2008	16.7	9.4	22.8	19.5	19.4	9.4	7.2	8.3	19.5	4.4	16.4	3.3
2009	4.4	5.0	6.1	6.1	5.0	9.4	8.3	6.7	4.4	3.9	5.0	3.9
2010	6.1	7.2	6.1	5.0	8.3	8.3	7.2	8.4	6.1	11.1	6.7	5.0
2011	4.4	7.2	4.4	5.0	6.1	6.7	5.0	23.9	9.4	6.1	5.0	5.0
2012	6.1	6.1	6.1	6.1	6.1	7.8	6.7	6.7	8.3	5.0	3.9	4.4
2013	5.0	7.2	7.2	6.1	6.1	22.2	7.2	7.2	7.2	6.1	0.0	3.3
2014	5.0	5.0	5.0	5.0	6.1	28.9						
Monthly Maximum Wind Speed (m/s) at Colaba Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	3.9	4.4	3.9	3.9	3.3	5.0	9.4	6.7	7.2	3.3	3.9	3.3
2006	5.0	3.3	5.0	7.8	3.9	8.3	12.8	10.0	5.0	3.3	3.3	2.2
2007	3.3	2.8	7.8	3.9	3.3	11.1	5.0	8.3	7.8	2.8	2.2	2.8
2008	2.8	3.3	3.3	3.3	13.9	6.1	4.4	6.3	3.9	2.2	2.2	2.2
2009	3.3	2.8	2.8	3.3	3.3	3.3	33.6	22.5	11.1	4.4	4.4	11.1
2010	3.9	8.3	3.9	6.7	11.1	4.4	8.3	12.2	3.3	3.9	3.9	16.7
2011	5.6	3.9	12.2	29.4	3.3	3.9	23.3	5.0	11.1	5.0	2.8	2.8
2012	6.1	5.6	8.3	3.9	3.9	5.0	5.0	11.1	6.6	3.3	2.8	2.8
2013	2.8	2.8	5.6	3.9	3.3	0.0	5.0	6.1	19.4	3.3	3.3	3.3
2014	3.3	3.3	3.3	3.3	3.9	16.7	39.2	11.1	16.7	11.1	2.2	3.3

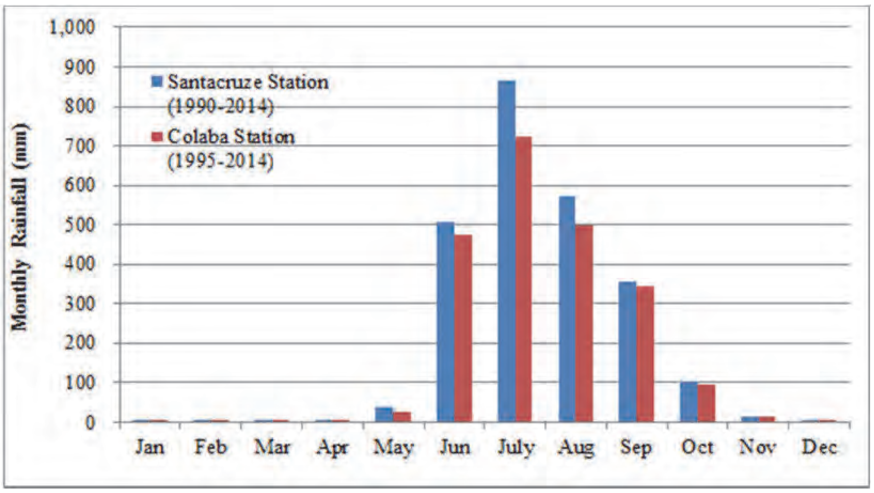
Source: JICA Study Team, IMD

Source: Google Earth

Figure 5.3.2 Location of Santacruz and Colaba

(3) Rainfall

Most of the annual rainfall occurs during the South West monsoon from June to September. Figure 5.3.3 shows the average monthly rainfall for the period 1995-2014 measured at Colaba station and for 1990-2014 at Santacruz station, Mumbai.



Source: JICA Study Team, IMD

Figure 5.3.3 Mean Monthly Rainfall

(4) Tidal Level

The dominant tide in the Mumbai Harbour is the semidiurnal tide with a period of 12 hours and 40 minutes. The tidal chart diagram of the Mumbai port is shown in Table 5.3.2. Based on the results of the previous F/S, the design Highest High Tide Level will be taken as +5.60m, above C.D. by the advice of CWPRS.

Table 5.3.2 Each Statistical Tide Level of Mumbai Port

Tide	Above(+) or Below(-)Chart Datum	Above(+) or Below(-) MSL of Indian Survey Datum
Design Highest High Tide Level (HHTL)	+ 5.60 m	+ 3.09 m
Highest High Water recorded	+ 5.39 m	+ 2.88 m
Mean High Water Spring Tides. (MHWS)	+ 4.42 m	+ 1.91 m
Mean High Water Neap Tides. (MHWN)	+ 3.30 m	+ 0.79 m
Highest Low Water.	+ 2.74 m	+ 0.23 m
Mean Sea Level. (MSL)	+ 2.51 m	+ 0.00 m
Lowest High Water.	+ 2.48 m	- 0.03 m
Mean Low Water Neap Tides. (MLWN)	+ 1.86 m	- 0.65 m
Mean Low Water Spring Tides. (MLWS)	+ 0.76 m	- 1.75 m
Chart Datum Level (CDL)	+ 0.00 m	- 2.51 m
Lowest Low Water recorded.	- 0.46 m	- 2.97 m

Source: JICA Study Team, MbPT

5.4 Utility, Facility and Navigation Survey

(1) Clearances of General Marine Viaduct Section

At the viaduct in the general marine section, the horizontal clearance is kept at a minimum of 50m and the vertical clearance is kept at a minimum of 9.1m above HHTL.

(2) Crossing Utilities in Marine Portion

There are some crossing utilities on the bridge alignment in the marine section. The kind and the required horizontal clearance were investigated and the results are shown in Table 5.4.1.

Table 5.4.1 Crossing Utilities and Clearances in Marine Portion

Utility	Chainage	Horizontal Clearance	Vertical Clearance
Tata Thermal Power Station, Intake and Discharge Channel	3+560	1x94m	31.0m (above CD)
Tata Thermal Power Station, Coal Berth Channel	4+830	2x94m	31.0m (above CD)
Tata Power Cable (1 cable)	4+960	Comfortable separation distance is more than 25m (minimum distance is 15m)	-
ONGC Pipeline (2 pipelines)	5+270		
Tata/MbPT Pipeline (13 pipelines)	5+400 ~5+575		
Pir Pau Jetty Head	5+800	-	6.0m (above jetty surface)
Thane Creek	8+900	2x94m	31.0m (above CD)
ONGC Pipeline (6 pipelines)	12+200 12+300	Comfortable separation distance is more than 25m (minimum distance is 15m)	-
BPCL Pipeline (1 pipeline)	12+350		
Panvel Creek	13+290	2x100m	31.0m (above CD)

Source: JICA Study Team

(3) Crossing Utilities in Land Section

There are some crossing roads and railway on the MTHL alignment in land section. The clearances of the crossing roads are shown in Table 5.4.2. The clearances of the crossing railways are shown in Table 5.4.3.

Table 5.4.2 Clearances of Crossing Roads

Crossing Road	Chainage	Vertical Clearance
Eastern Freeway and B Ramp	0+000	5.5m above road surface
Jetty Road	0+480	
Nhava Road	16+820	
Proposed CIDCO Coastal Road	17+300	
Proposed CIDCO Road	18+050	
Gavhan Road to School	18+170	
Proposed CIDCO Road	18+300	
Proposed CIDCO Road	18+540	
Proposed CIDCO Road	18+880	
Existing Road	20+170	
NH 54 (Road)	20+970	
JNPT Road (NH4B)	21+650	

Source: JICA Study Team

Table 5.4.3 Clearance of Crossing Railways

Crossing Railway	Chainage	Horizontal Clearance	Vertical Clearance
Railway (Sewri station - Cotton Green station)	0+000	Refer to drawings of the source	8.5m above rail track
Suburban Railways (Seawood – Uran)	18+500		6.5m above rail track
Railway (DFCC Corridor, Panvel Uran, JNPT railway)	21+200 to 21+350		8.5m above rail track

Source: JICA Study Team

6. PRELIMINARY DESIGN

6.1 Design Standard for Road Design

(1) Geometric Design Standard

At the section where the MTHL passes through plain and rolling terrain, the design speed of the main alignment applies 100kph (IRC: SP:87-2013). However, at the east side over Shivaji Nagar IC to Chirle IC where is mountainous and steep terrain, it applies 60kph (IRC: SP:87-2013). The values for the geometric design in the main alignment and interchange alignments are shown in Table 6.1.1 and Table 6.1.2 (IRC:73-1980, IRC SP:87-2013 and Japanese standard compared to determine adoption value.).

Table 6.1.1 Geometric Design Standard of Main Alignment

Items		Unit	Values to be applied
Width of each carriageway		m	3.50
Shoulder Width	Left Side	m	2.50
	Right Side	m	0.75
Central median width	Earth work section	m	3.0-5.0
	Bridge/Viaduct	m	1.50
Taper transition from single lane to multi-lane		rate	1:15-1:20
Cross fall		%	2.5
Design speed for main line		km/h	
Minimum Horizontal Curve Radius (Ruling)		m	400
Minimum Horizontal Curve Length		m	170
Minimum Horizontal Radius(Ruling)Without Super elevation		m	2,600
Maximum Super-elevation (rotation about median edge)		%	5%
Minimum Transition Length			
	R = 400m	m	115
	R = 600m	m	80
	R = 1,000m	m	50
	R = 1,800m	m	30
	R = 2,500m	m	not required
	R = 4,200m	m	not required
Minimum Radius without transition curve		m	2,000
Super elevation rubbed rate			1/150
Sight Distance	Safe Stopping	m	180
	Overtaking	m	640
Minimum vertical gradient		%	0.5
Maximum vertical gradient		%	2.5
Minimum length of vertical curve		m	60m
Minimum Radius of vertical curve, Top		m	6,500
Bottom		m	3,000
			10.0

Source: JICA Study Team

Table 6.1.2 Geometric Design Standard of Interchange Ramps

Items		Unit	Values to be applied
Width of each carriageway		m	3.50
Shoulder Width	Sewri	m	0.25*
	Shivaji/Nagar,SH 54, Chilre	m	0.50
Design Speed		kph	
Minimum Horizontal Radius		m	60
Minimum Horizontal Curve Length			-
Minimum Horizontal Radius(Ruling)Without Super elevation		m	420
Cross fall		%	2.5
Maximum super elevation		%	7.0
Minimum Transition Length		m	
	R = 45m		45
	R = 60m		60
	R = 90m		90
	R = 100m		100
	R = 150m		150
	R = 170m		170
	R = 200m		200
	R = 240m		240
	R = 300m		300
Minimum Radius without transition curve		m	500
Super elevation rubbed rate			1/100
Sight Distance	Safe Stopping	m	45
	Overtaking	m	90
Minimum vertical gradient		%	0.5
Maximum vertical gradient		%	3.3
Minimum length of vertical curve		m	30
Minimum Radius of vertical curve, Top		m	450
Bottom		m	450

* Confirmed with MMRDA in the meeting on 20th May 2015. The shoulder width was classified as follows.
- 0.25m width: Sewri is a bridges section or restricted land area.
- 0.50m width: Shivaji Nagar, SH54 and Chirle are earth work sections and not restricted land area.

Source: JICA Study Team

(2) Traffic Lanes

Six lanes (three each way) for the MTHL have been decided by the upper plan of Maharashtra state government. In this study, it was reviewed based on the forecast of future traffic volume using the Manual of Specifications and Standards for Expressways (IRC:SP:99-2013). The result of the review indicates that 6-lanes will be required in 2032 (10 years after it opens for traffic). Although 8-lanes will be required in 2042, it is assumed that the function of MTHL will be kept as metro will be constructed in parallel with MTHL. Hence, 6 traffic lanes shall be justified from the opening time.

The number of traffic lanes on ramps is shown in Table 6.1.3.

Table 6.1.3 Number of Traffic Lanes on Ramps

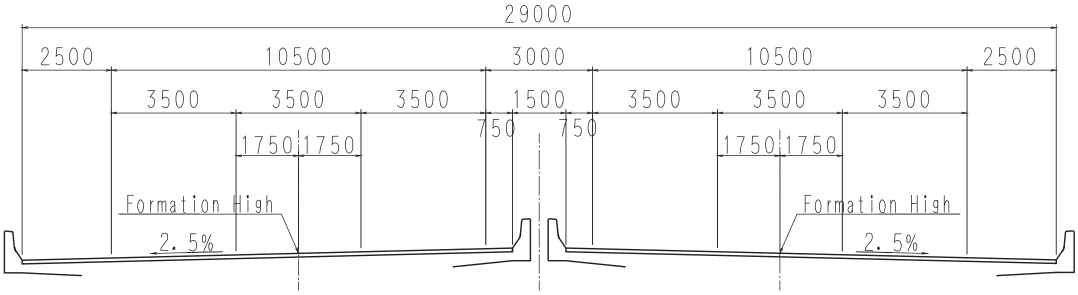
Ramp	Lane Number in 2012	Required Lane Number in 2042	**Applied Lane Number**
Sewri IC, all ramps	2	1 2 for C2	2
Shivaji Nagar IC	2	1	2
On-and-off ramps connecting to main alignment and Navi-Mumbai airport	2	2	2
Other ramps		1	
SH54IC, all ramps	2	2	2
Chirle IC, all ramps	3	1	2

Source: JICA Study Team

(3) Typical Cross Sections

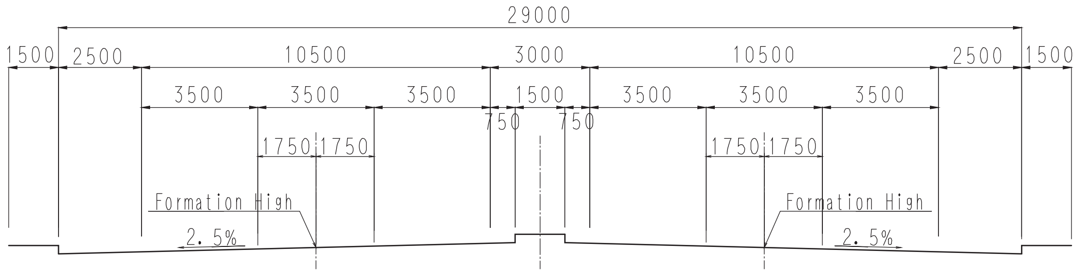
The typical cross sections are shown in Figure 6.1.1 to Figure 6.1.4.

Under Final FS 2012 Report, it was adopted that left shoulder width is 0.5m and right side shoulder is 0.25m. However, when it compares with the international standards on side shoulders, the Study Team pointed out concern on traffic safety at 100kph of design speed and securing parking space at emergency and discussed with MMRDA on other alternatives to improve the situation of traffic safety. As a result, the typical cross section shown in Figure 6.1.1 was accepted by MMRDA.



Source: JICA Study Team

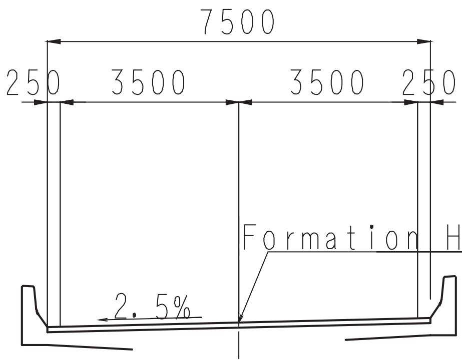
Figure 6.1.1 Main Alignment (Viaduct) Section



Source: JICA Study Team

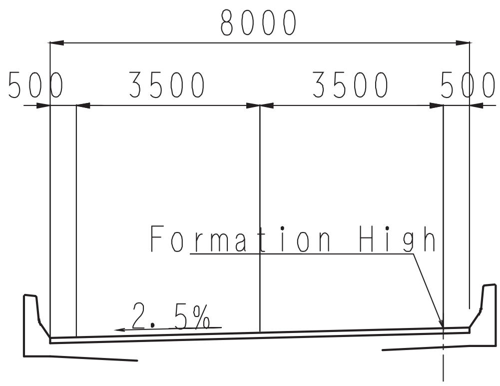
Figure 6.1.2 Main Alignment Earth Works Section (18+950 – 19+950)

Typical cross section for Interchanges basically provides 0.5m of both shoulders. However, the ROW limitation at Sewri IC obliges 0.25 m of both shoulders.



Source: JICA Study Team

Figure 6.1.3 Sewri IC

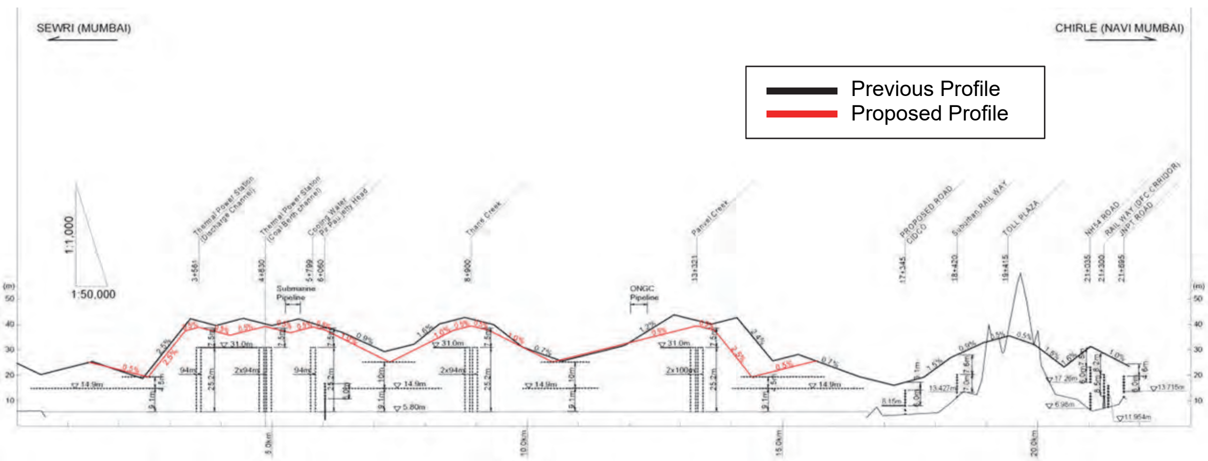


Source: JICA Study Team

Figure 6.1.4 Shivaji Nagar, SH54 and Chirle IC

(4) Vertical Alignment

There are some margins between vertical alignment and navigation clearance on the marine section in the Final Feasibility Study Report, 2012. Therefore, improvement of the vertical alignment is made shown in Figure 6.1.5.



Source: JICA Study Team

Figure 6.1.5 Proposed Vertical Alignment

(5) Study on the Number of Toll Booths

The toll booths for the main carriageway are located between Shivaji Nagar IC and SH54IC. It is projected that eight toll booths shall be required on the main carriageway in 2042 according to the traffic demand forecast with usage of ETC system being 30-40% at that time.

Table 6.1.4 Number of Toll Booths on Main Carriageway

Direction	Traffic Volume in 2042 (Vehicle/day)	Traffic Volume of Peak Hour in 2042 (Vehicle/ hour)	Traffic Volume for ETC lane (vehicle/hour)	Traffic volume for manual lanes (vehicle/hour)	Number of required ETC lanes	Number of required manual lanes	Total number of toll booths
Chirle	25,000	1,800	630	1,170	1	3	4
Sewri	23,000	1,550	540	1,010	1	3	4

Source: JICA Study Team based on Japanese Standard

Toll booths are provided on Shivaji Nagr IC. The number of toll booths at Shivaji Nagar IC was examined based on the forecast traffic volume in 2042. The projected number of toll booths required is shown in Table 6.1.5.

Table 6.1.5 Required Number of Tall Booths at Shivaji Nagar IC (2042)

Ramp (direction)	Required Toll Booth
Navi-Mumbai Airport ⇒ Swri	6
JNPT Port ⇒ Sewri	3
Sewri ⇒ Navi-Mumbai Airport	6
Sewri ⇒ JNPT Port	3
Navi-Mumbai Airport ⇒ Chirle	3
Chirle ⇒ Navi-Mumbai Airport	3

Source: JICA Study Team

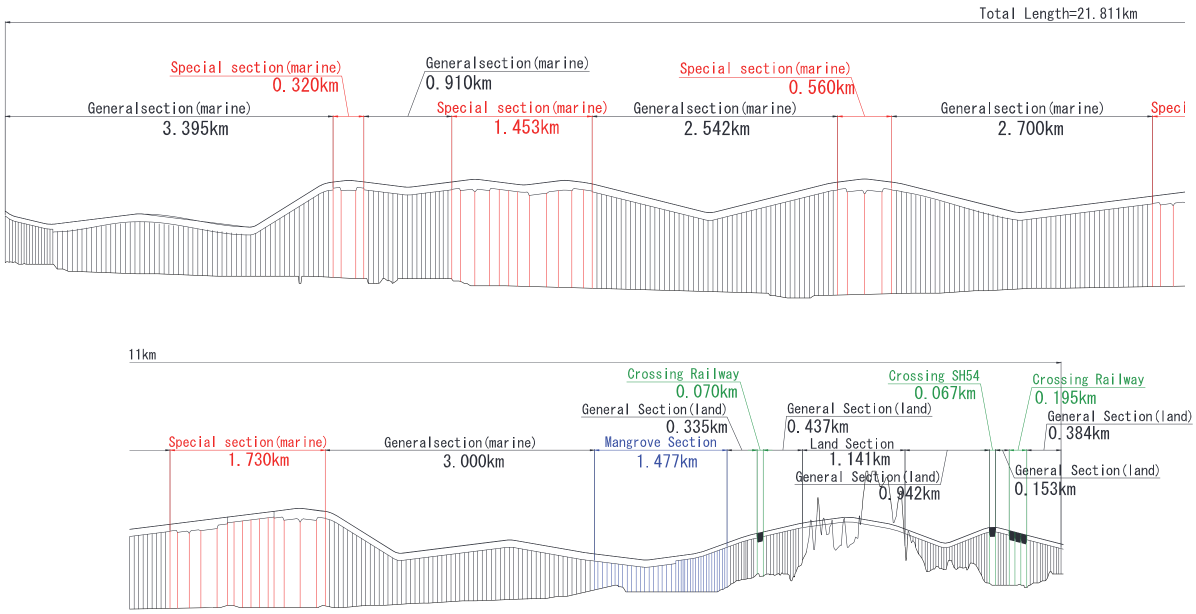
(6) Pavement on Bridge Surface

Whereas “Stone Mastic Asphalt (40mm) + Normal Dense Grade Asphalt (40mm)” is applied on the PC bridge surfaces, two layers (40mm+40mm) of Stone Mastic Asphalt is applied on the steel bridge surfaces in order to follow against larger deformation on the steel deck caused by vehicle loading.

6.2 Preliminary Design for Bridges

(1) Span Arrangement

The span arrangement for the whole MTHL is shown in Figure 6.2.1 and Table 6.2.1 to Table 6.2.2.



Source: JICA Study Team

Figure 6.2.1 Span Arrangement on Main Bridge

Table 6.2.1 Span Arrangement on Main Bridge-1

Chainage	Category	Span Arrangement
No. 0+495～No. 3+395	General Section (marine area)	2,900m (2@50m, 3@50m, 3x2@50m, 5@50m, 7x6@50m)
No. 3+395～No. 3+715	Special Section (marine area)	320m (85m+150m+85m)
No. 3+715～No. 4+625	General Section (marine area)	910m (2x6@50m, 40m+2@50m+40m, 40m+50m+40m)
No. 4+625～No. 6+078	Special Section (marine area)	1,453m (90m+2@150m+2@100m+93m, 120m+180m+120m+140m+120m+90m)
No. 6+078～No. 8+620	General Section (marine area)	2,542m (6x6@50m, 2x5@50m, 46m+3@50m+46m)
No. 8+620～No. 9+180	Special Section (marine area)	560m (100m+2@180m+100m)
No. 9+180～No. 11+880	General Section (marine area)	2,700m (9x6@50m)
No. 11+880～No. 13+610	Special Section (marine area)	1,730m (Mumbai→Navi Mumbai) (84m+2@130m+180m+115m, 74m+4@95m+65m, 112m+2@180m+100m) (Navi Mumbai→Mumbai) (98m+140m+150m+180m+90m, 55m+4@95m+65m, 100m+2@180m+112m)
No. 13+610～No. 16+610	General Section (marine area)	3,000m (10x6@50m)
No. 16+610～No. 16+840	Mangrove Section	230m (40m+3@50m+40m)
No. 16+840～No. 16+880	Crossing Road Section	40m
(Mumbai→Navi Mumbai) No. 16+880～No. 17+320 (Navi Mumbai→Mumbai) No. 16+880～No. 17+341	Mangrove Section	(Mumbai→Navi Mumbai) 440m (45m+4@50m, 45m+3@50m) (Navi Mumbai→Mumbai) 461m (45m+3@50m+30m+20m, 45m+3@50m, 21m)
(Mumbai→Navi Mumbai) No. 17+320～No. 17+471 (Navi Mumbai→Mumbai) No. 17+341～No. 17+482	Crossing Road Section	(Mumbai→Navi Mumbai) 151m (45m+49m+57m) (Navi Mumbai→Mumbai) 141m (57m+34m+50m)
(Mumbai→Navi Mumbai) No. 17+471～No. 18+087 (Navi Mumbai→Mumbai) No. 17+482～No. 18+087	Mangrove Section	(Mumbai→Navi Mumbai) 616m (46m, 2x30m, 2x20m, 14x30m, 2x25m) (Navi Mumbai→Mumbai) 605m (35m, 2x30m, 2x20m, 14x30m, 2x25m)
No. 18+087～No. 18+127	Crossing Road Section	40m
No. 18+127～No. 18+187	General Section (land area)	60m (2@30m)
No. 18+187～No. 18+217	Crossing Road Section	30m
No. 18+217～No. 18+317	General Section (land area)	100m (2x30m+2x20m)
No. 18+317～No. 18+357	Crossing Road Section	40m
No. 18+357～No. 18+421.5	General Section (land area)	64.5m (30m+34.5m)
No. 18+421.5～No. 18+491.5	Crossing Railway Section	70m

Source: JICA Study Team

Table 6.2.2 Span Arrangement on Main Bridge-2

Chainage	Category	Span Arrangement
(Mumbai→Navi Mumbai) No. 18+491.5～No. 18+574 (Navi Mumbai→Mumbai) No. 18+491.5～No. 18+554	General Section (land area)	(Mumbai→Navi Mumbai) 82.5m (37.5m+45m) (Navi Mumbai→Mumbai) 62.5m (37.5m+25m)
(Mumbai→Navi Mumbai) No. 18+574～No. 18+644 (Navi Mumbai→Mumbai) No. 18+554～No. 18+644	Crossing Road Section	(Mumbai→Navi Mumbai) 70m (2@35m) (Navi Mumbai→Mumbai) 90m (40m+50m)
No. 18+644～No. 18+884	General Section (land area)	240m (8@30m)
No. 18+884～No. 18+929	Crossing Road Section	45m
No. 18+929～No. 20+070	Land Area	
No. 20+070～No. 20+225	General Section (land area)	155m (4@30m+35m)
No. 20+225～No. 20+260	Crossing Road Section	35m
No. 20+260～No. 21+012	General Section (land area)	752m (35m+23@30m+27m)
No. 21+012～No. 21+079	Crossing Road Section	67m
No. 21+079～No. 21+232	General Section (land area)	153m (4@30m+33m)
No. 21+232～No. 21+427	Crossing Railway Section	3@65=195m
No. 21+427～No. 21+467	Crossing Road Section	40m
No. 21+467～No. 21+660	General Section (land area)	193m (38m+2@37m+3@27m)
No. 21+660～No. 21+730	Crossing Road Section	70m (2@35m)
No. 21+730～No. 21+811	General Section (land area)	81m (3@27m)

Source: JICA Study Team

(2) Bridge Type

1) Superstructures

The comparison on the bridge type at marine sections with obstacles/navigation channels is shown in Table 6.2.3. As a result, the steel box girder bridge with steel deck is selected at such sections.

Table 6.2.3 Bridge Type Selection at Special Marine Sections

Bridge type **Thane Creek (100+180+180+100)**			Option-1			Option-2			Option-3		
			Continuous 4 spans PC box girder bridge (Original Bridge Type)			Continuous 4 spans steel box girder bridge with steel slab			Continuous 4 spans extra-dosed bridge		
Bridge Image											
Structural performance	Applicability	Record of usage	Many	◎	△	Many	◎	◎	Some	○	○
		Standard span length	Economical span length is 50m to 140m	△		Standard span length is 60m to 200m	◎		Standard span length is 100m to 200m	◎	
	Durability		High	◎		High	◎		High	◎	
	Seismic resistance	Weight of superstructure	Moderate (because of heavy weight)	○		Advantageous (because of light weight)	◎		Moderate (because of heavy weight)	○	
Constructability	Construction method	Difficulty level of construction	Normal (Cantilever method)	○	○	Normal (Large block erection)	○	◎	Difficult (Cantilever after completion of pylon)	△	△
	Quality control	Construction at bridge site or construction at factory	At bridge site	△		At factory	◎		At bridge site	△	
Construction period (for whole MTHL when this bridge type is applied)			**6 years (from previous study)**		△	**Approximately 4.5 years***		◎	**Approximately 6 years**		△
Ease of maintenance	Periodic maintenance	Repainting	Not necessary	◎	◎	Repainting once in 35 years	△	○	Not necessary	◎	○
		Expansion joint	Replacement once in 20 years	○		Replacement once in 20 years	○		Replacement once in 20 years	○	
		Bearing	Replacement once in 40 years	○		Replacement once in 40 years	○		Replacement once in 40 years	○	
	Others								Necessary of high maintenance technology	△	
Aesthetics	Aesthetic view		Matching with the bridge type of general section		○	Matching with the bridge type of general section		○	Monumental appearance		◎
Environmental impact	Marine environmental conservation	Size of foundation	Normal	○	○	Small	◎	◎	Large	△	△
		Size of pier	Normal	○		Thin	◎		Thick	△	
	Environmental impact during construction		Moderate	○		Small (because of short construction period)	◎		Large (because of long construction period)	△	
New Technology (Technical Transfer)			None		△	New type of steel girder Large block erection Thick anti-corrosion coating		◎	None		△
Evaluation			**2**			**1**			**3**		
Construction cost (Ratio)		for Thane Creek Portion	1.00		◎	1.29		○	1.37		△
		for entire section	1.00			1.07			1.13		
Economic Benefit (Economical Internal Return Ratio)			Approx. 14%		◎	Approx. 14%		◎	Approx. 13%		○

Legend: ◎ Good/ Superior, ○ Moderate, △ Poor/Inferior

Source: JICA Study Team

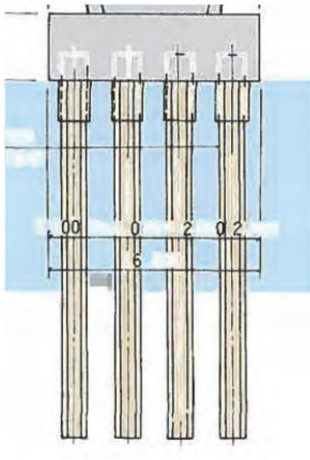
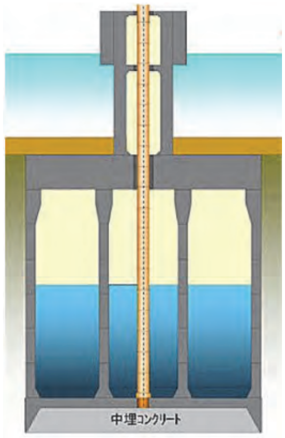
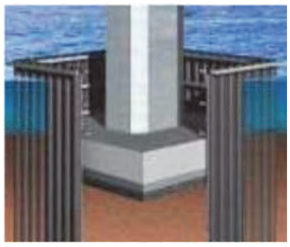
The bridge types in other sections are shown in the following;

- General Section: PC Box Girder Bridge with 50m in span length
- Mangrove Section: PC Box Girder Bridge with 50m in span length
- Crossing Railway and Crossing SH54: Steel Truss Bridge
- Crossing Road Section: PC Box Girder Bridge with 30m in span length

2) Substructures

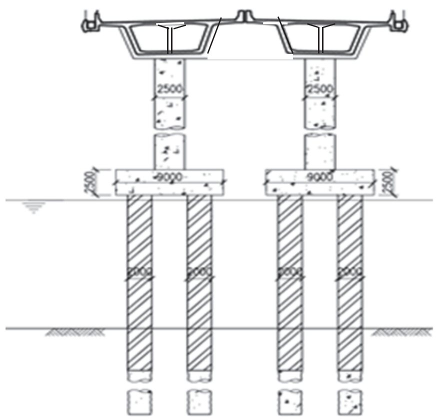
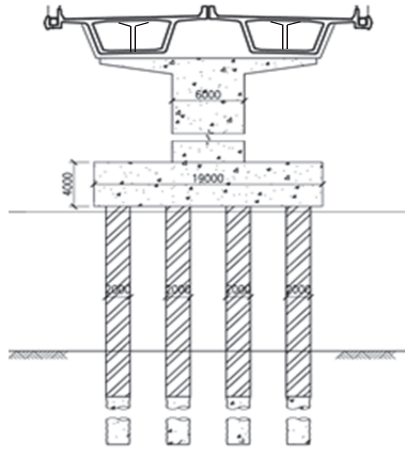
A bored pile type is selected as a result of comparison of the foundation type at marine sections with obstacles/navigation channels shown in Table 6.2.4. A single column-pier type is also selected as a result of comparison of the pier type at the same sections shown in Table 6.2.5.

Table 6.2.4 Comparison of Foundation Forms for Marine Bridge Sections

	Bored Pile foundation	Caisson foundations	Steel pipe sheet pile foundations
Diagram			
Properties	• Pile foundations are common practice in India. There are many cases of their application.	• Caisson foundations are fairly common practice in India.	• There are no cases of this type of foundation being constructed.
	• Pile foundations have an advantage considering the scale of bridge loads.	• The bridge loads are not large enough to make caisson foundations a valid choice.	• The bridge loads are not large enough to make caisson foundations a valid choice.
	• There are no construction issues.	• Large-scale equipment is required for construction below depth of 0 m underwater, which is a disadvantage compared to group pile foundations.	• This method has some issues because this one has not been used in India.
Conclusion	Suitable	Feasible	Not feasible

Source: JICA Study Team

Table 6.2.5 Comparison of Pier Forms (Pier)

	Single-column piers	Hammerhead piers
Diagram		
Structural performance	This form has good stability against asymmetric erection forces of the superstructure's main girders during construction, because its columns are immediately below where the girders will load.	Superstructure erection loads and the main girder loads may act asymmetrically on the pier during construction, so there is a risk of generating large rotational moments in the pier heads. Therefore, it is necessary to design girders to ensure their rigidity.
Constructability	This form is good for ease of construction, because precast pier caps could be adopted.	It is easy to construct columns and pier caps compared to the other option but requires careful construction of the pier beams
Economic efficiency	OK	OK
Conclusion	This form was adopted for its good stability and ease of construction during superstructure erection, and good aesthetics. [Adopted]	This form was rejected for its potential to detrimentally affect the main girders during construction. [Rejected]

Source: JICA Study Team

The substructure types in other sections are selected as follows;

- General Section: (foundation) bored pile, (pier) RC Single-column piers
- Mangrove Section: (foundation) bored pile, (pier) RC Single-column piers
- Crossing Railway and Crossing SH54: (foundation) bored pile, (pier) RC Single-column piers
- Crossing Road Section: (foundation) bored pile, (pier) RC Single-column piers

(3) Bridge Type at Interchange

The bridge types in ramp sections are selected shown in the following;

- Sewri IC: (superstructure) PC box girder bridge, (pier, foundation) RC piers, bored pile

- Shivaji Nagar IC: (superstructure) RC hollow slab bridge, (pier, foundation) RC piers, bored pile
- SH54 IC: (superstructure) PC box girder bridge, (pier, foundation) RC piers, bored pile
- Chirle IC: (superstructure) Steel truss bridge, PC box girder bridge, RC hollow slab bridge (pier, foundation) RC piers, bored pile

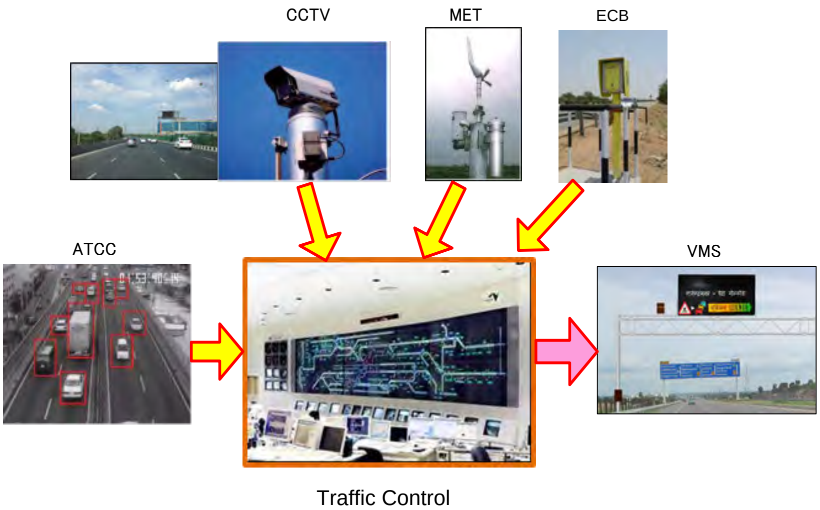
(4) Countermeasure against Salt Damage on Steel Bridge

A thick anticorrosion coating has frequently been applied on marine steel bridges and has high reliability. In addition, maintenance is relatively easy. Hence, “a thick anticorrosion coating” is recommended for steel bridges in MTHL.

(5) ITS

1) Traffic Management System

A Traffic Management System is a support system to manage the traffic on MTHL safely and efficiently. The conceptual system configuration is shown in Figure 6.2.2. The system consists of the Information collection system including CCTV, Emergency Call Box (ECB), Automatic Traffic Counter-cum-Classifier (ATCC) and Meteorological Observation System (MET), and the Information dissemination system including Variable Message Signs (WMS).



Source: JICA Study Team

Figure 6.2.2 Conceptual System Configuration

The objective and function of the traffic management system is shown in Table 6.2.6.

Table 6.2.6 Information Collection System and Information Dissemination System

Facility	Objective / Function
CCTV : on-road (Closed Circuit Television)	- Monitoring of traffic condition, traffic congestion and accidents, etc. - Operation such as zoom, turning by remote control from the traffic control center
CCTV : under-girder (Closed Circuit Television)	- Monitoring of security under the bridge
MET (Meteorological Observation System)	- Monitoring of weather condition of Mumbai bay - Precipitation, fog, wind direction, wind velocity
ECB (Emergency Call Box)	- System to enable reporting of incidents to the traffic control center at the time of first aid in a disaster, trouble and accidents, etc.
ATCC (Automatic Traffic Counter-cum-Classifier)	- Measurement of traffic volume - Classification of vehicle type
VMS (Variable Message Sign)	- Dissemination of information such as road condition and weather condition

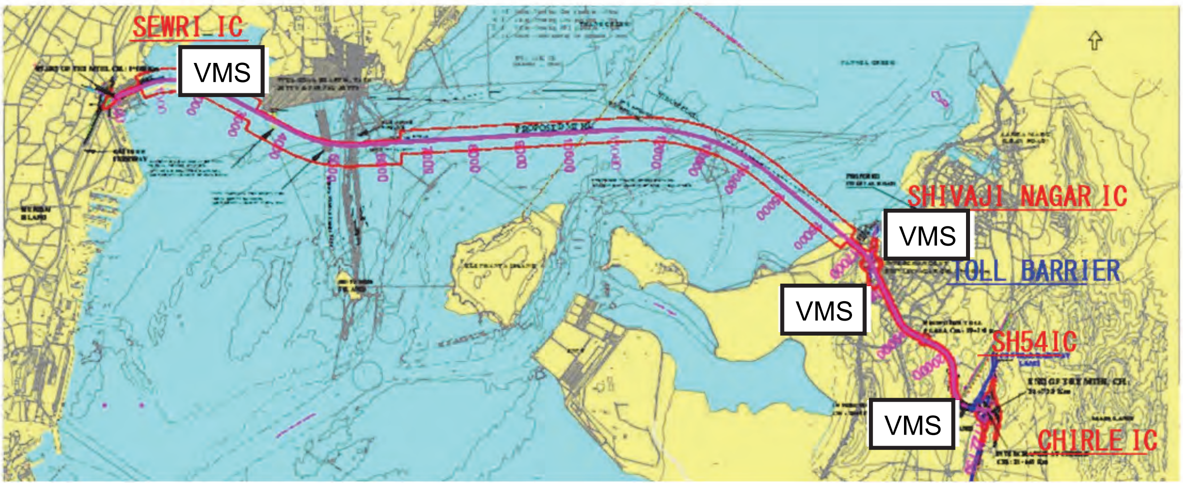
Source: JICA Study Team

The deployment plan for the traffic management system is shown in Table 6.2.7 and Figure 6.2.3.

Table 6.2.7 Deployment Plan for Road Side Facilities

Facility	Quantity	Interval	Location
CCTV: on-road	132	Approx.333 m	Road side
CCTV: under-girder	22	Approx. 1 km	Under slab of median
ECB	44	Approx.1 km	Road side
VMS	4	—	Entrance of toll plaza After getting on toll road /Sewri side
MET	3	Approx. 7 km	Road side
ATCC	4	—	Between Sewri IC and Shivajinagar IC/each direction Between Shivajinagar IC and SH54 IC/each direction

Source: JICA Study Team



Source: JICA Study Team

Figure 6.2.3 Locations for the Installation of VMS (Recommended)

7. CONSTRUCTION PLANNING

7.1 Construction Overview

Summary of the project component including construction method is shown in Table 7.1.1 and Table 7.1.2.

Table 7.1.1 Summary of the Construction - 1/2: Main Alignment

Construction Environment	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Pier No.	Substructure Type Foundation Type
	Start	End			
Typical Marine Section	0+495	1+045	PC Box Girder (Span-by-Span)	MP1 (0+495) MP12 (1+045)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
	1+045	3+395		MP13 (1+095) MP58 (3+345)	
Special Marine Section	3+395	3+715	Steel Box Girder with Steel Slab (Large Block Erection)	MP59 (3+395) MP62 (3+715)	Wall Pier: Voided Rectangular Pile: ϕ2,400 (in situ)
Typical Marine Section	3+715	4+625	PC Box Girder (Span-by-Span)	MP63 (3+765) MP80 (4+585)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Special Marine Section	4+625	6+078	Steel Box Girder with Steel Slab (Large Block Erection)	MP81 (4+625) MP93 (6+078)	Wall Pier: Voided Rectangular Pile: ϕ2,400 (in situ)
Typical Marine Section	6+078	8+620	PC Box Girder (Span-by-Span)	MP94 (6+128) MP143 (8+574)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Special Marine Section	8+620	9+180	Steel Box Girder with Steel Slab (Large Block Erection)	MP144 (8+620) MP148 (9+180)	Wall Pier: Voided Rectangular Pile: ϕ2,400 (in situ)
Typical Marine Section	9+180	11+880	PC Box Girder (Span-by-Span)	MP149 (9+230) MP201 (11+830)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Special Marine Section	11+880L	13+610L	Steel Box Girder with Steel Slab (Large Block Erection)	MP202 (11+880)L MP217 (13+610)L	Wall Pier: Voided Rectangular Pile: ϕ2,400 (in situ)
	11+880R	13+610R		MP202 (11+880)R MP217 (13+610)R	
Typical Marine Section	13+610	16+610	PC Box Girder (Span-by-Span)	MP218 (13+660) MP276 (16+560)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Mangrove Section	16+610	16+840	PC Box Girder (Span-by-Span)	MP277 (16+610) MP281 (16+800)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Road Crossing Section	16+840	16+880	PC Box Girder (Span-by-Span)	MP282 (16+840) MP283 (16+880)	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
Mangrove Section	16+880L	17+320L	PC Box Girder (Span-by-Span)	MP284 (16+925)L MP292 (17+270)L	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
	16+880R	17+341R		MP284 (16+925)R MP293 (17+320)R	
Road Overbridge	17+320L	17+471L	PC Box Girder (Span-by-Span)	MP293 (17+320)L MP296 (17+471)L	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
	17+341R	17+482R		MP294 (17+341)R MP297 (17+482)R	
Mangrove Section	17+471L	18+087L	PC Box Girder (Crane Full Span)	MP298(17+517)L MP317(18+062)L	Column Pier: ϕ2,500 Pile: ϕ2,000 (in situ)
	17+482R	18+087R		MP298(17+517)R MP317(18+062)R	

Source: JICA Study Team

Table 7.1.2 Summary of the Construction - 2/2: Main Alignment

Construction Environment	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Pier No.	Substructure Type Foundation Type
	Start	End			
Road Overbridge	18+087	18+127	PC Box Girder (Full Staging)	MP318 (18+087) MP319 (18+127)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	18+127	18+187	PC Box Girder (Crane Full Span)	MP320 (18+157)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	18+187	18+217	PC Box Girder (Crane Full Span)	MP321 (18+187) MP322 (18+217)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	18+217	18+317	PC Box Girder (Crane Full Span)	MP323 (18+247) MP325 (18+297)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	18+317	18+357	PC Box Girder (Full Staging)	MP326 (18+317) MP327 (18+357)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	18+357	18+421.5	PC Box Girder (Full Staging)	MP328 (18+387)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Railway Overbridge	18+421.5	18+491.5	Steel Truss (Crane Full Span)	MP329 (18+421.5) MP330 (18+491.5)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	18+491.5L	18+574L	PC Box Girder (Full Staging)	MP331 (18+529.5)L	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
	18+491.5R	18+554R		MP331 (18+529.5)R	
Road Overbridge	18+574L	18+644L	PC Box Girder (Full Staging)	MP332 (18+574)L MP334 (18+644)L	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
	18+554R	18+644R		MP332 (18+554)R MP334 (18+644)R	
Typical Land Section	18+644	18+884	PC Box Girder (Crane Full Span)	MP335 (18+675) MP341 (18+854)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	18+884	18+929	PC Box Girder (Full Staging)	MP342 (18+884) MA2(18+929)	Inverted T Abutment Pile: ϕ1,000 (in situ)
Earthworks Section	18+929	20+070			
Typical Land Section	20+070	20+225	PC Box Girder (Crane Full Span)	LA1 (20+070) LP4(20+190)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	20+225	20+260	PC Box Girder (Crane Full Span)	LP5(20+225) LP6(20+260)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	20+260	21+012	PC Box Girder (Crane Full Span)	LP7(20+295) LP30(20+985)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	21+012	21+079	PC Box Girder (Crane Full Span)	LP31(21+012) LP32(21+079)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	21+079	21+232	PC Box Girder (Crane Full Span)	LP33(21+109) LP36(21+199)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Railway Overbridge	21+232	21+427	Steel Truss (Crane Full Span)	LP38(21+232) LP40(21+427)	Column Pier: ϕ3,250 Pile: ϕ1,500 (in situ)
Road Overbridge	21+427	21+467	PC Box Girder (Crane Full Span)	LP41(21+467)	Column Pier: ϕ3,250 Pile: ϕ1,500 (in situ)
Typical Land Section	21+467	21+660	PC Box Girder (Crane Full Span)	LP42(21+505) LP46(21+633)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	21+660	21+730	PC Box Girder (Crane Full Span)	LP47(21+660) LP49(21+730)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	21+730	21+811	PC Box Girder (Crane Full Span)	LP50(21+757) LP54(21+811)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)

Source: JICA Study Team

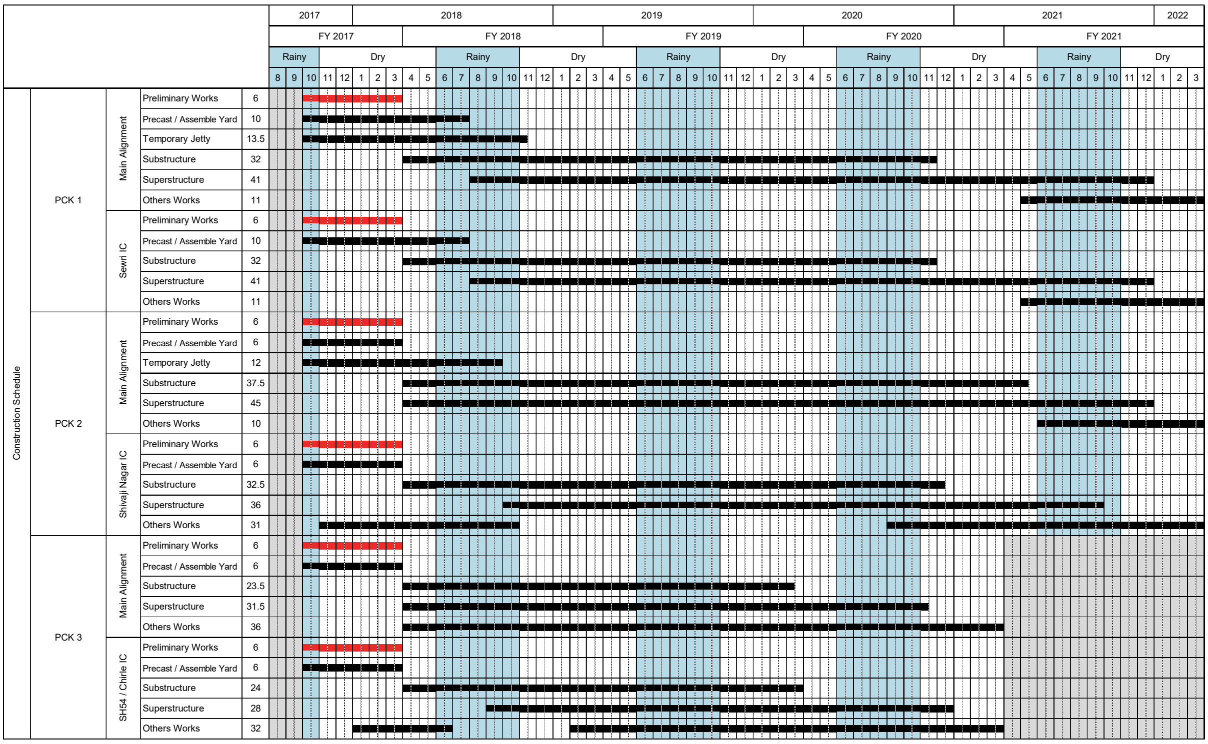
7.2 Contract Package

The Project is divided into 4 contract packages comprising three civil packages and one ITS.

- Package 1: 10.4km (CH. 0+000 to CH. 10+380)
- Package 2: 7.8km (CH. 10+380 to CH. 18+187)
- Package 3: 3.6km (CH. 18+187 to CH. 21+834)
- Package 4: ITS and Operation & Maintenance Facility/Equipment

7.3 Construction Schedule

In India there are two defined seasons: Rainy (June to October) and Dry (November to May). In the monsoon season heavy rain falls usually during a short space of time, also there are only a few days that is not possible to work due to continuous rains. However, the operation of barges maybe limited due the monsoon influence on tidal hydrodynamics. A coefficient of 1.35 was applied in the elaboration of the construction schedule to consider the loss of productivity during the rainy season. The construction schedules for all major works are shown Figure 7.3.1:



Source: JICA Study Team

Figure 7.3.1 Construction Schedule

8. PROJECT COST ESTIMATE

The estimated total project cost is shown in Table 8.1.1. Package 5 is to be conducted by MMRDA.

Table 8.1.1 Total Project Cost

Items	Foreign Currency Portion (million JPY)			Local Currency Portion (millon INR)			Total (million JPY)		
	Total	JICA Portion	Others	Total	JICA Portion	Others	Total	JICA Portion	Others
Package-1 (Western Off-Shore)	1,685	1,685	0	65,116	65,116	0	120,772	120,772	0
Package-2 (Eastern Off-Shore)	923	923	0	48,556	48,556	0	89,723	89,723	0
Package-3 (Navi Mumbai)	127	127	0	13,005	13,005	0	23,911	23,911	0
Package-4 (ITS)	0	0	0	1,444	1,444	0	2,640	2,640	0
Package-5 (Geo-Technical Investigation)	0	0	0	196	0	196	359	0	359
Dispute Boads for Pkg-1/2/3/4	337	337	0	0	0	0	337	337	0
Price Escalation	138	138	0	4,051	4,051	0	7,546	7,546	0
Physical Contingency	321	321	0	13,237	13,217	20	24,529	24,493	36
Consulting Services	3,609	3,609	0	1,805	1,805	0	6,911	6,911	0
Land Acquisition	0	0	0	9,969	0	9,969	18,231	0	18,231
Administration Cost	0	0	0	4,838	0	4,838	8,849	0	8,849
VAT	0	0	0	9,079	0	9,079	16,604	0	16,604
Import Tax	0	0	0	579	0	579	1,059	0	1,059
Interest during Construction	4,507	0	4,507	0	0	0	4,507	0	4,507
Front End Fee	553	0	553	0	0	0	553	0	553
Project Cost	**12,201**	**7,140**	**5,060**	**171,875**	**147,194**	**24,681**	**326,531**	**276,333**	**50,198**

Source: JICA Study Team

9. OPERATION AND MAINTENANCE OF MTHL

9.1 Operation and Maintenance Plan

In general, the O/M of a toll road on which vehicles can be driven at a high speed (100km/h), such as MTHL, is divided into four major components: 1) Inspection, 2) Maintenance, 3) Traffic Management, and 4) Toll Management.

(1) Inspection and Maintenance Plan

The types and frequency of the inspection works are planned according to the Operation and Maintenance Manual of BWSL, which runs at the western off-shore line of Mumbai peninsula and inspection works conducted on expressways in Japan.

(2) Maintenance Plan

Routine Maintenance includes cleaning, vegetation and minor pavement repair, etc. In general, Maintenance Requirements are set for maintenance of National Highways by Concession agreement in India. In MTHL, the maintenance work that is equal to other Indian toll roads is required.

(3) Toll Management Plan

The toll plazas of MTHL are planned in Shivajinagar IC toll plaza (CH:17+342) and a main toll plaza (CH:19+370; main carriageway between Shivajinagar IC and SH54 IC). Both toll plazas shall be located in Navi Mumbai side.

CCTV cameras shall be installed at each lane in the Toll Plaza and CCTV images shall be monitored in the Toll Office in order to monitor the situations of traffic and toll collection at tollgates. Vehicle types shall be identified and checked by toll collectors and vehicle type identifiers installed at the tollgates.

(4) Traffic Management Plan

The major services generally required in the Traffic Management are as follows:

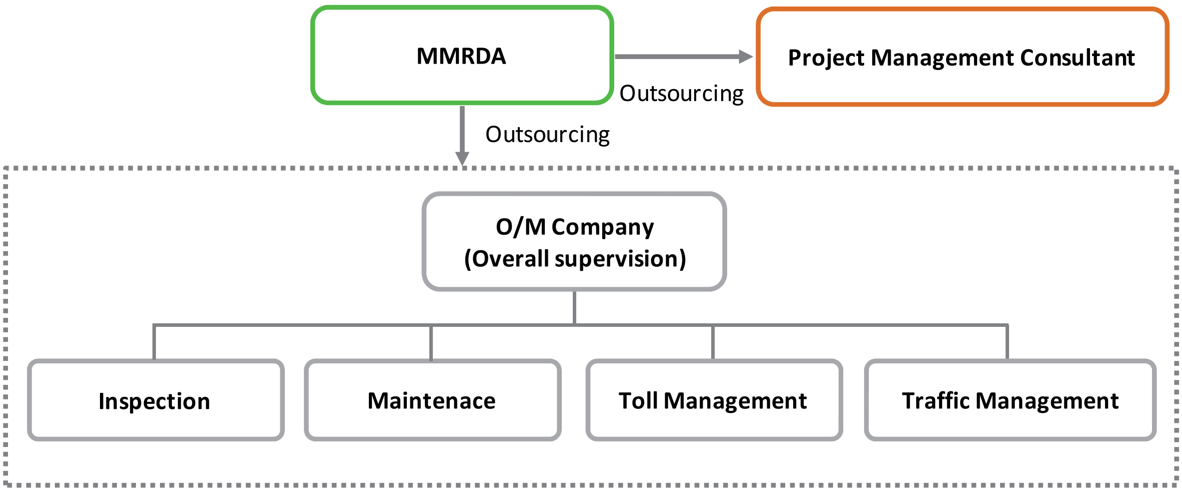
- Collection of 1) traffic information including congestion, 2) road information including objects on the road and 3) weather information from the road patrols and the roadside facilities (including CCTV cameras, traffic counters and emergency telephones) and implementation of appropriate measures against the situation
- Warning to and enforcement of laws and rules on traffic violators (speeding, overloading, etc.) in cooperation with the traffic police

- Accumulation and analysis of the traffic, road and weather information collected from the road patrols and the roadside facilities (hereinafter referred to as "the Road Traffic Information")
- Provision of the Road Traffic Information to road users on variable-message signs (VMS) and the Internet.

9.2 Operation and Maintenance Organization

(1) Overall Organizational Structure

MMRDA intends to outsource the Operation and Maintenance (O/M) of MTHL after the completion of its construction. And the supervision of outsourced Operation and Maintenance works shall be planned to be conducted by Project Management Consultants because it seems difficult for MMRDA to supervise the Operational and Maintenance works directly due to lack of such experience. Figure 9.2.1 shows the recommended overall organizational structure for O/M for MTHL.

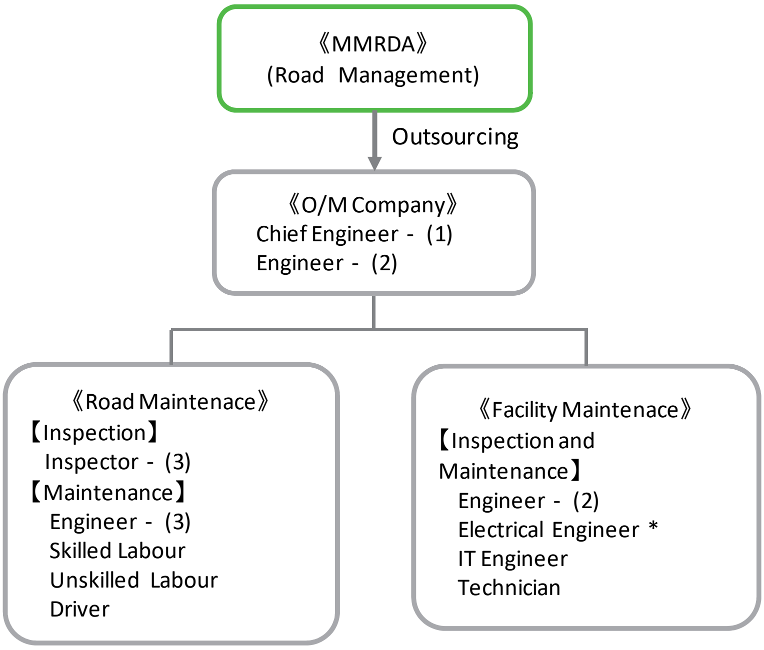


Source: JICA Study Team

Figure 9.2.1 Overall Organizational Structure for O/M

(2) Organizational Structure for Inspection and Maintenance

Figure 9.2.2 shows the recommended organizational structure for the inspection and maintenance of MTHL.



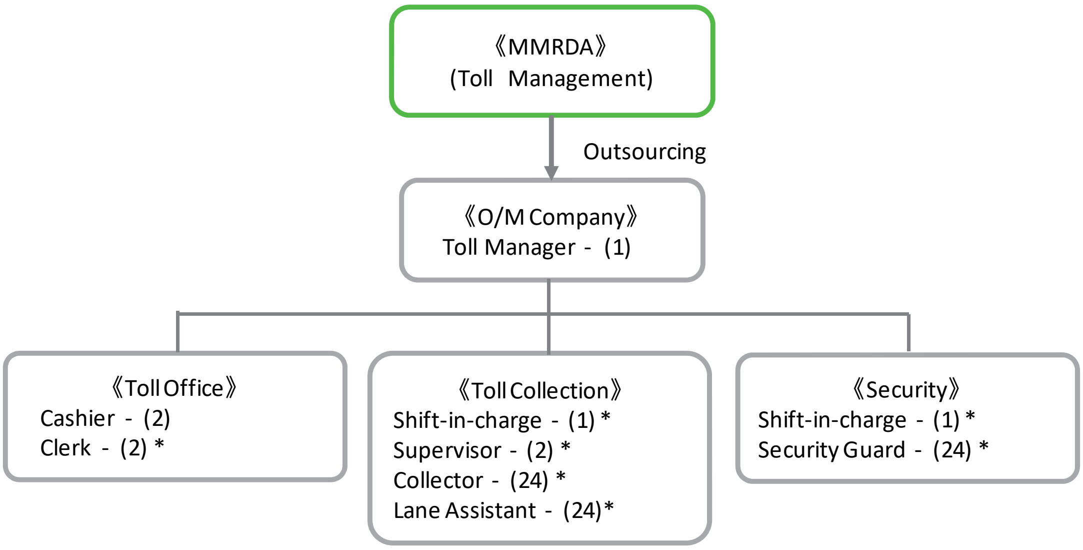
* 8 hours a day in 3 shifts

Source: JICA Study Team

Figure 9.2.2 Organizational Structure for Inspection and Maintenance (Recommended)

(3) Organizational Structure for Toll Management

The recommended organizational structure is shown in Figure 9.2.3 designed by reference to other toll roads in India. As the toll collection has to be performed 24 hours a day/365 days a year, a design of four teams working eight-hours a day in 3 shifts has been adopted as the standard work shift system.



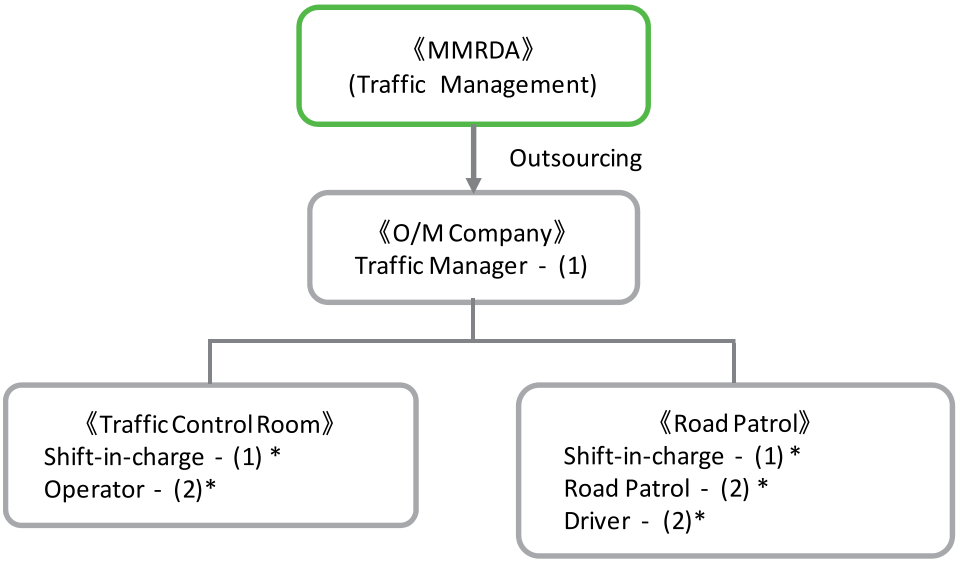
* 8 hours a day in 3 shifts

Source: JICA Study Team

Figure 9.2.3 Organization Structure for Toll Collection (Recommended)

(4) Organizational Structure for Traffic Management

Figure 9.2.3 shows the recommended organizational structure for the implementation of the traffic management of MTHL. As the traffic control has to be performed 24 hours a day/365 days a year, a design of four teams working eight-hour shifts in turns has been adopted as the standard work shift system.



*: 8 hours a day in 3 shifts
Source: JICA Study Team

Figure 9.2.4 Organizational Structure for Traffic Management (Recommended)

9.3 Operation and Maintenance Cost Estimation

The Operation and Maintenance Cost for MTHL is estimated based on the recommended Operation and Maintenance Plan in 9.1 and recommended Operation and Maintenance Organizational Structure in 9.2. And the Periodic Maintenance Cost shall be estimated as well.

(1) Routine Operation and Maintenance

Table 9.3.1 shows the rough estimated cost of Routine Operation and Maintenance.

Table 9.3.1 Rough Estimated Cost of Routine Operation and Maintenance

	Item	Estimated Amount (in million INR)	Interval
1	Project Management Consultant	16	Every year
2	Inspection & Maintenance	95	Every year
3	Toll Management	101	Every year
4	Traffic Management	40	Every year
5	Maintenance Office	10	Every year
6	Others (Electricity)	10	Every year

Source: JICA Study Team

(2) Periodic Maintenance

Table 9.3.2 shows the rough estimated cost of Periodic Maintenance.

Table 9.3.2 Rough Estimated Cost of Periodic Maintenance

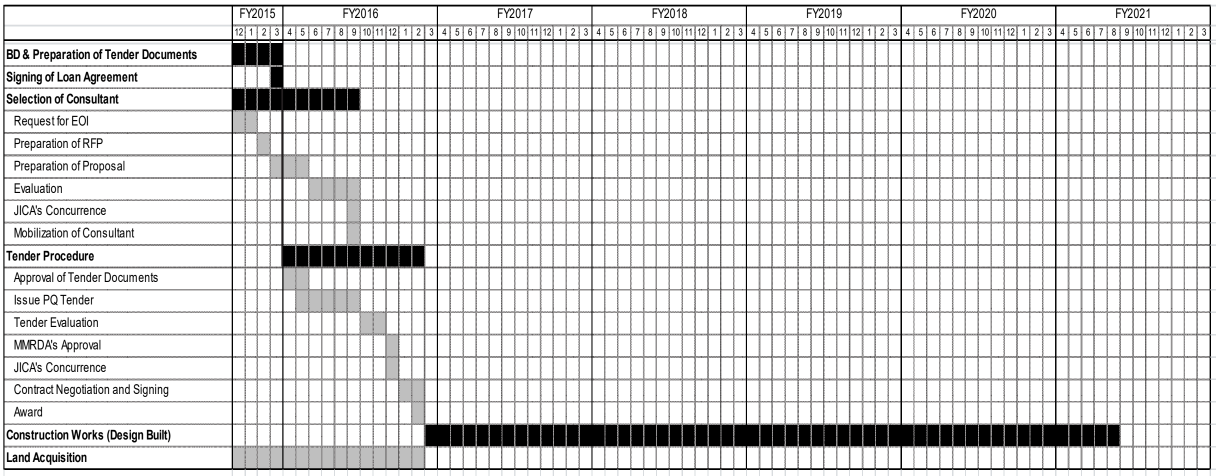
	Item	Estimated Amount (in million INR)	Interval
1	Pavement	427	15 years (5 years)
2	Road marking	42	10 years (5 years)
3	Touch-up painting	121	15 years (10 years)
4	Repainting	455	25 years (15 years)
5	Expansion device	163	20 years (5 years)
6	Bridge inspection passage	119	20 years (5 years)
7	Noise barrier	128	20 years
8	Traffic Management system	448	10 years
9	Toll Management system	200	10 years

( ): Implementation period as reference

Source: JICA Study Team

10. PROJECT IMPLEMENTATION PLAN

The implementation schedule for the project is shown in Figure 10.1.1 with assumption applying Design-Build scheme.



Source: JICA Study Team (based on the discussion of MMRDA with JICA on 6 August 2015)

Figure 10.1.1 Implementation Schedule

11. ECONOMIC AND FINANCIAL ANALYSIS

Toll rates are assumed as in the following three cases.

- Case 1 : It is the amount of 50% decrease of Case 2
- Case 2 : As a base case, it is set based on a "willingness to pay survey in 2011", and it is escalated up to 2022 as the year of beginning commercial operation.
- Case 3 : It is the amount of 50% increase of Case 2

11.1 Financial Analysis

The result of the financial analysis is shown in Table 11.1.1.

In the Case 1, project IRR has the low rate of minus 1.13%. Repayment for the yen loan cannot be made in the 23 years of the whole project period.

In the Case 2, project IRR is still at a low rate, 1.77%. Repayment for the yen loan cannot be made in the 10 years of the whole project period.

In the Case 3, project IRR is still at a low rate of 3.36%. Repayment for the yen loan cannot be made in the initial 8 years of the whole project period.

Table 11.1.1 The result of financial analysis

Case 1

	Amount (million INR)
Total Revenue	165,219
Total CAPEX	180,707
Total OPEX	21,801
Total Project Cost	202,508
Balance	-37,289

Project IRR	**-1.13%**
FIRR on MMRDA	N/A
DSCR	
Max DSCR	2.83
Average DSCR	0.96
Min DSCR	0.34

Case 2

	Amount (million INR)
Total Revenue	279,211
Total CAPEX	180,707
Total OPEX	21,801
Total Project Cost	202,508
Balance	76,702

Project IRR	**1.77%**
FIRR on MMRDA	2.41%
DSCR	
Max DSCR	5.56
Average DSCR	1.73
Min DSCR	0.51

Case 3

	Amount (million INR)
Total Revenue	375,202
Total CAPEX	180,707
Total OPEX	21,801
Total Project Cost	202,508
Balance	172,694

Project IRR	**3.36%**
FIRR on MMRDA	6.29%
DSCR	
Max DSCR	8.18
Average DSCR	2.39
Min DSCR	0.58

Source: JICA Study Team

11.2 Economic Analysis

In all the cases, Case 1, Case 2 and Case 3, the EIRR exceeds 12% based on the evaluation standards on infrastructure projects in India. This indicates that implementation of the project is relevant from the viewpoints of the national economy as well as from the regional economy.

In order to comprehend the effects on the cost-benefit analysis from uncertainties due to changes in the socio-economic situation, a sensitivity analysis was carried out. Case 2, as the basic scenario, was tested by putting variable factors which could significantly impact the cost-benefit analysis. Specifically, variables are; ±10% of total initial investment cost 161,743 million INR, ±10% of benefit (VOC and TTC). However, in all scenarios, the EIRR is calculated to be more than 12%.

Table 11.2.1 Summery of sensitivity analysis (EIRR)

		Benefit		
		-10%	Base case	+10%
Cost	-10%	13.7%	14.4%	15.1%
	Base case	13.0%	13.7%	14.3%
	+10%	12.3%	13.0%	13.7%

Source: JICA Study Team

12. ENVIRONMENTAL IMPACT ASSESSMENT

12.1 Necessity of Environmental and Social Considerations

An Environmental Certificate for MTHL is not required in accordance with the Environmental Protection Law (2006, 2009, 2012). However since the alignment of MTHL passes through the Coastal Regulation Zone (CRZ), MMRDA has prepared a Rapid EIA 2012 based on a relevant survey for one season, and then the Rapid EIA has been reviewed and issued CRZ clearance on July 2013 with 5 years validity from MoEF.

In this Study, a supplemental EIA has been prepared based on the Rapid EIA 2012 and a gap analysis between JICA Guidelines for Environmental and Social Considerations 2010 and the Rapid EIA 2012. Additionally, comments from external specialists on the natural environmental area have been referred to for setting up adequate and practical mitigation measures.

12.2 Supplemental Environmental Analysis and Activities

(1) Result of Gap Analysis

The gap analysis between the Existing Rapid EIA and JICA Guidelines for Environmental and Social Consideration 2010 was conducted, and then a following supplemental analysis and activities were carried out from April to September 2015.

- Implementation of Social Impact Study (Census, socio-economic survey and inventory of loss assets)
- Holding public consultations at the scoping stage and draft supplemental EIA stage
- Implementation of quantitative analysis on pollution items (Air, Noise, Vibration and CO2)
- Preparation of mitigation measures for the natural environment (literature survey on other projects and interviews with wildlife specialists)

(2) Result of Environmental Analysis

An outline of the analysis results are shown below;

Table 12.2.1 Result of Analysis of Supplemental EIA

Item	Result
1. Pollution (Air, Noise, Vibration, water, soil pollution and sedimentation etc.)	The result of the quantitative analysis on air, noise and vibration indicates they are not expected to exceed standard values. With regard to water quality such as turbidity, project activities do not give significant impacts due to mitigation measures. The excavated soil is to be tested and necessary treatment and reuse or disposal will be conducted under relevant waste laws.
2. Natural Environment (Protected area, ecosystem and tidal flow)	Cutting mangrove and impacts on feeding area of migratory birds and habitats of fauna during construction is expected by construction activities. Migratory birds that are currently feeding there may avoid the construction area temporarily, however, they may gradually come back again to the same place due to implementation of mitigation measures such as setting up noise barriers and appropriate lighting system. Additionally it was analysed that the existence of bridge piers will only have negligible impacts on tidal flow. Thus it is supposed that it is not likely to have significant impacts on the ecosystem.
3. Social Environment (Land acquisition, resettlement)	Land acquisition in Navi Mumbai side has almost been completed by CIDCO. On the other hand, in Mumbai side Sewri, land acquisition is not necessary because a Government agency owns the land, however, informal inhabitants and some shops are located in the affected area. Thus a social impact study has been carried out and established a compensation policy and livelihood restoration program in accordance with relevant Indian laws and JICA Guidelines. The principles of the compensation policy and restoration program have been explained through twice meeting with project affected persons and a consensus was achieved.

Source: The Survey Team

(3) Mitigation Measures and Monitoring Plan

More than 50 mitigation measures have been planned in the environmental management plan on the Supplemental EIA. Implementation of these mitigation measures and monitoring shall be done with adequate corroboration under MMRDA, General Consultant, Project Contractor, Environmental authorized agencies such as the Environmental Department of Maharashtra State and the Ministry of the Environment & Forests.

12.3 Public Consultation and Information Disclosure

Two public consultations at the scoping stage on 29th July 2015 and then in the draft EIA stage on 15th September 2015 have been held on the process of the supplemental EIA.

In these meetings, the project outline, positive and negative impacts, mitigation measures, monitoring plan and tentative project schedule have been explained and opinions exchanged between MMRDA and the participants. The supplemental EIA is finalized based on such opinions and disclosed in public after the review and approval process in MMRDA.

Figure 12.3.1 Photos of the Public Consultation on EIA

12.4 Recommendations on EIA

The following actions are recommended from the view of natural and social environmental considerations. MMRDA should discuss and respond regarding the following items under cooperation with other relevant organizations and agencies.

(1) Implementation of Baseline Survey before Construction Stage

For implementation of effective mitigation measures, a comprehensive ecosystem baseline survey should be carried out in the project area before detailed design.

Items to be surveyed are migratory birds, benthos, fish, mangroves and mudflats

Major Relevant Agencies: MMRDA, GC, JICA

(2) Construction Contractor's Responsibility

The following conditions should be included in the bidding documents for the construction contractor

- The contractor shall comply with the environmental management plan in the Supplemental EIA and CRZ conditions issued on July 2013
- The contractor shall comply with relevant Indian laws and JICA Guidelines for Environmental and Social Considerations (2010) when the contractor develops his construction yard, and then he must conduct appropriate mitigation measures and monitoring.

Major Relevant Agencies: MMRDA, General Consultant, Contractor

(3) Compensatory Planting of Mangroves

Implementation of compensatory planting of mangroves should be carried out under instruction of MOEF, so as not to have adverse impacts on the surrounding ecosystem. This detailed plantation plan should be prepared by the GC and Contractor under discussion with MMRDA, Maharashtra State and MoEF during the detailed design stage.

Major Relevant Agencies: MMRDA, GC, Contractor, Maharashtra State and MoEF

13. LAND ACQUISITION AND RESETTLEMENT

13.1 Legal Frameworks of Land Acquisition and Resettlement

Although MMRDA is the solely responsible implementation agency for MTHL, applicable legal frameworks will be different among Mumbai side (Sewri section), Sea-link section, and Navi Mumbai section. Within Sewri section, Resettlement and Rehabilitation Policy for Mumbai Urban Transport Project, 2000 (R&R/MUTP) enforced by Government of Maharashtra will be applied. Within Sea-link section, a new compensation policy for project affected fishermen set by MMRDA will be applied since there are no legal frameworks for present fishing activities. For Navi Mumbai section, City and Industrial Development Corporation of Maharashtra (CIDCO)'s special policies based on the land law will be applied as CIDCO has been the solely planning and development authority of the section and acquired new development land including MTHL alignment with its policies.

Table 13.1.1 Key Legislation Relevant to Land Acquisition and Safeguard

Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act (LARR2013) & Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Maharashtra) Rules 2014 (LARR_MH2014) <applicable in Sewri section and on-going land acquisition in Navi Mumbai section (27Ha)>	• Applicable for all public and private (relatively large scale entities defined by Companies Act 2013) projects • Combination of LA1894 and NRRP2007 with improvement of applicability and condition of compensation with livelihood recovery support • Mandatory of SIA and Social Management Plan (SMP) by the individuals & institutions registered or empanelled in the Database of Qualified Social Impact Assessment Resource Partners and Practitioners • Appointment of the SIA team by Social Impact Assessment Unit of the appropriate government agency separate from proponents including responsible/implementation agencies of infrastructure projects
Resettlement and Rehabilitation Policy for Mumbai Urban Transport Project 1997 (amended in 2000) (R&R/MUTP)	• Adapted policy for the World Bank Mumbai Urban Transport Project, 1995 and formally adapted by GoM in 1997, and amended in 2000 • The Resettlement and Rehabilitation policy addressing and mitigating the gap between Indian legal frameworks and WB Operational Policies (OP) in involuntary resettlement WB OP 4.12 • Adapted policy for the JICA Mumbai Metro Phase III project
CIDCO Rehabilitation Scheme (12.5% Scheme)** <applicable in Navi Mumbai section>	• Specially designed and applicable LAND-to-Land compensation packages in Navi Mumbai development by CIDCO since 1990's • For 100% of PAP's land (assuming undeveloped land), given 12.5% of the "Developed" land including social facilities and public utilities accounting for 3.75% (net housing/commercial land would be 8.75%) • Permissible Floor Space Index** (FSI) for the plot allotted: 1.5 and up to 15% of build up area for commercial component
CIDCO Rehabilitation Scheme (22.5% Scheme) <ONLY applicable for limited projects*** in Navi Mumbai>	• Specially designed and applicable LAND-to-Land compensation packages ONLY for Navi Mumbai International Airport (NMIA) and MTHL without cash compensation since early 2015 • For 100% of PAP's land (assuming undeveloped land), given 22.5% of the "Developed" land including social facilities and public utilities
MTHL– Fisher-Folks Compensation Policy 2015	• The compensation and rehabilitation policy of MTHL as per JICA Guidelines on Environmental and Social Consideration 2010 • Definition of potential project impacts and eligible project affected fishermen and their compensation • Defining the setup of separate grievance redress mechanism apart from Sewri and Navi Mumbai sections involving relevant agencies

** 12.5% scheme with cash compensation had been applied for past land acquisition (69ha:70%) by CIDCO. It is still applicable for any PAPs for on-going acquiring land (27ha:30%) if PAPs prefer.

FSI: ratio between the liveable area on all floors of the building to the actual area of that plot of land

*** 22.5% scheme is ONLY applicable for on-going land acquisition (27ha:30%) for MTHL if PAPs prefer.

Source: JICA Study Team

13.2 Scope of Land Acquisition and Resettlement Impact

In order to grasp the number and situation of the Project Affected Persons, JICA Study Team conducted a census/socioeconomic survey compliance with MMRDA BSES for Sewri section. for the Sea-link section, the MMRDA fisheries compensation policy development committee was formed including evaluation methodologies. Throughout the discussions among experts and representatives of fishermen, detailed fisheries surveys were conducted In Navi Mumbai section, it is confirmed that there were no possession of land by non-title holders or farming activities. Thus, the impact would be only land acquisition without resettlement. The outline of land acquisition and socio-economic impact of the project is as follows.

Table 13.2.1 Overall Project Impacts

<table>
<tr><th></th><th>IMPACT</th><th>Sewri</th><th>Sea Link</th><th>Navi Mumbai</th><th>Total</th></tr>
<tr><td>1</td><td>Acquisition of Land/Water (Ha)</td><td>8.6</td><td>810</td><td>96</td><td>914.6</td></tr>
<tr><td>1.1</td><td>Private Land/Water (Ha)</td><td>0</td><td>0</td><td>85.0</td><td>85.0</td></tr>
<tr><td>1.2</td><td>Government Land/Water (Ha)</td><td>8.6</td><td>810</td><td>11.0</td><td>826.6</td></tr>
<tr><td>2</td><td>Land Lease (Ha)</td><td>13.8</td><td>810</td><td>19.0</td><td>824.8</td></tr>
<tr><td>2.1</td><td>Private Land (Ha)</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>2.2</td><td>Government Land (Ha)</td><td>13.8</td><td>810</td><td>19.0</td><td>842.8</td></tr>
<tr><td>3</td><td>Impact on Structure (No.)</td><td>317</td><td rowspan="5">NA</td><td rowspan="4">NA**</td><td>317</td></tr>
<tr><td>3.1</td><td>Loss of Residence (No.)</td><td>229</td><td>229</td></tr>
<tr><td>3.2</td><td>Loss of Business (No.)</td><td>53</td><td>53</td></tr>
<tr><td>3.3</td><td>Impact on community structures (no.)</td><td>10</td><td>10</td></tr>
<tr><td>3.4</td><td>Impact on government structures (no.)</td><td>25</td><td>1</td><td>26</td></tr>
<tr><td>4</td><td>Project Affected Persons (No.)</td><td>1,554</td><td>7,545</td><td></td><td>9,099</td></tr>
<tr><td>4.1</td><td>Households/ Businesses (No.)</td><td>282</td><td>0</td><td rowspan="5">NA**</td><td>282</td></tr>
<tr><td>4.2</td><td>Affected Persons (No.)</td><td>1,272</td><td>7,545</td><td>8,817</td></tr>
<tr><td>5</td><td>Legal Title Holders/Lessee (No.)</td><td>0</td><td rowspan="2">NA</td><td>0</td></tr>
<tr><td>6</td><td>None tile Holders (No.)</td><td>282</td><td>282</td></tr>
<tr><td>7</td><td>Vulnerable Group Household (No.)</td><td>58</td><td>95*</td><td>58</td></tr>
</table>

NA – Not applicable
* Detailed surveys for project affected fishermen were completed in October 2016 and confirmed the number of affected fishermen
** It is confirmed that no residential use and no livelihood recovery are required through the field observation in 2015 and consultation with responsible CIDCO officials. It might be required to acquire a part of a public school land.

Source: MMRDA, CIDCO & BSES data from JICA study team

13.3 Mitigation Measures for Project Affected Stakeholders

In Sewri section, mitigation measures will be enforced based on R&R_MUTP. In Sea-link section mitigation measures will be enforced based on MMRDA Fisheries Compensation Policy. In Navi Mumbai section, land acquisition shall be done based on CIDCO 12.5% with cash defined by LARR_MH 2014 for only land compensation by CIDCO22.5% scheme.

<u>Sewri Section</u>: It is confirmed that all PAPs are non-title holders. MMRDA will offer a tenement (20.9 m2) per family at Bhakti Park. MMRDA developed the Bhakti Park for many other PAPs from the public infrastructure development work. Those PAPs will be transferred,

with relocation support, public transportation tickets etc. Vocational training is not the part of the compensation package, MMRDA will give necessary assistances for the PAPs. Such support is not primarily monetary, and social development and human resource development support projects implemented by Maharashtra State and other public institutions.

Sea-link Section: Based on MMRDA 's Fishery Compensation Policy (2015), monetary compensation will be paid depending on the impacted categories (ref. Table 13.3.2 Entitlement Matrix). Damages from incidental accidents and unforeseen impacts from project activities will be assessed by the GRC and they will be compensated by MMRDA.

Navi Mumbai Section: Only land acquisition shall be one in Navi Mumbai section. The compensation will be done based on cash compensation with land compensation by CIDCO12.5% scheme or only land compensation by CIDCO 22.5% scheme.

13.4 Grievance Redress Mechanism

Sewri Section & Navi Mumbai: Based on MMRDA's GRM experiences, in order to make short and timely decision, a singe committee member GRC will be formed instead of multi committee members' committee. The first level decision is made by the Field Level Grievance Redress Committee (FLGRC) at the field level, and the second level decision is made Senior Level Grievance Redress Committee (SLGRC).

Sea-link Section: Due to the necessity of the special knowledge in fishing and its damage compensation, MMRDA will form a grievance redress committee as follows:

Chairman	Chief, Social Development Cell of MMRDA
Member	Assistant Commissioner, Fisheries (Marine) Mumbai Suburb District
Member	Assistant Commissioner, Fisheries (Marine) Thane and Raigad District
Member	Deputy Collector, Mumbai District
Member	Deputy Collector, Raigad District
Secretary	Superintending Engineer, Engineering Division of MMRDA

Source: MMRDA Principal Compensation Policy (2016)

13.5 Organization Structure of Land Acquisition and Resettlement Assistance

Various specialized groups are required to adequately implement the land acquisition, resettlement and livelihood recovery support. As the centre, the project manager (project management unit) will manages the MMRDA Social Development Division (SDC), MMRDA Public Relations Division (PR UNIT), GRM, and Independent Evaluation Consultant for proper implementation.

13.6 Cost & Source of Land Acquisition & Resettlement Assistance

The cost for implementation of the Resettlement and Rehabilitation Plan is summarized in the following table.

Table 10.12: Costs for Land Acquisition and Resettlement & Rehabilitation

	Description	Quantity	(Unit)	Rate (INR)	Cost	
					(INR)	(INR/Year)*
1	**Land Acquisition (Total)**				**5,392,381,413**	**1**
1	Sewri		sq.m		3,595,900,000	
	Demolition / Land Clearing cost				1,500,000	
2	Sea-Link		sq.m		1,688,400,000	
3	Navi Mumbai	43,786.57	sq.m	2,430	106,400,000	1
	Demolition / Land Clearing cost				1, 81, 413	
2	**Resettlement/ Replacement (Total)**				**273,464,363**	
1.1	Sewri-Residential	NA**	sq.m		0	
1.2	Sewri-commercial	NA**	sq.m		0	
1.3	Sewri-MPT Structure	lump sum			192,249,137	
2	Sea-Link	0	sq.m	0	0	
3	Navi Mumbai	lump sum			45,215,226	
3	**Land Lease Total (5years)**				**1,800,043,497**	
1	Sewri*				1,800,043,497	332,336,835
2	Sea-Link	NA ***				0
3	Navi Mumbai	NA ****				0
4	**Resettlement and Rehabilitation**				**2,234,739,200**	
1	Sewri					
	Livelihood recovery assistance				TBD	
	Moving allowance				TBD	
	Commute allowance*****	335		11,520	3,859,200	
2.1	Sea-link (Compensation C1)	95	family	584,000	55,480,000	
2.2	Sea-link (Compensation C2)	2,485	family	292,000	725,620,000	
2.3	Sea-link (Compensation C3)	4,965	family	292,000	1,449,780,000	
3	Navi Mumbai	0			0	
5	**Contribution towards Community Revolving Fund****** (Total)**				**282,000**	
1	Sewri	282		1000	282,000	
6	**Construction Stage Monitoring (Total)**				**8,200,000**	
1	NGO Cost	lump sum			2,500,000	
2.1	Cost for Monitoring & Evaluation	lump sum			700,000	Sewri&Navi MB
2.2	Cost for Monitoring & Evaluation	lump sum			3,500,000	Sea-Link
3	Cost of Public Relation Consultant	lump sum			1,500,000	
7	**Post Resettlement Activity**	**282**		**20,000**	**5,640,000**	
Sub-Total (1 to 7)					9,678,750,473	
Miscellaneous items @ 10% of sub total					967,875,047	
GRAND TOTAL (Round @1,000)					**10,646,626,000**	

* Annual escalation 2-4% (ANNEXURE-II, #CE.MTHL/92/2460(G) of MPT Letter to MMRDA dated 27AUG, 2015)

** R&R/MUTP entitle matrix #4. Resident structure owner: PH/DH/SRD Option of 20.91m^2 in multi-story buildings without cash compensation for the existing housing structures.

*** Not applicable as for the Sea-link section the cost of acquisition is already considered as per the Agreement between both the Govt. Organizations.

**** Not applicable as the Navi Mumbai land will be cleared by CIDCO & handed over to the MMRDA.

***** For Livelihood recovery employees are provided with Railway fare transport on yearly basis, as per the R&R/MUTP

****** Revolving fund is as per the R&R/MUTP

TBD: To Be Defined

Source: JICA Study Team

13.7 Resettlement Monitoring Plan

MMRDA's compensation policy in Sewri section (R&R/MUTP) was originally developed for the Mumbai Urban Transport Project (MUTP) funded by the World Bank group so that detailed rules for the monitoring are also provided. As the implementation agency of the MUTP, MMRDA has been applying the R&R/MUTP for long time. MMRDA has conducted following two types of monitoring:

- Internal Monitoring: Mainly monitoring the progress of land acquisition and resettlement,
- Independent evaluation: Evaluating the status of PAPs' livelihood recovery (right after resettlement, mid, and completion of construction).

Monitoring by the Fisher Folks Compensation Committee (FCC), whichi is the primary inter-authority committee for supervision of implementing Fisheries Compensation Management Plan, shall be done on Month/ Quarterly basis

13.8 Result of Stakeholder Meetings with Project Affected Households

Sewri Section: In order to adequately disclose project information and encourage the PAP's involvement in MTHL project formulation, three stakeholder meetings were held and discussions held among MMRDA, the JICA Study Team, representative in the Sewri society and actual PAPs. It has been recognized that the majority of the PAPs have been supportive of MTHL and look forward to the project implementation and relocation soon.

Sea-Link Section: Throughout the field observations and communication with key officials of DoF, the JICA study team confirmed that almost the entire alignment of is an active fishing area. MMRDA formed the fisheries compensation policy through discussion with relevant authorities and representatives from 9 potentially affected fishing societies. During fishery compensation policy formulation, discussions with fishery representatives were conducted twice. Before the detailed fishery survey was conducted, explanation of the survey and explanation of fishery compensation policy were conducted at the survey villages. Finally, after the detailed fisheries surveys, stakeholder meetings were conducted to present the result of the surveys and collecting opinions form the project affected fishermen. Through these consultations, it is confirmed that general understanding of the fishery compensation policy. However in the same time, it is confirmed that there are some different opinions such as equal compensation for all fishermen.

Navi Mumbai: Because land acquisition and its negotiation are done by CIDCO privately. There are no plans to conduct stakeholder meeting in public.

14. CONSIDERATION FOR CLIMATE CHANGE

14.1 Disadvantage and Mitigation Measure for Climate Change

There are two points of view regarding the vulnerability due to climate change.

- The vulnerability of the viaducts themselves
- The increase in the vulnerability of the viaducts due to changes in the natural environment

The MTHL has a design life of 100 years. Therefore the viaducts by themselves are not vulnerable. On the other hand, there are the factors listed below that increase the vulnerability of the structures due to changes in the natural environment for the MTHL.

- Temperature rise
- Sea level rise
- Increase in rainfall and storms
- Increase in wind speed
- Storm surge and tsunami

14.2 Affected MTHL and Mitigation Measures

(1) Affected MTHL and Mitigation Measures for Temperature Rise

The maximum allowable change in the maximum temperature within the design life of the bridges is less than 10 degrees Celsius. Most of the viaduct in MTHL is made up of concrete bridges. Concrete bridges are generally less susceptible to the effects of temperature. The steel bridges are furnished with some special parts. The steel bridges are generally more susceptible to the effects of temperature. Therefore, the amount of movement of the expansion joints is a little bit larger. <u>The expansion joints must be replaced</u> if the temperature increases.

(2) Affected MTHL and Mitigation Measures regarding Sea Level Rise

A sea level rise under the MTHL would impact fishing boats and large ships if it exceeded 60 cm, however, the threat of this is negligible and therefore the MTHL does not need to design mitigation measures regarding sea level rise.

(3) Affected MTHL and Mitigation Measure for Increase in Rainfall and Storm intensity

It is assumed that the rainfall will decrease around the Mumbai area. Therefore, the mitigation measures in the MTHL do not need to address an increase in rainfall.

The MTHL will have CCTVs and meteorological equipment installed because the MTHL which is high-standard road is controlled access. When the rainfall is harder, the CCTVs and the meteorological stations will provide information to the traffic control center. Then the traffic control center relays the information to the drivers regarding speed limits and road closed etc. through the VMS. Therefore the MTHL can be considered as a countermeasure for harder rainfall.

(4) Affected MTHL and Mitigation Measure for Increase in Wind Speed

It is assumed the wind speed will not increase around the Mumbai area because the rainfall is expected to decrease in this area. The cyclones sometimes come to western Mumbai but the MTHL has the countermeasures to the passengers.

The steel bridges vibrate because of the wind. The countermeasure for high wind is to install fairings at the end of girders and/or provide vibration control devices in the girder.

15. CONCLUSION

The conclusions of the Survey are as follows;

- It is concluded that the project is technically and economically feasible and is acceptable from the viewpoints of environmental and social considerations. The necessary mitigation measures are included as a part of the Project implementation.
- The final MTHL alignment, which connects the Eastern Freeway at Sewri in Mumbai side with National Highway 4B at Chirle in the Navi Mumbai including four interchanges, was carefully set considering all constraints such as including navigation channels, pipelines, jetties and minimizing the adverse impacts on both the environment and resettlement including the flamingos and the World Heritage site of the Elephanta Island. This is the only alignment that makes it possible to avoid the land occupancy of MbPT port yard and facility and still maintain its function as a highway with 100km/h design speed.
- As per the result of the future traffic demand forecast, construction of 6 lanes (three lanes each way), constructing MTHL in a single phase is justified.
- While a Pre-stressed Concrete box girder superstructure is suitable for 50 m spans in portion with no obligatory spans, a steel box girder superstructure is suitable for obligatory spans (max.180m). For the viaduct on the land the Pre-stressed Concrete box girder is suitable for 30m spans. A steel girder type superstructure is adopted for the Railway over Bridges (ROBs).
- ITS facility and equipment is an indispensable component for the MTHL project which is a fully access-controlled toll road. Accordingly, the ITS shall be installed on viaducts and the Bridge portions from commencement of operation.
- MMRDA is an appropriate implementation agency for the Project as they have vast experience in infrastructure works and have carried out the feasibility study for the Project.

The Preparatory Survey on the Project for Construction of Mumbai Trans Harbour Link

In

The Republic of India

FINAL REPORT

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transport Officials
AADT	Annual Average Daily Traffic
AH	Affected Household
AIDS	Acquired Immunodeficiency Syndrome
APs	Affected Persons
ATC	Area Traffic Control
ATCC	Automatic Traffic Counter-cum-Classifier
BMC	Brihanmumbai Municipal Corporation
BEST	Bombay Electric Supply & Transport
BWSL	Bandra Worli Sea Link
CES	Consulting Engineering Services
CIDCO	City and Industrial Development Corporation of Maharashtra Limited
CTS	Comprehensive Transport Study
CRZ	Coastal Regulation Zone
CVCS	Classified Vehicle Count Survey
CWC	Central Water Commission
CWPRS	Central Water & Power Research Station
ECB	Emergency Call Box
EIA	Environmental Impact Assessment
EMA	External Monitoring Agency
EMP	Environmental Management Planning
EPs	Entitled Persons
ETC	Electronic Toll Collection system
ETMS	EFKON Toll Management System
FS	Feasibility Study
GC	Generalized Cost (in Rs.)
GDP	Gross Domestic Product
HPC	High Performance Concrete
HHTL	Highest High Tide Level
IMF	International Monetary Fund
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IPT	Intermediate Public Transport
IRC	Indian Road Congress
JICA	Japan International Cooperation Agency
JRA	Japan Road Association
JNPT	Jawaharlal Nehru Port Trust
km	kilometer

LRFD	Load and Resistance Factor Design
MAD	Mean absolute difference
MbPT	Mumbai Port Trust
MET	Meteorological Observation System
MCGM	Municipal Corporation of Greater Mumbai
MCNM	Municipal Corporation for Navi Mumbai
MMB	Mumbai Maritime Board
MMR	Mumbai Metropolitan Region
MMRDA	Mumbai Metropolitan Region Development Authority
MoT	Ministry of Transport
MOEF	Ministry of Environment and Forest
MSL	Mean Sea Level
MSRDC	Maharashtra State Road Development Corporation Ltd.
MTHL	Mumbai Trans Harbour Link
MUIP	Mumbai Urban Infrastructure Project
MUTP	Mumbai Urban Transport Project
NAPCC	India's National Action Plan on Climate Change
NGO	Non-Governmental Organizations
NMMC	Navi Mumbai Municipal Corporation
NMIA	Navi Mumbai International Airport
ODA	Official Development Assistance
PAHs	Project Affected Households
PC/PSC	Prestressed Concrete
PCC	Pure Car Cargo
PCU	Passenger Car Unit
PMO	Project Management Office
PPP	Public Private Partnership
POL	Petroleum, Oil and Liquids
RAP	Resettlement Action Plan
RC	Reinforced Concrete
RFID	Radio Frequency Identification
RL	Reduced Level
ROW	Right of Way
RPCS	Railway Passenger Count Survey
Rs	Rupees
SEZ	Special Economic Zone
SMP	Social Management Plan
SOI	Survey of India
SPT	Standard Penetration Test
USD	United States Dollar

UK	United Kingdom
UNFCCC	United Nation Framework Convention on Climate Change
VMS	Variable Message Sign
VOC	Vehicle Operating Cost
VOT	Value of Time

1. BACKGROUND, OBJECTIVES AND IMPLEMENTATION OF THE SURVEY

1.1 Background of the Project

Although the urbanization in the Republic of India (hereinafter called India) has been rapidly progressing, the infrastructure development in the urban areas has not caught up speed of development of the urbanization. Particularly, the heavy traffic congestion in the urban areas due to the lack of a road network hinders the economic development in the urban areas. Given this situation, the necessity of a comprehensive infrastructure development plan was given great importance for the growing economic developments.

Mumbai Metropolitan Region, which includes Greater Mumbai and Navi Mumbai, had about 22.8 million population as of 2011 and the population density reached 20,694 people per km^2 in the centre of Greater Mumbai, which makes it one of the most overpopulated cities in the world.

The Navi Mumbai, which is on the east side of Greater Mumbai across the Mumbai Bay, has large potential for development. The Government of Maharashtra has been facilitating various infrastructure projects in Navi-Mumbai area, such as the Navi Mumbai International Airport, Special Economic Zone (SEZ), expansion of Jawaharlal Nehru Port in order to secure sustainable economic development in MMR. Furthermore, the State Government has also facilitated construction of National Highway 4B to Jawaharlal Nehru Port and Mumbai-Pune Expressway. Similarly, the Mumbai Trans Harbour Link (MTHL) would be an important infrastructure project to improve the connectivity between Greater Mumbai and Navi-Mumbai facilitating the economic development in Mumbai Metropolitan Region.

Mumbai Metropolitan Region Development Authority (MMRDA) invited bids in 2013 for implementation of the MTHL project on a Public-Private Partnership (PPP-DBFOT) basis. However, there was no response to the bid process. Subsequently, MMRDA decided to implement the project on EPC (Design-Build) basis with the assistance an Official Development Loan (ODA) loan from Japan International Cooperation Agency (JICA).

1.2 Outline of the Project

The project involves construction of about 22 km of full access-controlled link across the Mumbai bay between Sewri in Mumbai and Chirle in Navi Mumbai with four interchanges in Mumbai and Navi Mumbai (see Location Map).

1.3 Objectives of the Survey

The objectives of the Survey are to provide the necessary information and data on the objective, scope, cost, schedule, procurement method, implementation agency, and operation & management system of the Project for application for a Japanese ODA loan scheme on time in response to its appraisal procedure with consideration of environmental and social aspects

1.4 Contents of the Survey

The major contents of the Survey are as follows;

(1) Confirmation of Necessity and Relevance of the Project

- Review of the previous studies
- Additional engineering surveys comprising a topographic survey, geological investigation, traffic survey, and environmental and social consideration surveys
- Preparation of the project outline including the major facilities and components.

(2) Confirmation of Necessity and Relevance of the Project

- Preliminary design of roads and bridges
- Construction planning, cost estimate and implementation schedule
- Proposal of maintenance and operation system for MTHL
- EIA and SIA preparation
- Economic and Financial analysis
- Preparation of recommendations for project implementation

1.5 Survey Implementation

The output of the Survey will made available as described in the schedule below.

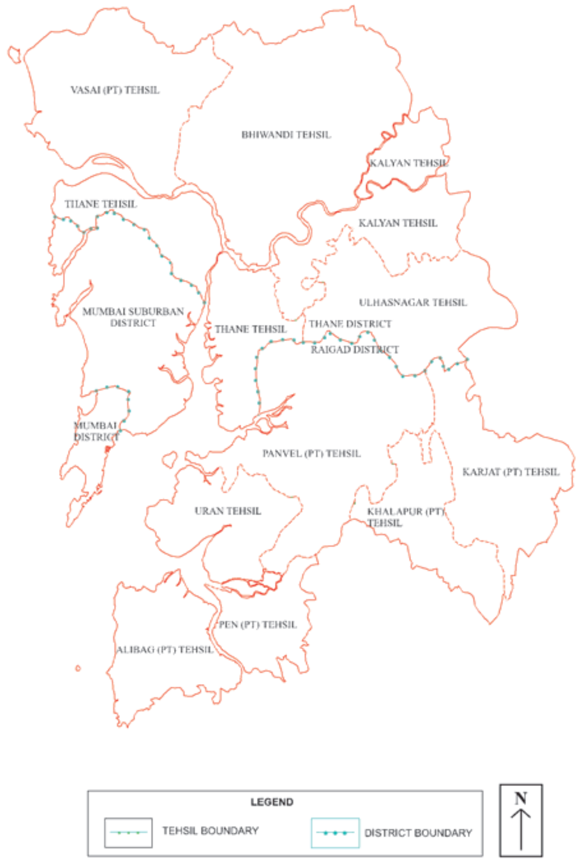
- Middle of April 2015 : Submission of Inception Report
- Middle of August 2015 : Submission of Interim Report
- End of February 2016 : Submission of Draft Final Report
- End of November 2016 : Submission of Final Report

2. GENERAL APPRECIATION AND DEVELOPMENT PLAN

2.1 Socio-Economic Conditions of the Project Area

2.1.1 Introduction

India is located in south Asia and is the second most populous country in the world holding 12.1 billion people (2011) in the seventh largest country in the world by area with 3.28 million km^2. India consists of 29 states and 7 union territories. The Indian economy is the world's seventh-largest by nominal GDP with USD 2,308 billion according to the IMF statistics in 2015. Thanks to the market-based economic reform, India became one of the world’s fastest growing economies and has accomplished its average annual GDP growth rate of 5.8% over the past two decades. In the 2010-11 period its economic growth was recorded as 6.1%. India can be characterized as pluralistic, multilingual, and a multi-ethnic society with rich natural resources.



Source: Comprehensive Transportation Study, MMRDA, 2008

Figure 2.1.1 MMRDA Jurisdiction Area

Mumbai is the largest city in India and it functions not only as the capital of the Maharashtra State but also as the gateway to India for foreign trade as well as the financial and commercial centre of India. Furthermore, Mumbai lies in its uniqueness as a city with very high population density, substantial size of slums and migrant population. The following classifies the administrative jurisdiction related to the Mumbai area.

2.1.2 Mumbai Metropolitan Region (MMR)

The Mumbai Metropolitan Region (hereinafter called MMR) is located on the western coast of Maharashtra State of India, and spreads over 4,355 km^2 with 22.8 million in population in 2011, which is one of the most populous areas in the world, comprising 8 Municipal Corporations, Greater Mumbai, Thane, Kalyan-Dombivali, Navi Mumbai, Ulhasnagar, Bhiwandi- Nizamapur, Vasai-Virar and Mira-Bhayandar; and 9 Municipal Councils, including Ambarnath, Kulgaon-Badalapur, Matheran, Karjat, Panvel, Khopoli, Pen, Uran, and Alibaug, along with more than 1,000 villages in Thane and Raigad Districts.

Although MMR is also the capital of Maharashtra State, it has been developed as a financial and commercial center of India and many headquarters of financial institutions are located there, particularly in Greater Mumbai. Furthermore, since the Mumbai Bay forms a natural harbour, namely Mumbai Port on the Greater Mumbai side and Jawahalal Nehre Port on the Navi Mumbai side, maritime trade of the two ports accounts for approximately 70% of the national maritime trade in India.

The Mumbai Metropolitan Region Authority (hereinafter called MMRDA) is the responsible agency for not only preparing long term plans but also implementing strategic projects as well as financing infrastructure development in MMR.

2.1.3 Greater Mumbai Area

Greater Mumbai, which was previously known as Bombay, lies on a peninsula with a width of 12km at its broadest point and is approximately 40km in length in the north-south direction and is surrounded on three sides by water; namely the Arabian Sea to the west and south and Harbour Bay and Thane Creek to the east. Greater Mumbai had an area of 437 km^2 and a population of 12.48 million in 2011. Many historical buildings such as the Gate of India, Mumbai Station and administrative bodies and financial centres are located in this area.

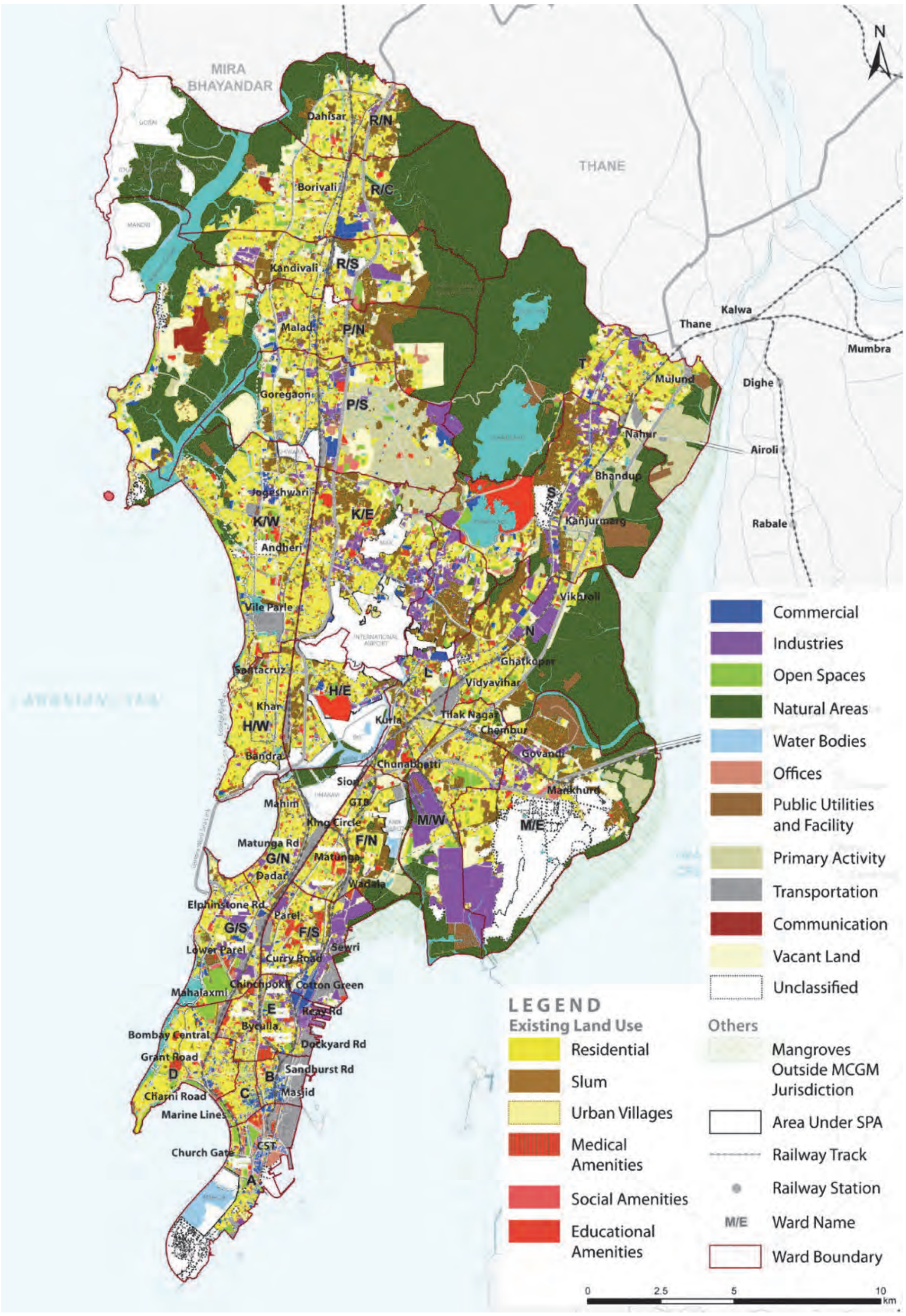
The area started its development in the 16th century after the cession of a group of islands to the Portuguese, and then became a possession of Britain in the 17th century as the gateway to India. Until the 1970s, Greater Mumbai had develped with textile industry and sea port operation. However, the local economy has gradually diversified since then to include finance, gems & jewellery, leather processing, information technology, and entertainment. Nowadays, Greater Mumbai has become the business & financial capital of India. The headquarters of all major banks, financial institutions, and stock exchanges such as the State Bank of India, Life Insurance Corporation of India, the National Stock Exchange of India and Tata Group are located in the Greater Mumbai area.

On one hand, Greater Mumbai has faced the major urbanization issues that are common in many fast-growing cities in developing countries, particularly widespread poverty and unemployment. The second largest slum in Asia, named Dharavi, is located in central

Mumbai with approximately one million people living in 2.39 km^2, which maybe the most densely populated area in the world with a population density of at least 335,000 persons per km^2. Furthermore, the limited availability of land in the city area causes expensive housing and office rent, which results in long commuting time on crowded buses and railways from suburban areas.

Greater Mumbai has an international port, which has been the principal gateway to India, and has handled general cargo. Recently, it has also developed special berths for dealing with Petroleum, Oil and Lubricants (POL), chemicals and Pure Car Cargo (PCC). According to the annual report of 2013-2014 prepared by Mumbai Port Trust, which is operating the port owned by the Government, the Mumbai Port handled traffic of 59.18 MT, which accounts for 10.65% of the total freight handled by the major ports of India.

Since 1865, Greater Mumbai has been administrated by the Municipal Corporation of Greater Mumbai (GCGM), including development and maintenance of infrastructure and public facilities. The budget of the city body for 2011 is INR 204,173 million (USD 4,436 Mil). Figure 2.1.2 shows the land use plan for 2014-2034 for Greater Mumbai.



Source: Greater Mumbai Land Use Plan 2014-2034

Figure 2.1.2 Greater Mumbai Future Land Use Plan for 2014-2034

2.1.4 Navi Mumbai

Navi Mumbai is one of the world's largest planned townships developed at the opposite side of Greater Mumbai across the Mumbai Bay. It started its development in 1972 in order to facilitate decongestion of the Greater Mumbai area as recommended by Mumbai Metropolitan Regional Planning Board under the Maharashtra State.

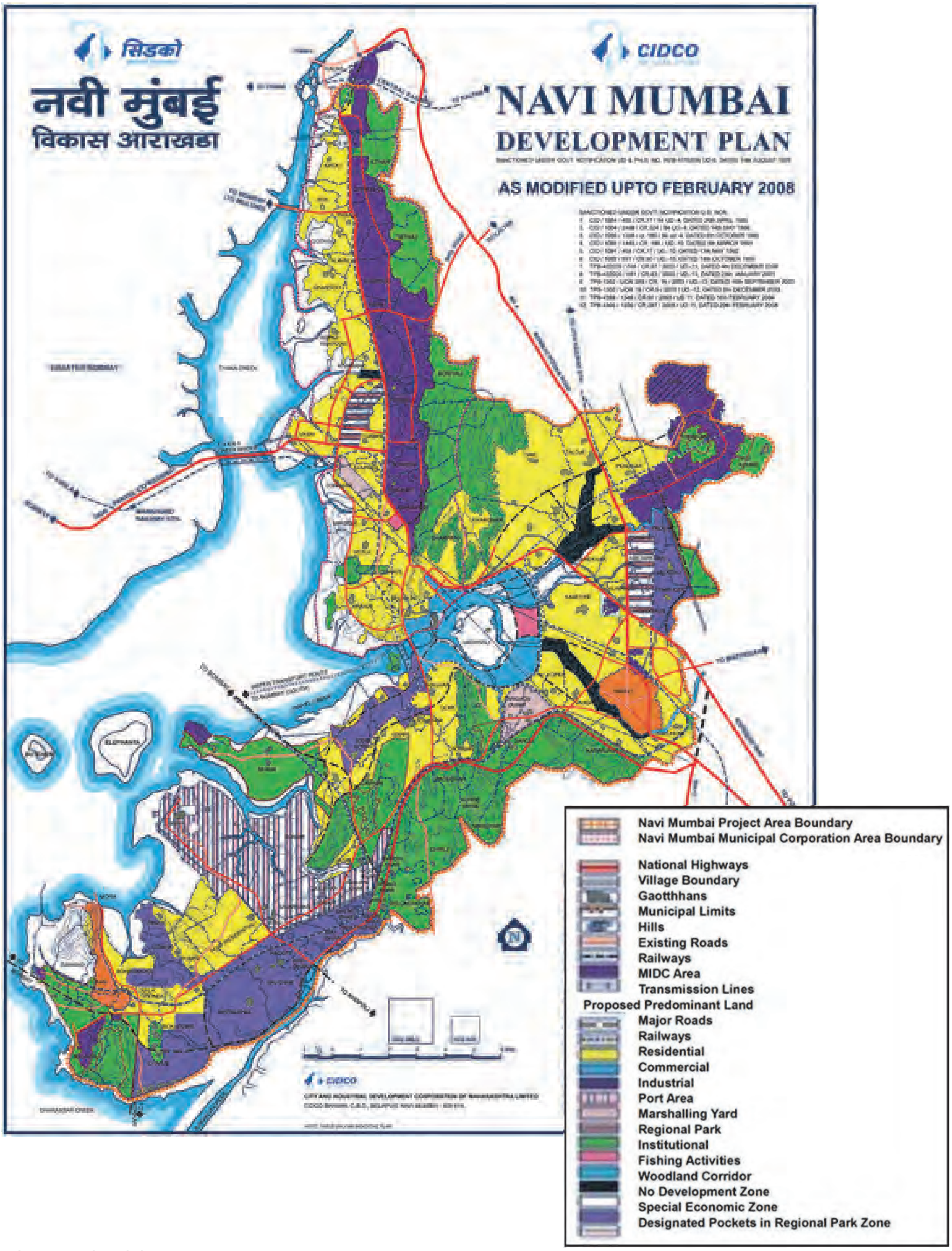
The development area of Navi Mumbai spreads across 344 km^2 with 150km of creek line, including 14 well-planned nodes along mass transport corridors, and 45% of the land reserved for green area. According to the latest census in 2011, the population of Navi Mumbai was approximately 1.12 million, of which 35% of the total population has shifted from Greater Mumbai.

The City and Industrial Development Corporation of Maharashtra Limited (CIDCO), which was established in 1970 under the Indian Companies Act, 1956 and designated as the New Development Authority for development of Navi Mumbai area, has been involved in planning and development of New Towns for Navi Mumbai by selling land and properties constructed in order to recover all cost of development.

Much effort has been made to attract various industries from Greater Mumbai so far in order to promote development of the Navi Mumbai side. Petrochemical industries in the manufacturing sector built production units in the Navi Mumbai area in the first decade of its development history. Whereas 277 factories are located in the Taloja Industrial Area, approximately 391 factories are located in the Thane Belapur Industrial Belt, including all types of process industries such as chemical, paper, plastic, etc. at present. The wholesale traders in steel also shifted to Kalamoboli in Navi Mumbai. Furthermore, major wholesale agricultural produce markets including vegetables and fruit also was shifted to the Agriculture Produce Market Complex (APMC) from Greater Mumbai by 1996 and has contributed to creating job opportunity to people in Navi Mumbai. In the recent years, CIDCO has been promoting to attract IT and Information Technology Enabled Services (ITES) in Mumbai rather than labour-intensive factories.

Navi Mumbai holds the biggest container handling port, Jawahalal Neharu Port, which was chartered as Indian's International trade port in 1989, and presently deals with around 60% of the country's container cargo.

Figure 2.1.3 shows the Navi Mumbai Development Plan.



Source: CIDCO HP

Figure 2.1.3 Navi Mumbai Development Plan

2.2 Overview of National Development Plan and Road Sector Development Plan

2.2.1 National Transport Policy

India Transport Report: Moving India to 2032, which summarizes a comprehensive and long term national transport policy for the next 20 years, was compiled in 2014 after a series of discussions in 21 meetings over almost 4 years by a High Level National Transport Development Policy Committee (NTDPC) set up by the Government of India. The report covers not only technical issues and policies of transport sectors but also emphasizes on the importance of institutional and human resource development, financial arrangement, and participation of the private sector in infrastructure development, as well as comprehensively discussing the issues and development policy for not only the road sector but also other important transport sectors including railways, ports and shipping, urban transport and civil aviation.

The report eventually recommended the following points for Roads and Road Transport planning and development for next 20 years;

- Roads shall be regarded as a part of an integrated multi-modal system of transport, and development of primary road networks must be coordinated with planning of the railway network development, connectivity with ports, airports, SEZ, and logistic hubs.
- Continuation of expansion of rural connectivity through the current Pradhan Mantri Gram Sadak Yojana (PMGSY) scheme.
- Further expansion of the national and state highway network in tune with the economic growth and other development projects and connectivity to Asian Highways
- Necessity of legal framework revision of the private sector participation in highway projects to facilitate further participation.
- Necessity of review of the user fees on the national highways
- Facilitation of capacity development of state highway agencies
- Establishment of a Road Safety and Traffic Management Board to tackle the road safety issues

2.2.2 Current Situation of the Road Network in India

India Transport Report: Moving India to 2032 also well summarizes the current situation of Indian's road network. The road network development since independence is shown in Table 2.2.1. The road network of India is relatively well developed comparing to other developing countries in terms of density relative to both population and land area. Whereas in India, the density is 336 km/100,000 people and 1382km/1,000 km^2, in China it is 288 km/100,000 people and 403km/1,000 km^2 while in Pakistan it is 149 km/100,000 people and 335km/1,000 km^2.

Table 2.2.1 Road Network Development since 1951 ('000km)

Road Network	1951	1961	1971	1981	1991	2001	2011
(i) Total Length	400	524	915	1,485	2,327	3,374	4,690
(ii) National Highways	22	24	24	32	34	58	71
(iii) State Highways	-	-	57	94	127	132	164
Surfaced Roads	157	263	398	684	1,113	1,602	2,502

Source: India Transport Report: Moving India to 2032, NTDPC

From the table, it can be said that the Government of India has been concentrating on road network development in the last 30 years, particularly improvement of rural connectivity.

Table 2.2.2 shows the future investment plan for the road network expansion for next 20 years. The investment plan for the next 20 years envisages achieving the expansion of 12,500 km for the Expressway network, and 180,000km for the National Highway network by both the governments and the private sector. Regarding the State Highway, the re-classification of the State Highway to National Highway shall be made so that the physical target for the expansion of the State Highway was not indicated in the India Transport Report.

Table 2.2.2 Further Investment Plan for Road Network Development

	Period				Total
	2012-17	2017-22	2022-27	2027-32	2012-32
Expressway (km)	500	2,000	4,000	6,000	12,500
National Highway (km)	-	80,000	-	100,000	180,000
State Highway (km)	-	-	-	-	-

Source: India Transport Report: Moving India to 2032, NTDPC

Table 2.2.3 shows the future investment plan for road network development by road class and the target period. As shown in the table, the Government planned the huge amount of investment (average of approximately 360 million USD per year) in the road network development in the next 20 years, while facilitating the investment from the private sector. Thus, it can be said that the Indian Government is still focusing on the expansion of the road network for economic and social development.

Table 2.2.3 Further Investment Plan for Road Network Development

(Billion INRs)

Scheme	2012-2017		2017-22		2022-27		2027-32		2012-32	
	Total	Private Sector	Total	Private Sector	Total	Private Sector	Total	Private Sector	Total	Private Sector
Expressway	200	Nil	600	100	1,200	300	1,800	1,000	3,800	1,400
National Highway	2,150	600	3,150	800	4,200	1,150	5,700	1,450	15,200	4,000
Special Scheme:SARDP-NE+ Arunachai package (Central Sector)	250	Nil	400	Nil	500	50	600	50	1,750	100
Other specific Scheme (Central Sector)	100	Nil	150	Nil	200	Nil	200	Nil	650	Nil
State Highways	2,100	150	2,700	250	3,200	350	3,600	400	11,600	1,150
Major District Roads	1,000	Nil	1,300	Nil	1,600	Nil	2,100	Nil	5,700	Nil
Rural Roads	1,450	Nil	1,850	Nil	1,300	Nil	1,100	Nil	5,700	Nil
Total	7,250	750	10,150	1,150	12,200	1,850	15,100	2,900	44,700	6,650

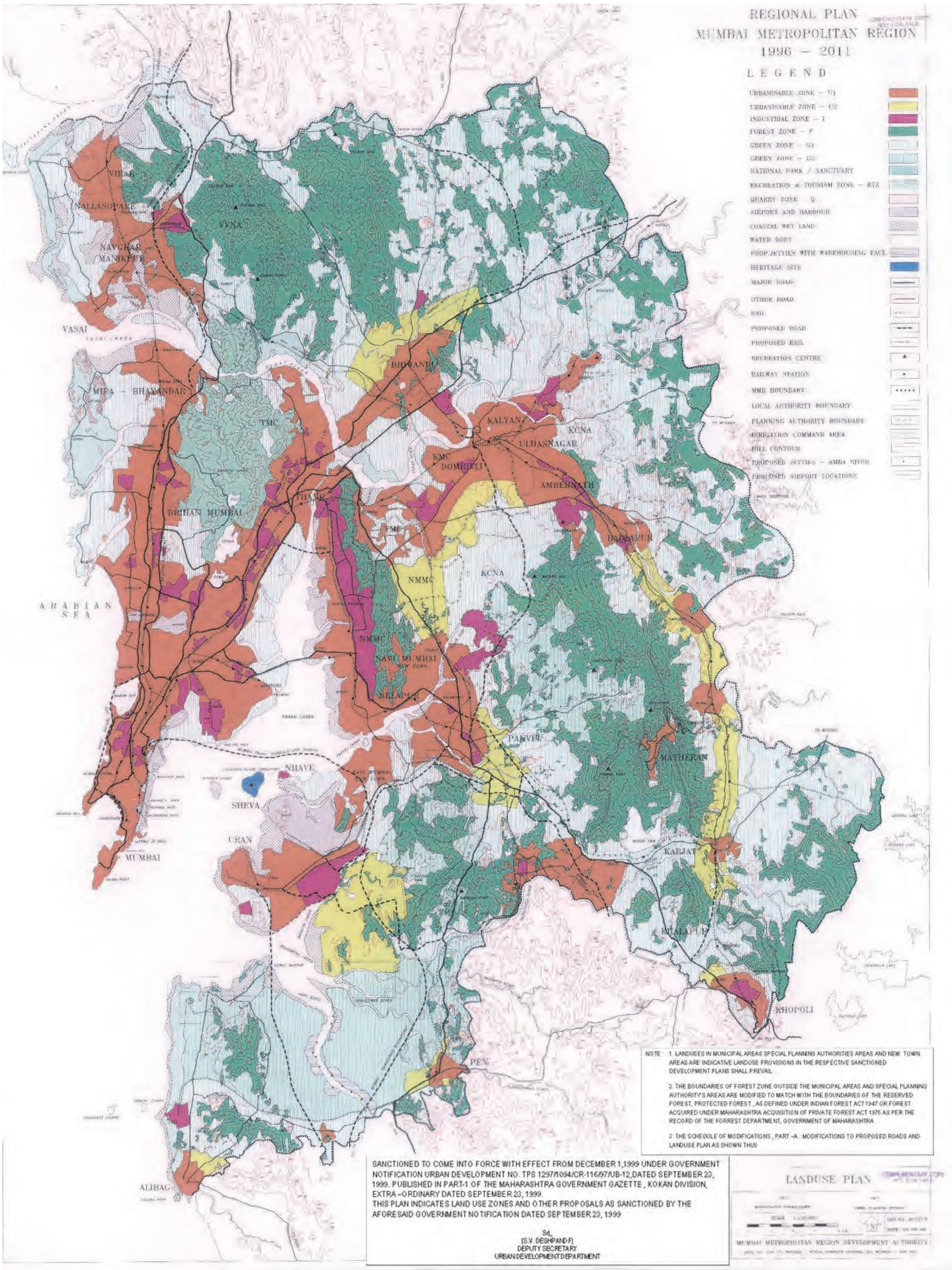
Remarks: SARDP-NE: Special Accelerated Road Development Program in North East under the Ministry of Development of the North Eastern Region

Source: India Transport Report: Moving India to 2032, NTDPC

2.3 Master Plan and Transport System in MMR

2.3.1 Regional Master Plan for MMR

MMRDA was the responsible organization to prepare the Regional Mater Plan for MMR and the first Regional Master Plan for MMR was compiled in 1973. After considering various planning aspects, MMRDA prepared the revised Regional Plan for the period 1996-2011, which was approved by the State Government on 23rd September, 1999 and it came into force with effect from 1st December, 1999. At present, the 2nd revision of the Regional Plan for MMR (2011-2031) is still in progress. As per the Metropolitan Planning Committee (MPC) Act, 1999, this revision of the Regional Plan will be carried out by the MPC, while receiving support from MMRDA. For preparing a new Development Plan, MPC set up five study groups comprising (1) Land Use, (2) Industry and Investment, (3) Environment, (4) Transportation, and (5) Housing and envisage including outputs of the CTS, business plan for MMR, Chitale Committee Report and the Concept Plan for MMR. Figure 2.3.1 shows the 1st revision of the Regional Development Plan for MMR (1996-2011).



Source: MMRDA

Figure 2.3.1 Regional Development Plan for MMR (1996-2011)

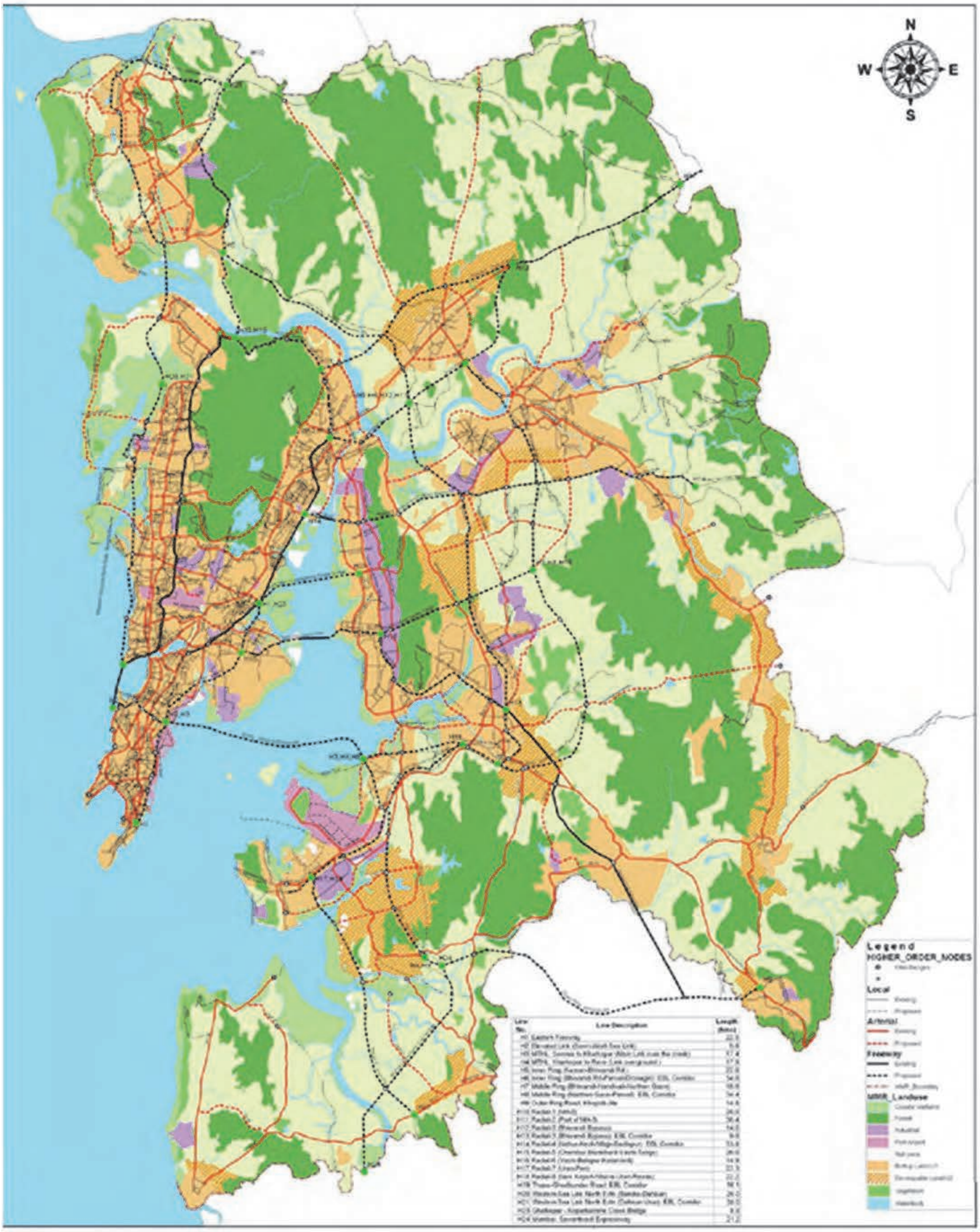
2.3.2 Comprehensive Transportation Study (CTS) for MMR

The Comprehensive Transportation Study (CTS) for Mumbai Metropolitan Region (MMR), which was guided by MMRDA and supported by World Bank, was completed in July 2008 over 25 years after the issuance of the last comprehensive transport study. The CTS formulated short term (2016), medium term (2021) and long term (2031) transportation strategies and guidance for MMR, and recommended specific public transport and highway development projects by each targeted year. The report provided a vision for MMR's future transportation as a seamless, integrated system, in which commuters can make their journeys safely and conveniently by various modes of transport, particularly by public transport, and recommended the development of Multi Modal Corridors in MMR to take care of the varied travel demands of the region for the horizon period up to 2031.

Accordingly, whereas the CTS recommended developing the metro and suburban railway network in the MMR, it also proposed to develop the highway network in the region with a cumulative length of 982km by 2016, 1229km by 2021 and 1739km by 2031. The MTHL was categorized as the road to be completed by 2016 at that time. Thus, the MTHL has been regarded as the priority road for MMR for a long time, considering its function and importance connecting between the Greater Mumbai and Navi Mumbai.

2.3.3 Current Situation of the Road Network in MMR

The present road network of MMR comprises Expressways, National Highways, State Highways, Major District Roads, other district roads and village roads. Although there is no recent data available for the road network of MMR, the CTS report described that according to MMRDA's estimate as of 1998, the total length of the road network in MMR is 7,003.5 km, out of which National Highways, State Highways and Major District Roads total 942.87km. In the Greater Mumbai area three urban arterial roads (Western Freeway, Eastern Freeway and Sion – Panvel highway) are functioning as the backbone of the peninsula, the west-east direction has not developed well. Figure 2.3.2 indicates the present road network in MMR.



Source: Comprehensive Transportation Study, MMRDA, 2008

Figure 2.3.2 Planed Road Network in MMR in 2016

The present situation of the road network for MMR can be partially obtained from the survey results conducted in the CTS. The road network survey was conducted for 2,321 km of the roads in MMR including the length, the number of lanes, the width of the ROW, and pavement condition. Table 2.3.1 shows the road length by each administrative area of MMR.

Table 2.3.1 Road Network Length by Administrative Area surveyed in CTC

Region/Area Name	Surveyed Network Data (km)	Share (%)
Greater Mumbai	787	33.9
Navi Mumbai	130	5.6
Panvel	38	1.6
Region East of Panvel	32	1.4
Khalamboli – Kharghar - Taloje	95	4.1
Uran	104	4.5
Pen Alibag	191	8.2
Vasai- Viral	113	4.9
Mira-Bhayandar	65	2.8
Thane	96	4.1
Kalyan Dombivli U/A	150	6.5
Bhiwandi - Nizampur	93	4.0
Region North of Bhiwandi(rural)	149	6.4
Ambemath – Badlaapur-Ulhasenagar	138	5.9
Karjat-Khopoli-Matheran	138	5.9
Total	2,321	100

Source: Comprehensive Transportation Study for MMR, MMRDA 2008

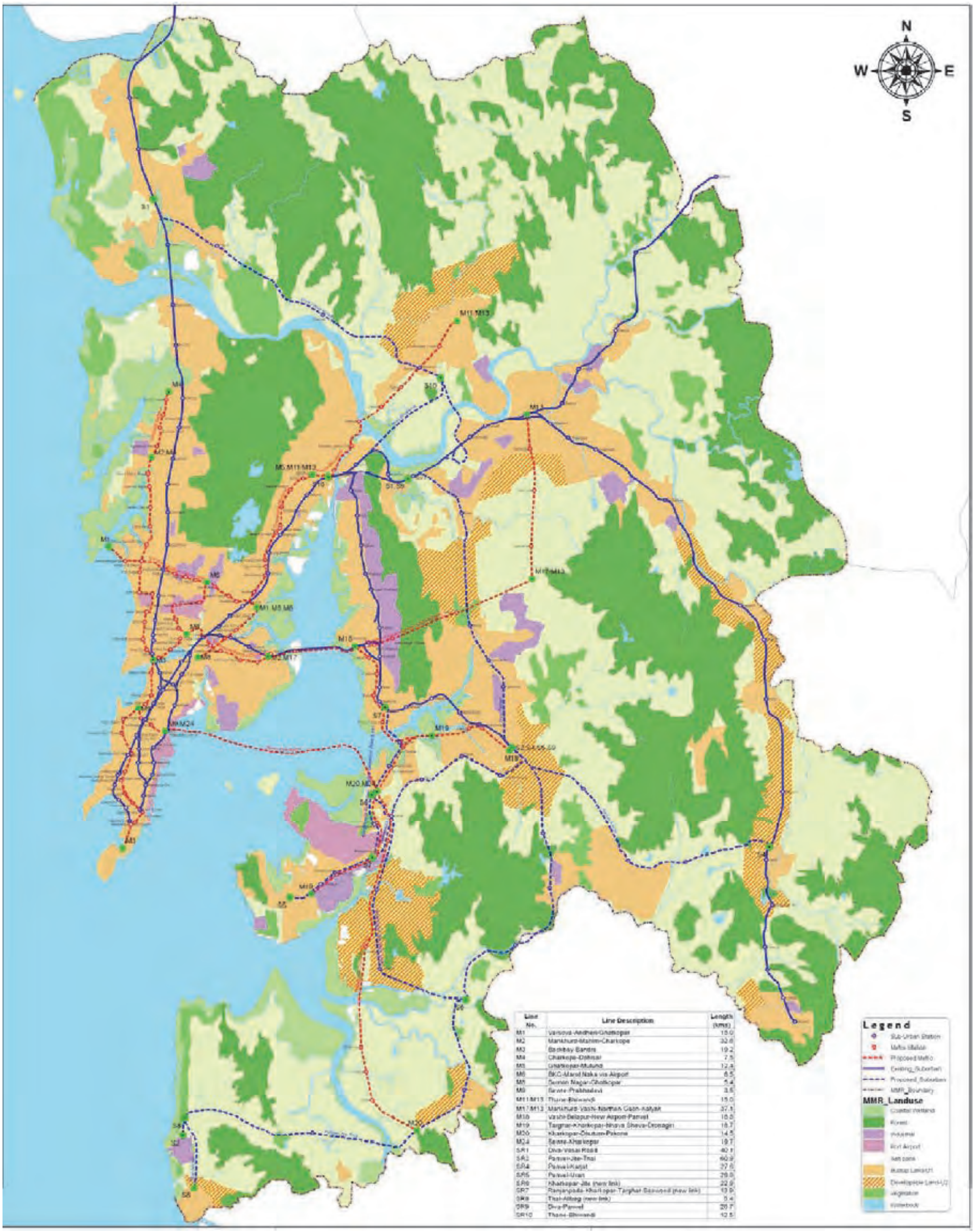
In terms of the number of lanes, whereas 52.5% of the total road network has 2-lanes, 31.0 % of the total road network has more than 4-lane roads. The remaining are single lane roads.

Regarding the pavement conditions of the surveyed road network of MMR, it was observed that the pavement is in good condition for 39% of the total length, and for 38% of the length the pavement condition is satisfactory. Approximately 23% of the total length is in poor condition.

2.3.4 Other Transport Systems in MMR

Public transport comprising trains and buses has been mainly utilized by people in MMR rather than private cars according to the CTS for MMR. Particularly, the train mode for passengers accounts for 52%, particularly for relatively long distance trips because of a very mature and efficient railway network in MMR as well as low fares. The average weekday suburban railway travel demand was estimated as 15 million passengers /km in 2005 at an average trip length of 26km. The bus system is also a predominant transport mode in MMR. The bus mode carried 3.55 million passengers in 2005, which represents 26.3% of total travel demand in MMR. Further improvement and expansion of suburban railway systems has been implemented in Mumbai Transport Project II approved in 2010 and supported by WB.

In addition to suburban railway and bus systems, mass transit systems have been implemented with PPP schemes mainly in the Greater Mumbai area by MMRDA based on the Master Plan for Mumbai Metro prepared in 2003. The Master Plan includes 9 corridors covering a length of 146.5km, out of which 32.5km was proposed as an underground structure and the remaining was elevated. As of 2015, Line 1 measuring 11.4km in length routing from Versova-Andheri-Ghatkopar has already been completed and Line 2 measuring 32.0 km in length, connecting Charkop-Bandra-Mankhurd, is under construction. Figure 2.3.3 shows the transport network plan in MMR in 2016.



Source: Comprehensive Transportation Study, MMRDA, 2008

Figure 2.3.3 Planed Transport Network in MMR in 2016

2.4 Major Development Plans in Navi Mumbai Area

2.4.1 Introduction

This sub-chapter describes the various development plans in the Navi Mumbai area, which clarifies the importance of connecting the Greater Mumbai and Navi Mumbai areas. The locations of each development area are indicated in the Location Map.

2.4.2 Navi Mumbai International Airport

The existing Mumbai Airport, which is located in Greater Mumbai, handled 29 million passengers in 2011-12 and must provide further enhancement of passenger and freight handling capacity is quickly reaching saturation. Therefore, the Navi Mumbai International Airport has been planned for the Navi Mumbai side. According to the plan of the Navi Mumbai International airport plan managed by CIDCO, the airport will spread over 1,160 ha including 2 parallel runways for simultaneous and segregated parallel operation with full-length taxi ways on either side of the runways, and can accommodate new large aircraft compatible to aerodrome code 4-F, as well as having ultimate capacity of 60 million passengers per annum at the final stage of the airport development plan. Since the airport was planned as a state of the art “Greenfield“ international airport, the airport plan includes an idea to develop a mangrove park with 245 ha on Waghivali Island next to the airport area as well as to re-generate 370 ha of mangrove forest at Kamoth and Moha Creek. The airport project will be implemented in 4 phases by PPP scheme and the target passenger capacity of each phase is indicated in Table 2.4.1.

Table 2.4.1 Targeted Passenger Capacity of Navi Mumbai International Airport by Phase

Phase	Operation Year	Traffic (Million Passengers per Annum)	Project Cost (IDR Million)
1	2019	10	621.5
2	2022	25	369.9
3	2027	45	316.2
4	2031	60	149.8
Total			1,457.4

Source: Navi Mumbai New Airport Brochure, CIDCO, Feb. 2014 modified the operations year based on the interview with CIDICO by the JICA Study team

The airport plan also proposes enhancement of the connectivity with the new airport by not only road but also railway. In the road connectivity, the proposal particularly cited the MTHL and Vasai to Alibaug Multi Modal Corridor.

According to the interview with CIDCO, the concessioner for the project implementation has been already selected and the construction work has commenced as of October 2016 in order to secure the opening target of 2019.

2.4.3 Special Economic Zone Development

The Navi Mumbai Special Economic Zone (NMSEZ), special duty-free area with the total area of 2,140 ha, including 3 nodes of Navi Mumbai, namely Dronagiri with 1,390 ha, Ulwe with 400 ha and Kalamboli with 350 ha designed to facilitate foreign investments in comprehensive economic activities, including manufacturing, trading, IT service and financial services. The SEZ project was initiated in 2000 according to the revision of the Export-Import Policy of the Government and formally approved in 2002. The project has been implemented though public-private partnership scheme and the strategic investors have been selected by CIDCO though an international bidding process. CIDCO and these strategic investors have formed a special purpose company, i.e. NMSEZ Private Limited, to accelerate the progress. As of 2014, 1,842 ha have been handed over the investors.

However, the progress of the SEZ development has been stagnant mainly due to non-enactment of the Maharashtra SEZ Act, the global recession and difficulty in attracting the investors due to the slow progress of the new airport development and MTHL realization. Notwithstanding the stagnancy, the owner investors for 3 nodes have built the boundary walls and water supply system, roads with drainage systems and the building works are under progress at present.

2.4.4 Expansion of Jawahalal Neharu Port

Jawahalal Neharu Port (JNP) is the largest container port in India, comprising three dedicated container terminals with 2,581 ha of the land area operated by JNP Trust, although it has been dealing with bulk and cement ships. JNP started its operation in 1989 and handled 63.8 million tons of cargo in 2014-15 including 4.467 million TEU containers, which accounts for approximately 56 % of the total containers handled by all major ports in India. The maximum permissible draft at JNP varies from 6.0m to 14.5m depending on the purpose of the berth. The JNP has been connecting with 31 Container Freight Stations (CFS) and 34 Inland Cargo Depots (ICD).

JNP Trust is now planning to invest around INR 60 million to develop deeper navigation facilities. According to the plan, the approach channel will be deepened to 13.5 m which enables the port to handle fourth and fifth generation container ships, which have the capacity to carry more than 3,000 TEU for the fourth generation and more than 6,000 TEU for the fifth, compared to the current third generation cargo ship with a limit of 3,000 TEU. Furthermore, an additional railway track connecting the Indian Railway, and upgrading the approach roads to the national highway and to Navi Mumbai by doubling the present width are also included in the port expansion plan.

2.5 Japanese Firms' Operation in India

2.5.1 Introduction

According to the list of Japanese firms operating in India as of Oct. 2013 prepared by the Embassy of Japan and JETRO, there are 1072 Japanese firms, which comprises both local subsidiaries and non-subsidiaries of the Japanese firms, operating in India. The list of Japanese firms is provided in Appendix 2.1. The number of the Japanese firms in India has been rapidly increasing, e.g. by 16% from 2012.

In the Maharashtra State, Japanese firms established a total of 397 branches, representative offices or sales offices, out of which 248 of the Japanese firms have their business bases in Mumbai. Since Mumbai is the finance and foreign trading center of India, the majority of the Japanese firms are the ones in the finance, insurance, trading and logistics sectors. On the other hand, there are 105 of the business bases of the Japanese firms in Pune and its surrounding area. Since many foreign manufacturers, particularly in the auto mobile sector, have established their production base in the area because of the availability of educated human resources and advantageous location to deliver the products to the local market of India, the Japanese manufacturers, including automobiles and their related devices production, have built production bases in the area. In 2013, JETRO Mumbai signed a memorandum of understanding (MOU) with Maharashtra Industrial Development Corporation (MIDC), supporting MIDC to develop a new industrial zone in Pune exclusively for Japanese manufacturers and to promote recruiting activities for Japanese firms to invest in the new industrial zone. Considering this trend, more Japanese manufacturers are expected to establish their production bases in the Pune area in the future.

According to the interview with the logistics firms located in Mumbai, such Japanese firms in Pune often use the Mumbai Port for importing the materials required for production. Accordingly, they have high expectation that opening of the MTHL would contribute to shortening the transport time between the Mumbai Port and Pune, since the present route causes unreliable delivery due to restrictions on entering the city areas in the Mumbai and Pune areas.

2.5.2 Japanese Firm's Operation in MMR and Maharashtra State

According to the list of Japanese firms prepared by JETRO in 2013, several Japanese construction companies have been performing their activities in the Indian market as listed in Table 2.5.1. Except for one of the firms, all of the firms have established their subsidiary firms in India and have been performing activities in the Indian Market.

Table 2.5.1 Japanese Construction Companies in India

Name of Company	Locations of its Activity
Kajima India PVT	Ahmedabad, New Delhi, Gurgaon, Alwar
Maeda Corporation India PVT	New Delhi, Chennai, Pune, Bangalore
Shimizu Corporation India	Chennai, Mumbai, Bangalore
SMCC Construction India	Chennai, Pune, Vadodara, Bangalore, New Delhi
Penta-Ocean Construction India PVT	Gurgaon
Taisei Corporation	Gurgaon (liaison office), Kolkata
Takenaka India PVT	Ahmedabad, Bangalore, Alwar, Chennai
L&T Chiyoda	Vadodara
JFE Engineering India	Mumbai

Source: Japanese Firm List, EOJ and JETRO, 2014

However, their activities have been limited to only building works such as construction of factories/buildings awarded from the Japanese manufacturers who invested in India and there has been little experience of civil works such as bridge and road works in India. Whereas only Shimuzu Corporation has experience in civil works in Delhi Metro Phase-1 project, JFE Engineering has been undertaking the Delhi Freight Corridor Project, with both projects being funded by Japanese ODA Loan.

2.6 Construction Industry in India

2.6.1 Overview

The construction industry has been contributing to the national economy. It accounted for approximately 8% of GDP in the five year period from 2006-07 to 2010-11, which was valued at INR 3,850 billion in 2010-11, and it has been continuing with the upward growth from 5% to 10% since 2005-06.

Approximately 31,000 enterprises were involved in the construction industry and 41 million people were working for the construction industry in 2011, which was the second largest employer after the agricultural sector.

By value, Indian construction projects can be subdivided into infrastructure projects (49%), real estate and housing projects (42%) and industrial projects (5%). Thus, the construction industry is expected to continuously develop further supported by a large amount of investment in the infrastructure, real estate and housing projects. Table 2.6.1 shows the growth of the construction sector.

Table 2.6.1 Growth of Construction Industry in India

Year	2006-07	2007-08	2008-09	2009-10	2010-11
GDP from Construction (billion INR)	2,850	3,150	3,330	3,560	3,850
Share of GDP (%)	8.0	8.1	8.0	7.9	7.9
Growth rate for GDP in Construction (%)	10.3	10.7	5.4	7.0	8.1

Source: Handbook of Statistics RBI 2011

2.6.2 Construction Firms, Registration and Tender System

It was estimated in 2011 that there were approximately 31,000 firms in the construction industry of India. However, the majority of the firms are in the small scale category with less than 200 workers and only 350 enterprises have more than 500 employers.

Both central and local governments provide registration systems for the contractors who have intention to participate in the public works. According to “Enlistment Rules 2005” established by the Central Public Works Department of India, there are five classes for civil works, and each class has the criteria to be fulfilled to register, which comprises (i) Past work experience of the completed works in last 5 years, (ii) Financial soundness, (iii) Engineering establishment including the necessary number of certified human resources, (iv) possession of construction machinery and equipment. Depending on the registration class, the amount of the tendering limit shall be defined. For example, the highest class of the contractor, called “Class 1” of the Civil Category, can participate in public projects up to INRs 200 million in contract price. Table 2.6.2 shows the criteria of the registration of civil contractors for road works.

Table 2.6.2 Registration Criteria of Civil Contractors for Road/Civil Works

Class	Tendering Limitation (INRs Mil.)	Past experience in last 5 yrs (INRs Mil.)	Financial Soundness (INRs Mil.)	Engineering Establishment	Machinery
I	200	3 projects worth INRs 20, two for roads and one for any civil works or 2 projects worth INRs 40 or 1 project worth INRs 107	Banker's certificate of INR 130	a) 1-graduate engineer with 5 years experience b) 1-graduate engineer with 2 years experience c) 1-diploma engineer with 5 years experience d) 2-diploma engineers each with 2 years experience	i) 1-Wet macadam mix plant ii) 2-Paver finishers iii) 5-Road rollers iv) 5-Trucks/Tippers v) 2-Vibrator road roller
II	50	3 projects worth INRs 8, two for roads and one for any civil works or 2 projects worth INRs 12.5 or 1 project worth INRs 25	Banker's certificate of INR 33.5	a) 1-graduate engineer with 5 years experience b) 2-diploma engineers including one with 5 years experience	i) 1-Wet macadam mix plant ii) 1-Paver finishers iii) 3-Road rollers iv) -Trucks/Tippers v) 1-Vibrator road roller
III	12	3 projects worth INRs 2, two for building and one for any civil works or 2 projects worth INRs 3, one for building and one for any civil work or 1 project worth INRs 6 for building	Banker's certificate of INR 8	a) 1-graduate engineer with 3 years experience	i) 1-concrete mixer ii) 1-mortar mixer iii) 2-Needle vibrator iv) 1-Beam vibrator vi) 4-Slab vibrator
IV	5	3 projects worth INRs 8, two for roads and one for any civil works or 2 projects worth INRs 12.5 or 1 project worth INRs 25	Banker's certificate of INR 3.1	a) 1-diploma engineer with 3 years experience	i) 1-concrete mixer ii) 1-mortar mixer iii) 2-Needle vibrator iv) 1-Beam vibrator vi) 1-Slab vibrator

Remarks: No specific requirements for road works for Class-III and IV
Source: Enlistment Rules 2005, Central Public Works Department

In the case of a large scale project worth more than INRs 200 million, the client set the pre-qualification criteria for the tendering to determine the eligible bidders depending on the project features and this classification system cannot be utilized.

"CPWD Works Manual 2014" issued by Central Public Works Department briefly describes the tender procedure for public works. For projects worth less than INRs 200, if a contractor is enlisted in the CPWD or relevant agencies and state governments, he shall be eligible to tender for works up to the amount permitted by virtue of his enlistment limit in the respective agencies and only a financial bid shall be submitted at the tender.

In the case of a project worth more than INRs 200 million, a two or three envelope system shall be applied for the bid. Whereas the two envelope system requires (i) Documents related to eligibility criteria and (ii) Financial bid in the separate envelope, the three envelope system requests the bidder to submit (i) Documents related to eligibility criteria, (ii) Technical bid, and (iii) Financial bid separately. In the two envelope system, Envelope-1 containing the documents related to eligibility criteria shall be opened first and such documents shall be evaluated by the client or the competent authority. Financial bids of the qualified bidders shall then be opened at the notified time, date and place in presence of the bidders. In the three envelope system, Envelope-1 containing the documents related to eligibility criteria shall be opened first. Technical bids of the bidders who meet the eligibility criteria shall then be opened at the designated time, date and place in front of the bidders. After the finalization of the technical bids, the financial bids shall be opened. Although the validity of the bids shall be set from the date of opening the technical bids, it is normally set up to 90 days for the projects managed by the national agencies.

The normal tendering procedure for civil works is as follows;

- **Public notice of the tender and delivery of the bid documents:** 14 days for the project worth more than INRs 200 million in the estimated cost.
- **Tender period:** this is determined by the client depending on the complexity of the project and type of the contract such as Design-Build contract. During the tender period, a pre-bidding conference shall be held and the bidders can make clarifications of the bid documents by the notified date in the bid documents
- **Tender evaluation:** Contract negotiation with the bidder who is ranked first after both technical and financial bid evaluation
- **Contract award** with the bidder who can reach the agreement on the contract conditions and contract price with the client.

3. REVIEW OF PREVIOUS STUDIES ON MTHL

3.1 Previous Studies of MTHL

A bay crossing concept with a bridge between Greater Mumbai and the mainland was first proposed by Wilbur Smith and Associates who conducted extensive studies and submitted a study report to the Ministry of Transport on 19 December 1963. Together with other projects, the report proposed the construction of a sea link, known as the Uran Bridge, to connect Greater Mumbai with the mainland. However, the report at that time recommended waiting until the time when "the Trans-Thana area develops further and more community services are extended to Uran", which is presently called Navi Mumbai.

Following that report, there was a series of studies undertaken to materialize the bay crossing concept such as the "Regional Plan" in 1973, "The Comprehensive Road Transport Plan" in 1983, "Bombay Urban Transport Project" in 1984 and "Comprehensive Transport Plan" in 1994. Table 3.1.1 shows the recent feasibility studies and documents. Through such studies, various road alignments have been studied by different organizations over the years

Among them, the "Final Feasibility Study Report: Detailed Feasibility Study and Bid Process Management for Selection of Developer for MTHL: Sewri to Nhava in MMR, Maharashtra State, India 2012" (hereinafter the "Final Feasibility Study Report, 2012") is the latest feasibility study to prepare the bid documents for a BOT scheme, which incorporated outcomes of the previous studies.

For the last BOT tender, in May 2012 MMRDA shortlisted five consortiums out of six that had expressed an interest in the project. However, by August 5, 2012, none of the five shortlisted firms submitted a bid on the project. As a result, the MMRDA decided to scrap the BOT scheme for the project in August 2013.

Considering the precedent, it is worthwhile to extract essential knowledge and considerations from the previous studies and identify any differences from the current practice applying to the similar nature of the project in order to prepare the concrete plan for realization of MTHL. For this purpose, a review of previous studies was conducted mainly focusing on the Final Feasibility Study in 2012 in this chapter.

Table 3.1.1 Previous Studies and Documents for MTHL in Recent Years

No.	Title	Document Issued Date	Prepared By	Remarks
Feasibility Study				
1	Techno-Economic Feasibility Study for Mumbai Trans Harbour Link	Aug-2004	CES	Full Feasibility Study
BOT Tender				
2	BOT Tender Documents (Vol.1,2 & 3)	Jul-2006	STUP & JMI etc.	BOT Scheme
3	BOT Financial Proposal	Dec-2007	Reliance Energy & Hyundai	
4	BOT Financial Proposal (Vo. 1 & 2)	Feb-2007	IL & FS. SKIL, Laing O'Rourke	
Design and Build Tender				
5	Tender Document for Design & Build MTHL, Vol 1-6	Oct-2008	MSRDC / STUP	Design and Built Scheme
Metro Study				
6	Detailed Project report for Mumbai Trans Harbour Metro Rail Link	Apr-2010	RITES	Rail Bridge Feasibility Study
Pre-Feasibility Study				
7	Study on Mumbai Trans Harbour Link in the Republic of India	Mar-2011	METI, Japan	Pre-feasibility Study by Japanese Government
Feasibility Study and BOT Tender				
8	Final Feasibility Report (Vo. 1 & 2)	Dec-2012	ARUP, CES and KPMG	Full Feasibility Study and BOT Tender

Source: JICA Study Team

3.2 Review of Traffic Demand Forecast

3.2.1 Overview

Although the previous studies on MTHL are listed below, the following studies[1] from over the last 12 years, which are now in the public domain, shall be focused on in the review for the traffic demand forecast;

- Techno-Economic Feasibility Study for Mumbai Trans Harbour Link prepared by Consulting Engineering Services (CES), 2004;
- Comprehensive Transportation Study for Mumbai Metropolitan Region (CTS) prepared by Lea International, 2008;

[1] In fact, there have been several requests by the government for the private sector to develop this project in recent time. However the Study Team does not have access to such reports and in any case, it would not be appropriate to include them at this time.

- Mumbai Trans Harbour Link prepared by Arup et al, 2012; and
- Study on the Mumbai Trans Harbour Link Road, prepared by Ernest and Young Shin Nihon LLC et al, 2012.

3.2.2 Techno-Economic Feasibility Study for MTHL

This analysis for MTHL was undertaken approximately 10 years ago. It assumed that the bridge would be open to traffic in 2011. The analysis was based on the earlier 2003 Mumbai Urban Infrastructure Project. The study considered three possible development scenarios namely with a car reference toll[2] of 100 Rs:

- Scenario 1 ~ MTHL without the Navi Mumbai International Airport (NMIA) and without Special Economic Zones (SEZ);
- Scenario 2 ~ MTHL without the NMIA and with SEZ; and
- Scenario 3 ~ MTHL with NMIA and with SEZ.

Under Scenario 1, MTHL was forecast to attract a daily traffic volume of around 46,000 passenger car units (pcu) of traffic rising to 73,000 pcu by 2022, which is the currently proposed opening date of MTHL. A growth rate of some 4.3% per annum was applied. Even at this time, it was realized that the development of both the SEZ and the airport were important in the estimation of traffic on MTHL. From this project, the traffic in 2022 was estimated to increase by 15% with the inclusion of SEZ and a further 12% with the inclusion of NMIA in the scenario. This would increase the traffic in 2022 to 93,200 pcu.

3.2.3 Comprehensive Transportation Study (CTS) for MMR

This study outlined the model that all subsequent analyses of demand forecast for the MTHL[3] are built upon. The model follows the principle of the classic four step transport model with modules for generation, distribution, mode split and assignment. The database used for development of the model was based on a home interview survey of 60,000 households in the metropolitan region in 2005, which provided the database for model development. The overall planning process associated with CTS is shown for completeness in Figure 3.2.1.

The study forecast that the population of metropolitan Mumbai will grow from 20 million in 2005 to 34 million in 2031[4] with an annual growth rate of a little over 2 per cent per annum. During the same period, this study assumed that the private vehicle ownership is expected to grow by a factor of nearly four and half times (or at approximately 6% p.a.).

2 The toll will vary by vehicle class. However a reference toll is that for a single car for purposes of comparison.
3 In this study, MTHL is shown in the 2011 network. The daily flow would be expected to be around 46,000 pcu.
4 Today MMRDA's population forecast remains at 34 million for the Mumbai Metropolitan Region (MMR) in 2031.

The study proposes an extensive increase in transport infrastructure up to the year 2031. The forecast for MTHL crossing in 2031 is around 102,700 pcu per day[5] at the reference toll of 100 Rs. The estimate of traffic flow in 2022 is 73,200 pcu.

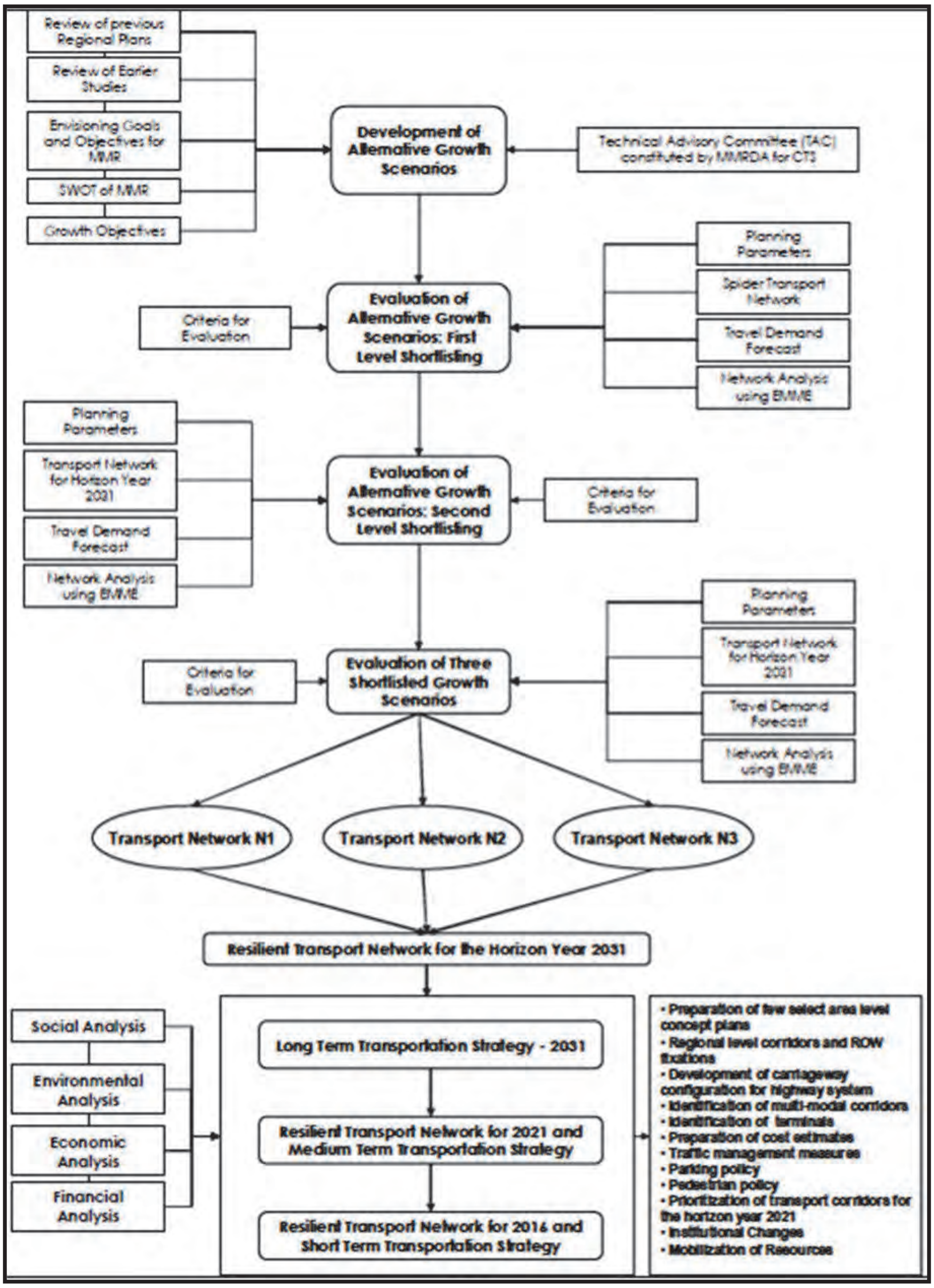
3.2.4 Final Feasiblity Study Report 2012

The objective of this study was to determine the feasibility of the MTHL via a BOT scheme and preparation of tender documents. This study followed on from CTS with an enhancement to build the 'best estimate' of the existing travel patterns following any socio-economic changes since the completion of CTS.

The methodology for future forecasts follows the procedures of CTS whilst maintaining the balance between supply and demand as seen in Figure 3.2.2. The model structure configuration essentially followed the same structure as CTS. The anticipated opening of NVMIA was assumed as 2017 at MAP rising to 10 MAP by 2018.

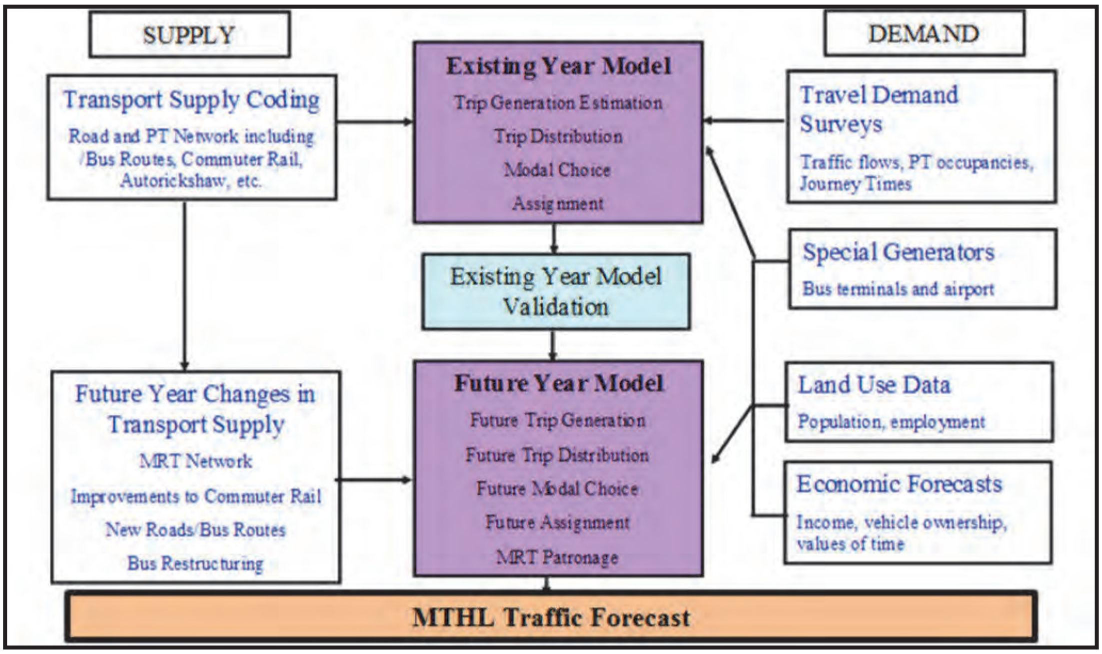
The forecast traffic volume on MTHL was estimated at 68,000 pcu at the opening in 2017, with a car reference toll of 150Rs. This volume is forecast to increase to 89,000 pcu and then 140,600 by 2021 and 2031 respectively. The study suggests that the provision of a parallel rail link only reduces the traffic on MTHL by around seven per cent.

[5] This volume is derived by the adoption of a peak hour factor of 7%. The reference toll for a car is 100 Rs.



Source: CTS

Figure 3.2.1 Overall Planning Process



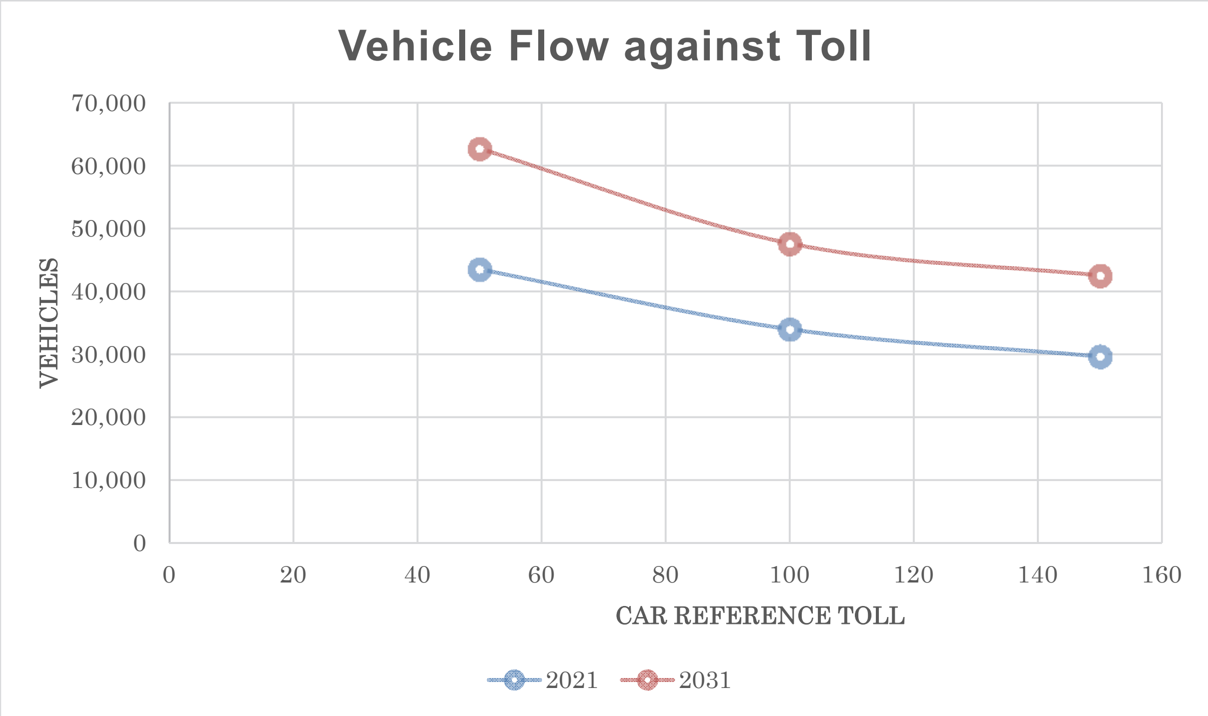
Source: Mumbai Trans Harbour Link prepared by Arup et al

Figure 3.2.2 Structure of the Travel Demand Model

3.2.5 Study on the MTHL Road

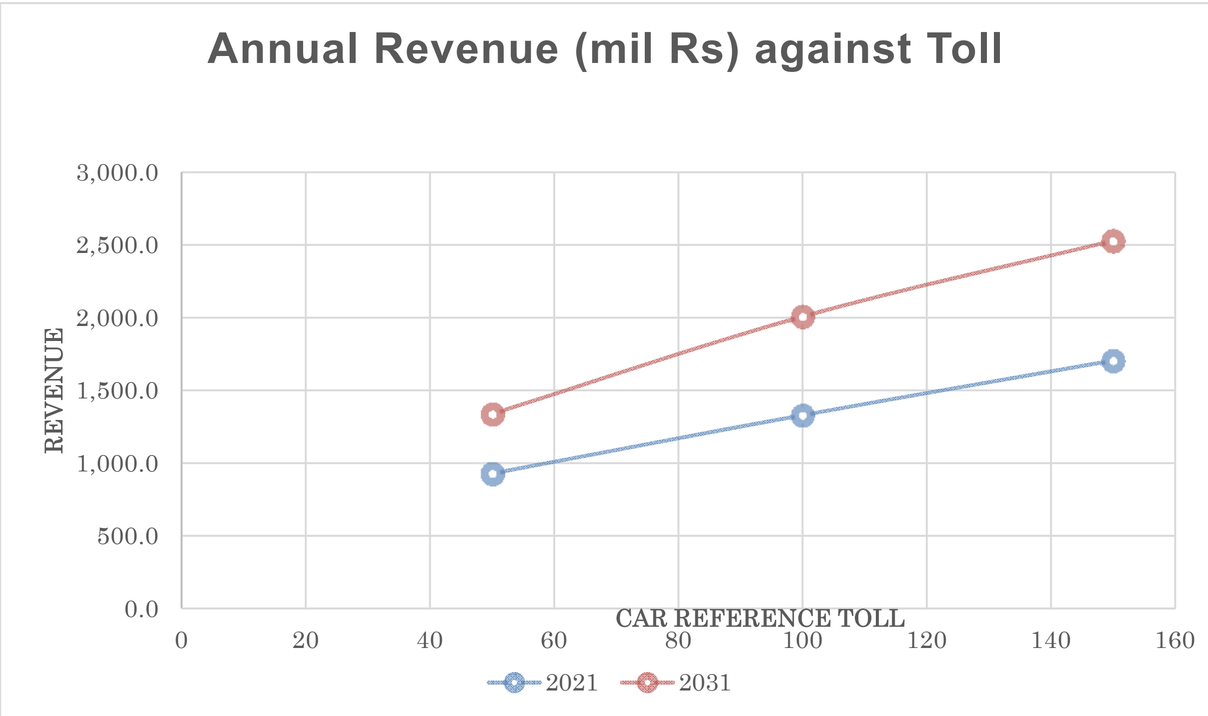
The focus of this study was to determine the feasibility of the project's construction via a PPP scheme. The study was conducted by the Ministry of Economy, Trade and Industry, Government of Japan. This study also adopted a broad approach linked closely with CTS. However, the transport model developed to estimate transport demand is essentially independent of CTS since the series of transport data developed by CTS including the base and future year matrices was not available. A simple approach to the transport demand forecast, the entropy maximization method, was adapted and base and future year matrices were created using that method.

This project required assessment of financial viability. Through the analyses of three reference toll levels (as seen in Figure 3.2.3 and Figure 3.2.4), the project was found to be sensitive to toll variation. A INR 50 toll attracts nearly 50% more traffic than a INR 150 toll, although the INR 150 toll yields a revenue around 50% higher.



Source: Study on the Mumbai Trans Harbour Link Road, Ernest and Young Shin Nihon LLC et al

Figure 3.2.3 Impact of Toll on Vehicle Flow



Source: Study on the Mumbai Trans Harbour Link Road, Ernest and Young Shin Nihon LLC et al

Figure 3.2.4 Impact of Toll on Revenue

3.2.6 Findings from Earlier Studies

The Earlier estimates of traffic on MTHL are shown in Table 3.2.1. The principal finding from the earlier studies reviewed is that there is a need for the MTHL to proceed to construction in a timely manner.

Note: It is difficult to compare demand forecasts between projects since all of these earlier studies used different assumptions and were undertaken for different reasons.

Table 3.2.1 Earlier Estimates of Traffic on MTHL

Project	Year of Project Undertaking	Reference Toll (Rs)	Estimated Volume in 2022 (pcu)
CES Study	2004	100	93,200
CTS	2008	100	73,200
MTHL: Final FS 2012	2012	150	94,000
MTHLR[6]	2011	150	48,000

Source: JICA Study Team

3.2.7 Consideration

Based on the review of earlier studies, the forecasted traffic volumes on MTHL were found to be significantly different depending on the future assumptions employed such as future network, toll system and future development plan including Navi Mumbai airport and SEZ. In particular, several conditions have been rapidly changing as a result of rapid economic growth of the study area. Therefore, appropriate and realistic future assumptions for the transport demand forecast need to be decided based on in-depth discussion with relevant agencies.

[6] This traffic volume was originally estimated in vehicles as seen in the earlier figures and has now been converted to pcu for inclusion in this traffic.

3.3 Review of Road Plan

3.3.1 MTHL Alignments

The first recommended draft plan of MTHL was dated back to the 1970s. Subsequently, committees were formed in 1972 and 1978 to study the possible alternatives for establishing the sea link across the Mumbai bay. The committees identified two alternative routes, a northern route linking Sewri with Nhava and a southern route linking Colaba (southern tip of Mumbai Island) with Uran, and suggested to carry out necessary engineering studies for the alternative routes.

A Steering Group, which was constituted in 1981, reviewed the previous studies and recommended that a priority should be given to the construction of a northern route.

(1) Alignment by Peter Frankael and Partners (PFP), 1982

Five alternative alignments between Sewri on the Greater Mumbai and Nhava on the mainland were identified and studied. All the alignments started from Sewri.

The study recommended the northern most alignment for the sea link connecting Sewri with Nhava through a low elevated bridge skirting the harbour to the north.

Total length is 22.61km and it comprised the following sections (refer to Figure 3.3.1):

- Section 1: Sewri side's approach 0.7 km
- Section 2: Embankment over Sewri mudflats 2.32 km
- Section 3: Viaduct 13.19 km
- Section 4: Embankment on Nhava mudflats 2.20 km
- Section 5: Nhava side's approach 4.20 km

The embankments of Section 2 and 4 had a road level of +7.00m above Chart Datum (CD) considering run-up of waves to be approximately 1.0m above HHTL of 5.38m. The Central Water & Power Research Station (CWPRS) study had recommended that the embankment section shall be provided with an opening to cater for the non-tidal inflow. Accordingly, the embankment on the Sewri side was proposed to terminate 350m west of the Green Island.

Subsequently the recommended northern alignment was modified by Expert Group by shifting it to south of the jetty head in order to satisfy Bhabha Atomic Research Centre (BARC) requirements. This shifted alignment was approved by the Prime Minister's Office (PMO) in 1984.

Source: Peter Frankael and Partners (PFP)

Figure 3.3.1 Alignment Recommended by PFP, 1982

(2) Alignment by Consulting Engineering Services (CES), 1996

CES were appointed to review and update the feasibility study for the recommended northern alignment in 1996 taking into account the subsequent developments after the 1982 study.

During the study, the Consultants held discussions and had interaction with the concerned departments including Mumbai Port Trust (MbPT), and studied various parameters and suggested modifications. Among them the most important suggestions from the Consultants are as follows:

Mudflats and Mangroves

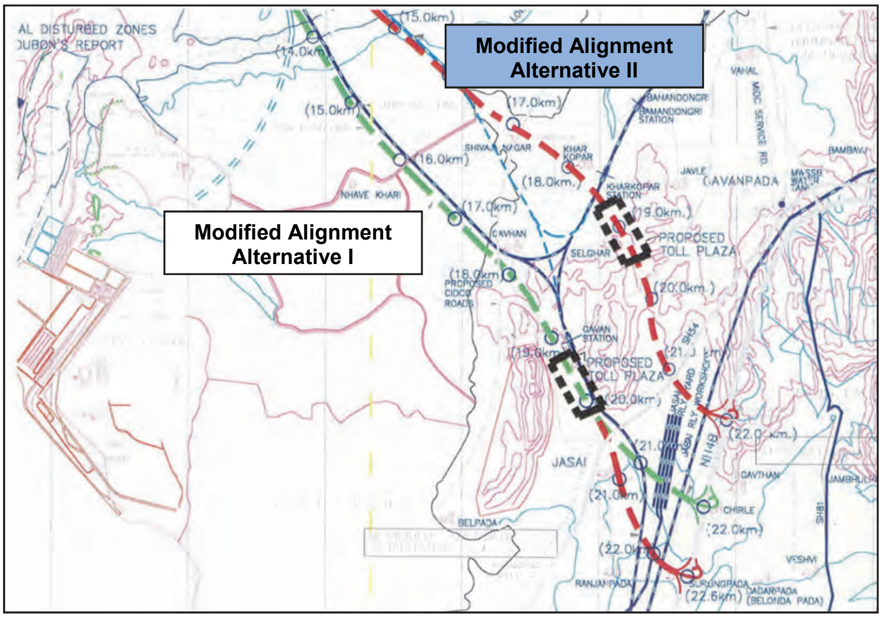
With respect to the alignment traversing the mudflats, both at Sewri and Nhava, it was recommended that the link should be constructed with viaducts instead of embankment in order to minimize the encroachment and the disturbance to the mudflats and the existing hydrological conditions.

Underpass Interchange at Sewri

The Underpass IC at Sewri was proposed because of avoiding the complex elevated interchange, unnecessity of connection with the existing roads and difficulty in land acquisition from MbPT.

Modification of Nhava Approach

The Consultants identified two alternatives as shown Figure 3.3.2. The Alternative II, which is the less costly option to reduce the length of the link and acceptable to CIDCO, was recommended.



Source: Alignment by Consulting Engineering Services (CES)

Figure 3.3.2 Alternative Alignments on Nhava Side, 1998

Table 3.3.1 Elements of Alternative Alignments on Nhava Side, 1998

Location	Route Terminating in Navi Mumbai at	
	Length in km Surungpada (Alt-I)	Length in km North of Chirle (Alt-II)
Sewri Interchange	0.850	0.850
• Embankment on Sewri mudflats with Eastern Freeway Interchange Ch. 0.600 km to Ch. 1.580 km	0.980 *	0.980 *
• Viaduct with transitions (ramp portion) Ch. 0.600 km to Ch. 18.42 km Ch. 0.600 km to Ch. 17.58 km	 17.82 -	 - 16.98
• Embankment at Nhava Ch.18.42 km to Ch.18.76 km Ch.17.58 km to Ch.17.92 km	 0.34 -	 0.34 -
• Road in Grade leading to toll plaza up to termination point Ch. 18.76 km to 22.60 km Ch. 17.92 km to 22.00 km	 3.84 -	 - 4.08
• Rail link termination at Panvel-Uran link Ch. 18.76 km to 19.00 Ch. Ch. 17.92 km to 19.00 ch.	 0.24 -	 - 1.08
Total Length of Alignment • For Road Link • For Rail Link	 22.85 km 20.40	 22.25 km 20.40

* Not considered in calculating total length of MTHL

Source: Alignment by Consulting Engineering Services (CES)

(3) Alignment by Consulting Engineering Services (CES), 2004

The alignment proposed by the Consultants under Alternative II at the end point on NH4B (north of Chirle) was finally accepted and proposed to be taken up for construction. This alignment satisfied various issues raised in the previous study.

Sewri IC and Connection with Eastern Freeway

Sewri IC is the starting point of the proposed MTHL link. The MTHL link was to be connected to both the Eastern Freeway and the local road network. At that time, the alignment of the Eastern Freeway and improvement of the East-West corridor had been under study and was taken up by MMRDA. Therefore, only the approach ramp was proposed to be constructed.

Viaduct over Sewri Mudflats

PFP had proposed construction of embankments over the Sewri mudflats. However, to satisfy the environmental requirements, it was suggested that the MTHL be provided with elevated viaducts across the mudflats. The mudflat section is approximately 5km long, and an elevated bridge with 50m span length was proposed along this section.

Main bridges in the marine section

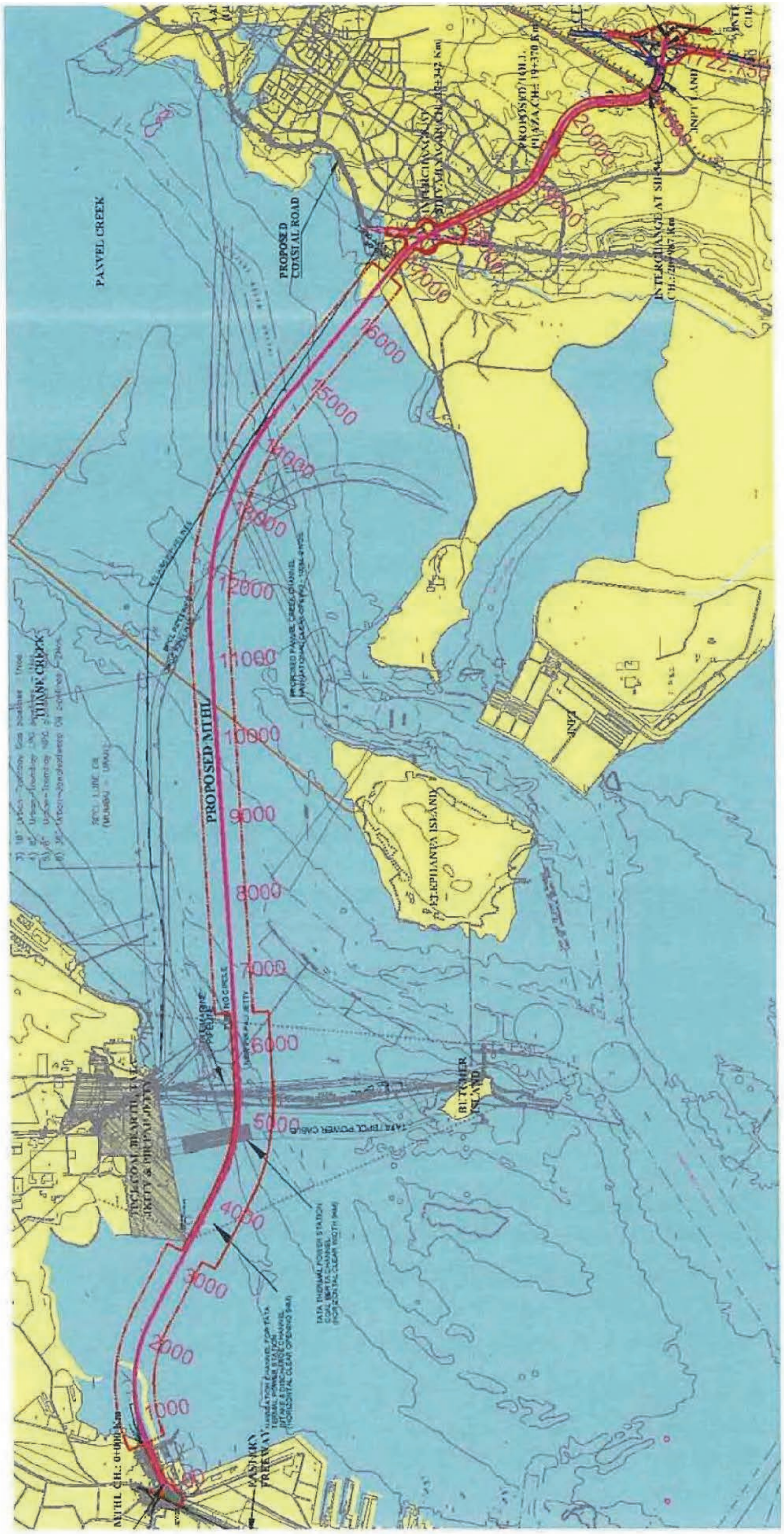
The main bridge extends for 9.6km across the sea. The study identified that the alignment contained three obligatory spans crossing several jetties, the central channel, Panvel Creek and submarine pipelines.

Nhava Approaches and ending north of Chirle

The alignment suggested by CES (Alternative II) was reviewed by CIDCO officials and was recommended as a better option. The advantages of this alignment ending north of Chirle include: i) reduction of road/rail crossings, ii) a shorter overall length, and iii) avoidance of crossing about 2.7km of mangroves.

(4) Alignment by Final Feasibility Study 2012

The start of the alignment had been taken as Sewri IC (3-level IC) where the MTHL connects to the alignment of the Eastern Freeway. The alignment continued to southeast to meet NH4B keeping Shivaji Nagar and Selghar villages to the south, and Kharkopar to the north, before crossing SH-54 and Panvel-Uran railway line. Since the horizontal alignment was shifted, it became necessary to stay an adequate distance from the Tata Thermal Power Station land. The latest alignment of MTHL is shown in Figure 3.3.3. As described above, the road alignment was fixed with extreme care after several studies over a long term.



Source: Final Feasibility Report (ARUP, CES and KPMG), 2012

Figure 3.3.3 MTHL Alignments, 2012

3.3.2 Control Points and Geometry

The following sub-chapter summarized several control points, which determined the latest alignment in both horizontal and vertical directions that were proposed in the Final Feasibility Study 2012

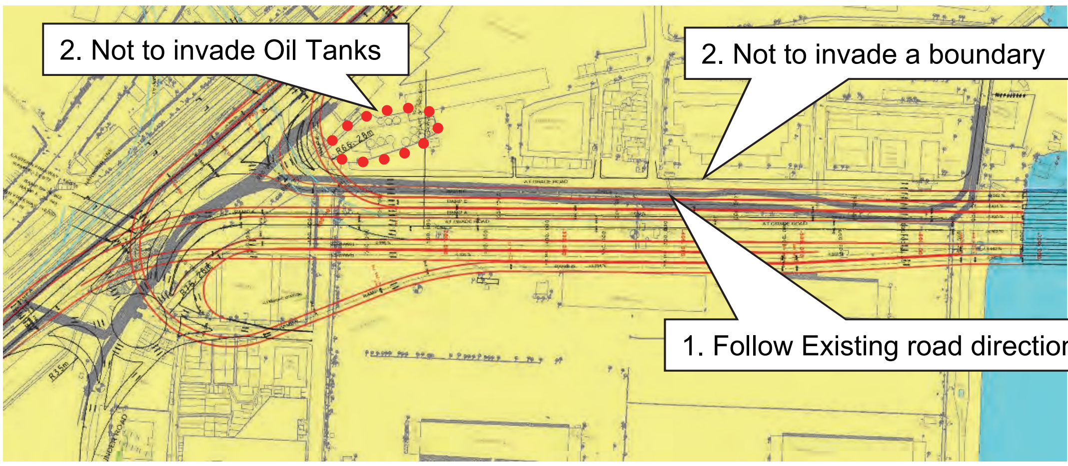
(1) Control Points of Horizontal Alignment

Horizontal alignment was determined in consideration of the following control points.

<u>Mumbai side</u>

Horizontal alignment at the beginning section was determined by keeping the following control points.

1. Follow the existing road direction
2. Not to invade the existing Oil Company or Oil Tanks
3. Connect with Eastern Freeway (Viaduct section)



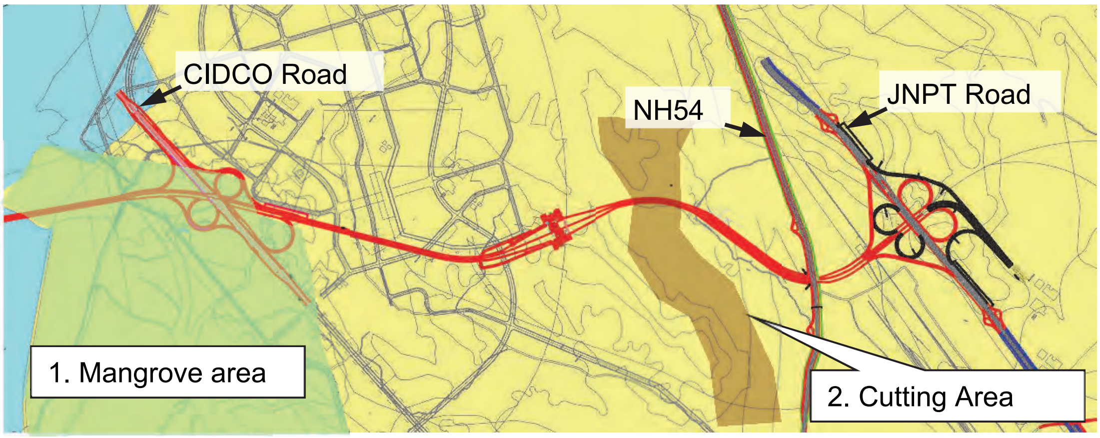
Source: JICA Study Team

Figure 3.3.4 Control Points at Mumbai Side

Navi Mumbai Side

This alignment was set so as not to invade the listed control points below. The curve radiuses are to set to be more than IRC standard.

1. Pass through the edge of the mangrove area.
2. Pass the hilly area which minimizes the rock cut volume.
3. Connect with CIDCO Road , NH54 and JNPT Road



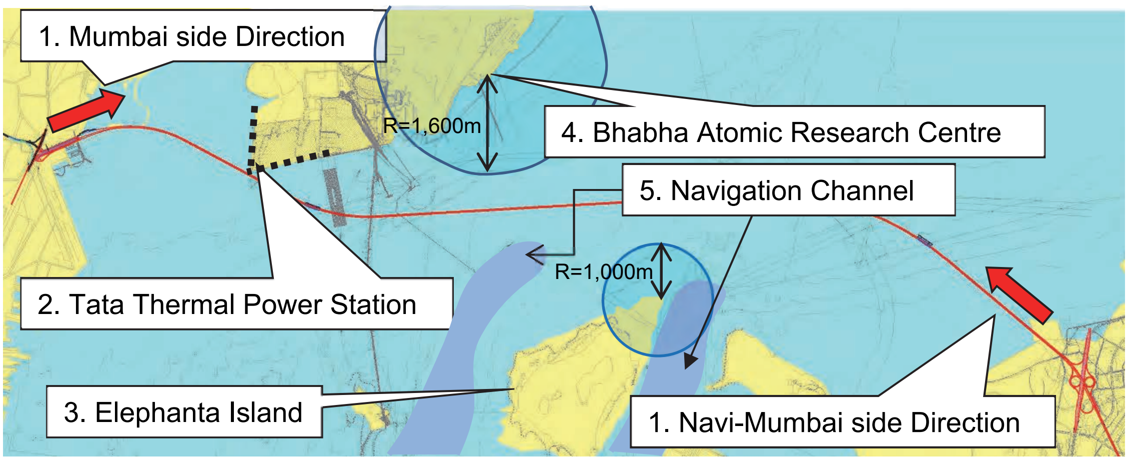
Source: JICA Study Team

Figure 3.3.5 Control Points at Navi Mumbai

Marine Section

The holizontal alignment was composed of three curves in order to avoid Tata Thermal Power Station and to keep the alignment direction set at both Mumbai and Navi-Mumbai sides

1. Keep alignment directions set at both Mumbai & Navi Mumbai sides.
2. Not to invade the Tata Thermal Power Station land
3. Set more than 1,000m away from Elephanta Island.
4. Set more than 1,600m away from Bhabha Atomic Research Centre
5. Not to interfere with navigation channels for large vessels

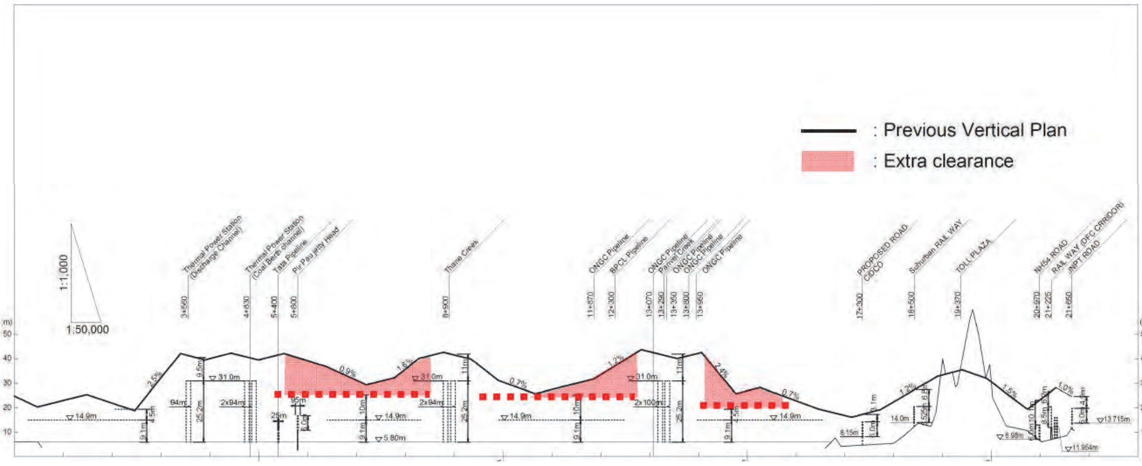


Source: JICA Study Team

Figure 3.3.6 Control Points on the Sea

(2) Control Points of Vertical Alignment

The control points of vertical alignment are shown in Figure 3.3.7. It was found that there is extra clearance in some sections in the vertical alignment, which are indicated with red shadows. It will be worthwhile to explore the possibility of lowering the vertical alignment to reduce the construction cost for the project.



Source: JICA Study Team

Figure 3.3.7 Control Points of Vertical Alignment

(3) Control Points of Vertical Alignment

All geometric factors applied to main carriageway in the latest alignment fulfilled the IRC standards for 100km/h design speed.

3.3.3 Summary of the Horizontal Alignment

This sub-chapter summarizes the history of the latest horizontal alignment:

(1) Bay Crossing Route

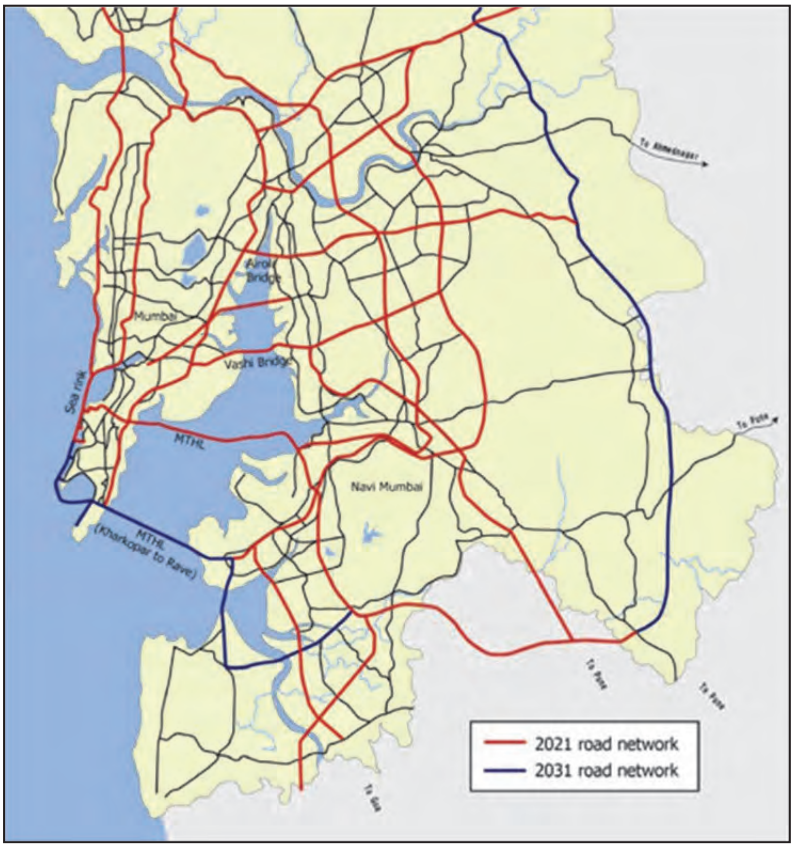
<u>Beginning points at Mumbai side</u>

Northern route (connected at Sewri) was recommended in 1981 by a steering group for the project, however, the details of the study documents could not be found. Therefore, the review was carried out with the current viewpoint.

According to the master plan of the Mumbai Metropolitan Region that contains all development aspects including the road network, MTHL on the Mumbai side starts from Sewri connecting with Chirle on the Navi Mumbai side in a road network in the future. The following are the reasons to set such route:

- There is another plan for a southern route linking Colaba (southern tip of Mumbai Island) with Uran in the said master plan.

- There is a plan linking the western freeway via an east-west corridor.
- There is a plan for widening Vashi Bridge on the northern side of Sewri.

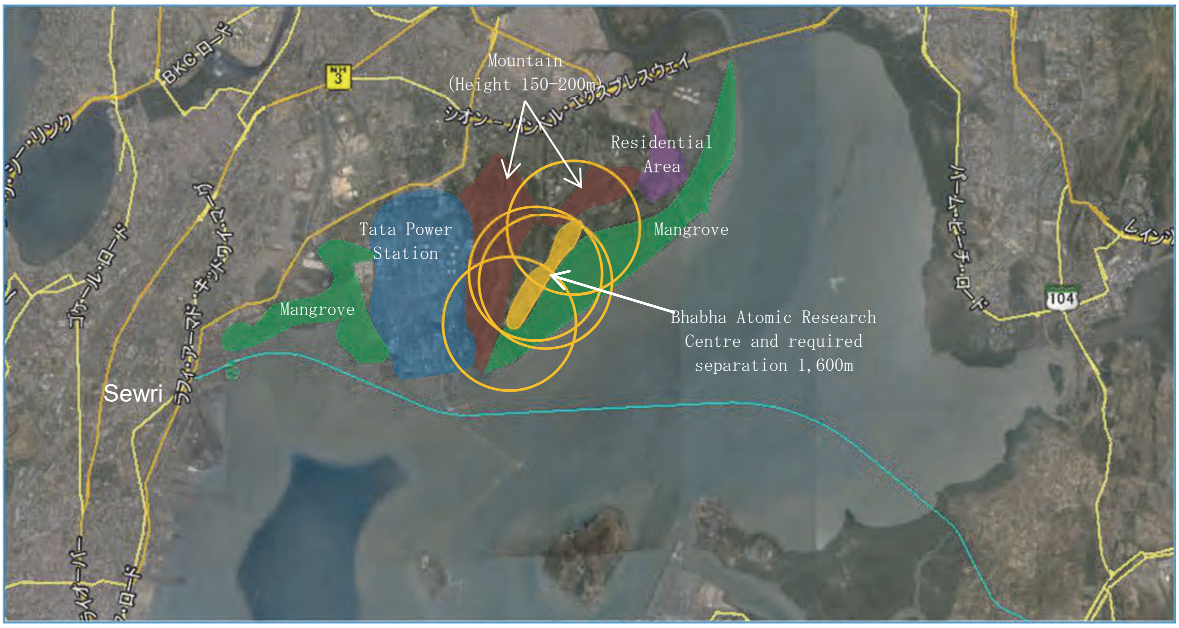


Source: Comprehensive Transport Study for Mumbai Metropolitan Region

Figure 3.3.8 Future Road Network

In addition, regarding the starting point of the route, it seems impossible to start the route from the northern side where Tata Power Station and Bhabha Atomic Research Center are located since there is no space to construct a new approach road given the following considerations:

- Not to interfere to Tata Thermal Power Station
- Keep more than 1,600m away from Bhabha Atomic Research Centre
- Necessity of a large volume of earth cut from the mountain
- Should not be far from the most congested population area of Greater Mumbai



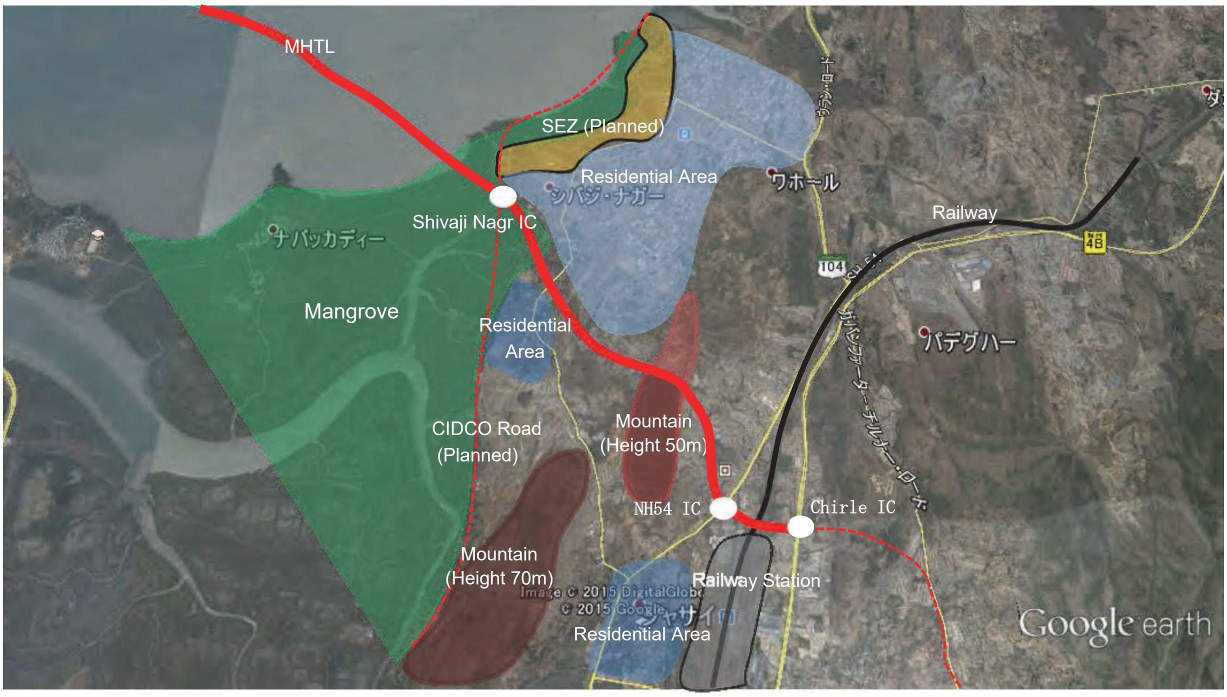
Source: JICA Study Team

Figure 3.3.9 Land Use Map for Northern Area of the Proposed Alignment

<u>Ending points at Nhava (Navi-Mumbai) side</u>

Regarding the alignment on the Nhava side, the route comparison was conducted in 1996 as described before. It is clear that the proposed alignment was fixed in consideration of the following:

- The connection with CIDCO Road linking with Navi-Mumbai Airport, NH54, and JNPT Road connected to Jawaharlal Nehru Port.
- Future extension plan of MTHL connecting to Mumbai-Pune Expressway from Chirle (ending point of MTHL).
- Close access of alignment of MTHL to Planned Special Economic Zone.
- Minimize passage through the present residential area as much as possible, which minimizes the resettlement.
- Minimize the volume of cut soil on the hilly section
- Minimize the impact on the mangrove forest.



Source: JICA Study Team

Figure 3.3.10 Control Points of Alignment on Nhava (Navi Mumbai) Side

Control of Alignment in Marine Section

As shown in Figure 3.3.6, alignment on the marine section was determined in consideration of the following control points:

- Not to interfere with Tata Thermal Power Station
- Keep more than 1000m away from Elephanta Island.
- Keep more than 1,600m away from Bhabha Atomic Research Centre
- Not to interfere with the navigation channel for large vessels of Jawaharlal Nehru Port

(2) Consideration of Additional Route Alignment

The above route does not consider the influence of mud flat area which is a feeding ground of Flamingos that have been flying in every year since 1995. Therefore, an alternative is considered that follows the original north route in order to focus on the environmental influence of the mud flat area (Table 3.3.2).

The two routes as alternative are as follows.

- Option-1: Original route alignment (This route is based on FS report in 2012).
- Option-2: This route avoids mud flat area as much as possible.

Table 3.3.2 Comparison Table of North Route

Features		Option-1			Option-2		
		This route is original rote based on F/S Report, 2012 (Avoid MbPT land)			This route avoids mud flat area (feeding ground of migrate birds) as much as possible		
Route Alignment							
Impact for marine environment	Mud flat area	5.6 km (Mumbai Side: 4.0 km, Navi Mumbai Side: 1.6km)	△	○	3.1 km (Mumbai Side: 1.5 km, Navi Mumbai Side: 1.6 km)	◎	◎
	CRZ area	2.25 km (Mumbai Side: 1.65 km, Navi Mumbai Side: 0.6 km)	◎		2.25 km (Mumbai Side: 1.65 km, Navi Mumbai Side: 0.6 km)	◎	
	Mangrove area	Same	◎		Same	◎	
	Migrate bird	Influence area for bird of passage is 5.6km	△		Influence area for bird of passage is 3.1km	◎	
	Tidal current	Same	◎		Same	◎	
Impact for residential impact	Fisherman	Same	◎	◎	Same	◎	○
	House	Approximately 280 houses	◎		Approximately 350 houses	△	
Road alignment	Road length	21.8 km	◎	◎	22.3 km	○	○
	Road plan	There are not many curves and accident does not occur likely	◎		There are not many curves and accident does not occur likely	◎	
Engineering aspect	Construction period	Almost same		◎	Almost same		◎
Construction cost for entire section		-		◎	Approximately 2,750 million rupees more expensive than Option-1		△
Evaluation		○					

Legend: ◎ Good/ Superior, ○ Moderate, △ Poor/Inferior

Source: JICA Study Team

Route alignment of option-2 is generally the same as the proposede route in 2015 by a local NGO in order to avoid the negative impacts on the Flamingos and the mud flat area. The official discussions between MMRDA and MBPT showed that the route alignment of option-2 will have significant impacts on management of the unloading pier and future plans for a MBPT site (reservoir). And more dividing of the MBPT site now in use is expected. Therefore, this route alignment cannot be accepted.

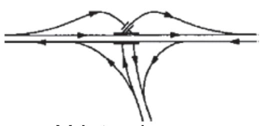
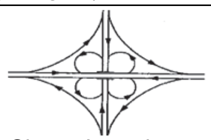
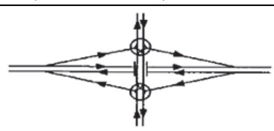
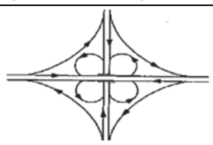
(3) Conclusion

As a result of these considerations it was deemed that the negative impact on the birds will be minimized in Option-2. Unfortunately, the number of resettlements of residential homes will be increased in Sewri IC and the road length will increase, resulting in an increase in construction costs. Additionally, the response from MMRDA to NGO stated that Option-1 (Original route alignment) is recommended.

3.3.4 Interchange Plan

There are four interchanges in this route, each with unique features. The following table summarizes the common features and the factors that determine the type that will be adopted. It seems that in each instance the appropriate interchange shape has been adopted.

Table 3.3.3 Interchange Type

Type	Common Features	Adopted Factors
Sewri (Eastern Freeway (viaduct))		
 Y-Interchange	- More than three-layered. - The elevated areas by bridge structure increases - It doesn't need a large site	- Access road is the viaduct - Limited existing land areas - Extend to east-west corridor in future.
Shivaji Nagar (CIDCO Proposed Road)		
 Clover-Interchange	- Crossing bridge is required in only one place. - It requires a large area	- Sufficient land area is avaialble - Simple structure is preferred
SH54 (SH54 Road)		
 Diamond Interchange (half)	- The cost is lower. - It doesn't need a large site.	- Interchange suitable for half type is preferred.
Chirle (JNPT Road)		
 Clover-Interchange	- Crossing bridge is required in only one place. - It requires a large site	- Sufficient area is available - Simple structure is preferred

Source: JICA Study Team

As for the interchange type, Y-type and Clover-type are normally applied to the connection of highways. Trumpet-type and Diamond-type are normally applied to the connection of frontage (local) roads.

However, the trumpet type was not selected for Shivaji Nagar IC or Chirle IC . This is because of the following reasons.

- Clover-type was adopted in consideration of traffic demand since the road class of the connected frontage road was high.
- the clover-type is common in India so that it has high familiality with Indian driver

In addition, since the land required for the clover-type has already been acquired it would be quite difficult to change it. Therefore, the type is chosen with respect to the previous design.

Regarding the weaving length between the on-ramp nose and the off-ramp nose, it satisfies the Japanese standard.

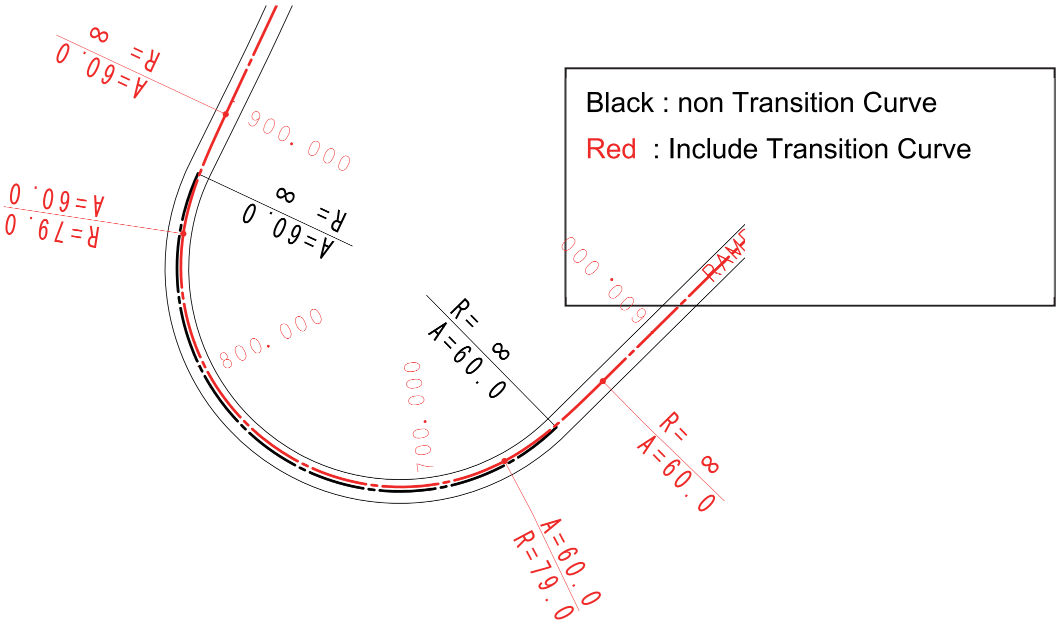
The number of traffic lanes on each interchange and number of toll booths are as per the traffic volume forecast studies and the Final Feasibility Study Report, 2012. Accordingly, Chirle interchange has 3 lanes and Shivajinagar interchange has 2 lanes.

3.3.5 Others

(1) Transition Curve of IC

Transition Curves for interchanges were considered for all ramps in the previous study. Transition Curves are also considered for the Main alignment curves.

The alignment showing the transition curves can be seen in the figure below. The adjusted curve radius can cope with a minor correction.



Source: JICA Study Team

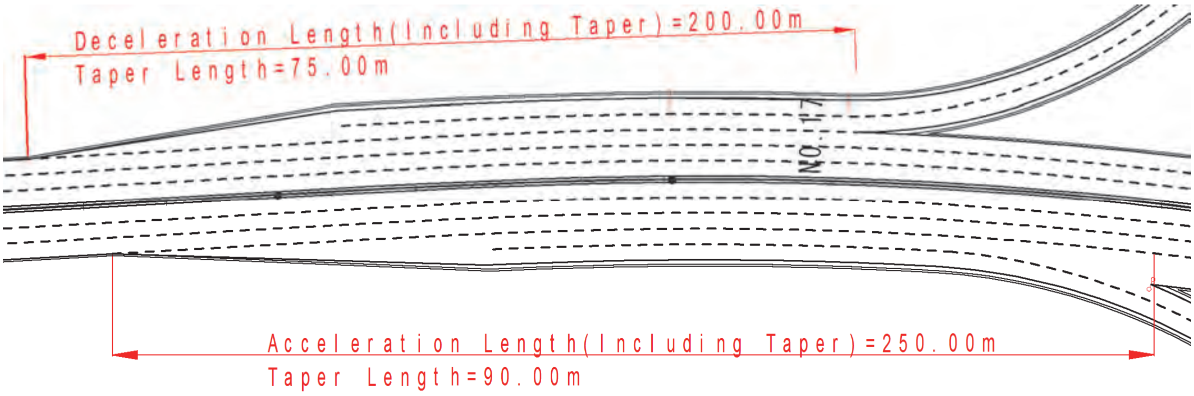
Figure 3.3.11 Transition Curve for Interchange (e.g. Ramp B at Sewri IC)

(2) Deceleration, Acceleration Lane Lengths and Shift Design

Shivaji Nagar Interchange is to be provided with Deceleration and Acceleration lanes. However for Sweri Interchange, the Shift type is applied. This decision was made on the basis of the following assumptions:

- When the traffic on the ramp decelerates from or accelerates onto the main road, the Deceleration and Acceleration design is applied. For this case, each road standard is different.
- For diversion of ramp and ramp, or confluence, the shift type is applied. For this case, each road standard is the same.

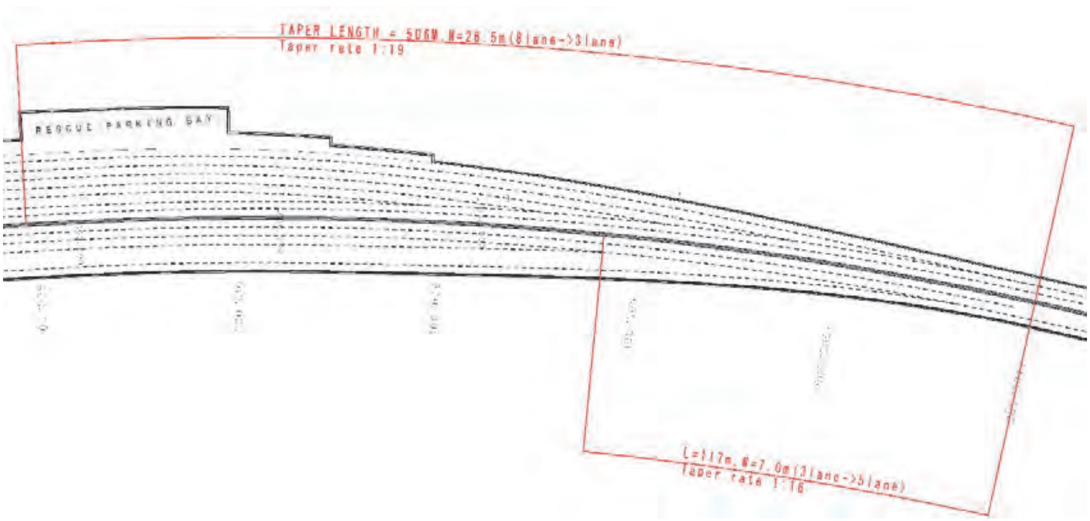
Shavaji Nagar Interchange (Deceleration, Acceleration)



Source: JICA Study Team

Figure 3.3.12 Deceleration and Acceleration Length Type

Sewri Interchange (Shift)



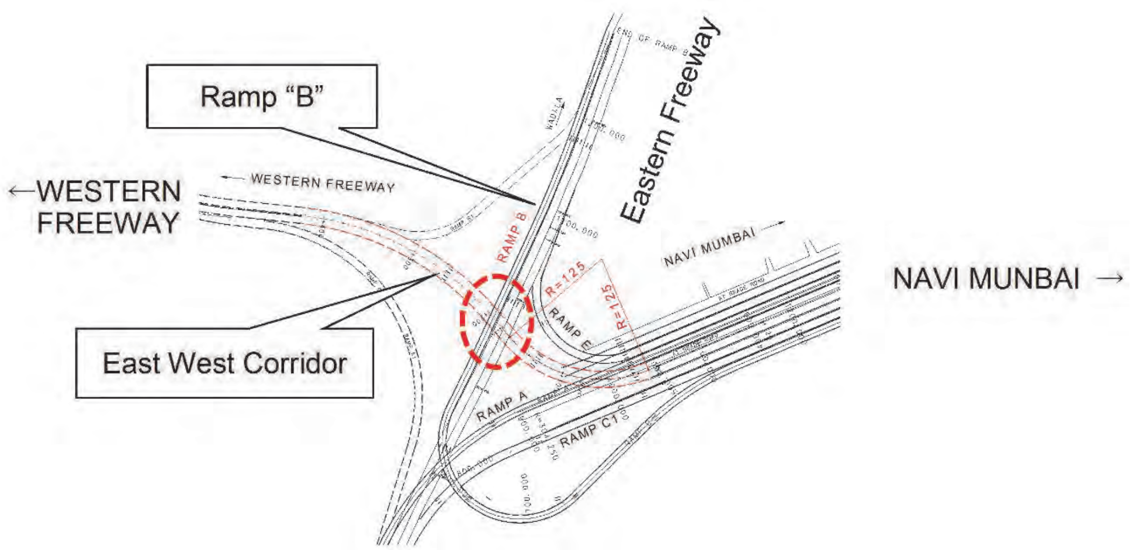
Source: JICA Study Team

Figure 3.3.13 Shift Type

The shift length of a 2-lane ramp requires more room for safety than a 1-lane ramp. Therefore, it is proposed to refer to the Japanese standard for the shift length of the ramps. Refer to '6.4 Design Standard for Road Design' for the details.

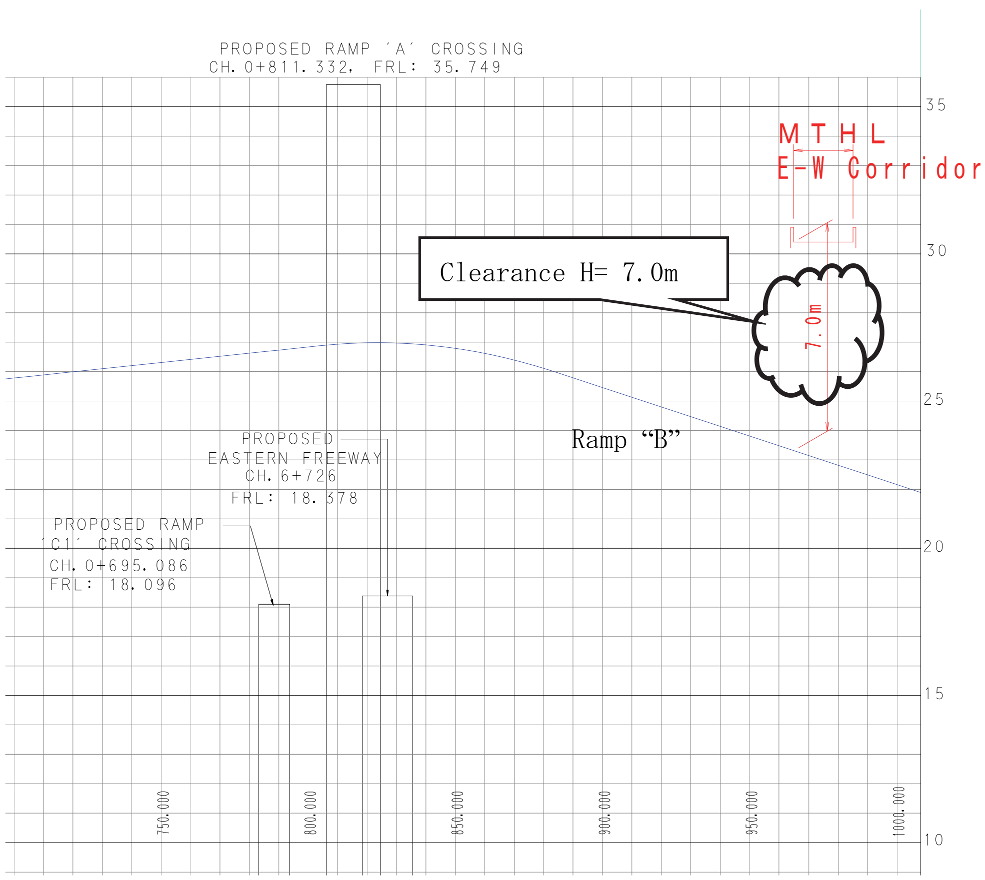
(3) Vertical Clearance of Ramp B at Sewri IC

The vertical clearance of Ramp B at the Sewri Interchange was reviewed.



Source: JICA Study Team

Figure 3.3.14 Studying Point of Clearance



Source: JICA Study Team

Figure 3.3.15 Clearance between Ramp “B” and East West Corridor

As a result, 7m of vertical clearance can be secured between Ramp B and the main carriageway of the East-West Corridor (necessary vertical clearance of ramp B= 6m + 1m girder depth of east-west corridor).

It was confirmed in the meeting with MMRDA that the form of superstructure of the East-West Corridor shall be a steel truss type and the vertical clearance of Ramp B was approved by the superintendent of the railway.

3.4 Review of Bridge Plan

3.4.1 Control Points for Bridge Plan

The Final Feasibility Study Report 2012 provided information about both pipelines/cables on the seabed and fault zones across the Project route shown in Table 3.4.1, which will be the control points for the bridge plan.

Table 3.4.1 Pipelines/Cables and Fault Zones across the Project Route

Pipelines/Cables and Fault Zones	Remarks on Bridge Plan
• There are existing oil/product/freshwater pipelines and power/telephone cables laid on the seabed between Butcher Island oil terminal and the valve station on the west side of the Pir Pau Jetty approach. • There are existing ONGC/GAIL oil/gas pipelines, IPCL/NOCIL chemical product pipelines, and other cables crossing the MTHL alignment in the Panvel Creek area.	• Since the locations of these obstacles were identified by as-built records, the precise locations shall be mapped out through a further on-site survey. • Although it was stated in the Final FS 2012 that the minimum horizontal clearance between the proposed pile caps for MTHL bridge and the existing ONGC pipelines is 15m, the final positions of the piers are subject to be approved by MbPT and ONGC.
• The existence of fault zones that were identified across the MTHL alignment in the vicinity of Thane Channel, approximately 300m south on the western side of the central channel and extending southeast away from the alignment. These should be considered in the span arrangement plan for MTHL. • The recent ground investigation in 2012 also indicates that the fault zone could be deeply weathered at approximately CH13+000 of the alignment.	• It was necessary to conduct the detailed soil investigation when the piers are planned on the fault zones. However, further desk studies found that there is no fault indicated in left colume (see Chapter 5.2.5)

Source: JICA Study Team

Table 3.4.2. summarises all obstacles/utilities on the marine section to be considered for bridge plan including the pipelines/cables mentioned in Table 3.4.1, and also provides the required span arrangement to avoid such obstacles.

Table 3.4.2 Crossing Utilities and Required Span Arrangement on Marine Section

Crossing Utilities	Navigation Clearance		Span Arrangement	Remarks
	Horizontal	Vertical above sea level (C.D.)		
(General)	50m	14.72m	50m	Agreed with MMB.
Tata Thermal Power Station, Intake and Discharge Channel	1 x 94m	31.00m	85m+150m+85m	Agreed with Tata Thermal Power Station
Tata Thermal Power Station, Coal Berth Channel	2 x 94m	31.00m	80m+2@150m+85m	Agreed with Tata Thermal Power Station
Tata Pipeline	-	-	90m+3@150m+85m	-
Pir Pau Jetty Head	-	+6m above jetty level		Agreed with MMB.
Thane Creek	2 x 94m	31.22m	100m+2@180m+100m	Agreed with MMB.
ONGC Pipeline BPCL Pipeline	-	-	100m+180m+110m	-
	-	-	110m+180m+100m	-
Panvel Creek	2 x 100m	31.22m	100m+2@180m+95m	Agreed with MMB.

Source: JICA Study Team

MTHL is planned to cross over some parts of the railways and road in the land sections. The clearances with the railway have already been concluded through the consultation with Indian Railway, and the ones for the crossing roads have also been determined through the discussions with relevant authorities like MbPT, JNPT, CIDCO, National Highway Authority of India (NHAI),Public Works Department (PWD), and Dedicated Freight Corridor Corporation (DFCC) etc.

3.4.2 Bridge Design Standards

The standards applied in the Final Feasibility Study Report, 2012 are shown in the following sections.

(1) Design Codes

Main code list for bridge structure design is updated in Table 3.4.3 based on the review in the study.

Table 3.4.3 Main Code List for Bridge Structure Design

Code No.	Title
IRC: 5-1998	Standard Specifications & Code of Practice for Road Bridges. Section I - General Features of Design
IRC: 6-2010	Standard Specifications & Code of Practice for Road Bridges. Section II - Loads and Stresses
IRC: 7-1971	Recommended Practice for Numbering Bridges and Culverts
IRC: 18-2000	Design Criteria for Pre-stressed Concrete Road Bridges (Post-Tensioned Concrete)
IRC: 21-2000	Standard Specifications and Code of Practice for Road Bridges. Section III - Cement Concrete (Plain and Reinforced)
IRC: 22-2008	Standard Specifications and Code of Practice for Road Bridges. Section VI - Composite Construction
IRC: 24-2010	Standard Specifications and Code of Practice for Road Bridges. Section V - Steel Road Bridges (Limit State Method)
IRC: 45-1972	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges.
IRC:46-1972	A Policy on Roadside Advertisements
IRC: 54-1974	Lateral and Vertical Clearances at Underpasses for Vehicular Traffic.
IRC: 78-2000	Standard Specifications and Code of Practice for Road Bridges. Section VII - Foundations & Substructure
IRC: 83-1999 Part I	Standard Specifications and Code of Practice for Road Bridges. Section IX - Bearings, Part 1 : Metallic Bearings
IRC: 83-1987 Part II	Standard Specifications and Code of Practice for Road Bridges, (Part-II) Section IX - Bearings, Part II: Elastomeric Bearings
IRC:83-2002 Part III	Standard Specifications and Code of Practice for Road Bridges, (Part-II) Section IX - Bearings, Part III: Pot, Pot-cum-PTFE Pin and Metallic Bearings
IRC: 89-1997	Guidelines for Design & Construction of River Training & Control Works for Road Bridges.
IRC: 112-2011	Code of Practice for Concrete Road Bridges
IRC:SP-13-2004	Guidelines for the Design of Small Bridges and Culverts
IRC:SP-18-1978	Manual for Highway Bridge Maintenance Inspection
IRC:SP-33-1989	Guidelines on Supplemental Measures for Design, Detailing & Durability of Important Bridge Structures.
IRC:SP-35-1990	Guideline for Inspection and Maintenance of Bridges
IRC:SP-37-2010	Guidelines for Load Carrying Capacity of Bridges
IRC:SP-40-1993	Guidelines on Techniques for Strengthening and Rehabilitation of Bridges
IRC:SP-47-1998	Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
IRC:SP-54-2000	Project Preparation Manual for Bridges
IRC:SP-56-2011	Guidelines for Steel Pedestrian Bridges
IRC:SP-65-2005	Guidelines for Design and Construction of Segmental Bridges
IRC:SP-66-2005	Guidelines for Design of Continuous Bridges
IRC:SP-67-2005	Guidelines for use of External and Unbonded Prestressing Tendons in Bridge Structures
IRC:SP-69-2005	Guidelines and Specifications for Expansion Joints
IRC:SP-70-2005	Guidelines for the Use of High Performance Concrete in Bridges
IRC:SP-71-2006	Guidelines for the Design and Construction of Pre-tensioned Girder of Bridges
IRC:SP-80-2008	Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures

Source: JICA Study Team

(2) Design Life

A design life of 100 years was adopted for the bridge structure. The design lives of various bridge components/members are listed in Table 3.4.4.

Table 3.4.4 Design Life

Structural Components	Design Life
Foundations, Piers, Abutments, Deck	100 years
Bearings, Movement Joints	40 years (20 years for minor components)
Parapets/handrails	50 years (metal), 100 years (concrete)
Drainage System	20 years

Source: JICA Study Team

(3) Design Loading

Table 3.4.5 lists various types of loading as well as the corresponding design code, and further specifications that were made.

Table 3.4.5 Design Loads

Loading Type	Code	Notes
1. Dead Loads	IRC: 6-2010	HPC density taken as 2.6 T/m^3 Outer parapet load intensity of 5kN/m
2. Environmental Loads		
Wind Loads	IRC: 6-2010	Based on wind speed data for Mumbai
Temperature Loads	IRC: 6-2010	Based on max. and min. temperature record in Mumbai
Water Currents	IRC: 6-2010	Water current speed obtained by Concessionaire; not less than 3 m/s
Wave and Abnormal Wave Loads	IS:4651-Part-III-1997, “Shore Protection, Planning & Design” No. 4 by US Army Coastal Research Centre	Tide data obtained from Central Water and Power Research Station (CWPRS) Technical Report No. 3955
Seismic Actions	IRC, IS:1893-1984 Section 6, IS:1893-2001	Seismic Zone III, with Z-factor of 0.16 for Maximum Earthquake projected, and 0.08 for Operating Basis Earthquake. Importance factor of 1.5.
3. Live Loads		
Traffic Loads	IRC: 6-2010	Designed for Class 70R design vehicle, Class A
Fatigue Loads	BS: 5400	-
Pedestrian Loads	-	No footpath on MTHL, therefore only maintenance walkway with distributed load of 2kN/m2 and concentrated load of 3 kN on 200mm x 200mm square surface
4. Accidental Loads		
Vehicle Impact on Substructure or Parapet	IRC: 6-2010	-
Ship Impact on Piers	AASHTO-LFRD Bridge Design	Assume that 4000 tonne vessel hit at travelling speed of 10 knots
5. Construction Loads	-	Considered in accordance with construction method.

Source: JICA Study Team

(4) Materials

1) Reinforced Concrete

All concrete grades to be applied have minimum cube strength of 45MPa. Grades of various structural members, as well as other concrete specifications, are given in Table 3.4.6.

Table 3.4.6 Reinforced Concrete Properties

Components/Items	Specification
1. Concrete Grades	
Bored piles and caissons	45 MPa
Pile caps	45 MPa
Pile cap skirts	55 MPa
Walls, abutments	45 MPa
Piers	55 MPa
Deck	55 MPa
Parapets and median	45 MPa
2. Cement Mixture	
Cementitious content	Min. 400kg/m^3 (including PFA and silica fume)
Water-to-Cement Ratio	Grade 55-60 : Max. 0.35 Grade 40-50 : Max. 0.40
3. Steel	
Steel Reinforcement	In accordance with Bureau of Indian Standards and IRC: 21-2000. Galvanised steel as per IS: 12584-1988.
Reinforcement cover	As per clause 15 of IRC: 112-2011 for “extreme condition” from CH. 0+495 Km to CH 18+087 Km and “very severe” elsewhere.
4. Reinforcement couplers	As per IRC:21-2000

Source: JICA Study Team

2) Pre-Stressed Concrete

Pre-stressed concrete shall comply with the specifications given in Table 3.4.7.

Table 3.4.7 Prestressed Concrete Properties

Components	Specification
Segmental concrete construction	IRC: SP 65.
External prestressing	IRC: SP:67-2005
Prestressing strand steel	IRC: 18-2000.
Prestressing ducts and anchorages	Designed to allow sheath and tendons to be replaced. Sheath material is proven corrosion-resistant durable non-metallic material such as high-density polyethylene or polypropylene.
Tendon grouting	IRC:18-2000, Appendix 5

Source: JICA Study Team

3) Structural Steel

Structural steel shall comply with IRC: 24-2010 and IS: 8000. Details regarding the specifications for painting on the structural steel shall be referred to international standards.

3.4.3 Outline of Bridge Plan

The outline of the bridge plan for MTHL in the previous study is shown in Table 3.4.8 to Table 3.4.14. MTHL passes through the general sections on both land and water, obstacles in the marine mangrove forest area, and flyover sections over railways and roads on the land section.

Table 3.4.8 Marine Bridge Properties (1/3)

	Chainage From	Chainage To	Bridge Type	Span Length	Pier	Substructure Type
General (Marine)	0+495	1+045	PSC box girder bridge (span by span method)	2@50m=100m 3@50m=150m 2@50m=100m 2@50m=100m 2@50m=100m	MP1 (0+495) MP3 (0+595) MP6 (0+745) MP8 (0+845) MP10 (0+945) MP12 (1+045)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
	1+045	2+795		5@50m=250m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m	MP13 (1+095) MP17 (1+295) MP23 (1+595) MP29 (1+895) MP35 (2+195) MP41 (2+495) MP46 (2+745)	Pile bent pier : φ2.4m - 2piers
	2+795	3+395		6@50m=300m 6@50m=300m	MP47 (2+795) MP53 (3+095) MP59 (3+395)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
Special (Marine)	3+395	3+715	PSC box girder bridge (cantilever method)	85m+150m+85m =320m	MP60 (3+480) MP61 (3+630)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
General (Marine)	3+715	4+595	PSC box girder bridge (span by span method)	6@50m=300m 6@50m=300m 40m+4@50m+40m =280m	MP62 (3+715) MP68 (4+015) MP74 (4+315) MP80 (4+595)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
Special (Marine)	4+595	5+060	PSC box girder bridge (cantilever method)	80m+2@150m+85m =465m	MP81 (4+675) MP82 (4+825) MP83 (4+975)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
General (Marine)	5+060	5+310	PSC box girder bridge (span by span method)	5@50m=250m	MP84 (5+060) MP89 (5+310)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
Special (Marine)	5+310	5+935	PSC box girder bridge (cantilever method)	90m+3@150m+85m =625m	MP90 (5+400) MP91 (5+550) MP92 (5+700) MP93 (5+850)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
General (Marine)	5+935	8+635	PSC box girder bridge (span by span method)	6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m	MP94 (5+935) MP100 (6+235) MP106 (6+535) MP112 (6+835) MP118 (7+135) MP124 (7+435) MP130 (7+735) MP136 (8+035) MP142 (8+335) MP148 (8+635)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
Special (Marine)	8+635	9+195	PSC box girder bridge (cantilever method)	100m+2@180m+100m =560m	MP149 (8+735) MP150 (8+915) MP151 (9+095)	Pier : 6mx3m - 4piers Pile : φ2.4m - 8piles
General (Marine)	9+195	10+395	PSC box girder bridge (span by span method)	6@50m=300m 6@50m=300m 6@50m=300m 6@50m=300m	MP152 (9+195) MP158 (9+495) MP164 (9+795) MP170 (10+095) MP176 (10+395)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
	10+395	11+295		6@50m=300m 6@50m=300m 6@50m=300m	MP177 (10+435) MP182 (10+695) MP188 (10+995) MP193 (11+245)	Pile bent pier : φ2.4m - 2piers
	11+295	11+635		6@50m+40m=340m	MP194 (11+295) MP201 (11+635)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles

Source: JICA Study Team

Table 3.4.9 Marine Bridge Properties (2/3)

	Chainage From	Chainage To	Bridge Type	Span Length	Pier	Substructure Type
Special (Marine)	11+635 (L)	12+075 (L)	PSC box girder bridge (cantilever method)	50m+100m+180m+110m =440m	MP201 (11+635 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP202 (11+685 (L))	
					MP203 (11+785 (L))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP204 (11+965 (L))	
					MP205 (12+075 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
	12+075 (L)	12+515 (L)		110m+180m+100m+50m =440m	MP206 (12+185 (L))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP207 (12+365 (L))	
					MP208 (12+465 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP209 (12+515 (L))	
Special (Marine)	11+635 (R)	12+115 (R)	PSC box girder bridge (cantilever method)	40m+40m+100m+180m+ 120m=480m	MP201 (11+635 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP202 (11+675 (R))	
					MP203 (11+715 (R))	
					MP204 (11+815 (R))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP205 (11+995 (R))	
					MP206 (12+115 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
	12+115 (R)	12+515 (R)		120m+180m+100m=400 m	MP207 (12+235 (R))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP208 (12+415 (R))	
					MP209 (12+515 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
General (Marine)	12+515	12+715	PSC box girder bridge (span by span method)	4@50m=200m	MP209 (12+515)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
	12+715	12+955		4@50m+40m=240m	MP213 (12+715)	
					MP218 (12+955)	
Special (Marine)	12+955 (L)	13+600 (L)	PSC box girder bridge (cantilever method)	50m+100m+2@180m+95 m+40m=645m	MP218 (12+955 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP219 (13+005 (L))	
					MP220 (13+105 (L))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP221 (13+285 (L))	
					MP222 (13+465 (L))	
					MP223 (13+560 (L))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP224 (13+600 (L))	
Special (Marine)	12+955 (R)	13+600 (R)	PSC box girder bridge (cantilever method)	40m+100m+2@180m+95 m+50m=645m	MP218 (12+955 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP219 (12+995 (R))	
					MP220 (13+095 (R))	Pier : 6mx3m - 2piers Pile : φ2.4m - 4piles
					MP221 (13+275 (R))	
					MP222 (13+455 (R))	
					MP223 (13+550 (R))	Pier : φ2.5m - 1piers Pile : φ1.5m - 4piles
					MP224 (13+600 (R))	
General (Marine)	13+600	14+500	PSC box girder bridge (span by span method)	6@50m=300m	MP224 (13+600)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP230 (13+900)	
				6@50m=300m	MP236 (14+200)	
					MP242 (14+500)	
	14+500	16+000		6@50m=300m	MP243 (14+550)	Pile bent pier : φ2.4m - 2piers
				6@50m=300m	MP248 (14+800)	
				6@50m=300m	MP254 (15+100)	
				6@50m=300m	MP260 (15+400)	
				6@50m=300m	MP266 (15+700)	
					MP271 (15+950)	
Mangrove part	16+000	17+257		6@50m=300m	MP272 (16+000)	Pier : φ2.5m - 2piers Pile : φ1.5m - 8piles
				6@50m=300m	MP278 (16+300)	
				3@53.333m=160m	MP284 (16+600)	
				47m	MP287 (16+760)	
				3@50m=150m	MP288 (16+807)	
				3@50m=150m	MP291 (16+957)	
				3@50m=150m	MP294 (17+107)	
					MP297 (17+257)	

Source: JICA Study Team

Table 3.4.10 Marine Bridge Properties (3/3)

	Chainage From	Chainage To	Bridge Type	Span Length	Pier	Substructure Type
Road Overpass	17+257 (L)	17+452 (L)	PSC box girder bridge (span by span method)	35m+45m+40m+40m +35m=195m	MP297 (17+257 (L))	Pier : φ2.5m - 1piers
					MP302 (17+452 (L))	Pile : φ1.5m - 4piles
Road Overpass	17+257 (R)	17+452 (R)	PSC box girder bridge (span by span method)	45m+45m+40m+40m +25m=195m	MP297 (17+257 (R))	Pier : φ2.5m - 1piers
					MP302 (17+452 (R))	Pile : φ1.5m - 4piles
Mangrove part	17+452	18+022	PSC box girder bridge (precast whole span method)		MP302 (17+452)	
				4@30m=120m	MP303 (17+482)	
				5@30m=150m	MP306 (17+572)	
				5@30m=150m	MP311 (17+722)	
				5@30m=150m	MP316 (17+872)	Pier : φ2.5m - 2piers
Road Overpass	18+022	18+082		20m+40m=60m	MP321 (18+022)	Pile : φ1.2m - 12piles
Mangrove part	18+082	18+232		5@30m=150m	MP323 (18+082)	
Road Overpass	18+232	18+352		3@40m=120m	MP328 (18+232)	
General (Land)	18+352	18+388		36m	MP331 (18+352)	
Railway Overpass	18+388	18+458	Steel Truss Bridge	70m	MP332 (18+388)	Pier : φ3.25m - 3piers
					MP333 (18+458)	Piles : φ1.5m - 12piles
General (Land)	18+458	18+922	PSC box girder bridge (precast whole span method)	44m	MP334 (18+502)	
				5@30m=150m	MP339 (18+652)	Pier : φ2.5m - 2piers
				5@30m=150m	MP344 (18+802)	Pile : φ1.2m - 12piles
				3@40m=120m	MA2 (18+922)	
Embankment	18+922	20+092				
General (Land)	20+092	21+172	PSC box girder bridge (precast whole span method)	5@30m=150m	LA1 (20+092)	
				5@30m=150m	LP5 (20+242)	
				5@30m=150m	LP10 (20+392)	Pier : φ2.5m - 2piers
				5@30m=150m	LP15 (20+542)	Pile : φ1.2m - 12piles
				5@30m=150m	LP20 (20+692)	
				3@30m=90m	LP25 (20+842)	
				18m	LP28 (20+932)	
Road Overpass				35m	LP29 (20+950)	Pier : φ1.5m - 3piers
				35m	LP30 (20+985)	Pile : φ1.2m - 10piles
General (Land)				32m+4@30m=152m	LP31 (21+020)	
					LP32 (21+052)	Pier : φ2.5m - 2piers
					LP36 (21+172)	Pile : φ1.2m - 12piles
	21+172	21+184.533	PSC-I girder bridge	12.533m	LP37 (21+184.533)	Pier : φ3.25m - 3piers
Railway Overpass	21+184.533	21+379.533	Steel Truss Bridge	3@65m=195m	LP40 (21+379.533)	Piles : φ1.5m - 12piles
	21+379.533	21+412	PSC-I girder bridge	32.467m	LP41 (21+412)	
General (Land)	21+412	21+715.78	PSC box girder bridge (precast whole span method)	3@30m=90m	LP44 (21+502)	
				3@30m=90m	LP47 (21+592)	
				23.78m	LP48 (21+615.78)	Pier : φ2.5m - 2piers
Road Overpass				35m	LP49 (21+650.78)	Pile : φ1.2m - 12piles
				35m	LP50 (21+685.78)	
General (Land)				30m	LA2 (21+715.78)	

Source: JICA Study Team

Table 3.4.11 Bridge Properties at Sewri IC

Ramp	Chainage From	Chainage To	Bridge Type	Elevation level	Maximum hight	Span Arrange	Substructures
Ramp A	Sewri	0+495	PSC box girder bridge	4F	37.00 m	Unknown	Pier : RC Pier Pile : Bored Pile
Ramp B				3F	27.00 m	Unknown	
Ramp C1				2F		Unknown	
Ramp E				2F		Unknown	
Ramp C2				1F		Unknown	
Ramp F				1F		Unknown	

Source: JICA Study Team

Table 3.4.12 Bridge Properties at Shivaji Nagar IC

Ramp	Chainage		Bridge Type	Span Arrangement	Substructures
	From	To			
Ramp JM	16+907	Coastal Road	PSC box girder bridge +PSC void slab bridge	3@50m+13@20m=410m	Pier : RC Pier Pile : Bored Pile
Ramp MA	16+857			3@50m+8@20m=310m	
Ramp CA	17+297	Coastal Road	PSC void slab bridge	11@20m=220m	
Ramp MJ	17+422			13@20m=260m	
Ramp AM	17+722	Coastal Road	PSC box girder bridge +PSC void slab bridge	30m+12@20m=270m	
Ramp AC	17+632			30m+16@20m=350m	

Source: JICA Study Team

Table 3.4.13 Bridge Properties at SH54 IC

Ramp	Chainage		Bridge Type	Span Arrangement	Substructures
	From	To			
Ramp MP	20+212	SH54	PSC box girder bridge	12@30m=360m	Pier : RC Pier Pile : Bored Pile
Ramp JM	20+242	SH54		10@30m=300m	

Source: JICA Study Team

Table 3.4.14 Bridge Properties at Chirle IC

Ramp	Chainage		Bridge Type	Span Arrangement	Substructures
	From	To			
Ramp MP	21+082	NH4B	PSC box girder bridge	3@30m=90m	Pier : RC Pier Pile : Bored Pile
			PSC-I girder bridge	12.533m	
			Steel truss bridge	3@65m=195m	
			PSC void slab bridge	23.222+5@20m=123.222m	
Ramp JM	21+052	NH4B	PSC box girder bridge	4@30m=120m	
			PSC-I girder bridge	12.533m	
			Steel truss bridge	3@65m=195m	
			PSC void slab bridge	25.062+12@20m=265.062m	
Ramp MJ	21+560	NH4B	PSC box girder bridge	30m	
				24m	
				35m	
				35m	
				30m	
				30m	
			PSC void slab bridge	14@20m=280m	
Ramp PM	21+560	NH4B	PSC box girder bridge	30m	
				24m	
				35m	
				35m	
				30m	
				30m	
			PSC void slab bridge	14@20m=280m	

Source: JICA Study Team

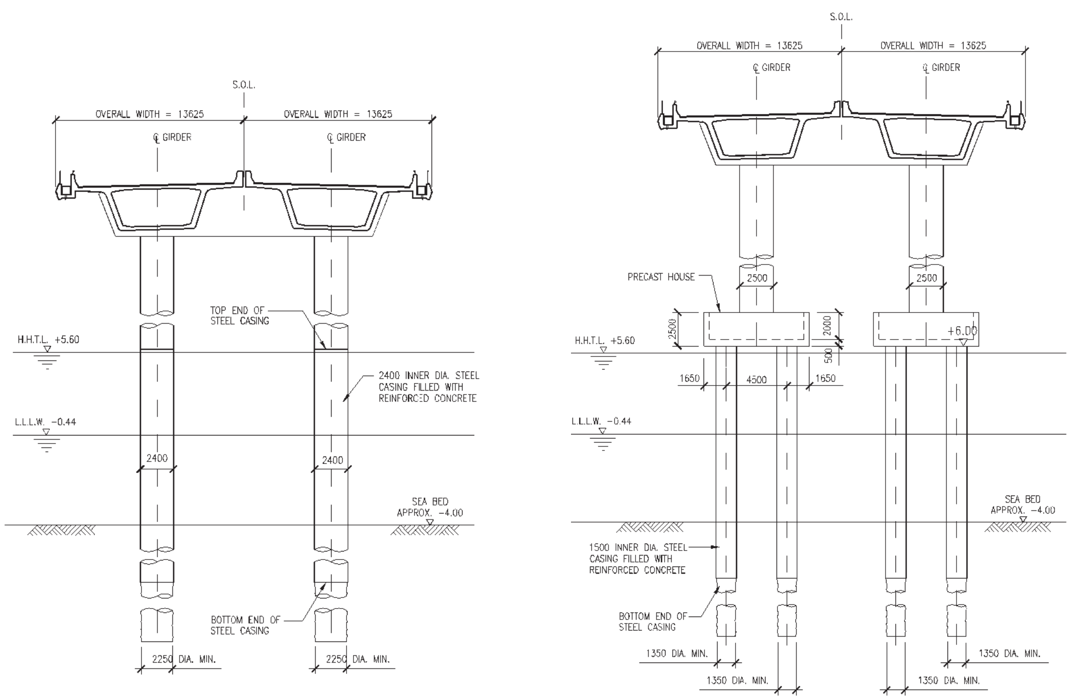
3.4.4 Review of Bridge Plan in Final FS 2012

(1) General Sections over both Water and Land

1) Outline of Bridge Structures

Superstructures in the general marine sections shall utilize PC continuous box girders with a standard span of 50m. Erection of the superstructure is to be performed employing the span-by-span method utilizing precast segments. For piers less than 20m high (road surface elevation < 30m) from the ground surface, a pile bent structure, for which pile caps are not required, has been selected in order to mitigate environmental impact and reduce construction cost. This pile bent structure is made of RC with a diameter of 2,400mm, encased in an 8mm-thick non-structural temporary steel pipe (Figure 3.4.1). For piers over 20m high, a pile cap structure has been selected. The elevation of the bottom of the pile cap has been set to +6.0m above sea level (C.D.). Cast-in-place bored piles with a diameter of 1,500mm are used for the foundation. The bored piles are also encased in 8mm-thick non-structural steel piping (Figure 3.4.1).

Superstructures for the general land section are PC simple box girders with a standard span of 30m. Vertical clearance is 15m.



(a) Pile Bent Structure with Two Columns (b) Pile Cap Structure with Two Columns

Source: JICA Study Team

Figure 3.4.1 Form of Substructure at General Section

Table 3.4.15 Pier Properties for the General Marine Sections

Structure type	Details
Pile bent structure	Pier height is less than 20m Pier with two-shafts of φ2,400mm (outside is steel pipe with 8mm in thickness)
Pile cap structure	Pier height is over 20m Diameter of pier: 2,500 mm Embedding precast formwork is used for pile cap Pile cap bottom is set at +6.00m above Chart Datum 4 nos. of cast-in-place bored pile with 1,500mm in diameter covered by 8mm thickness of steel pipe where is only section above the seabed

Source: JICA Study Team

2) Design Conditions that need to be clarified in Revising the Bridge Plan

- The reason that the pile cap bottom has been set at +6.0m above sea level (C.D.).
- The reason for application of the maximum continuous bridge length
- The locations where pile bent structures or where pile cap structures should be used
- Base of the pile cap bottom elevation of +6.0 m above sea level (C.D.)
- The reason that the standard span of land viaduct has been set to 30m

3) Additional Study Results and Proposal of Alternatives

For general marine sections

- General span length of 50m for PC box girder was determined on the basis of navigation clearance for both fishing boats and dredging operations near the navigation channel. This bridge type with 50m in span length can be justified from the view of the construction cost saving compared to other types and rich past records for application. The continuous bridge length shall be determined based on the preliminary structural analysis of the bridge.
- In order not to disturb tidal current by piers, the pile cap bottom is set at 40cm above HHTL and this has been confirmed by MMRDA.

For general land sections

- Standard practise for girder erection with spans of around 30m shall be by using large lifting capacity cranes after fabrication of precast PC girders at a yard. This method has produced satisfactory results from both economic and a workability-based viewpoints for several projects in the Mumbai vicinity
- PC simple box girder type was applied in order to reduce both the cost and period of construction.

For both marine and land sections

- It is necessary to conduct a preliminary study on the height range of application of pile bent structure for piers for a 6-span continuous rigid frame PC bridge.

(2) Obstacle/Navigation Channel Sections Over the Water

1) Outline of the Bridge Structures

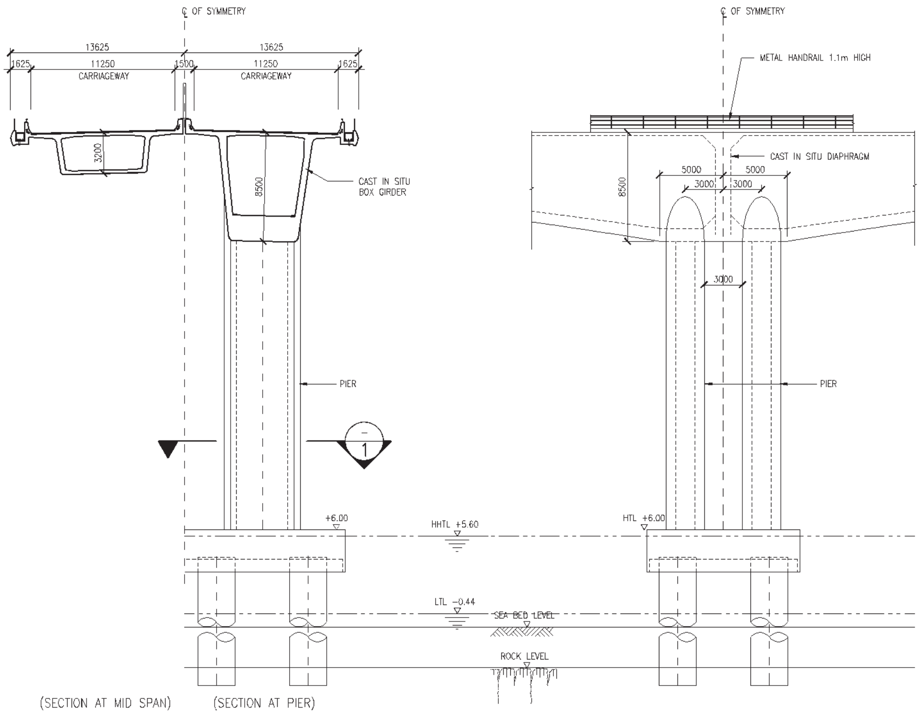
In the marine sections, the MTHL shall cross one discharge channel, three shipping channels and three sets of pipe lines. The navigation channels of the discharge channel and the shipping channel require a horizontal clearance of 94m and a vertical clearance of 31m above Chart Datum (C.D.). PC rigid frame box girder bridges of 150m and 180m in maximum span length are applied with cast-in-situ cantilever erection method. The span length of these bridges is shown in Table 3.4.16.

Table 3.4.16 Crossing Utilities and Span Arrangement

Chainage		Obstacles	Bridge Type	Span Length
From	To			
3+395	3+715	Tata Intake and Discharge Channels	PSC box girder bridges (cantilever method)	85m+150m+85m=320m
4+595	5+060	Tata Coal Berth Channel		80m+2@150m+85m=465m
5+310	5+935	Tata Power Cables Pir Pau Jetty		90m+3@150m+85m=625m
8+635	9+195	Thane Creek		100m+2@180m+100m=560m
11+635 (L)	12+515 (L)	ONGC pipelines BPCL pipelines		50m+100m+180m+110m=440m 110m+180m+100m+50m=440m
11+635 (R)	12+515 (R)			2@40m+100m+180m+120m=480m 120m+180m+100m=400m
12+955 (L)	13+600 (L)	Panvel Creek		50m+100m+2@180m+95m+40m=645m
12+955 (R)	13+600 (R)			40m+100m+2@180m+95m+50m=645m

Source: JICA Study Team

The substructure of the main span is a two-column pier connecting with the superstructure, forming a rigid frame structure. The foundation type is 2,400mm-diameter bored piles encased in 8mm-thick steel pipe. In addition, ship collision absorber devices are to be installed along the shipping channel. The elevation of the top of the pile caps are set at +6.00m above C.D..



Source: JICA Study Team

Figure 3.4.2 Substructure Type at Special Marine Sections

Table 3.4.17 Substructure Type for Special Marine Sections

Structure type	Details
Piers at expansion joints	Piers with pile cap Embedding precast formwork is used for pile caps Pile cap bottom is set at +6.00m above sea level (C.D.). 4 nos. of bored piles 1,500mm in diameter covered by 8mm thick steel pipe where is only section above the seabed
Main piers	Two-column piers 3.00m x 6.00m x 2 in size Embedding precast formwork is used for pile cap Pile cap top surface is set at +6.00m above sea level (C.D.). 4 nos of bored piles 2,400mm in diameter covered 8mm thick steel pipe where is only section above the seabed.

Source: JICA Study Team

2) Design Conditions to be clarified while Revising the Bridge Plan

- The bridge construction at obstacle/navigation channel marine sections is on the critical path of the construction schedule.
- A precise investigation for the pipeline positions is essential.
- Regarding the ship collision device, it is not clear whether a ship collision absorber shall be installed, or the pile cap itself shall be designed to resist the collision load.
- The reason for setting the elevation of the top of the pile cap at +6.0m above sea level (C.D.) should be confirmed.

3) Additional Study Results and Proposal of Alternatives

- Optimal bridge types should be considered in order to shorten the construction period, allowing earlier opening of MTHL to traffic.
- As the pier height increases (to satisfy navigation clearance for the shipping channel), the weight of the superstructure which the foundation has to resist also increases. If the bottom of the pile cap is set to a height of +6.00m above sea level (C.D.). (similarly to the general section), the number of bored piles should be increased, along with the construction cost. As a countermeasure, the top of the pile cap is set at the height of +6.00m above sea level (C.D.). This concept shall be confirmed with the MMRDA and it should be applied in the revised bridge plan for the reduction of construction cost.
- The foundation types should be reviewed and compared after obtaining information about practices in India.
- An investigation of the pipeline positions should be carried out in this study. Span arrangement will be proposed based on the pipeline position.
- The Final FS in 2012 proposed either installing an isolated ship collision absorber or designing the pile cap such that it can resist ship collision itself. The former shall be considered in further study.

(3) Mangrove Section at Navi Mumbai Side

1) Outline of Bridge Structures

In order to mitigate adverse effects on the mangrove forest section, PC rigid frame box girders with a standard span length of 50m are applied using the span-by-span erection method. In the section crossing the Shivaji Nagar IC, a PC box girder with a span length of 30m is planned. The substructure type is designed as a two-column pile cap structure.

Table 3.4.18 Substructure Type for Mangrove Section

Structure type	Details
Pile bent structure	Pier height is less than 20m Pier and foundation of 2,400mm diameter covered by an 8mm thick steel pipe
Pile cap structure	Pier height is less than 20m Diameter of pier: 2,500 mm Embedding precast formwork is used for pile cap Soil cover for pile cap is 0.5m thick 4 nos. of bored piles 1,500mm in diameter covered with an 8mm thick steel pipe

Source: JICA Study Team

2) Design Conditions that need to be clarified for Revising the Bridge Plan

- The application criteria between the pile bent type and pile cap type is not clear.

3) Additional Study Results and Proposal of Alternatives

- It is required to define the application criteria between the pile bent type and the pile cap type.

(4) Railway Overpass

1) Outline of Bridge Structures

As proposed by Indian Railways, which is the authority in charge of railways in India, the steel truss bridge type is planned over both the Nerul-Uran railway and Jasai Yard ROB overpass. Through the consultations between MMRDA and Indian Railway, both vertical and horizontal clearances have also been confirmed.

(5) Road Overpass

1) Outline of Bridge Structures

The superstructure is planned as a PC box girder and the pile cap type was applied for the substructure. The vertical clearance of 6.0m under the road is kept. Pier column is less than 20m in height.

Table 3.4.19 Substructure Properties for the Road Overpass Bridge

Structure type	Details
Pile cap structure	Pier height is less than 20m Minimum soil cover for pile cap is 0.5m in thickness Bored pile is 1,200mm in diameter

Source: JICA Study Team

(6) Sewri IC

1) Outline of Bridge Structures

Sewri IC links the MTHL to the Eastern Freeway, the East-West Corridor (planned for future construction) and other existing roads. It is a four-level stack interchange. The superstructure is designed as a PC continuous box girder. The substructure is developed with cantilever piers and rigid frame piers, and bored piles (1,200mm and 1,500mm in diameter) are proposed as its foundation. The heights of the off-ramps are shown in Table 3.4.20.

Table 3.4.20 Sewri IC Ramps

Ramp	Elevation level	Height Sta, 0+452	Maximum hight	Hight at Starting Point	Bridge Type
Ramp A	4F	20.0m	37m	18 m	PC Box Girder Bridge
Ramp B	3F	22.0m	27m	22 m	
Ramp C1	2F	20.0m		18 m	
Ramp E	2F	20.0m		18 m	
Ramp C2	1F	20.0m		6.5m	
Ramp F	1F	20.0m		6.5m	

Source: JICA Study Team

2) Design Conditions to be clarified for Revising the Bridge Plan

- The profile for the ramp alignment which connects the East-West Corridor with the main road of MTHL has not been shown. Furthermore, as the ramp may have a long span due to crossing the railway underneath, the profile of the other ramps may be affected.
- The superstructure of the ramps are planned as PC box girders. However, the construction method is not specified in the report so that further studies are required in terms of construction/erection method.
- As the pier arrangement of the ramp is not clearly shown in the report, it is difficult to confirm its span length or pier structure. Furthermore, as the ramp alignment is complicated, there is a concern that there could be negative impacts on the Eastern Freeway during the ramp construction.

3) Additional Study Result and Proposal of Alternatives

- As there has been some concern regarding the sufficiency of the vertical clearance for Ramp B, a consultation meeting was held with MMRDA. MMRDA explained that since the ramp bridge connecting between the East-West Corridor and the MTHL main carriageway will be constructed with a steel truss bridge,which has low height between deck surface and bottom of the superstructure, there is no problem with the vertical clearance with Ramp B. Furthermore, as the alignment and the shape of Ramp B have already been confirmed by the Technical Advisory Committee for MTHL, the present alignment (the position relating between Ramp B and East-West Corridor) should be restored. In conclusion, the profile of the ramps shall not be changed from the original plan in the Final Feasibility Study 2012.
- It was confirmed that the pier/foundation arrangement and its shape for ramp bridges along the railway properties have been agreed with the Indian Railway.
- As a result of reviewing construction practice in Indian, the curved PC box girder which is planned for the ramp bridges can be constructed with precast segments.

(7) Shivaji Nagar IC, SH54 IC and Chirle IC

1) Outline of Bridge Structure

Shivaji Nagar IC

PC box girder bridges are applied for span lengths of 50m. For 30 m span lengths, there is no indication of the bridge type in the report. For the substructure, the pile cap type is applied for all bridges.

SH54 IC

A PC box girder bridge of 30m span length, the same as the main road of MTHL, is applied. The substructure is proposed as a single column pier with pile cap.

Chirle IC

Jasai Yard ROB overpass across the railway is to be constructed with steel truss girder bridge. The other parts of the ramp are planned for span lengths of 20m, but the superstructure type is not specified in the report. The substructure is proposed as a single column pier with pile cap.

2) Design Conditions that need to be clarified for Reviewing the Bridge Plan

The span arrangement, particularly the 20m span length, shall examined for its appropriateness.

3) Additional Study Result and Alternatives

It is necessary to review both the span arrangements of the ramps and their bridge types in order to confirm their appropriateness.

(8) Others

1) Temporary Bridge/Platform during Bridge Construction in Marine Sections

As there is no plan given in the report for a temporary platform/jetty to access the construction sites in the marine sections, it is necessary to additionally study the structures for the temporary platform/jetty in this study

3.5 Review of Construction Cost and Schedule

3.5.1 Review of Construction Cost

The construction costs estimated in the Final FS Report 2012 are being referred to for the items listed below. The quantity of the work items were reviewed according to the preliminary design of the said report and revised to obtain more probable construction cost at that time.

- Interchange
- Marine Viaduct
- Land Viaduct
- Road Facilities: Tollgate, Administration Building, Rescue Centre, etc.
- Environmental Mitigation Plan
- Miscellaneous: Electric and Mechanical Systems

For a mega bridge project like MTHL, the use of common unit prices from the archived smaller scaled projects should be avoided. Considering the recent large scale bridge project in the Mumbai area, the following assumptions were applied to MTHL in the Final Feasibility Study 2012.

- The unit prices of the work items for the Western Freeway Project and the Sea Link, which are regarded as being similar in nature to this project, were basically referred to for the cost estimate of MTHL.
- However, since the Sea Link Project was constructed in the ocean area unlike MTHL which passes through a calm Mumbai Bay, the construction costs of the work items for MTHL can be assumed to be smaller. Accordingly, the unit prices applied to the Sea Link were reduced but considered price escalation from the 2007 prices for MTHL.
- Firstly, the basic unit price has been defined for a sea bridge with 50 m span length and a coefficient was applied to estimate the unit cost of bridges with different spans up to 120m in span length.
- For bridge spans longer than 120 m, the unit cost was increased by a factor between 25~30% based on the experience of the bridge projects in Hong Kong.

The unit costs estimated in the Final Feasibility Study 2012 are shown in Table 3.5.1.

Table 3.5.1 Estimated Unit Cost in Previous Study, 2012

Western Freeway Sea Link (Phase IIA)	Consultant's estimated rate (does not include IDC)	90,000 INR/m^2 (2008 price)
	Tender A rate (does not include IDC but includes risks)	128,600 INR/m^2 (2008 price)
	Tender B rate (includes IDC + Risks)	132,560 INR/m^2 (2008 price)
MTHL Returned Tenders	Tender A rate (includes IDC + Risks)	101,540 INR/m^2 (2007 price)
	Tender B rate (includes IDC + Risks)	84,230 INR/m^2 (2007 price)
Bandra Worli Sea Link Returned Tenders		91,000 INR/m^2 (1999 price) (average rate including standard viaducts and cable stay bridges)

Note: IDC = Interest During Construction
Source: Final FS Report for MTHL, 2012

The quantities and cost breakdown applied in the Final Feasibility Study 2012 and the unit prices are shown in Table 3.5.2. In this table the figures in the left column are quoted from the Final FS 2012 report and the ones in the right column are the results of the review into whether or not the unit prices were properly estimated on the basis of the said assumptions mentioned above.

As the results of the review works, there are some findings as follows;

- Improper quotation from the drawing (approach road length shall be 62m instead of 623m, which is indicated in red in the table
- Incrrect application of the unit prices for a PC bridge to a steel bridge
- Inaccurate application of the average price escalation coefficient of 5% without consideration of the variations in commodity indices from 2007 to 2012

Table 3.5.2 Review Results of Cost Estimation in Feasibility Study Report, 2012 1/2

Section			Final FS Report for MTHL, 2012			Reviewed FS Report		
No		Bridge Type	**Area** (m²)	**Unit Rate** (Rs/m²)	**Cost** (INR・Mil)	**Area** (m²)	**Unit Rate** (Rs/m²)	**Cost** (INR・Mil)
Interchange At Sewri ～0+495								
Ramp A	0+00	PC Box Girder	53,015	52,000	2,757	50,516	65,000	3,284
Ramp B		PC Box Girder						
Ramp C1		PC Box Girder						
Ramp E		PC Box Girder						
Ramp C2		PC Box Girder						
Ramp F	0+495	PC Box Girder						
Retained Approaches			6,565	9,500	623	6,565	11,900	78
At grade road and junctions			31,520	5,000	158	32,156	6,300	203
					3,537			**3,564**
Marine Viaducts 0+495～16+000(16+600)								
0+495	3+095	PC Box Girder	88,215	125,600	11,080	87,475	157,100	13,742
3+095	3+395	PC Box Girder	7,860	132,000	1,038	7,860	165,100	1,298
3+395	3+715	PC Box Girder	8,385	165,000	1,384	8,385	206,400	1,731
3+715	4+595	PC Box Girder	28,792	132,000	3,801	26,704	165,100	4,409
4+595	5+060	PC Box Girder	12,183	165,000	2,010	12,183	206,400	2,515
5+060	5+310	PC Box Girder	6,550	132,000	865	6,550	165,100	1,081
5+310	5+935	PC Box Girder	16,375	165,000	2,702	16,375	206,400	3,380
5+935	8+635	PC Box Girder	70,540	132,000	9,311	70,740	165,100	11,679
8+635	9+195	PC Box Girder	14,672	171,600	2,518	14,672	214,600	3,149
9+195	11+635	PC Box Girder	63,928	132,000	8,438	63,928	165,100	10,555
11+635	12+515	PC Box Girder	23,056	168,150	3,877	23,056	210,300	4,849
12+515	12+955	PC Box Girder	11,528	132,000	1,522	11,528	165,100	1,903
12+955	13+600	PC Box Girder	16,899	171,600	2,900	16,899	214,600	3,627
13+600	14+500	PC Box Girder	29,555	132,000	3,901	27,030	165,100	4,463
14+500	16+000	PC Box Girder	39,300	125,600	4,936	39,300	157,100	6,174
					60,281			**74,553**
Land Viaducts 16+000～18+170(16+600～18+170)								
16+000	16+600	PC Box Girder	20,960	87,900	1,842	15,720	157,100	2,470
16+600	16+800	PC Box Girder				5,555	109,900	610
16+800	18+170	PC Box Girder	33,976	87,900	2,986	34,130	109,900	3,751
					4,829			**6,831**
Land Viaducts 18+170～18+922								
18+170	18+404	PC Box Girder	18,650	49,500	923	5,800	61,900	359
18+404	18+444	**Steel girder**				1,000	195,000	195
18+444	18+922	PC Box girder				11,950	61,900	740
Road 18+922～ 20+092								
18+922	20+092	Toll Gate Plaza	58,400	5,000	292	59,566	6,300	375
Land Viaducts 20+092～21+715.78								
20+092	21+202	PC Box Girder	40,325	49,500	1,996	27,750	61,900	1,718
21+202	21+242	**Steel girder**				1,000	195,000	195
21+242	21+313.15	PC Box Girder				1,779	61,900	110
21+313.15	21+353.15	**Steel girder**				1,000	195,000	195
21+353.15	21+715.78	PC Box girder				9,071	61,900	561
			610,149		**3,211**			**4,448**

Source: Final FS Report for MTHL, 2012, MMRDA and JICA Study Team

Table 3.5.3 Review Results of Cost Estimation in Feasibility Study Report, 2012 2/2

Section	Final FS Report for MTHL, 2012			Reviewed FS Report		
	Area (m^2)	**Unit Rate** (Rs/m^2)	**Cost** (INR・Mil)	**Area** (m^2)	**Unit Rate** (Rs/m^2)	**Cost** (INR・Mil)
INTERCHANGE WITH COASTAL ROAD AT SHIVAJI NAGAR						
Viaducts	26,668	49,500	1,320	26,668	61,900	1,651
Approaches with ground improvement	10,525	11,500	121	10,525	14,400	152
At grade road and junctions	27,075	5,000	135	27,075	6,300	171
Sub Total Interchange with Coastal Road			**1,576**			**1,973**
INTERCHANGE WITH SH54						
Viaducts	7,091	49,500	351	7,091	61,900	439
Approaches with ground improvement	7,943	9,500	75	7,943	11,900	95
Sub Total with SH54			**426**			**533**
INTERCHANGE WITH NH4B AT CHIRLE						
Viaducts	22,719	49,500	1,125	22,719	61,900	1,406
Approaches with ground improvement	9,377	9,500	89	9,377	11,900	112
At grade road and junctions	10,527	5,000	53	10,527	6,300	66
Sub Total NH4B Interchange			**1,266**			**1,584**
MISCELLANEOUS						
Landscaping		Sum	65		Sum	81
Site Clearance		Sum	80		Sum	100
Drainage and Protection Works		Sum	10		Sum	13
Toll Plaza Building		Sum	145		Sum	181
Toll Plaza System		Sum	197		Sum	246
ROB's and other structures		Sum	20		Sum	25
Administration Building		Sum	45		Sum	56
Office for MMRDA + IE		Sum	21		Sum	26
Rescue Centres		Sum	20		Sum	25
EMP, DMP, ITS		Sum	790		Sum	988
Traffic Safety and Road Furniture		Sum	110		Sum	138
Electrical Works		Sum	305		Sum	381
Vehicles		Sum	33		Sum	41
Sub Total Miscellaneous			**1,841**			**2,301**
GRAND TOTAL	823,174		**76,969**	818,168		**95,788**

Source: Final FS Report for MTHL, 2012, MMRDA and JICA Study Team

Reflecting the review results mentioned above, the construction costs for MTHL at the 2012 prices were estimated to be NR 95,788 Million instead of INR 76,969 Million estimated in the Final Feasibility Study 2012. Note that the inflation rates are quoted from IMF statistics to calculate the price escalation coefficient for each year and that the unit price for steel bridges is applied by the JICA Study team based on the current Indian practices. Table 3.5.4 shows the results of the coefficients of price escalation based on the IMF figures, which are much higher, approximately 10% per year, than the assumption in the Final Feasibility Study 2012, and resulted in a price escalation ratio of 1.6 from 2007 to 2012.

Table 3.5.4 Inflation Rate (IMF)

Year	Inflation Rate in India			
	Final FS Report for MTHL, 2012		Reviewed FS Report	
2007	-		-	
2008	5.000	1.05	9.193	1.09193
2009	5.000	1.05	10.604	1.10604
2010	5.000	1.05	9.534	1.09534
2011	5.000	1.05	9.443	1.09443
2012	5.000	1.05	10.249	1.10249
Total		**1.276**		**1.596**

Source: Study Team based on IMF data

Table 3.5.5 shows the revised unit costs for each work item as a result of the review of the Final Feasibility Study 2012.

Table 3.5.5 Adjusted Unit Price (Values as of 2012)

Item	Previous Study Unit Cost (2012)	Previous Study Estimaded Inflation Rate	Unit Cost (2007)	IMF Inflation Rate	Reviewed Unit Cost (2012)
50m span marine viaduct on pile caps	132,000	1.276	103,448	1.596	**165,100**
50m span marine viaduct on pile bent	125,600	1.276	98,433	1.596	**157,100**
3x150m span viaduct across pipelines	165,000	1.276	129,310	1.596	**206,400**
2x180m span Thane Creek Bridge	171,600	1.276	134,483	1.596	**214,600**
180m span bridge across ONGC and BPCL Pipelines	168,150	1.276	131,779	1.596	**210,300**
50m span mangrove viaduct without utility trough	87,900	1.276	68,887	1.596	**109,900**
Viaducts	52,000	1.276	40,752	1.596	**65,000**
Main line land viaducts	49,500	1.276	38,793	1.596	**61,900**
Approaches with ground improvement	11,500	1.276	9,013	1.596	**14,400**
Approaches	9,500	1.276	7,445	1.596	**11,900**
At grade road and junctions	5,000	1.276	3,918	1.596	**6,300**
Landscaping	65	1.276	51	1.596	**81**
Site Clearance	80	1.276	63	1.596	**100**
Drainage and Protection Works	10	1.276	8	1.596	**13**
Toll Plaza Building	145	1.276	114	1.596	**181**
Toll Plaza System	197	1.276	154	1.596	**246**
ROB's and other structures	20	1.276	16	1.596	**25**
Administration Building	45	1.276	35	1.596	**56**
Office for MMRDA + IE	21	1.276	16	1.596	**26**
Rescue Centres	20	1.276	16	1.596	**25**
EMP, DMP, ITS	790	1.276	619	1.596	**988**
Traffic Safety and Road Furniture	110	1.276	86	1.596	**138**
Electrical Works	305	1.276	239	1.596	**381**
Vehicles	33	1.276	26	1.596	**41**

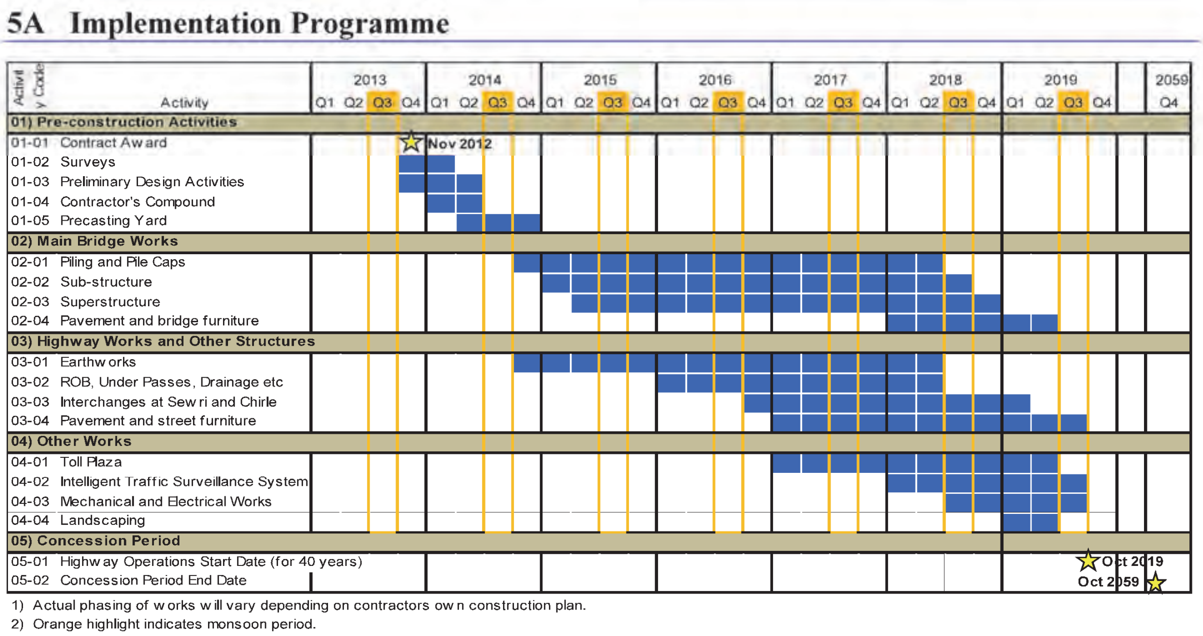
Source: JICA Study Team

3.5.2 Review of Construction Schedule

(1) General

The Final Feasibility Study 2012 estimated an implementation schedule of six years to complete the project as shown in Table 3.5.6, including the preparation period, survey, design and construction in a BOT scheme. In principle, the proposed schedule can be achievable if the contractor mobilizes sufficient working teams to the site.

Table 3.5.6 Construction Schedule in Previous Study



Source: Final FS Report for MTHL, 2012, MMRDA

The approximate quantities for the major works are shown below:

- Superstructure: Total Length = 21.7 km, Total width = 26.2 m
- Bridge Area: 550,000 m^2
- Foundations: φ1,200=1016 piles, φ1,500=1,604 piles, φ2,400=360 piles, Total=2,980 piles
- Substructure: 403 units
- Temporary jetty: 4.6 km

The construction period for the foundation, substructure and superstructure works are estimated to be three years and nine months, and there is a difference of three months between the commencement of each activity. However, in the area where temporary jetties are required for the execution of pile foundations, the schedule is very tight.

(2) Each Work Item

The following are brief descriptions of the major work items including the necessary team numbers and the construction period.

Temporary Jetty

The construction of a 4.6 km long temporary jetty shall be one of the critical paths for the entire work because typical solutions such as embankment construction or floating bridges cannot be applied due to the sensitive environmental area of the Serwi mudflat section.

During the high tide period, only barges carrying a crawler crane and other equipment would be able to access the area where it may be difficult or even impossible for the tugboats to enter. Therefore, the construction of the temporary jetty should progress from both ends.

Regarding the construction, it should be possible to complete the temporary jetty according to the proposed schedule if a double shift system working on both ends (4 working teams) is adopted.

Foundations

There are three different diameters in the bored pile works, mainly φ1,200 and φ1,500 diameter and approximated 25 m length. To install 2980 piles, considering a construction speed of 0.6 piles per day, 4 working teams will be required.

Substructure

The type of substructure is divided into 2 types in the marine section: a pile bent type and pile cap solution. Both alternatives have bored piles using a steel pipe as temporary guide pipe. The type of substructure on land has a typical solution (pile, pile cap, column). There are 403 substructures to be executed, considering an average 60 days to construct each substructure, 18 working teams (1.2 km/team) will be required.

Superstructure

Considering the span-by-span erection method, 26.2 m wide superstructure, it is estimated that approximately 1.5 m will be placed each day and that would require 1369 days (3¾ years) for completing the total erection, 11 working teams (2.0 km/year) will be required.

For the navigation channel and pipelines where the balanced cantilever method is required, the construction period is almost 3 times as long (0.5 m/day).

(3) Conclusion in the Review

There is a high possibility that construction of the Sewri mudflat section and long span sections in the marine portion shall be regarded as the critical path of the MTHL project.

However, if the necessary number of working teams is mobilized appropriately, it is possible to achieve the completion of the project in 6 years.

3.6 Economic Analysis

This Section reviews the economic and financial analyses for the project done by previous studies, and mainly focuses on the "Feasibility Study Report, 2012" as mentioned in the above section.

As a matter of course, the results of the economic and financial analyses would be different depending on the chosen assumptions. So this section reviews what assumptions are applied, and how outcomes are evaluated.

3.6.1 Financial analysis

(1) Assumptions

1) Initial investment cost

Initial investment cost in the Feasibility Study Report, 2012 is assumed as the base amount, which was 77,040 million INR. As stated in the above section, while the cost estimation of the Feasibility Study Report, 2012 is appropriate in terms of quantities, the ratio of price escalation was set at low levels, and therefore it could be said that the assumption of the initial investment cost is too low.

Table 3.6.1 Initial investment cost of Final F/S Report, 2012 and review in this study

Unit: INR million

Final F/S Report, 2012	This study
77,040	152,045

2) O&M cost

It is assumed that O&M cost in the Feasibility Study Report, 2012 is one percent of the total project cost, which amounts 1,010 million INR at the year of commercial operation days (COD). And it is annually escalated by 5%. It is difficult to clearly judge the appropriateness of the assumption of O&M cost, because initial investment cost as the basis of the O&M cost was set at low levels and there are no clear explanations of why one percent of the total project cost was chosen.

3) Traffic

Traffic volume in the Feasibility Study Report, 2012 is assumed as shown in the table below. Traffic volume in 2017 as the year of COD is approximately 45,000 per day.

Table 3.6.2 Traffic (Feasibility Study Report, 2012)

	Car/Taxi	LCV	Bus	HCV	MAV	Total
2017	29,725	6,325	2,325	5,225	1,375	44,975
2021	36,250	9,050	2,700	7,550	1,975	57,525
2031	53,550	15,300	3,575	12,800	3,325	88,550

This study carried out traffic demand forecasts for three cases (Case 1, 2, 3), traffic in Case 2 was worked out based on a similar toll rate setting to that used in the Feasibility Study Report, 2012. As shown in the table below, the traffic forecast has been calculated for two separate sections before/after the Shivaji Nagar interchange.

Table 3.6.3 Traffic (This Study)

Year	Sewri IC - Shivaji Nagar IC						
	Car	Taxi	LCV	Bus	HCV	MAV	Total
2022	24,129	2,643	1,460	881	1,016	1,026	31,155
2032	66,371	14,057	2,746	1,248	2,175	2,016	88,612
2042	94,143	20,171	3,714	1,248	2,690	3,069	125,035

Year	Shivaji Nagar IC - Chirle IC						
	Car	Taxi	LCV	Bus	HCV	MAV	Total
2022	4,886	114	460	881	349	90	6,780
2032	21,271	429	857	1,248	651	206	24,662
2042	43,286	2,286	1,191	1,248	746	376	49,132

Traffic at the opening year (year 2022) that was estimated in the Feasibility Study Report, 2012 is larger than what was estimated in this study, but the growth rate after year 2032 in this study is much larger than in the previous study.

4) Toll rates

Toll rates in the Feasibility Study Report, 2012 were set based on a “willingness to pay survey in 2011”, and it has been escalated to COD (2016-2017). Annual revision of toll rates was done utilizing the NHAI formula.

Table 3.6.4 Toll rates (Feasibility Study Report, 2012)

	2017
Car/Taxi	175
LCV	265
Bus	525
HCV	525
MAV	790

Case 2 in this study, the base case of toll rates is set based on the “willingness to pay survey in 2011”, and revision of toll rate also follows the NHAI formula. Therefore, while Case 2 in this study is a slightly higher rate than that in the Feasibility Study Report, 2012, basically there are no significant differences between the Feasibility Study Report, 2012 and this study.

Table 3.6.5 Toll rates (This Study)

Mode	Sew ri IC - Shivaji Nagar IC	Shivaji Nagar IC - Chirle IC
	km	km
	16.5	5
Car	180.00	55
Bus	420.00	130
LCV	240.00	70
HCV	420.00	130
MAV	600.00	180

(2) The results of the financial analysis

In the Feasibility Study Report, 2012, the Financial Internal Rate of Return (Project IRR and Equity IRR) which is calculated based on the above assumptions is shown in Table 3.6.6. The results showed that unless a Viability Gap Fund (VGF) is applied, the project does not become financially feasible.

Table 3.6.6 Financial Internal Rate of Return (Feasibility Study Report, 2012)

	Without VGF and additional revenue	With 40% VGF (without additional revenue)	With 40% VGF and additional revenue)
Project IRR	12.90%	15.60%	15.90%
Equity IRR	12.90%	16.80%	17.20%

Financial IRR in the Feasibility Study Report, 2012 was estimated to be a comparatively high ratio, although the project is a large scale toll road/bridge project, which generally it is regarded as being difficult to get an acceptable return on investment. The reasons are that; the initial investment cost set lower levels, and traffic volumes are estimated comparatively at optimistic side.

3.6.2 Economic Analysis

(1) Assumptions

1) Economic Cost

In the Feasibility Study Report, 2012, the economic cost is worked out by multiplying the conversion rate of 0.90 and the initial investment cost and O&M cost which are applied to the above financial analysis. Appropriateness for the initial investment cost and O&M cost as the basis of the economic cost is evaluated in the above section 3.6.1, 1) and 2).

2) Items of Economic Benefit

To work out economic benefit, the following items are applied. As a),b), and c) are typical benefit items on road projects, this study also use a) and b). c)~f) could be also regarded as benefit items for the project, but its appropriateness cannot be evaluated since the breakdown of benefit calculation is not stated in the report.

a) Direct saving of time and costs owing to shorter route of MTHL

b) Saving of time and costs owing to decongestion effect on alternate routes

c) Reduction in accidents on the alternate routes

d) Saving on the Capex and Opex on the alternate routes

e) Reduction in pollution (decongestion on alternate routes)

f) Savings in foreign exchange owing to reduced consumption of imported fuel:

(2) The results of the economic analysis

In the Feasibility Study Report, 2012, the Economic IRR based on the above assumptions is 14%. This exceeds the evaluation standard of 12% on infrastructure projects in India, which indicates that implementation of the project is relevant from the viewpoints of the national economy as well as the regional economy.

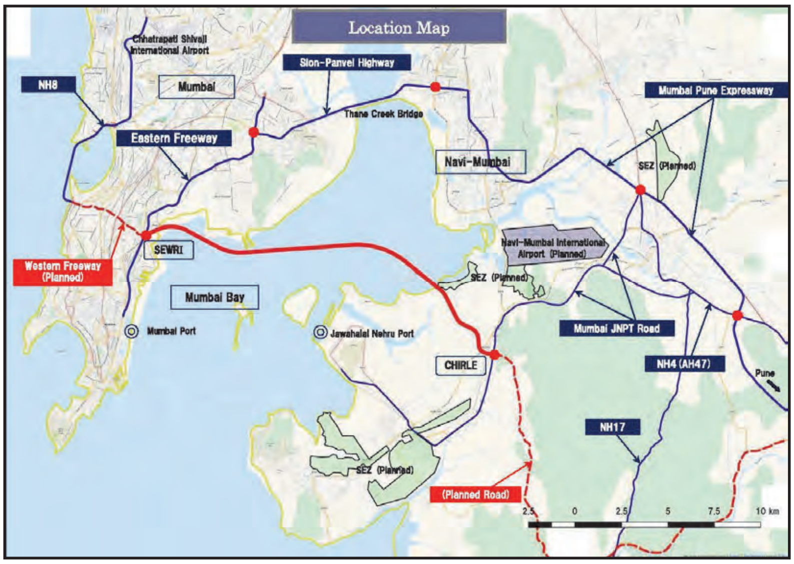
4. TRANSPORT DEMAND FORECAST

4.1 Overview

The preparation of the Transport Demand Forecast in a large complex metropolitan area such as the MMR is fraught with difficulty due to the time constraint of the project. The Study Team, with the assistance of their local consultant, adopted for the forecasting procedure via an existing transport model[7] developed by the local consultant hereafter simply referred to the transport model. The genesis of any recent transport demand forecast in the MMR is the transport demand model and procedures prepared for the Comprehensive Transport Study, the CTS model. This forms the basis of the demand analysis for this study that will lead to the preparation of the traffic forecasts for the MTHL. A locality map showing MTHL and associated highways is presented in Figure 4.1.1.

This chapter of the report includes a further five sections. The next section deals with the derivation of the transport model in relation to CTS whilst the subsequent section discusses the transport model structure which in essence is directly related to CTS. The section prior to the penultimate section brings to the attention of the reader the model validation in 2015. In this section, there is included a brief summary of the demand count data available for the model validation in 2015. The penultimate section of this chapter presents the key assumptions for the future such as transport infrastructure and socio-economic projections. The last section of this chapter extends the MTHL forecasts to the 2042 time horizon starting with the opening in 2022 followed by the mid-year time horizon of 2032.

[7] The adoption of this model which had been used in earlier analyses of MTHL was also recommended by MMRDA.



Source: JICA study team

Figure 4.1.1 Locality Map

4.2 Derivative of CTS

The transport model used in this demand analysis is that developed by the local consultant appointed by the JICA study team. The MTHL model is implemented using the Cube Voyager[8] software. This software is used throughout the world and is widely used for this type of application.

The MTHL model was originally developed and used for the analysis of Line 2 Metro for Mumbai and subsequently for a major toll road in Mumbai. The model draws on the rigorous mathematical procedures of the CTS model. The CTS, a large multi-year model development study produced a number of reports and working papers which provides useful references in the development of the transport demand model.

4.2.1 CTS

The CTS transport model, the forerunner of the MTHL transport model used in the demand forecast, is a traditional four step model with separate consideration for external traffic and goods vehicle modelling. The structural basis of CTS is that it uses 6 trip purposes for person travel, namely:

- Home Based Work Office (HBWF);
- Home Based Work Industry (HBWI);
- Home Based Work Other (HBWO);
- Home Based Education (HBE);

[8] For further details on the software, see http://www.citilabs.com.

- Home Based Other (HBO); and
- Non Home Based (NHB).

The CTS model uses the following vehicle types, namely:

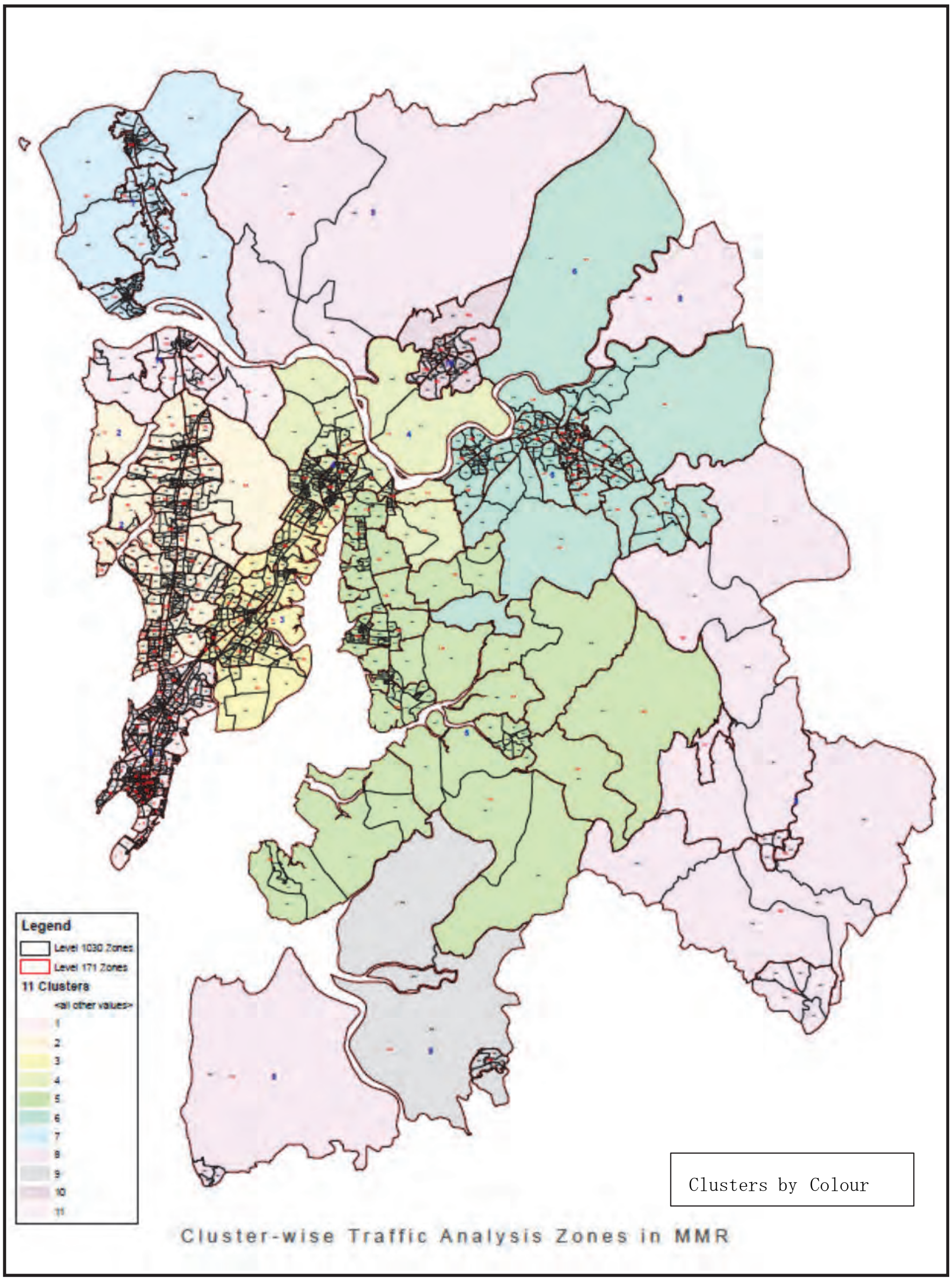
- Cars, motorcycle, and IPTs (a composite of Taxi and Auto Rickshaw)[9] for private person travel;
- Bus and Rail for public transport person travel; and
- Goods Vehicles (which in turn are split into Light Commercial Vehicles (LCV), Heavy Commercial Vehicles (HCV) and Multi Axle Vehicles (MAV))

4.2.2 Zone System

The transport model adopted for MTHL, as stated earlier, is a derivative of CTS and therefore, much of the discussion that follows in the next section with respect to the transport model is actually in reference to CTS. CTS however divided the MMR into 1030 internal traffic analysis zones and 11 clusters for the purpose of preparation of summaries of data sets. The detail zoning system of CTS is depicted in Figure 4.2.1 as well as the 11 summary zone groupings or clusters as defined in the terminology of CTS.

The significant difference between the transport structures of the model adopted for MTHL available from the local consultant is that the local consultant combined these 1030 traffic zones into 188 zones whilst maintaining the 11 summary clusters as seen in Figure 4.2.2. The transport model, in addition, has 9 cordon crossing points or external stations bringing the total number of traffic zones to 197.

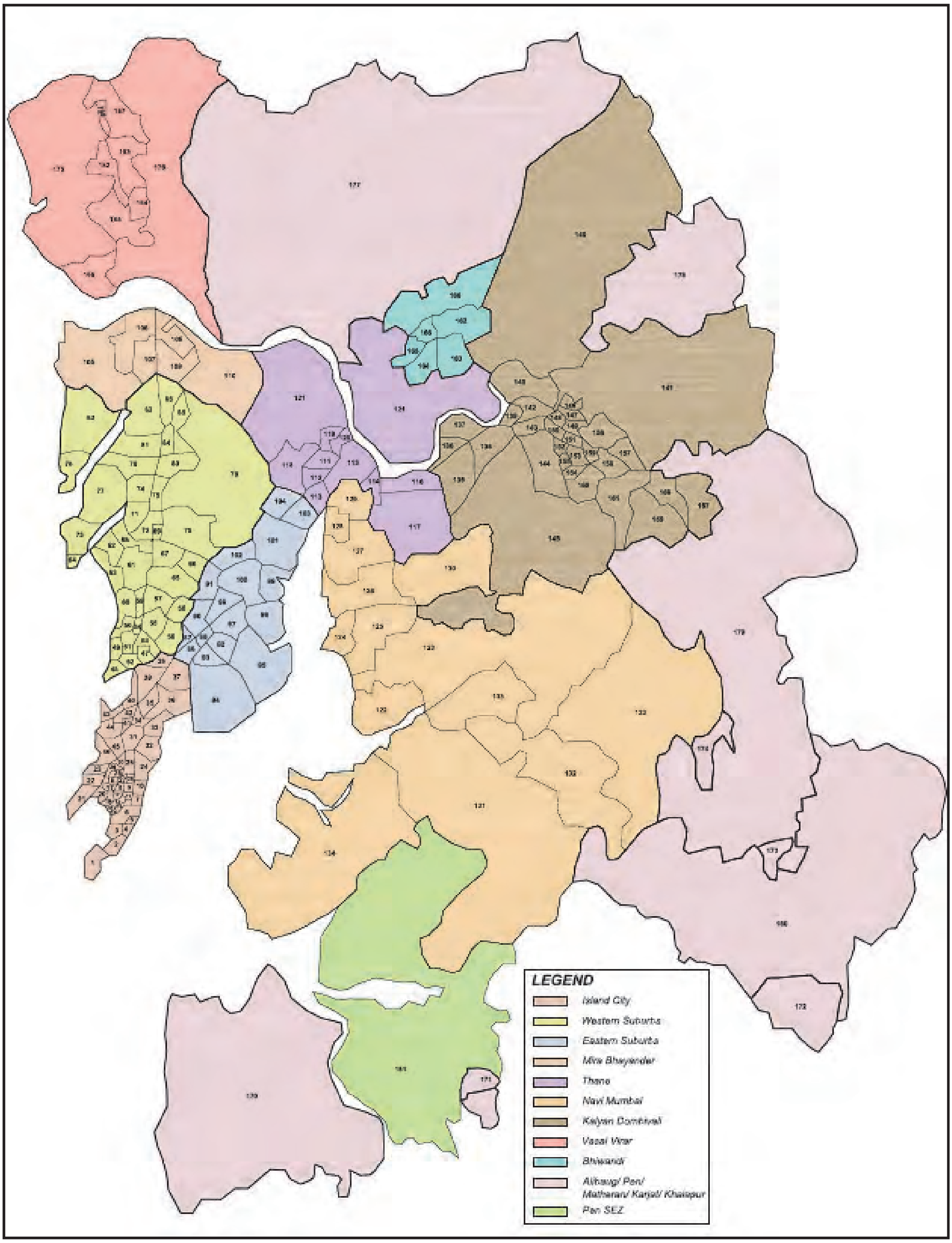
[9] For MTHL prepared by the JICA study team, taxis and auto rickshaw are separated for the economic analysis.



Source: Comprehensive Transportation Study for Mumbai Metropolitan Region (CTS) 2008

Figure 4.2.1 Original Zoning System of CTS Highlighting the 11 Cluster[10] Boundaries

[10] The names of the clusters are given in the section that presents the future assumptions.



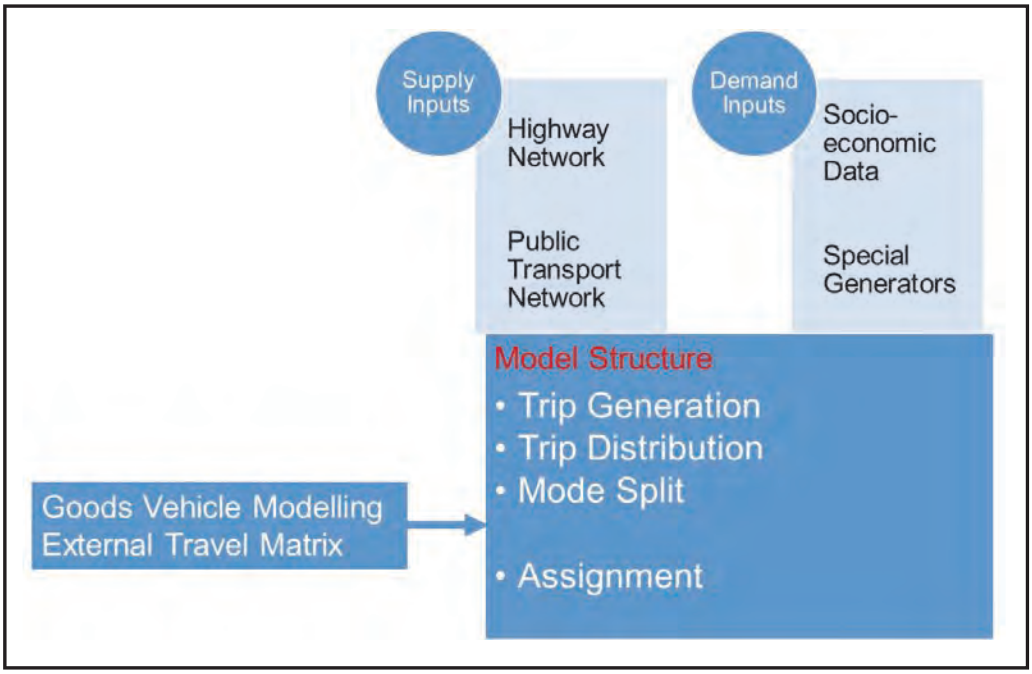
Source: JICA study team

Figure 4.2.2 Zoning System of the Transport Model

4.3 The Model Overview

4.3.1 Preparation of Inputs

The key structure of any transport model is the supply side for the infrastructure and on the demand side the socio-economic data as seen in Figure 4.3.1. In this section the basic inputs are presented on the supply side namely the network structure, which will also include the public transit fare structure[11]. The socio-economic inputs are discussed in later sections in respect to the future socio-economic forecasts which are the key inputs in the definition of demand.



Source: JICA Study Team

Figure 4.3.1 Model Analysis Structure

For the current study the following key attributes were used for the road network:

- Distance;
- Link class;
- Free Flow speed; and
- Capacity

The 16 road link classifications used in CTS (see Table 4.3.1 below) were reviewed and considered appropriate for use in this model. However, the link capacities used in CTS do not fully reflect the existing operational capacities of the road insofar as they do not allow for all the effects of side friction (pedestrian activities, hawkers etc.) plus the very bad condition

[11] Unless otherwise stated in this report chapter all costs are of the 2015 Rupee value.

of the existing roads and the subsequent impact these issues have on capacity and operating travel speeds. They are, therefore, somewhat theoretical. Consequently the study team in consultation with the local consultant have adjusted these capacities to be more compliant with the work that has been recently carried out on speed/flow relationships for roads in Mumbai region.

The speed flow curves are based on the link class code. Link class definitions and speed flow curves are shown in Table 4.3.1 and Figure 4.3.2, respectively. The model base year network is given in Figure 4.3.3. The major roads are shown in red in this figure of the base network. Besides travel time and travel distance being used in the network for the later generation of generalized cost, the many existing tolls are also included in the network for a similar reason and are documented in Table 4.3.2.

In the case of a public transport network, individual lines belong to one of five modes namely:

- Suburban rail;
- Ordinary bus;
- Air-conditioned bus;
- Metro rail; and
- Monorail.

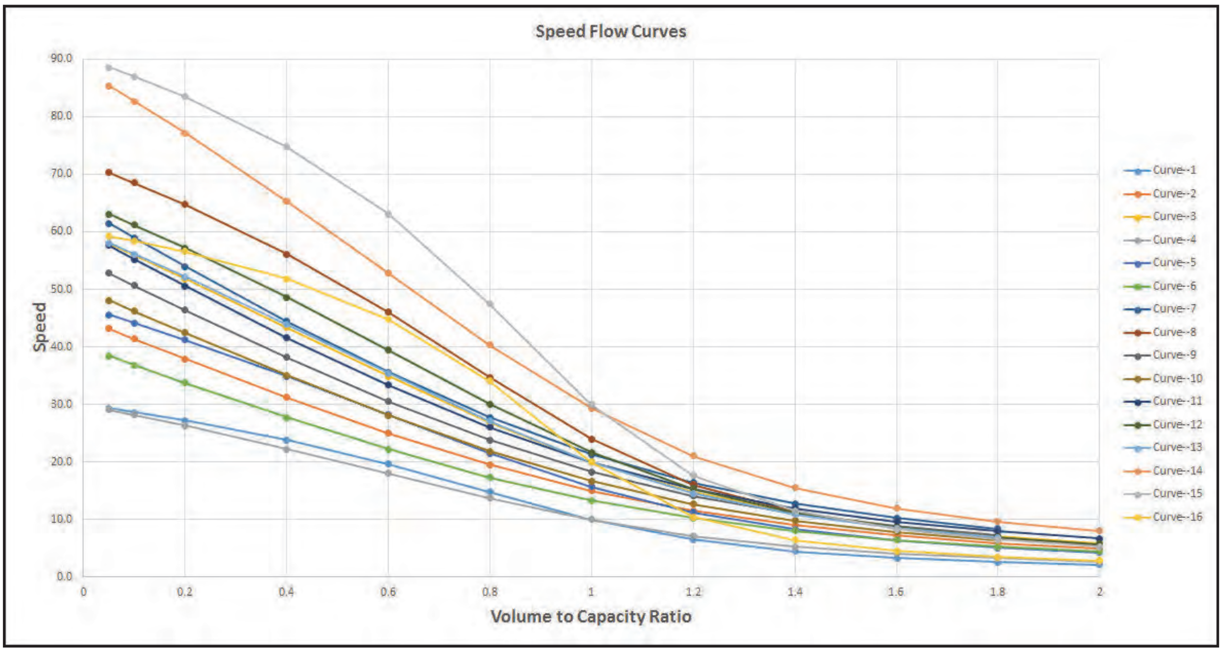
The transit fare structure is shown in Figure 4.3.4. It is noted in this figure that the air conditioned bus fare is higher in comparison to the non-air conditioned bus fare. Out of the 4,700 bus fleet of BEST (The Bombay Electric Supply & Transport), only about 6% are Air Conditioned Buses. There are about 365 routes of BEST of which there are approximately 20 Air Conditioned Bus Routes. At present the Air Conditioned routes are thus limited in scope in Mumbai. It is uncertain for how much longer BEST will even operate these 20 routes.

Table 4.3.1 Link Class Definitions

No	Lane Configuration	Divided/ Undivided	Operation	Capacity(1)
1	2/3 Lane	Undivided	One Way	1,050
2	2/3 Lane	Undivided	Two Way	875
3	2 Lane	Undivided	One Way	1,400
4	4 Lane (effective 2 lane)	Divided	Two Way	665
5	4 Lane	Undivided	One Way	805
6	4 Lane	Divided	Two Way	1,050
7	6 Lane	Divided	Two Way	1,050
8	6 Lane (Flyover)	Divided	Two Way	1,600
9	8 Lane	Divided	Two Way	1,400
10	10 Lane	Divided	Two Way	1,600
11	10 Lane (Service Road)	Divided	Two Way	1,600
12	2/3 Lane (regional)	Undivided	Two Way	770
13	4 Lane NH (regional)	Divided	Two Way	1,120
14	4/6 Lane (Bypass-Regional)	Divided	Two Way	1,280
15	Expressway (regional)	Divided	Two Way	1,280
16	Long Bridge (regional)	Divided	Two Way	2,000

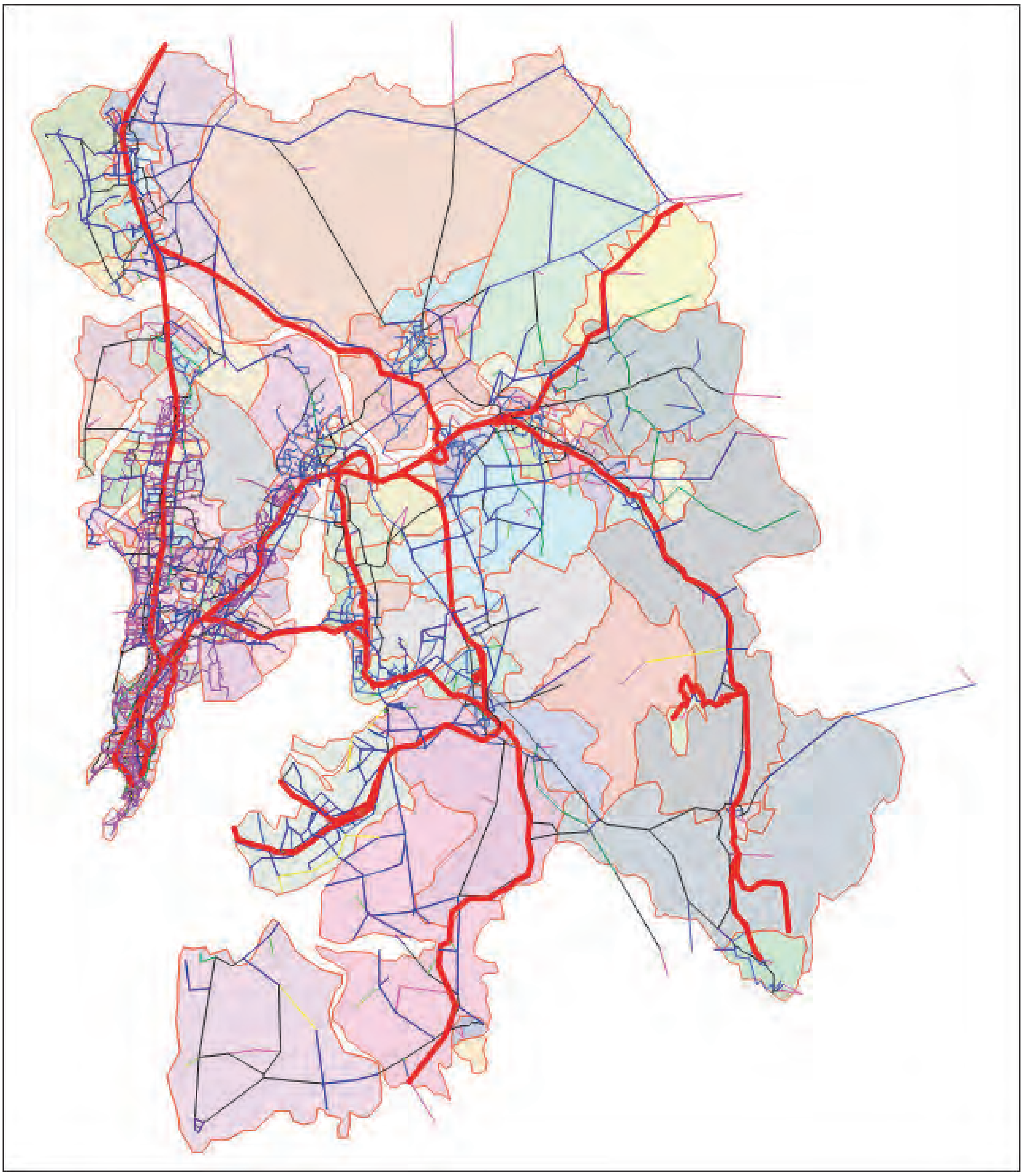
Note: (1) Capacity in PCUs per lane

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3.2 Speed Delay Curves



Source: JICA Study Team

Figure 4.3.3 Model Base Year Network

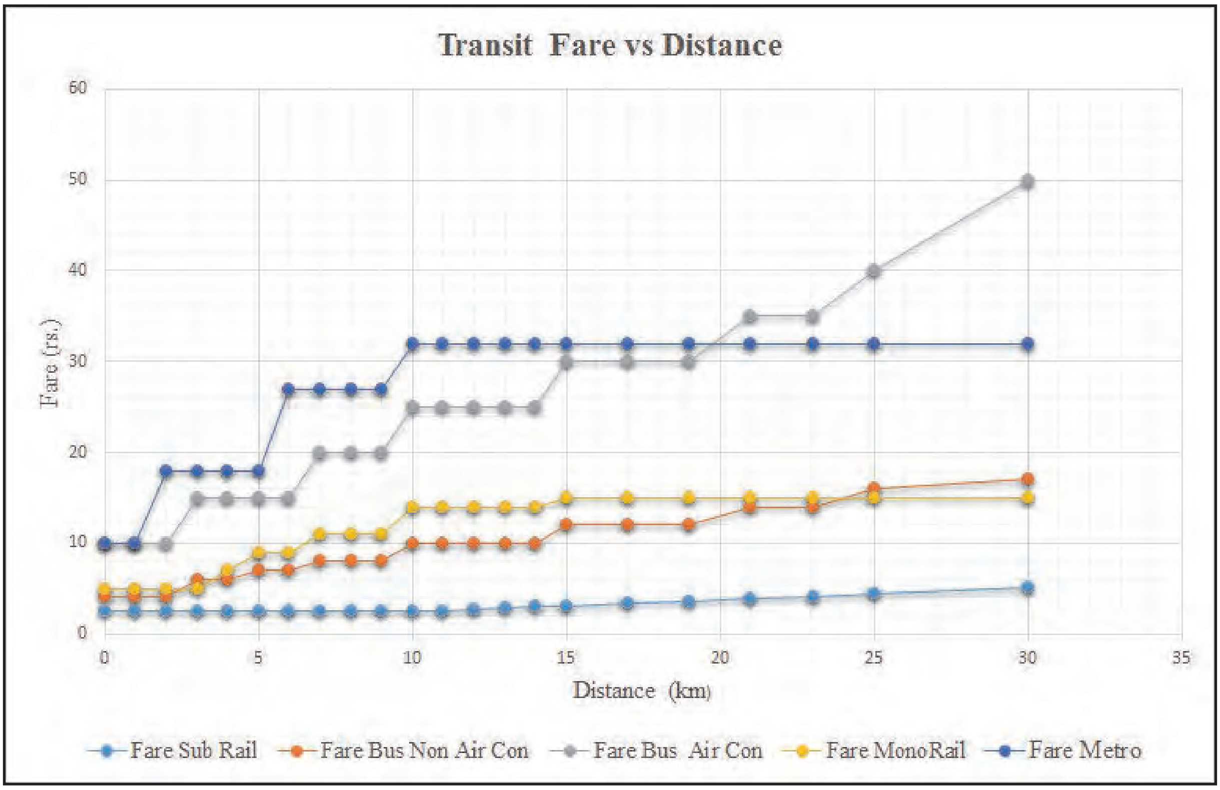
Table 4.3.2 Existing Vehicular Road Tolls by Vehicle Class (Rs.)[12]

Location	Car	LCV	SCV	MAV
BWSL	41	60	82	9999
Vashi (Thane Creek Bridge)	30	40	75	95
Airoli	30	40	75	95
Dahisar	30	40	75	95
Eastern Expressway (Mulund)	30	40	75	95
LBS Road (Mulund Check Naka)	30	40	75	95
NH 3 near Mumbai Entry	30	40	75	95
Kasheli Toll (Old Agra Road)	25	40	75	95
NH 4 (Shil Phata)	26	35	65	85
NH 4 (Lonavala)	15	20	30	45
Mumbai Pune Expressway (Khopoli)	165	255	354	1,116
NH 17 (Kharpada)	10	30	30	50
Mumbai Port Trust Road	30	9999	9999	9999
SH 54 Jasai	25	45	85	165
NH 4B Chirle	25	45	85	165
NH 4B Karanjada	25	45	85	165
Rasayani- Kon Toll	13	20	30	45
Arjunali Toll Plaza, Padgha (NH-3)	80	105	200	255
Mumbra Bypass Toll	25	40	75	130
Anjur-Chinchoti Phata Road	25	40	75	130
Kalyan-Shil Phata Road	25	40	75	130
Alibaug Toll	10	30	50	50
Aarey Colony Road	15	20	9999	9999

Note: (1) The figure 9999 is coded for when there is no appropriate toll.

Source: JICA Study Team

[12] It is stated government policy to remove the toll on the Thane Creek bridge at Vashi for small vehicles and that is reflected in the future demand analysis.



Source: JICA Study Team

Figure 4.3.4 Transit Fare Structure

4.3.2 Model Structure

The structure of the transport model[13], as stated earlier, is in effect a traditional four step model namely:

- Trip Generation;
- Trip Distribution;
- Mode Split; and
- Traffic Assignment[14].

Trip Generation[15] is a two-step process, namely:

- First step is to apply the CTS equations to the land use data; this is straightforward but the main drawback identified is that this does not take into account vehicle availability/income;
- The second step therefore, applies a system that splits households into low, medium and high income groups[16] based on the average household income for the zone. This

13 Only limited details of the model equations are supplied as these are documented in detail in the various CTS reports.

14 Prior to the assignment, additional traffic flows are included from special generators, commercial vehicles and external traffic.

15 The CTS report in 2005 reported that there were 1.65 trips per person per day in Mumbai with sixty per cent of those trips using the walk mode.

income segmentation as specified by CTS is based on Income Index assessed based on property rates published regularly by the real estate newspaper, Accommodation Times.

The actual generation rates are also dependent on the region within MMR and these are also applied across all three income levels namely, low, medium and high. Once the level of household income is established, it is then possible to allocate the households within a traffic zone into three vehicle ownership categories of No vehicle household, household with motorcycle and household with car. Then one applies the relevant trip rates at this stage. The equations associated with trip production are for the six purposes and are a function of the zonal characteristics of population, employment, resident workers, resident students and income. The trip attractions are a function of population and employment. The trip production equations for each trip purpose are defined below with the coefficients presented in Table 4.3.3. The equations are:

- HBWF = RWF_HBWF * resident workers
- HBWI = RW_HBWI * resident workers
- HBWO = RW_HBWO * resident workers
- HBE = RS_HBE * resident students + RS_HHI * Average zonal income
- HBO = POP_HBI * Population
- NHB = NHB_EBZ * Total employment

Table 4.3.3 Trip Production Coefficients

Region	RWF_HBWF	RW_HBWI	RW_HBWO	RS_HBE	RS_HHI	POP_HBI	NHB_EBZ
BCM	0.794	0.106	0.163	0.144	0.14	0.014	0.002
Thane	0.510	0.080	0.100	0.106	0.186	0.015	0.002
Navi Mumbai	0.827	0.083	0.159	0.890	0.423	0.014	0.001
Kalyan, Bhivandi	0.554	0.078	0.080	0.114	0.204	0.011	0.001
Mira Bhayander, Vasai-Virar	0.579	0.073	0.107	0.134	0.031	0.009	0.001
Rest of MMR	0.186	0.032	0.037	0.053	0.024	0.016	0.004

Source: JICA Study Team

Trip attraction equations for each purpose are defined below with coefficients defined in Table 4.3.4. The equations are:

- HBWF = HBWF_OJ * Employment office
- HBWI = HBWI_IJ * Employment industrial

[16] The medium income range is from 9,400 to 37,000 Rs for household income with an average of 22,000 Rs per month in 2012 value Rs. The medium and high income ranges are either side of the medium range with an average monthly income of 7,000 and 64,000 for the low and high incomes respectively. Also, each average was calculated by the arithmetical mean method.

- HBWO = HBWO_OTJ * Employment other
- HBE = HBE_OTJ * Employment other
- HBO = HBO_POP * population + HBO_TJ * employment total
- NHB =NHB_TJ * employment total

The key socio-economic parameters by region are presented in later sections of this chapter.

Table 4.3.4 Trip Attraction Coefficients

Region	HBWF_OJ	HBWI_IJ	HBWO_OTJ	HBE_OTJ	HBO_POP	HBO_TJ	NHB_TJ
BCM	0.747	0.516	0.302	0.207	0.005	0.019	0.002
Thane	0.798	0.501	0.252	0.276	-0.0003	0.058	0.005
Navi Mumbai	0.621	0.556	0.272	0.204	0.007	0.012	0.001
Kalyan, Bhivandi	0.76	0.183	0.182	0.318	0.006	0.023	0.001
Mira Bhayander, Vasai-Virar	0.725	0.504	0.236	0.193	0.001	0.046	0.001
Rest of MMR	0.582	0.096	0.154	0.19	0.003	0.07	0.005

Source: JICA Study Team

The Trip Distribution stage of the model, and later stages, requires generalized costs, and these need to be mode specific as well as specific to the income categories low, medium and high. The latter is handled by applying the income category specific value of time and the monetary components in the generalized cost formula. The mode specific generalized cost formulas are conventional with all the time and cost components of the journey being summed using appropriate weights. However in Mumbai, only travel time is included in the distribution equation.

From earlier Mumbai works the local consultant has available a table of friction factors for each of the six trip purposes. These factors will also be adopted for the MTHL analysis.

The friction factors are mostly derived from the Gamma family of curves and the formulas for deriving the friction factors are commonly used and their details are as follows where T stands for time, and ALPHA is equal to 0.001:

- FFHWF= exp(-1/HWF*T)*T^(-1/HWF) where HWF = 34.9;
- FFHWI = exp(-1/HWI*T)*T^(-1/HWI) where HWI = 28.3;
- FFHWO= exp(-1/HWO*T)*T^(-1/HWO) where HWO = 26.8;
- FFHBE = exp(-1/HBE*T)*T^ALPHA where HBE = 20.48;
- FFHBO = exp((-1/HBO) * ln(T)^2)*T^ALPHA where HBO = 3.42; and
- FFNHB = exp((-1/NHB) * ln(T)^2)*T^ALPHA where NHB = 2.9;

The original CTS report gives details about **Mode Split.** The report provides mode shares for the MMR area, it also contains details on average trip lengths by overall public and private mode. The overall public modal share for the MMR is 74% with an average trip length of 15.7 km with a combined private and public trip length of 14.4 km.

The model has three different principal private modes, CAR, MC and IPT, the latter being a composite mode of taxi and auto rickshaw. Income and vehicle availability help explain differences in trip rates. Mode split is therefore not only a matter of a split between private and public modes; it is also a matter of private mode usage as a function of household vehicle ownership. In the latter split it seems likely that trip distance is the determining factor with a bias towards using the mode corresponding to the household's vehicle ownership status.

Private mode costs are defined by private mode and income group and vehicle operating costs. It is also assumed that a proportion of private mode users are captive to their initial private mode. This effectively says that a proportion of CAR and MC users will in all circumstances use their private mode and will not consider using public transport. The values of time for the base year for car and non-car user are presented in Table 4.3.5.

Table 4.3.5 Value of Time[17] (Rs per hour)

Category	Income Group	Value
Non Car User	Low	13.5
Non Car User	Medium	42
Non Car User	High	123
Car User	Low	94
Car User	Medium	133
Car User	High	168
Taxi User	Not Applicable	50

Source: CTS and Local Consultant

Prior to the assignment, additional traffic is introduced into the travel mixture. Additional traffic is from three sources, namely, goods vehicles, external traffic and special generators. The goods vehicle or the commercial vehicle flow will likely have a significant impact on the traffic volume on MTHL (and consequently a major impact on MTHL revenue). However, since a large proportion of commercial traffic is accounted for both the external traffic and special generators, the conventional 4 stage model typically does not handle commercial vehicles very well, so another systematic approach has to be put in place to model commercial vehicle traffic in an appropriate way. A goods vehicle matrix[18] from CTS was available and it is this matrix, suitably factored, that is used to add to the matrices from the

[17] These cost values are in the units of 2012 Rs, the original year of the MTHL model calibration for the value of time.

[18] The two most important clusters were Navi Mumbai and the Island City with 27% and 14% of commercial vehicles, respectively.

external traffic and special generators to obtain the overall travel patterns. The special generator traffic is produced from such locations as airports or special generation zones. The level of development of such relevant locations to MTHL are presented in later sections.

The **Assignment of Persons and Vehicles** are the next steps, and it is necessary to check that both are producing the correct characteristics before the model can be considered validated. For Public transport, since there are few available cross check data and this forecast is now for the particular case of MTHL, this will be considered acceptable if the following criteria are matched for this MTHL model update, namely, the numbers of persons in mechanized transport crossing the Thane Creek Bridge and Airoli Bridge are matched. In this model update, there is not a significant set of statistics available for checking highway assignments other than the Thanee Creek and Island City Screen lines.

Within the model there are two separate highway assignment processes. The first assignment occurs as part of the standard 4 stage iterative process. This assignment is very conventional and the emphasis is on simplicity in order to keep the model run times low. The second assignment, the final assignment, occurs after the iterative 4 stage model process is concluded, and it is these results which are quoted, and used for the MHTL analysis. It is therefore only undertaken once and as such it can be made more detailed in order to gain maximum accuracy and detail. The details are shown in Figure 4.3.5. It is a Diversion Assignment where Tolled and un-tolled paths are considered for the Users of the highway system, including cars, goods vehicles and taxis. The cars are split into four income classes in order to better represent toll sensitivity.

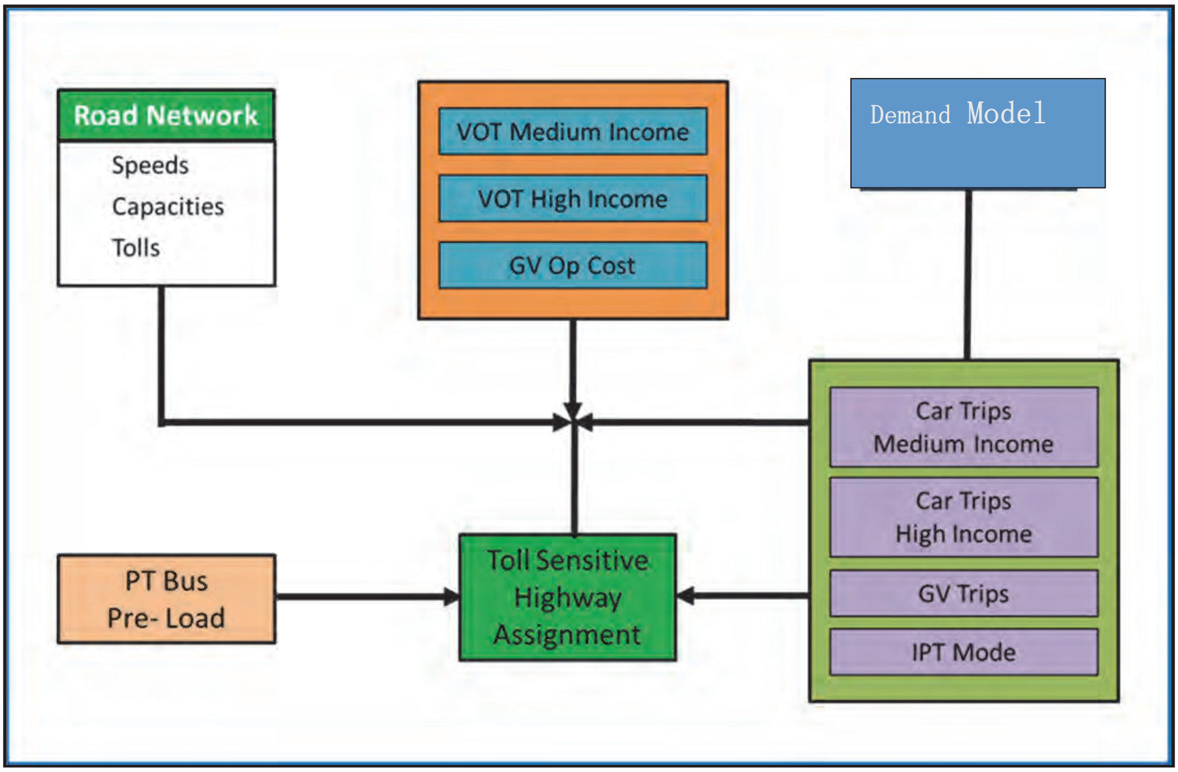
The first part of the vehicle assignment in the estimation of MTHL traffic is to build paths and collate the relevant costs. This is done separately for relevant traffic type and for each traffic type the best MTHL and non-MTHL path is built. The second step is to, for each traffic type, determine a MTHL diversion proportion, this is done using a conventional logit expression. The third step is then to derive a matrix of traffic for MTHL and non-MTHL options for each of the traffic types. The final step is then to assign those matrices to the paths built in the first step.

The **public transport assignment** allocates passenger matrix, which includes trips made by bus, suburban train and Intermediate Public Transport (IPT), and is assigned to the public transport network. The public transport assignment is done based on generalized time (GT) units of each mode. The stochastic user equilibrium algorithm will be utilized for the public transport assignment. Discomfort is taken care of by defining different multiple crowding curves for different PT modes. Every line in the public transport network will be allocated with its corresponding fare table and wait curves.

It should also be mentioned at this point that a capacity restraint procedure based on generalized cost is used in loading the assignment of the vehicle matrices as was briefly outlined earlier in this section. Tolls are, of course, also considered on major links as described in Table 4.3.2 for the base year. The VOC and other parameters of GC are based on the CTS values and other recent studies carried out by the local consultant working with the Study Team. The Generalized Cost formula used in the assignment is of the following form:

GC = VOT*TT + VOC*Distance + Toll

where,
GC = Generalized Cost (in Rs.)
VOT = Value of Time (in Rs./min)
VOC = Vehicle Operating Cost (in Rs./km)
TT = Travel time (in min)



Source: Local Consultant and JICA Study Team

Figure 4.3.5 Highway Assignment Procedure

Validation of the Model, as stated earlier, is undertaken after the completion of the traffic assignment. In this case, the validation is confined to the corridor of MTHL where the study team undertook travel characteristic counts.

4.4 Validation of 2015

After the initial assignment of the model with the updated network infrastructure and socio-economic data for the conditions of 2015, the initial model results did not correspond to the existing situation. It was thus necessary to confirm a procedure for final model validation that reflected the existing situation as noted from observed count data.

4.4.1 Existing Situation

The understanding of the existing traffic situation in the vicinity of the MTHL was achieved through a series of classified vehicle count surveys (CVCS), railway passenger count surveys (RPCS) and vehicle occupancy surveys at some 18 sites as described in Table 4.4.1 and as seen in Figure 4.4.1.

Table 4.4.1 Location of Traffic Count Sites

Site No	Survey Type	Survey Location	Duration
1	CVCS and Vehicle Occupancy Survey	NH-3 on Thane Creek	24 Hours
2		Kalwa Bridge	
3		Mulund-Airoli Bridge[19]	
4		Vashi Bridge (on Thane Creek)	
5		NH-4 near Taloja	
6		Sion-Panvel Highway (Taloja Creek Bridge)	
7		Amra Marg near Kille (On Panvel Creek)	
8		BPT Road on Eastern Freeway near Sewri Rly Stn	
9		Rafi Ahmed Kidwai Marg	
10		G D Ambekar Marg near Parel Village	
11		Dr Ambedkar Road near Parel	
12		N.M. Joshi Marg	
13		Senapati Bapat Marg	
14		Dr Annie Besant Road	
15		Khan Abdul Gaffar Khan Road	
16		NH-4B JNPT Road, Near Wawal Bus Stn	
17	RPCS	Thane Creek Railway Bridge	24 Hours
18		Vashi-Mankhurd Rail Sea Link	

Source: JICA Study Team

[19] The traffic count at this site was seen to be inconsistent with historical data and was replaced by historical counts.

Source: The JICA Study Team

Figure 4.4.1 Location of Traffic Surveys

4.4.2 Procedure of Validation

The key to the successful adoption of the transport model for this project is the adjustment of the transport model based on the validation result of the base year traffic forecasts against current classified vehicle count surveys and railway passenger count surveys. The adapted pcu factors by vehicle types were decided based on the advice of MMRDA and the adapted factors are shown in Table 4.4.2.

Table 4.4.2 PCU Factor by Vehicle Type

Vehicle Type	PCU	Vehicle Type	PCU
Two Wheeler	0.5	LCV (Light Commercial Vehicle)	1.5
Auto Rickshaw	0.75	2/3 Axle Truck	3.0
Car/Jeep/Taxi	1.0	MAV (Multi Axle Vehicle)	4.5
Mini Bus	1.5	Agricultural Tractor	1.5
Standard Bus	3.0	Animal Drawn Vehicle	6.0

Note: PCU factor for other vehicles was set as 4.5

Source: Mumbai Trans Harbour Link prepared by Arup et al, 2012 and Indian Roads Congress Code IRC-106-1990 “Guidelines for Capacity of Urban Roads”.

4.4.3 Validation Comparison

A comparison of traffic counts across three screen lines is shown in Table 4.4.3. There are two vehicular screen lines, namely, the Island City and Thane Creek with a transit screen line across Thane Creek as well. All screen lines are within a tolerance of 12% which is considered acceptable. In addition the individual vehicular counts were compared and this estimated comparison at this level resulted in a MAD ratio of 0.14. A value in the range of less than 0.25 is considered good.

The MAD ratio is a simple statistic to determine the closeness of fit between traffic count and link assignment estimate. It is defined as:

$$\text{MAD Ratio} = \sum \left| \frac{Count - Estimate}{Count} \right| * \frac{1}{n}$$

Where MAD ratio = Mean absolute difference ratio;
Count = Traffic Count;
Estimate = Estimate from Validation procedure; and
n = Number of observations.

Table 4.4.3 Screen line Comparison of Peak Hour Flow Counts[20,21]

No	Description	Direction	Observed	Estimated	% Difference
1	Island City Vehicular (pcu)	Both	25,972	27,251	4.9%
2	Thane Creek Vehicular (pcu)	Both	30,574	26,974	-11.8%
3	Thane Creek Transit (persons)	Both	170,000	167,110	1.7%

Source: JICA Study Team

4.5 Future Assumptions

There are four key sets of future assumptions that will impact the performance of the MTHL, namely, the overall socio-economic forecasts, the special major development areas both in Navi Mumbai and the Island City, the planned transport infrastructure, and the configuration of MTHL itself.

4.5.1 Key future Socio-Economic Forecasts

The Study Team reviewed the socio-economic forecasts of CTS and sought the advice of various agencies such as MMRDA, BMC, CIDCO and NMMC. Thus the Study Team was able to prepare key socio-economic forecasts that had been well reviewed for both population (see Table 4.5.1), households (see Table 4.5.2) and employment (see Table 4.5.3)for each of the 11 clusters at the base year of 2015 and the three future time horizons of 2022, 2032 and 2042[22,23]. These forecasts[24] were then reflected into the details of the 188

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[20] All seasonal factors were incorporated into the traffic counts.

[21] The peak hour is defined as being between 08:30 and 09:30.

[22] Socio-economic forecasts were available for 2021 and 2031. The years of 2022 and 2032 were estimated by extrapolation of the various agency data whilst the 2042 dataset was estimated by extrapolation with the growth rate cut-off of two and half percent per annum.

[23] In addition to these population and employment data, currently undeveloped or under developed areas such as land designated as SEZ or land designated for rejuvenation is included in the transport model as special generators. The overall potential of this land is considered relative to the 2042 timeframe.

[24] The key forecasts of population and employment were the control of all socio-economic model inputs.

traffic analysis zones. For reference, the 2011 census data is also shown in Table 4.5.1 and Table 4.5.3.

The population of the MMR is expected to increase from 23.9 million in 2015 to a total of 36.94 million in 2042, an overall rate of 1.6 percent per annum. The overall household size will decrease from 4.4 to 3.9 thus whilst population is increasing at 1.6 percent per annum, the growth in households grows 30% faster at 2.1 percent per annum.

During the same time period, employment is expected to increase from the current 10.48 workers to 18.2 million. The participation will also increase slightly over this time period from 0.44 to 0.49. However, the overall employment level grows at 2.1 percent per annum, a similar level to the growth in households.

The population of Mumbai (Island City plus the Eastern and Western Suburbs) itself is anticipated to increase from 12.73 million to 14.57 million between 2015 and 2042. Over this time period, the highest population growth rates are seen in Navi Mumbai. Such growth is expected to increase the transport requirements between Mumbai and Navi Mumbai.

Table 4.5.1 Distribution of Population Forecasts by Horizon Year (Million People)

No	Cluster Name	2011	2015	2022	2032	2042
1	Island City	3.15	3.07	2.94	2.80	2.80
2	Western Suburbs	5.60	5.76	6.04	6.50	6.95
3	Eastern Suburbs	3.73	3.90	4.19	4.51	4.82
4	Thane	1.92	2.04	2.28	2.91	3.62
5	Navi Mumbai	1.92	2.19	2.79	4.47	5.58
6	Kalyan Dombivali	2.38	2.85	3.84	4.84	5.97
7	Vasai- Virar	1.22	1.47	1.97	2.23	2.48
8	Rural Alibaug-Karjat-Khopoli	0.52	0.53	0.55	0.56	0.59
9	Pen SEZ	0.16	0.26	0.57	0.78	0.94
10	Bhiwandi	0.80	0.92	1.17	1.33	1.49
11	Mira Bhayander	0.81	0.91	1.11	1.39	1.71
Total		**22.21**	**23.90**	**27.45**	**32.32**	**36.94**

Source: MMRDA, BMC, CIDCO, NMMC and JICA Study Team.

Table 4.5.2 Household Distribution Forecasts by Horizon Year (Million Households)

No	Cluster Name	2015	2022	2032	2042
1	Island City	0.70	0.69	0.68	0.71
2	Western Suburbs	1.31	1.42	1.59	1.77
3	Eastern Suburbs	0.89	0.98	1.10	1.23
4	Thane	0.46	0.54	0.71	0.92
5	Navi Mumbai	0.50	0.65	1.09	1.42
6	Kalyan Dombivali	0.65	0.90	1.18	1.52
7	Vasai- Virar	0.33	0.46	0.54	0.63
8	Rural Alibaug-Karjat-Khopoli	0.12	0.13	0.14	0.15
9	Pen SEZ	0.06	0.13	0.19	0.24
10	Bhiwandi	0.21	0.27	0.32	0.38
11	Mira Bhayander	0.21	0.26	0.34	0.44
Total		**5.44**	**6.43**	**7.88**	**9.41**

Source: MMRDA, BMC, CIDCO, CTS, NMMC and JICA Study Team.

Table 4.5.3 Distribution of Employment Forecasts by Horizon Year (Million People)

No	Cluster Name	2011	2015	2022	2032	2042
1	Island City	2.35	2.44	2.60	2.86	3.13
2	Western Suburbs	2.44	2.55	2.77	3.11	3.40
3	Eastern Suburbs	1.19	1.23	1.32	1.45	1.59
4	Thane	0.61	0.75	1.06	1.49	1.86
5	Navi Mumbai	0.99	1.21	1.70	2.40	3.00
6	Kalyan Dombivali	0.74	0.87	1.15	1.60	1.92
7	Vasai- Virar	0.36	0.45	0.65	0.96	1.19
8	Rural Alibaug-Karjat-Khopoli	0.11	0.12	0.14	0.16	0.18
9	Pen SEZ	0.14	0.20	0.35	0.54	0.68
10	Bhiwandi	0.32	0.36	0.44	0.56	0.64
11	Mira Bhayander	0.25	0.29	0.38	0.50	0.60
Total		**9.50**	**10.48**	**12.56**	**15.65**	**18.20**

Source: MMRDA, BMC, CIDCO, NMMC and JICA Study Team.

4.5.2 Major Developments in Navi Mumbai

In addition to the growth in attractiveness of each cluster with respect to population and employment, there are also special development areas often referred to as SEZ or in modelling terms, the relevant special generators. The staged development of these zones is shown in Table 4.5.4. At the time of the opening of the MTHL in 2022, these localities on the Navi Mumbai side of the project are expected to have reached a level of 20% completion and move towards a 90% level of full build out by 2042. The level of redevelopment of the Mumbai Port Trust is likely to only reach a build out of 50% by 2042.

In addition to the growth in attractiveness of each cluster with respect to population and employment, a new airport is also planned for Navi Mumbai. The anticipated opening of the airport is in 2019 with an estimation of 10 million passengers per year. With respect, to the time horizons of this study the anticipated passengers for the use of the airport are 15.8, 34.7 and 53.1 million passengers per year[25] in 2022, 2032 and 2042, respectively. These assumptions of the airport opening as well as the projected level in the development zones are in built within the framework of the transport model.

Table 4.5.4 Major Planning Development Levels in Special Development Zones

Cluster Node Name	*Traffic Analysis Zone*	*Ultimate Development Level (person)*	*Percentage Development Level*			
			2015	*2022*	*2032*	*2042*
Navi Mumbai SEZ Employment	202 to 207	281,000	0	20	50	90
Navi Mumbai SEZ Population	202 to 207	790,000	0	20	50	90
Mumbai Port Trust Area Development-Population	201	125,000	0	5	15	50
Mumbai Port Trust Area Development-Employment	201	50,000	0	5	15	50
Navi Mumbai Airport (MAP)	208 & 209	60,000,000	0	26	58	89

Source: MMRDA, BMC, CIDCO and NMMC

4.5.3 Future Transport Infrastructure

Between now and 2042, it is anticipated that significant transport infrastructure[26] is likely to be constructed within the MMR. Some of this transport infrastructure[27] will impact the performance and hence the attractiveness of MTHL. The time of completion[28] of significant projects is shown in Table 4.5.5. In addition, selected projects are highlighted on the network assumption map of Figure 4.5.1.

The project that may have the largest negative impact on MTHL is the GK Bridge as this provides an additional crossing of Thane Creek. The completion of this project is included at an early stage. The other project of likely impact is the widening of Thane Creek Bridge. This project, in the opinion of the Study Team, will not likely happen in the immediate future, but such a project should still be included in the later time horizon.

The major project not listed in the aforementioned table is the impact of the opening of the operation of the Delhi Mumbai Industrial Corridor. The likely major impact of this project is to

[25] This forecast is based on the interpolation of the airport forecast years of 2025, 2035 and 2045 estimating the number of annual passengers (in millions) at the time horizons of 25, 45 and 60 respectively.

[26] As well as future infrastructure, it should be noted at the time of opening of MTHL, the private vehicle toll on the existing Thane creek bridge will be removed as this is stated government policy.

[27] It is noted that approximately 146 km of Metro are intended for completion in Mumbai by 2022. Not all of that metro is included in the modelling analysis. Only that section of the metro deemed by the team's local consultant in conjunction with the study team as relevant to impact MTHL is included in this study analysis.

[28] The timing of the commencement of operation of infrastructure projects was determined after extensive discussions with relevant agencies and a review of associated feasibility studies.

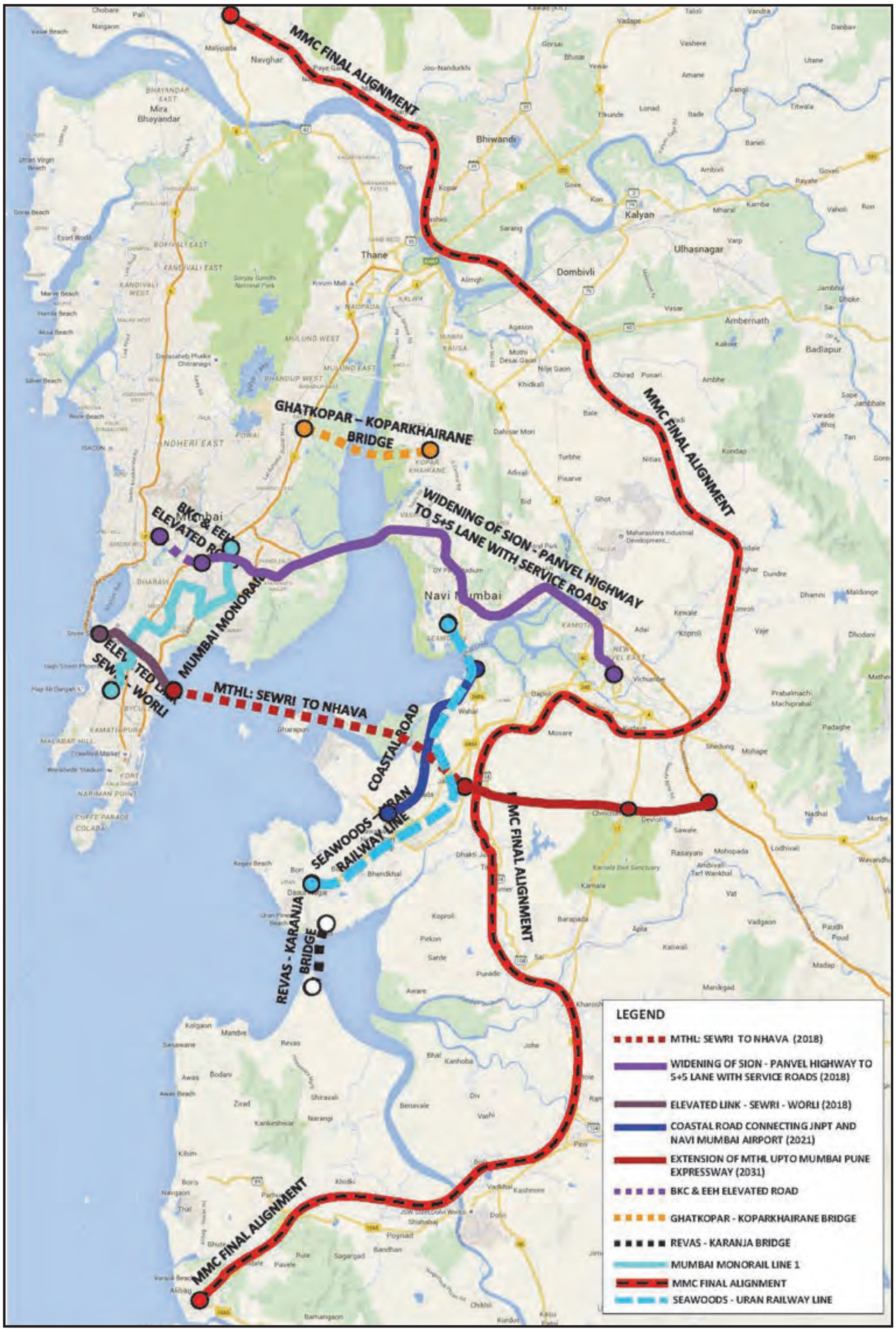
reduce the truck traffic travelling though Navi Mumbai to access the port. This impact will be included with an appropriate adjustment to the truck travel matrix[29].

Table 4.5.5 Network Year for Project Inclusion

Project Name	2022	2032	2042
Ghatkopar - Koparkhairane Bridge (GK Bridge)	X	X	X
Coastal Road from JNPT to Navi Mumbai Airport	X	X	X
Sewri to Worli Elevated Link (2+2 Lanes)	X	X	X
Elevated road between BKC and Eastern Express Highway near Sion	X	X	X
Monorail from Jacob Circle to Chembur	X	X	X
Navi Mumbai Metro – Belapur-Kharghar – Taloja	X	X	X
Rewas Karanja Bridge (RK Bridge)		X	X
MTHL extension to Mumbai Pune Expressway		X	X
Navi Mumbai Coastal Road from Vashi to Thane		X	X
Multimodal Corridor from Virar to Alibaug		X	X
Line 2 Metro and Line 3 Metro		X	X
Navi Mumbai Metro - Taloja -Kalamboli- Khandeshwar - New Airport (2021)		X	X
Coastal Road from Navi Mumbai Airport to Thane along Palm Beach Marg and Creek			X
Widening of Thane Creek Bridge			X

Source: JICA Study Team

[29] This impact is expected to be minimal as the commercial traffic on NH8 and NH3 (main highways from Delhi) bound for JNPT is observed as being in the order of 5%.



Source: JICA Study Team

Figure 4.5.1 Selected Network Assumptions for the Analysis of MTHL

4.5.4 MTHL Configuration

The project is coded into the model with three lanes of traffic in each direction. The reference toll is presented in Table 4.5.6 for each vehicle class in Year 2015 monetary value. The toll for a car or small vehicle in the opening year of 2022 was established at INR 180[30] (Year 2022 value) on the main bridge link. The toll on the short link between Chirle and Shivaji Nagar is distance proportional to the main bridge link. In addition to vehicular traffic, it is expected that BEST will provide some public bus routes across the MTHL.

Table 4.5.6 Base Toll (INR) Level by Vehicle Class per Vehicle between Interchanges

Vehicle Type	Chirle - Shivaji Nagar	Shivaji Nagar - Sewri	Comment
Car	40	130	This is also referred to as the small vehicle reference toll.
Taxi	40	130	
Bus	90	300	
LCV	50	170	
HCV	90	300	
MAV	130	430	

Source: MMRDA and JICA Study Team

4.6 Future Demand on MTHL

At the opening year 2022, the daily traffic on the main bridge is expected to be 39,300 pcu for the reference toll presented in Table 4.5.6. The traffic is projected to increase up to 103,900 pcu/day by 2032 and up to 145,500 by the year 2042. The daily breakdown by vehicle class on the main bridge link is presented in Table 4.6.1.

Due to government policy to withdraw the toll on the Thane Creek bridges at Vashi and Airoli for small vehicles and buses, and delay of airport development, year wise future demands on MTHL are decreased in comparison with the Mumbai Trans Harbour Link Study in 2012. Furthermore, future demand between Shivaji Nagar IC and Chirle IC is lower than between Sewri IC - Shivaji Nagar IC due to new development of the toll-free coastal road to Shivaji Nagar IC.

At opening in 2022, the traffic flow on MTHL represents a diversion of 10% of traffic across all Thane Creek, which will increase to 16% in 2032. If only Thane Creek Bridge is considered, then the diverted traffic from that bridge will be 21% in 2022 which will rise to 35% in 2032.

[30] A deflationary rate of 5% per annum was adopted

Table 4.6.1 Traffic Forecast Volume on the Main Bridge Link by Vehicle Class[31]

(Unit: pcu)

Vehicle Type	Sewri IC - Shivaji Nagar IC			Shivaji Nagar IC – Chirle IC		
	2022	2032	2042	2022	2032	2042
Car	24,100	66,400	94,100	4,900	21,300	43,300
Taxi	2,700	14,100	20,200	100	400	2,300
Bus	2,700	3,700	3,700	2,700	3,700	3,700
LCV	2,200	4,100	5,600	700	1,300	1,800
HCV	3,000	6,500	8,100	1,000	2,000	2,200
MAV	4,600	9,100	13,800	400	900	1,700
Total	**39,300**	**103,900**	**145,500**	**9,800**	**29,600**	**55,000**

Source: JICA Study Team

[31] Details of ramp volumes are not included in this chapter but are input into the design phase of the project.

5. NATURAL CONDITIONS ALONG MTHL

5.1 Topographic Survey

5.1.1 Outline of Topographical Survey

(1) General

Objectives of a topographical survey are to obtain the base map for road and bridge design and to obtain the basic information in order to analyse the tidal levels and the ocean waves. The target areas are as follows;

- Main road alignment (on Land and Sea)
- Planned Interchange (3 areas)
- 2 lines on the sea

(2) Previous Survey

Bathymetry survey was conducted in the following investigation, 2013.

Table 5.1.1 Previous Topographical Survey

Report	Date	Outline
Supplementary Geotechnical Investigations for the proposed Mumbai Trans Harbour Link (MMRDA)	Feb 2013	Bathymetry Survey along MTHL alignment (KM4+200-KM14+900) x 200m

Source: JICA Study Team

(3) Topographical Survey

1) Baseline Data

Topographical survey was carried out as follows

Table 5.1.2 Baseline of Topographical Survey

Survey Period	Bathymetrical Survey: From 3rd May to 6th May, 2015 Survey on Land: From 12th May to 22th May,2015
Main Equipment	Bathymetrical Survey: Multi-beam Echo Sounder Survey on Land: Total Station
Geodetic Datum	WGS84 (UTM Conversion: Zone43)
Surveying Benchmark	M.S.L.=+2.15m above chart datum

Source: JICA Study Team

2) Survey Items and Location

Topographical survey items and quantities are shown in Table 5.1.3.

Table 5.1.3 Survey Items and Quantities

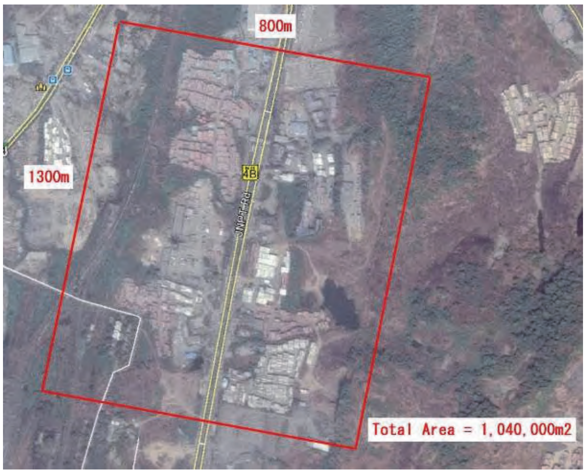
Item	Unit	Quantity	Note
Plane Survey by Total Station for Land	m^2	3,190,000	• Eastern Freeway Interchange: 450,000m^2 • Navi-Mumbai Side: 1,100,000m^2 (5,500m x 200m) • Shivajinagar Interchange: 600,000m^2 • Chirle Interchange: 1,040,000m^2
Plane Survey for Sea	m^2	825,000	• 16,500m x 50m
Centerline / Profile Leveling Survey for Land	m	6,500	• Mumbai Side: 1,000m • Navi-Mumbai Side: 5,500m
Cross Section Survey for Land	m	17,500	• Main Line: 17,500m (350 line x 50m)
Centerline / Profile Leveling Survey for the Cross Roads on Land	m	3,400	• Eastern Freeway: 1,500m • At Shivajinagar Interchange: 600m • At Chirle Interchange: 1,300m
Cross Section Survey for the Cross Roads on Land	m	8,500	• Eastern Freeway: 3,750m (75 line x 50m) • At Shivajinagar Interchange: 1,500m (30 line x 50m) • At Chirle Interchange: 3,250m (65 line x 50m)
Profile Leveling Survey for Land	m	1,200	• 800m + 400m (2 line)
Profile Leveling Survey for Sea	m	16,540	• 8,380m + 8160m (2 line)

Source: JICA Study Team

Survey locations for interchanges are shown in Figure 5.1.1.

(a) Eastern Freeway Interchange

(b) Shivajinagar Interchange



(c) Chirle Interchange

Source: JICA Study Team

Figure 5.1.1 Location of the Plane Surveys

Survey lines of the bathymetric survey were determined considering planned alignment and plan of hydrological analysis, which are shown in Figure 5.1.2.

Source: JICA Study Team

Figure 5.1.2 Bathymetric Survey Location

3) Photos of Field Work

Photos of field work are shown in Figure 5.1.3.

Topographic survey work at Seweri site

Survey vessel for bathymetry survey

Figure 5.1.3 Photos of Survey Work

5.1.2 Survey Results

(1) Topographic Map and Cross Sectional Survey

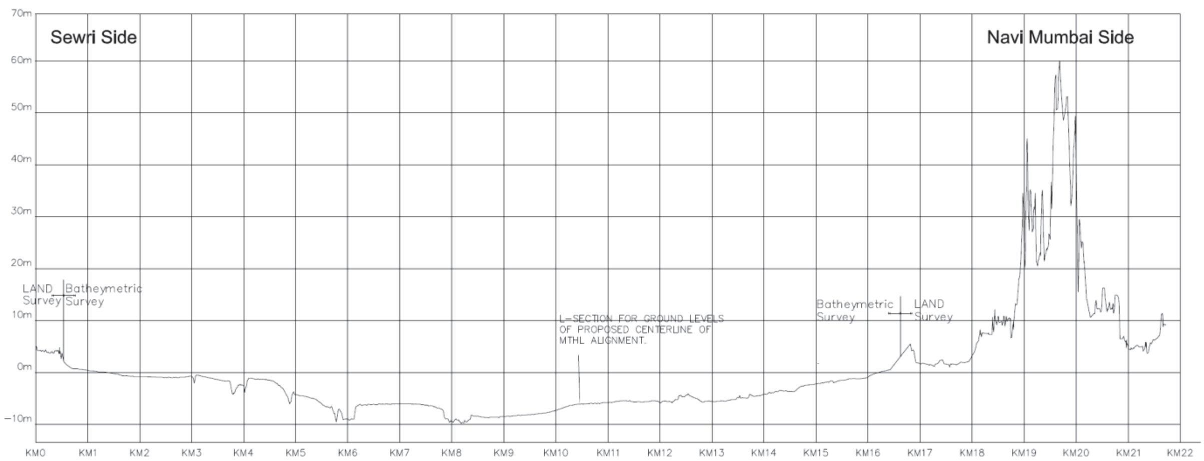
Topographic map and cross sectional survey results were utilized as base drawings on the basic design drawings. The topographic map, end point of the project, Navi Mumbai side is shown in Figure 5.1.4.

Source: JICA Study Team

Figure 5.1.4 Topographic Map, End Point of the Project, Navi Mumbai Side

(2) Topographical Profile along MTHL

Topographical map, longitudinal profile drawing and cross sectional drawing were made for the base map of the preliminary design based on the topographical survey results. Topographical profile along MHTL is shown in Figure 5.1.5. This profile shows that the project route passes over a plain whose elevation is about 5m at the beginning point, and it passes through some hills, about 5m to 60m in Navi Mumbai Side. On the sea, the elevation of the seabed along the project route is shallower than -3m in the section from KM0.5 to KM4.0, and maximum depth is about 10m at around KM6.0 and KM8.0.



Source: JICA Study Team

Figure 5.1.5 Topographical Profile along MTHL

(3) Topography of the Site

The land in Mumbai city had consisted of 7 islands before the 18^{th} century, and the reclamation work was conducted during the 18^{th} century. Presently, the land consists of the plain and low hills with the elevations of 5m to 20m. The land of Navi Mumbai lies on the Decan Traps that were formed by volcanic eruption. These traps (Basalt) are well known as the world largest land formed by volcanic action. The land around Navi Mumbai city consists of hills with elevations of 50m to 300m. The project route is to start in the reclamation area at the beginning section with the elevation of 5m, and passes through the hills with maximum elevation of 60m in Navi Mumbai Side.

5.2 Geological Survey

5.2.1 Outline of Geological Survey

(1) Objectives

Geological Survey was carried out to obtain geological and geotechnical information at bridge sites on MHTL. The objectives of the Works are to execute investigations in detail as follows:

- Clarify the geological conditions, and geological strata and their characteristics, of the construction site for a preparatory survey.
- Determine geotechnical properties of the geology at the bridge sites.

(2) Local Geology

The area of Mumbai city is located on the said Deccan Traps, which is well known as the world largest land formed by volcanic eruption which occurred between the end of the Mesozoic Cretaceous and early Cenozoic. Deccan Traps are composed of many kinds of Basalt rocks and with a thickness of more than 2,000m. Above this rock, is a stiff silty clay layer which is weathered from the rock. On the sea section, marine sediments cover the bottom with the thickness of about 2m to 20m on the layers.

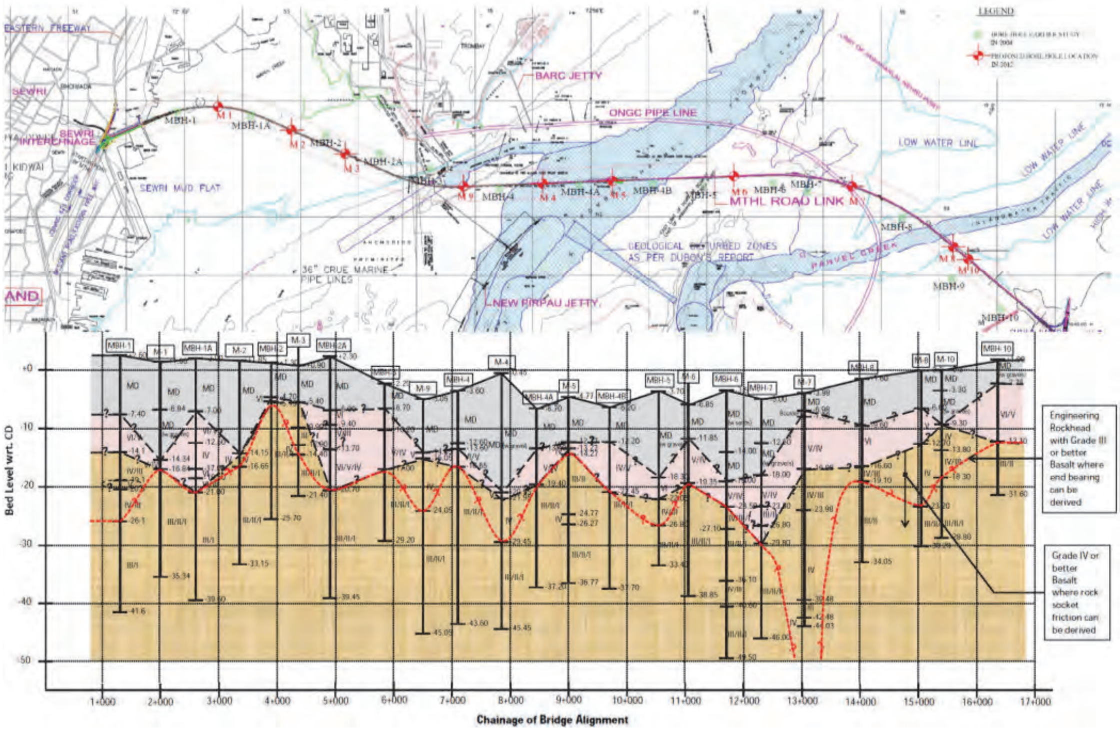
(3) Previous Surveys

Geological surveys carried out in recent years are as shown in Table 5.2.1. A total of 38 boreholes were drilled in these studies and a geological profile was made referring to the results as shown in Figure 5.2.1. The results show that weathered rock layer and marine sediment with about 10m thickness is lying on the basalt rock layer.

Table 5.2.1 Geological Surveys in the Past

Report Name, Date	Organization	Outline
Techno-Economic Feasibility Study for Mumbai Trans Harbour Link, August, 2004	MSRDC	Borehole Survey, 14 points
Supplementary Geotechnical Investigations for the proposed Mumbai Trans Harbour Link (Sewri to Nhava), Feb, 2013	MMRDA	Borehole Survey on the sea, 10 points Borehole Survey in Nhava end, 10 points Borehole Survey in Sewri end, 4 points

Source: JICA Study Team



Source: 2013 F/S

Figure 5.2.1 Geological Profile along MTHL, 2013 F/S

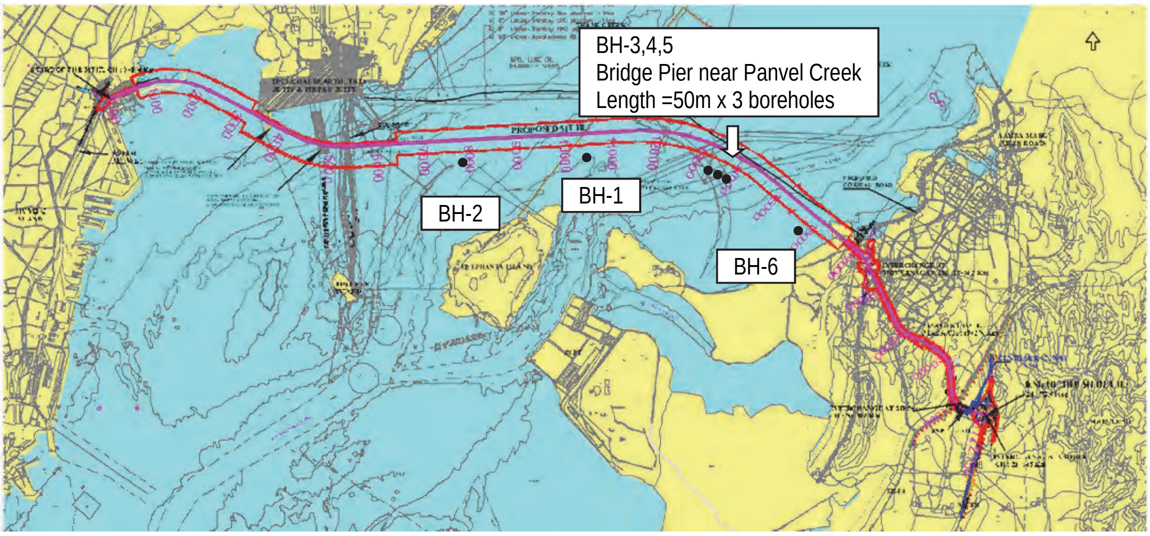
(4) Outline of the Survey

Borehole surveys were planned in order to verify the past survey results and confirm the geological condition at main bridge pier locations. Locations of boreholes are shown in Table 5.2.2 and Figure 5.2.2.

Table 5.2.2 Location of the Borehole Survey

No.	Borehole No.	Distance (KM)	Coordinates		Borehole Depth (m)	Main Objective
1	BH-1(2015)	10+500	E284389.00	N2101122.00	25.5	For verification of the previous survey
2	BH-2(2015)	8+000	E281555.00	N2100932.00	25.5	
3	BH-3(2015)	13+100	E286953.00	N2100893.00	25.5	At Bridge Pier near Panvel Creek
4	BH-4(2015)	12+990	E286846.00	N2100932.00	26.2	
5	BH-5(2015)	13+460	E287282.00	N2100749.00	22.2	
6	BH-6(2015)	15+500	E288918.00	N2099540.00	22.2	For verification of the previous survey
Total					147.1	

Source: JICA Study Team



Source: JICA Study Team

Figure 5.2.2 Borehole Location

Laboratory tests were carried out to obtain the supplemental information of soil stratum. The items and quantity are shown in Table 5.2.3.

Table 5.2.3 Laboratory Soil Tests

Test Item	Unit	Qty.	Standards
Specific Gravity	Sample	31	Indian Std, or BS1377
Natural Moisture Contents	Sample	2	Indian Std, or BS1377
Particle Size Distribution	Sample	47	Indian Std, or BS1377
Atterberg limits	Sample	27	Indian Std, or BS1377
Unconfined Compression	Sample	20	Indian Std, or BS1377
Consolidation	Sample	2	Indian Std, or BS1377

Source: JICA Study Team

5.2.2 Geological Survey Results

(1) Survey Results

1) Borehole Survey Results

Borehole survey results were summarized in the detailed borehole logs and attached at the end of the report.

2) Soil Stratums

The layers which are confirmed in the borehole survey results are summarized with soil or rock types, thickness and brief outline in Table 5.2.4. Weathered Basalt rock (Layer 6) are confirmed in all boreholes and the depth of the top of the layer is from 10m to 35m below the floor of the sea bed. These are matched with the survey results in the past. The photos of weathered Basalt and Basalt layer are shown in Figure 5.2.3.

Table 5.2.4 Soil Stratum

Segment	No.	Type	Thickness	Brief Description
Marine Sediment	Layer1	Soft Clay	0~10m	The layer lies under the surface of the seabed. SPT N values are from 1 to 3. Very soft to soft consistency, muddy in several places.
Weathered Rock	Layer2	Stiff Clay	0~7m	Clay or silt with fine sand in several places. SPT N values are from 15 to 40. Medium to Stiff consistency.
	Layer3	Dense Sand	0~7m	Dense Sand with cobbles in several places. The layer is confirmed in the section from KM13 to KM16. SPT N values are over 50.
	Layer4	Dense Gravel	0~5m	Dense Gravel with silt or clay. The layer is confirmed at KM 13+260.SPT and values are over 50.
Rock	Layer5	Weathered Basalt	2~25m	Highly or moderately weathered basalt rock. RQD values are from 0 to 50. Fractured in several places.
	Layer6	Basalt	-	Weathered basalt rock. RQD values are from 0 to 50.

Source: JICA Study Team

Source: JICA Study Team

Figure 5.2.3 Core Photo of Basalt Rock

3) Laboratory Test Results

Laboratory test results are attached in the Appendices. The brief description of the results are summarized for each layer and shown in Table 5.2.5.

Table 5.2.5 Laboratory Test Results

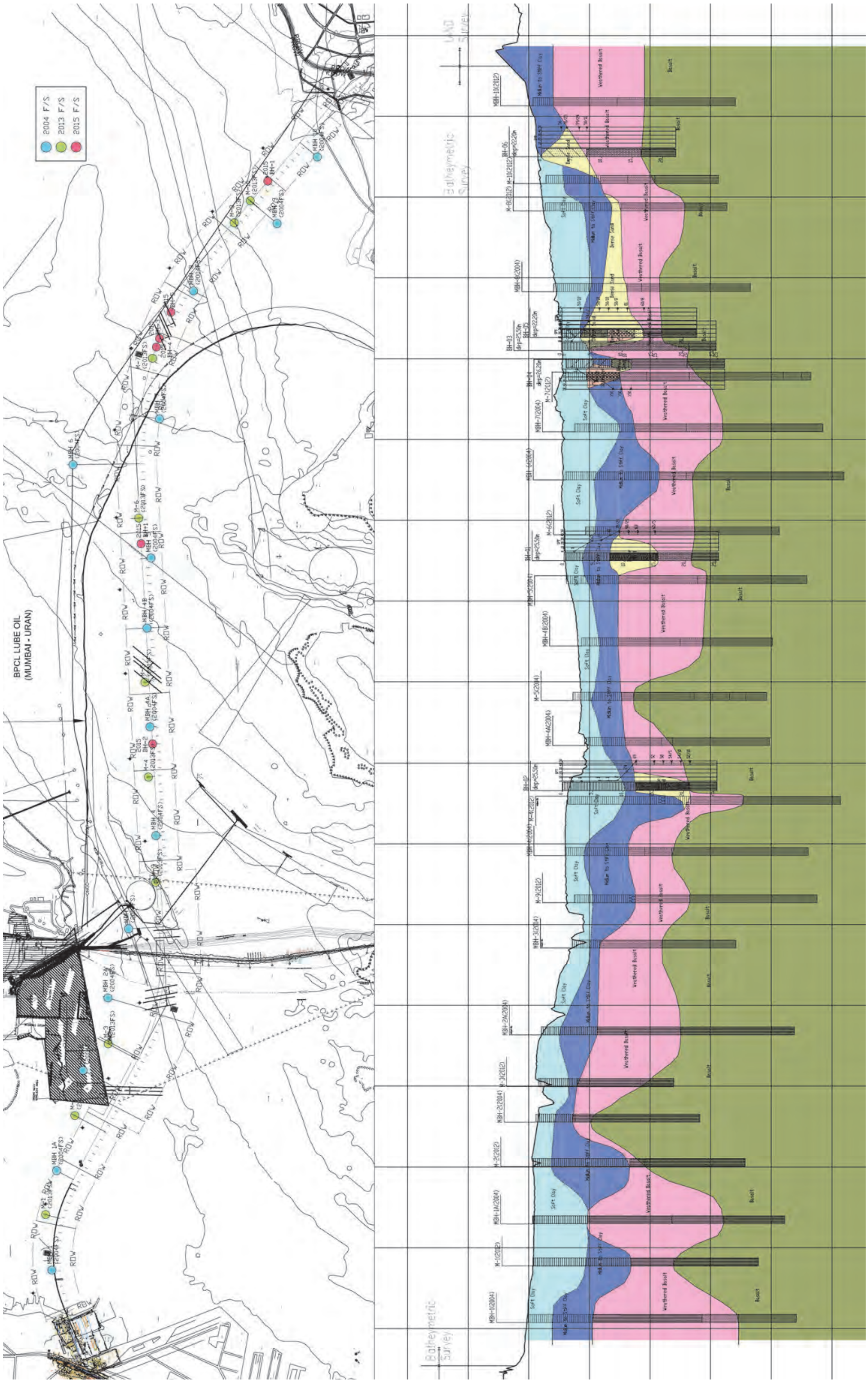
Segment	Type.	Thickness	Soil class	Brief Description, Average of the results
Layer1	Soft Clay	0~10m	CH	Specific gravity : 2.57(g/cm^3) Grain Size: Gravel 0%, Sand 0~10%, Silt 50~60%, Clay 40~50% Atterberg Limit: LL 59%, PL 29%, IP 30% Consolidation: CC 0.85, e0 1.70
Layer2	Stiff Clay	0~7m	CH	Specific gravity : 2.59(g/cm^3) Grain Size: Gravel 7%, Sand 10%, Silt 40%, Clay 39% Atterberg Limit: LL 67%, PL 28%, IP 39%
Layer3	Dense Sand	0~7m	SM	Specific gravity : 2.52(g/cm^3) Grain Size: Gravel 5%, Sand 80%, Silt 12%, Clay 8%
Layer4	Dense Gravel	0~5m	GP	Specific gravity : 2.52(g/cm^3) Grain Size: Gravel 45%, Sand 35%, Silt 15%, Clay 5%
Layer5	Weathered Basalt	2~25m	SP	Specific gravity : 2.51(g/cm^3) Grain Size: Gravel 13%, Sand 64%, Silt 13%, Clay 21%
Layer6	Basalt	-	-	-

Source: JICA Study Team

The unconfined compression test for basalt rock was carried out with 20 test pieces. Average density is 2.7g/cm^3 and compression strength is from 5.5~112MPa, Ave.49 MPa according to the results. Thus it can be determined that the basalt rock has enough strength to be the supporting layer for the pile foundation.

5.2.3 Geological Profile along MTHL

Geological profile along MTHL was made with reference to the survey results in the past and these borehole survey results. It is shown in Figure 5.2.4.



Source: JICA Study Team

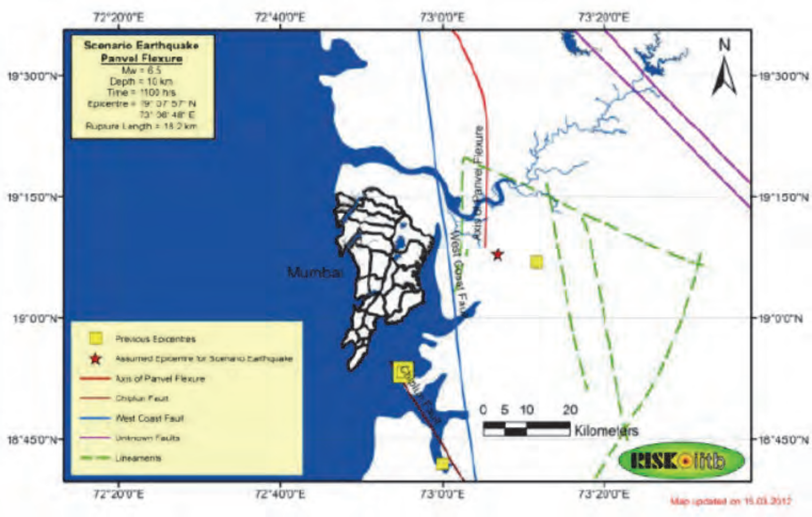
Figure 5.2.4 Geological Profile along MTHL

5.2.4 Evaluation on the Geological Condition

- Basalt rock or weathered Basalt rock layer is stable with high compression strength (Ave. 40MPa) and can be considered as the bearing layer of the foundation.
- Weathered Basalt layer is confirmed at 10m~35m depth under the seabed.
- Soft clay layer is confirmed with the thickness of 0m to 7m under the seabed. Therefore the appropriate measures are required to construct footings or caisson foundations.
- Dense sand or gravel layer is confirmed in several places above the Basalt layer. Thus supplemental measures are required to construct the piles.

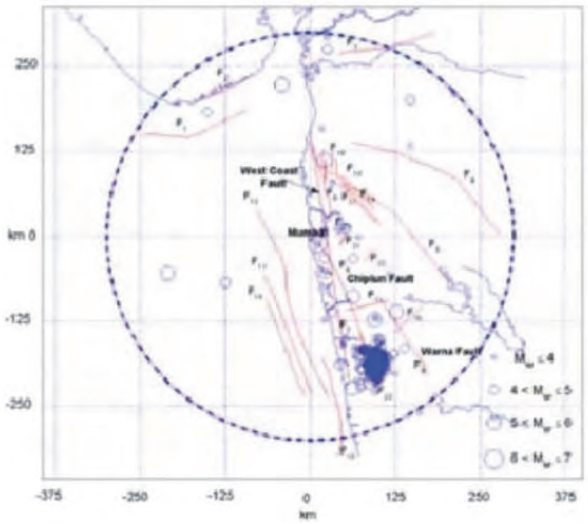
5.2.5 Seismic History

Earlier studies identified fault zones around the project area. Regarding the faults in the Mumbai area, the West Coast Fault is known to be seismically active (Nandy, 1995 and Dessai, 1995). The location of the fault is shown in Figure 5.2.5, and it is located outside of the bridge section of MTHL. Meanwhile, it is not clear whether other faults are seismically active or not. Historical earthquakes happened and were recorded as shown in Figure 5.2.6, and Table 5.2.6. These records show that there have already been a few earthquakes with intensity VI+ causing damage during the last 400 years. The dotted line circle in Figure 5.2.6 has a radius of about 300km from Mumbai city and it shows that there have been no earthquakes with magnitude more than 7 in the 400 years inside the circle. Additionally, Mumbai area belongs to Zone III in the 'Criteria For Earthquake Resistant Design of Structures (IS.1893-2002)', which means the possibility of the occurrence of an earthquake is moderate. Based on these matters, it can be determined that the risk of the possibility and magnitude of the earthquake is moderate in this region.



Source: Geological Survey of India, 2000

Figure 5.2.5 Lineaments of the West Coast of India near Mumbai, Adapted from Seism Tectonic Atlas of India



Source: Seismic Hazard for Mumbai City, CURRENT SCIENCE, 1494 VOL. 91, NO. 11, 10 DECEMBER 2006

Figure 5.2.6 Major Historical Earthquakes in Mumbai Region

Table 5.2.6 Major Historical Earthquakes in Mumbai Region

Year	Month	Intensity (MMI) / Magnitude (R)
1594	--	IV
1618	May	IX**
1678	--	IV
1832	October	VI
1854	December	IV
1865	December	IV
1877	December	IV
1896	April	III
1906	March	VI
1910	September	III
1924	January	IV
1928	November	III
1929	February	V
1933	July	V
1935	September	III
1937	January	III
1941	May	IV
1951	April	VIII
1961	January	III
1963	March	IV
1964	November	III
1965	July	III
1965	December	IV
1966	May	V
1967	April	4.5
1967	June	4.2
1998	May	3.6

*Source: Compiled from catalogues of IMD, NGRI, EPRI and MERI.
**There is some uncertainty about this damage being caused due to an earthquake.

Source: A postulated earth quake damage scenario For Mumbai, ISET Journal, 1999

5.3 Meteorological and Hydrological Survey

5.3.1 General

Mumbai lies on the western coast of the Arabian Sea, and is classified a “Tropical wet and dry or savanna climate” (by Köppen-Geiger classification: Aw). The Aw climate has a pronounced dry season, with the driest month having rainfall less than 60 mm and less than 1/25 of the total annual rainfall. The summer and the winter climate are controlled by the south-west / north-east monsoons, and the autumn and spring seasons are practically indistinguishable. Mumbai comes under the direct influence of the south-west monsoon from June to September, it is usually very heavy, and 93% or more of the annual rainfall occurs from June to September. November to March is the North East monsoon period. Although occasional high wind speeds are experienced during the North East monsoons, rainfall is negligible.

Rivers flowing into the Mumbai Bay are as shown in Table 5.3.1 and Figure 5.3.1. Although it is ranked as the river of a relatively small basin compared to many other Indian rivers, there are two basins totalling 1,358 km^2 in the upper river basin of the MTHL. The rivers in the target region have steep slopes in the upper reaches, and traverse the coastal plains that have elevations of 0 to 150m for 50 to 100 kms before joining the Arabian Sea.

Table 5.3.1 Rivers Flowing Into the Mumbai Bay

No.	River Name	Tributary Name	Watershed ID	Drainage Area (km^2)	No. of Dams	No. of Barrages/Weirs /Annicuts	Remarks (CWC Hydrometric Observation Site)
1	Panvel	Kasadi, Kalundre, etc.	B14BHT36	425.9	1	0	
2	Thane	Thane	B14BHT37	932.3	2	0	
3	Patalganga	Patalganga	B14BHT38	575.4	6	0	
4	Amba	Amba	B14BHT39	698.4	5	0	2 Sta. (Pali -310 km^2, Nagathone -420km^2)
5	Amba	Amba	B14BHT40	727.3	6	0	1 Sta. (Pen -125 km^2)
Total areas of 1+2 basins				1,358.1	3	0	Upstream of MTHL
Total areas of 1+2+3+4+5 basins				3,359.2	20	0	Inflow Area into Mumbia Bay

Source: India-WRIS (Water Resources Information System of India, CWC)

Source: India-WRIS (Water Resources Information System of India, CWC

Figure 5.3.1 Rivers Flowing into the Mumbai Bay

5.3.2 Data Collection Items for Meteorology and Hydrology

In order to predict the tidal flow and tide level, it is necessary to collect and correlate the collectable data and conditions concerning the hydrology and hydraulics of the bay or related inflow rivers surrounding the targeted areas.

Regarding data about meteorology and hydrology in Mumbai, the meteorological data are operated by IMD, the ocean hydrological data (such as tide level, current, storm-surge and bathymetric features) or port information/data are operated by MMB, MbPT, SOI, and CWPRS. And the river hydrological data (such as river water level, discharge and sediment-flow) are operated by CWC.

The data collection items are shown in Table 5.3.2. The station location map for data collection is shown in Figure 5.3.2.

Table 5.3.2 Data Collection Items

Survey Items			Related Organization	Remarks
Meteorological Survey				
		Information of Meteorological Stations, Temperature, Relative Humidity, Wind Speed&Directions, Evaporation, Sunshine Hours, Rainfall, etc.	Mumbai- IMD of MES	
Hydrological and Port infromation Survey				
	Data collection of related rivers			
		Information of Hydrological Stations, Annual Maximum Discharge, Annual Maximum Water Level, Daily Discharge, etc.	CWC of MWR, SOI of MST	
		Catchment Basin Information, Morphology, etc.		
	Data collection of the Mumbai Bay			
		Tidal Condition (Chart datum, etc.), Astronmical Tide at Certain years, Strom Surge Situations, etc.	MMB, MbPT of the Maharashtra State, SOI of MST, CWPRS of MWS	
		Nautical Chart for Port of Mumbai, Other Bathymetric Survey Information, Grain Size distribution results of Bed Materials, etc.		
	Navigation Channel and Port information			
		Navigation Channel (Tidal creek) information / requirement	MMB, MbPT of the Maharashtra State	
		List of Vessels(ships)		
		Facilities, Trade and Traffic volume (past/future) information of Port		
Bibliographical Survey				

Abbreviation: IMD (India Meteorological Department) of MES (Ministry of Earth Sciences),
CWC (Central Water Commission) of MWR (Ministry of Water Resources) ,
CWPRS (Central Water and Power Research Station) of MWR
MMB (Maharashtra Maritime Board), MbPT (Mumbai Port Trust) of Maharashtra State Government
SOI (Survey of India) of MST (Ministry of Science and Technology)
MSRDC (Maharashtra State Road Development Corporation ltd.)

Source: JICA Study Team

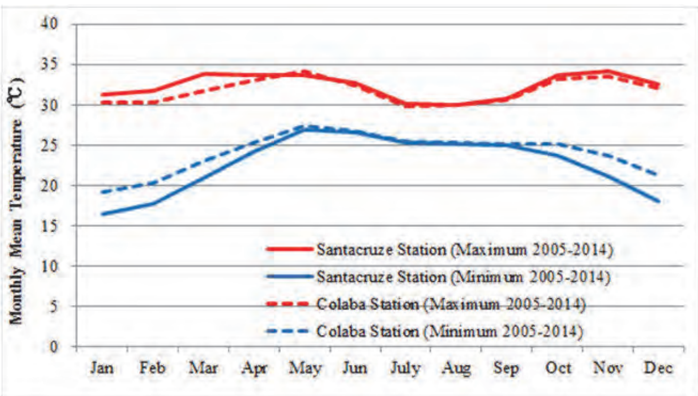
Figure 5.3.2 Station Location Map for Data Collection

5.3.3 Meteorological Survey

(1) General Weather Conditions

1) Temperature

The mean daily maximum temperature ranges from 30°C to 34°C, but during the winter period the minimum temperature may fall to about 17°C. Highest recorded temperature was 40.6°C in March 2011 at Colaba station. The hotter months are March to June and October to November, as shown in Figure 5.3.3.

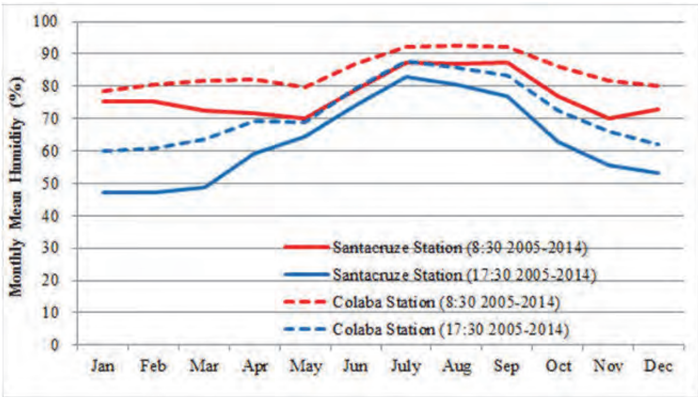


Source: JICA Study Team, IMD

Figure 5.3.3 Mean Monthly Maximum and Minimum Temperature

2) Humidity

Relative humidity is high in the morning and lower in the evening, and it ranges from 63% to 93% being the highest in the south-west monsoon period. During the winter months (November-January) relative humidity ranges from 47% to 82%.



Source: JICA Study Team, IMD

Figure 5.3.4 Mean Monthly Relative Humidity at 8:30 and 17:30

3) Wind Speed and Direction

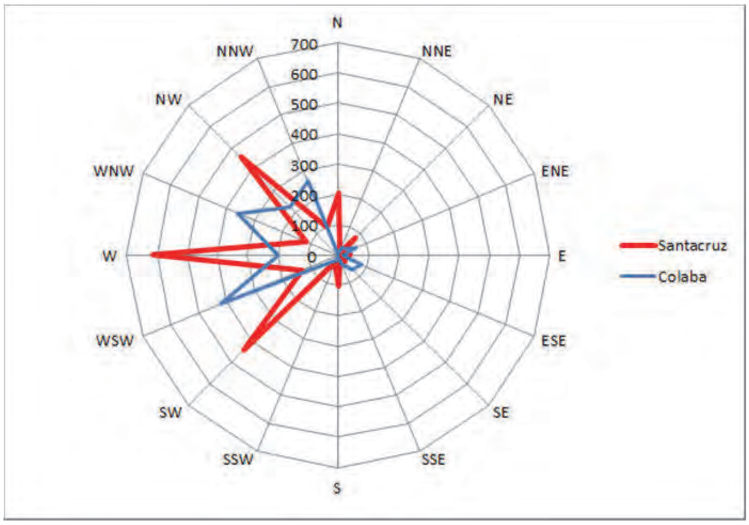
The monthly maximum wind speed during 2005-2014 and the wind rose are shown in Table 5.3.3 and Figure 5.3.5. From this Figure, it is shown that annual wind direction is dominated by winds coming from the northwest to southwest quadrant. Historical maximum wind speed recorded is 28.9 m/s at Santacruz station in 2014 and 39.2 m/s at Colaba in 2014.

On the other hand, the design wind speed to be used for the bridge superstructure design, has been defined as 44m/s for Mumbai area (Zone 5) by IS-875 (Indian Standard). According to statistical analysis result in the literature, this basic wind speed (for design) of IS-875 is a safe-side value, and it is predicted as a value over a 50 year return period. (See Table 5.3.4.)

Table 5.3.3 Monthly Maximum Wind Speed (2005-2014)

Monthly Maximum Wind Speed (m/s) at Santacruz Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	12.2	6.1	5.0	6.1	5.0	12.2	9.4	11.1	8.3	5.0	5.0	3.9
2006	4.4	4.7	6.1	7.2	5.6	6.1	8.9	6.1	6.1	4.4	3.9	3.9
2007	4.4	22.5	6.7	6.7	6.7	8.3	8.4	10.6	16.7	5.6	3.9	3.9
2008	16.7	9.4	22.8	19.5	19.4	9.4	7.2	8.3	19.5	4.4	16.4	3.3
2009	4.4	5.0	6.1	6.1	5.0	9.4	8.3	6.7	4.4	3.9	5.0	3.9
2010	6.1	7.2	6.1	5.0	8.3	8.3	7.2	8.4	6.1	11.1	6.7	5.0
2011	4.4	7.2	4.4	5.0	6.1	6.7	5.0	23.9	9.4	6.1	5.0	5.0
2012	6.1	6.1	6.1	6.1	6.1	7.8	6.7	6.7	8.3	5.0	3.9	4.4
2013	5.0	7.2	7.2	6.1	6.1	22.2	7.2	7.2	7.2	6.1	0.0	3.3
2014	5.0	5.0	5.0	5.0	6.1	28.9						
Monthly Maximum Wind Speed (m/s) at Colaba Station												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	3.9	4.4	3.9	3.9	3.3	5.0	9.4	6.7	7.2	3.3	3.9	3.3
2006	5.0	3.3	5.0	7.8	3.9	8.3	12.8	10.0	5.0	3.3	3.3	2.2
2007	3.3	2.8	7.8	3.9	3.3	11.1	5.0	8.3	7.8	2.8	2.2	2.8
2008	2.8	3.3	3.3	3.3	13.9	6.1	4.4	6.3	3.9	2.2	2.2	2.2
2009	3.3	2.8	2.8	3.3	3.3	3.3	33.6	22.5	11.1	4.4	4.4	11.1
2010	3.9	8.3	3.9	6.7	11.1	4.4	8.3	12.2	3.3	3.9	3.9	16.7
2011	5.6	3.9	12.2	29.4	3.3	3.9	23.3	5.0	11.1	5.0	2.8	2.8
2012	6.1	5.6	8.3	3.9	3.9	5.0	5.0	11.1	6.6	3.3	2.8	2.8
2013	2.8	2.8	5.6	3.9	3.3	0.0	5.0	6.1	19.4	3.3	3.3	3.3
2014	3.3	3.3	3.3	3.3	3.9	16.7	39.2	11.1	16.7	11.1	2.2	3.3

Source: JICA Study Team, IMD



Source: JICA Study Team, IMD

Figure 5.3.5 Wind Rose (Accumulative Wind Speed each Wind Direction), 2005-2014

Table 5.3.4 Prediction of Design Wind Speeds with Gumbel using All Annual Maximum Wind Speed Records

Station ID	Wind Zone of IS:875	Basic Wind Speed of IS:875 Vb(m/s)	Revised basic wind speed Vb_R(m/s)	Wiind Speed with T= 50 yrs	Percentage difference ID:875	Remarks
Bombay/Colaba	3	44	33	28	-26%	
Bombay/Santacruz	3	44	40	35	-8%	

Note. In the calculation of the literature, it is used annual maximum values over the threshold.

Source: "Basic wind speed map of India with long-term hourly wind data", N. Lakshmanan (Structural Engineering Research Centre), Current Science (India), Vol. 96, No. 7, Apr 2009.

(2) Rainfall

1) Annual Rainfall and Seasonal / Long-Term Fluctuation

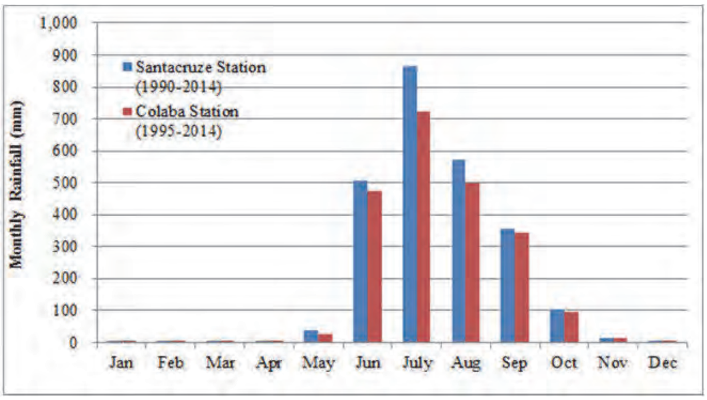
Most of the annual rainfall occurs during the South West monsoon from June to September. Figure 5.3.6 shows the average monthly rainfall for the period 1995-2014 measured at Colaba and 1990-2014 at Santacruz station, Mumbai. Also, the fluctuation of the annual rainfall is shown in Figure 5.3.7. The following can be inferred from these observed data or past literature:

a) Average annual rainfall is 2181mm at Colaba and 2455mm at Santacruz.

b) Average monthly rainfall during South West monsoon is 500 mm or more.

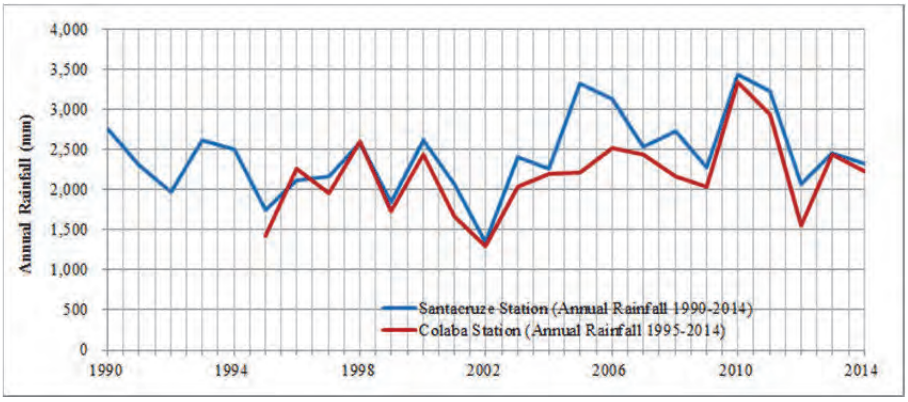
c) Maximum rainfall normally occurs in the month of July, followed by August.

d) According to the literature, the number of annual rainy days is 91 days, and average number of days with rainfall which exceeds 30mm is 20 days.



Source: JICA Study Team, IMD

Figure 5.3.6 Mean Monthly Rainfall



Source: JICA Study Team, IMD

Figure 5.3.7 Fluctuation of Annual Rainfall

Table 5.3.5 Monthly Rainfall at Santacruz and Colaba Stations

Monthly Rainfall	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Santacruze 1990-2014													
1990	0.0	2.8	2.9	0.0	133.4	740.5	339.0	888.0	564.8	95.1	Trace	Trace	2,766.5
1991	0.0	0.0	0.0	0.4	0.6	905.8	1,045.7	285.4	58.7	Trace	Trace	7.3	2,303.9
1992	0.0	0.0	0.0	0.0	Trace	129.8	603.6	863.2	339.6	38.9	0.0	0.0	1,975.1
1993	0.0	0.0	0.0	0.0	Trace	373.5	810.6	396.0	904.6	130.1	Trace	0.3	2,615.1
1994	17.8	Trace	0.0	2.0	5.8	553.1	953.6	504.9	386.5	79.7	0.5	0.0	2,503.9
1995	1.5	Trace	Trace	0.0	Trace	82.2	661.5	419.4	527.5	61.2	Trace	0.0	1,753.3
1996	0.7	0.0	0.0	0.0	Trace	219.3	996.9	377.2	283.8	237.0	0.8	Trace	2,115.7
1997	1.7	0.0	0.0	0.0	0.0	515.2	504.1	743.3	324.3	0.0	61.1	21.8	2,171.5
1998	0.0	0.0	0.0	0.0	0.3	540.7	520.9	587.7	540.4	376.6	22.7	Trace	2,589.3
1999	Trace	Trace	0.0	0.0	61.4	521.3	497.3	173.1	371.8	222.0	0.0	0.0	1,846.9
2000	0.0	0.0	0.0	0.0	387.8	364.8	1,229.8	496.1	79.0	58.0	0.0	5.9	2,621.4
2001	2.0	Trace	0.0	1.1	22.9	634.5	747.1	493.2	118.0	56.5	Trace	0.0	2,075.3
2002	0.0	0.0	0.2	0.0	1.0	455.9	102.8	669.0	116.9	Trace	0.7	0.2	1,346.7
2003	0.0	5.0	0.0	0.0	0.0	783.1	892.0	434.9	284.4	12.1	Trace	0.0	2,411.5
2004	Trace	0.0	0.0	0.0	69.7	253.6	818.6	938.2	155.9	21.9	0.5	0.0	2,258.4
2005	0.3	0.0	0.2	Trace	0.3	563.5	1,454.5	527.1	744.1	32.2	0.0	0.0	3,322.2
2006	0.0	0.0	13.1	0.0	45.0	481.1	1,061.4	951.5	336.3	238.6	4.2	0.0	3,131.2
2007	Trace	0.3	Trace	0.0	0.0	749.8	737.1	605.0	437.3	0.0	5.4	0.0	2,534.9
2008	0.0	Trace	0.0	0.0	1.0	800.5	950.2	627.0	327.9	17.3	0.1	Trace	2,724.0
2009	0.0	0.0	0.0	0.0	0.3	216.4	1,142.2	290.3	322.2	223.3	77.5	Trace	2,272.2
2010	0.0	Trace	0.0	0.7	0.0	712.1	1,250.4	1,036.5	328.9	64.0	47.2	0.0	3,439.8
2011	0.0	0.0	0.0	0.0	Trace	661.7	1,312.9	855.2	274.7	120.1	0.0	0.0	3,224.6
2012	0.0	0.0	0.0	0.0	0.0	298.5	627.9	377.1	563.9	198.5	0.0	0.0	2,065.9
2013	0.0	0.0	0.0	0.0	Trace	1,029.8	891.1	256.3	191.3	85.7	0.0	0.0	2,454.2
2014	Trace	0.0	0.0	0.0	0.0	87.3	1,468.5	458.0	285.8	23.4	5.8	1.5	2,330.3
25 yrs Average	1.1	0.4	0.7	0.2	38.4	507.0	864.8	570.1	354.7	104.0	11.9	1.9	2,455.3
	0.0%	0.0%	0.0%	0.0%	1.6%	20.6%	35.2%	23.2%	14.4%	4.2%	0.5%	0.1%	100.0%
Colaba 1995-2014													
1995	0.8	0.0	0.0	0.0	Trace	101.4	499.1	261.6	436.0	133.1	Trace	0.0	1,432.0
1996	3.2	0.0	0.0	0.0	0.0	272.2	1,009.3	456.1	429.5	94.3	2.1	0.0	2,266.7
1997	1.7	0.0	0.0	0.5	0.0	572.9	476.5	490.3	349.9	0.0	5.8	63.4	1,961.0
1998	0.0	0.0	0.0	0.0	Trace	510.3	613.7	755.6	292.2	415.4	6.8	Trace	2,594.0
1999	0.0	0.2	0.0	0.0	87.9	538.3	467.6	177.5	357.6	95.3	0.0	0.0	1,724.4
2000	0.0	0.0	0.0	Trace	188.3	352.0	1,130.1	635.3	122.1	6.5	0.0	10.8	2,445.1
2001	0.7	0.0	0.0	1.1	22.4	568.4	534.5	370.2	83.0	78.3	0.0	0.0	1,658.6
2002	0.0	0.0	14.8	0.0	1.9	436.8	103.5	604.9	130.6	0.7	0.0	0.4	1,293.6
2003	0.0	0.0	0.0	0.0	Trace	679.8	763.6	309.9	278.1	0.0	0.0	0.0	2,031.4
2004	Trace	.	0.0	0.0	0.0	30.1	310.1	806.1	786.9	189.6	69.3	4.5	2,196.6
2005	0.8	Trace	Trace	Trace	0.0	560.0	645.0	398.1	593.3	20.4	0.0	Trace	2,217.6
2006	0.0	0.0	7.3	0.0	128.0	430.6	937.5	578.6	184.0	246.0	8.2	0.0	2,520.2
2007	Trace	4.2	0.0	0.0	0.7	803.3	524.8	687.4	420.5	0.0	2.4	0.0	2,443.3
2008	0.0	0.0	0.0	0.0	0.0	735.5	689.6	370.6	348.1	13.4	3.1	0.3	2,160.6
2009	0.0	0.0	Trace	0.0	2.3	265.9	771.3	204.5	519.8	158.3	120.2	Trace	2,042.3
2010	Trace	Trace	0.0	0.3	0.0	947.4	1,099.0	849.8	272.9	122.4	55.7	0.0	3,347.5
2011	0.0	0.1	0.0	0.0	0.7	461.2	1,284.2	798.8	334.4	65.6	0.0	0.0	2,945.0
2012	0.0	0.0	0.0	0.0	0.0	177.1	393.0	520.2	340.0	127.5	0.0	0.0	1,557.8
2013	0.0	0.0	0.0	0.0	0.0	954.7	874.5	234.8	307.2	66.1	6.4	0.5	2,444.2
2014	0.9	7.8	0.0	0.0	0.0	55.0	1,356.9	432.4	291.7	46.2	4.2	30.0	2,225.1
20 yrs Average	0.5	0.7	1.2	0.1	25.4	472.6	724.2	497.1	343.9	94.0	15.0	6.5	2,181.2
	0.0%	0.0%	0.1%	0.0%	1.2%	21.7%	33.2%	22.8%	15.8%	4.3%	0.7%	0.3%	100.0%

Note. "Trace" amount means a micro amount which cannot be measured.

Source: JICA Study Team, IMD

2) Exceedance Probability of Rainfall

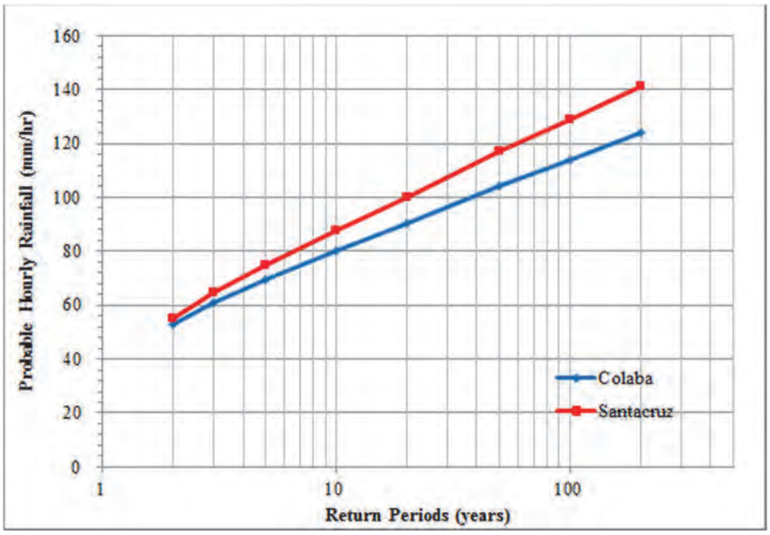
The rainfall pattern analysis has been calculated by Indian Institute of Technology at 2012. The exceedance probability rainfall during 1 hour and 24 hours are shown in Table 5.3.6.

At present, the roadside drainage in Mumbai is designed for rainfall intensity of 50 mm/hr, at a return period of 2 years. However values in the above Table are higher than 50mm/hr. Also, as per rainfall on 26th July 2005, the maximum rainfall intensity per hour was recorded at 190.3 mm/hr.

Table 5.3.6 Rainfall for each Return Period

Return Period (years)		Colaba (mm/hr)		Santacruz (mm/hr)		Remarks
		1 hour	24 hour	1 hour	24 hour	
(year)	(%)	(mm/hour)	(mm/day)	(mm/hour)	(mm/day)	
2	50%	53.1	177	55.2	204	
3	33.3%	60.8	208	64.5	240	
5	20%	69.4	242	74.9	280	
10	10%	80.1	286	87.9	330	
20	5%	90.5	327	100	378	
50	2%	104	281	117	440	
100	1%	114	421	129	486	
200	0.5%	124	461	141	533	

Source: "Study of Spatio – Temporal Variations of Rainfall Pattern in Mumbai City, India", Journal of Environmental Research and Development, Vol. 6 No.3, Jan-March 2012



Source: "Study of Spatio – Temporal Variations of Rainfall Pattern in Mumbai City, India", Journal of Environmental Research and Development, Vol. 6 No.3, Jan-March 2012

Figure 5.3.8 Probable Hourly Rainfall

5.3.4 Hydrological Survey

(1) Characteristics of Rivers Flowing Into the Mumbai Bay

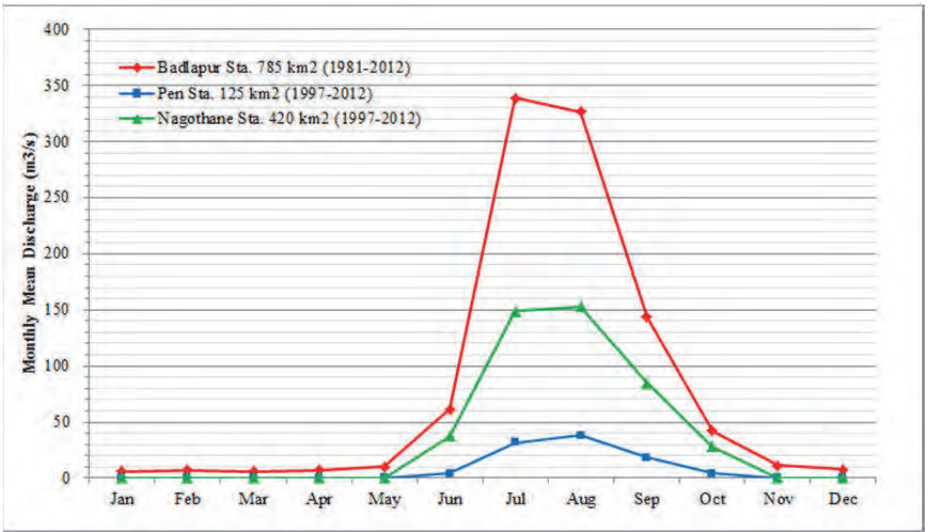
There are no gauging stations in rivers located in the upstream of MTHL. Therefore, the hydrological data of the following 3 gauging stations is collected. (Although the storm water of Pen and Nagothone stations flows into the Mumbai bay, Badlapur station is located in the Ulhas River basin outside of the Mumbai bay basin.)

Table 5.3.7 and Figure 5.3.9 show monthly mean discharge of past observed records at the 3 gauging stations. It shows that the most intense discharge occurs from June to September, the same as the seasonal trend of the rainfall.

Table 5.3.7 Monthly Mean Discharge at Gauge Stations

Station Name	Catchment Area (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean Discharge (m^3/s)
		Monthly Mean Discharge (m^3/s)												
Badlapur	785	6.0	7.3	6.3	7.4	10.3	61.2	339.1	326.5	143.5	42.2	11.0	7.9	1,754
Pen	125	0.0	0.0	0.0	0.0	0.0	4.1	31.8	37.9	18.5	4.2	0.5	0.0	222
Nagothane	420	0.0	0.0	0.0	0.0	0.0	37.5	148.7	153.2	84.5	28.2	0.2	0.0	872
		Monthly Mean Discharge per Catchment Area ($m^3/s/km^2$)												
Badlapur		0.0077	0.0093	0.0081	0.0094	0.0131	0.0780	0.4320	0.4160	0.1828	0.0537	0.0140	0.0101	2.2342
Pen		0.0000	0.0000	0.0000	0.0000	0.0000	0.0326	0.2542	0.3030	0.1482	0.0335	0.0037	0.0002	1.7753
Nagothane		0.0000	0.0000	0.0000	0.0000	0.0000	0.0892	0.3541	0.3648	0.2011	0.0671	0.0005	0.0000	2.0768

Source: JICA Study Team, CWC



Source: JICA Study Team, CWC

Figure 5.3.9 Monthly Mean Discharge at Gauge Stations

The maximum discharges for each return period from the upstream basin of the MTHL, are calculated from past annual maximum discharge data of the 3 stations, as shown in Table 5.3.8. The discharge which flows into the Mumbai bay does not significantly influence the tidal movement in the bay. This is because the maximum discharge of 100 year return period is estimated at only 7340 m^3/s, which is not significant compared with the flow characteristics of the entire bay.

Table 5.3.8 Maximum Discharge each Return Period at Gauging stations

Station Name			Badlapur	Pen	Nagothane	Remarks
Catchment Area (km^2)			785	125	420	
Data No.			32	16	16	
Records of Annual Maximum Discharge (m^3/s)	1981		1557			
	1982		1785			
	1983		2600			
	1984		1631			
	1985		1517			
	1986		3427			
	1987		1503			
	1988		4440			
	1989		1603			
	1990		2707			
	1991		1989			
	1992		2667			
	1993		1500			
	1994		3542			
	1995		1500			
	1996		2372			
	1997		3075	366	1727	
	1998		1978	285	750	
	1999		1240	344	1100	
	2000		2450	212	508	
	2001		1103	223	370	
	2002		3635	242	687	
	2003		2645	89	640	
	2004		3615	281	574	
	2005		4483	732	1290	
	2006		2856	204	910	
	2007		1575	118	1021	
	2008		2209	222	1588	
	2009		2597	87	1063	
	2010		1708	229	853	
	2011		1956	263	768	
	2012		1701	147	1008	
Mean Value		(mm/day)	2348.9	252.8	928.5	
Std. Deviation		σ_{n-1}	907.399	151.202	372.830	
Annual Maximum Discharge each Return Period (m^3/s)	1.1	K_T -1.132	1,322	82	506	
	2	-0.164	2,200	228	867	
	5	0.719	3,002	362	1,197	
	10	1.305	3,533	450	1,415	
	20	1.866	4,042	535	1,624	
	25	2.044	4,204	562	1,690	
	50	2.592	4,701	645	1,895	
	100	3.137	5,195	727	2,098	
	200	3.679	5,687	809	2,300	
	500	4.395	6,337	917	2,567	
Catchment Area of Upstream of MTHL			1,358	km^2		Average Inflow to MTHL location of Mumbai Bay.
Annual Maximum Unit Discharge each Return Period (m^3/sec/km^2)	1.1		(1.6838)	0.6528	1.2059	0.9293 * 1358 km2 = 1262m3/s
	2		(2.8024)	1.8233	2.0649	1.9441 * 1358 km2 = 2640m3/s
	5		(3.8239)	2.8923	2.8493	2.8708 * 1358 km2 = 3899m3/s
	10		(4.5003)	3.6000	3.3687	3.4844 * 1358 km2 = 4732m3/s
	20		(5.1490)	4.2789	3.8670	4.0729 * 1358 km2 = 5532m3/s
	25		(5.3548)	4.4943	4.0250	4.2596 * 1358 km2 = 5785m3/s
	50		(5.9888)	5.1577	4.5118	4.8348 * 1358 km2 = 6566m3/s
	100		(6.6180)	5.8162	4.9951	5.4056 * 1358 km2 = 7342m3/s
	200		(7.2450)	6.4723	5.4766	5.9744 * 1358 km2 = 8114m3/s
	500		(8.0722)	7.3379	6.1118	6.7249 * 1358 km2 = 9133m3/s

Note. The probable discharge per drainage area is estimated by average value between Pen and Nagothane stations.

Source: JICA Study Team, by analysing CWC hydrological data

(2) Tidal Level and Current etc. around the Mumbai Bay

1) Each Statistical Tide Level

The dominant tide in the Mumbai Harbour is the semidiurnal tide with a period of 12 hours and 40 minutes. The tidal chart diagram of the Mumbai port is shown in Table 5.3.9. (Ground elevation of land survey of Mumbai region is normally indicated as zero from the MSL of Mumbai Port, by the regulation of Indian survey datum of SOI.) From the tidal chart diagram, fluctuations of average spring and neap tides are observed as 3.66m and 1.44m. Also, the difference between recorded highest high tide and lowest low tide is 5.85m, the recorded highest high tide including storm surge of cyclone etc. is 5.39m above CD level.

Based on the results of the previous F/S, the design Highest High Tide Level will be taken as +5.60m, above C.D. by the advice of CWPRS.

Table 5.3.9 Each Statistical Tide Level of Mumbai Port

Tide	Above(+) or Below(-)Chart Datum	Above(+) or Below(-) MSL (Indian Survey Datum)
Design Highest High Tide Level (HHTL)	+ 5.60 m	+ 3.09 m
Highest High Water recorded	+ 5.39 m	+ 2.88 m
Mean High Water Spring Tides. (MHWS)	+ 4.42 m	+ 1.91 m
Mean High Water Neap Tides. (MHWN)	+ 3.30 m	+ 0.79 m
Highest Low Water.	+ 2.74 m	+ 0.23 m
Mean Sea Level. (MSL)	+ 2.51 m	+ 0.00 m
Lowest High Water.	+ 2.48 m	- 0.03 m
Mean Low Water Neap Tides. (MLWN)	+ 1.86 m	- 0.65 m
Mean Low Water Spring Tides. (MLWS)	+ 0.76 m	- 1.75 m
Chart Datum Level (CDL)	+ 0.00 m	- 2.51 m
Lowest Low Water recorded.	- 0.46 m	- 2.97 m

Source: JICA Study Team, MbPT

2) Cyclones

Cyclones may occur in the period of May/June or October/November. The last severe cyclone off the coast of Mumbai was experienced in June 1996. Prior to this cyclones occurred in 1992 and 1982.

3) Tidal Currents

The tidal currents in the Mumbai Bay are essentially caused by the tides and are not influenced to any extent by monsoons etc. The tidal flow is unsteady and the magnitude and direction of the tidal current varies with respect to location, time and depth. According to the past observation results of tidal currents which were carried out during June 2004, maximum velocity is observed as 0.77m/s on locations along the proposed MTHL. Also, on the nautical chart, maximum velocity is described as 3knot (1.54m/s) at the time of flood-tide and 2knot (1.03m/s) at ebb-tide. In addition, it was reported that the combination of ebb tide and heavy discharge from creeks during wet weather, at times, resulted in currents of up to 4 knots (2.06m/s).

4) Waves

The predominant waves are the swell waves generated by deep sea storms.

The predominant direction of waves is from the South West during June to September. These waves arise mainly just before and during monsoons with wave heights reaching a maximum of 1.5 m under normal conditions and wave period ranging from 6 to 10 seconds, although the wave heights can be much higher during cyclonic storms. (The study on development of the port of Mumbai in India, Final report, 1998, JICA)

During the continuance of the North-East monsoon, North-Easterly winds known as "Elephantas" blow for short durations during the months of October-November. As the fetch-length and duration of these winds are limited, the "Significant height" of the resulting waves is not likely to exceed 1 metre with period ranging from 3 to 5 seconds.

5) Siltation

It is a well-known fact that Mumbai Bay is prone to siltation. Although the rate of siltation is not alarming, it is quite substantial and cannot be ignored. The problem of siltation is mainly due to tidal action which causes the movement of a large water mass which fills and empties the creeks, resulting in the influx of silt. In addition to the tidal activity, other factors such as strength and direction of currents, river discharges, wave action, flow conditions, salinity changes and nature of the bed contribute to the amount of siltation in the harbour. The patterns of the currents play all important roles in transporting sediments and redistributing the bed material within the harbour. The bed material, being very fine in nature, is easily brought to suspension by the slightest disturbance and is transported depending on the direction and speed of current. And, the moment currents become weak, the material in suspension begins to settle rapidly.

A number of siltation studies have been carried out in the past by various organisations. According to the mathematical model studies for siltation of CWPRS (technical report No.4030), the siltation in the vicinity of MTHL had been forecast to reach the following depths:

- Pir Pau Channel, Turning Circle, Berth (New) 0.67m
- Pir Pau Berth (Old) 2.00m
- Pir Pau Channel and Turning Circle (Old) 0.70m, 1.30m

(3) Estimation of Storm Surge and Astronomical Tide

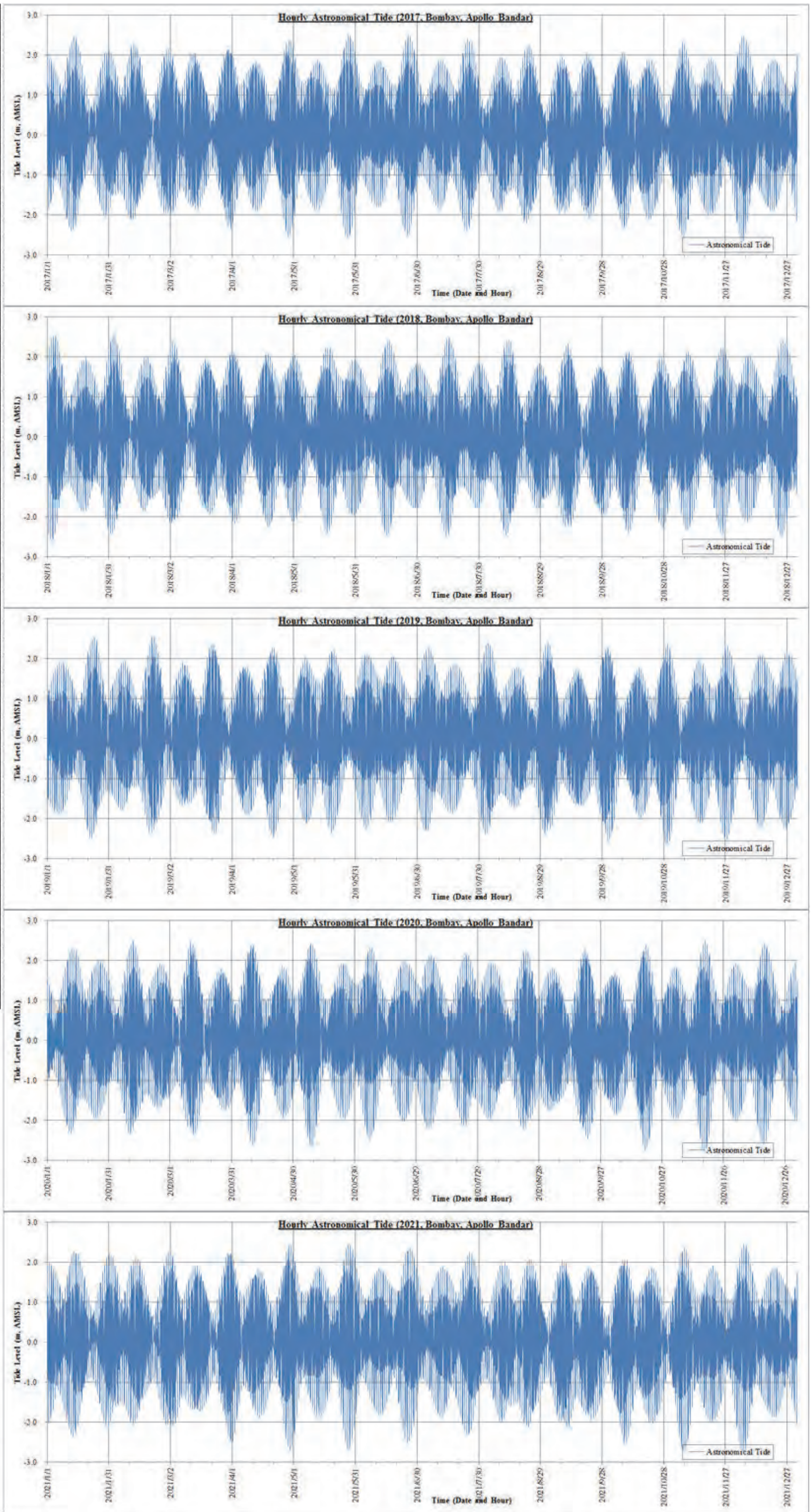
1) Astronomical Tide

Harmonic analysis of astronomical tide had been performed by SOI. The harmonic constants of 60 tidal components at Mumbai station (Apollo Bandar) by SOI are shown in Figure 5.3.10. The astronomical tides in the future years of 2017-2021 were calculated and predicted by using 40 constants among these constants. These results are useful for the work plan by ship or barge for MTHL construction.

2) Storm Surge

Storm surge heights depend on the intensity of the cyclone and consequent very strong winds and the topography of the seabed near the point where a cyclone crosses the coast. Elevation of the total sea level increases when peak surge occurs at the time of astronomical high tide. The coastal belt around the Mumbai Bay is also vulnerable to significant surges. However, past studies or the informative references concerning the prediction of storm surge for the Mumbai bay area are few. Therefore, in the detailed design stage of MTHL, the prediction of storm surge shall be studied, together with the potential of Tsunami generation.

Location	Bombay		
Latitude	18	55	18.91667
Longitude	72	50	72.83333
Z0	251.5	2.515	
code	Amplitude:H		Lag:g
Sa	4.3	0.043	33.1
Ssa	3.6	0.036	187.4
Mm	1.7	0.017	145.4
MSF	0.9	0.009	184.5
Mf	1.6	0.016	28.0
2Q1	0.6	0.006	33.4
σ1	1.3	0.013	78.8
Q1	4.1	0.041	58.0
ρ1	0.8	0.008	55.9
O1	20.1	0.201	51.8
MP1	0.9	0.009	79.4
M1	1.4	0.014	49.9
χ1	0.6	0.006	32.9
π1	1.1	0.011	45.2
P1	11.8	0.118	55.7
S1	2.1	0.021	183.9
K1	42.5	0.425	55.5
ψ1	0.3	0.003	104.8
φ1	0.9	0.009	52.1
θ1	0.3	0.003	25.3
J1	3.3	0.033	78.5
SO1	0.8	0.008	172.9
OO1	2.2	0.022	97.8
OQ2	0.9	0.009	128.2
MNS2	1.2	0.012	279.8
2N2	5.4	0.054	280.8
μ2	6.2	0.062	319.1
N2	28.7	0.287	326.5
ν2	5.3	0.053	318.2
OP2	1.5	0.015	102.7
M2	122.7	1.227	345.4
MKS2	1.8	0.018	253.6
λ2	0.5	0.005	13.8
L2	2.9	0.029	328.2
T2	3.0	0.030	43.9
S2	47.9	0.479	24.6
R2	1.2	0.012	327.6
K2	13.0	0.130	14.1
MSN2	1.3	0.013	74.0
KJ2	0.9	0.009	166.5
2SM2	1.4	0.014	139.1
MO3	1.6	0.016	94.6
M3	2.0	0.020	45.5
SO3	1.1	0.011	200.7
MK3	0.8	0.008	191.0
SK3	3.1	0.031	241.7
MN4	0.7	0.007	296.1
M4	3.5	0.035	321.6
SN4	0.1	0.001	1.7
MS4	3.2	0.032	42.6
MK4	0.9	0.009	4.6
S4	0.6	0.006	297.3
SK4	0.3	0.003	210.5
2MN6	0.7	0.007	48.9
M6	0.7	0.007	61.7
MSN6	0.2	0.002	95.5
2MS6	0.7	0.007	68.6
2MK6	0.6	0.006	66.5
2SM6	0.2	0.002	164.7
MSK6	0.2	0.002	69.2



Source: JICA Study Team, MMB (SOI)

Figure 5.3.10 Harmonic Constants and Astronomical Tide Forecast at 2017-2021

5.3.5 Hydraulic Effect due to the Construction of MTHL

Regarding the hydraulic impact due to the construction of MTHL, the CWPRS has studied the approved alignment finalized by the experts and the span arrangement proposed in the Feasibility Study of 2012. (CWPRS Technical report No. 5165, 2014)

The CWPRS have given the observations that "The proposed alignment will not have adverse impacts on the overall tidal hydrodynamics of the region under consideration". In other words, it is concluded that existing condition for tides and tidal-currents will not have significant changes, and shows that it does not have any hydraulic impacts under the conditions of the MTHL alignment and the span arrangement at the time of the 2012 F/S.

5.4 Utilities, Facilities and Navigation Survey

5.4.1 General

The utility and navigational survey is conducted in order to clarify the specifications (location, size, kind, owner, etc.) of the utilities, obstacles and navigation channels (under-ground utilities, aerial lines, power poles, hazardous objects, marine structures, etc.) for preparing a plan of MTHL.

5.4.2 Survey Items for Utilities, Facilities and Navigation

The survey for the utilities, obstacles, and navigation, will be conducted to assist the following organizations, as shown in Table 5.4.1. In the survey, their category, utility owner, location, kind, size, and construction year etc. will be clarified. Also, as the need arises, the comments from these organizations regarding the alignment of the proposed MTHL will be collected, and the as-built drawings, the present-state survey and the future plans, etc. will also be collected.

Table 5.4.1 Survey Items for Utilities, Facilities and Navigation

Section		Length	Main Utilities and Obstacles	Organization (Utility Owner)	Remarks
1	Mumbai Side (Sewri) Land Section	0.49 km	Power Cable/Pole Under-ground Utilities Existing Road Existing Railway Others	IOCL, BPCL, BMC, HPCL, and Others	
2	Marine (Mumbai Bay) section	18.33 km	Tata Intake/Discharge Channel Tata Coal Berth Channel Oil, Product, Freshwater Pipelines Power, Telephone Cables Pir Pau Jetty Thane Creek (Navigation Channel) ONGC&BPCL&Reliance Pipelines Panvel Creek (Navigation Channel) Others	MbPT, ONGC, BPCL Refinery, Reliance, TATA power, and Others	
3	Navi Mumbai side (Chirle) Land section	3.39 km	Power Cable/Poles Under-ground Utilities Existing Road Proposed Road Existing Railway Others	MJP, Deepak Fertilizer, CIDCO, GAIL India Limited, and Others	

Source: JICA Study Team

5.4.3 Utilities

The location and size, etc. of the seabed pipelines (ONGC, Reliance, etc.) in the marine portion are shown in Table 5.4.2 and Figure 5.4.1. Regarding utilities in the land portion, there are also many utilities on the roads as listed in Table 5.4.4. And details of their utilities are shown in Appendix (subcontract report) and drawings.

Source: JICA Study Team

Figure 5.4.1 Location Map of Seabed Pipelines and Cables

Table 5.4.2 Utility List at Marine Portion

No.	Chainage	Utility Name	Size (inch)	Purpose	Remarks
1	4 + 960.0	TATA/BPCL Power Cable	-	Power	
2	5 + 270.0	ONGC Seabed Pipeline	36" * 2	Oil	
3	5 + 400.0	MbPT Seabed Pipeline	8"	Fresh water	
4	5 + 400.0	MbPT Seabed Pipeline	30"	White oil	
5	5 + 400.0	MbPT Seabed Pipeline	30"	White oil	
6	5 + 400.0	MbPT Seabed Pipeline	30"	White oil	
7	5 + 400.0	MbPT Seabed Pipeline	36"	Black oil	
8	5 + 400.0	MbPT Seabed Pipeline	42"	Crude oil	
9	5 + 480.0	MbPT Seabed Pipeline	8"	Fresh water	
10	5 + 500.0	MbPT Seabed Pipeline	12"	White oil	
11	5 + 510.0	MbPT Seabed Pipeline	16"	Naptha	
12	5 + 530.0	MbPT Seabed Pipeline	16"	HSD	
13	5 + 545.0	MbPT Seabed Pipeline	24"	Black oil	
14	5 + 560.0	MbPT Seabed Pipeline	24"	Crude oil	
15	5 + 575.0	MbPT Seabed Pipeline	24"	Crude oil	
16	12 + 20.0	ONGC Seabed Pipeline	8"	LPG	
17	12 + 20.0	ONGC Seabed Pipeline	8"	NGL	
18	12 + 20.0	ONGC Seabed Pipeline	18"	Gas	
19	12 + 20.0	ONGC Seabed Pipeline	36"	Oil	
20	12 + 200.0	ONGC Seabed Pipeline	36"	Oil	
21	12 + 300.0	ONGC Seabed Pipeline	20"	Gas	
22	12 + 350.0	BPCL Seabed Pipeline	10"	LPG	
23	14 + 100.0	Reliance Seabed Pipeline	12"	Petroleum	This does not cross.

Source: JICA Study Team

5.4.4 Utilities and Clearances

(1) Clearances of General Marine Viaduct Section

At the general viaduct in the marine section, the horizontal clearance is kept at a minimum 50m and the vertical clearance is kept at a minimum 9.1m above HHTL. The HHTL is 5.8m above Elevation 0.00 (Chart Datum)

(2) Crossing Utilities in Marine Portion

There are some crossing utilities in the bridge alignment in the marine section. The kind and the required horizontal clearances for them were investigated and the result is shown in Table 5.4.3.

Table 5.4.3 Crossing Utilities and Clearances in Marine Portion

Utility	Chainage	Horizontal Clearance	Vertical Clearance	Source
Tata Thermal Power Station, Intake and Discharge Channel	3+560	1x94m	25.2m (above HHTL)	Agreed in Detailed Feasibility Study, 2012.
Tata Thermal Power Station, Coal Berth Channel	4+830	2x94m	25.2m (above HHTL)	Ditto
Tata Power Cable (1 cable)	4+960	Comfortable separation distance is more than 25m (minimum distance is 15m)	-	Ditto
ONGC Pipeline (2 pipelines)	5+270			Ditto
Tata/MbPT Pipeline (13 pipelines)	5+400 ~5+575			Ditto
Pir Pau Jetty Head	5+800	-	6.0m (above jetty surface)	Confirmed in Detailed Feasibility Study, 2012.
Thane Creek	8+900	2x94m	25.2m (above HHTL)	Letter from MMB on 31/8/2012[32].
ONGC Pipeline (6 pipelines)	12+20 12+200 12+300	Comfortable separation distance is more than 25m (minimum distance is 15m)	-	Minutes of Meeting with ONGC and CES on 2/5/2012[33].
BPCL Pipeline (1 pipeline)	12+350			Agreed in Detailed Feasibility Study, 2012.
Panvel Creek	13+290	2x100m	25.2m (above HHTL)	Letter from MMB on 31/8/2012.

Source: JICA Study Team

(3) Crossing Utilities in Land Section

There are some crossing roads and railway in the bridge alignment in the land section. The clearances of the crossing roads are shown in Table 5.4.4.

32 Letter No. MMB/ENG/MTHL/1942, 31st, August, 2012
33 Minutes of Meeting, ONGC and CES, 2nd, May, 2012

Table 5.4.4 Clearances of Crossing Road

Crossing Road	Chainage	Vertical Clearance	Source
Eastern Freeway and B Ramp	0+000	5.5m above road surface	IRC SP 87-2013
Jetty Road	0+480		
Nhava Road	16+820		
Proposed CIDCO Coastal Road	17+300		
Proposed CIDCO Road	18+050		
Gavhan Road to School	18+170		
Proposed CIDCO Road	18+300		
Proposed CIDCO Road	18+540		
Proposed CIDCO Road	18+880		
Existing Road	20+170		
NH 54 (Road)	20+970		
JNPT Road (NH4B)	21+650		

Source: JICA Study Team

The clearances of the crossing railways are shown in Table 5.4.5.

Table 5.4.5 Clearance of Crossing Railway

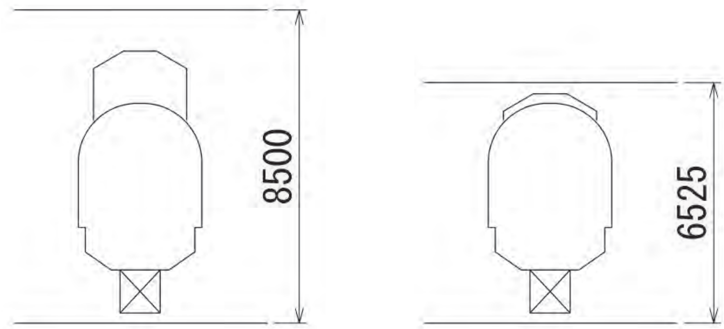
Crossing Railway	Chainage	Horizontal Clearance	Vertical Clearance	Source
Railway (Sewri station - Cotton Green station)	0+000	Refer to drawings of the source	8.5m above rail track	Drawing No. MMRDA-102/SEWRI-WORLI-MTHL/SEWRI-ROB/RLY/
Suburban Railways (Seawood – Uran)	18+500		6.5m above rail track	Drawing No. 2180581/ I/ ROB-01[34], MMRDA
Railway (DFCC Corridor, Panvel Uran, JNPT railway)	21+200 to 21+350		8.5m above rail track	Drawing No. 2180581/ I/ ROB-01[35], MMRDA

Source: JICA Study Team

The clearance limit of railways is shown in the following Figure.

[34] Construction of ROB on Nerul – Uran Line at between KM 44 – 45 at Railway Construction Department CH 8+400, Drawing No. 2180581/ I/ ROB - 01

[35] Construction of ROB on MTHL (CH. 21+333) across Panvel – Uran/ JNPT RLY. Line between KM. 83/23 – 83/27, Drawing No. 2180581/I/ROB - 01



Railway (Sewri - Cotton Green, DFCC corridor, Panvel-Uran, JNPT Railway)

Suburban Railway

Source: JICA Study Team

Figure 5.4.2 Vertical Clearance of Railways

5.4.5 Other Information related to the MTHL Project

(1) Port Facility, Port Limit and Navigation Channel

The port facility and the channel for navigation etc. in the vicinity of the MTHL are listed in Table 5.4.6. Among the listed facilities, eight facilities and channels cross the MTHL. The port limit between MbPT and JNPT is located at CH.10+580, as shown in Figure 5.4.3.

Table 5.4.6 Port Facilities and Channels in the Vicinity of MTHL

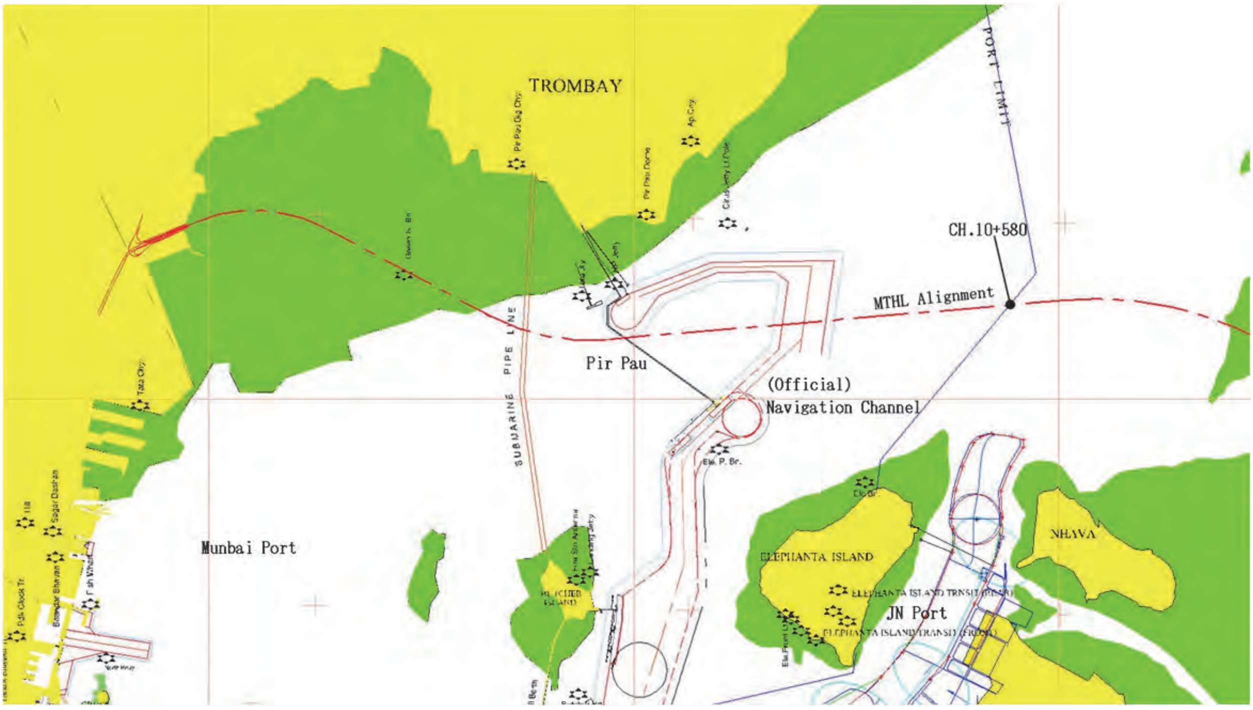
	No.	Chainage	Port Facility Name	Size, Type	Remarks
	1	0 + 500.0	Sewri Ford Jetty		
Crossing	2	3 + 550.0	TATA Discharge Channel	94m width * 1 channel	
	3	4 + 870.0	TATA Coal Berth Jetty		
Crossing	4	4 + 870.0	TATA Coal Berth Channel	94m width * 2 channels	
Crossing	5	5 + 300.0	TATA Coal Conveyor	5m width * 1	future plan
	6	5 + 790.0	BSR/TATA Jetty		
Crossing	7	5 + 790.0	TATA Cooling Water Channel	94m width *1 channel	
Crossing	8	6 + 30.0	Pir Pau Jetty		
	9	6 + 150.0	Stanvac Jetty		
Crossing	11	8 + 900.0	Navigation Channel for Thane Creek (Trombay Channel)	94m width * 2 channels	
Crossing	12	13 + 320.0	Navigation Channel for Panvel Creek	94m width * 2 channels	

Source: JICA Study Team

(2) Vessel Operating Route in the Existing Channel

Figure 5.4.3 shows the navigational channel map (CAD) collected from MbPT.

The existing navigation channel is dredged once a year after monsoonal season, for maintaining the fairway depth as shown on the nautical chart.



Source: MbPT

Figure 5.4.3 Navigation Channel around MTHL Alignment