MUMBAI METROPOLITAN REGION DEVELOPMENT AUTHORITY
THE REPUBLIC OF INDIA

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

FINAL REPORT

July 2016

JAPAN INTERNATIONAL COOPERATION AGENCY

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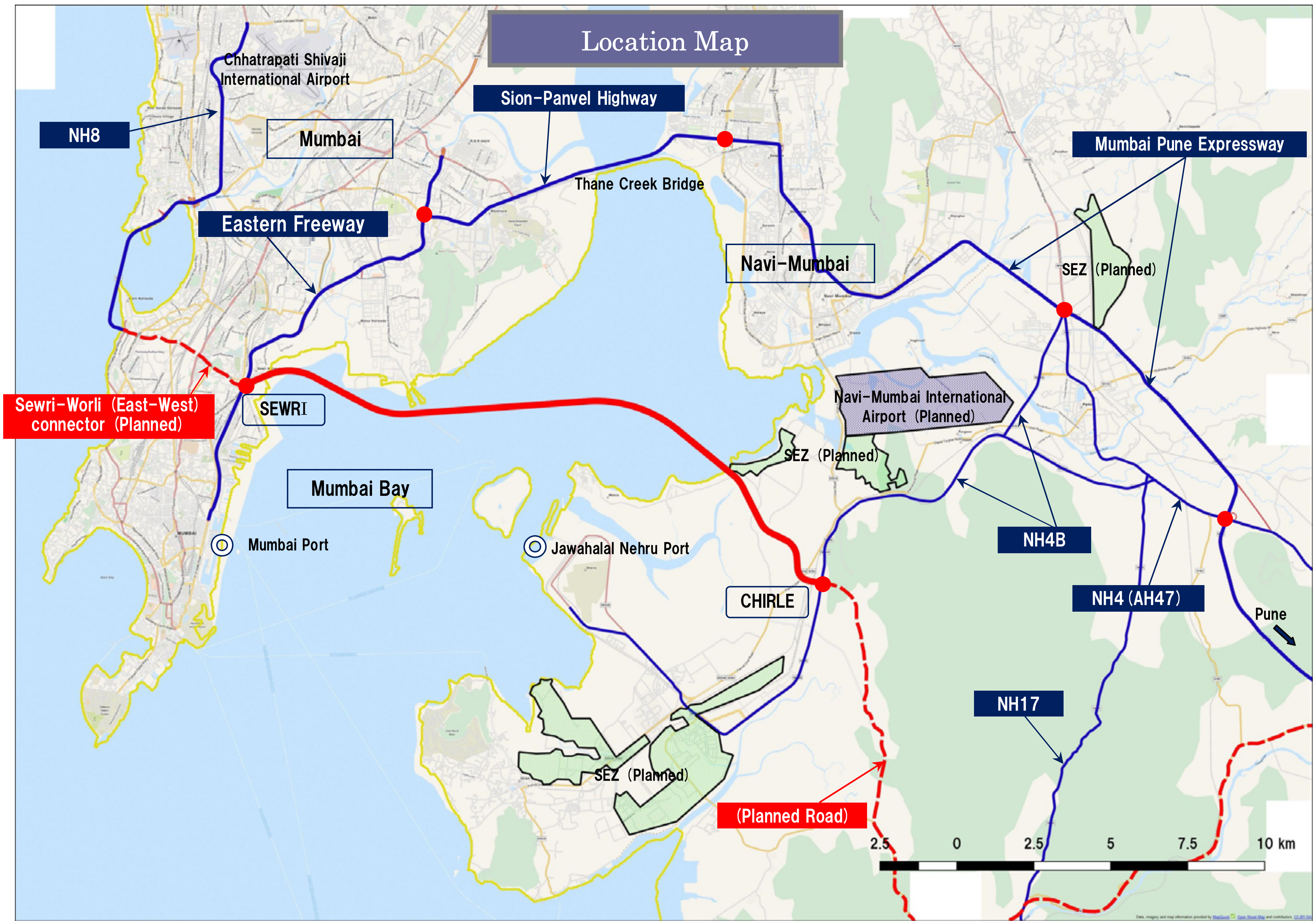

Location Map
Chhatrapati Shivaji International Airport
Sion-Panvel Highway
NH8
Mumbai
Mumbai Pune Expressway
Thane Creek Bridge
Eastern Freeway
Navi-Mumbai
SEZ (Planned)
Sewri-Worli (East-West) connector (Planned)
SEWRI
Navi-Mumbai International Airport (Planned)
SEZ (Planned)
Mumbai Bay
Mumbai Port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

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In

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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, infrastructure development in the urban areas has not caught up its development speed. Particularly, the heavy traffic congestion in the urban areas due to a lack of road network hinders the economic development in the urban areas. Given this situation, the necessity of comprehensive infrastructure development plan was given the importance for the growing economic developments in the 12th Five-Year (April 2012 to March 2017) investment plan.

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

The Navi Mumbai which is in the east side of Greater Mumbai across the Mumbai Bay and 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 the 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) had invited bids in 2013 for implementation of the MTHL project on 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 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 long full access-controlled link across the Mumbai bay between Sewri in Mumbai and Chirle in Navi Mumbai with 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 to 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 topographic survey, geological investigation, traffic survey, 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 road and bridge
- 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 Feburary2016 : Submission of Draft Final Report
- Middle of June 2016 : Submission of Final Report

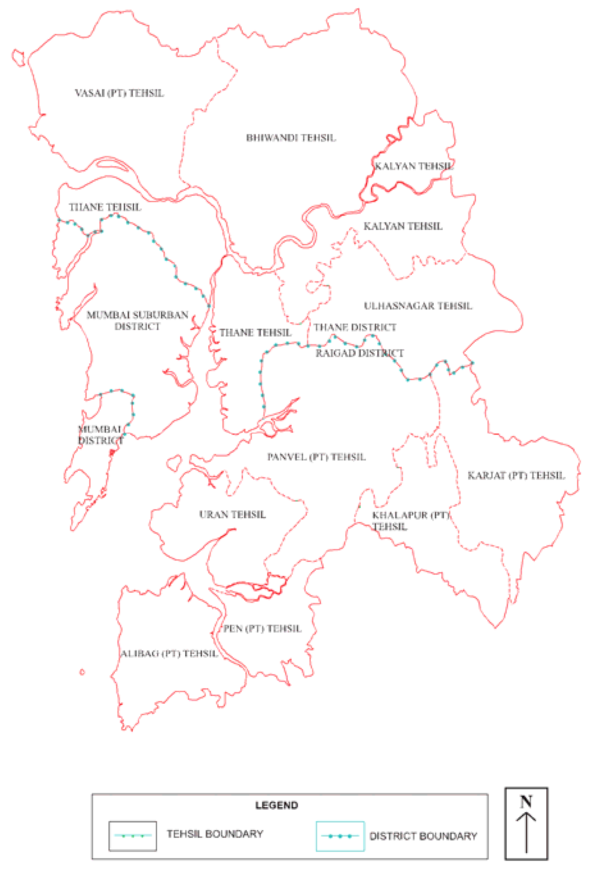
2. GENERAL APPRECIATION AND DEVELOPMENT PLAN

2.1 Socio-Economic Conditions of the Project Area

2.1.1 Introduction

India is located in the south Asia and is the second most populous country holding 12.1 billion people (2011) in the seventh largest by area with 3.28 million km^2 in the world. 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 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.

Mumbai is the largest city in India has and it functions not only as the capital of the Maharashtra State but also the gateway of 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 slum and migrant population. The following classifies the administrative jurisdiction related to the Mumbai area.



Source: Comprehensive Transportation Study, MMRDA, 2008

Figure 2.1.1 MMRDA Jurisdiction 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 area in the world, comprising 8 Municipal Corporations such as 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 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 particularly in Greater Mumbai. Furthermore, since the Mumbai Bay forms a natural harbour, namely Mumbai Port at Greater Mumbai side and Jawahalal Nehre Port at Navi Mumbai side, maritime trade of 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 plan but also implementing the strategic project as well as financing infrastructure development in MMR.

2.1.3 Greater Mumbai Area

Greater Mumbai, which was previously known as Bombay, lies on the peninsula with a width of 12km where it is broadest and approximately 40km in length in the north-south extent 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 has 437 km^2 with the population of 12.48 million in 2011. Many historical buildings such as the Gate of India, Mumbai Station and administrative bodies and financial centers are located in this area.

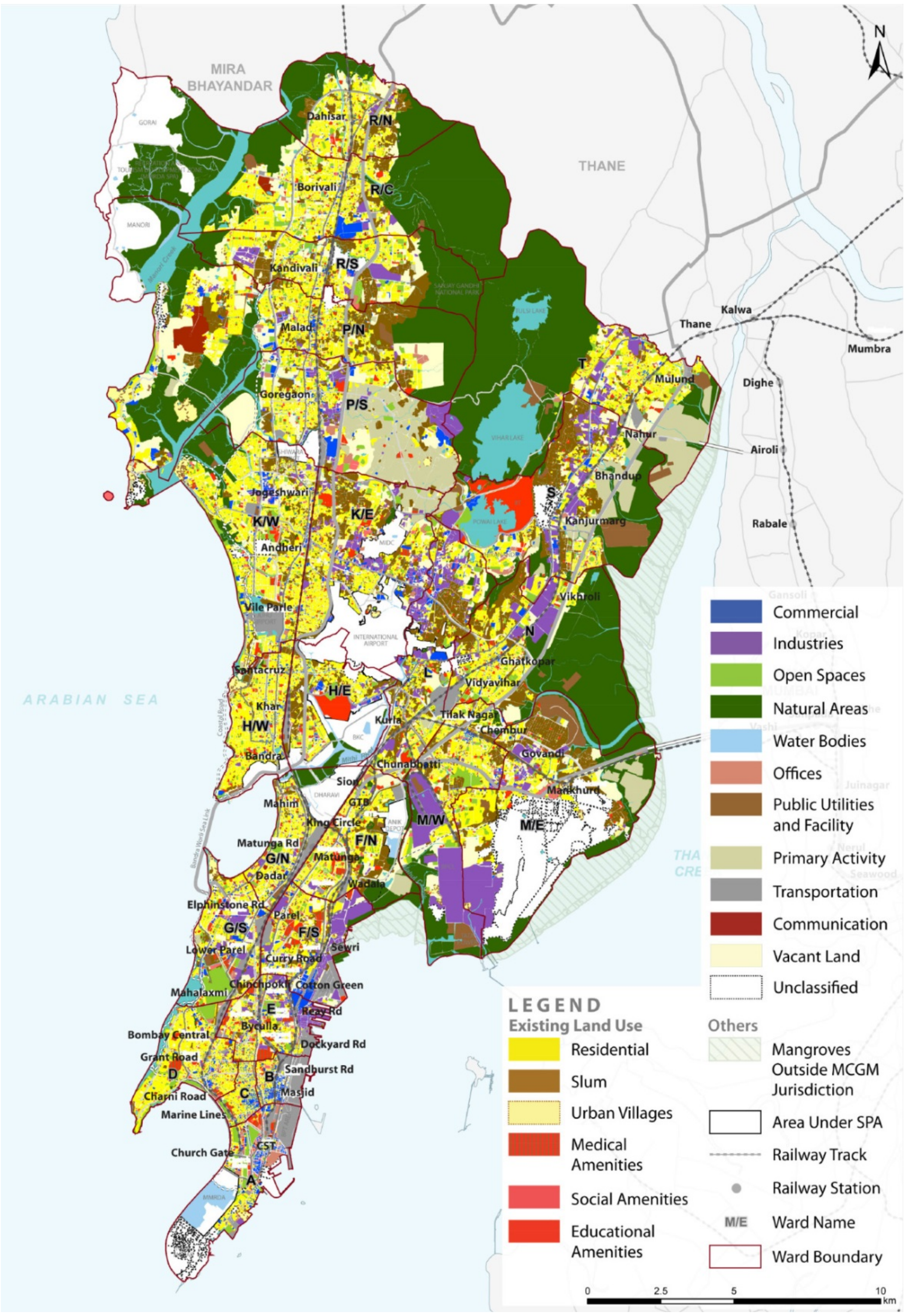
The area started its development in 16th century after the cession of a group of islands to Portuguese, and then possession of Britain in 17th century as the gateway of India. Until the 1970th, Great Mumbai owned its property for textile mills and sea ports. However, the local economy has gradually diversified 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 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 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 the 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 bus and railways from suburban areas.

Great Mumbai holds 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, who is operating the port owned by the Government, the Mumbai Port handled traffic of 59.18 MT, which accounts for 10.65% of 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 recommended by Mumbai Metropolitan Regional Planning Board under the Maharashtra State.

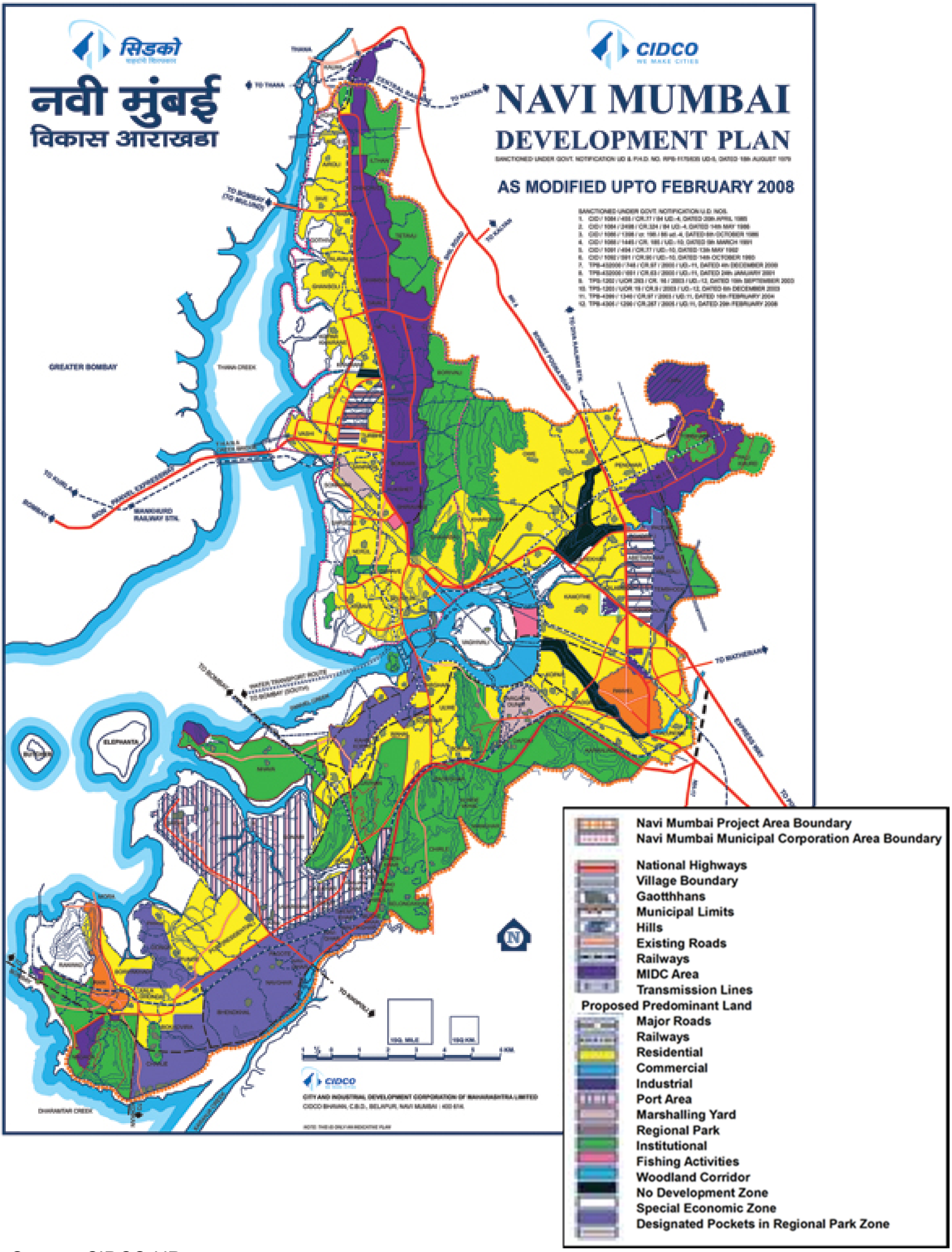
The development area of Navi Mumbai spreads 344 km^2 with 150km of creek line, including 14 well-planned nodes along mass transport corridors, and 45% of the land reserved for green area. According to the latest census in 2011, the population of Navi Mumbai is approximately 1.12 million, of which 35% 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 attracting 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 vegetable 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 peoples 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 chartered Indian's International trade 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 12th National Development Plan (2012-2017)

Although the economic growth in the Eleventh Plan (2007-2011) period achieved almost 7.9% compared to the 8% target as a whole, the economic growth has slowed down to 6.2% in 2011-12 due to not only the global economic crises, but also stagnation of major investment projects in energy and transport with a variety of implementation problems as well as some changes in tax treatment in the 2012-2013, and the period of 2012-2013, which is projected to be lower.

In this circumstance, the Twelfth National Development Plan (The Twelfth Plan) for 2012-2017 was formulated through participatory process with various stakeholders. The Twelfth Plan aims to reverse the present slowdown trend of economic growth to upward to the average 8% in the target period through increase in investment and application of revival policies to bring back the many strength of the economy which India has already held.

For achieving this goal, the Twelfth Plan targets three pillars of the visions; Faster, More Inclusive and Sustainable Growth. The Twelfth Plan emphasizes the necessity of the faster economic growth not only because it expects to improve the income of people and production in all sectors, but also enables financial capital programs for inclusiveness to expand their programs to the poor and the excluded groups. The second vision of “More Inclusive” has a variety of dimensions in the policy application. This vision contains “Inclusiveness as Poverty Reduction”, “Inclusiveness as Group Equity”, which targets different socio-economic groups, including cast , tribe, and other backward classes, “Inclusiveness as Regional Balance”, and “Inequality” in terms of income and living standards, and “Inclusiveness as Empowerment”, which facilitates empowerment and participation not only marginal groups and women but also improvement of governance, accountability of government staff. The third vison “Sustainable Growth” stresses on reconciling the development and protecting environment as well as focuses on application of countermeasures against the climate change issues because it is said that India will be one of the countries most severely affected from global warming sequences.

The Twelfth Plan emphasizes not only the necessity of capacity development of relevant institutions but also infrastructure development in order to achieve the realization of “Faster, More Inclusive and Sustainable Growth”. In the former topic, the national government will establish National Investment Approval Board chaired by the Prime minister and including all key ministries in order to deal with statutory clearances under various Acts for large scaled infrastructure projects. In terms of the latter aspect, although the Twelfth Plan addresses the policies in all sectors associated with infrastructure development, it focuses on the aggressive promotion of PPP scheme for toll roads projects under BOT basis as well as improvement of the connectivity by roads in Jammu & Kashmir, the North East and other Special Category States. As a target to be achieved in the road sector, the Twelfth Plan stipulates the following targets;

- Connect all villages with all-weather roads by the end of the Twelfth Plan
- Upgrade national and state highways to the minimum two-lane standard by the end of the Twelfth Plan
- Complete Eastern and Western Dedicated Freight Corridors by the end of the Twelfth Plan

2.2.2 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 emphasizing on the importance of institutional and human resource development, financial arrangement, and participation of 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 coordinate with planning of railway network development, connectivity with ports, airports, SEZ, and logistic hub
- Continuation of expansion of rural connectivity through the current Pradhan Mantri Gram Sadak Yojana (PMGSY) scheme.
- Further expansion of 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 Road Safety and Traffic Management Board to tackle the road safety issues

2.2.3 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 from 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) of which National Highways	22	24	24	32	34	58	71
(iii) of which State Highway	-	-	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 next 20 years envisages to achieve the expansion of 12,500 km for Expressway network, and 180,000km for National Highway one 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. From the table, the Government planned the huge amount of investment (approximately average 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 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

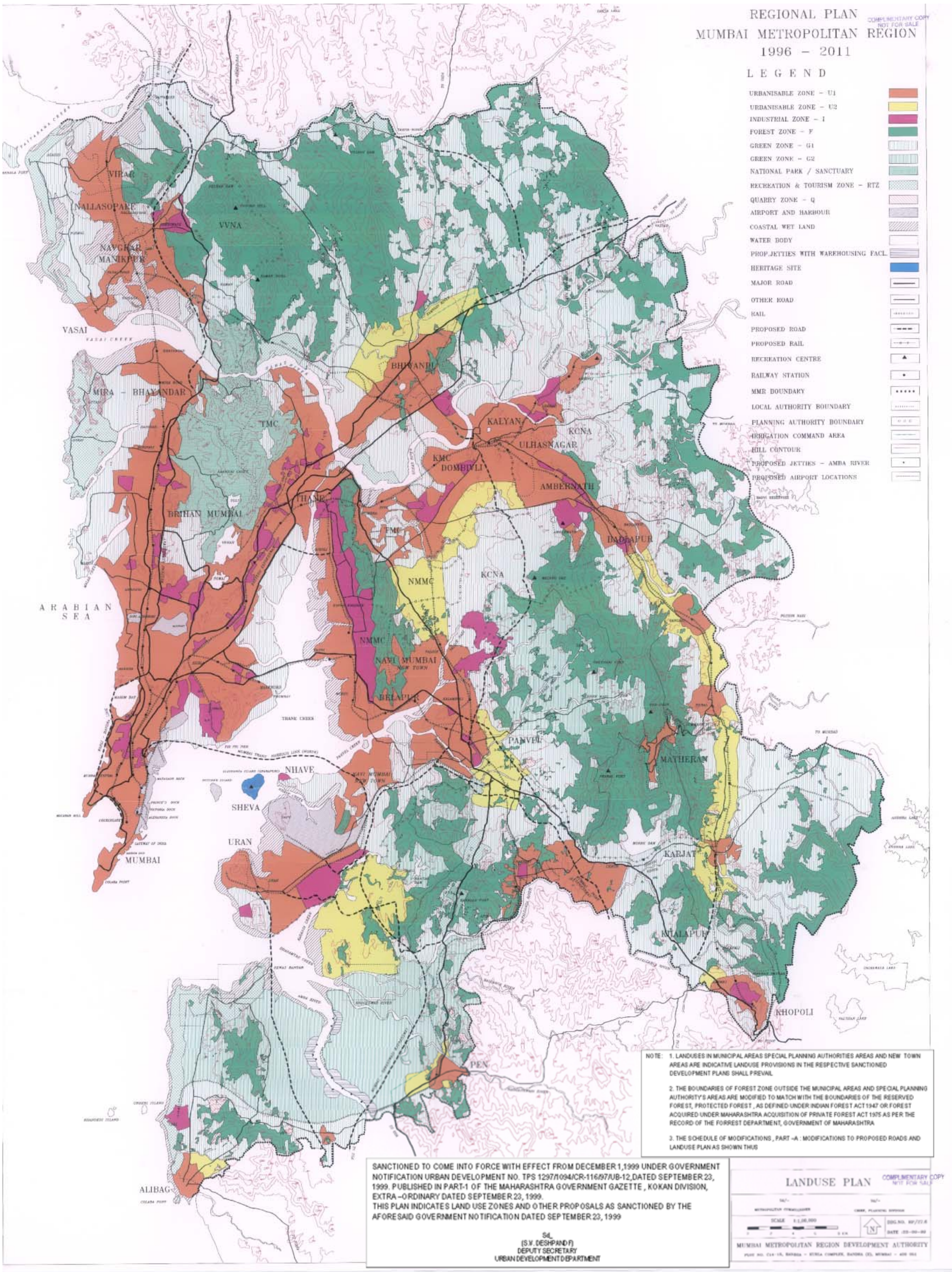
Remarks: SARDP-NE: Special Accelerated Road Development Program in North East under Ministry of Development of North Eastern Region

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 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 the four study groups comprising (1) Land Use, (2) Industry and Investment, (3) Environment, (4) Transportation, and (5) Housing and envisage to include outputs of the CTS, business plan for MMR, Chitale Committee Report and Concept Plan for MMR. Figure 2.3.1 shows the 1st revision of Regional Development Plan for MMR (1996-2011).



Source: MMRDA

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

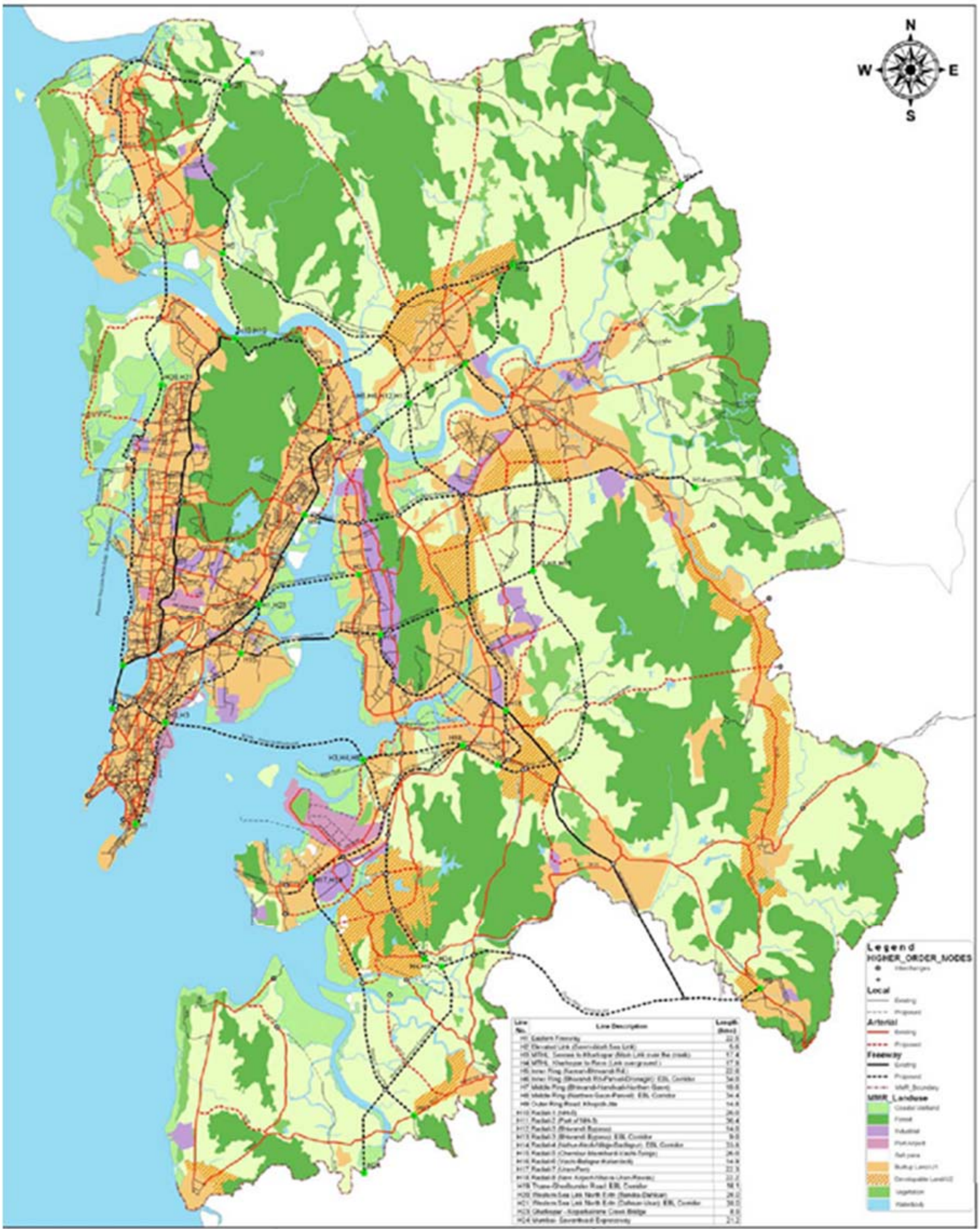
2.3.2 Comprehensive Transportation Study (CTS) for MMR

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 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 Corridor 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 to developing the metro and suburban railway network in the MMR, it also proposed to develop the highway network in the region with 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 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 recently available data for the road network of MMR, the CTS report described that according to MMRDA's estimate as of 1998, the total length of road network in MMR is 7,003.5 km, out of which National Highways, State Highways and Major District Roads is 942.87km. In the Greater Mumbai area, whereas 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 situations 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 lane, the width of ROW, and pavement conditions. 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

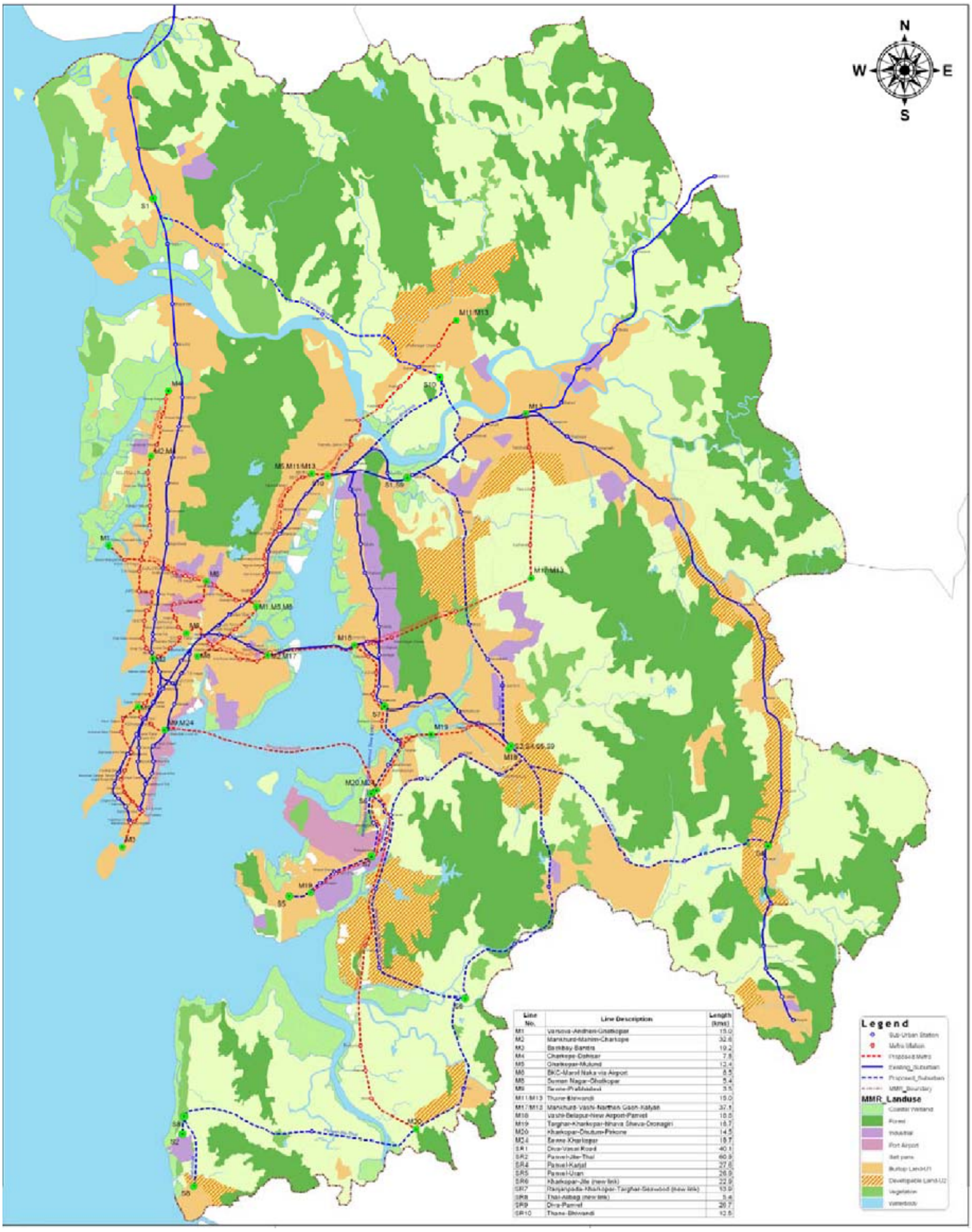
In terms of the number of lane, whereas 52.5% of the total road network has 2-lane road, 31.0 % of the total road network has more than 4-lane roads. The remaining is a single lane road.

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. On the one hand, the 23% of the total length is in poor condition.

2.3.4 Other Transport System in MMR

Public transport comprising train and bus has been mainly utilized by people in MMR rather than a private car according to the CTS for MMR. Particularly, train mode for passenger accounts for 52%, particularly relatively long distance trip 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 average trip length of 26km. Bus system is also predominant transport mode in MMR. The bus mode carried 3.55 million passenger in 2005, which occupies 26.3% of total travel demand in MMR. Further improvement and expansion of suburban railway system has been implemented in Mumbai Transport Project II approved in 2010 supported by WB.

In addition to suburban railway and bus system, mass transit system has been implemented with PPP scheme in mainly 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 Location Map.

2.4.2 Navi Mumbai International Airport

Due to fast reaching saturation of the existing Mumbai Airport, which was receiving 29 million passengers in 2011-12, located in Greater Mumbai and further enhancement of passenger and freight handling capacity, the Navi Mumbai International Airport has been under planning at the Navi Mumbai side. According to the plan of the Navi Mumbai International airport plan managed by CIDCO, the airport spreads 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 aircrafts 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 into 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	Operations Year	Traffic (Million Passenger per Annual)	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 and modified the operations year based on the interview to CIDICO by 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 will be selected within 2015 and the construction work will be commenced in early 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 a 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 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 due to mainly non-enactment of the Maharashtra SEZ Act, global recession and difficulty to attract the investors due to 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, road with drainage system 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 presently 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 IRs 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 ship, which have the capacity to carry more than 3,000 TEU for the fourth generation and more than 6,000 TEU for the fifth one, comparing to the current third generation cargo with up to 3,000 TEU. Furthermore, an additional railway track connecting the Indian Railway, 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 Firm's Operation in India

2.5.1 Introduction

According to the list of Japanese firms operating in India as of Oct. 2013 prepared by Embassy of Japan and JETRO, there are 1072 of 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 the sales office, 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 finance, insurance, trading and logistics sector. On the one hand, there are 105 of the business bases of the Japanese firms in Pune and its surrounding area. Since many foreign manufacturers particularly in auto mobile sector have established its production base in the area because of availability of educated human resources and advantageous location to deliver the products to the local market of India, the Japanese manufacturers including automobile and its related device production have built the 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 the new industrial zone in Pune exclusively for Japanese manufacturers and 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 Pune area in future.

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

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 one firm, 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 Company 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 have 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's 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 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.

According to the 12th Five-Year Plan (2012-17), approximately USD 1 trillion is planned to invest for the infrastructure over this period. 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

However, there are some issues to be solved for further development of the industry. The 12th Five Year Plan pointed out the issues; (i) Insufficient structured training and skill building programs, (ii) No unified legal framework regulating the construction industry in India, (iii) Lack of efficient and stable system for dispute resolution, (iv) Inadequate financing scheme to the construction firms, (v) Low investment of the firms in the research and development to acquire the cutting-edge technology.

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 the registration system for the contractors who have intention to participate in the public works. According to “Enlistment Rules 2005” established by 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 experiences of the completed works in last 5 years, (ii) Financial soundness, (iii) Engineering establishment including the necessary number of the 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 with INRs 20, two for roads and one for any civil works or 2 projects with INRs 40 or 1 project with 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 with INRs 8, two for roads and one for any civil works or 2 projects with INRs 12.5 or 1 project with 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 with INRs 2, two for building and one for any civil works or 2 projects with INRs 3, one for building and one for any civil one or 1 project with 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 with INRs 8, two for roads and one for any civil works or 2 projects with INRs 12.5 or 1 project with 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 roads works for Class-III and IV
Source: Enlistment Rules 2005, Central Public Works Department

In case of the large scale of a project with 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 the project with 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 financial bid shall be submitted at the tender.

In case of the project with more than INRs 200 million, 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 one 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 open 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 designated time, date and plan 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 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 with more than INRs 200 million in the estimated cost.
- **Tender period:** it 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, pre-bidding conference shall be held and the bidders can make the clarification 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 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 as 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, "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) is the latest feasibility study to prepare the bid documents for BOT scheme, which incorporated outcomes of the previous studies.

For the last BOT tender, in May 2012 MMRDA shortlisted five consortiums out of six ones that had expressed an interest in the project. However, by August 5, 2012, none of the five shortlisted firms submitted the 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 worth to extract essential knowledge and considerations from the previous studies and identify a gap 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 is 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 in below, the following studies[1] in the public domain over the last 10 years shall be focused on the review purpose for 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 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 forecasted to attract a 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 provides the database for model development. The overall planning process associated with CTS is shown for completeness in Figure 3.2.1.

The study forecasted 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.

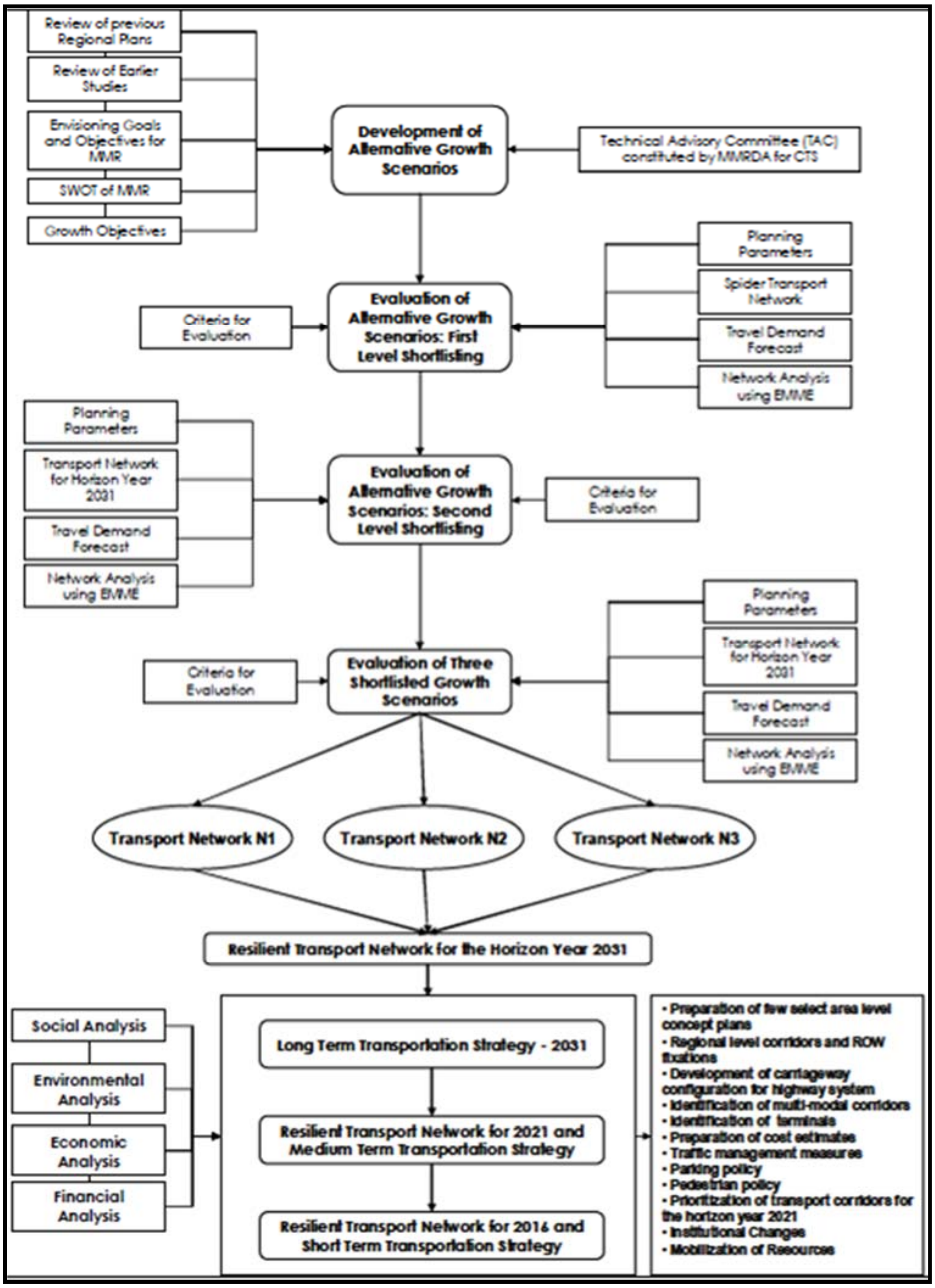
3.2.4 MTHL (2012)

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.

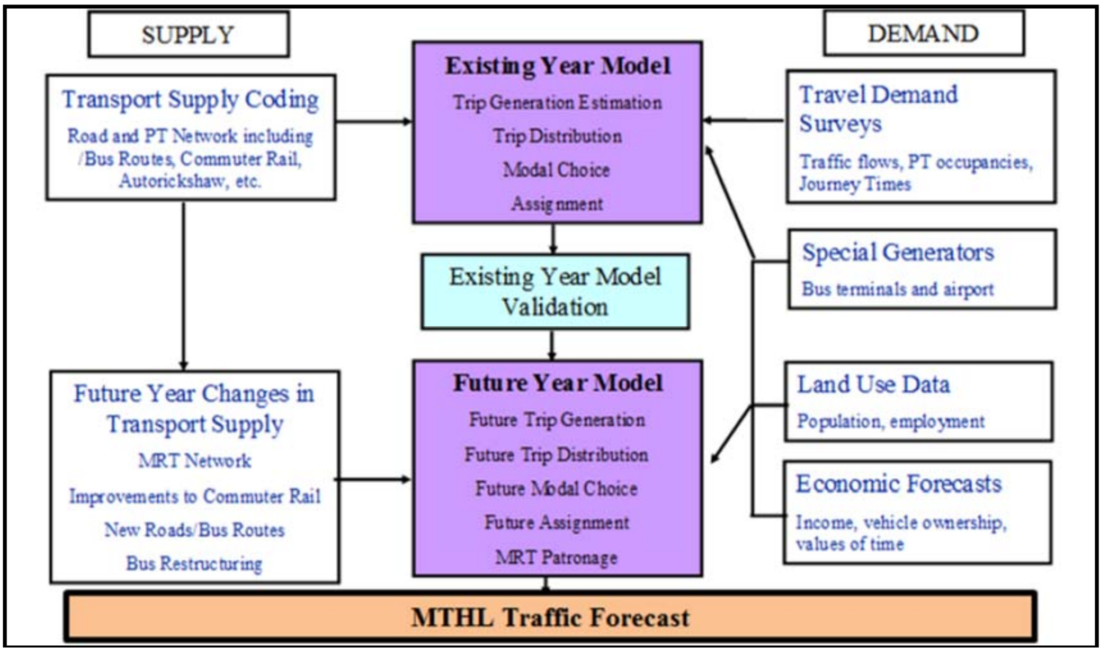
The forecast traffic volume on MTHL was estimated at 68,000 pcu at the opening in 2017, with a car reference toll of 150Rs. This volume is forecast to increase to 89,000 pcu and then 140,600 by 2021 and 2031 respectively. The study suggests that the provision of a parallel rail link only reduces the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



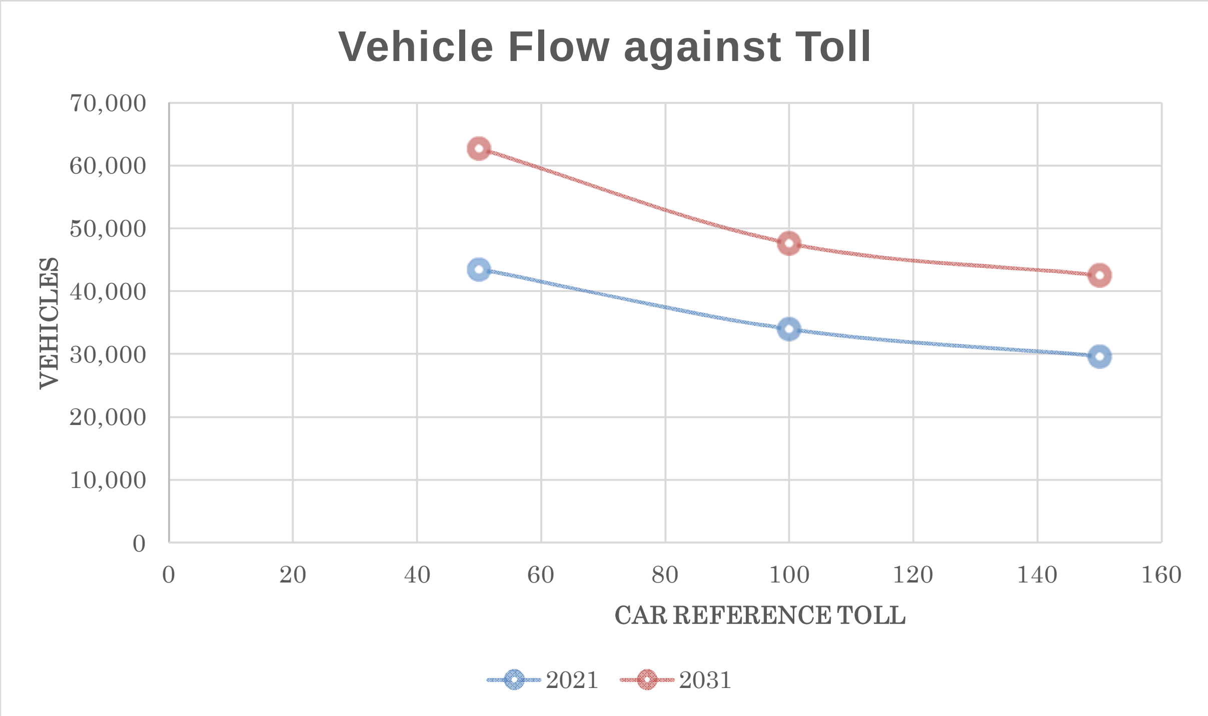
Source: Mumbai Trans Harbour Link prepared by Arup et al

Figure 3.2.2 Structure of the Travel Demand Model

3.2.5 Study on the MTHL Road

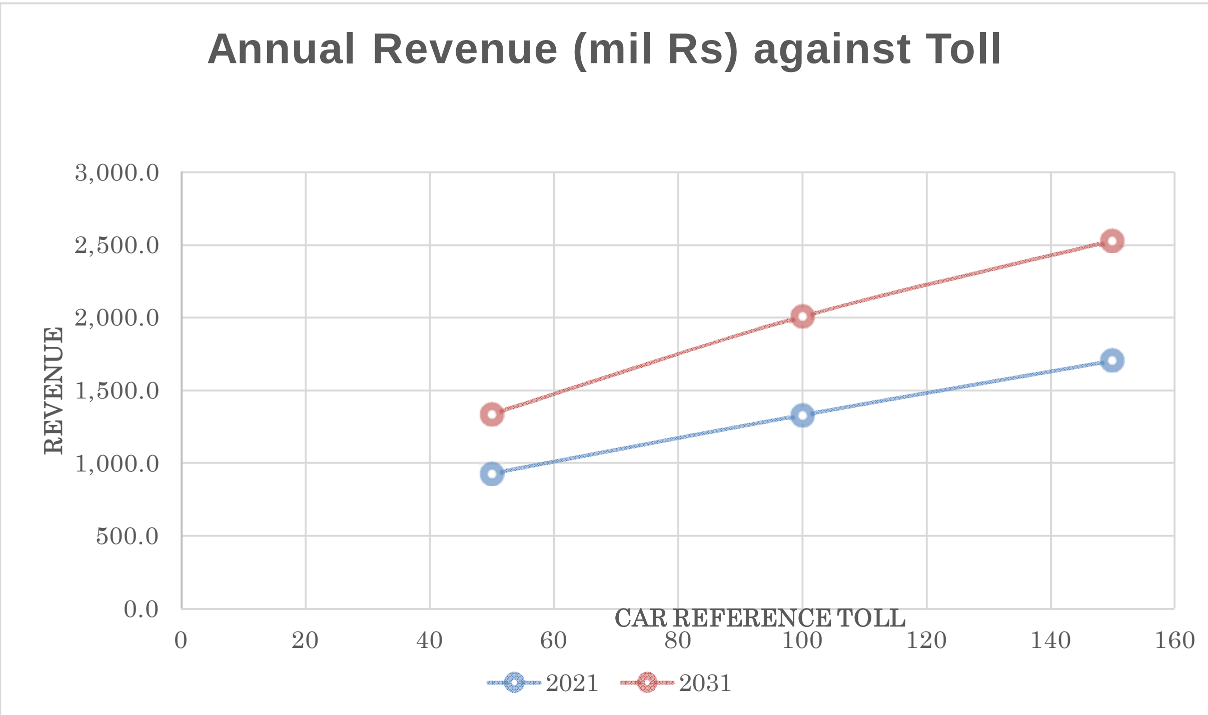
The focus of this study was to determine the feasibility of the project's construction via a PPP scheme. The study was conducted by the Ministry of Economy, Trade and Industry, Government of Japan. This study is also adopting a broad approach linked closely with CTS. However, the transport model developed 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. Simple approach of transport demand forecast such as entropy maximization method was adapted and base and future year matrices were created using the 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 50 Rs toll attracts nearly 50% more traffic than a 150 Rs toll, although the 150 Rs 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 as shown in Table 3.2.1. The principal findings from the earlier studies reviewed is that there is a need for the MTHL to proceed to construction in a timely manner.

Note: While 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 significantly different against future assumptions 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 of transport demand forecast needs 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 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 main land were identified and studied. All the alignments started from Sewri.

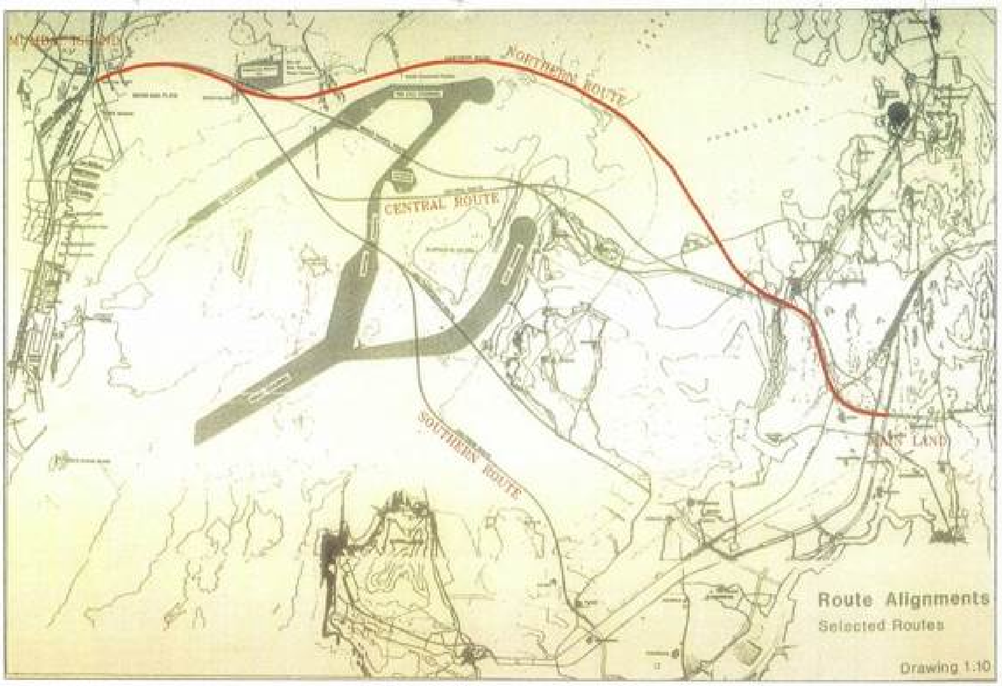
The study recommended the northern most alignment for the sea link connecting Sewri with Nhava through a low elevated bridge skirting the harbour to the north.

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 embankment of Section 2 and 4 had a road level of +7.00m above Chart Datum (CD) considering run-up of wave 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 at 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 Reserch Centre (BARC) requirements. This shifted alignment was approved by 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 largest suggestion from the Consultants is as follows:

Mudflats and Mangroves

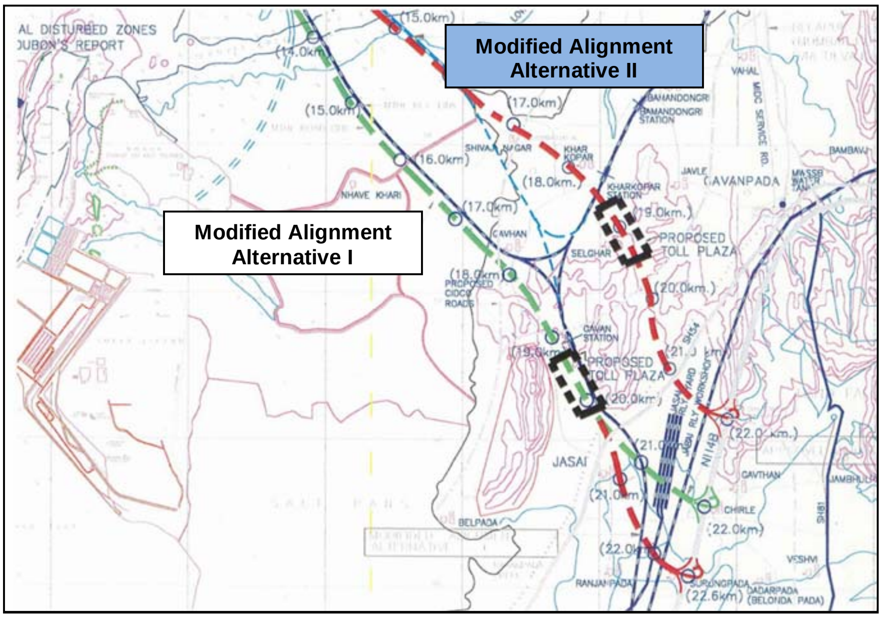
With respect to the alignment traversing the mudflats, both at Sewri and Nhava, it was recommended that the link should be constructed with viaducts instead of embankment in order to minimize the encroachment and the disturbance to the mudflats and the existing hydrological conditions.

Underpass Interchange at Sewri

The Underpass IC at Sewri was proposed to avoid the complex elevated interchange, unavailability of road 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	17.82	-
Ch. 0.600 km to Ch. 17.58 km	-	16.98
• Embankment at Nhava		
Ch.18.42 km to Ch.18.76 km	0.34	0.34
Ch.17.58 km to Ch.17.92 km	-	-
• Road in Grade leading to toll plaza up to termination point		
Ch. 18.76 km to 22.60 km	3.84	-
Ch. 17.92 km to 22.00 km	-	4.08
• Rail link termination at Panvel-Uran link		
Ch. 18.76 km to 19.00 Ch.	0.24	-
Ch. 17.92 km to 19.00 ch.	-	1.08
Total Length of Alignment		
• For Road Link	22.85 km	22.25 km
• For Rail Link	20.40	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) is 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 Eastern Freeway and local road network. At that time, the alignment of Eastern Freeway and improvement of East-West corridor was taken up by MMRDA had been under study. Therefore, only approach ramp was proposed to be constructed.

Viaduct over Sewri Mudflats

PFP had proposed construction of embankment 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 in span length was proposed along this section.

Main bridges in the marine section

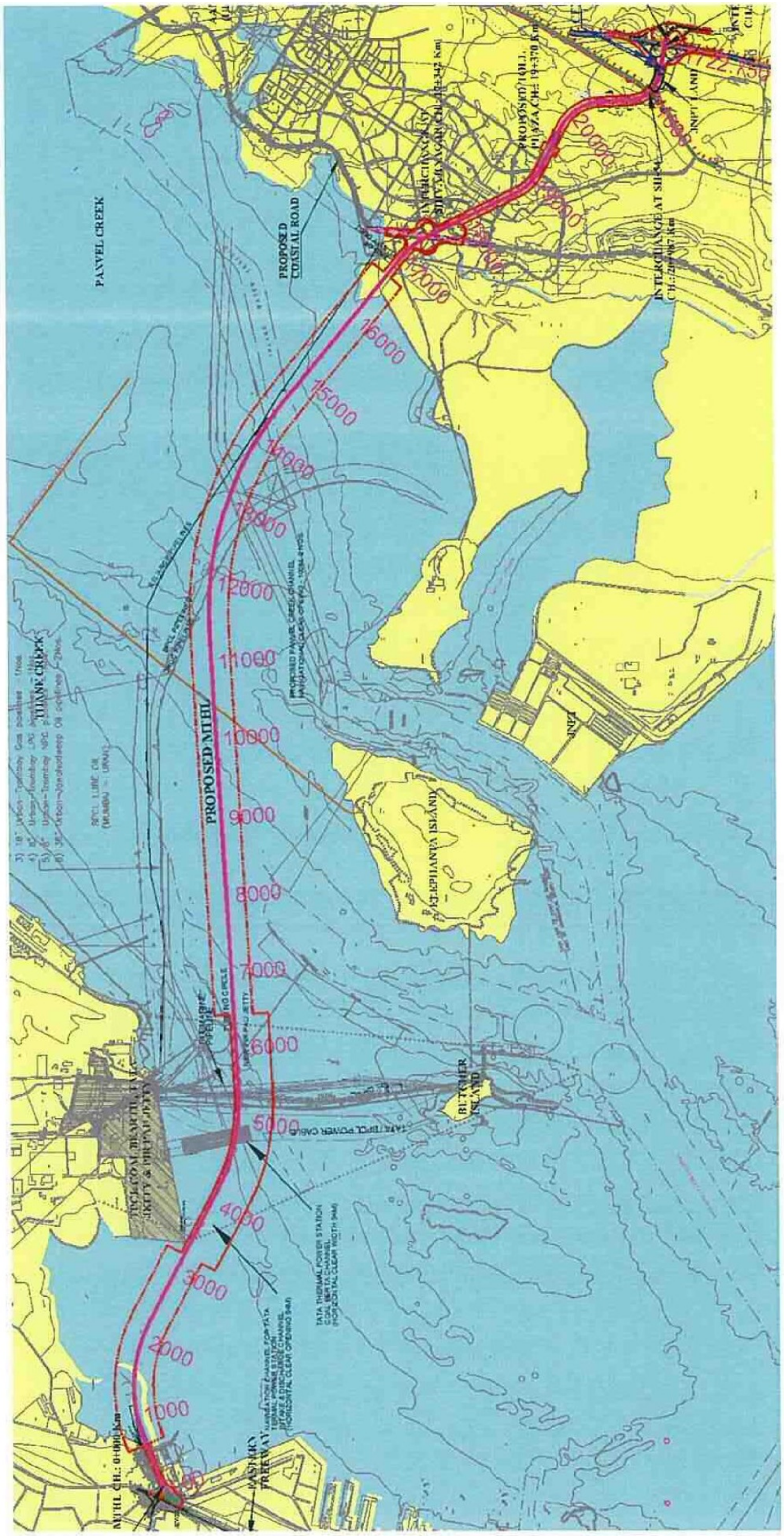
The main bridge extends 9.6km long across the sea. The study identified that the alignment contained three obligatory spans crossing several jetties, the central channel and Panvel Creek and submarine pipelines.

Nhava Approaches and ending at 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 at 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 Eastern Freeway. The alignment continued to southeast to meet NH4B by 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 to keep a 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 cares after several studies in 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 proposed in Final Feasibility Study 2012

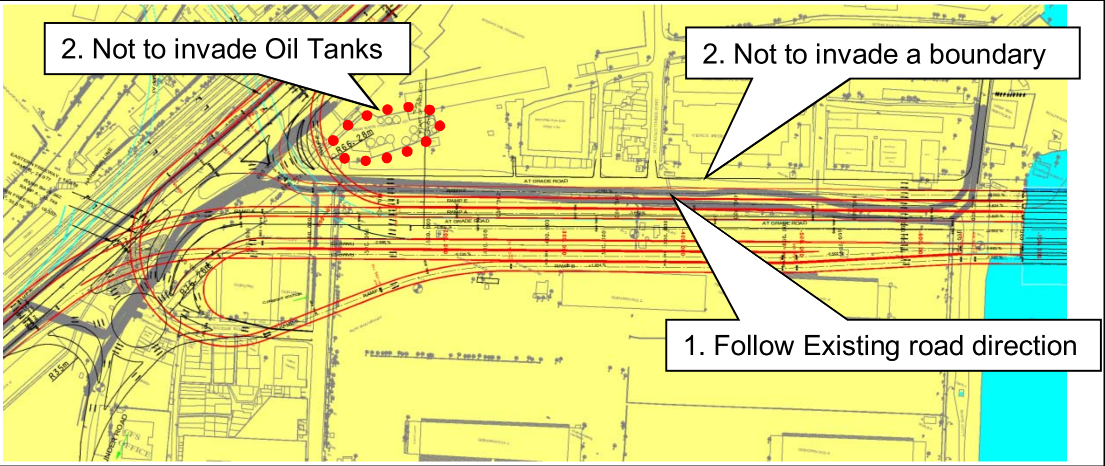
(1) Control Points of Horizontal Alignment

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

Mumbai side

Horizontal alignment at the beginning point was determined by keeping the above control points.

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



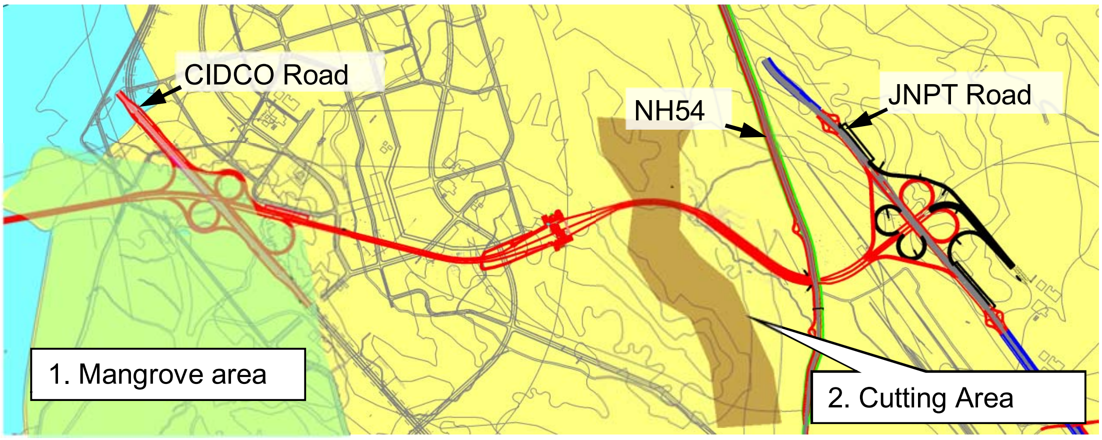
Source: JICA Study Team

Figure 3.3.4 Control Points at Mumbai Side

Navi Munbai Side

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

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



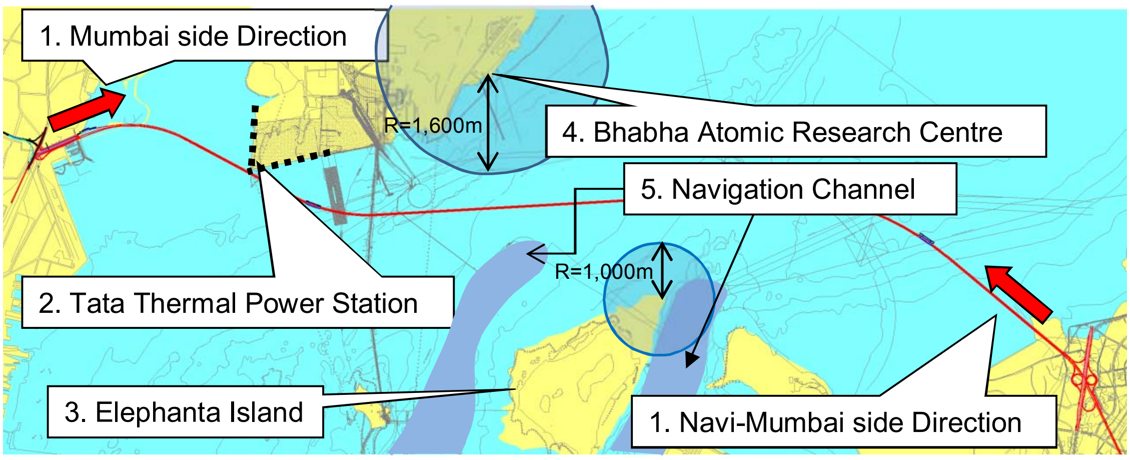
Source: JICA Study Team

Figure 3.3.5 Control Points at Navi Mumbai

Marine Section

The 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 to navigation channels for large vessels

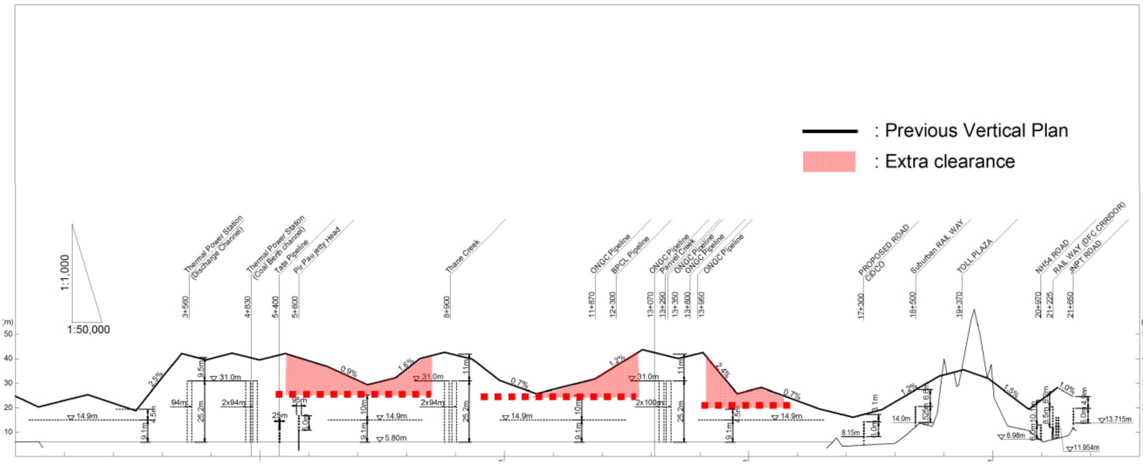


Source: JICA Study Team

Figure 3.3.6 Control Points on the Sea

(2) Control Points of Vertical Alignment

The control points of vertical alignment shows in Figure 3.3.7. It was founded that there is an extra clearance in some sections on the vertical alignment, which are indicated with red shadows. It will be worth to explore the possibility to lower 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 geometrical factors applied to main carriageway in the latest alignment fulfilled the IRC standards at 100km/h of the design speed.

3.3.3 Summary of the Horizontal Alignment

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

(1) Bay Crossing Route

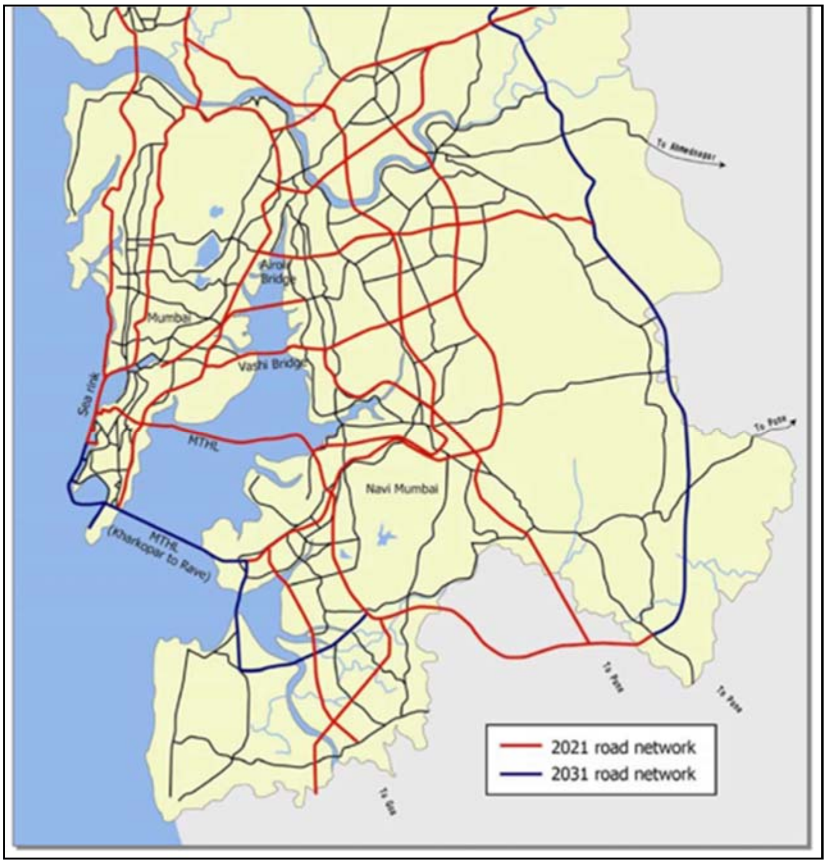
<u>Beginning points at Mumbai side</u>

Northern route (connected at Sewri) was recommended in 1981 by a steering group for the project, however, the details of the study documents were not able to find out. Therefore, review was carried out in a 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 Munbai side in a road network in the future. The following are the reasons to set such route:

- There is another plan on southern route linking Colaba (southern tip of Mumbai Island) with Uran in the said master plan.
- There is a plan linking western freeway via east-west corridor.

- There is a widening plan of Vashi Bridge on the northern side of Sewri.

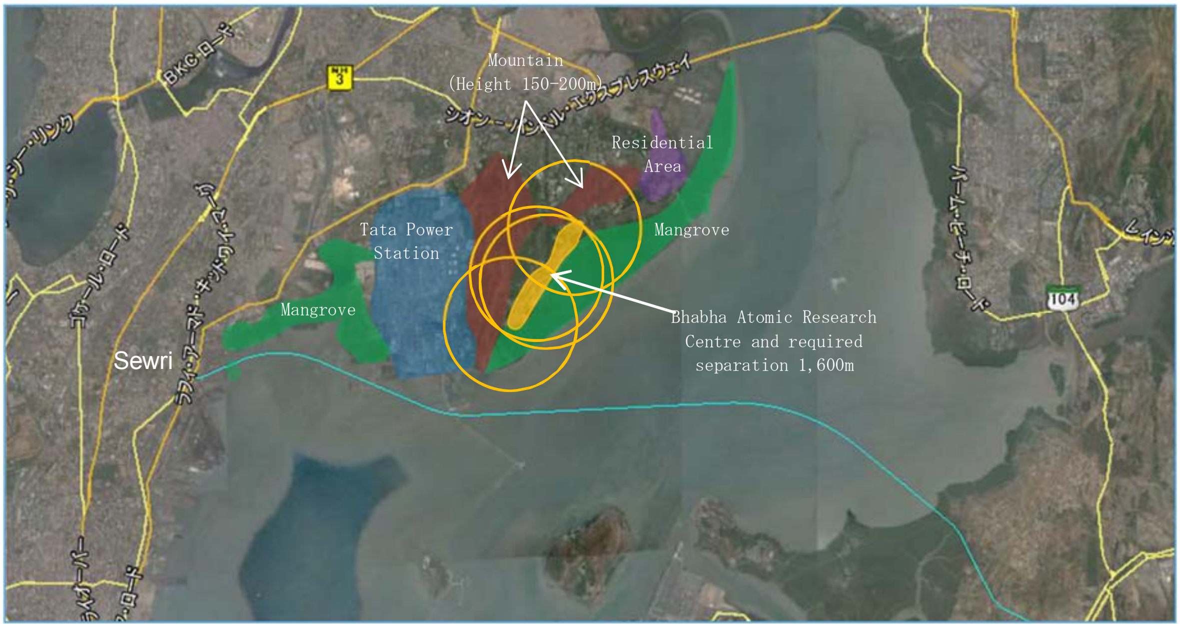


Source: Comprehensive Transport Study for Mumbai Metropolitan Region

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 new approach road.

- 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 cutting of the mountain
- Became far away from the most congested population area of Greater Mumbai



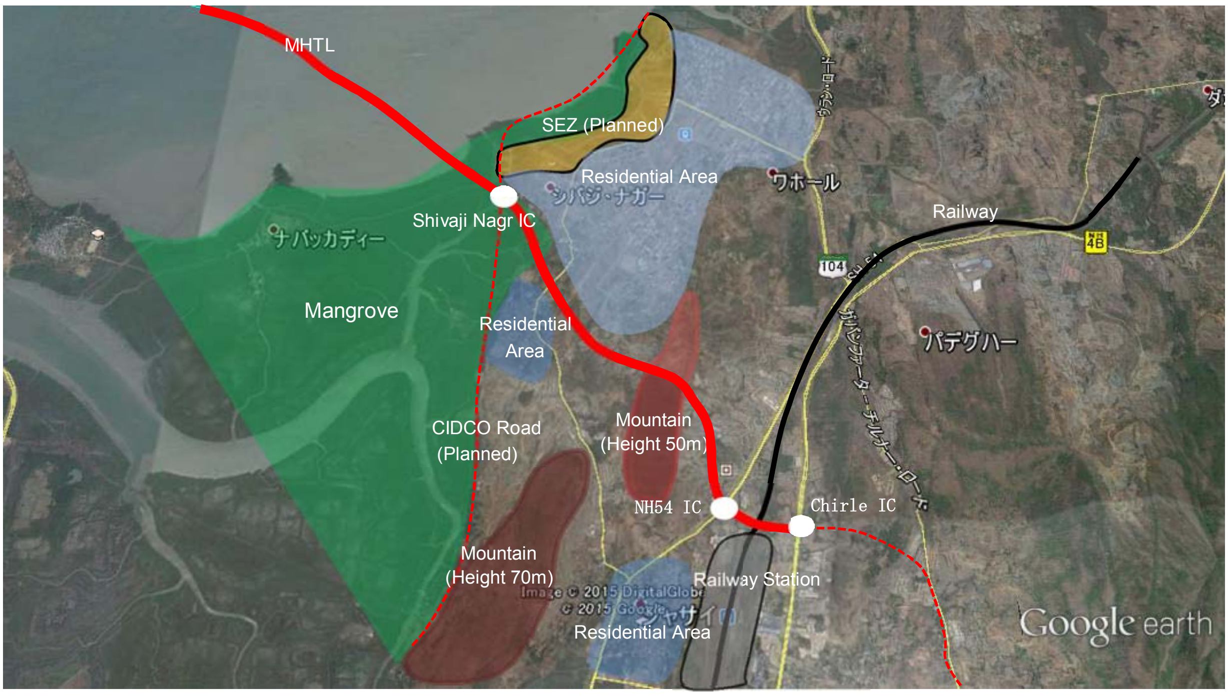
Source: JICA Study Team

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

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

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

- 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.
- Avoidance of passage through the present residential area as possible, which minimizes the resettlement.
- Minimize the volume of cutting soil on the hilly section
- Minimize the impact on mangrove forest.



Source: JICA Study Team

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

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

(2) Consideration of Additional Route Alignment

The above route is not considered the influence of mud flat area where is feeding ground of Flamingos coming flying from 1995 on. Therefore, the alternative is considered with original north route to focus on environmental influence of 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 Comparsion 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 same with alternative route which proposed by local NGO to make an objection as having influence to Flamingos and mud flat area in 2015. As a result of official discussion between MMRDA and MBPT, the route alignment of option-2 will have significant impact on management of unloading pier and future plans of MBPT site (reservoir). Andmore dividing of MBPT site now in use is expected. Therefore, this route alignment cannot be accepted.

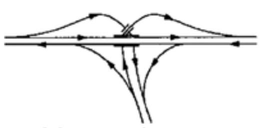
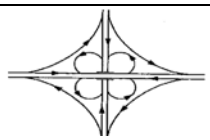
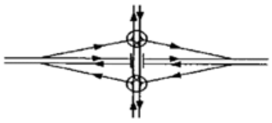
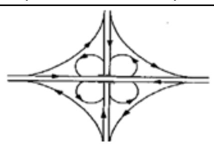
(3) Conclusion

As a result of consideration, influence area for bird of passage will be minimum length in Option-2. However, the number of resettlement of residential will be increased in Sewri IC and road length will get longer, resulting in an increase in construction costs. Additionally, with above answer from MMRDA to NGO, the 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 makes the type adopted. It seems to have adopted the appropriate interchange shape.

Table 3.3.3 Interchange Type

Type	Common Features	Adopted Factors
Sewri (Eastern Freeway (viaduct))		
 Y-Interchange	- More than three-layered. - The bridges increases - It doesn't need a large site	- Access road is the viaduct - To be restricted the site - Extend to east-west corridor in future.
Shivaji Nagar (CIDCO Proposed Road)		
 Clover-Interchange	- Crossing bridge requires only one place. - It requires a large site	- No restrict the site - Simple structure is preferred
SH54 (SH54 Road)		
 Diamond Interchange (half)	- The cost is cheaper. - It doesn't need a large site.	- Interchange suitable for half type is prefferd.
Chirle (JNPT Road)		
 Clover-Interchange	- Crossing bridge requires only one place. - It requires a large site	- No restrict the site - Simple structure is preferred

Source: JICA Study Team

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

However, Shivaji Nagar IC and Chirle IC were not selected Trumpet type. 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.
- It was considered the driver by adopting the clover-type with many adaptation examples in India.

In addition, since the land acquisition has been conducted in clover-type, it is quite difficult to change it. Therefore, the type is respect to previous design.

Regarding the weaving length of between on-ramp nose and off-ramp nose, it is satisfied with the length of Japanese standard.

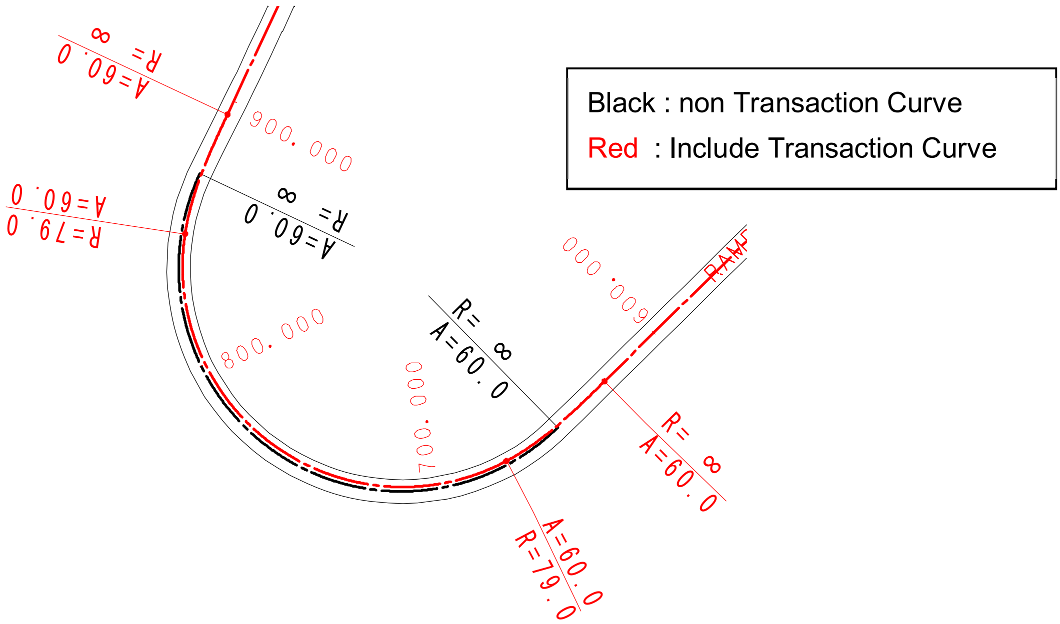
The number of traffic lanes on each interchange and no. of toll booths are as per the traffic volume forecast studies & Final Feasibility Study Report, 2012. Accordingly, Chirle interchange has 3 lanes and Shivajinagar interchange has 2 lanes.

3.3.5 Others

(1) Transition Curve of IC

Transition Curves for interchanges were considered for all ramps in the previous study. On the other hand, it is considered to the Main alignment curves.

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



Source: JICA Study Team

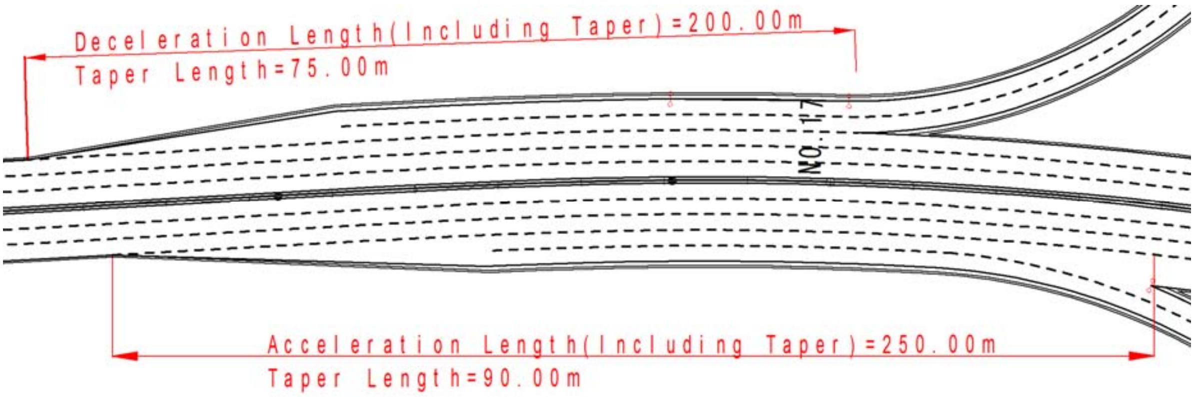
Figure 3.3.11 Transition Curve for Interchange (e.g. Ramp B at Sewri IC)

(2) Deceleration, Acceleration Length and Shift

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

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

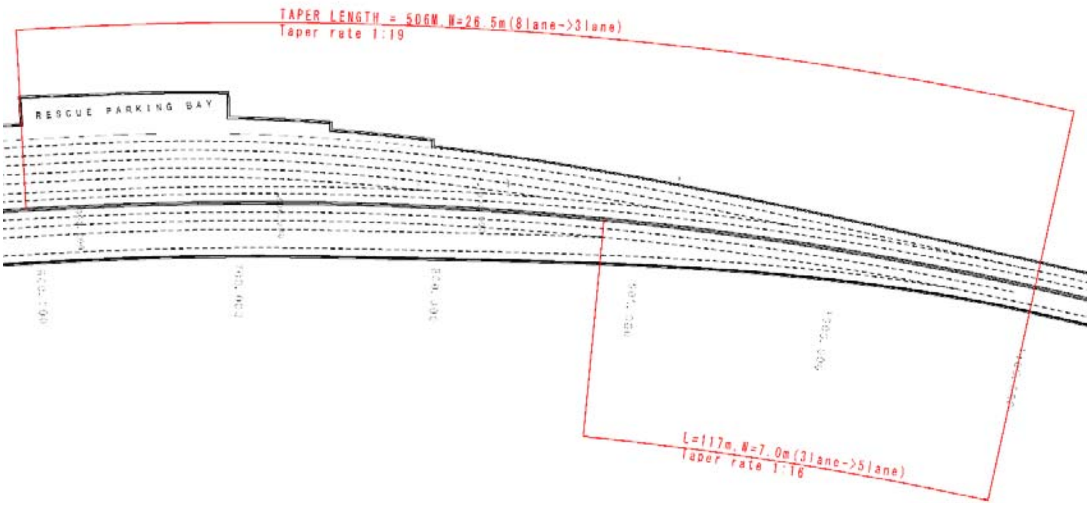
Shavaji Nagar Interchange (Deceleration, Acceleration)



Source: JICA Study Team

Figure 3.3.12 Deceleration and Acceleration Length Type

Sewri Interchange (Shift)



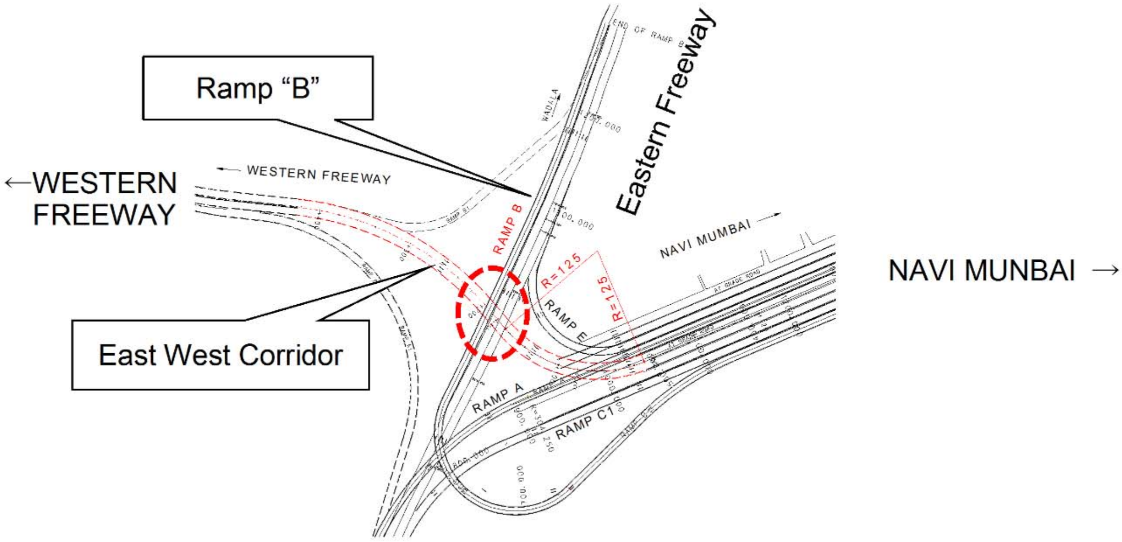
Source: JICA Study Team

Figure 3.3.13 Shift Type

The shift length of 2-lane ramp is required more safety than 1-lane ramp. Therefore, it is proposed to refer Japanese standard for the shift length of ramps. Refer to ‘6.4 Design Standard for Road Design’ about the detail.

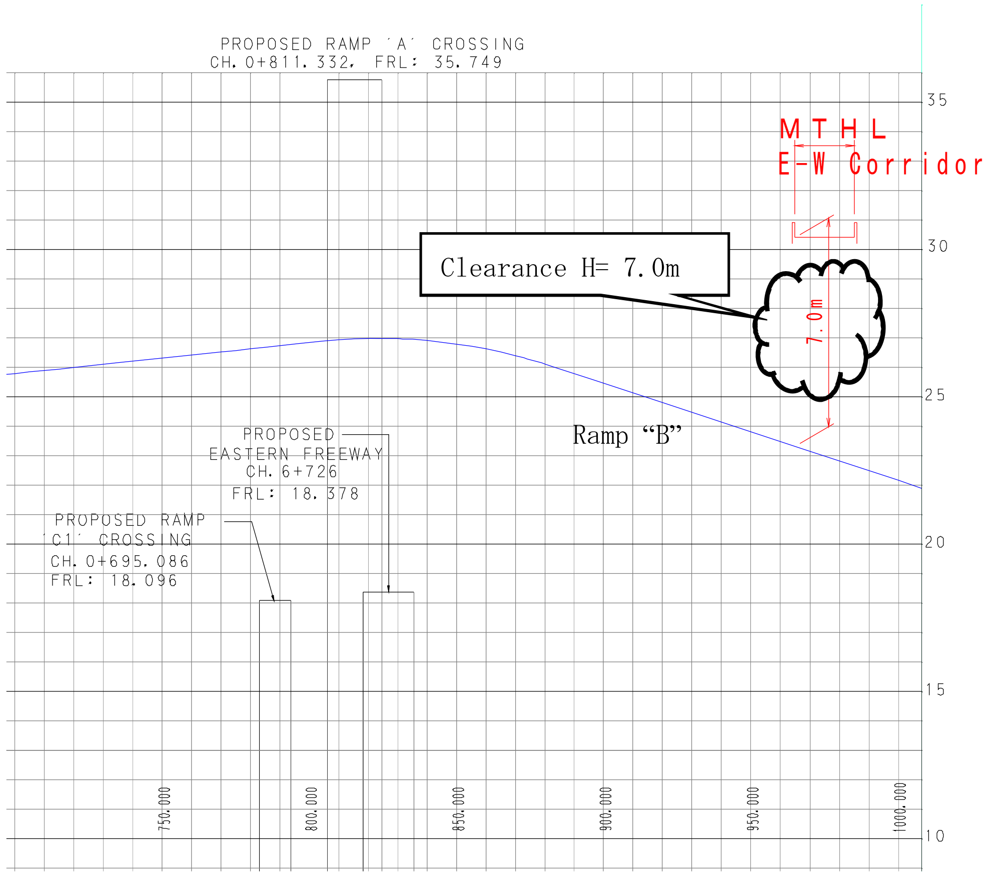
(3) Vertical Clearance of Ramp B at Sewri IC

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 Ramp "B" and East West Corridor

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

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

3.4 Review of Bridge Plan

3.4.1 Control Points for Bridge Plan

The Final Feasiblity Study Report 2012 described the information about both pipelines/cables on the seabed and faut zones accros 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
• 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. • 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 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 piers are subjects to be approved by MbPT and ONGC.
• The existence of fault zones that were identified accross 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, shoud be considered in the span arrangement plan for MTHL. • The recent ground investigation in 2012 also indicates that the fault sozne could be a deeply weathered at approximately CH13+000 of the alignment.	• It is necessary to condulct the detailed soil investigation when the piers are planed on the falut zones

Source: JICA Study Team

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

Table 3.4.2 Crossing Utilities and Required Span Arrangement on Marine Section

Crossing Utilities	Navigation Clearance		Span Arrangement	Remarks
	Holizontal	Vertical above (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 planed to crosse over some of railways and road on land sections. Whereas the clearances of the railway have been already concluded through the consultation with Indian Railway, the ones for the crossing roads have also determined through the discussions with relevant authorites 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 Final Feasibility Study Report, 2012 are shown in the following sections.

(1) Design Codes

Main code list for bridge structure design are 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 Specification 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 tonnes vessel hit at travelling spped at 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.Stainless steel reinforcement in splash zone	(“Splash zone” is the 5m area above HHWL to 5m below LLWL) Ribbed bar steel as per BS6744:2001
5.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. Regaring 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 marine, obstacle ones on the marine, mangrove forest area, and flyover sectons over railways and roads on the land section.

Table 3.4.8 Marine Bridge Properties (1/3)

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

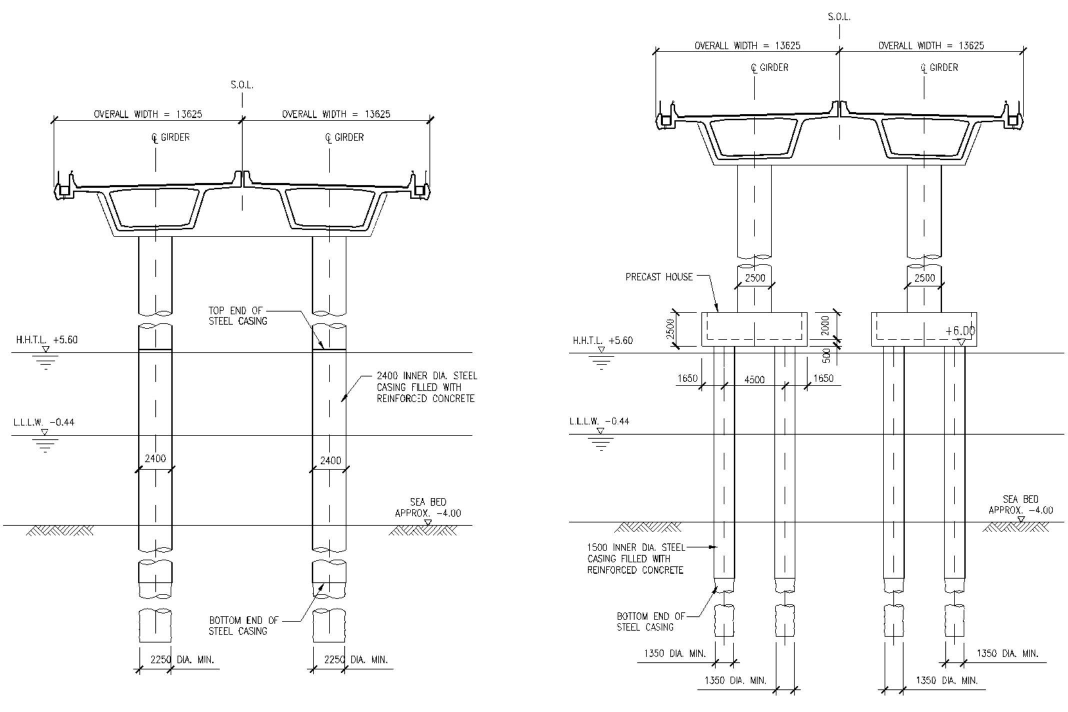
3.4.4 Review of Bridge Plan in Final FS 2012

(1) General Sections on both Marine 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 superturucture is to be performed by span-by-span method utilizing precast segments. For piers less than 20m high (road surface elevation < 30m) form 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 by 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 (C.D) above sea level. Cast-in-place bored piles with a diameter of 1,500mm are used for the foundation. The bored piles are also encased by 8mm-thick non-structural steel piping (Figure 3.4.1).

Superstructures for the general land section lare PC simply box girder 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 Section

Structure type	Details
Pile bent structure	Pier height is less than 20m Pier with two-shaft 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 thickness 8mm of steel pipe outside within only water

Source: JICA Study Team

2) Design Conditions to be clarified for Revising Bridge Plan

- The reason why pile cap bottom has been set at +6.0m above C.D.
- The reason for application of the maximum continuous bridge length
- The locations where pile bent structures or pile cap structures should be used
- Base of the pile cap bottome elevation of +6.0 m above CD
- The reason why 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 dreading operation near the navigation channel. This bridge type with 50m in span lengt can be justiied 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.
- According to recommendation related to environment (preventing tidal current's effect due to pier), pile cap bottom is set at 40cm higher above HHTL. This has been confirmed from MMRDA.

For general land sections

- Standard practise for girder erection with spans of around 30m shall be made by using large lifiting capacity of cranes after fabrication of precast PC girders at the yard. This method has produced satisfactory results from both an economic and a workability-based viewpoint 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 an 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 on Marine

1) Outline of the Bridge Structures

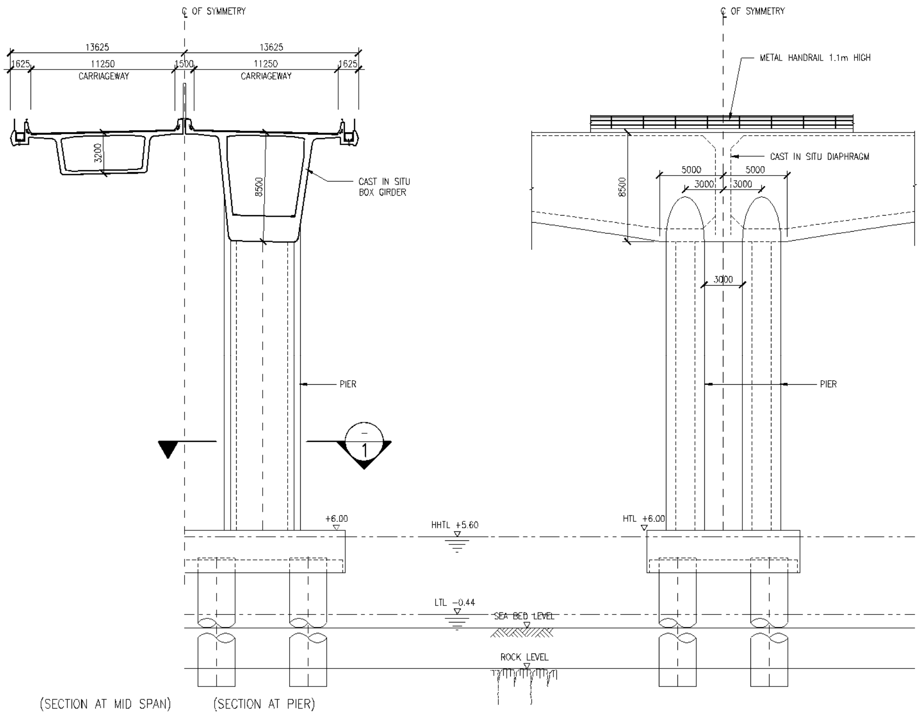
In the marine sections, the MTHL shall cross one discharge channel, three shipping channels and three sets of pipe lines. The navigation channels of the discharge channel and the shipping channel require a horizontal clearance of 94m and a vertical clearance of 31m above C.D. PC rigid frame box girder 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 of bored piles encased in 8mm-thick steel pipe. In addition, a ship collision absorber devices are installed along the shipping channel. The elevation of the top of the pile caps are sent at +6.00m above C.D..



Source: JICA Study Team

Figure 3.4.2 Substructure Type at Obstacle Sections on Marine

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 cap Pile cap bottom is set at +6.00m above C.D. 4 nos. of bored pile with 1,500mm in diameter covered by thickness 8mm of steel pipe outside only within water
Main piers	Pier of two-column with 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 C.D. 4 nos of bored pile with 2,400mm in diameter covered by thickness 8mm of steel pipe outside only within water

Source: JICA Study Team

2) Design Conditions to be clarified for Rivising Bridge Plan

- The bridge construction at obstacle/navigation channel sections on marine is on the critical path of construction schedule.
- A precise investigation for the pipeline positions is essential.
- Regaring 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 why the elevation of the top of the pile cap has been set at +6.0m above 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 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 C.D. (similarly to the general section), the number of the bored pile 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 C.D. This concept shall be confirmed with the MMRDA and it should be applied in the reivised bridge plan for the reduction of construction cost.
- The foundation type should be comparatively reviewed after obtaining the information about practices in India.
- An investigation for pipelines position should be carried out in this study. And span arrangement will be proposed based on the investigation result of 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 flora area of the mangrove forest section, PC rigid frame box girders with a standard span length of 50m are applied with using the span-by-span erection method. In the section crossing the Shivaji Nagar IC, a PC box girder of 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 in diameter covered by thickness 8mm of steel pipe outside
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 in thickness 4 nos. of the bored pile with 1,500mm in diameter convered by thickness 8mm of steel pipe outside

Source: JICA Study Team

2) Design Conditions to be clarified for Revising Bridge Plan

- It is not clear of application criteria between the pile bent type and pile cap one.

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 one.

(4) Railway Overpass

1) Outline of Bridge Structures

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

(5) Road Overpass

1) Outline of Bridge Structures

The superstructure is planned as PC box girder and the pile cap type was applied as substructure. The vertical clearance of 6.0m underneath a 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 Bridge Plan

- The profile for the ramp alignment which connects 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 others ramps may be affected.
- The superstructure of the ramps have been 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 and pier structure. Furthermore, as the ramp alignment is complicated, there is a concern on an effect to Eastern Freeway during the ramp construction.

3) Additional Study Result and Proposal of Alternatives

- As it is possibility not to satisfy the vertical clearance for Ramp B, a consultation meeting was held with MMRDA. MMRDA explained that since the ramp bridge connecting between East-West Corridor and MTHL main carriageway is supposed to be a steel truss bridge, there is no problem for the vertical clearance of 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 Final Feasibility Study 2012.
- It was confirmed that foundation's arrangement and shape along railway of their properties have been agreed with the Indian Railway.
- As a result of interviewing construction practice in Indian, the curved PC box girder which is planned for the ramp bridges can be constructed by span by span method with precast segment.

(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 length of 50m. For 30 m in span length, there is no indication of the bridge type in the report. For substructure, the pile cap type is applied for all bridges.

SH54 IC

A PC box girder bridge of span length 30m same to 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 from steel truss girder crossed. The other parts of the ramp is planned for span length of 20m,which the superstructure type is not specified in the report. The substructure is proposed as a single column pier with pile cap.

2) Design Conditions to be clarified for Reviewing Bridge Plan

A span arrangement, particularly 20m of the span length, shall examined its appropriateness.

3) Additional Study Result and Alternatives

It is necessary to review both span arrangeme of the ramps and its bridge type in order to confirm its appropriateness.

(8) Others

1) Temporary Bridge/Platform during Bridge Construction on Marine

As there is no plan for temporary platform/jetty to access to the construction sites on marine in the report, it is necessary to additionally study the structures of 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 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 the 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 Western Freeway Project and Sea Link one, which are regarded as a similar nature of the project, were basically referred for the cost estimate of MTHL.
- However, since the Sea Link Project was constructed in the ocean area unlike MTHL which passes through the clam marine area inside the Mumbai Bay, the construction costs of the work items for MTHL can be assumed smaller. Accordingly, the unit prices applied to the Sea Link was 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 in span length and a coefficient was applied to estimate the unit cost of a bridge 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 is 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, whereas the figures in the left column are quoted from the Final FS 2012 report, the ones in the right column are the review results 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 read in the table
- Improper application of the unit price for PC to a steel bridge
- Inaccurate application of the averages price escalation coefficient of 5% without consideration of the varied 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** (m^2)	**Unit Rate** (Rs/m^2)	**Cost** (INR・Mil)	**Area** (m^2)	**Unit Rate** (Rs/m^2)	**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 (m²)	**Unit Rate** (Rs/m²)	**Cost** (INR・Mil)	**Area** (m²)	**Unit Rate** (Rs/m²)	**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 shall be INR 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 bridge 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 is much higher, approximately 10% per year, than the assumption in the Final Feasibility Study 2012, and resulted in 1.6 times in the price escalation ratio 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 cost for each work item as a result of the review works of 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**

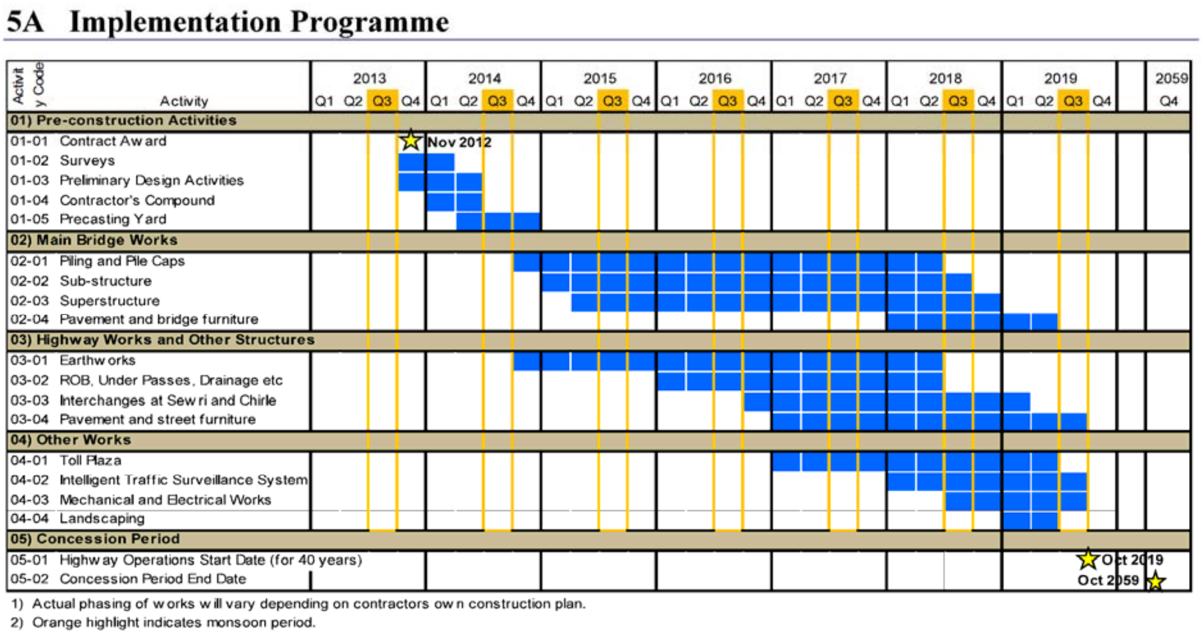
Source: JICA Study Team

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 BOT scheme. In principle, the proposed schedule can be achievable if the contractor mobilizes the 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 of foundation, substructure and superstructure works are estimated for 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 number and the construction period.

Temporary Jetty

The construction of 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 environment area of the Serwi mudflat section.

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

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

Foundation

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

Substructure

The type of substructure is divided in 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 nos. of 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, approximately 1.5 m erection per day and 1369 days (3¾ years) for completing its 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 slower (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 MTHL project.

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

3.6 Economic Analysis

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

As a matter of course, results of economic and financial analysis would become different scenario depending on giving assumption. So this section reviews what assumptions are applied, and how outcomes are evaluated.

3.6.1 Financial analysis

(1) Assumption

1) Initial investment cost

Initial investment cost in Feasibility Study Report, 2012 is assumed as the base amount 77,040 million INR. As the above section, while the cost estimation of Feasibility Study Report, 2012 is appropriate in terms of quantities, the ratio of price escalation is set in low levels, and therefore it could be said that the assumption of the initial investment cost is 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 Feasibility Study Report, 2012 is one percent of the total project cost, amounts 1,010 million INR at the year of commercial operation days (COD). And it is annually escalated 5% of escalation. It is difficult to clearly judge appropriateness of the assumption of O&M cost, because initial investment cost as the basis of the O&M cost is set low levels and there are no clear explanation of one percent (of the total project cost).

3) Traffic

Traffic volume in Feasibility Study Report, 2012 is assumed as 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 forecast for three cases (Case 1, 2, 3), traffic on Case 2 was worked out based on similar toll rate setting on Feasibility Study Report, 2012. As the table below, traffic forecast has been figured out on two separate sections before/after 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) on Feasibility Study Report, 2012 is larger than one on this study, but growth rate on this study is much larger than previous study after year 2032.

4) Toll rates

Toll rates in Feasibility Study Report, 2012 is set based on “willingness to pay survey in 2011”, and it is escalated to COD (2016-2017). Annual revision of toll rates is made by 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, base case of toll rates is set based on “willingness to pay survey in 2011”, and revision of toll rate also follows NHAI formula. Therefore, while Case 2 in this study is slightly high rate than one on Feasibility Study Report, 2012, basically there are no significant difference between 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 financial analysis

In Feasibility Study Report, 2012, Financial Internal Rate of Return (Project IRR and Equity IRR) which is calculated based on the above assumptions is as follows. Unless otherwise applied Viability Gap Fund (VGF), the project is not 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 Feasibility Study Report, 2012 indicates comparatively high ratio, while the project is a large scale toll road/bridge project - generally it is regarded difficult to return on investment. The reasons are that; the initial investment cost set lower levels, traffic volume are estimated comparatively large extent.

3.6.2 Economic Analysis

(1) Assumption

1) Economic Cost

In Feasibility Study Report, 2012, economic cost is worked out by multiplying conversion rate 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 basis of 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),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 route

c) Reduction in accidents on the alternate route

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

e) Reduction in pollution (decongestion on alternate route)

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

(2) The results of economic analysis

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

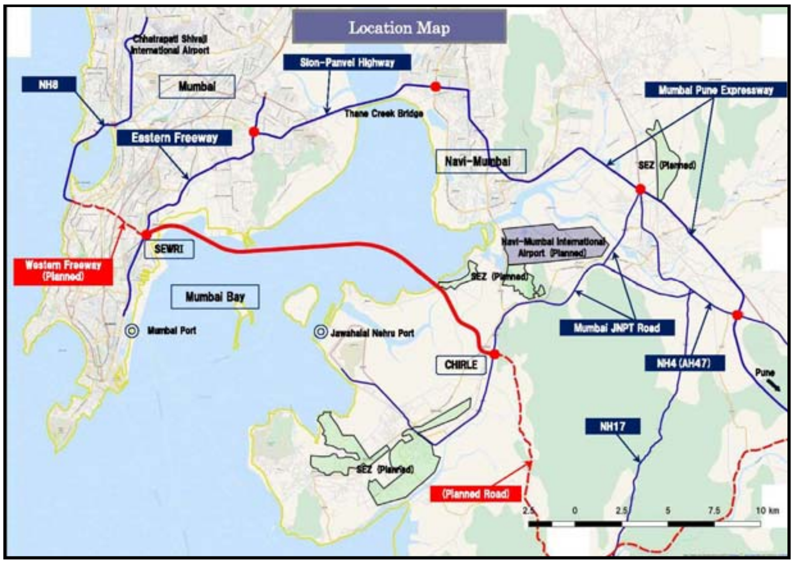
4. TRANSPORT DEMAND FORECAST

4.1 Overview

The preparation of the Transport Demand Forecast in a large complex metropolitan area such as the MMR is fought 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 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 in the future such as transport infrastructure and socio-economic projections. The last section of this chapter delivers 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 in 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:

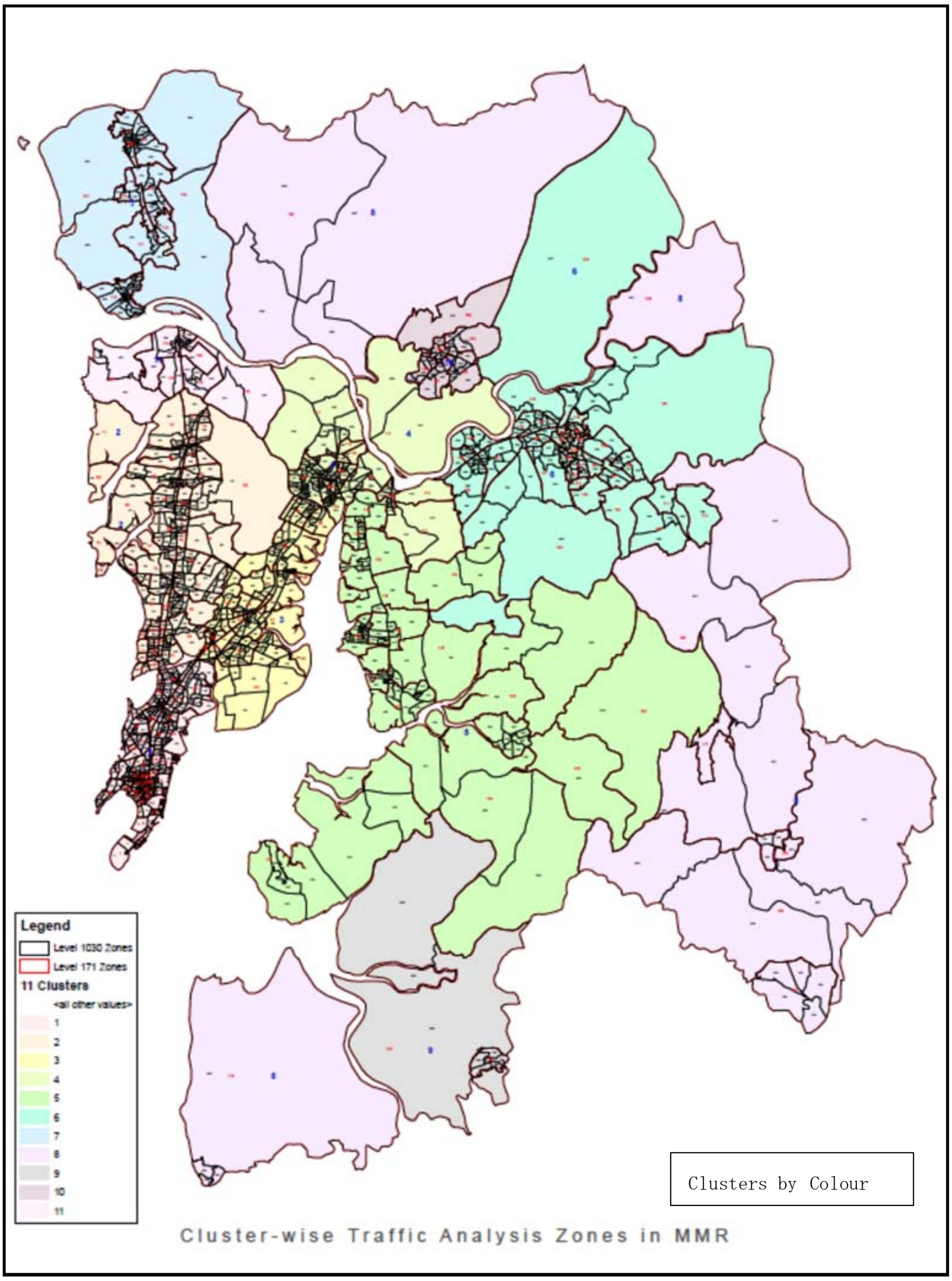
- Cars, motorcycle, and IPTs (a composite of Taxi and Auto Rickshaw)[9] for private person travel;
- Bus and Rail for public transport person travel; and
- Goods Vehicles (which in turn are split into Light Commercial Vehicles (LCV), Heavy Commercial Vehicles (HCV) and Multi Axle Vehicles (MAV))

4.2.2 Zone System

The transport model adopted for MTHL as stated earlier is a derivative of CTS so much of the discussion that follows in the next section with respect to 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 datasets. 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.

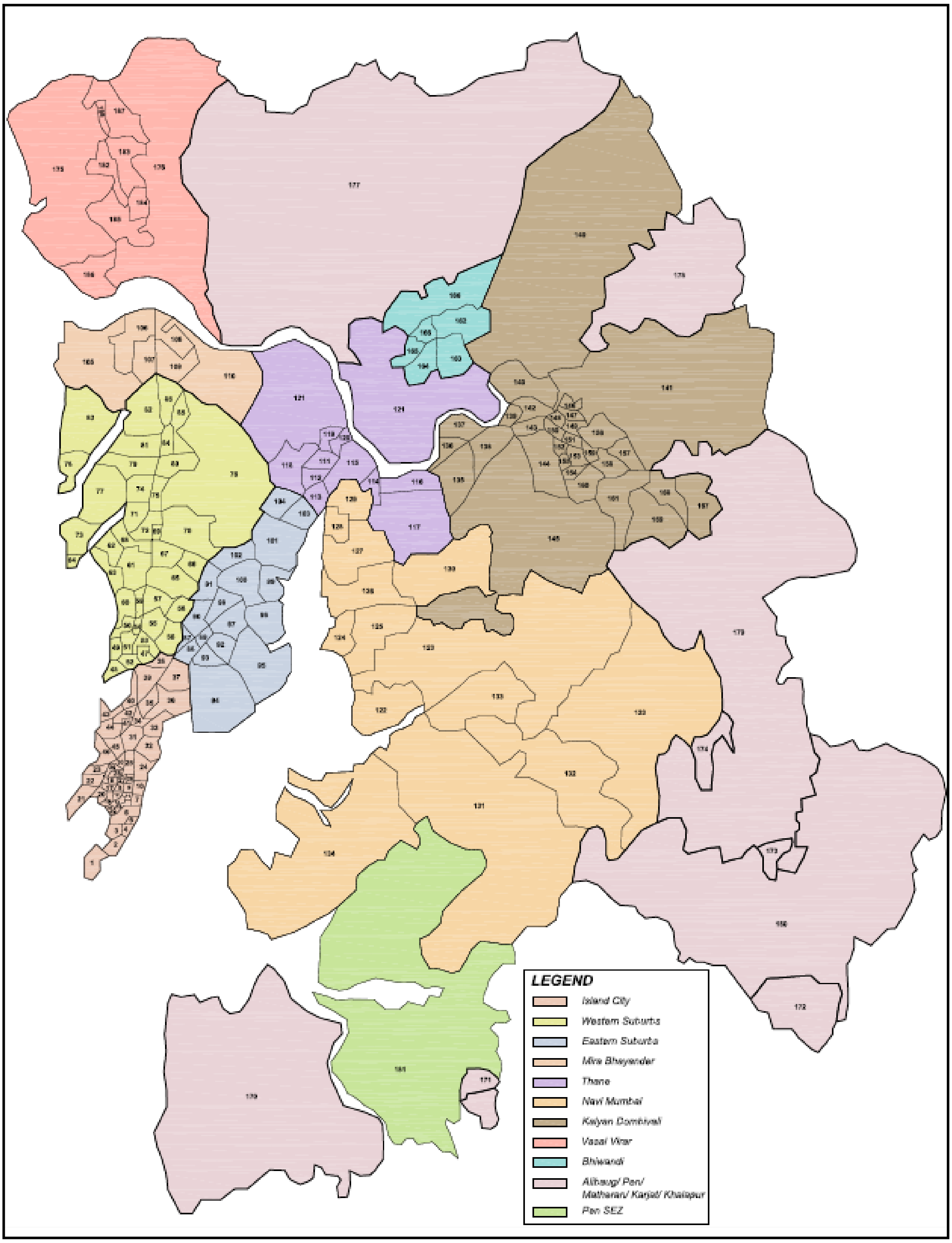
[9] For MTHL prepared by the JICA study team, taxis and auto rickshaw are separated for the economic analysis.



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 name of the clusters are given in section that presents the future assumptions.



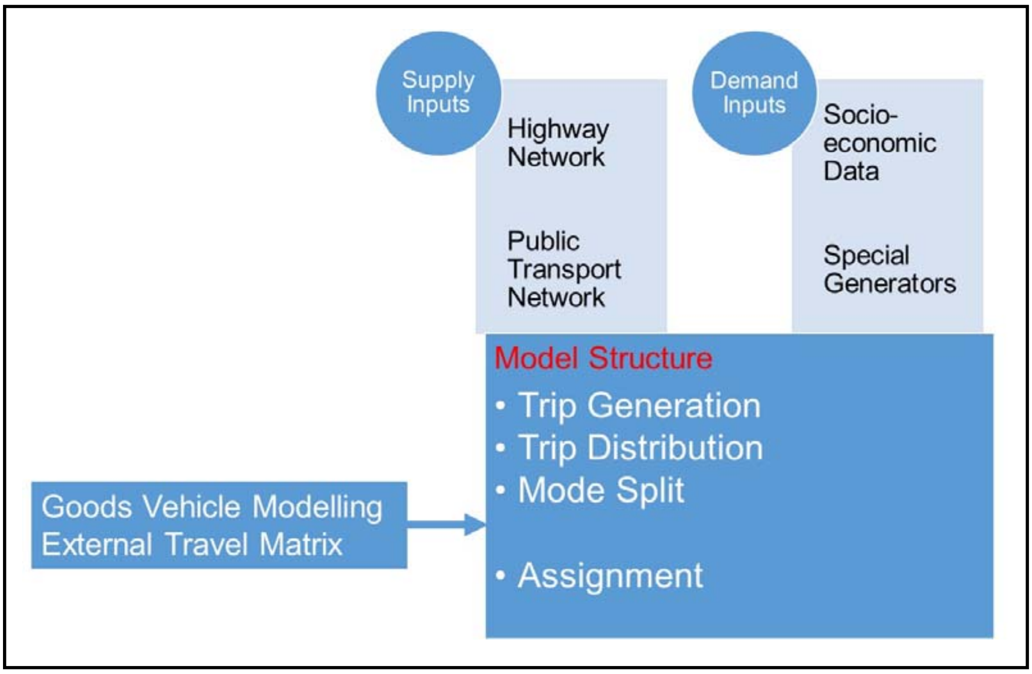
Source: JICA study team

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 recently have carried out on speed/flow relationships for roads in Mumbai region.

The speed flow curves are based on the link class coded. 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 public transport network individual lines belong to one of five modes namely:

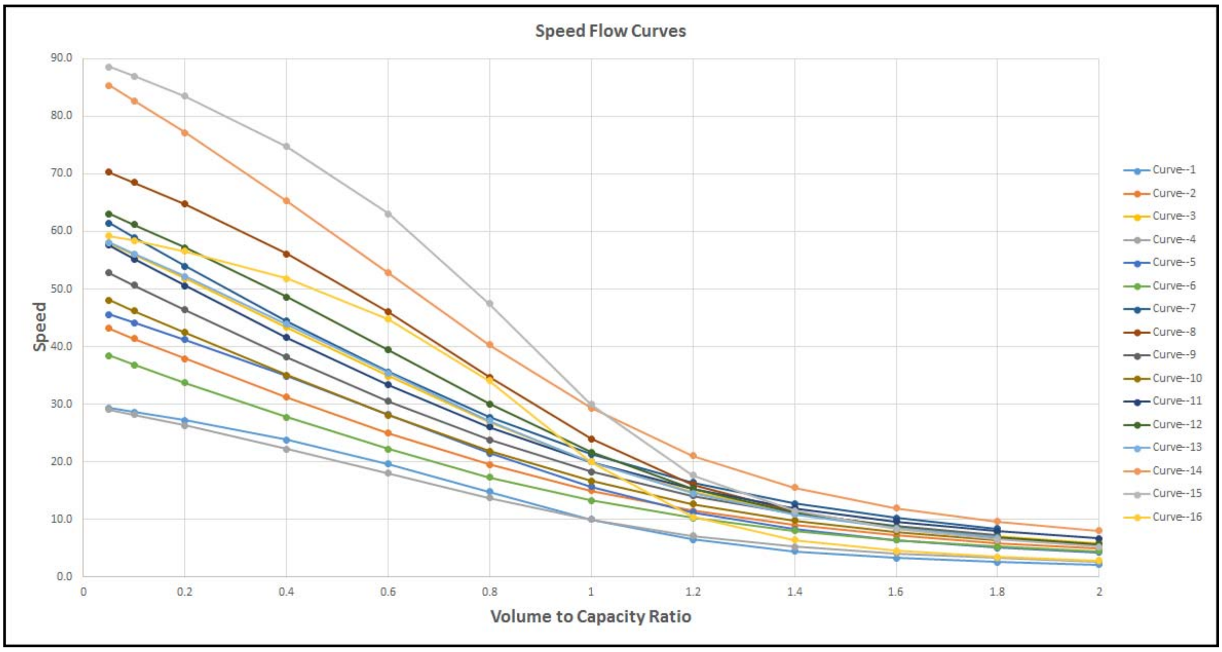
- Suburban rail;
- Ordinary bus;
- Air-conditioned bus;
- Metro rail; and
- Monorail.

The transit fare structure is shown in Figure 4.3.4. It is noted in this figure that the air conditioned bus fare is high 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

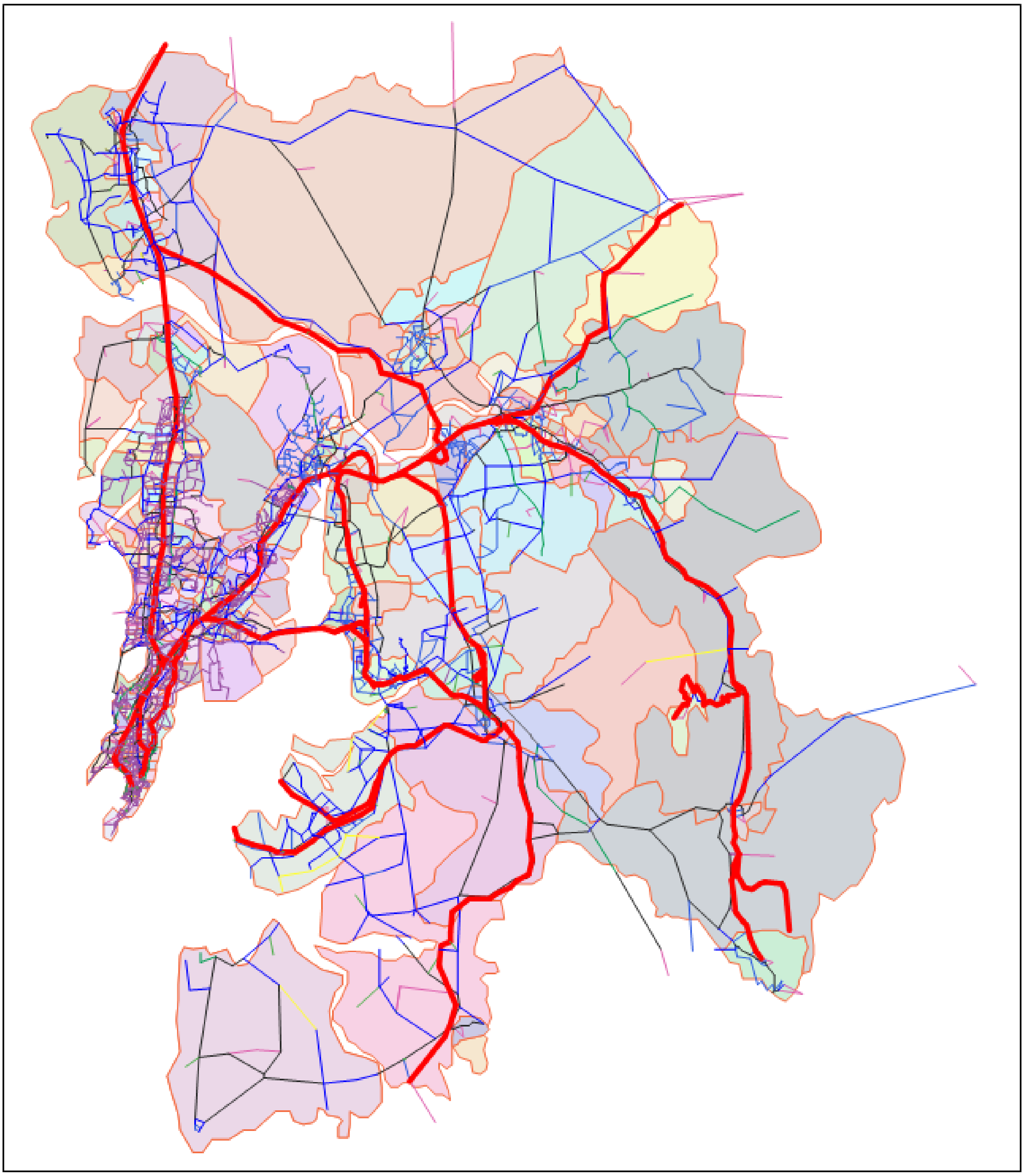
No	Lane Configuration	Divided/ Undivided	Operation	Capacity(1)
1	2/3 Lane	Undivided	One Way	1,050
2	2/3 Lane	Undivided	Two Way	875
3	2 Lane	Undivided	One Way	1,400
4	4 Lane (effective 2 lane)	Divided	Two Way	665
5	4 Lane	Undivided	One Way	805
6	4 Lane	Divided	Two Way	1,050
7	6 Lane	Divided	Two Way	1,050
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

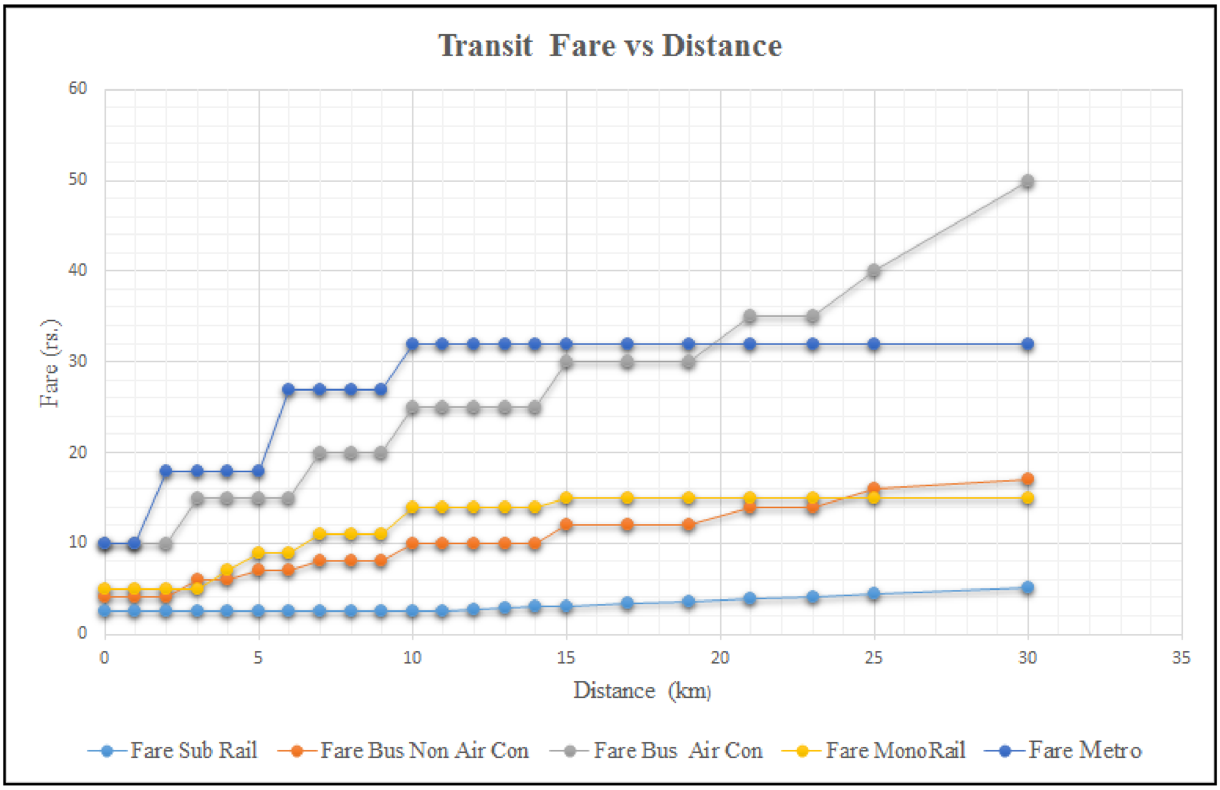
Figure 4.3.3 Model Base Year Network

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 is therefore applied that splits households into low, medium and

[13] Only limited detail of the model equations is supplied as these are documented in the 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.

high income groups16 based on the average household income for the zone. This income segmentation as specified by CTS is based on Income Index assessed based on property rates published regularly by a 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

[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 caliculated by arithmetical mean method.

- HBWI = HBWI_IJ * Employment industrial
- 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 to 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 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 large proportion of commercial traffic is accounted for in the definition of the external traffic and special generators. In particular, all external goods traffic are accounted for leaving only

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

some of the internal goods traffic to be allowed for. 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 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 there are few available cross check data apart for very high level figures. Therefore now in 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 Screenline.

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), is assigned on 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 by defining different multiple crowding curves

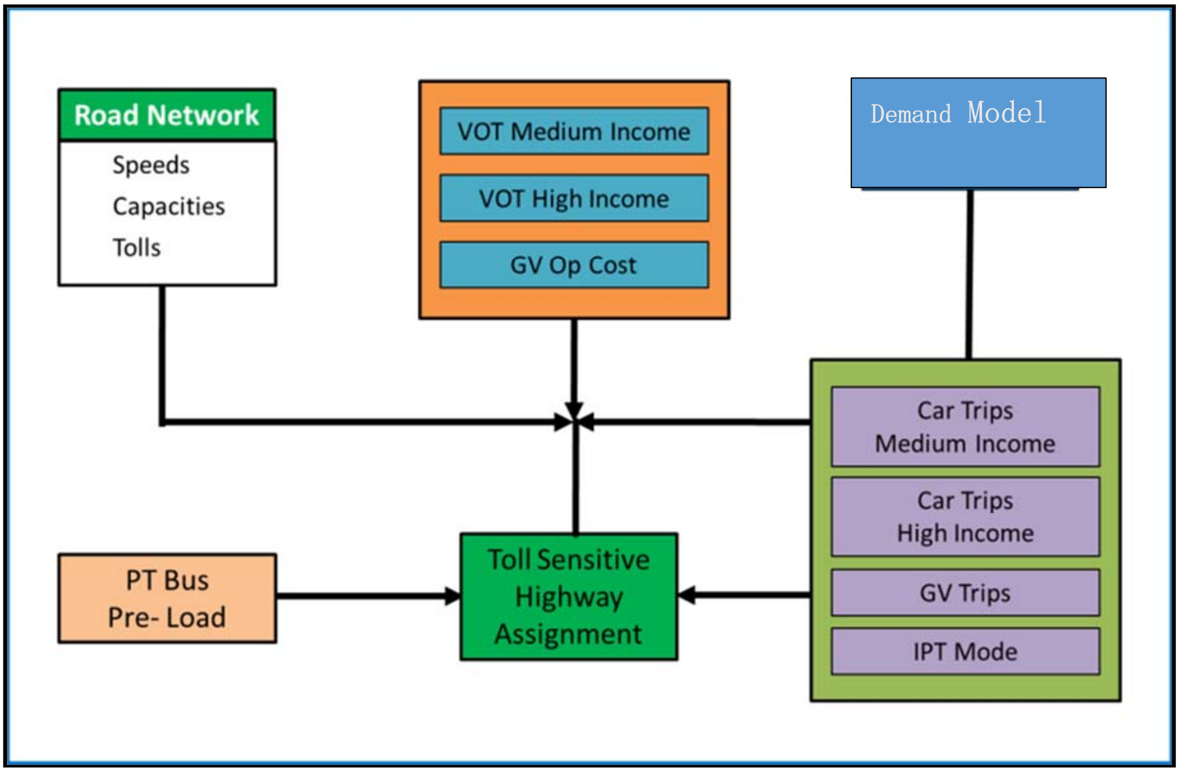
[18] The two most important clusters were Navi Mumbai and the Island City with 27% and 14% of commercial vehicles respectively.

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 assignment of the vehicle matrices as 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 survey (CVCS), railway passenger count survey (RPCS) and vehicle occupancy survey 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 transport model based on validation result of the base year traffic forecasts against current classified vehicle count survey and railway passenger count survey. The adapted pcu fators by vehicle types were decided based on advice of MMRDA and the adapted factores 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 screenlines is shown in Table 4.4.3. There are two vehicular screenlines namely the Island City and Thane Creek with a transit screenline across Thane Creek as well. All screenlines 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 Screenline 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

Four keys sets of 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 reviewed key socio-economic forecasts 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

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.

forecasts[24] were then reflected into the detail of the 188 traffic analysis zone. 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 10.48 to 18.2 million. The participation will also increase slightly over this time period from 0.44 to 0.49. However 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 expect to increase the transport requirements between Mumbai and Navi Mumbai.

Table 4.5.1 Distribution of Population Forecasts by Horizon Year (Mill 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.

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

Table 4.5.2 Distribution of Household Forecasts by Horizon Year (Mill 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 (Mill 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 dis-benefit 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 million annual passengers at this 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 extension discussions with relevant agencies and a review of associated feasibility studies.

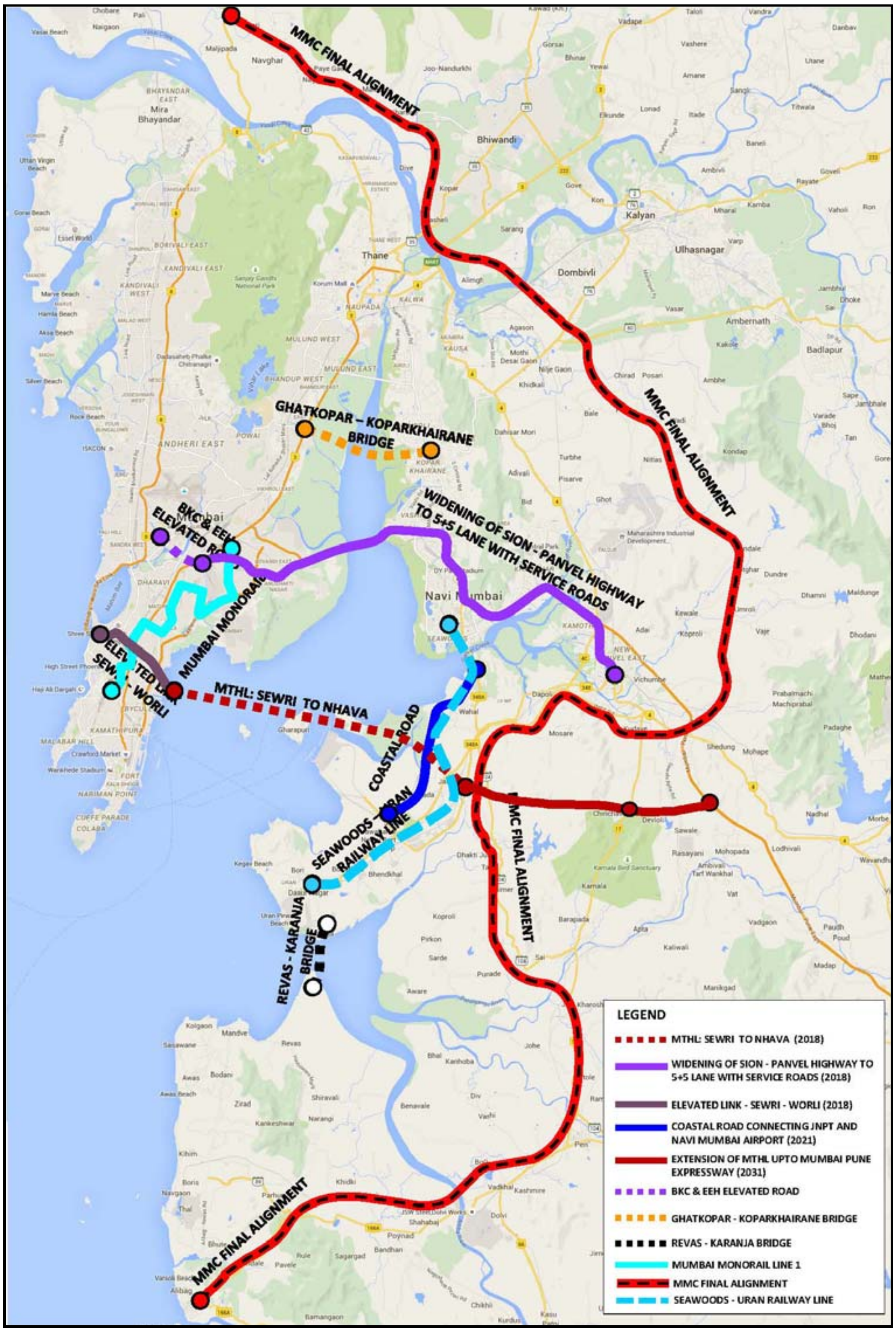
reduce the truck traffic travelling though Navi Mumbai to access the port. This impact will be included with an appropriate adjustment to truck travel matrix[29].

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 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 180 Rs[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 route across the MTHL.

Table 4.5.6 Base Toll (Rs) 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 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 demand on MTHL are decreased in comparison with 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 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 be increased up 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 be raised up 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 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 level and the ocean wave. 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 investigations, 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 were 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: Multibeam 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

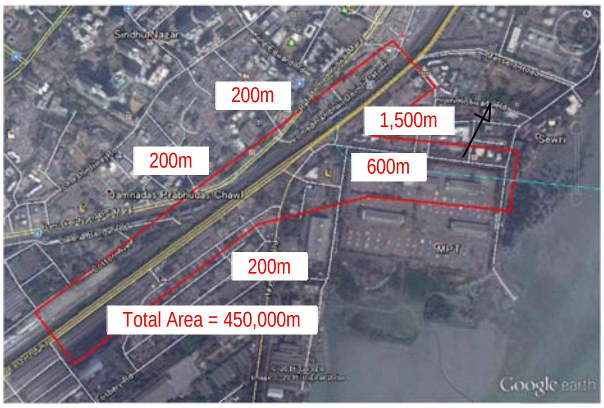
Topographical survey items and quantities are shown in Table 5.1.3.

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

(c) Chirle Interchange

Source: JICA Study Team

Figure 5.1.1 Location of the Plane Surveys

Survey lines of 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 batheymetry survey

Figure 5.1.3 Photos of Survey Work

5.1.2 Survey Results

(1) Topographic Map and Cross Sectional Survey

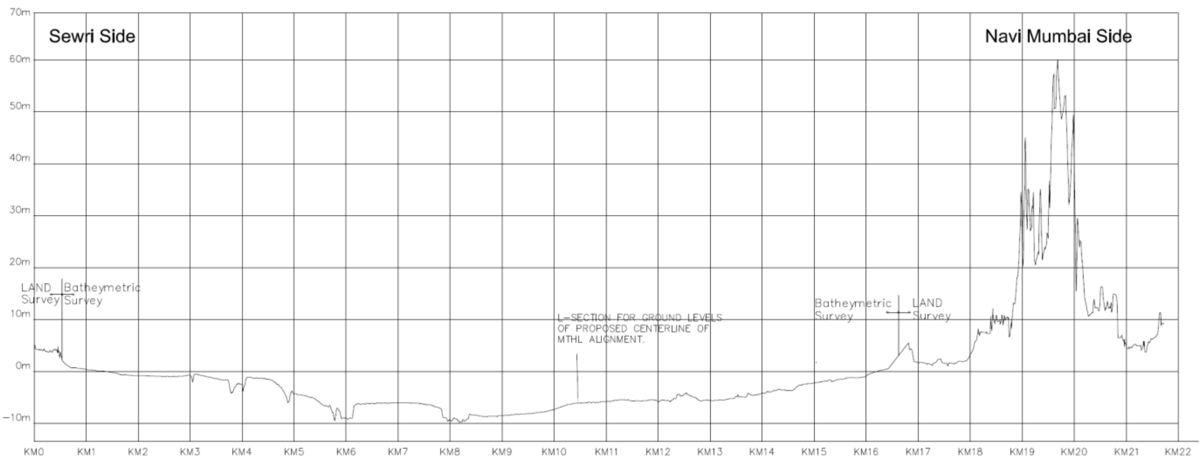
Topographic map and cross sectional survey results were utilized as base drawings on the basic design drawings. The topographic map, end point of the project, Navi Mumbai side is shown in Figure 5.1.4.

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 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 on the 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 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 18th century, and the reclamation work was conducted during 18th century. Presently, the land consists of the plain and low hills with the elevation of 5m to 20m. The land of Navi Mumbai lies on the Decan Traps had formed by the 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 the hills with elevation 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, geotechnical information at bridge sites on MHTL. The objectives of the Works are to in detail as follows:

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

(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 Mesozoic Cretaceous and early Cenozoic. Deccan Traps are composed of many kinds of Basalt rocks and with 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 with the thickness about 2m to 20m on the layers.

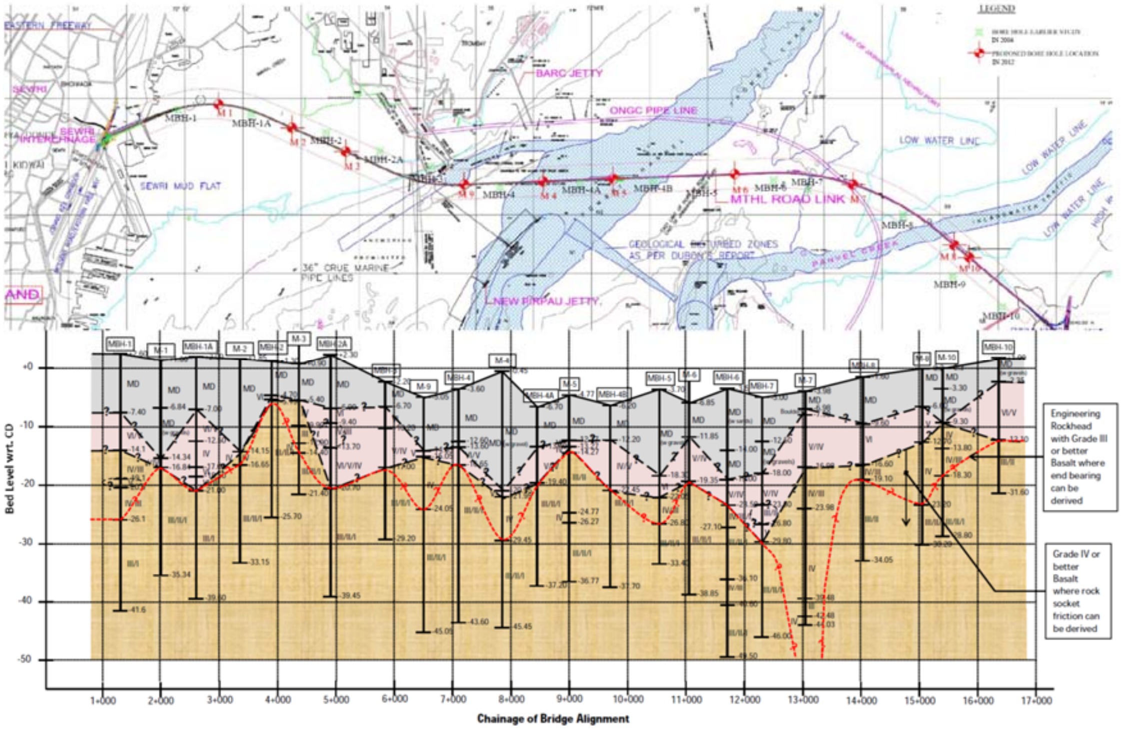
(3) Previous Survey

Geological surveys carried out in recent years are as shown in Table 5.2.1. 38 boreholes were totally drilled in these studies and 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 is lying based on basalt rock layer with about 10m thickness.

Table 5.2.1 Geological Survey 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

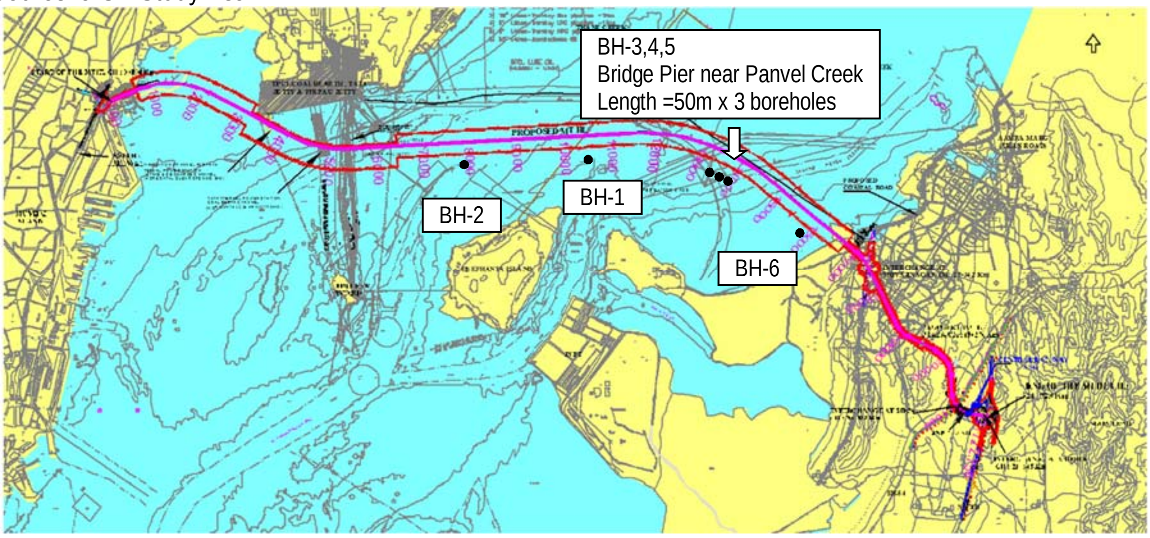
(4) Outline of the Survey

Borehole survey were planned in order to verify the past survey results and confirm the geological condition at main bridge pier location. 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 per hole (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 (Layer6) are confirmed in all boreholes and the depth of surface of the layer is from 10m to 35m from the sea bed. These are matched with the survey results in the past. The photo 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
Marin 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 is confirmed at KM 13+260.SPT Nvalues 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 Appendices. The brief description of the results are summarized in each layer and shown in Table 5.2.5.

Table 5.2.5 Laboratory Test Results

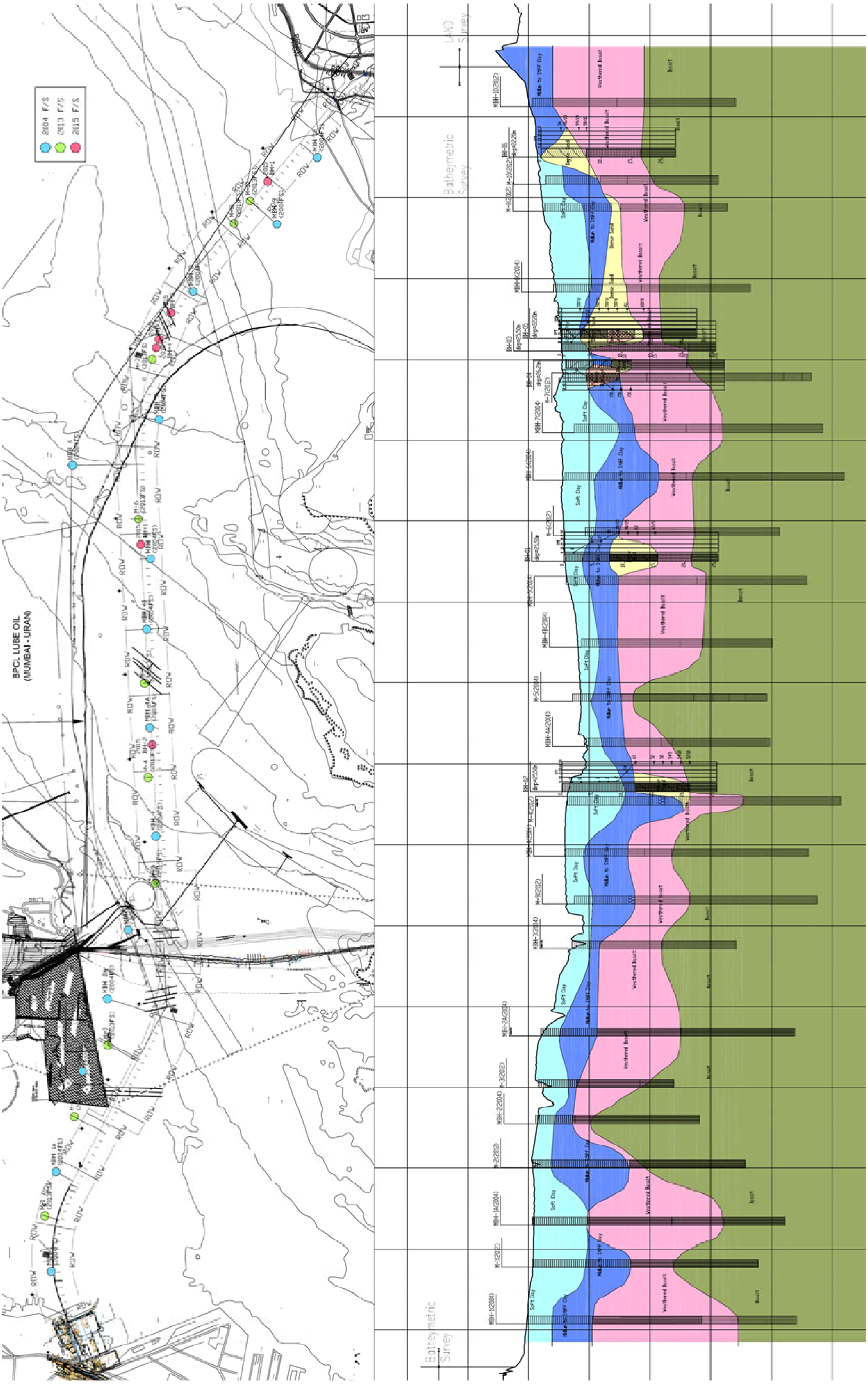
Segment	Type.	Thickness	Soil class	Brief Description, Average of the results
Layer1	Soft Clay	0~10m	CH	Specific gravity : 2.57(g/cm^3) Grain Size: Gravel 0%, Sand 0~10%, Silt 50~60%, Clay 40~50% Atterberg Limit: LL 59%, PL 29%, IP 30% Consolidation: CC 0.85, e0 1.70
Layer2	Stiff Clay	0~7m	CH	Specific 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 as 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 this borehole survey results. It is shown in Figure 5.2.4.



Source: JICA Study Team

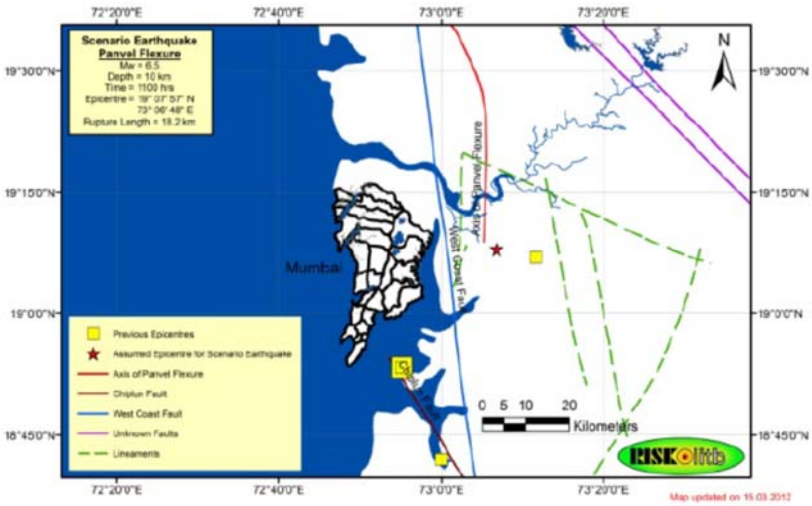
Figure 5.2.4 Geological Profile along MTHL

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 upper the Basalt layer. Thus supplemental measures are required to construct the piles.

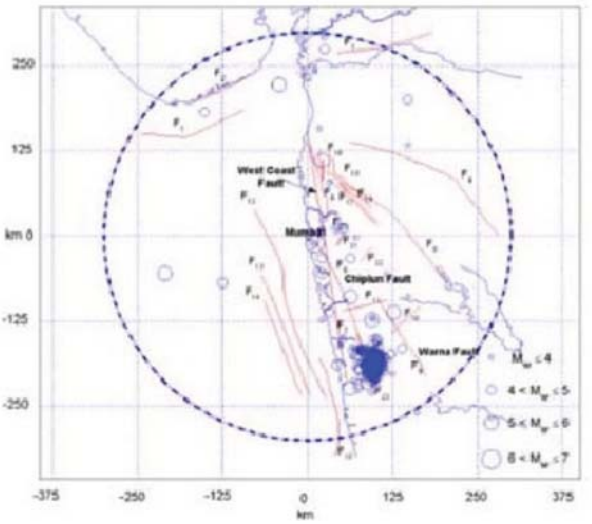
5.2.5 Seismic History

Earlier studies identified fault zone around the project area. Regarding the faults in the Mumbai area, 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 locates outside of the bridge section of MTHL. Meanwhile, it is not clear whether other faults are seismically active or not. Historical earthquake were happened and recorded as shown in Figure 5.2.6, Table 5.2.6. These records show that there have already been a few earthquakes with intensity VI+ damage during last 400 years. The circle of dot-line shows about 300km from Mumbai city in Figure 5.2.6. It shows that there have been no earthquakes with magnitude more than 7 in the 400 years in 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 Arabian Sea, and is classified a “Tropical wet and dry or savanna climate” (by Köppen-Geiger classification: Aw). The climate of Aw have 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 in Indian rivers, there are basins of 1,358 hectares, only in the upper river basin of the MTHL. The rivers in the target region have steep slopes in the upper reaches, and traverse on the coastal plains 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 of 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-feature) or port information/data are operated by MMB, MbPT, SOI, 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

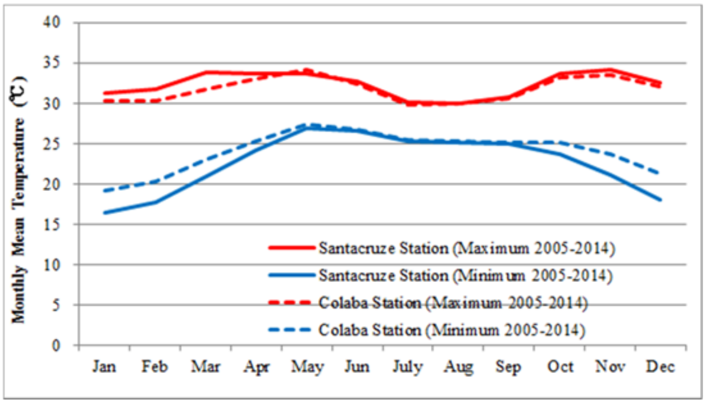
Figure 5.3.2 Station Location Map for Data Collection

5.3.3 Meteorological Survey

(1) General Weather Conditions

1) Temperature

The mean daily maximum temperature ranges from 30°C to 34°C except during the winter period when 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.

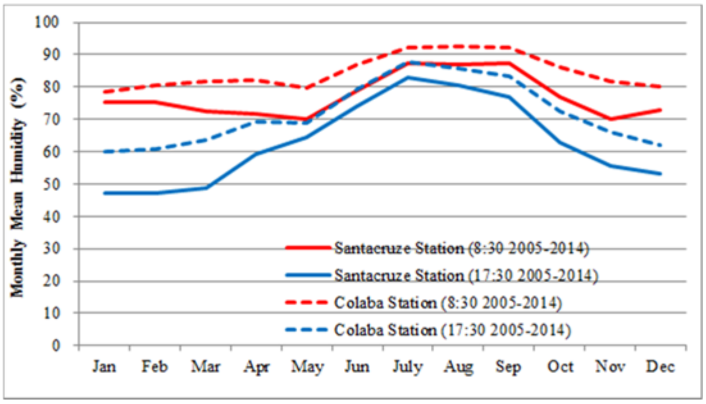


Source: JICA Study Team, IMD

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

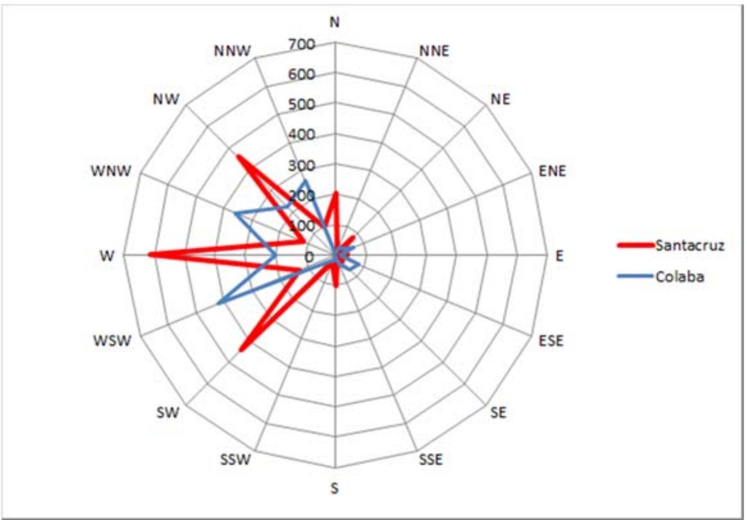
The monthly maximum wind speed at 2005-2014 and the wind rose are shown in Table 5.3.3 and Figure 5.3.5. From this Figure, it is shown that annual wind direction is dominated by northwest from the southwest. Historical maximum wind speed is recorded 28.9 m/s at Santacruz station of 2014 and 39.2 m/s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

On the other hand, the design wind speed to be used for the bridge superstructure design, have 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 safety-side value, and it is predicted as a value over 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

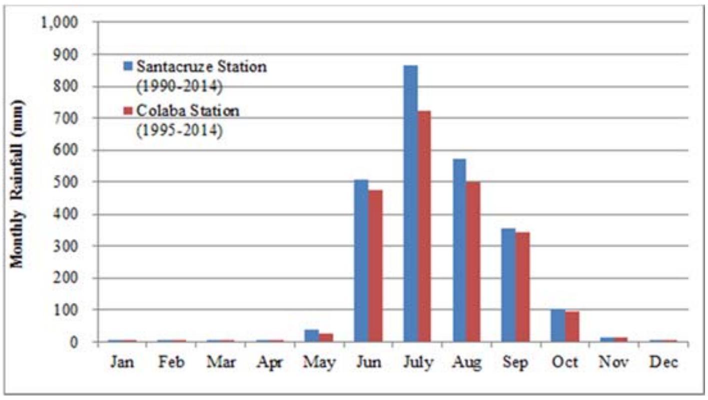
Most of the annual rainfall occurs during South West monsoon from June to September. Figure 5.3.6 shows the average monthly rainfall for the period 1990(1995)-2014 measured at Colaba and Santacruz station, Mumbai. Also, the fluctuation of the annual rainfall is shown in Figure 5.3.7. The followings can 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.

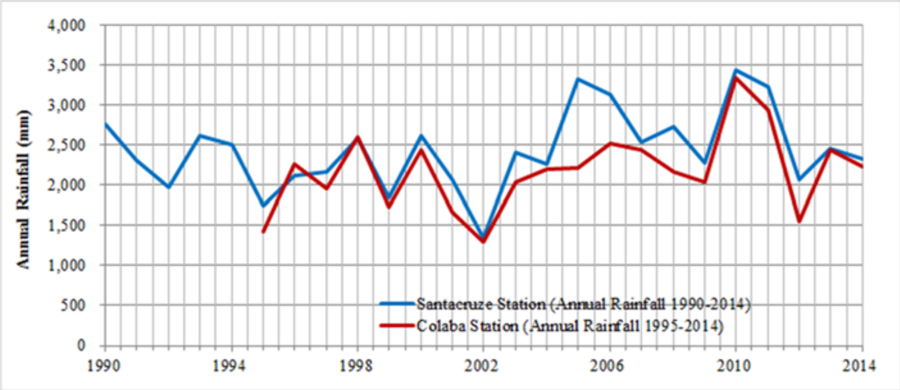
c) Maximum rainfall normally occurs in the month of July, followed by August.

d) According to the literature, number of annual rainy days is 91 days, and average number of days 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 measure.

Source: JICA Study Team, IMD

2) Exceedance Probability of Rainfall

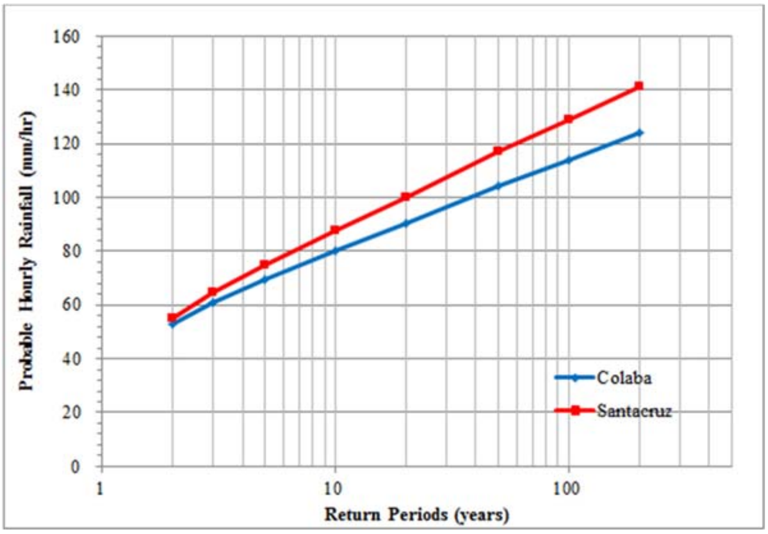
The rainfall pattern analysis has been calculated by Indian Institute of Technology at 2012. The exceedance probability rainfall during 1 hour and 24 hours are shown in Table 5.3.6.

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 of above Table are higher than 50mm/hr. Also, as per rainfall on 26th July 2005, the maximum rainfall intensity per hour was recorded 190.3 mm/hr.

Table 5.3.6 Rainfall for each Return Periods

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

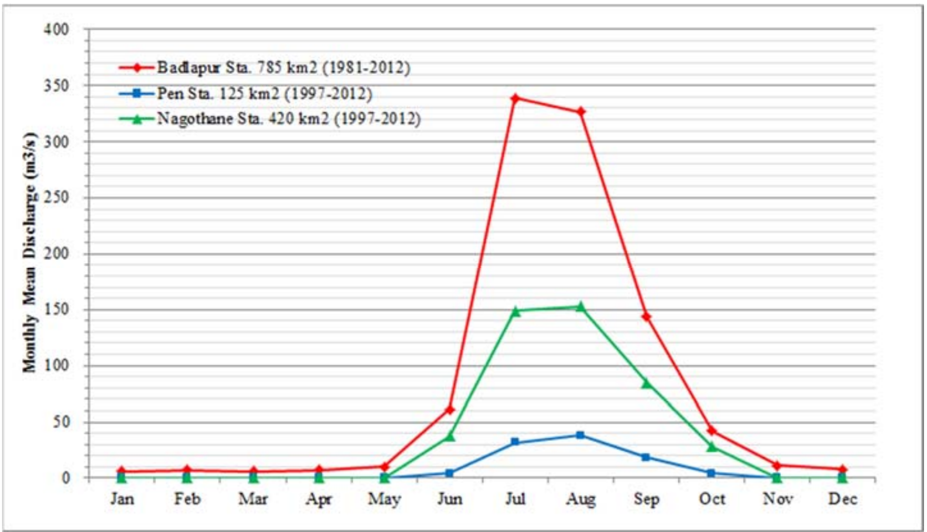
There are no gauging stations in rivers located in the upstream of MTHL. Therefore, the hydrological data of the following 3 gauging stations is collected. (Although the storm water of Pen and Nagothone stations flows into the Mumbai bay, Badlapur station is located in the Ulhas River basin of outside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

Table 5.3.7 and Figure 5.3.9 shows monthly mean discharge of past observed records at 3 gauging stations. It shows that many of discharge occurs from June to September, as same as 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 of each return period at upstream basin of the MTHL, are calculated from past annual maximum discharge data of 3 stations, as shown in Table 5.3.8. The discharge which flows into the Mumbai bay has not influenced dominantly to the tidal movement in the bay. Howbeit, for example, maximum discharge of 100 year return period is estimated as 7340 m^3/s.

Table 5.3.8 Maximum Discharge each Return Period at Gaugin 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 from 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 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 CDL.

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(-) from Chart Datum	Above(+) or Below(-) from 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

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 the earlier cyclone 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 current which were carried out during June 2004, maximum velocity is observed as 0.77m/s on location along the proposed MTHL. Also, on the nautical chart, maximum velocity is described as 3knot (1.54m/s) / 2knot (1.03m/s) at the time of flood-tide / 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 wave is from 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 creates the movement of large water mass to fill and empty 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 bed contribute to the amount of siltation in the harbour. Current pattern plays 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 begin 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 forecasted to reach the followings:

- 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

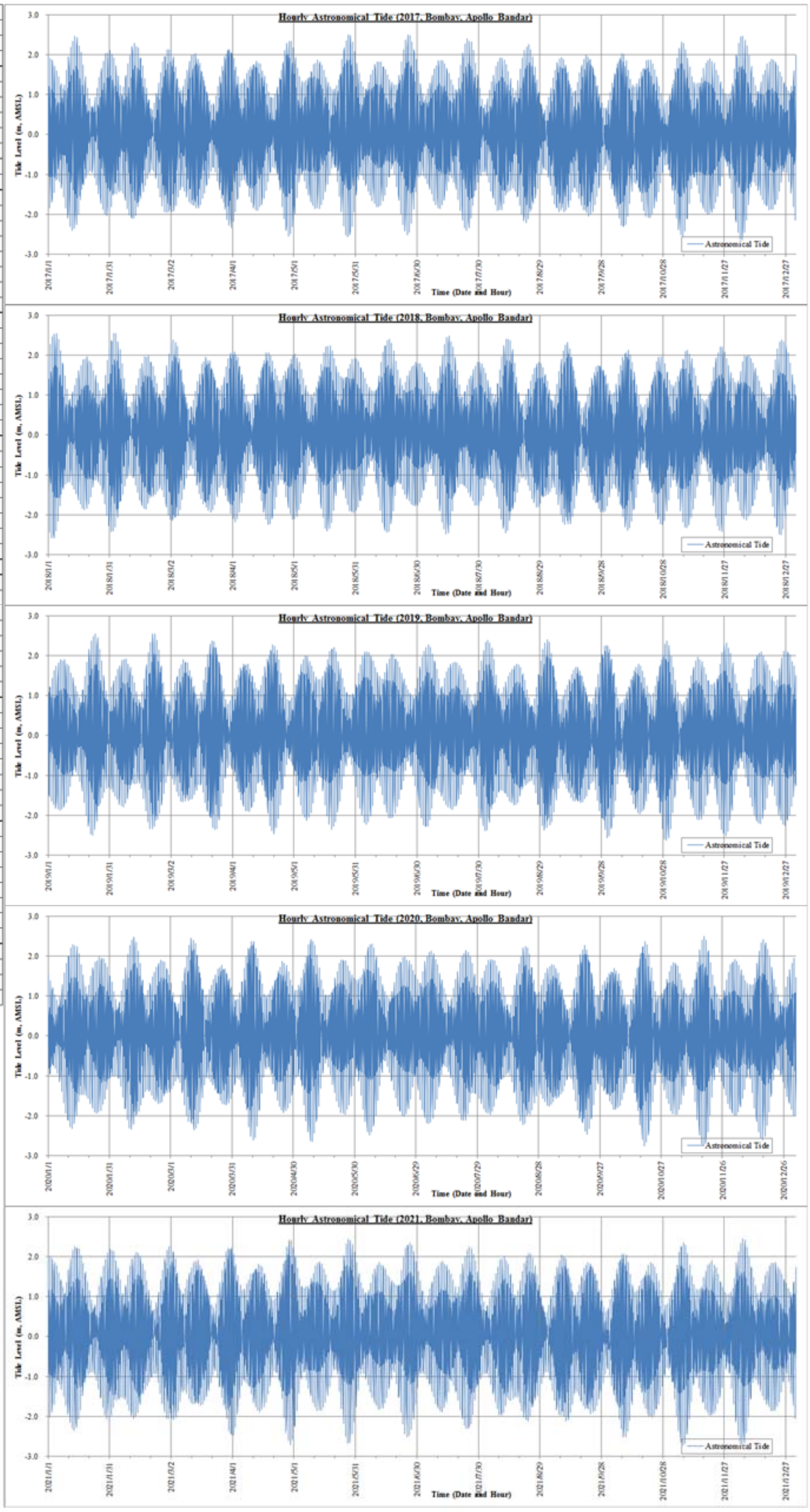
1) Astronomical Tide

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 tide at future year of 2017-2021 is calculated and predicted, by using 40 constants among these constants. These results are useful for the work plan by ship 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 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	121.2
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 to the construction of MTHL, the CWPRS has studied the approved alignment finalized by the experts and the span arrangement proposed in Feasibility Study of 2012. (CWPRS Technical report No. 5165, 2014)

The CWPRS have given the observations that "The proposed alignment will not have adverse impact on 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 mostly changes, and shows that it does not given any hydraulic impacts under conditions of the MTHL alignment and the span arrangement at the time of 2012 F/S.

5.4 Utility, Facility and Navigation Survey

5.4.1 General

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

5.4.2 Survey Items for Utility, Facility and Navigation

The survey for the utility, obstacles, and navigation, is conducted to 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 comment to the alignment of proposed MTHL from these organizations is collected, and the as-built drawing, the present-state survey and the future plan, etc. are collected.

Table 5.4.1 Survey Items for Utility, Facility and Navigation

Section		Length	Main Utilities and Obstacles	Organization (UtilityOwner)	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/Pole 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 marine portion are shown in Table 5.4.2 and Figure 5.4.1. Regarding utilities on the land portion, there are also many utilities on 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 on marine section, the horizontal clearance is kept minimum 50m and the vertical clearance is kept minimum 9.1m above HHTL. The HHTL is above 5.8m of Chart Datum (0.0).

(2) Crossing Utilities in Marine Portion

There are some crossing utilities on the bridge alignment in marine section. The kind and the required horizontal clearance of them were investigated and its 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 on the bridge alignment in 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

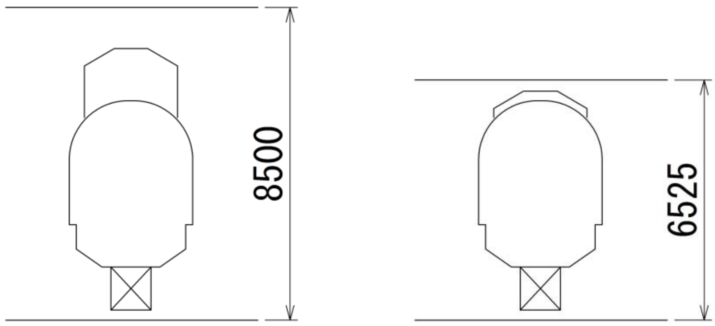
Crossing Railway	Chainage	Horizontal Clearance	Vertical Clearance	Source
Railway (Sewri station - Cotton Green station)	0+000	Refer to drawings of the source	8.5m above rail track	Drawing No. MMRDA-102/SEWRI-WORLI-MTHL/SEWRI-ROB/RLY/
Suburban Railways (Seawood – Uran)	18+500		6.5m above rail track	Drawing 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 of listed facilities, the facilities and channels which is crossed the MTHL are 8 facilities. 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

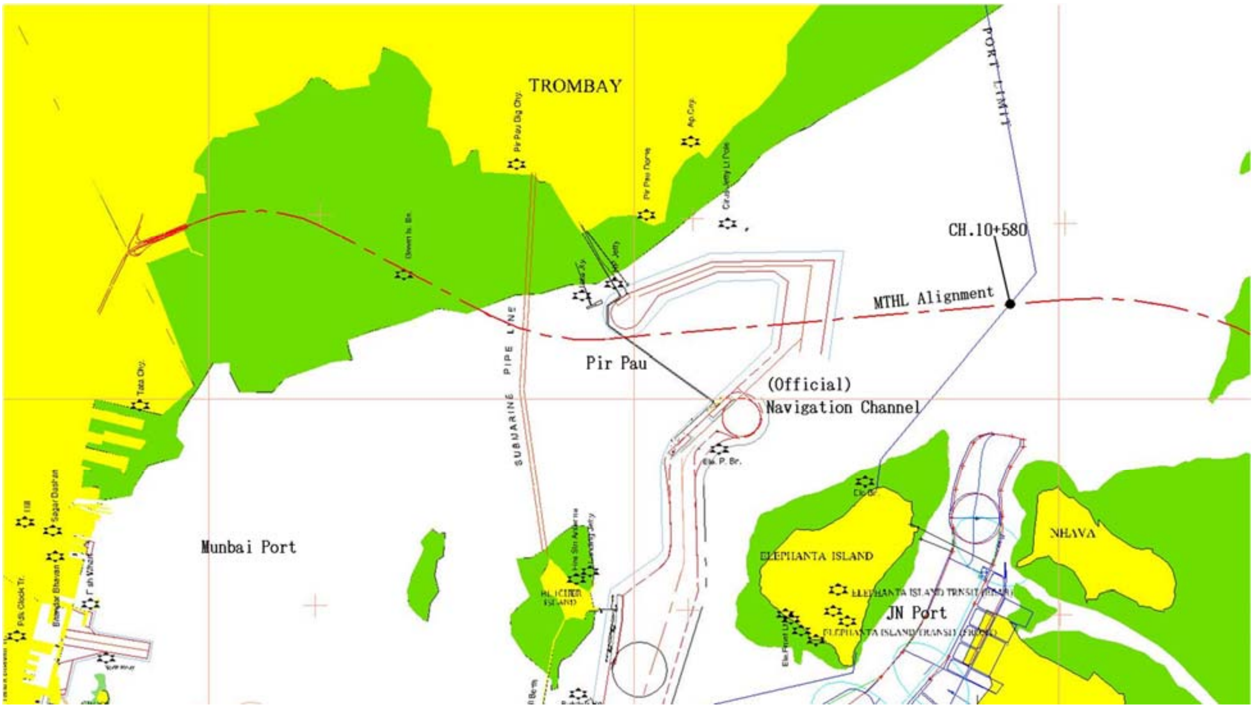
	No.	Chainage	Port Facility Name	Size, Type	Remarks
	1	0 + 500.0	Sewri Ford Jetty		
Crossing	2	3 + 550.0	TATA Discharge Channel	94m width * 1 channel	
	3	4 + 870.0	TATA Coal Berth Jetty		
Crossing	4	4 + 870.0	TATA Coal Berth Channel	94m width * 2 channels	
Crossing	5	5 + 300.0	TATA Coal Conveyor	5m width * 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 at the Existing Channel

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

As the present dredging condition of existing navigation channel, it is dredged once a year after monsoonal season, for maintaining the fairway depth on the nautical chart.



Source: MbPT

Figure 5.4.3 Navigation Channel around MTHL Alignment

6. PRELIMINARY DESIGN

6.1 Introduction

The preliminary design of MTHL deal with in this chapter comprises various engineering aspects.

The purpose of this preliminary design are 1) to calculate appropriate project quantities and project costs in order to formulate Japanese Yen loan scheme and 2) to carry out basic study in order to prepare the bid document in Design Built scheme.

This project comes after various studies spanning around 40 years, and as such, the previous study results are reflected. However, improvements have been proposed where appropriate.

A notable proposed improvement point is the bridge form in the sections where long spans are required, such as creeks, jetties and pipelines. In these sections, steel box girders with steel slabs have been proposed in order to shorten the construction period, improvement of the quality and the site safety during construction and technology transfer although the PC box girder was applied in previous study. Countermeasures for salt damage to steel bridges are described in chapter 6.5.4.

Design standards for road and bridge design (given in chapter 6.2 and 6.3) are mainly based on IRC latest codes and previous study results.

6.2 Design Standard for Road Design

6.2.1 Design Standard

(1) Design Standard for Road Design

Road design standards to be applied in this study are given in the following table. Of these, IRC SP 87-2013 and IRC 73-1980 are given precedence

Although IRC SP 87-2013 is mainly applied to widening of highways to 4-6 lanes through Public Private Partnerships (PPP), it can be applied to non-PPP projects as well. Some values specified in the geometric design standards in IRC SP87-2013 are based on IRC 73-1980.

Table 6.2.1 Geometric Design Standards in India

Title of Publication	Code No.
Manual of Specifications & Standards for Six Laning of Highways through Public Private Partnership	IRC SP 87-2013
Manual of Specifications & Standards for Four Laning of Highways through Public Private Partnership	IRC SP 87-2013
Two-laning of Highways through Public Private Partnership Manual of Specifications & Standards	IRC SP 73-2007
Geometric Design Standards for RURAL (NON-URBAN) HIGHWAYS	IRC 73-1980
Geometric Design Standards for URBAN ROADS IN PLAINS	IRC 86-1983
Recommendations About the Alignment Survey and Geometric Design of Hill Roads	IRC 52-1981

Source: JICA Study Team

[About SP: 99-2013]

Applicable geometric design standards are SP: 87-2013 and SP: 99-2013. For the road design, SP: 87-2013 was adopted in consideration of the following:

- Legally, the Project Highway is not classified as Expressway, National Highway and State Highway.
- In Final FS 2012, the design complied with SP: 87-2010, or the one before the revision to SP: 87-2013.
- Because the construction is managed by the Mumbai Metropolitan Region Development Authority (MMRDA), SP: 99-2013, which is inappropriate for urban areas, is not appropriate.
- The SP-99-2013 is mainly for earth work (Green Field).
- The intention of MMRDA: Highway standard has been used as the road design standard, so SP: 87-2013, which is a highway standard, shall be the one to follow for

the design.

(2) Design Standard for Environmental Crearance

The road design should be designed design standard for road design, EIA notification and CRZ notification. The EIA notification and CRZ notification is shown in 12.3.

6.2.2 Composition of Cross Section

The following policies are applied for the width of the road, road shoulder, and emergency platform.

(1) Width of Carriageway

Under IRC: SP-87-2013, the width of carriageway is 3.5 meters when the design speed is 100km/h. For reference, if the large vehicle ratio is low, the width of a lane is 3.5 meters under the proposed standards on the geometry design of Japan standard. The same width applies to Asian highways as well. According to the traffic demand forecast, the large vehicle ratio will be up to as low as 9.4% (2022), allowing judgment that the lane width at 3.5 meters will ensure sufficient safety and road functions.

Table 6.2.2 Forecast of Large Vehicle Ratio at MTHL

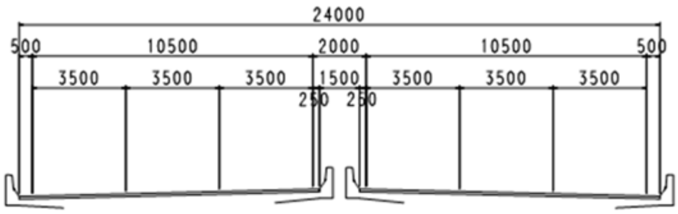
2022	9.4%
2032	6.1%
2042	5.6%

Source: JICA Study Team

(2) Widhth of Shoulder

1) Result of Previous Studies

Under Final FS 2012 Report, it was adupted left side shoulder width is 0.5m and right side shoulder is 0.25m. However, when it compers with the international standard, design speed shall be restricted less than 80kph in consideration of safety.



Source: JICA Study Team

Figure 6.2.1 Tipical Cross Section (Final FS 2012)

2) Function of Shoulder

Shown berow the main function of shoulder.

Passage function of the vehicles:

Keep some lateral clearace to secure safety and comfortability for the vehicles.

Stopping function of the vehicles:

Prevent the confunsion of a driver from traffic accident since the accident vehicle can be separated form carriageway.

Table 6.2.3 Function of Shoulder

Shoulder Width	Function
2.4m － 3.6m	All vehicle can park temporary
1.25m － 1.8m	Some lateral clearance can be secured for passing vehicles. Sedan can park temporaray.
0.5m －0.75m	Minimum lateral clearance can be secured for passing vehicle. No temporary parking space.

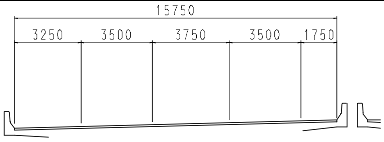
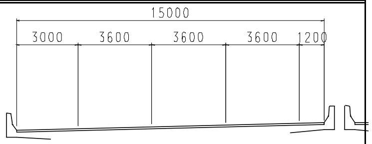
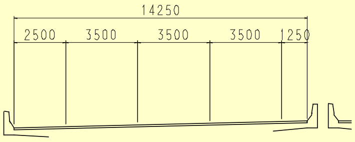
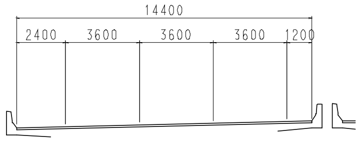
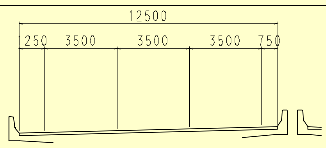
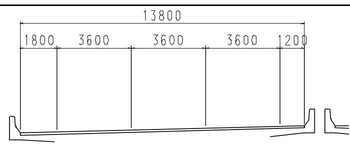
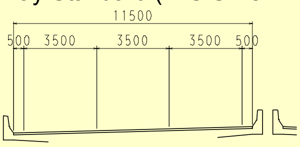
Source: Japan Stantard

The shoulder width shall be desided to compar the international shoulders.

(3) Tipical Cross Section

To plan the tipical cross sections based on Indian Standard and Japanese Standard for each design speed. After planning, to seleIct the tipical Cross Section from the each design speed.

Table 6.2.4 Ideal Cross Section by Design Speed

Design Speed	Indian Standard	Japanese Standard	Reference (AASHTO)
120		 Construction Cost 14,900crore INR(1.30) (3,400 crore INR UP)	 Construction Cost 14,100crore INR(1.23) (2,700 crore INR UP)
100	Highway Standard (IRC SP 87 2013) is specified with design dpeed 100kph. However, when it compares with the international standard, design speed shall be restricted with less than 80kph (60kph) in consideration of safety.	 Construction Cost 13,500crore INR(1.18) (2,100 crore INR UP)	 Construction Cost 13,600crore INR(1.19) (2,200 crore INR UP)
80		 Construction Cost 12,200crore INR(1.07) (800 crore INR UP)	 Construction Cost 13,200crore INR(1.15) (1,800 crore INR UP)
60	Highway Standard (IRC SP 87 2013  Construction Cost 11,400crore INR(1.00)		

Source: Japan Study Team

To select the tipical crooss section of each design speed.

1. Tipical cross section of 120kph: This design speed was not studied by Final FS 2012, therefore do not plan the case of 120kph in this study.
2. Tipical cross section of 100kph, 80kph: Highway Standard (IRC SP 87 2013) is specified with design dpeed 100kph. However, when it compares with the international standard, this design speed shall be restricted with less than 80kph (60kph) in consideration of safety. Therefore, to select from Japan standard
3. Tipical cross section of 60kph: To select from Indian standard

1st recommendation

Desigin Speed is 100kph

Operative speed (speed limit): 100kph

2nd recommendation

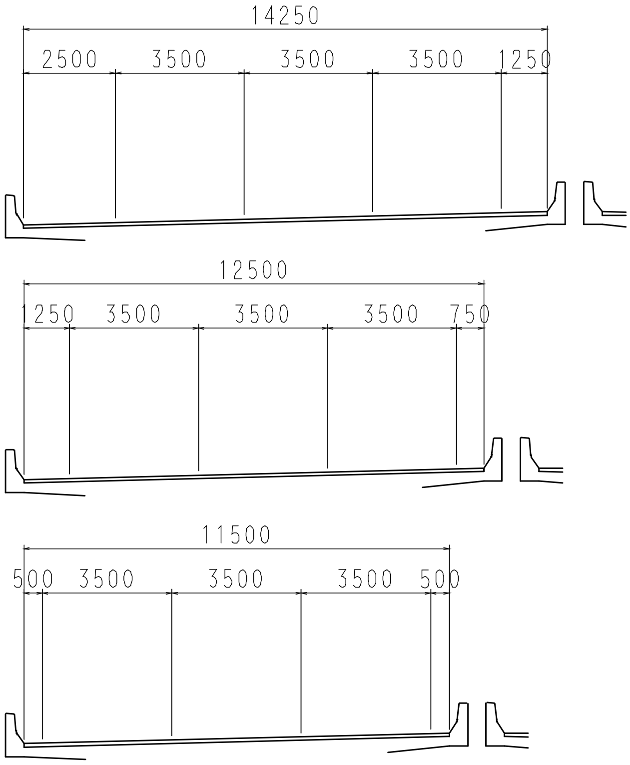
Desigin Speed is 100kph

Operative speed (speed limit): 80kph

3rd recommendation

Desigin Speed is 100kph

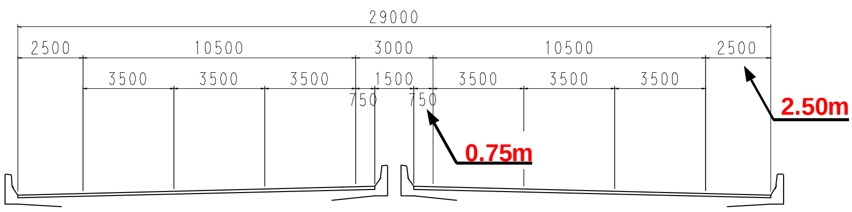
Operative speed (speed limit): 80kph



Source: Japan Study Team

Figure 6.2.2 Comparison Tipical Cross Section

Shown below Figure 6.2.5, the final tipical cross section. It was determinined the meeting with MMRDA.



Source: Japan Study Team

Figure 6.2.3 Comparison Tipical Cross Section

6.2.3 Road Classification and Design Speed

The MTHL is classified plain and rolling, the design speed of main alignment is 100kph. However, at the east side, over Shivaji Nagar IC, is mountainous and steep. Therefore, over Shivaji Nagar IC to Chirle IC section is 60kph.

Table 6.2.5 Design Speed

Unit: Kph

Nature Terrain	Design Speed	
	Ruling	Minimum
Plain and Rolling	100	80
Mountainous and Steep	60	40

Source: IRP SP 87-2013

6.2.4 Geometric Design Standard

Geometric design standards applied to preliminary design of MTHL are as follows. These values mainly follow IRC code. However, some values are based on previous designs from 2012 which were approved by the MMRDA in the meeting on 20 April 2015.

(1) Main Alignment

Geometric design standards for main alignment are given below. As reference, the values of Japanese standard and AASHTO are also described in table below.

Table 6.2.6 Geometric Design Standard of Main Alignment

Items		Unit	Values to be applied	IRC 73-1980	IRC SP-87-2013	Japan Standard	AASHTO
Main Road Alignment (Ch 0+495 – 21+723)							
Width of each carriageway		m	3.50	3.50	3.50	3.50	3.6
Shoulder Width	Left Side	m	2.50	-	0.50	2.50	3.0
	Right Side	m	0.75	-	0.50	0.75	1.2
Central median width	Earth work section	m	3.0-5.0	3.0-5.0	3.0-5.0	3.0	
	Bridge/Viaduct	m	1.50	1.50 (1.20)	-	3.0	
Taper transition from single lane to multi-lane		rate	1:15-1:20	1:15-1:20	-	1/15	
Cross fall		%	2.5	2.0 – 2.5	2.5	2.0	1.5-2.0
Design speed for main line		km/h	100				
Minimum Horizontal Radius Curve (Ruling)		m	400	360	400	460	328
Minimum Horizontal Curve Length		m	170	-	-	170	
Minimum Horizontal Radius(Ruling)Without Super elevation		m	2,600	2,600	2,600	5,000	3,720
Maximum Super-elevation (rotation about median edge)		%	5%	7%	5%	10%	12%
Minimum Transition Length	R = 400m R = 600m R = 1,000m R = 1,800m R = 2,500m R = 4,200m	m m m m m m	115 80 50 30 not required not required	115 80 50 30 not required not required	115 80 50 30 not required not required	85	56
Minimum Radius (No use transaction Curve)		m	2,000	2,000	2,000	3,000	2,770
Super elevation rubbed rate			1/150	-	-	1/150	1/227
Sight Distance	Safe Stopping	m	180	180	180	160	185
	Overtaking	m	640	640	640	500	320
Minimum vertical gradient		%	0.5	0.5	0.5	-	
Maximum vertical gradient		%	2.5	3.3	2.5 (Ruling) 3.3 (Limiting)	3.0	3.0
Minimum length of vertical curve		m	60m	60m	60m	85m	
Minimum Radius of vertical curve, Top		m	6,500	-	-	6,500	
, Bottom		m	3,000	-	-	3,000	
			10.0	-	-	10.0	

Source: JICA Study Team

(2) Interchange Alignment

Geometric design standards for Interchanges are given below.

IRC 73-1980 is applied to interchange ramps since IRC SP 87-2013 does not contain applicable provisions. For items not covered therein, design guidelines and Japanese Highway Standards shall be used.

The vicinity of interchange is the section where the running speed changes. There is no Indian standard for this section. Below tables shows the geometric design of interchange ramps and main alignment near the interchanges respectively.

Table 6.2.7 Geometric Design Standard of Interchange Ramps

Items		Unit	Values to be applied	IRC 73-1980	Japan Standard	AASHTO
Width of each carriageway		m	3.50	3.50	3.50	3.6
Shoulder Width	Sewri	m	0.25*	0.5*	0.75	3.0
	Shivaji/Nagar,SH54, Chilre	m	0.50	0.5*	0.75	1.2
Design Speed		kph	40			
Minimum Horizontal Radius		m	60	60	50	36
Minimum Horizontal Curve Length			-	-	70	45
Minimum Horizontal Radius(Ruling)Without Super elevation		m	420	420	600	804
Cross fall		%	2.5	2.0 – 2.5	2.0	1.5-2.0
Maximum super elevation		%	7.0	7.0	10.0	10
Minimum Transition Length	R = 45m R = 60m R = 90m R = 100m R = 150m R = 170m R = 200m R = 240m R = 300m	m	45 60 90 100 150 170 200 240 300	45 60 90 100 150 170 200 240 300	35	22
Minimum Radius (No use transaction Curve)		m	500	500	500	594
Super elevation rubbed rate			1/100	-	1/100	1/143
Sight Distance	Safe Stopping	m	45	45	40	
	Overtaking	m	90	90	150	65
Minimum vertical gradient		%	0.5	0.5	-	160
Maximum vertical gradient		%	3.3	3.3	6.0	5.0
Minimum length of vertical curve		m	30	30	35	
Minimum Radius of vertical curve, Top		m	450	-	450	
, Bottom		m	450	-	450	

* Confirmed to MMRDA in the meeting on 20th May 2015. The shoulder width was classified as follows.

- 0.25m width: Sewri is the bridges section or restricted land area.
- 0.50m width: Shivaji Nagar, SH54 and Chirle are earth work section and not restricted land area.

Source: JICA Study Team

Table 6.2.8 Geometric Design Standard in the Vicinity Interchange (Main Alignment)

Item		Unit	Japanese Standard		
Design Speed		kph	100	80	60
Minimum Horizontal Radius		m	1,500	1,100	500
Maximum Vertical Grade		%	2.0	3.0	4.5
Minimum Radius Vertical Curve	Top	m	25,000	12,000	6,000
	Bottom	m	12,000	8,000	4,000
Weaving Length		m	275	215	215

Source: JICA Study Team

Table 6.2.9 Geometric Design Standard in the Vicinity Interchange (Ramp)

Item		Unit	Japanese Standard		
Design Speed		km/h	100	80	60
Minimum Horizontal Radius		m	200	170	100
Minimum Transaction		m	70	60	50
Minimum Radius Vertical Curve	Top	m	1,000	800	450
	bottom	m	850	700	450

Source: JICA Study Team

(3) Transition Curves and Extra Width of Interchange

The transition curves and extra width were not considered for interchange design in Fimal FS 2012. They are necessary for vehicle to have smooth entry from straight section into a circular curve. Therefore, the standard of transition Curves and Extra Width are considered for interchanges in this study as follows.

As for the main alignment, it was considered in previous design, and the widening is not required that curve radiuses are large.

Table 6.2.10 Minimum Transition Lengths (Design Speed 40km/h)

Curve Radius (m)	Minimum Transition Length (m)
R= 45	Not Applicable
R= 60	75
R= 90	50
R=100	45
R=150	30
R=170	25
R=200	25
R=240	20
R=300	No Required

Source: IRC-73-1980

In Indian standard, the lane widening width is given the different for one-lane road and 2-lane road. On the other hand, in Japanese standard, it is given per lane. Table 6.2.7 shows the respective values.

The adapted radius of all ramps in MTHL is about 100m. And extra width of Indian standard in 100m radius is wider than Japanese one. Therefore, India standard is applied for the extra width at horizontal curves.

Table 6.2.11 Extra Width at Horizontal Curves

India standard			Japan Standard	
Radius curve (m)	Two-lane road	One-lane road	Radius Curve (m)	Each one lane
More than 300m	-	-	More than 160m	-
101 to 300	0.6	-	160 to 90	0.25
61 to 100	0.9	-	90 to 60	0.50
41 to 60	1.2	0.6	60 to 45	0.75
21 to 40	1.5	0.6	45 to 32	1.00
Less than 20m	1.5	0.9	32 to 26	1.25
			26 to 21	1.50
			21 to 19	1.75
			19 to 16	2.00
			16 to 15	2.25

Source: IRC-73-1980 and Japanese standard

(4) Acceleration and Deceleration Lane

The two types of acceleration and deceleration lane are adapted to the merging/diverging section. The one is “taper transition type”, other one is “deceleration and acceleration type”. The applications are classified as follows.

- In case of the each road design speeds are equal; the taper transition type is adopted.
- In case of the road design speeds are different, to the deceleration and acceleration type is adopted.

This classification is the same as previous study in 2012.

Table 6.2.12 Types of Acceleration and Deceleration Lane

Type	Interchange
Taper Form	Sewri IC
Acceleration and Deceleration	SH54IC,Shivaji Nagar IC, Chirle IC

Source: JICA Study Team

Table 6.2.13 Taper Transition Length and Acceleration Deceleration

Taper form

Items	Unit	Value	IRC SP-87-2013
Taper transition From single lane to multi-lane	rate	1:15-1:20	1:15-1:20

Acceleration and Deceleration Form

Items	Unit	Value	IRC SP-87-2013
Deceleration Length	m	145	145
Acceleration Length	m	150	150

Source: JICA Study Team

(5) Suggestion of Deceleration and Acceleration Lane

The acceleration and deceleration type is applied as the form of merging/ diverging between the acceleration and deceleration lane and the ramp for the following reasons:

- Acceleration and deceleration type is applied for diverging and merging sections of interchanges under both Indian standard and Japanese standard.
- The form of merging/diverging needs to be unified for the entire road, and application of the acceleration and deceleration type is preferable because it is common.
- The acceleration and deceleration type clarifies the acceleration and deceleration section between the ramp and main road, which differ from each other in terms of the speed of vehicles, and therefore reflects safety considerations.
- The taper form type should be applied where the number of lanes with the same speed limit increases or decreases. The acceleration and deceleration type should be applied for sections where the speed of vehicles changes.

At the Sewri IC, four lanes merge and diverge at the same time. Accordingly, with the method applied for this interchange, two adjacent ramps are merged with each other, and where the merger is completed, still another ramp is merged with it.

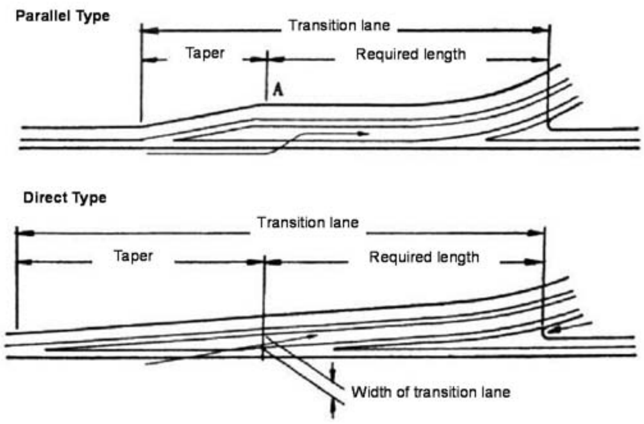
The acceleration and deceleration type is divided into parallel type and direct type. This time, the direct type is applied for both acceleration and deceleration because most interchanges are circular curves. Parallel type is applied only for the acceleration section on the SH54IC side of Shivaji Nagar IC and weaving section of Chirle IC. Features of the parallel type and direct type are as described below.

1) Parallel Type

Transition lane is shifted after some parallel section. The drivers can confirm the status of the main alignment before shifting.

2) Direct Type

Directly come together or separate from the main alignment. It is not affected by the status of the main alignment.



Source: Japanese standard

Figure 6.2.4 Parallel Type and Direct Type

3) Planning Method for the Confluence and Separation of 2-Lane Ramps

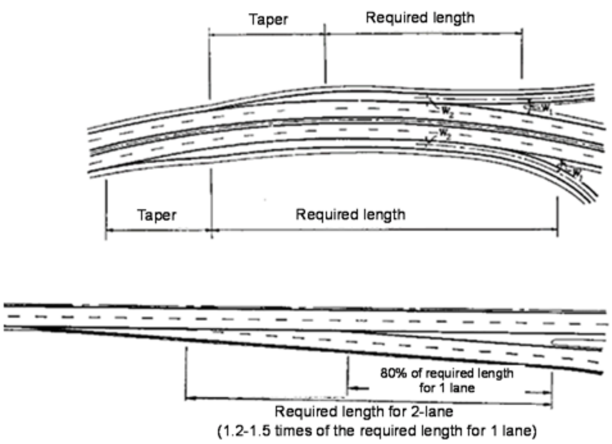
As for the confluence and separation of 2-lane ramps, it is desirable that not only connecting to the end of transition length from the ramp nose, but also it establishes the point of the securing of 2 traffic lanes in the middle. In this study, to use properly parallel type and direct type.

<u>Parallel Type: Straight Section</u>

SH54 side acceleration of Shivaji Nagar IC /Weeving section of Chirle IC

<u>Direct Type: Curve Section</u>

Other than those above IC



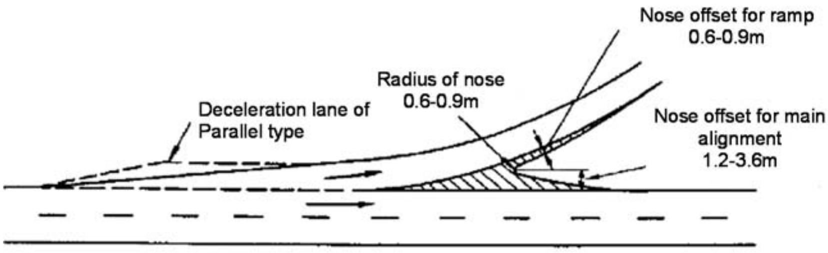
Source: Japanese standard

Figure 6.2.5 Confluence and Separation of 2-Lane Ramps

4) Other Details

Nose offset

In case of the driver takes the wrong direction, some spaces shall be provided in front of the nose in order to come back to main alignment smoothly. However, it is impossible to provide it in Sewri IC because of the site restriction.



Source: Japanese standard

Figure 6.2.6 Nose Offset

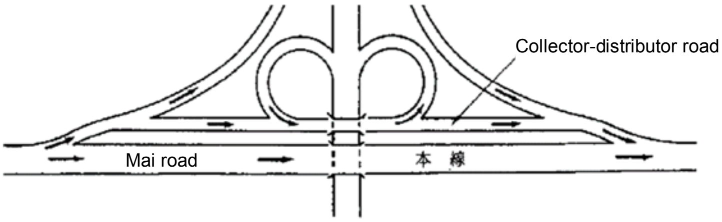
Correction of speed change section

If the vertical gradient of the main road exceeds 2%, the length of the speed change section needs to be corrected (Japanese standard). However, the correction is not necessary because the vertical gradient of the interchange section is 2% or below.

Collector-distributor road

At an interchange with successive separation and confluence of on-ramp and off-ramp like Chirle IC, a collector-distributor road for dispersing the traffic on the main road and the ramp may be created.

However, a collector-distributor road will not be provided because the site conditions have been finalized and space for the collector-distributor road cannot be secured.

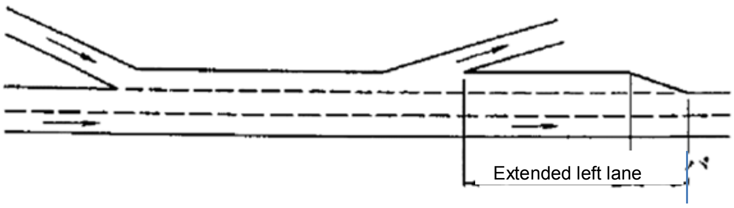


Source: Japanese standard

Figure 6.2.7 Collector-Distributor Road

Extended left lane for changing to the main road

Where an on-ramp is followed immediately by an off-ramp, the left lane is extended to give enough space to vehicles changing to the main road. An extended left lane is provided at Chirle IC. Shivaji Nagar IC also has such a section. However, the section has a setback for securing sight distance, and it was deemed possible to use this extra space as a lane for changing to the main road.



Source: Japanese standard

Figure 6.2.8 Extended Left Lane for Changing to the Main Road

Figure 6.2.5 shows the applied deceleration and acceleration length in MTHL.

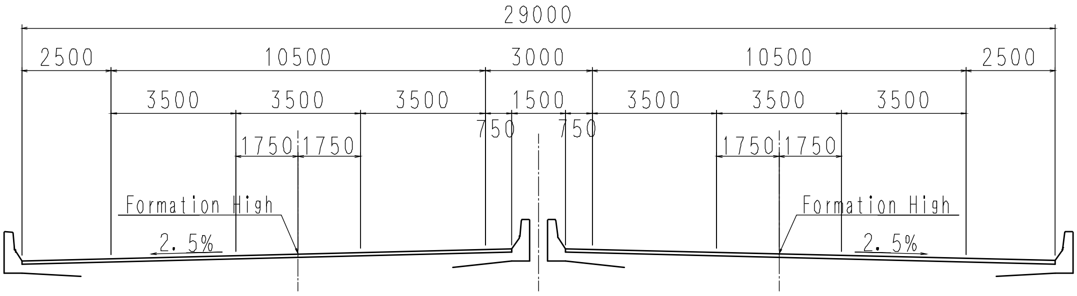
Table 6.2.14 Deceleration and Acceleration Length

		Japan Standard			India Standard
Design speed(km/h)		100	80	60	100
Base deceleration length except tater length	1-lane 2-lane	90 130	80 110	70 90	80m(1Lane)
Base Acceleration l expect tater length	1-lane 2-lane	180 260	160 220	120 160	95m(1Lane)
Taper Length	1-lane	60	50	45	55
Outflow angle	1-lane 2-lane	1/25	1/20	1/15	-
In flow angle	1-lane 2-lane	1/40	1/30	1/20	-
Nose Distance	-	275	215	215	-

Source: JICA Study Team

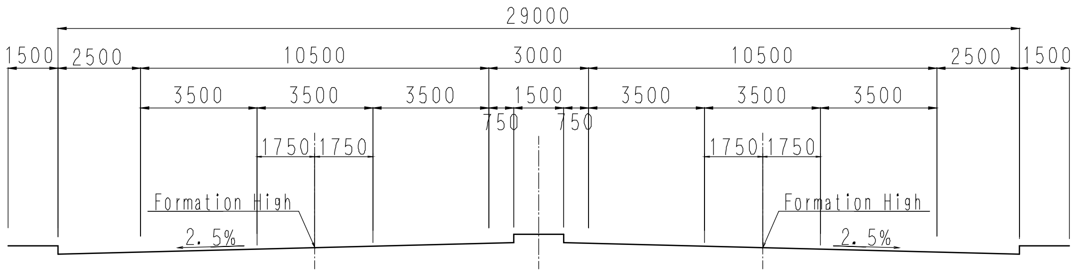
6.2.5 Typical Cross Section

Shown below the each of tipical cross section.



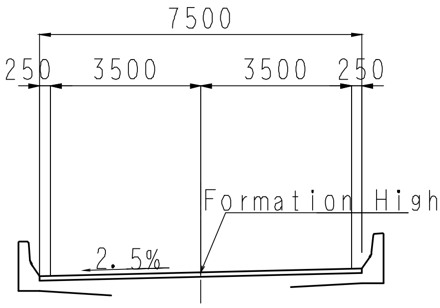
Source: JICA Study Team

Figure 6.2.9 Main Alignment (Viaduct) Section



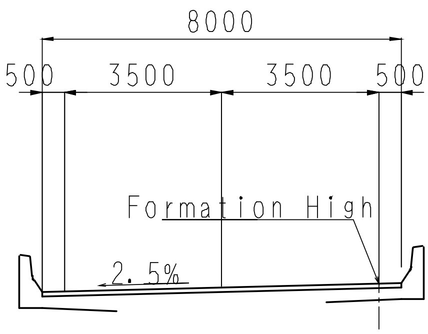
Source: JICA Study Team

Figure 6.2.10 Main Alignment Earth Works Section (18+950 – 19+950)



Source: JICA Study Team

Figure 6.2.11 Sewri IC



Source: JICA Study Team

Figure 6.2.12 Shivaji Nagar, SH54 and Chirle IC

6.3 Design Criteria for Structural Design

6.3.1 Design Codes

Main code list for bridge structure design is shown in Table 6.3.1.

Table 6.3.1 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: 6-2014	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-18-1996	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 Specification 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-74-2007	Guidelines for Repair and Rehabilitation of Steel Bridges
IRC:SP-80-2008	Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures
Japanese Standard	Handbook for protection of bridge painting and corrosion protection (December, 2005)

Source: JICA Study Team

6.3.2 Design Concept

(1) Design Life

The target design life for main structures shall be 100 years according to IRC: 112-2011.

(2) Environmental Equipments for Bridges Design

The following environmental requrements shall be in corporated into the bridges plan and design.

- The bridge type shall be considered not to give significant impacts on flying course of migratovy birds in mud flat area, e.g. the lesser flamingo.
- The span arrangement and substructure type shall be considered to minimize an advise environmental impact in tidal and mangrove areas.

6.3.3 Design Loads

There are several loads to be considered for the bridge design.

(1) Dead Loads

The dead load shall include the weight of all components of the structure, utilities attached, pavement wearing surface and future overlays. In absence of precise information, the unit weights prescribed by IRC: 6-2014 can be used to calculate the dead load of the structure.

Table 6.3.2 Unit Weight of Bridge Materials for Dead Load Calculation

Material		Weight (t/m^3)
Concrete	Asphalt	2.2
	Cement-Plain	2.5
	Cement-Reinforced	2.5
	Cement-Prestressed	2.5
Steel	(Rolled or Cast)	7.8

Source: IRC: 6-2014

The unit weight of High Performance Concrete (hereinafter called HPC) shall be taken as 2.6 t/m^3, which shall be applied to bridges on marine to prevent the salt damage recommended by Technical Committee for MTHL

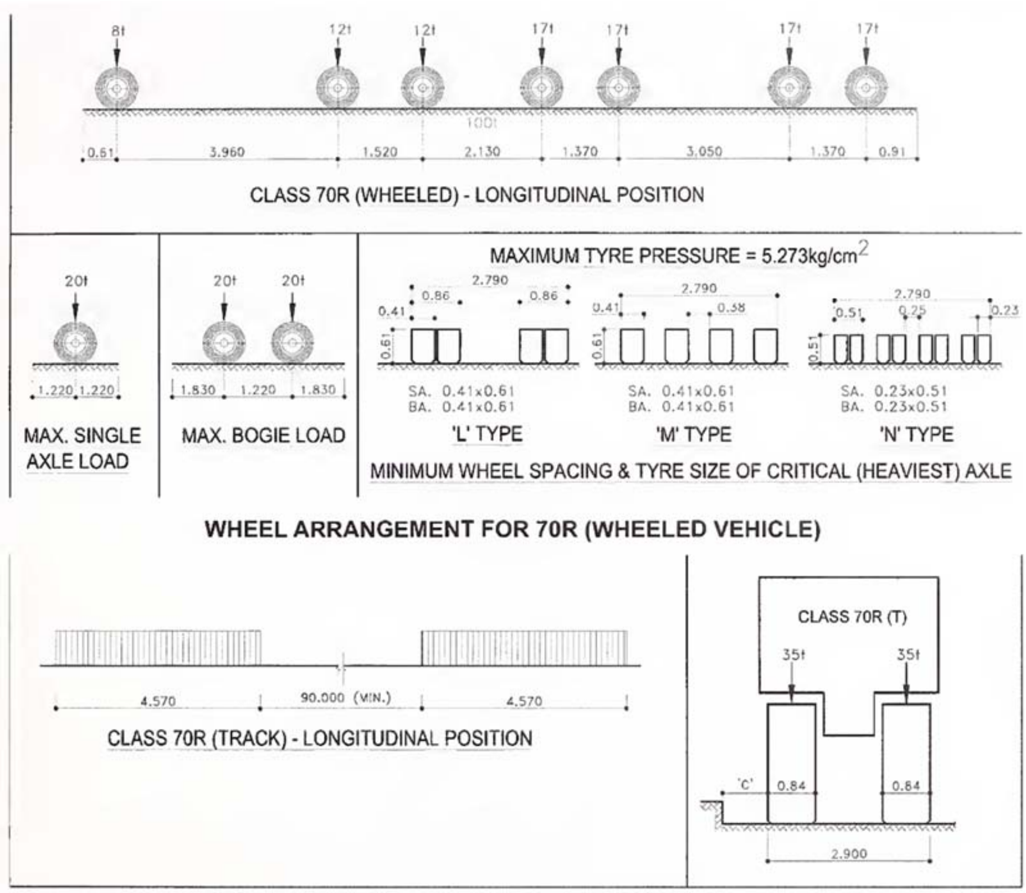
A load intensity of 5 kN/m along each outer parapet and the central median parapet shall be allowed for services such as lighting, emergency telephones, fire hydrants, etc.

(2) Live Loads

Traffic loading shall be as defined in IRC: 6-2014 with Class 70R design vehicle and Class A.

1) Class 70R Tracked and Wheeled Vehicles

The weights and spacing of axles and wheels for the design truck shall be as per the specification shown in Figure 6.3.1.

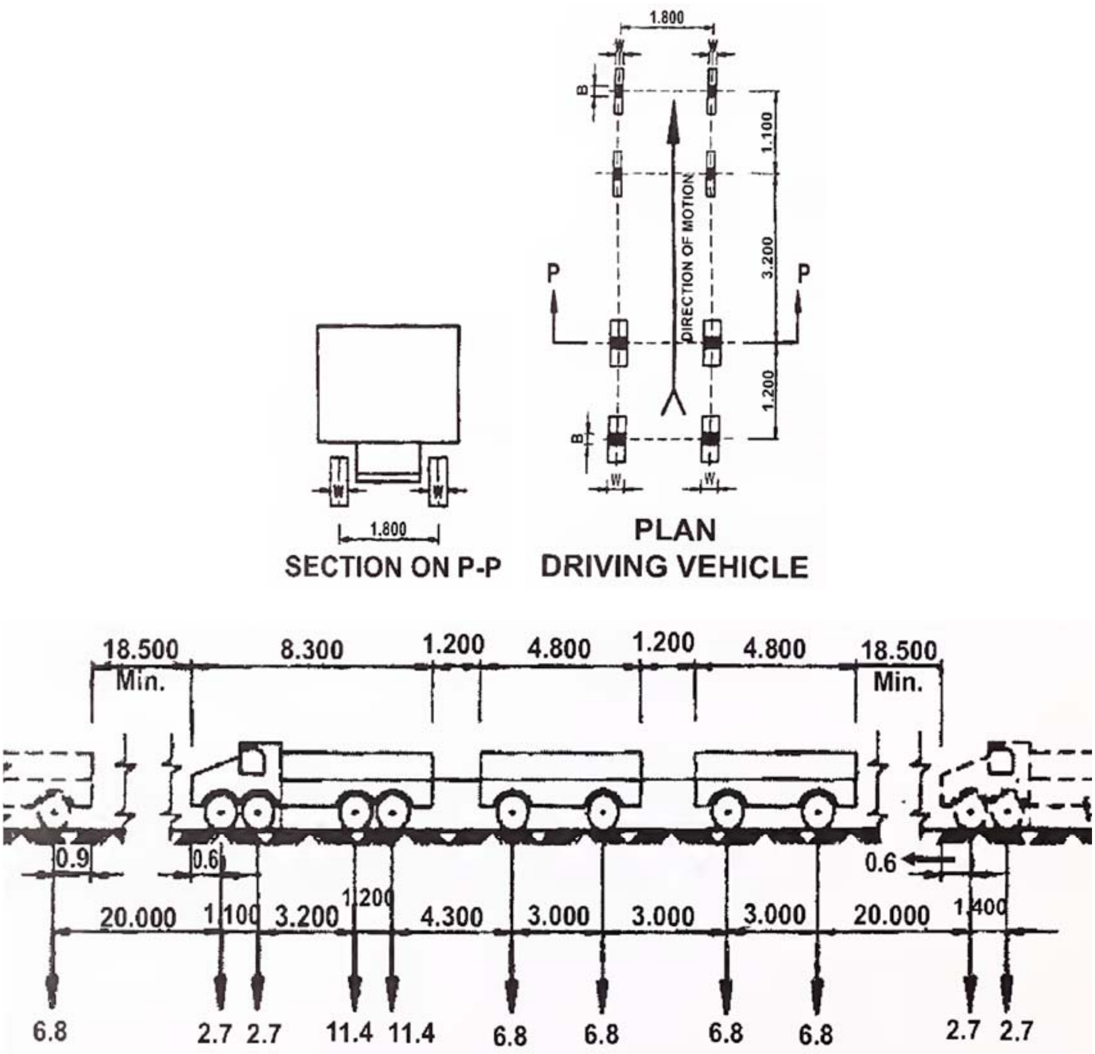


Source: IRC: 6-2014

Figure 6.3.1 Class 70R Tracked and Wheeled Vehicles

2) Class 'A' Train of Vehicles

The weights and spacing of axles and wheels for the design truck shall be as per the specifications for Class A shown in Figure 6.3.2.

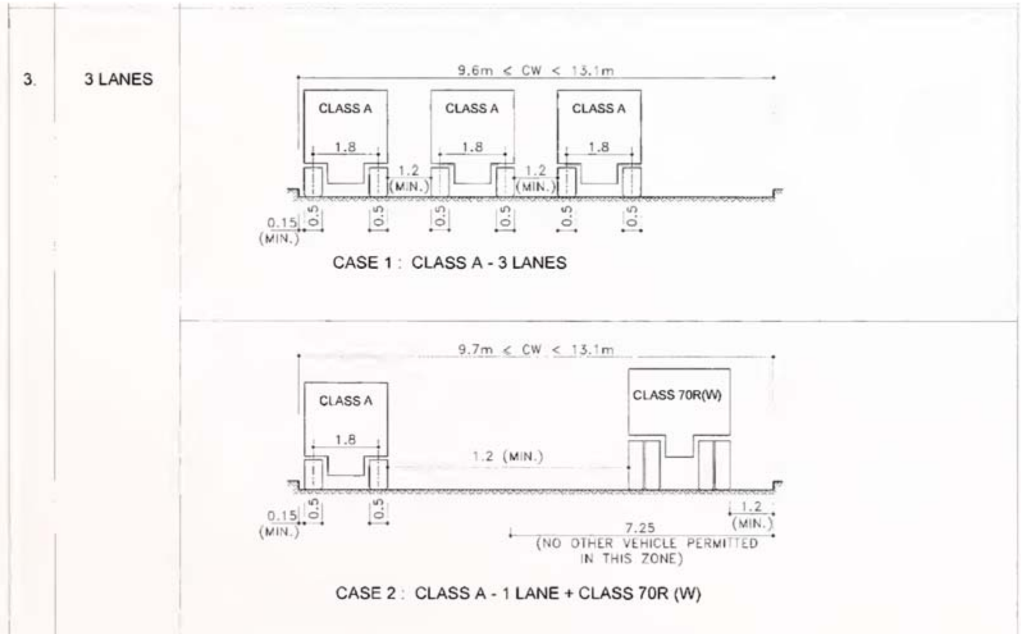


Source: IRC: 6-2014

Figure 6.3.2 Class 'A' Train of Vehicles

3) Combination of Live Loads

The live load combination on carriageways shall be considered for the design as shown in Figure 6.3.3.



Source: IRC: 6-2014

Figure 6.3.3 Live Load Combination

4) Reduction in the Longitudinal Actions on Bridges Accommodating more than Two Traffic Lanes

For bridges with more than two traffic lanes, the longitudinal actions (bending moment, shear force and torsion in longitudinal direction) should be reduced to account for the possibility that all lanes will be subjected to the characteristic loads simultaneously. This reduction shall be in accordance with Table 6.3.3.

Table 6.3.3 Reduction in Longitudinal Effect

Number of lanes	Reduction in longitudinal effect
2	No reduction
3	10% reduction
4 or more	20% reduction

Source: IRC: 6-2014

5) Impact

(a) Class A Loading

For the members of any bridge designed for Class A loading, the impact fraction shall be determined from the following equations (applicable for spans between 3 m and 45 m).

- For RC/PC bridges =4.5/(6+L) (3m<L<45m)
- For steel bridges = 9/(13.5+L) (3m<L<45m)

(b) Class 70R Loading

a) Bridge for Spans of 9m or more

The value of the impact percentage shall be taken as follows (for spans of 9 m or more):

[RC/PC bridges]

- Tracked vehicles: 10 percent up to a span of 40 m and for spans in excess of 40 m: 4.5/(6+L)(40m<L<45m).
- Wheeled vehicles: 25 percent for spans up to 12 m and for spans in excess of 12 m: 4.5/(6+L)(12m<L<45m)

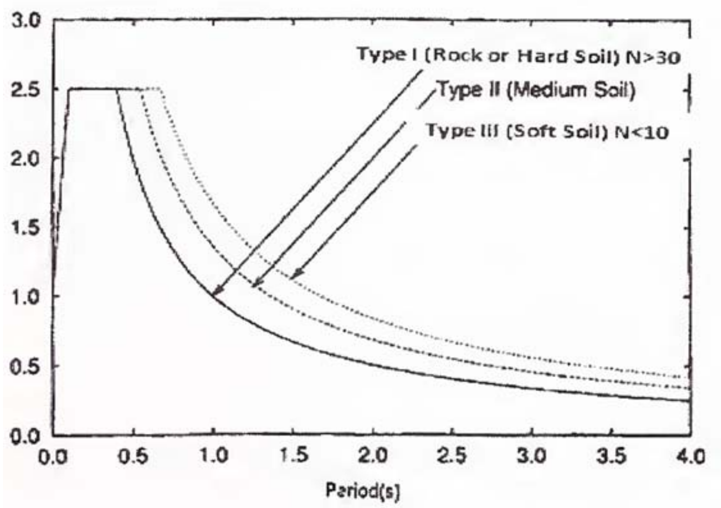
[Steel bridges]

- Tracked vehicles: 10 percent for all spans
- Wheeled vehicles: 25 percent for spans up to 23 m and for spans in excess of 23 m: 4.5/(6+L)(23m<L<45m)

On condition of span length in excess of 45m, the impact percenge for 45m in span length shall be utilized.

(3) Earthquake Load

The design shall be based on the IRC: 6-2014 and IS: 1893-1984. The elastic seismic acceleration method shall be adopted using spectra as defined in Figure 6.3.4.



Source: IRC: 6-2014

Figure 6.3.4 Response Spectra

The following equiation shall be applied to calculate the seismic force for the bridge design.

Feq=Ah=(Z/2) x (I) x (Sa/g)

Where

Feq: Resistance force against Earthquake

Ah: Coefficient of Secimic Force

Z: Area Factor (Z=0.16)

I : Importace Factor of the Bridge (I=1.5)

Sa/g: Response Factor from Figure 6.3.4

(4) Wind Load

Winds loads shall be based on the basic wind speed for Mumbai, as defined in IRC: 6-2014.

1) Basic Wind Speed

The basic average wind speed for MTHL bridges shall be 44m/s and the average wnd load shall be 879N/m2 because the bridge elevation in MTHL is lower than 50m in elevation from the ground level, considering the historical date in the Mumbai area.

2) Design Wind Force on Superstructure

(a) Transverse Wind Force

The transverse wind force F_T (in N) shall be taken as acting at the centroids of the appropriate areas and horizontally and shall be estimated from:

$F_T = P_Z A_1 G C_D$

Where,

P_Z : The hourly mean wind pressure in N/m^2
A_1 : The solid area in m^2
G : The gust factor

- For bridge decks supported by single beam or box girder, C_D shall be taken as 1.5 for b/d ratio of 2 and as 1.3 if b/d > 6. For intermediate b/d ratios C_D shall be interpolated.
- For deck supported by two or more beams or box girders, where the ratio of clear distance between the beams of boxes to the depth does not exceed 7, C_D for the combined structure shall be taken as 1.5 times C_D for the single beam or box.
- For deck supported by single plate girder it shall be taken as 2.2. When the deck is supported by two or more plate girders, for the combined structure C_D shall be taken as 2 (1 + c/20d), but not more than 4, where c is the centre to centre distance of adjacent girders, and d is the depth of windward girder.

(b) Longitudinal Force

The longitudinal force on bridge superstructure F_L (in N) shall be taken as 25 percent and 50 percent of the transverse wind load as calculated as per '(a) Transverse wind force' for beam/box/plate girder bridges and truss girder bridges respectively.

(c) Vertical Wind Load

An upward or downward vertical wind load F_V (in N) acting at the centroid of the appropriate areas, for all superstructures shall be derived from:

$$F_v = P_Z A_3 G C_L$$

Where,

- P_Z : The hourly mean wind pressure in N/m^2
- A_3 : The area in plan in m^2
- C_L : The lift coefficient which shall be taken as 0.75 for normal type of slab, box, I-girder and plate girder bridges.
- G : The gust factor as defined in '(a) Transverse wind force'.

3) Design Wind Force on Substructure

The substructure shall be designed for wind induced loads transmitted to it from the superstructure and wind loads acting directly on the substructure. Loads directly acting on the substructure shall be calculated as follows;.

$$F_t = P_Z A_1 G C_D$$

Where,

- P_Z : The hourly mean wind pressure in N/m^2
- A_1 : The area in plan in m^2
- C_d : The resistance coefficient depending on the shape of substructure according to Table 6 of IRC 6-2014.
- G : The gust factor as defined in '(a) Transverse wind force'.

(5) Water Currents

The current speed in each direction acting to a substrucure should be taken as not less than 3m/s.

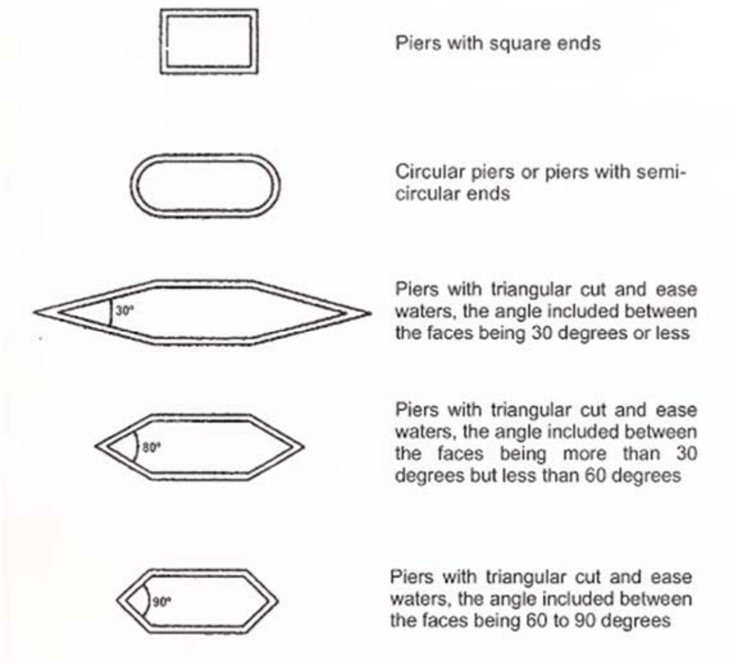
On piers parallel to the direction of the water current, the intensity of pressure shall be calculated from the following equation:

$$P = 52KV^2$$

Where,

- P: intensity of pressure due to water current, in kg/m^2
- V: the velocity of the current at the point where the pressure intensity is being calculated, in metre per second
- K: a constant having the following values for different shapes of piers illustrated in Figure 6.3.5.

- Square ended piers (and for the superstructure): 1.50
- Circular piers or piers with-circular ends: 0.66
- Piers with triangular cut and ease waters, the angle included between the faces being 30° or less: 0.50
- Piers with triangular cut and ease waters, the angle included between the faces being more than 30° but less than 60°: 0.50 to 0.70
- Piers with triangular cut and ease waters, the angle included between the faces being more than 60° but less than 90°: 0.70 to 0.90



Source: IRC: 6-2014

Figure 6.3.5 Shapes of Bridge Piers

(6) Temperature Load

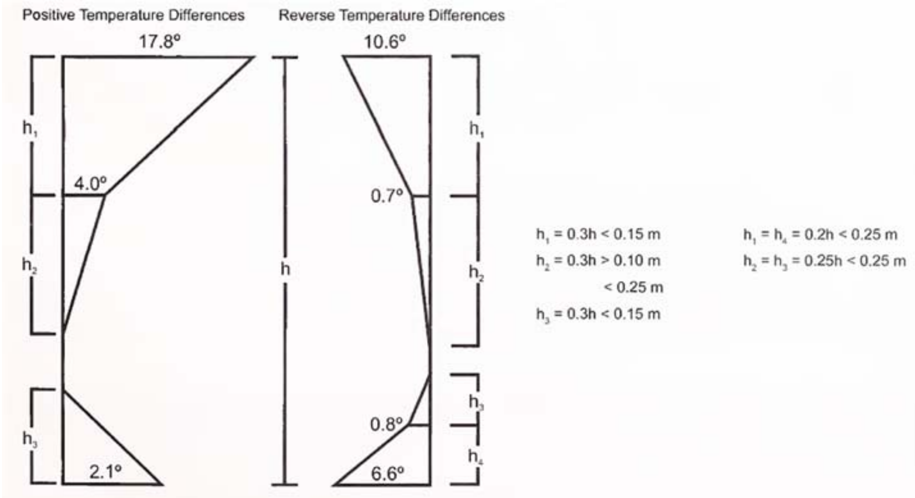
1) Design Temperature Range

Loads incurred by change in temprature shall be based on a difference between the basic maximum and minimum temperature in Mumbai. According to historical data, whereas the maximum temperature is approximately 40°C, the minimum temperature is approximately 10°C. The bridge location having difference between maximum and minimum air shade temperature is >20°C.

The temperature range considering the bridge design shall be ±10° C according to IRC:6-2014.

2) Thermal Gradient

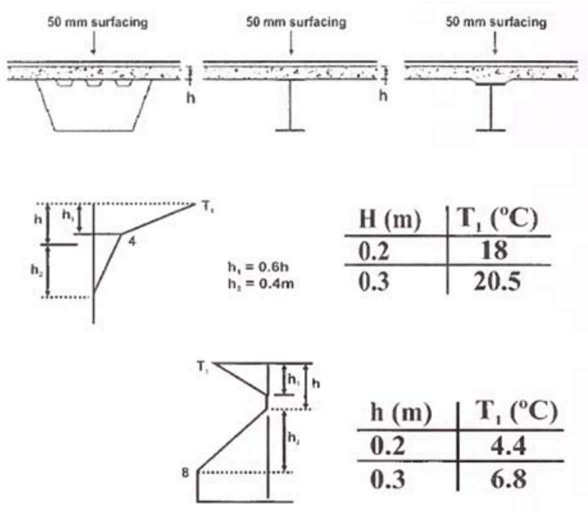
Positive and reverse temperature differences for the purpose of design of concrete bridge decks shall be assumed as shown in Figure 6.3.6 according to IRC:6-2014. These design provisions are applicable to concrete bridge decks with 50 mm of wearing surface.



Source: IRC: 6-2014

Figure 6.3.6 Design Temperature Differences for Concrete Bridge Decks

So far as steel and composite decks are concerned, Figure 6.3.7 may be referred for assessing the effect of temperature gradient. These design provisions are applicable to the bridge decks with 50 mm of wearing surface.



H (m)	T_1 (°C)
0.2	18
0.3	20.5

h (m)	T_1 (°C)
0.2	4.4
0.3	6.8

Source: IRC: 6-2014

Figure 6.3.7 Temperature Differences across Steel and Composite Section

(7) Special Loads

1) Vehicle collision Impact with Substructure and Guardwall

Design impact loads from vehicles colliding with the substructure shall be as defined in IRC: 6-2014.

The nominal loads given in Table 6.3.4 shall be considered to act not only horizontally but also parallel to the carriageway as Vehicle Collision Loads. Loads normal to the carriageway below and loads parallel to the carriageway below shall be considered to act separately and shall not be combined.

Table 6.3.4 Nominal Vehicle Collision Loads on Guardwall of Bridge

	Load Normal to the Carriageway Below (Ton)	Load Parallel to the Carriageway Below (Ton)	Point of Application on Bridge Support
Main load component	50	100	At the most severe point between 0.75 and 1.5 m above carriageway level
Residual load component	25(10)	50(10)	At the most severe point between 1 m and 3 m above carriageway level

Source: IRC: 6-2014

The loads indicated are assumed for vehicles travelling at speeds of 60 km/hour. In case of vehicles travelling at lower speed, the loads may be reduced in proportion to the square of the speed, but not less than 50 percent.

The guardwall on the bridge shall be designed for the residual load component only.

2) Ship Collision Impact on Piers

Piers shall be designed for ship collision impact as per IRC: 6-2014.

(a) Design Vessel

The design vessel for the briges accorss Thane and Panvel Creek navigation challens is given in Table 6.3.5.

Table 6.3.5 Type and Specification of Ship

Type	Ship
DWT	4,000 tonnes
Length	LOA = 96.0m
Beam	BM = 13.8m
Vessel Transit Speed	VT = 10 knots
Minimum Impact Velocity	VMIN = 2 knots

Source: IRC: 6-2014

(b) Barge Collision Energy: KE

$KE = 500 \times C_H \times W \times V^2$

Where,

KE = Barge Collision Energy (N-m)

W = Barge Displacement Tonnage (T) : 4,000 tonnes

V = Barge impact speed (m/sec) : 10knots=10/1.9438=5.145m/sec

C_H = Hydrodynamic coefficient= 1.05 to 1.25 for Barges depending upon the clearance under keel available.

- If clearance under keel is more than 0.5 x Draft, CH=1.05;
- If clearance under keel is less than 0.1 x Draft, CH= 1.25.
- For any intermediate values of under keel clearance, linear interpolation shall be done.

(c) Barge Damage Depth: a_B

$a_B = 3{,}100 \times \{[1+1.3\times10^{(-7)} \times KE]^{0.5}-1\}$

Where,

a_B: Barge bow damage depth (mm)

(d) Barge Collision Impact Force: PB

The barge collision impact force shall be determined based on the following equations;

For a_B <100mm, $P_B=6.0 \times 10^4 \times (a_B)$, in N

For a_B ≥100mm, $P_B=6.0 \times 10^6 + 1{,}600 \times (a_B)$, in N

6.3.4 Materials

(1) Concrete

The concrete performances were determined by Technical Advisory Committee for MTHL which had been held 2012 to 2013. As a result the high performance concrete is used in structures. The cube strength in each part is shown in Table 6.3.6.

Table 6.3.6 Concrete Strength

Parts	Strength (MPa)
Concrete for bored piles and caissons	45
Pile caps	45
Pile cap skirts	55
Abutments, Walls	45
Piers	55
Deck	55
Parapets and median	45

Source: Technical Advisory Committee, 2012-2013
Feasibility Final Report of Detailed Feasibility Study and Bid Process Management for Selection of Developer for MTHL, 14th, December, 2012

(2) Reinforcement Steel

The specification of reinforcement steel is based on IRC: 21-2000 and its strengths depending on the steel type are shown in Table 6.3.7.

Table 6.3.7 Reinforcement Steel Strength

Types	Strength (MPa)	Elastic Modulus (GPa)
Fe 240	240	200
Fe 415	415	200
Fe 500	500	200

Source: IRC: 21-2000

(3) Pre-Stressing Steel

The specification of pre-stressing steel is based on IRC: 112-2011 and its strength by the steel type are shown in Table 6.3.8.

Table 6.3.8 Pre-Stressing Steel Strength

Class	Type of Pre-stressing Steel	Area (mm^2)	Yield Strength (kN)	Yield Strength (kN)
I	11.1mm, 7 ply	70.0	105.86	108.00
	12.7mm 7 ply	92.9	139.90	144.10
	15.2mm 7 ply	139.0	192.83	216.20
II	11.1mm 7 ply	74.2	117.21	124.10
	12.7mm 7 ply	98.8	156.11	165.30
	15.2mm 7 ply	140.0	222.23	234.60

Source: IRC: 112-2011

(4) Steel

The specification of steel is based on IRC: 24-2010.

6.3.5 Design Standard for Environmental Crearance

The bridge design should be designed design standard for bridge design, EIA notification and CRZ notification. The EIA notification and CRZ notification is shown in 12.3.

6.4 Preliminary Design for Road

6.4.1 General

As described in chapter 3, the road horizontal alignment of the main carriageway complies with Indian standards and has been designed with extreme care in previous studies. Additionally, it is in accordance with the result of topographic survey.

On the other hand, while the clearance needed by the crossing object is secured in the vertical alignment, the position and limits of the ship route have been reviewed. Accordingly, the vertical alignment has also been reviewed in consideration of economic efficiency. Points that were examined in this study, including the vertical alignment, are as listed below.

1) Improvement of the vertical alignment: Vertical alignment plan that matches the ship-route position and ship-route limits on the sea section
2) Number of lanes on the main road and number of toll booths: Changed based on the result of traffic demand analysis
3) Interchange alignment: The alignment was corrected in consideration of the transition curve and nose interval, and diversion and confluence plan is implemented for 2-lane ramps.
4) Number of ramp lanes and toll booths: Number of lanes decided in consideration of vehicle traffic and number of toll booths based on the result of traffic demand analysis
5) Emergency platforms: Interval between emergency platforms based on Japanese standard
6) Cutting section plan: Vertical alignment and standard cross-section
7) Pavement structure: Suggestion of the optimal pavement structure with a special focus on pavement on the box girder with steel deck slabs
8) Drainage plan: Surface drainage plan on the marine section

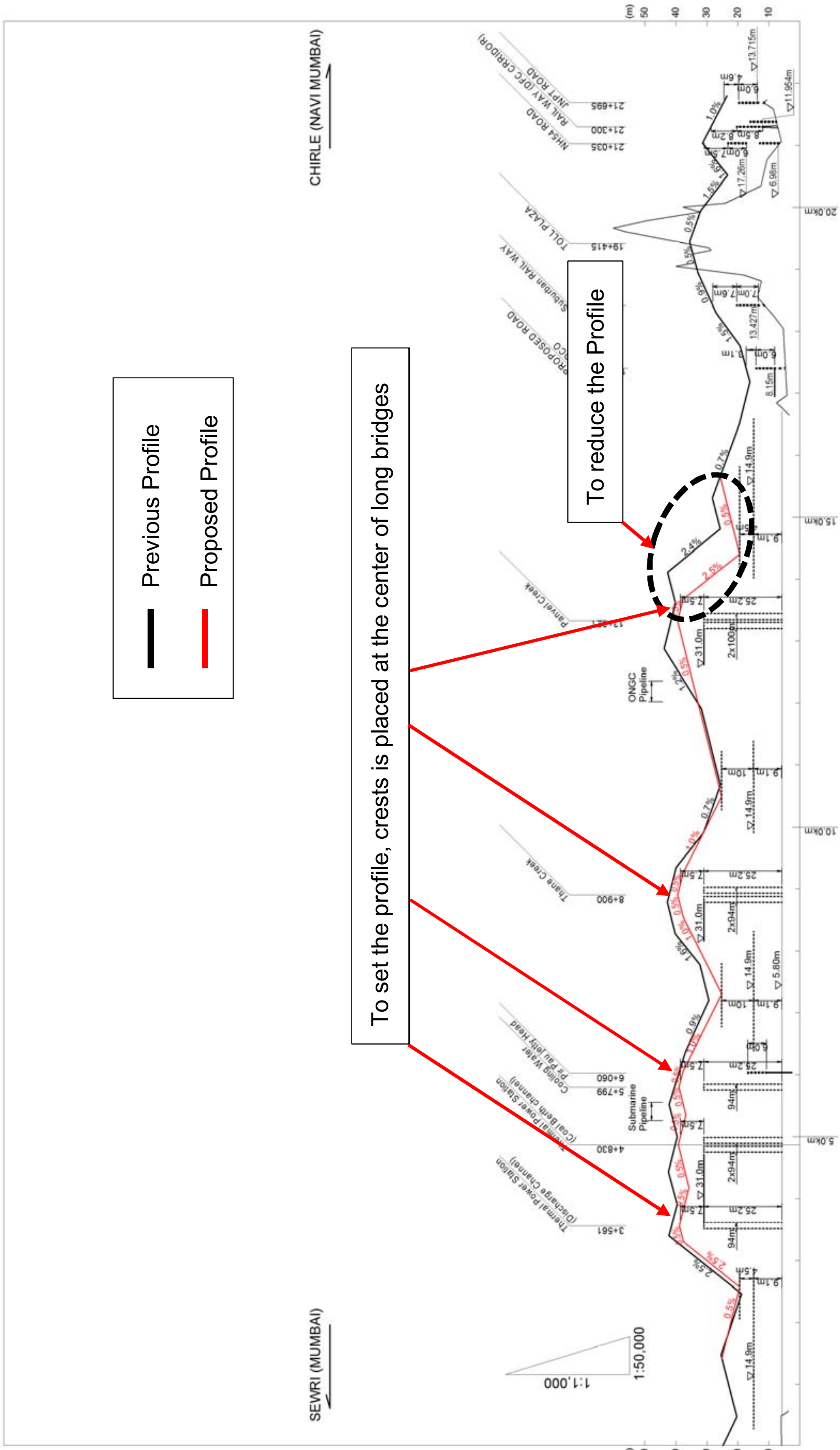
6.4.2 Preliminary Design for Road

There are some margin between vertical alignment and navigation clearance on the sea section in Final FS 2012. Therefore, improvement of the vertical alignment was studied.

The conditions of vertical study are:

- According the design standard, maximum vertical gradient is 2.5%.
- The top of the vertical curves shall be placed on the centre of bridge span.
- Sharp angles shall be avoided.

Figure 6.4.1 shows the proposed vertical alignment.



Source: JICA Study Team

Figure 6.4.1 Proposed Vertical Alignment

6.4.3 Review of Traffic Lanes on Main Alignment

6-lane of main alignment was decided by the upper plan of Maharashtra government. In this study it was reviewed based on the forecasted result of future traffic volume by using Manual of Specifications and Standards for Expressways (IRC:SP:99-2013).

The result of the review, 6-lane will be required in 2032 (10years later after traffic open). Although 8-lane 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.

Table 6.4.1 Required Traffic Lanes

Year	Traffic Volume (vehicle/day)	Traffic Volume (PCU/day)	Design Service Volume for Expressways(PCU/day) Based on SP:99-2013	Required Traffic lanes
2022	31,155	39,300	< 86,000 4-lane	4-lane
2032	88,613	103,886	< 130,000 6-lane	6-lane
2042	125,000	145,510	< 173,000 8-lane	8-lane

Source: JICA Study Team

6.4.4 Study on the Number of Toll Booths on Main Alignment

The toll booth of main alignment is located between Shivaji Nagar IN and SH54IC. As mentioned in chapter 3, although 14 toll booths were considered in previous study, it is not clear the reason. Therefore, it is studied in consideration of the result of traffic demand forecast in 2042. As a result, 8 toll booths shall be provided.

Table 6.4.2 Number of Toll Booth on Main Alignment

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 lane (vehicle/hour)	Number of required ETC lane	Number of required manual lane	Total number of toll booth
Chirle	25,000	1,800	630	1,170	1	3	4
Sewri	23,000	1,550	540	1,010	1	3	4

Note: The capacity of manual lane is 780 vehicles/hour for 2 booths, 1230 vehicles/hour for 3 booths and 1670 vehicles/hour for 4 booths

Source: JICA Study Team based on Japanese Standard

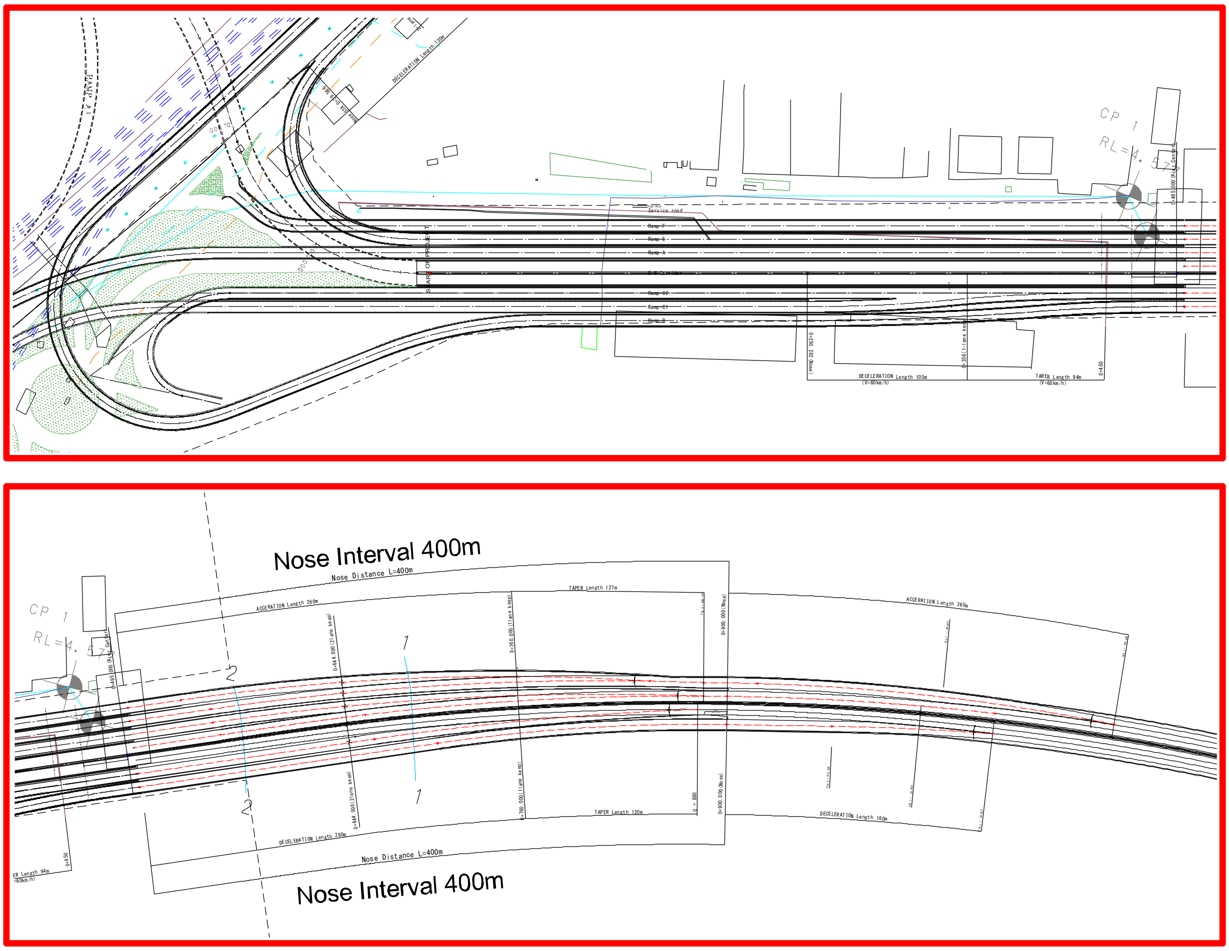
6.4.5 Improvement of Interchange Alignment

In Final FS 2012, transition curves were not considered in all ramps. On the other hand, it was considered in main alignment.

Following figures shows the difference of with/without the transition curve for each interchange. Although there is a little difference in the drawings, the traveling performance and safety will be improved by considering the transition curves.

(1) Ramp Alignment

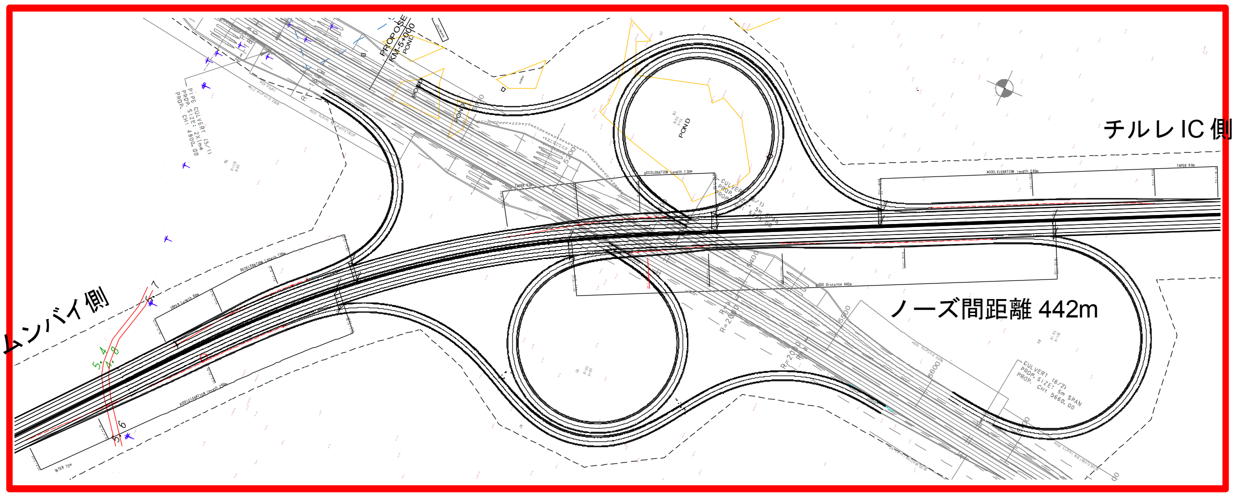
The adjacent ramps are joined, then, the ramps are joined again. Nose distance is secured 400m. It is rather than standard distance, 275m.



Source: JICA Study Team

Figure 6.4.2 Sewri IC

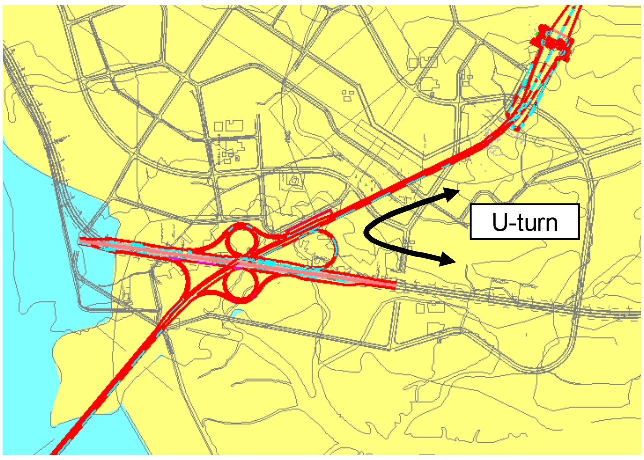
Nose distance is one place. Nose distance 442m is secured standard nose distance 275m.



Source: JICA Study Team

Figure 6.4.3 Shivaji Nagar IC

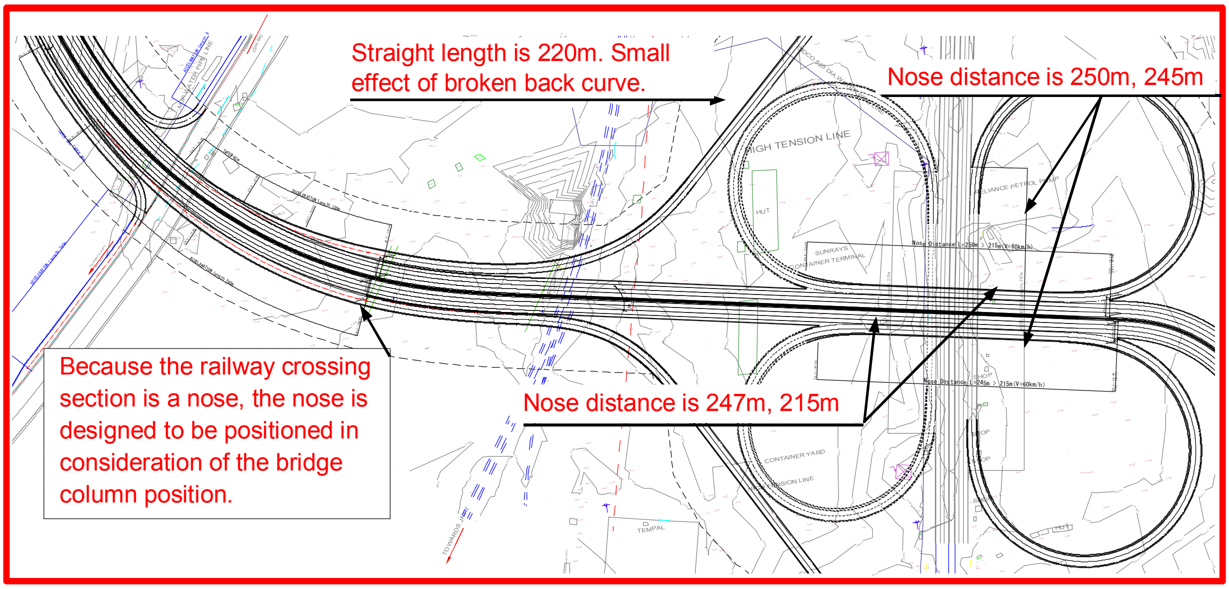
Shivaji Nagar is not full access interchange. The ramp corresponding to the U-turn route is not installed.



Source: JICA Study Team

Figure 6.4.4 Planned Shivaji Nagar IC

Shivaji Nagar is a provisional interchange with extension plan. It is designed 60km/h including the near main road.



Source: JICA Study Team

Figure 6.4.5 Chirie IC

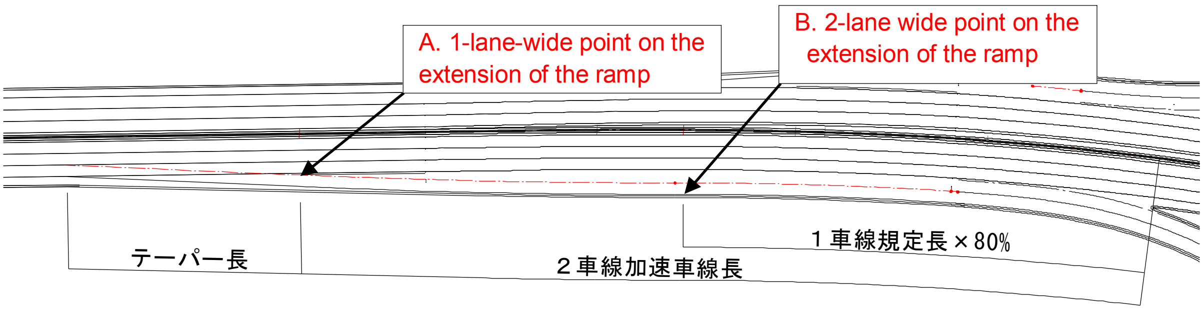
(2) Approach to Acceleration and Deceleration Section

The plan of 2-lane ramp is based on 2 control point, showing in the following A and B.

A. Specified length of 2-lane section is secured as an acceleration and deceleration section. Width equivalent to one lane is secured at the end of the tapered section.

B. Width equivalent to two lanes is secured in the middle of the acceleration and deceleration section (at a point that is away from the nose by a distance which is 80% of the specified length of one lane).

2-lane-wide point in the middle of the acceleration and deceleration section will ensure smooth alignment and smooth transition to and from the main road. The all planning ramps are based on A and B, because of all ramps have 2-lane.



Source: JICA Study Team

Figure 6.4.6 Diversion and Merger Form of a 2-Lane Ramp

6.4.6 Study of the Number of Lanes on Interchange Ramps

The number of traffic lanes on interchange ramps are provided more than 2-lane in Final FS 2012. However, it is not clear the reason. Therefore, it is studied based on the Japanese standard in consideration of the result of traffic demand forecast in 2042.

Required number of traffic lanes from the traffic demand forecast is shown in below.

<u>Sewri IC</u>

2-lane is required to C2 ramp connecting main alignment and Mumbai port. Other ramps require 1-lane.

<u>Shivaji Nagar IC</u>

2-lane is required to on-and-off ramps connecting main alignment and Navi-Mumbai Airport. Other ramps require 1-lane.

<u>SH54IC</u>

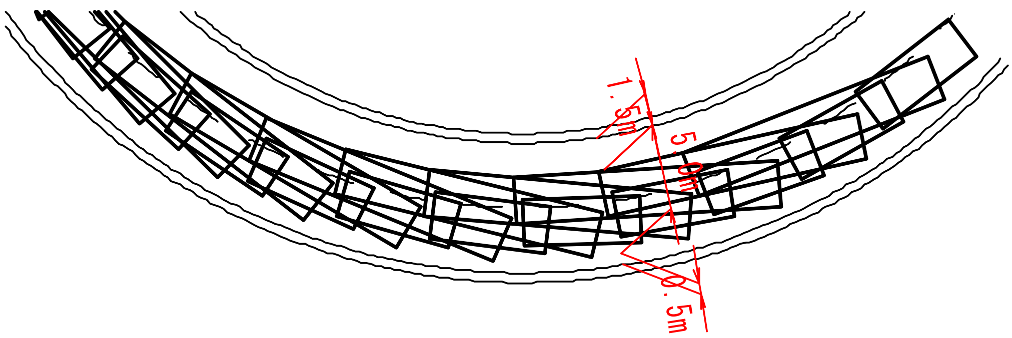
1-lane is required on both ramps.

<u>Chirle IC</u>

1-lane is required to all ramps.

From the above, the required numbers of ramps are 1-lane or 2-lane. However, in case of 1-lane, the width shall be kept enough for the passing vehicle next (side) to the disabled vehicle.

In case of the small curve radius, the required width of semitrailer will be approximately 6.0m (=5m +0.5m on both side as some room width). This width is not so different from 2-lane width with 7.0m.



Source: JICA Study Team

Figure 6.4.7 Traveling Locus of Semitrailer (SH54IC)

In addition, the ROW has been secured in consideration of 2-lane ramp of previous study. Therefore, the numbers of traffic lanes on ramps are decided as follows.

Table 6.4.3 Number of Traffic Lanes on Ramps

Ramp	Lane Number in 2012	Required Lane Number in 2042	**Applied Lane Number**	Remarks
Sewri IC, all ramps	2	1 2 for C2	2	Except for connection ramp to western freeway
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

6.4.7 Study on the Number of Toll Booths on Interchange Ramps

Toll booths are provided on Shivaji Nagr IC. The traffic volume passing Shivaji Nagar IC turned out more than the previous study result. The reason is mentioned in section 4.3.

In this section, the number of toll booths at Shivaji Nagar IC was examined based on the forecasted traffic volume in 2042.

As a result, 6 toll booths will be required for the ramps connecting main alignment and Navi-Munbai airport in 2042. Other ramps require 3 toll booths.

Table 6.4.4 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

On the other hand, ROW of Shivaji Nagar IC has already been secured and maximum 4 toll booths can be provided to the ramps connecting main alignment and Navi-Mumbai airport within the current ROW. In case of 4 toll booths, it will be utilized without any congestion until 2032. However, after 2032, it is proposed to do away with the toll booths on ramps and establish large toll booth on main alignment (around Ch.17+000) newly. Besides, it is recommended that necessary environmental clearances shall be obtained before establishment of the new toll booth.

For sections where the lanes are broadened, such as an acceleration and deceleration section of an interchange and a toll gate, the extra space is designed to be the alternative to an emergency platform for effective utilization of the space.

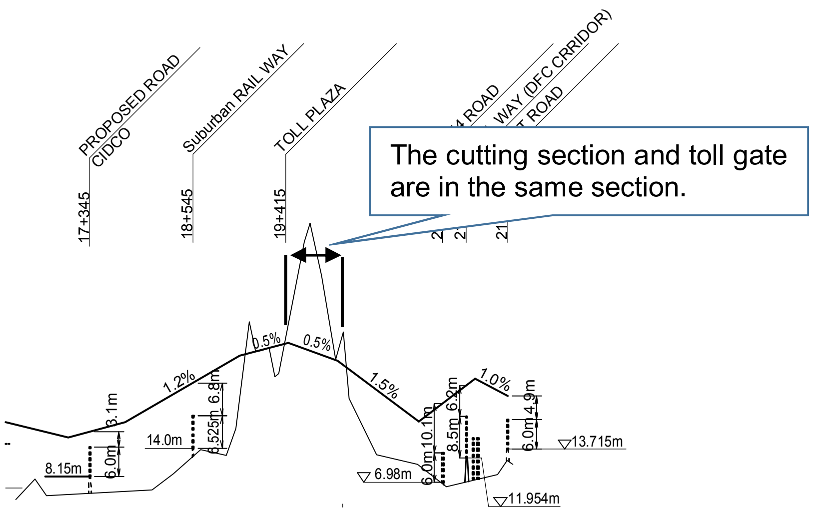
6.4.8 Design of Cutting Section

There is a large cutting section with 25m height in Navi-Numbai side. The cutting section was studied on the basis of the previous study. The blasting shall be used for excavation since there is basalt rock on Navi-Munbai side according to the geological condition. Accordingly, the cutting slope can be adopted with 1:0.5. Before the cutting, have to reconsider the cutting slope and width of berm based on geometrical survey in mountain section.

In the cutting section, changing the height of the upper and lower line, it can be considered a method to reduce the amount of soil. But there is Toll Gate, to change the upper and lower road is difficult.

Source: JICA Study Team

Figure 6.4.8 Typical Cross Section of Cutting



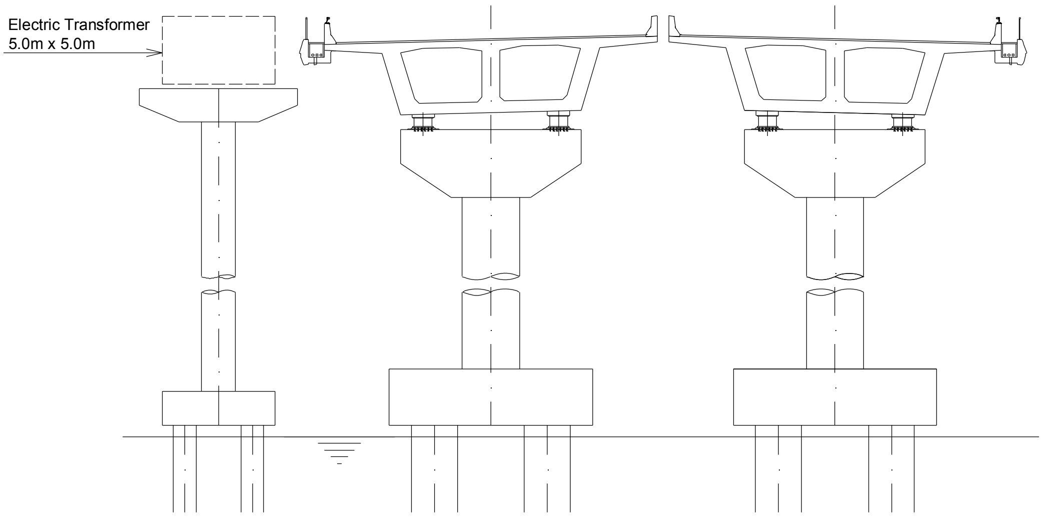
Source: JICA Study Team

Figure 6.4.9 Toll Gate and Cutting Section

6.4.9 Platform for Electric Transformer and Emergency Rescue Station

The support structure for the platform for electric transformer/subatation shall be separatery provided apart from the bridge piers. From discussion with Bombay Electric Supply & Transport (BEST) authorities, the electric transformer/substation is needed to supply the electricity along MTHL. BEST requested construction of the platform of 5.0m x 5.0m size at every 3km interval along the bridge on both sides for placing electric transformer/substation of adequate capacity. Image of the platform is shown in Figure 6.4.10.

The emergency rescue stations are installed along MTHL alignment on both sides of the inbound and outbound lanes.The emergency rescue station structure is a single span with dimensions of 50m length and 7m width and will be installed within the median opening area of the general section of the MTHL i.e.PC Box Girder Bridge section.



Source: JICA Study Team

Figure 6.4.10 Platform for Electric Transformer on Pier

6.4.10 Pavement Design

(1) General Requirement

The pavement must be designed to accept the required traffic demand without major structural distress. The required performance of pavement is as follows:

- Keep comfortable for the driving
- Improve comfortable and safety feeling for the road user by keeping flatness of the road surface and moderate sliding resistance
- Create beautiful road landscape by using the pavement material suitable for neighboring environment.

In addition, the main role for using asphalt materials and asphalt layers on bridge is to protect the bridge system from some possible defects and to give better properties for their durability.

(2) Layers on the Bridge Deck

Pavement on bridge shall be met a large number of requirements as described below:

- Resistance to permanent deformation
- Skid resistance
- Rigidity
- Evenness
- Aging resistance, etc.

It also must protect the bridge structure under the heavy load of traffic and weather conditions and is also required to absorb traffic load and transfer them to the supporting bridge structures.

As mentioned above, there are the different requirements for the pavement structure on a bridge. Those functions cannot be fulfilled by one pavement material. Several layers are required for the pavement in order to satisfy the different requirements.

In general, the asphalt pavement on the bridge can be divided into four different layers: sealing/bonding layer (primer), waterproofing layer, protecting layer and surface layer. Waterproofing layer and protecting layer are often called waterproofing system.

The sealing layer can be made from various materials, including bituminous materials.

1) Sealing/Bonding Layer (Primer)

Asphalt layers cannot directly be bonded on a concrete or steel slab. Therefore, an intermediate sealing layer is necessary to establish a good bond to the waterproof layer.

Functions of bonding layer on the steel bridge are:

- Assuring a enough strong adhesion the steel deck and the waterproofing layer
- Giving a reliable protection against corrosion
- Bing resistant to fatigue
- Being resistant to shear forces

The bridge deck surface has to be prepared properly to be clean, dry, sound, and free of all bond-inhibiting substances.

2) Waterproofing System

Waterproofing system consists of waterproofing layer and protective layer.

(a) Waterproofing layer

The durability of bridges greatly depends on the effectiveness of the bridge deck waterproofing system and expansion joints.

The main function requirements for the waterproofing are:

- Tightness under all conditions
- Adhesion between the bridge deck and the bituminous layer
- Mechanical resistance (loads from the traffic, thermal action)
- Compatibility with bituminous mixture
- Resistance to high temperatures during the application of the hot asphalt mixture

The waterproofing products can be divided two main categories:

<u>Sheet Type</u>

It consists of preformed sheets mainly based on bituminous polymeric and elastomeric materials. They are bonded to bridge deck by using bitumen adhesive.

<u>Liquid (Splay) Type</u>

This type is divided into following categories viz. acrylics, Methyl methacrylate polymer, polyurethanes and bituminous base materials.

In this project it is recommended to apply liquid type in consideration of workability and experience in India. Liquid type spray to be recommended /specified shall be IRC/ISO/BBA or equivalent accredited. The bridge deck water proofing system manufacturer shall have a minimum 20 years international track record.

(b) Protective layer

This layer serves as a second waterproofing layer and has to protect corrosion and to make a flexible transfer of load from the surface layer to the deck.

Recently other than mastic asphalt, the Stone Mastic Asphalt (SMA) which added some fiber reinforcement material is applied.

The functions such as flow property resistance, abrasion resistance, sliding resistance, the reflection crack suppressant effect are improved by applying this SMA, and quality and the durability are also improved.

(c) Surface / Asphalt Layer

High skid resistance, flat surface and low noise are required to surface layer for safe and comfortable drive. To ensure durability of the required characteristics of the surface layer, the surface layer needs to have the followings:

- sufficient resistance against deterioration
- resistance against oil, water and minerals
- less susceptibility to weather conditions
- protection of the bridge deck and the waterproofing layer
- high stability
- resistance to fatigue
- resistant to permanent deformation
- Possession of the function of loading dispersion

The surface layer is made of asphalt. Generally asphalt mixture types used on the bridge are Normal Dense Grade Asphalt (NDGA), Mastic Asphalt (MA) and Stone mastic Asphalt (SMA).

(3) Asphalt Layers

1) Asphalt Layers on Concrete Bridge Deck

Concrete bridge decks are the most common and they are also susceptible to cracking under live loading and shrinkage. The estimated life of concrete bridge is 100 years. One condition to ensure this long lifetime is waterproofing of the deck together with a high quality asphalt pavement.

The main function of asphalt pavement is waterproofing under all conditions, and it have to keep mechanical stability/strength for traffic loads.

The asphalt layers normally consist of a protecting layer and a surface layer. As mentioned above, MA and SMA are normally applied as the protecting layer in consideration of the quality and high durability.

The surface layer should be made with a hard grade or polymer-modified bitumen.

Table 6.4.5 shows the comparison of the asphalt layers on concrete bridge deck.

MTHL is the prime route. Temperature becomes very high in summer and traffic volume will be increased in future.

Therefore, SMA with polymer-modified bitumen which is superior in flow property resistance, waterproof resistance and durability is applied to the protecting layer.

For the surface layer, NDGA is recommended to apply in consideration of workability, maintenance and cost.

The pavement thickness on bridge deck is 80mm based on the past experience of international projects.

Table 6.4.5 Asphalt Layers on Concrete Bridge Deck

Asphalt Layer	Case -1	Case-2	Case-3
Protecting layer	MA (40mm)	SMA(40mm)	SMA(40mm)
Surface layer	SMA (40mm)	SMA (40mm)	NDGA (40mm)
Total Thickness	80mm	80mm	80mm
Features	- MA has high durability and flexibility. But it is required special asphalt, plant and machine.	- SMA is the improved asphalt that natural fiber material is mixed and reinforced. - It has high flow property resistance and waterproofing property. - Conventional plant and method can be used.	- Applying SMA to the protecting layer keeps sufficient function. - Conventional plant and method can be used.
Flow property resistance	A	A	B Protecting layer (SMA) has high resistance
Against deflection	A+	A	B Not required on the concrete bridge deck
Adhesive property	A+	A	B
Waterproof property	A+	A+	B Protecting layer (SMA) has high resistance
Workability	B (Necessary special plant and machine)	A	A
Construction period	B	A	A
Durability	A	A	A+ High durability on the concrete bridge deck
Initial Cost	C	A	A
LCC	A	A	A+ High durability on the concrete bridge deck
Maintenance	C	A	A
Evaluation	-	-	**Recommended**

Legend: A+: Superior/Very good, A: Good, B: Moderate, C: Inferior/Poor

Source: JICA Study Team

2) Asphalt Layers on Steel Bridge Deck

There are large deformations in the steel deck so that fatigue of asphalt layer is more important for steel bridges than for concrete bridges. According to the table below, the pavement that is superior in deformation resistance (against deflection) is Case-1 and 3. However, Case-2 is recommended to apply on steel bridge deck in MTHL in consideration of workability, maintenance, initial cost, and so on.

Table 6.4.6 Asphalt Layers on Steel Bridge Deck

Asphalt Layer	Case -1	Case-2	Case-3
Protecting layer	MA (40mm) (Guss Asphalt)	SMA with Type II (40mm)	SMA with Type III (40mm)
Surface layer	MA (40mm) (Guss Asphalt)	SMA with Type II (40mm)	SMA with Type II (40mm)
Total Thickness	80mm	80mm	80mm
Features	- MA has high durability and flexibility. But it is required special asphalt, plant and machine. - It has high deformability.	- SMA is the improved asphalt that natural fiber material is mixed and reinforced. - It has high flow property resistance and waterproofing property. - Conventional plant and method can be used.	- SMA with Type III applied to the protecting layer has high performance against deflection. - Conventional plant and method can be used. However, a material of Type III has to be imported.
Flow property resistance	A	A	A
Against deflection	A+	A	A+
Adhesive property	A+	A	B
Waterproof property	A+	A	A+
Workability	C (Necessary special plant and machine)	A	A
Construction period	B	A	A
Durability	A+	A	A
Initial Cost	C	A	B
LCC	A	A	A
Maintenance	C	A	B
Evaluation	-	**Recommended**	-

Legend: A+: Superior/Very good, A: Good, B: Moderate, C: Inferior/Poor

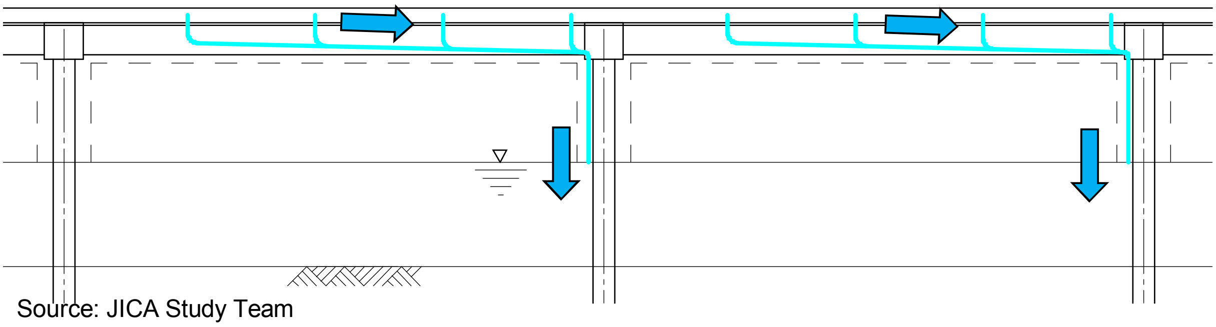
Note: Type II: polymer-modified bitumen type II, Type III: polymer-modified bitumen type II

Source: JICA Study Team

6.4.11 Drainage Design

The surface drainage on the marine section can be directly discharged. However, in the mud flat section, the surface run-off shall be collected and discharged without erosion of the mud flat.

An image of the drainage flow is shown in the figure below.

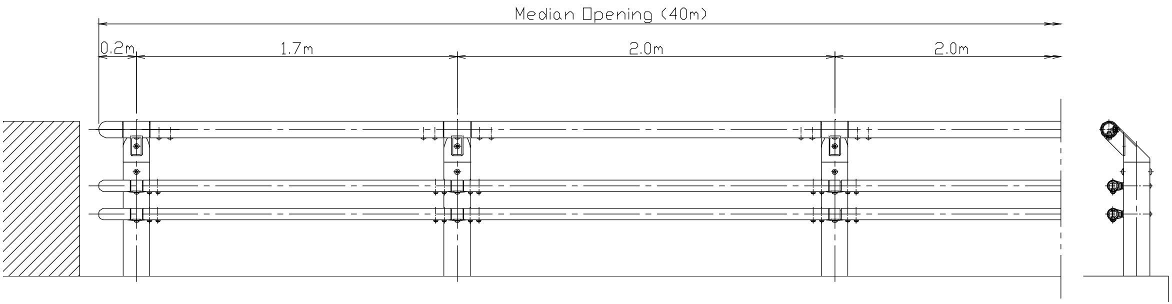


Source: JICA Study Team

Figure 6.4.11 Drainage Flow in Mud Flat Area

6.4.12 Median Opening for Emergency Exist

The median opening shall be provided for traffic operation during the maintenance and repair works after operation as well as for emergency exist for vehicles at serious accidents on the carriageway. The median opening shall be installed at 2km interval according to the Japanese expressway design standards.



Source: JICA Study Team

Figure 6.4.12 Median Opening for Emergency Exist

6.4.13 Noise Barrier

The noise barrier shall be installed at tidal area in Mumbai side and Navi Mumbai side to protect the lesser flamingo from the noise of traffic.

Table 6.4.7 Noise Barrier

Chainage	Length	Height
CH. 0+500 to 4+000 (North side)	3,500m	3m
CH. 0+500 to 5+500 (South side)	5,000m	3m
CH. 16+980 to 17+580 (Both side)	600m	3m

Source: JICA Study Team

6.4.14 View Barrier

The view barrier shall be installed to blind the driver on the MTHL to the Bhabha Atomic Research Centre. It is installed along the north edge line only of the main carriageway.

Table 6.4.8 View Barrier

Chainage	Length	Height
CH. 4+000 to 10+000 (North side)	6,000m	3m

Source: JICA Study Team

6.4.15 Safety Fence

The safety fences shall be installed during across the roads, railways and shipping channels to protect the road users, railways and ships from the falling object.

Table 6.4.9 Safety Fence

Chainage	Length	Height	Facilities to be Protected
CH. 5+500 to 6+078 (South Side)	578 m	3m	Pipeline, conveyer, etc.
CH. 8+720 to 9+080 (South Side)	360m	3m	Thane Coal Berth
CH. 13+138 to 13+510 (Both Side)	372m	3m	Panvel Navigation Channel
CH. 16+840 to 16+880 (Both Side)	484 m	3m	Road
CH. 18+087 to 18+127 (Both Side)	40 m	3m	Road (Planned)
CH. 18+187 to 18+217 (Both Side)	30 m	3m	Road
CH. 18+317 to 18+357 (Both Side)	40 m	3m	Road (Planned)
CH. 18+424 to 18+492 (Both Side)	68 m	3m	Subran Railway/Road
CH. 18+574 to 18+644 (Both Side)	70 m	3m	Road (Planned)
CH. 18+884 to 18+929 (Both Side)	45 m	3m	Road (Planned)
CH. 20+225 to 20+260 (Both Side)	35 m	3m	Road
CH. 21+009 to 21+079 (Both Side)	70 m	3m	SH54
CH. 21+228 to 21+423 (Both Side)	195 m	3m	Railway
CH. 21+659 to 21+729 (Both Side)	70 m	3m	NH4B

Source: JICA Study Team

6.5 Preliminary Design for Bridge

6.5.1 Introduction

The MTHL structure comprises an elevated sea portion and mostly elevated land portion with various bridge types and spans.

Whereas the Sewri IC consists of a grade-separated interchange, three ICs at the Navi Mumbai side consists of grade separators and land approach at grade commensurate with the vertical profile.

On the marine section of MTHL, a PC box girder with basic span length of 50m, which is typically applied in India since it is easy to construct, easier maintain and economical, is recommended in Final FS 2012. It can be judged that the slection of this type is approprate from the viewpoint of strucutural rational. The standard continuous span is six continuous spans of 50m in order to reduce the bending moment of the structure and eliminate the need for bearings and expansion joints.

On the land portion, a PC box girder type with basic span length of 30m is recommended in the study in consideration of constructactability, cost and construction period. This type is also commonly applied in India and hence easy to construct. Moreover, the number of expansion joints is reduced, hence maintenance requirements are reduced and driving is smoother.

As for the locations in which long span bridge (150-180m) is required to cross significant obstacles such as channels, pipelines and creeks, the comparison of the optimum bridge type is carried out in this chapter. The steel box girder bridge with steel deck is selected because construction period can be greatly shortened by using the large block erection method.

6.5.2 Improvement of Main Bridge Plan

(1) Span Arrangement

1) General Section (Free of Obstacles)

The basic span length of 50m in the marine area is determined considering fishing boats and vessels for seabed dredging. There is a fishing port nearby the MTHL and the fishing ships which go in and out of the port for fishing activities shall cross under the MTHL. Furthermore, sand from rivers easily accumulates in the Mumbai bay necessitating periodic dredging of the Mumbai bay sea bed.

There are areas where span length is 40m but it is confirmed that there is no effect on fishing ship transportation and sea bed dredging activities. The above was indicated in both Final Feasibility Report, 2012 and Advisory Technical Committee.

The span length in land area is planned as 30m basically. The bridge with its span length of 30m gives satisfactory results in India, and is an economical type.

2) Special Section on Marine Area

The span arrangement was determined based on the utility survey in section 5.4 and the determined span length is shown in Table 6.5.1.

Table 6.5.1 Crossing Utilities and Span Arrangement

Obstacles	Horizontal clearance	Chainage	Span arrangement (m)
Tata Intake and Discharge Channels	94m	No. 3+395～No. 3+715	85+150+85=320m
Tata Coal Berth Channel	2x94m	No. 4+625～No. 6+078	90+2@150+2@100+93=683m 120+180+120+140+120+90=770m
Pipelines	-		
Coal Conveyor	5m		
Cooling Water	94m		
Pir Pau Jetty	-		
Thane Creek	2x94m	No. 8+620～No. 9+180	100+2@180+100=560m
ONGC pipelines BPCL pipelines	-	No. 11+880～No. 13+610	(Mumbai to Navi Mumbai) 84+2@130+180+115=639m 74+4@95+65=519m 112+2@180+100=572m (Navi Mumbai to Mumbai) 98+140+150+180+90=658m 55+4@95+65=500m 100+2@180+112=572m
Panvel Creek	2x100m		

Source: JICA Study Team

3) Mangrove Section (Navi Mumbai side)

There is a mangrove area that occupies about 2km from the sea shore vicinity along the MTHL in Navi Mumbai side. The mangrove section is divided between the shore area and land area at the Shivaji Nagar IC. The span length is 50m at the mangrove section from Feasibility Study Report, 2012. Since sea water will be blocked at the Shavaji Nagar IC after completion of the planned coastal road by CIDCO near the IC, the 30m span can be generally applied from Shivaji Nagar IC to Chirle IC in consideration of construction cost and construction period.

Source: JICA Study Team

Figure 6.5.1 Mangrove Section (Navi Mumbai Side)

Reduction of the adverse impact on the mangrove on the shore section has been also studied in this study and a span length of 80m is proposed. However, this proposal is not adopted due to the high construction cost.

4) Railway Crossing Section

Regarding the railway crossing, consultations were made between MMRDA and Indian Railway. Through the consultation, a bridge type, pier location and shape were concoluded. Determined span length at each railyway crossing is shown in Table 6.5.2.

Table 6.5.2 Crossing Railways and Span Length

Crossing railways	Horizontal clearance	Chainage	Span length (m)
Suburban railway	70m	No. 18+421.5～No. 18+491.5	70m
Railways (DFCC corridor, Panvel-Uran, JNPT railway)	195m	No. 21+232～No. 21+427	3@65=195m

Source: JICA Study Team

Source: JICA Study Team

Figure 6.5.2 Crossing Railway Section

5) Crossing Road Section

The span length was studied with reference to the Utility, Facility and Navigation Survey (shown in section 5.4) and was decided considering the horizontal clearance for the crossing roads. The existing and planned crossing roads were identified in consultation with CIDCO. Determined span lengths are shown in Table 6.5.3.

Table 6.5.3 Crossing Road and Span Length

Crossing roads	Horizontal clearance	Chainage	Span length (m)
Existing Road	About 6m	No. 16+840～No. 16+880	40m
CIDCO Coastal Road (Planned)	About 27m	(Mumbai to Navi Mumbai) No. 17+320～No. 17+471 (Navi Mumbai to Mumbai) No. 17+341～No. 17+482	(Mumbai to Navi Mumbai) 45+49+57=151m (Navi Mumbai to Mumbai) 57+34+50=141m
Planned Road	About 33m	No. 18+087～No. 18+127	40m
Existing Road	About 7m	No. 18+187～No. 18+217	30m
Planned Road	About 24m	No. 18+317～No. 18+357	40m
Existing Road	About 6m	No. 18+421.5～No. 18+491.5	70m
Existing Road	About 4m	No. 18+421.5～No. 18+491.5	70m
Planned Road	About 30m	(Mumbai to Navi Mumbai) No. 18+574～No. 18+644 (Navi Mumbai to Mumbai) No. 18+554～No. 18+644	(Mumbai to Navi Mumbai) 35+35=70m (Navi Mumbai to Mumbai) 40+50=90m
Planned Road	About 30m	No. 18+884～No. 18+929	45m
Existing Road	About 15m	No. 20+225～No. 20+260	35m
SH54	About 26m	No. 21+012～No. 21+079	67m
Planned Road	About 12m	No. 21+427～No. 21+467	40m
NH4B	About 25m	No. 21+660～No. 21+730	2@35=70m

Source: JICA Study Team

(a) SH54

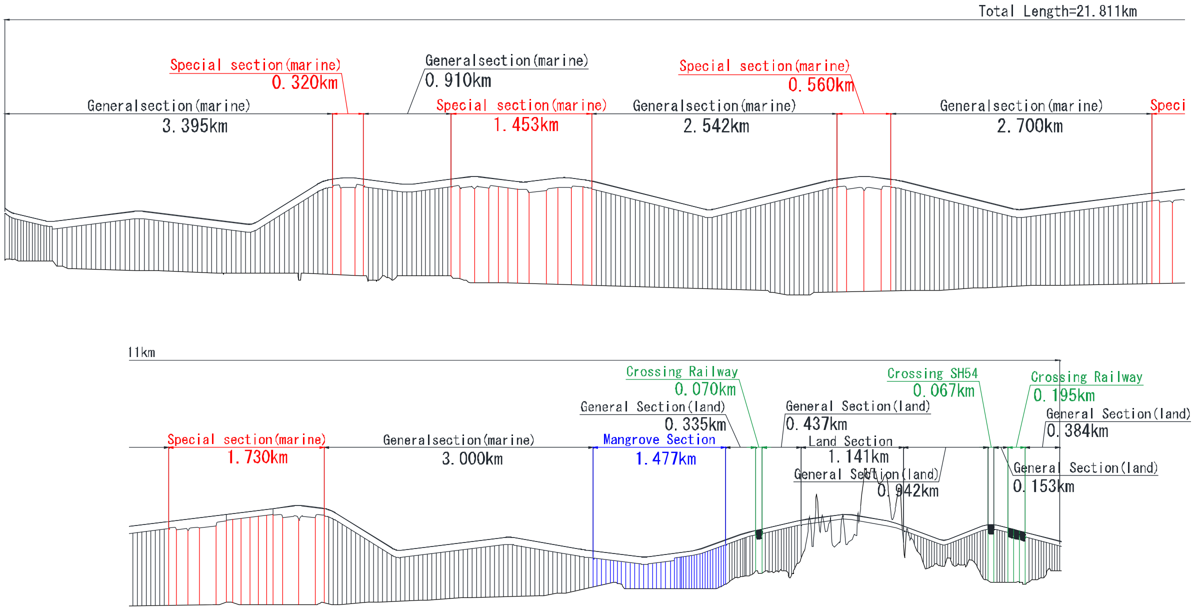
(b) NH4B

Source: JICA Study Team

Figure 6.5.3 Crossing Road Section

6) Conclusion

The span arrangement for whole MTHL is shown in Figure 6.5.4 and Table 6.5.4 to Table 6.5.5.



Note: General section (marin section), span arrangement 50m
General section (land section), span arrangement 30m
Special section, span arrangement is shown in Table 6.5.4 and Table 6.5.5

Source: JICA Study Team

Figure 6.5.4 Span Arrangement on Main Bridge

Table 6.5.4 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 6.5.5 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 (4x30m+35m)
No. 20+225～No. 20+260	Crossing Road Section	35m
No. 20+260～No. 21+012	General Section (land area)	752m (35m+23x30m+27m)
No. 21+012～No. 21+079	Crossing Road Section	67m
No. 21+079～No. 21+232	General Section (land area)	153m (4x30m+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+2x37m+3x27m)
No. 21+660～No. 21+730	Crossing Road Section	70m (2x35m)
No. 21+730～No. 21+811	General Section (land area)	81m (3x27m)

Source: JICA Study Team

(2) Bridge Type

1) General Sections on Marine and Land

(a) Superstructures

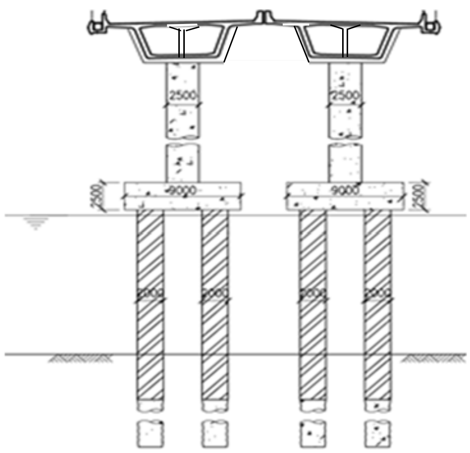
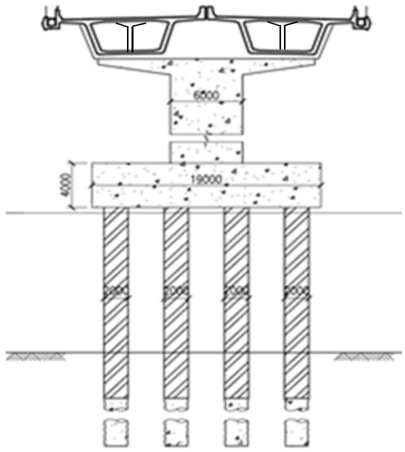
Essentially, the span length is planned as 50m in marine areas and 30m in land areas. Generally, a PC box girder type in India use spans of length ranging from 30m to 50m. PC box girder bridges are generally accepted as more economical than other bridge types in this range in Inida. In Japan, there exist many PC box girder bridges for span length from 30m to 60m with same reason in India. Therefore, it is said that PC box girder bridges are optimal. On the other hand, as the maintenance costs are high, moreso on the sea, the number of both expansion joint and bearing that require periodic maintenance should be reduced as much as possible. Resultantly, continuous bridges and rigid frame structures structurally connecting superstructure with substructure are selected. In land areas, simple beam bridges are accepted due to their lower cost and shorter construction periods. However, the bridge deck shall be structurally connected after erection of girders in order to reduce the number of expansion joint.

(b) Substructures and Foundations

a) Pier Type

A comparison of substructure form was undertaken between separate single-column piers and integrated hammerhead piers for both direction.

Table 6.5.6 Comparison of Pier Form (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 colume and pier cap compared to other option but requires careful construction of pier beam
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 main girders during construction. [Rejected]

Source: JICA Study Team

Considering hammerhead piers, there is a possibility that torsional moments will be generated in the main girder during erection, because of one-sided (eccentric) loading of the main girder and launching gantry. Therefore, the overhang of the pier head (crossbeam) has been designed with a haunch to ensure rigidity.

The comparison assessed overall design considering structural integrity, constructability and economy, and determined that single-column piers should be adopted.

In addition, single-column piers were also chosen because of a need to adopt similar substructure forms for viaduct sections both over water and on land.

A number of options were considered for the foundation form, including pile bents, cast-in-situ concrete piles, steel pipe sheet pile foundations and caisson foundations. The span lengths for the viaduct sections over water are 50m and the span lengths for those over land are 30 m, so the span lengths are relatively short and the loads to be supported by piers and foundations are considered small.

Steel pipe sheet pile foundations and caisson foundations are normally applied to medium to large bridge spans, so it would be economically disadvantageous to apply them to this viaduct. In addition, cast-in-situ concrete piles are often employed for small to medium bridge spans, so it is considered reasonable to apply them to this viaduct.

In the analysis, a pile bent type for both pier and foundation was considered. However, application of 2,400mm in diameter for pier and foundation, which is the maximum size of pile in Indian practice, can not satisfy the structural requirements as a result of the structural anlysis due to lower bearing capacity.

The pile diameter for cast-in-situ concrete piles was decided by comparing several pile diameters.

2) Obstacle Section on Marine

(a) Superstructures

The main span length for bridges in the obstacle section on marine becomes 150m and 180m. Bridge types that fit to the span range should be selected. The results of this primary selection are shown in Table 6.5.7.

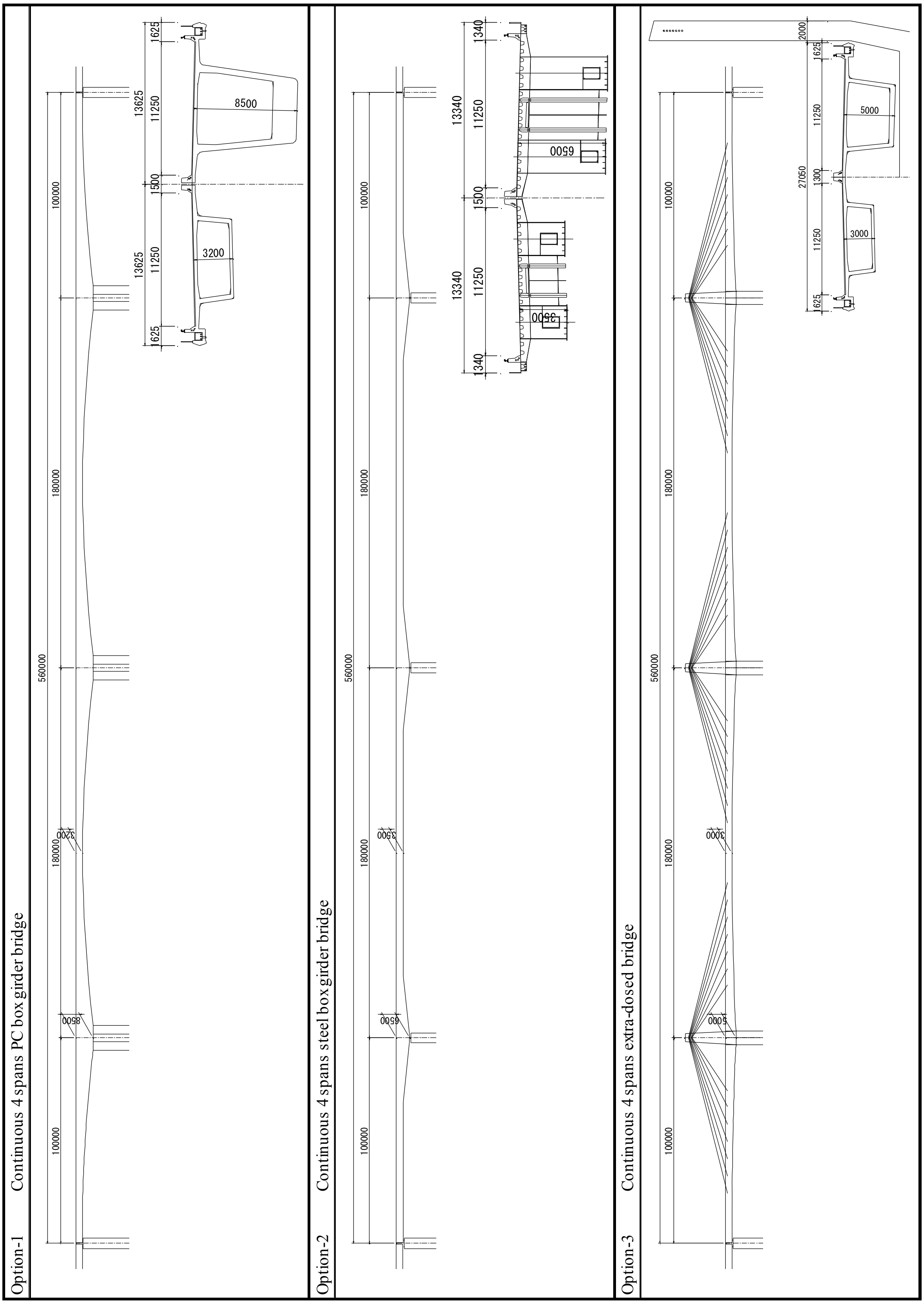
Table 6.5.7 First Selection for Bridge Types

Bridge types	Normal span	Selection reason	Yes or No
PC rigid frame box girder bridges	50m to 140m	Though the span length exceeds the normal span length, this can be selected.	Yes
Steel deck slab box girder bridges	30m to 200m	There are many satisfactory construction results. This can be selected.	Yes
Steel truss bridges	40m to 120m	This can be used but the span length is rather larger than the normal span length and the economical aspect is bad. The aesthetic is not good due to discontinuous parts at the begin point and ending point of the bridges.	No
Steel arch bridges	50m to 200m	This can be used but there is almost no case of 4-span or 5-span continuous bridges, this should not be adopted. The aesthetic is not good due to discontinuous parts at the ends of the bridges.	No
PC extradosed bridges	100m to 200m	There are many satisfactory construction results. This can be selected.	Yes
PC stay cable bridge	110m to 400m	This can be used but the economical aspect is bad comparing to PC extradosed bridges.	No

Source: JICA Study Team

The second comparative review shall be carried out for three alternatives in the above table. The comparison table is shown in Table 6.5.8 and Table 6.5.9. Here the target bridge is for Thane Creek with span of 180m.

Table 6.5.8 Second Selection for Bridge Types (1/2)



Source: JICA Study Team

Table 6.5.9 Second Selection for Bridge Types (2/2)

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 evaluation method for each factor is indicated as follows.

Structural Performance

There are three aspects of structural performance: Applicability, Durability, and Seismic Resistance.

The applicability of structures is evaluated based on construction records. It is assumed that higher the frequency of construction of a particular structure, the higher its applicability is. However, even in the case of high construction record, if the span length is larger than the normal span length for the structure type, the applicability is not high. Therefore, the applicability shall be evaluated considering construction frequency records based on span lengths.

The durability of structures refers to the life of the structures. The higher the durability is, the longer the structure can be used. The bridge is composed of deck slab, main girders, piers, and piles. As the deck slab receives direct live load, its durability is different from the main girders, piers and piles. RC deck slab has a short life comparing to PC deck slab and steel deck slab. It is said generally that the life is about 50 years for RC deck slab and 100 years for PC deck slab and steel deck slab. Therefore, the evaluation shall be concentrated on deck slab's durability.

The seismic resistance is evaluated based on the weight of structures. The seismic forces and the weight of structures are closely related. The heavier the structure is, the larger the acting seismic force is. Conversely, the lighter the structure is, the smaller the acting seismic force is. In order to reduce the acting seismic forces, the weight of structures should be decreased. Therefore, this item shall be evaluated based on the weight of structures.

Constructability

There are two aspects of Constructability: Difficulty of Construction and Quality Control.

The difficulty of construction is an important aspect to construct a bridge safely. The higher the difficulty level is, the higher the construction accuracy is required. The difficulty level of construction depends on construction methods. The simple construction method is precast segment and span by span method. The high difficulty level of construction method is pointed out such as cantilever method. Furthermore, the extradosed bridge and the cable stay bridge have higher difficulty level of construction due to the construction of cables in addition to cantilever construction. Therefore, the evaluation point shall be put at construction method.

Quality control of construction is an important aspect to construct a bridge of high quality. It is easy to control the quality of a structure which is made in factory. In result, the structure shall have high quality and be supplied stably to the site. On the other hand, it is difficult to control the quality of a structure which is made in-situ, and in order to get stably a high quality, extremely high quality control is required. Therefore where a structure is made is a key point for evaluation.

Construction Period

Navi Mumbai Airport is currently under construction and is planned to be opened in 2019. The Special Economic Zone is also being constructed simultaneously. After finishing these constructions, transportation between Mumbai and Navi Mumbai is expected to increase drastically. Thus, it is desirable that the Mumbai Trans Harbour Link shall be opened for traffic as soon as possible. Reducing the construction period is important in consideration of economic activities of Mumbai and Navi Mumbai.

Ease of Maintenance

There are two aspects of ease of maintenance: Repainting and Member Replacement.

The repainting is necessary to lengthen the life of bridges. Otherwise, a steel member shall be corroded from the location where the painting is deteriorated and this causes a huge scale of remedy for the bridges. A thick anticorrosion coat has a life of about 35 years and it is necessary to repaint. As it takes cost for repainting, a structure which does not require repainting is expected. Therefore, the evaluation point shall be put on whether repainting is required or not.

Replacement of both members and accessories is necessary to keep bridges safe for users. The members which are necessary to be replaced are expansion joints and bearing supports. The replacement interval is about 20 years for the expansion joints and about 40 years for the bearing supports. As it takes cost for replacing the expansion joints and bearing supports, a structure which does not require expansion joints and bearing supports is preferred. Furthermore, it is necessary to close the existing road when replacing the expansion joints or bearing supports. Therefore, the evaluation point shall be put on whether expansion joints and bearing supports are required or not.

Aesthetics

The MTHL is an important line which connects Navi Mumbai to the centre part of Mumbai. And as it is also a gate to enter Mumbai from the Navi Mumbai Airport, the Project Road becomes a new land mark. When a tourist gets off the Navi Mumbai Airport, one of structures which the tourist can see in his first view is the Project Road and it represents Mumbai growth. Therefore, evaluation point related to aesthetics is carried out.

Environmental impact

The Project Road is planned to cross the Mumbai bay. As the Mumbai bay is the home for various kinds of fishes, flamingos, mangrove etc…, it is important to protect the natural environment. The shorter construction period of structures, the smaller scale of piers and foundations and the lesser water pollution at construction are expected to mitigate adverse effects to the natural environment. Therefore, the evaluation point shall be put on the construction period and scale of piers or foundation.

New technology application (Technical transfer)

The new technology which is more meaningful than the existing technology should be adopted in MTHL construction project. As the adopted new technology shall be transferred to Indian counterparts and this contributes to the technical growth of Indian, the evaluation point shall be put on whether a new technology is adopted or not.

Construction cost

The construction cost including foundations, abutments, piers and superstructures is shown in Table 6.5.9.

Economic benefit (Economical Internal Return Ratio)

The economic benefit is calculated at target when the MTHL is opened for 40 years.

Conclusion

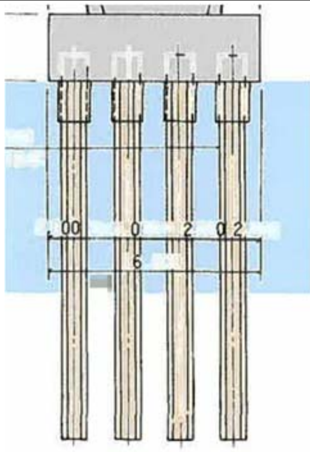
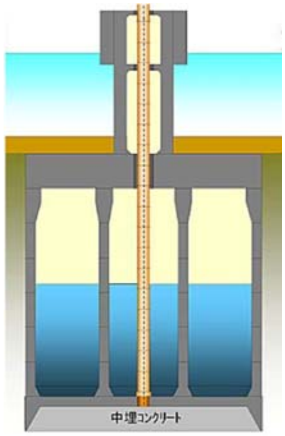
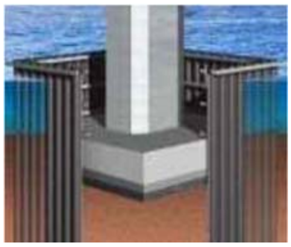
According to results in Table 6.5.8 and Table 6.5.9, the Option-2: steel box girder with steel slab shall be adopted for the superstructure.

(b) Substructures

A number of options were considered for the foundation form, including cast-in-situ concrete piles, steel pipe sheet pile foundations and caisson foundations. Since a steel box girder with steel deck type was seleted for the span lengths ranging 150 m from 180 m in the comparison mentioned above, the superstructure weight can be regarded medium-sized but not large sized.

From the above, a comparison of multiple-pile foundations (cast-in-situ concrete piles), caisson foundations and steel pipe sheet pile foundations was undertaken to determine the form of foundations.

Table 6.5.10 Comparison of Foundation Form for Marine Bridge Sections

	Group pile foundations	Caison foundations	Steel pipe sheet pile foundations
Diagram			
Properties	・ Pile foundations are common practice in India. There are many cases of their application.	・ Caison 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 equipmentis required for construction below depth of 0 m underwater, which is a disadvantage compared to group pile foundations.	・ This method has some issuses because this one has no experience in India.
Conclusion	Suitable	Feasible	Not feasible

Source: JICA Study Team

In India, multiple-pile and caisson foundations are common foundation types. The superstructure for bridge sections of the viaduct over water is a steel box girder form (with a maximum span length of 180m), so the loads are not large and there is an advantage to adopting multiple-pile foundations.

A caisson foundation is a suitable foundation type for relatively large loads. However, large construction facilities would be necessary to construct foundations of 10 m or more in deep for the sections that are over water.

The degree of difficulty for constructing this bridge is high because it crosses the sea, so it is believed that adopting Steel pipe sheet pile foundations, which are an uncommon form of construction in India, should be avoided.

For the reasons described above, multiple-pile foundations (cast-in-situ concrete piles) have been adopted for the foundations of the bridges of the viaduct.

In addition, the diameter of cast-in-situ piles will be determined based on the results of performance comparisons.

3) Mangrove Section in Navi Mumbai Side

(a) Superstructures

Environmental factor is a important point to determine the structural type. The PC box girder type with 50m in span length, which is the same one for general marine section, was finally selected in consideration of minimizing the adverse impact on mangrove forest and constuctablity in the area.

Altough the option spanning 80m with steel box girder was studied as the alternative option to further minimize the adverse impact on the mangrove forest, it was abandoned due to significantly high cost compered to the selected option.

(b) Substructures

Single-column piers have been adopted for the substructure, similar to the general sections over water. Cast-in-situ concrete piles have been adopted for the foundations, again similar to the general sections over water.

Similar to the sections over water, cast-in-place pile foundations with undersides at +6.00 m above C.D. were adopted for the mangrove forest area, because they would have less effect on the forests compared to the excavations needed to have pile caps below ground level.

4) Railway Crossing Part

(a) Superstructures

MMRDA had consulted with the related railway administrators about the railway crossing part before this study and it has already been agreed that steel truss bridges shall be adopted.

(b) Substructures

As mentioned above, foundation type has also been decided in consultation between MMRDA and the related railway administrators. Basing on the agreement, bored piles are adopted for the foundation.

5) Road Crossing Part

(a) Superstructures

The span length is 50m which is adopted this area generally. Therefore PC box girder with rigid frame type is applied.

(b) Substructures

The substructure of the overpass section consists of single-column piers, based on it needing to be the same structure type as the general land-based sections.

The foundations will be cast-in-situ concrete piles, which are also the same as the general land-based sections.

6.5.3 Improvement of Bridge Plan for Interchange Ramps

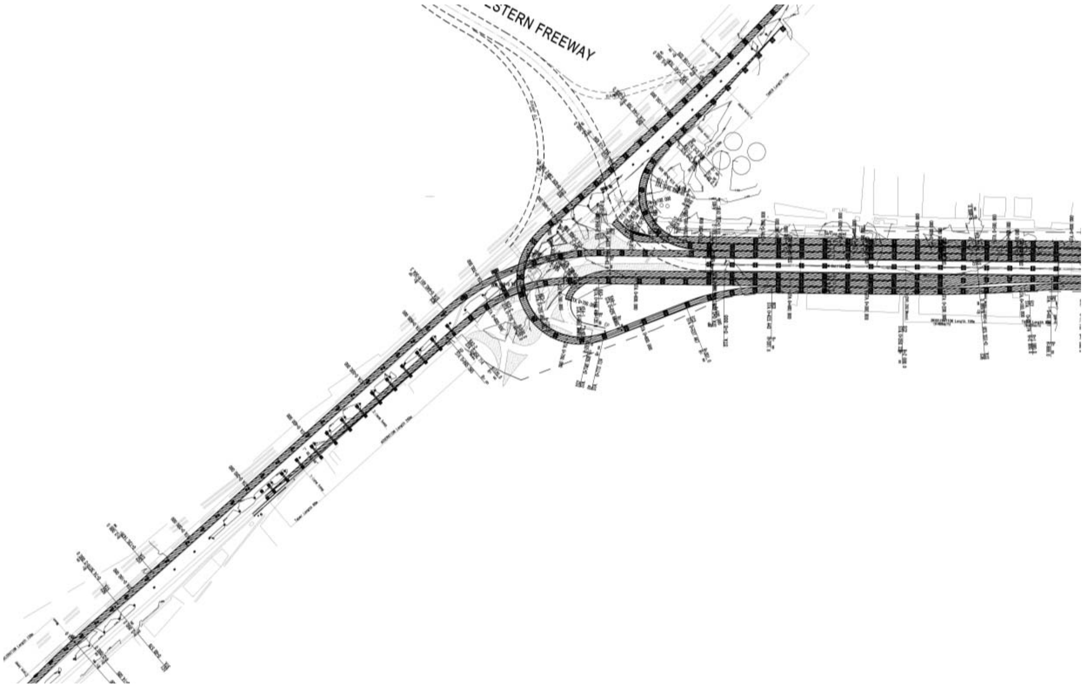
The MTHL includes four (4) interchanges.

- Sewri IC (Mumbai side)
- Shivaji Nagar IC (Navi Mumbai side)
- SH54 IC (Navi Mumbai side)
- Chirle IC (Navi Mumbai side)

(1) Sewri IC

1) Span Arrangement and Superstructure

The Sewri IC is planned with PC box girder having basic span length of 30 m considering economic and construction period. The span length at cross ramp and connecting existing roads is determined considering clearance of the crossing objects, which is ranging from30 m to 50m. The span arrangement is shown in Figure 6.5.5 and Table 6.5.11.



Source: JICA Study Team

Figure 6.5.5 Span Arrangement at Sewri IC

Table 6.5.11 Span Arrangement of Each Ramp at Sewri IC

Ramp	Pier Number	Channage	Bridge Type	Span Arrangement
Ramp A	AP1 - MP1	-0+495	PC box	1,698m (26m, 23m, 30m, 7x26m, 25m, 3x35m, 17x26m, 35m, 2x51m, 35m, 2x25m, 2x30m, 60m, 23m, 15x30m, 50m)
Ramp B	BP1 - MP1	-0+495	PC box	1,530m (2x33m, 4x26m, 21m, 2x30m, 3x26m, 31m, 11x26m, 32m, 49m, 23m, 3x35m, 2x30m, 25m, 18x30m, 50m)
Ramp C1	C1P1 - C2P9		PC box	910m (12m, 22m, 11x26m, 30m, 25m, 30m, 23m, 30m, 32m, 50m, 40m, 11x30m)
Ramp C2	C2A1 - MP1	-0+495	PC box	500m (15x30m, 50m)
Ramp E	EP1 - MP1	-0+495	PC box	908m (20m, 2x26m, 32m, 4x26m, 31m, 15m, 25m, 2x30m, 44m, 25m, 15x30m, 50m)
Ramp F	FA1 - MP1	-0+495	PC box	440m (13x30m, 50m)

Source：JICA Study Team

2) Substructures and Foundation

A pile bent type cannot be applied for the ramp because the superstructure of the ramp has a curved alighnment with widening sections. The ramp structure will be a basic single-column hammerhead pier. However, ramp A partically has a straddle pier where it crosses the East Freeway and cast-in-situ pile foundations shall be adopted.

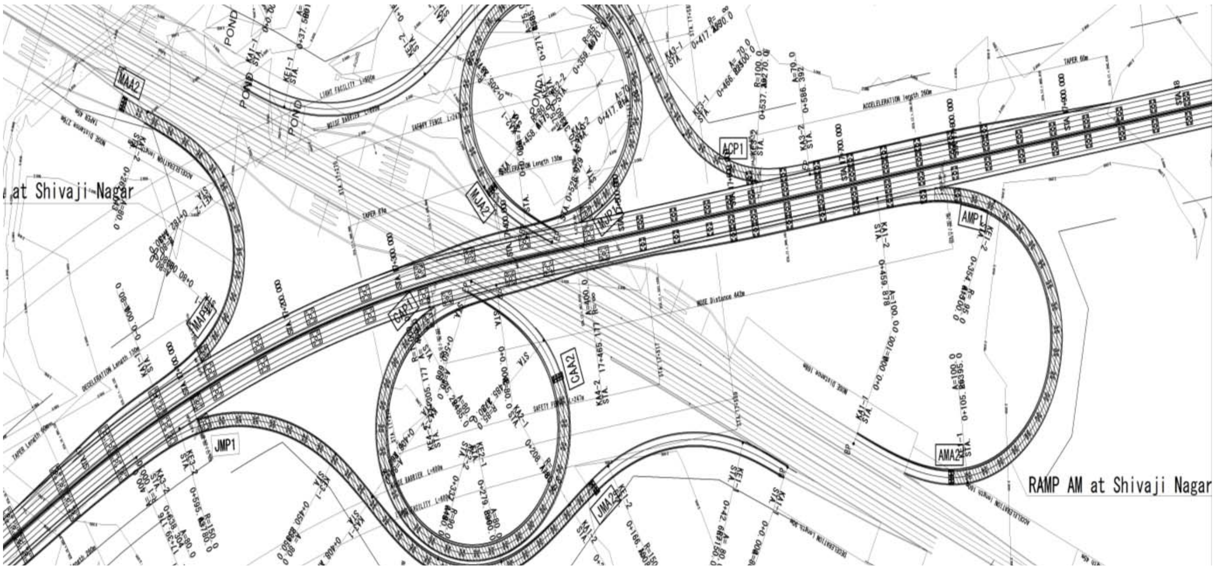
(2) Shivaji Nagar IC

1) Span Arrangement and Superstructure

There are no restrictions for construction of Shivaji Nagar IC. Therefore, the RC hollw slab type, which has many track records of construction in India due to economical cost, is selected. The superstructure can be constructed at the staging with support beam

2) Substructure and Foundation

The substructure shall consist of single-column hammerhead pier and cast-in-situ pile foundations shall be adopted.



Source: JICA Study Team

Figure 6.5.6 Span Arrangement at Shivaji Nagar IC

Table 6.5.12 Span Arrengement at Shivaji Nagar IC

Ramp	Pier No.	Channage	Type	Span Arrangement
MA Ramp	MP289 - MAA2	No. 17+125 -	RC hollow slab	225m (15x15m)
AC Ramp	MP302 -ACA2	No. 17+617 -	RC hollow slab	285m (19x15m)
JM Ramp	MP288 - JMA2	No. 17+105 -	RC hollow slab	390m (26x15m)
MJ Ramp	MP296 - MJA2	No. 17+471 -	RC hollow slab	388m (11m, 2x10m, 7x15m, 14m, 5x13m, 12m, 2x13m, 9x15m)
CA Ramp	MP293 - CAA2	No. 17+320 -	RC hollow slab	373m (10m, 12x15m, 6x13m, 7x15m)
AM Ramp	MP308 - AMA2	No. 17+797 -	RC hollow slab	285m (19x15m)

Source：JICA Study Team

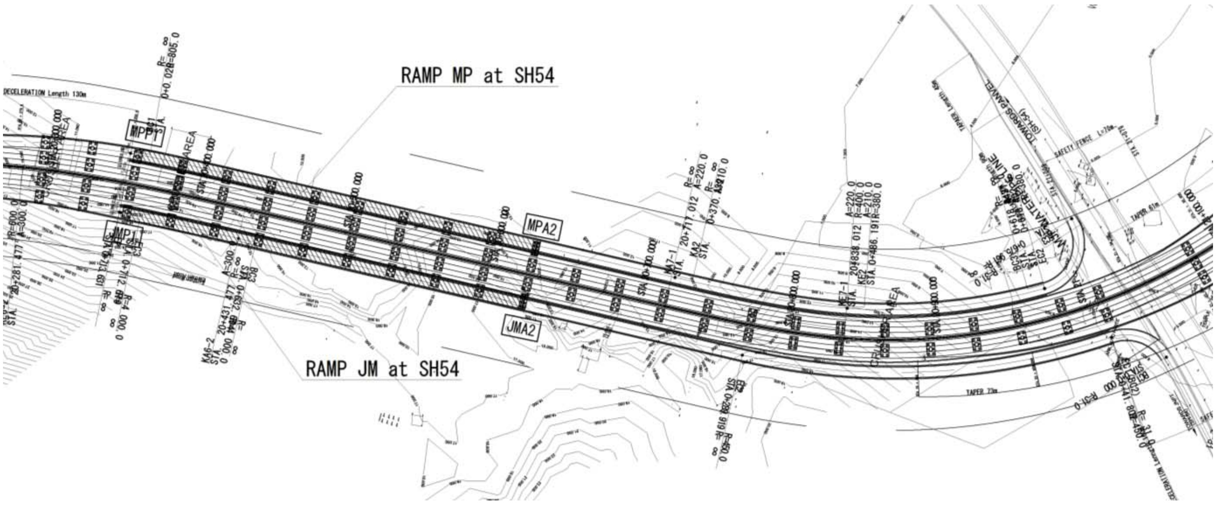
(3) SH54 IC

1) Span Arrengement and Superstructure

A PC box girder type, which is same as for the main road, shall be adopted because SH54IC runs larallel to the main road.

2) Substructure and Foundation

The substructure shall consist of single-column hammerhead pier and cast-in-situ pile foundations shall be adopted.



Source: JICA Study Team

Figure 6.5.7 Span Arrangement at SH54 IC

Table 6.5.13 Span Arrengement at SH54 IC

Ramp	Pier No.	Channage	Type	Span Arrangement
MP Ramp	LP9 - MPA2	No. 20+355 -	PC box	270m (9x30m)
JM Ramp	LP9 - JMA2	No. 20+355 -	PC box	270m (9x30m)

Source：JICA Study Team

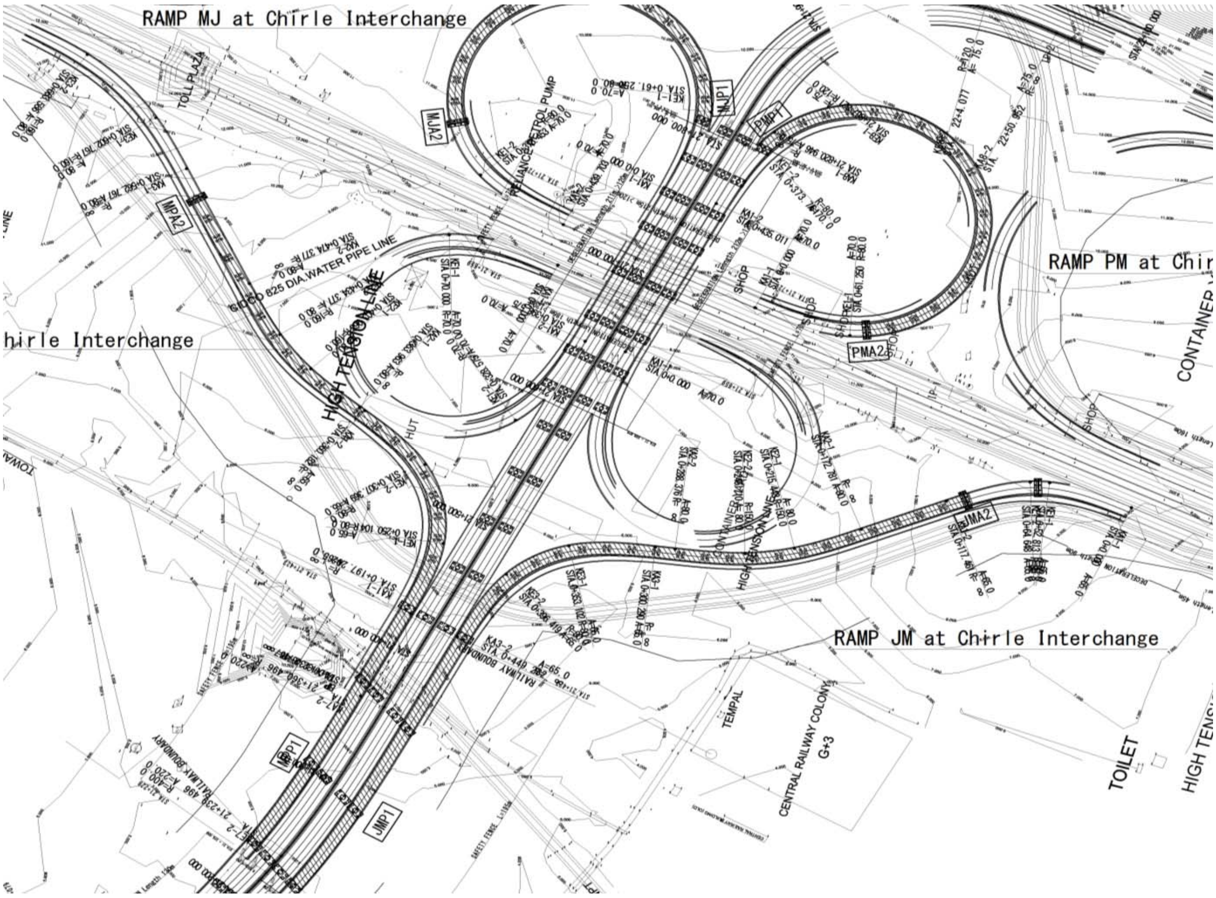
(4) Chirle IC

1) Span Arrengement and Superstructure

There are no restrictions for construction of Chirle IC. Therefore, a RC hollw slab type, which has many track records of construction in India due to ecomoical cost, is selected. This type can be constructed at staging with support beam. The steel box grider type is adopted for the part across over the railway.

2) Substructure and Foundation

The substructure shall consist of single-column hammerhead pier and cast-in-situ pile foundations shall be adopted.



Source: JICA Study Team

Figure 6.5.8 Span Arrangement at Chirle IC

Table 6.5.14 Span Arrengement at Chirle IC

Ramp	Pier No.	Channage	Type	Extension Ramp (Only Bridge)
MP Ramp	LP37 - MPA2	No. 21+232 -	Steel truss bridge PC box girder bridge RC hollow slab bridge	535m (3x65m, 40m, 20x15m)
JM Ramp	LP37 - JMA2	No. 21+232 -	Steel truss bridge PC box girder bridge RC hollow slab bridge	535m (3x65m, 40m, 20x15m)
MJ Ramp	LP52 - MJA2	No. 21+811 -	RC hollow slab bridge	270m (18x15m)
PM Ramp	LP52 - PMA2	No. 21+811 -	RC hollow slab bridge	300m (20x15m)

Source：JICA Study Team

6.5.4 Consideration to Salt Damage

It is necessary to pay attention to a corrosion issue since a steel box girder was applied to marine section. This sub-chapter describes (i) examples of the steel bridges on marine, (ii) anticorrosion method for steel bridge, (iii) recommended specifications for anticorrosion method for MTHL bridge, and (iv) maintenance method for the steel bridge.

(1) Examples of Steel Bridges on Marine

1) Long-Life Steel Bridges on Marine

Generally, it is thought that a steel bridge has much more problematic with corrosion than a concrete bridge on marine. However, there are some examples which keep its life with a healthy condition for more than 100 years by carrying out appropriate anti-rust treatment and maintenance. The typical examples of such steel marine bridge are the Force Bridge which was completed in 1890 in Edinburgh, Scottland and the Brooklyn Bridge which was constructed in 1883 completion in New York, USA.

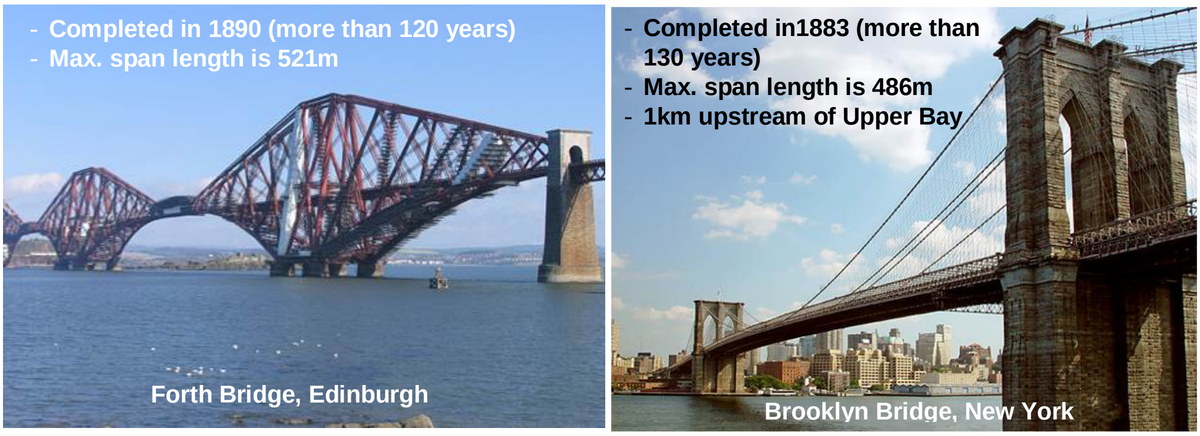


Figure 6.5.9 Examples of the Steel Bridges on the Sea

2) Examples of Marine Steel Bridges in Japan

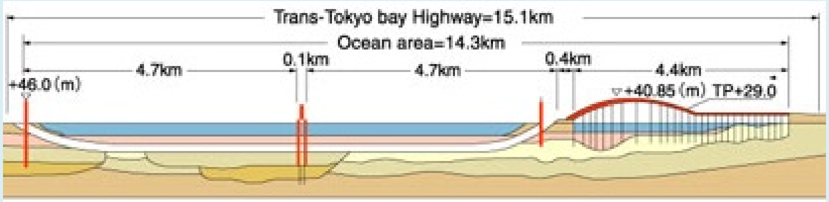
In Japan, there have been a lot of marine steel bridges because of its topographical feature as island country, and the issue of corrosion on the steel bridge has already been overcome with long time research on this topic The main reasons why a steel bridge is applied to the marine bridge are as follows.

- Long span length is required for navigation channels and etc.
- Quality control is easy and the quality is stable because of production in a factory.
- Site work (on the sea) can be shortened and is superior in safety.
- Maintenance is easy since corrosion and damage can be observed from outside.
- Partial repair can be done easily.
- Extension of its life is possible by conducing appropriate maintenance

The followings are major steel marine bridges in Japan.

Tokyo Bay Aqua-Line

- Shield Tunnel (9.5km) + Steel Box Girder 4.4km
- Completed in 1997
- Large Block Erection by Floating Crane



Steel box girder with steel deck. Maximum span length is 240m. Thick anti-corrosion coating was applied. Steel column at tidal portion was covered by titanium plate and one at underwater portion by electric anticorrosion method.

Source: JICA Study Team

Figure 6.5.10 Steel Marine Bridge in Japan (Tokyo Bay Aqua-Line)

Honshu - Shikoku Connecting Bridge

- Completed in 1999 (3 routes)
- 3 route total length: 89+37.3+59.4 = 185.7km
- 3 route total bridge length: 6.5+9.4+9.5 = 25.4km

Akashi Bridge (longest suspension bridge) and Tatara Bridge (2nd longest cable-stayed bridge) are included in Honshu – Shikoku Bridge.

Most bridges are steel bridge with thick anti-corrosion coating. In addition, Cable-coating was also applied to cable-stayed bridge and suspension bridge. Those bridges are compilation of Japanese advanced technology and are kept soundness condition more than 20 years after completion by conducting appropriate maintenance.

Source: JICA Study Team

Figure 6.5.11 Steel Marine Bridge in Japan (Honshu – Shikoku Bridge)

Iou Island Bridge
- Steel Box Girder (max. span 240m) with thick anti-corrosion coating
- Completed in 2011
- Large Block Erection by Floating Crane




Source: JICA Study Team

Figure 6.5.12 Steel Marine Bridge in Japan (Iou Island Bridge)

Tokyo Gate Bridge
- Steel Truss + Steel Box Girder
- Completed in 2012
- Large Block Erection by Floating Crane


Main bridge is a 3 span continuous steel truss-box bridge and Approach Bridges are a steel box girder with steel deck. Maximum span length is 440m. Truss structure of main bridge was applied in consideration of ship navigation channel with 54m height and aviation limit of Tokyo airport. Steels for Bridge High Performance Structure (SBHS) and thick anti-corrosion coating were applied.



Source: JICA Study Team

Figure 6.5.13 Steel Marine Bridge in Japan (Tokyo Gate Bridge)

Source: JICA Study Team

Figure 6.5.14 Steel Marine Bridge in Japan (Irab Bridge)

(2) Anticorrosion Method for Steel Marine Bridge

A road bridge has to show its function continuously as a part of the road network for a long term after traffic opening. Hence, it should be avoided to spoil the function and to give an adverse impact on the surroundings even temporarily.

A steel is easily corroded on the sea because salt perticles splashed in air and adhered on the surface of the steel promote a corrosion phenonenon of the steel. Accordingly, corrosion environment is undoubtedly severe on the sea.

Therefore, there are some minumu conditions which the anticorrosion method for a steel marine bridge meets in order to show the required function of anticorrosion.

- Possessing high reliability and much practical experience
- Maintenance (partial repair and full-scale repair) is possible

The anticorrosion method for a steel bridge can be classified into foure methods namely, coating, application of weathering steel, improvement of the corrosion environment, and electric protection (see Table 6.5.11). Among those, methods that have been applied a lot are coating and application of weathering steel. Improvement of the environment is impossible on the sea and electric protection is usually applied to steel in the water, but is hardly applied on the sea.

Although application of weathering steel can be applicable to one on land where is away from the sea, it is difficult to apply it on the environment where stable rust can not be developed.

A thick anticorrosion coating has much application experience on marine bridges and has high reliability. In addition maintenance is relatively easy. Hence, thick an anticorrosion coating is recommended to steel bridges in MTHL.

Table 6.5.15 Comparison of Anticorrosion Method for Steel Bridge

Method	Coating		Weathering Steel	Hot Dip Galvanizing	Metal Spraying
	Ordinary Coating	Thick Anticorrosion Coating			
Principle of Anti-corrosion	Isolation from external environment by coating	Isolation from external environment by coating and anti-corrosion by zinc rich paint	Development of stable rust	Isolation from external outside by zinc thermal sprayed coating	Isolation from external outside by metal sprayed coating
Painting Method	Coating by spray, brush, roller		Add some alloy elements during fabrication	Soak in zinc tank in factory	Spray by thermal spray gun
Applicable Place	Land (**not applicable in high salinity area**)	**Marine and Coastal Area**	Low salinity area	Anywhere	
Appearance	Any color can be painted on the surface		Dark brown	Charcoal white	Silver white
Cost	Moderate	Slightly High	Slightly High	Very High	Very High
Maintenance	Repainting in every 30 years on land	(every 35 years)	No need repainting	Painting after 25 years (no experience)	Metal spray or painting after 60 years (no experience)
Evaluation	Not applicable	**Applicable and Recommended**	Not applicable	Not recommended	

Source: JICA Study Team based on handbook of Coating and Anticorrosion Handbook, Japan

However in case the bidders propose the metal spraying method which has higher durability than the thick anticorrosion coating, applicability of the metal spraying methods are to be judged using the table below.

Table 6.5.16 Comparison of Metal Spraying Method and Painting Method

	Metal Spraying Method				Painting Method
	1) Al-Mg	2) Aluminum	3) Zinc	4) Zn-Al	5) Thick Anticorrosion Coating (MTHL)
Blasting	ISO Sa3	ISO Sa3	ISO Sa2 1/2	ISO Sa2 1/2	Refer to above table
Material	Alloy of Al-Mg	Aluminum	Zinc	Alloy of Zn-Al	
Spraying	Plasma Spraying	Flame Spraying or Arc Spraying	Flame Spraying or Arc Spraying	Flame Spraying or Arc Spraying	
Thickness	More than 150μm	More than 150μm	More than 100μm	More than 100μm	
Remarks	The durability is high however the cost is really high. It is difficult to carry out the metal spraying on large area one time because this method needs to spray the metal materials within 4 hours after the blasting. Therefore this method needs time to effort. The past record is really few near marine and coastal area. The uneven area cannot be applied. In case of the condition the sealing treatment, undercoating, intermediate coating and top coating are applied on this coating.				The cost is low. It has many past records. The uneven area can be applied.

Source: JICA Study Team based on Structure Painting Vol.41 Metal Spraying on Steel Bridge, Japan

(3) Recommended Specifications for Anticorrosion Method to MTHL Bridges

A thick anticorrosion coating is recommended to steel box girders in MTHL in accordance with the above comparison result.

The steel marine bridge with the anticorrosion coating can be kept the durability more than 100 years by conducting the appropriate maintenance. As mentioned previously, the thick anticorrosion coating is applied to most steel marine bridges these days since there is a little difference in detail.

This anticorrosion coating is satisfied below standards;

- ISO 2810-2004: Paints and varnishes - Natural weathering of coatings - Exposure and assessment
- ISO 9223-1992: Corrosion of metals and alloys - Corrosivity of atmosphrers - Classification
- ASTM D1014-02: Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates

The coating includes Primer, Under coating 1, Under coating 2, Intermediate coat, and Top coat and prevention of corrosion is made in combination on those. Each role is as follows:

1) Primer

Steel materials that blast processing was carried out easily generate corrosion. In order to prevent this, the prompt coating after blasting is called a primary primer.

2) Under Coating 1

It has a role to prevent corrosion of steel materials. Inorganic zinc paint is used.

3) Under Coating 2

It has a role to prevent the penetration of corrosive materials such as water or the salt. Under coat epoxy resin paint is used.

4) Intermediate Coat

It has a role to bond under coating with the top coat. Fluororesin paint is applied.

5) Top Coat

There is a function to keep luster and hue for a long time by choosing well weatherproofing resin and pigment.

Table 6.5.17 shows the specification of the recommended thick anticorrosion coating for steel bridges in MTFL. The equivalent specification that secures the long durability same as the said specification shall be applicable if any.

Table 6.5.17 Specification of Recommended Thick Anticorrosion Coating

Outer Surface painting System		Paint Name	Standard Thickness (μm)
Pre-treatment	First base plate conditioning	Primitive plate blasting	-
	Primer	Inorganic zinc primer	(15)
Factory paint	Secondary base plate conditioning	Assembled member blasting	-
	Under coating 1	Inorganic zinc paint	75
	Mist coating	Under coat epoxy resin paint	-
	Under coating 2	Under coat epoxy resin paint	120
	Intermediate coat	Intermediate fluororesin paint	30
	Top coat	Top coat fluororesin paint	25

Source: JICA Study Team based on handbook of Coating and Anticorrosion Handbook, Japan

(4) Maintenance Method for Steel Bridge

1) Periodic Inspection

Visual inspection shall be carried out twice a year. Especially coating appearance should be checked such as rusting, spalling, swelling, discoloration, etc. The observation results shall be recorded including the leaking and stagnant of water.

2) Detailed Inspection

Detailed inspection shall be carried out once in five years and as needed by visual inspection, using mobile units and equipment. In addition, it needs to grasp the severety of coating deterioration by approaching all parts as much as possible.

3) Re-Painting

It is predicted that a repainting of girder requires once in 35-40 years based on the deterioration speed mentioned below

- Top coat: 25 μ m / (2/3 μ m / year) = 37.5 year

6.5.5 Preliminary Design of Substructures and Foundations

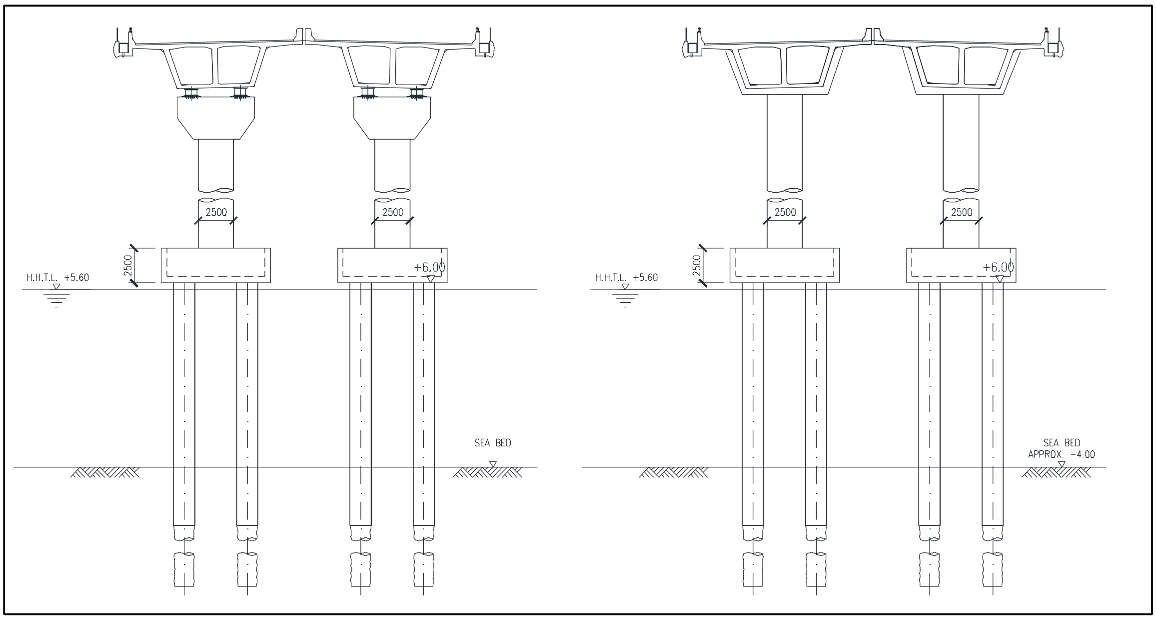
(1) General Viaduct Sections on both Marine and Land and Mangrove ones

Single-column piers with pile caps supported by cast-in-situ concrete piles are applied for substructures of PC box-girder bridge sections on general sections on both marine and land as well as mangrove ones.

The sections where a cast-in-situ concrete pile is adopted are: between CH 0+495 and 3+395 for a length of 2,900 m, 3+715 and 4+465 for a length of 910 m, 6+078 and 8+620 for a length of 2542 m, 9+180 and 11+880 for a length of 2,700 m, and 13+610 and 16+840 for a length of 3,230 m.

Single-column piers with cast-in-situ group pile foundations have 2,500-mm of diameter columns in the form of single-column bents. The beam ends shall bear onto pier caps, and intermediary piers have a rigid structure by integrating the two prestressed concrete box girders with a solid crossbeam and they do not have bearings. The advantage of this arrangement is its easyness of maintenance.

The underside of elevation of pile caps is set at +6.00 m above C.D., so it is above the high water level. The reason for this arrangement is to minimize the piers' effect on the tidal currents and to reduce the adverse impact on the environment by not excavating during pile cap construction. In addition, it is possible to construct the pile caps without considering the influence of sea level, thereby improving the substructure's ease of construction. Furthermore, it is possible to improve the efficiency of the pile cap construction, such as by using left-in-place pre-cast moulding.



Source: JICA Study Team

Figure 6.5.15 Single-Column Piers with Pier Cap

Cast-in-situ pile diameters of 1,500 mm and 2,000 mm were selected for comparison after considering current practice of 50-m-span structures in India and the loading of the PC box girder. The results of the comparison are shown in Figure 6.5.15.

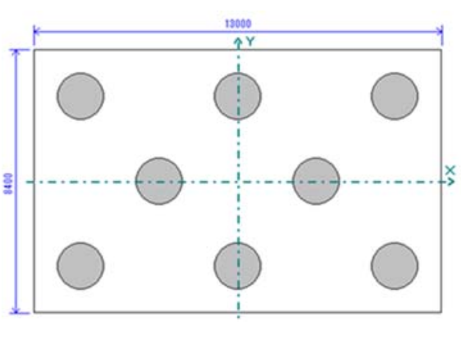
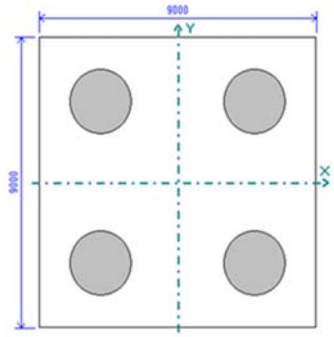
Averaged pier heights were used for the comparison. The number of piles required with 2,000-mm-diameter piles was found to be half the number required with 1,500-mm-diameter piles. Finally the 2,000-mm-diameter piles were adopted because they were found to have lower construction costs and also because they contributed to reducing construction times.

Piles supported by a diameter of 2,000 mm piles shall have steel pipe casing during their construction. The steel piping is considered as a means to reduce the detrimental effect on the marine environment.

The related of diremeter of pile and thickness of steel pipe is shown in below:

- In case that more than 2.0m diremeter pile is used, 16mm thickness steel pipe is adopted.
- In case that 1.5m to 2.0m diremeter pile is used, 12mm thickness steel pipe is adopted.
- In case that less than 1.5m diremeter pile is used, 8mm thickness steel pipe is adopted.

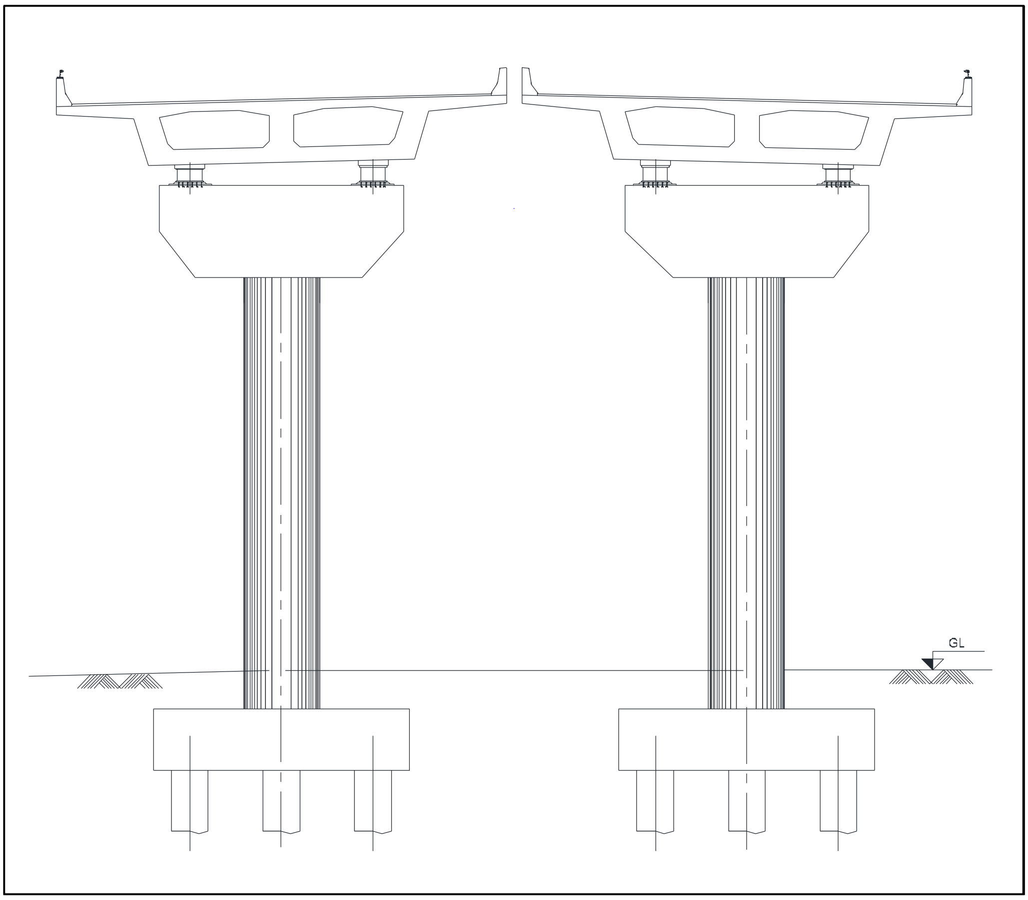
Table 6.5.18 Pile Diameter Comparison Table for General Marine Viaduct Sections

	1,500-mm-diameter piles	2,000-mm-diameter piles
Pile arrangement diagram		
Cost estimation	8 piles of dia. 1,500 mm Length = 29 m 1,700 USD/m × 29 m × 8 ＝394 400 USD	4 piles of dia. 2,000 mm Length = 29 m 2,900 USD/m × 29 m × 4 ＝336 400 USD
Appraisal	Conclusion: 1,500-mm-diameter piles were rejected.	Conclusion: 2,000-mm-diameter piles were adopted for their lower construction costs and shorter construction period compared to 1,500-mm- diameter piles.

Source: JICA Study Team

CH 16+480-17+517 (total length of 677m) section on land applies a cast-in-situ concrete pile as the general marine section because the scale of superstructure is 50m. In this section, since the exsisting ground level is relatively high, the soil cover on the pile cap was kept 1.2m. The diameter of the pile requires 2,000 mm as same as the marine section.

Whereas 50m of span arrangement with PC box girder is appled to the section from the end of the marine portion to Shivaji Nagar IC, 30 m of span arrangement wit same bridge type is adopted to Shivaji Nagar IC to the end of MTHL considering construction cost, constructability and construction period. In the 30m span arrangement section with PC box girder, 2,500 mm diameter of single colume pier with hammer beam was applied in order to set the bearings for superstructure. Its soil cover of the minimum 1.2m shall be kept as same as the other land section.



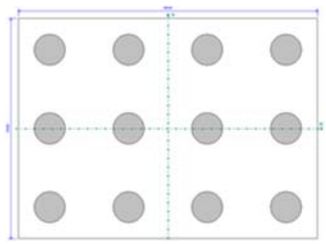
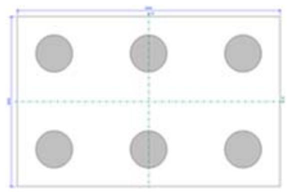
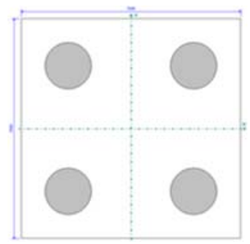
Source: JICA Study Team

Figure 6.5.16 Pier Form of General Land Sections

Cast-in-situ pile diameters of 1,000 mm, 1,200 mm and 1,500 mm were selected for comparison after considering current 30-m-span structures in India and the loading of the PC box girder. The results of the comparison are shown in Table 6.5.19.

Averaged pier heights were used for the comparison. Piles with a diameter of 1,000 mm were found to be far less economical than those with diameters of 1,200 mm or 1,500 mm. Furthermore, piles with a diameter of 1,200 mm were found to be five percent more economical than those with a diameter of 1,500mm. The genral land section on the Navi Mumbai side in the vicinity of the toll plaza has shallow support layers. Construction of larger-diameter piles may encounter issues in this portion due to the shallow support layers and the construction costs of the foundation may increase. Therefore, this portion should be adjusted and smaller-diameter piles of diameter 1,200 mm shall be adopted.

Table 6.5.19 Pile Diameter Comparison Table for General Land-Based Sections

	1,000-mm-diameter piles	1,200-mm-diameter piles	1,500-mm-diameter piles
Pile arrangement diagram			
Cost estimation	12 piles of dia. 1,000 mm Length = 7 m 750 USD/m × 7 m × 12 ＝63 000 USD	6 piles of dia. 1,200 mm Length = 7 m 960 USD/m × 7 m × 6 ＝40 320 USD	4 piles of dia. 1,500 mm Length = 7 m 1,500 USD/m × 7 m × 4 ＝42 000 USD
Appraisal	Conclusion: 1,000-mm-diameter piles were rejected because they have higher construction costs than 1,200-mm-diameter and 1,500-mm-diameter piles.	Conclusion: 1,200-mm-diameter piles were adopted for their significantly lower construction costs than 1,000-mm-diameter piles and their 5% lower construction costs than 1,500-mm-diameter piles.	Conclusion: 1,500-mm-diameter piles were rejected because larger-diameter piles may encounter issues due to shallow support layers and the construction costs of the foundation may increase.

Source: JICA Study Team

Table 6.5.20 Result of Substructure at General Section and Mangrove Section

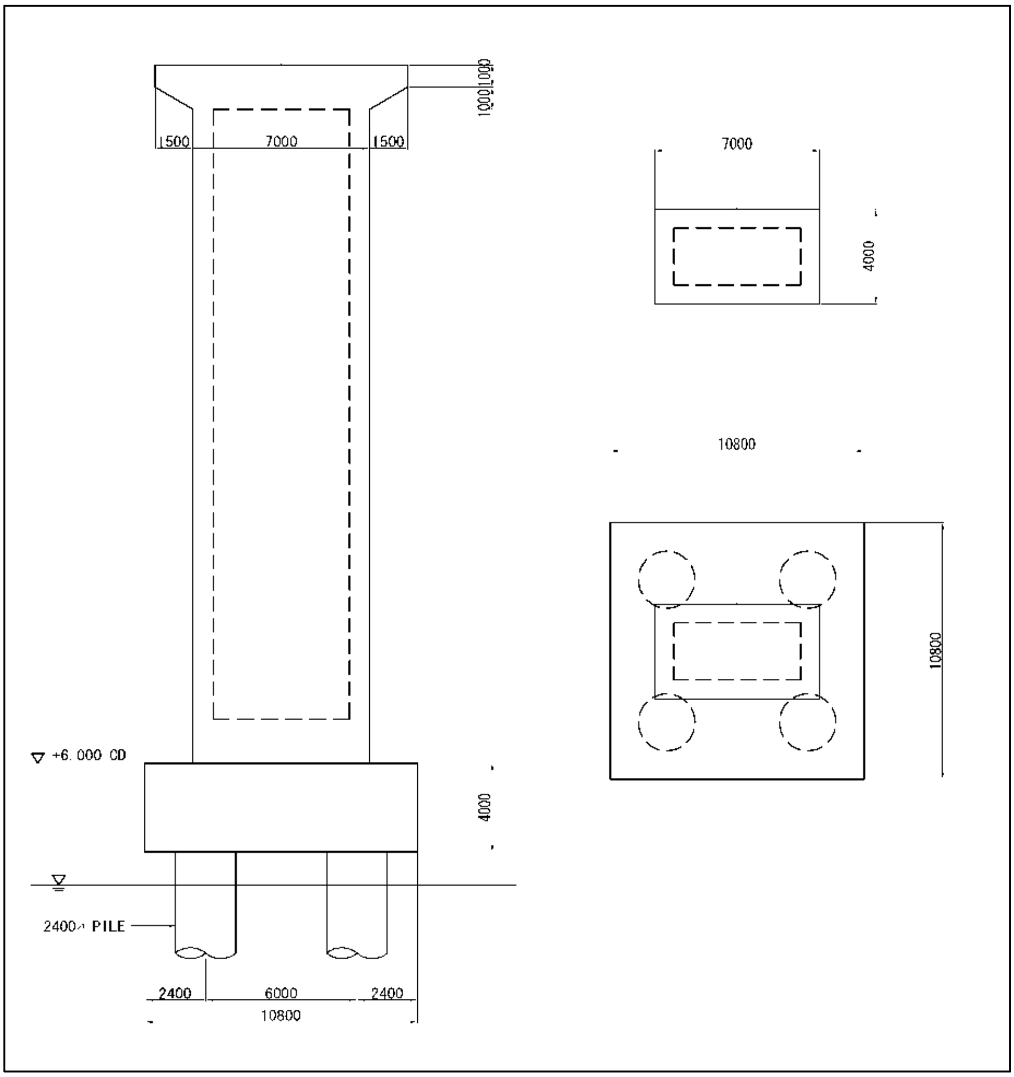
<table>
<tr><th>Category</th><th>Chainage</th><th>Substructure</th><th>Foundation</th></tr>
<tr><td>General Section
(marine area)</td><td>No. 0+495～No. 3+395
No. 3+715～No. 4+625
No. 6+078～No. 8+620
No. 9+180～No. 11+880
No. 13+610～No. 16+610</td><td rowspan="2">Pile cap bottom is set at +6.00m above C.D.</td><td rowspan="3">φ2.0m - 4piles</td></tr>
<tr><td rowspan="3">Mangrove Section</td><td>No. 16+610～No. 16+840</td></tr>
<tr><td>No. 16+840～No. 17+517</td><td rowspan="3">Pile cap top is set below 1.2m from ground surface</td></tr>
<tr><td>No. 17+517～No. 18+087</td><td rowspan="2">φ1.2m - 6piles</td></tr>
<tr><td>General Section
(land area)</td><td>No. 18+127～No. 18+187
No. 18+217～No. 18+317
No. 18+357～No. 18+424
No. 18+492～No. 18+574
No. 18+644～No. 18+884
No. 20+070～No. 20+225
No. 20+260～No. 21+009
No. 21+079～No. 21+228
No. 21+423～No. 21+659
No. 21+729～No. 21+834</td></tr>
</table>

Source: JICA Study Team

(2) Bridges in Obstacle Sections on Marine

Bridges in obstacle sections on marine have longer spans than general viaduct sections on marine due to the existence of waterways. A steel box girder with steel deck was applied to this section. In the sections between CH 3+395 and 3+715 for a length of 320 m, between 4+625 and 6+078 for a length of 1453 m, between 8+620 and 9+180 for a length of 560 m, and between 11+880 and 13+610 for a length of 1730 m, a rectangular hollow column with hammerhead is selected in order to reduce weight.

If the pile cap undersides were positioned at +6.00 m above C.D. in the same way as the general marine sections are positioned above sea level and are visible, then there would be an excessive length of pile protruding beneath the pile cap and the size of foundations would be excessively large. To avoid excessively large foundations, the pile cap topsides shall be positioned at +6.00 m above C.D..



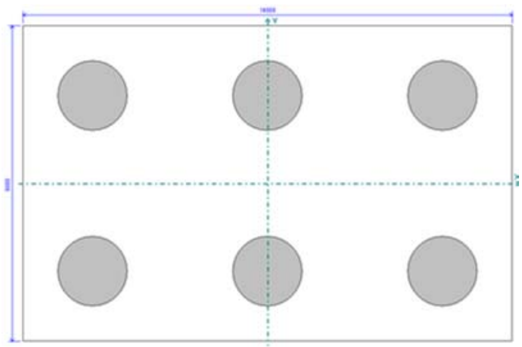
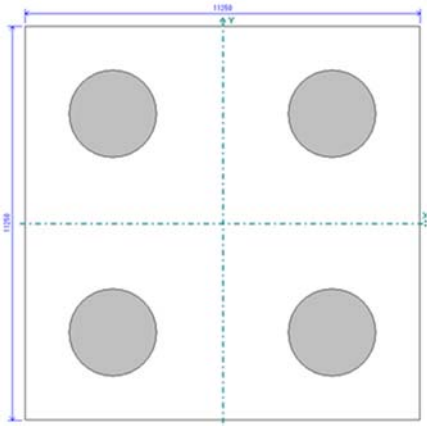
Source: JICA Study Team

Figure 6.5.17 Substructure Form of Marine Bridge Sections

The cast-in-situ pile diameters of 2,000 mm and 2,400 mm were selected for comparison after considering the loads being applied. The spans of the obstacle sections on marine vary between 100 m and 180 m. Considering that span length and thus loads vary greatly over these sections, it was decided that a single representative pier was not sufficient for comparison, so the number of piles for all piers were calculated for the comparison.

The comparison considers 60 pier-base pile groups and calculates the number of piles required for piles with a diameter of 2,000 mm and 2,400 mm, and compares the total number of piles for all pile groups. Although the construction costs are almost the same, 2,400-mm-diameter piles were adopted because their construction time would be approximately 30% shorter than 2,000-mm-diameter piles.

Table 6.5.21 Pile Diameter Comparison Table for Obstacle Marine Bridge Sections

	2,000-mm-diameter piles	2,400-mm-diameter piles
Pile arrangement diagram		
Cost estimation	60 pile groups of 4 to 8 piles ∴ 348 piles of dia. 2,000 mm Average length = 31 m 2,900 USD/m × 31 m × 348 =31 285 200 USD	60 pile groups of 4 piles ∴ 240 piles of dia. 2,400 mm Average length = 31 m 4,100 USD/m × 31 m × 240 =30 504 000 USD
Appraisal	Conclusion: 2,000-mm-diameter piles were rejected.	Conclusion: 2,400-mm-diameter piles were adopted for their approximately 30% shorter construction period compared to 2,000-mm-diameter piles. The overall construction costs are similar for both pile types.

Source: JICA Study Team

(3) Railway Overpass

Piers of steel truss bridge for the railway overpass shall be two-single-column pier, which are similar to the general land sections. Pile foundations with diameters of 1,200 mm were selected after considering the load sizes.

(4) Highway Overpass

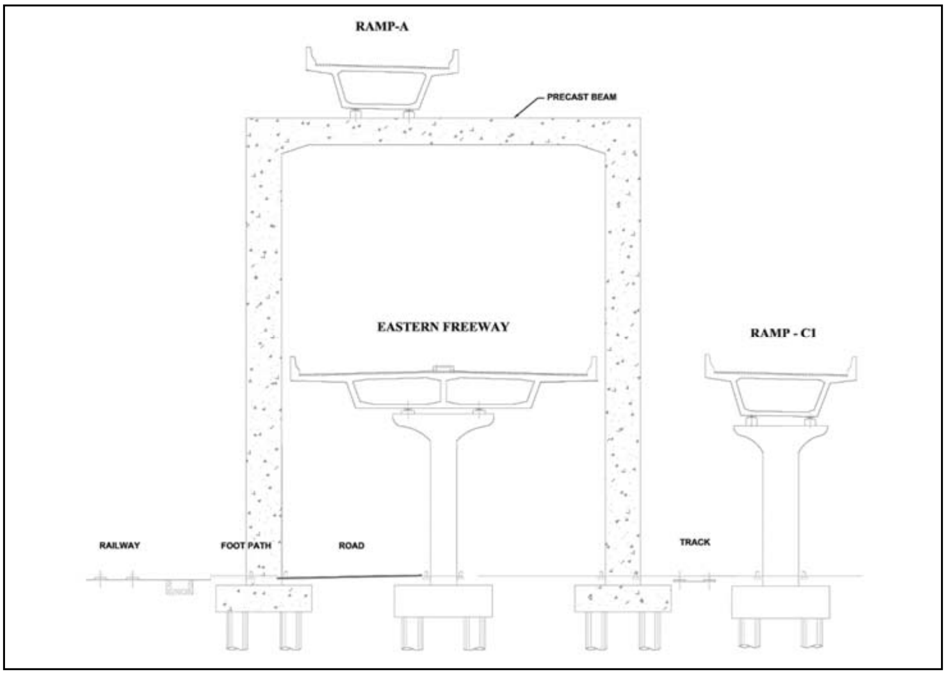
Piers of PC box girder for the highway overpass shall be two-single-column pier, which are similar to the general land sections. Pile foundations shall be cast-in-situ with diameters of 1,200 mm.

(5) Interchange Sections

1) Sewri IC

The piers of Sewri IC, which support PC box girders, shall be hammerhead piers. Cast-in-situ pile foundations with diameters of 1,200 mm were selected after considering the loads of the PC box girders with spans of 30 m to 50 m.

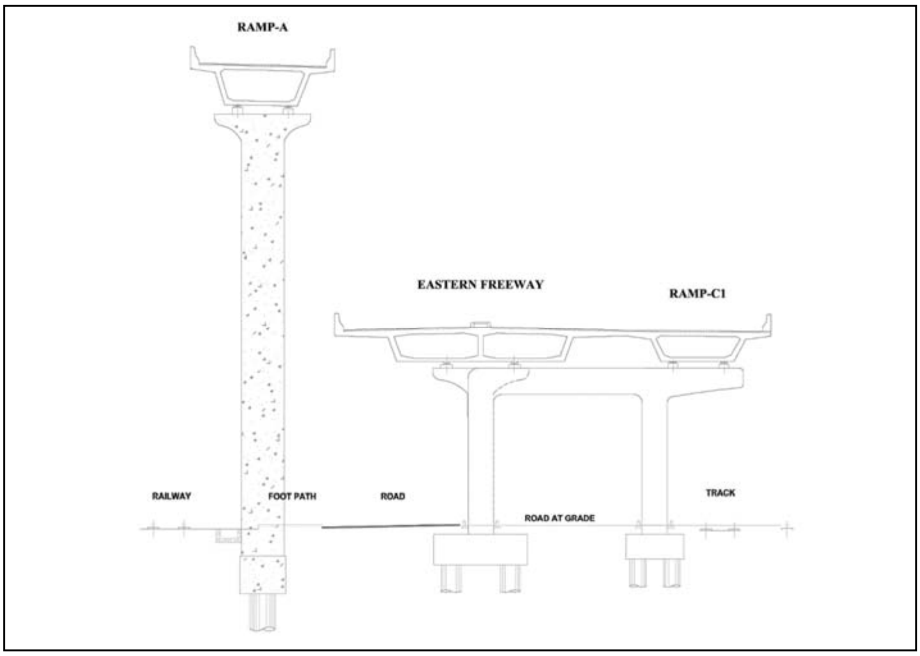
Ramp A mainly has hammerhead piers; however, one rigid-frame straddle bent type shall be adopted for the flyover section where ramp A crosses over the East Freeway. The crossbeam of the straddle bent shall be constructed at a high elevation above the freeway, so cast-in-situ concrete construction is expected to be difficult. In this case, a prestressed concrete crossbeam or similar method shall be used.



Source: JICA Study Team

Figure 6.5.18 Ramp A Cross Section Showing the Rigid-Frame Straddle Bent

After Ramp A crosses over the East Freeway and runs parallel to it, the pile foundations shall have piles placed in tandem (in line) because of the narrow space between the piers and the boundary of a railway track. Where Ramp A runs parallel to the railway track, it shall have piles with a diameter of 1,500 mm and each pier shall have two piles placed in parallel to the ramp. Furthermore, at the point where Ramp A crosses over the East Freeway, there are span lengths of about 50m and piles in tandem with a diameter of 2,000 mm are necessary, because the loads are larger than other piers.

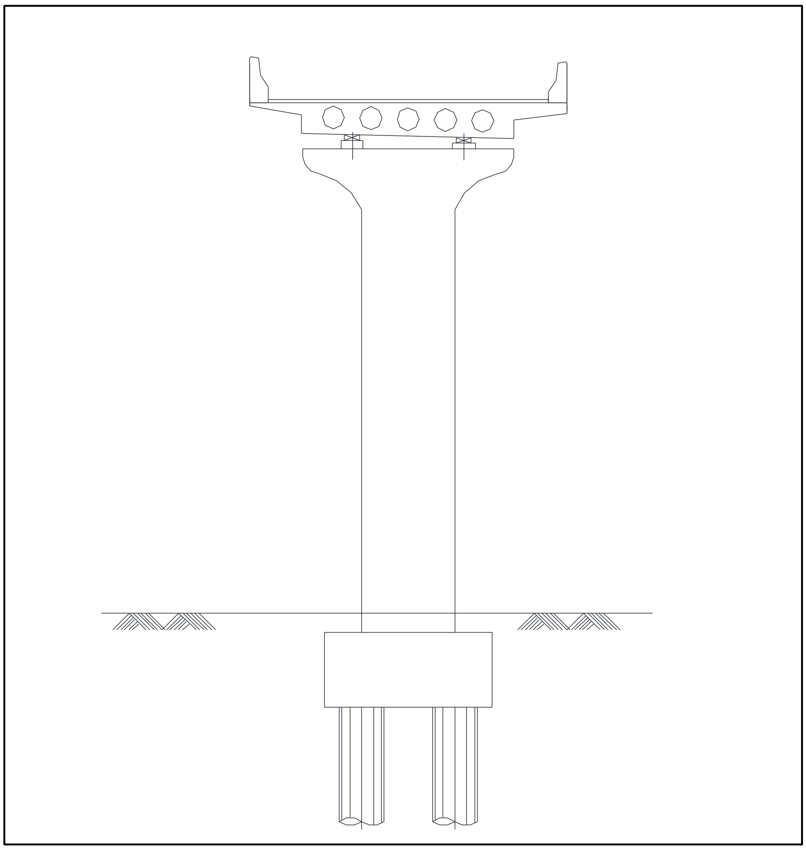


Source: JICA Study Team

Figure 6.5.19   Ramp A Cross Section Showing a Hammerhead Pier

2)   Shivaji Nagar IC

The interchange shall have RC hollow slab type with 15-m spans and the pier shall be single-column hammerhead pier. Considering the loads, the foundations shall be cast-in-situ concrete piles with a diameter of 1,000 mm.

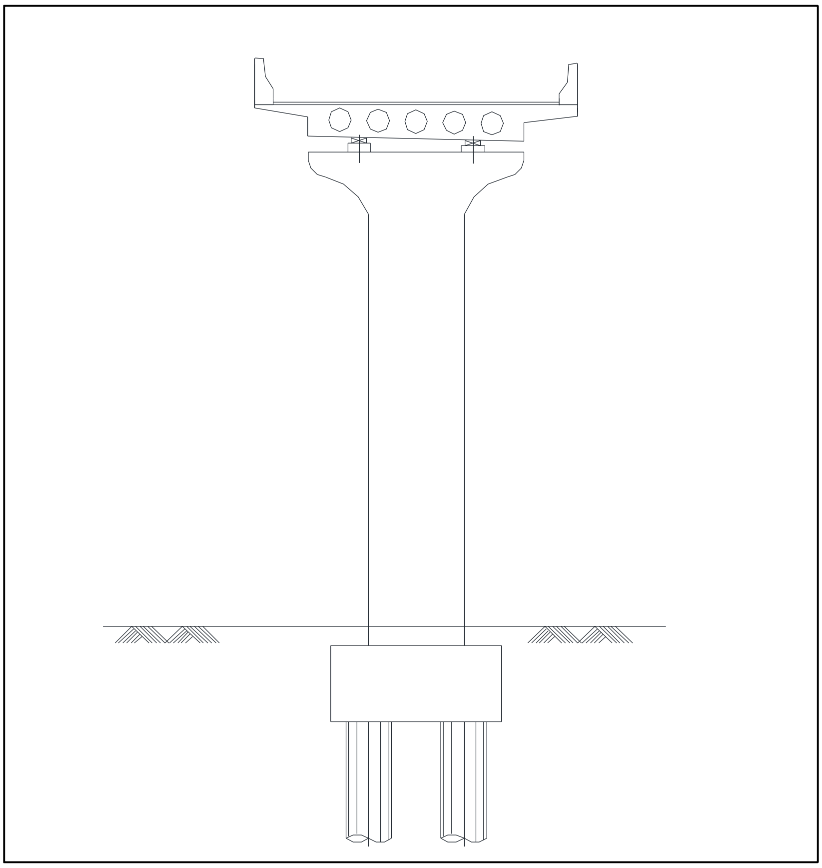


Source: JICA Study Team

Figure 6.5.20 Shivaji Nagar IC Cross Section

3) SH 54 IC and Chirle IC

The interchanges shall have RC hollow slab type with 15-m spans and the pier columns shall be single-column hammerhead pier. Considering the loads, the foundations shall be cast-in-situ concrete piles with a diameter of 1,000 mm.



Source: JICA Study Team

Figure 6.5.21 SH 54 IC and Chirle IC

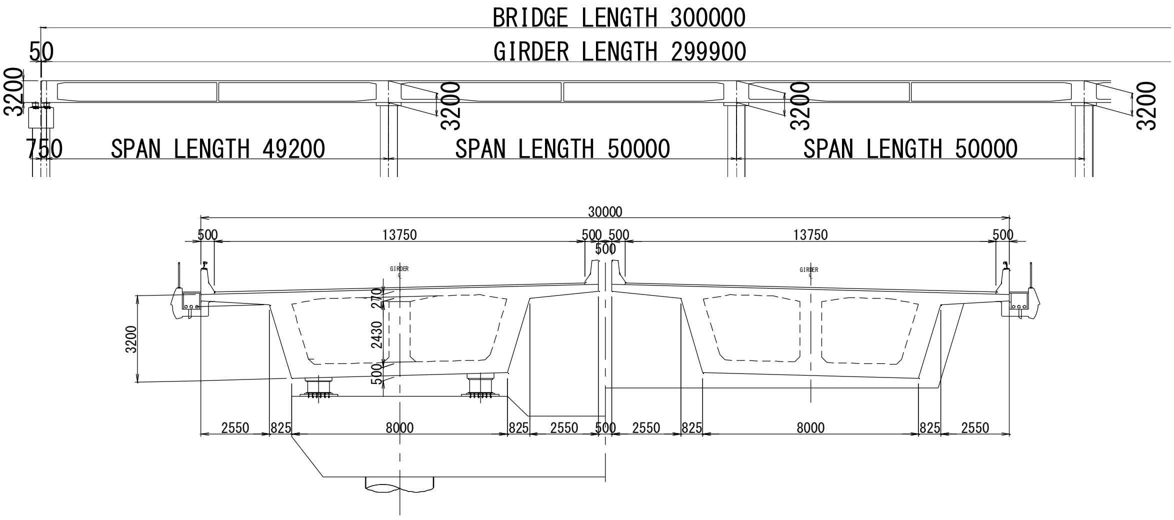
6.5.6 Preliminary Design of Superstructures and Foundations

(1) General Section (Marine and Land)

Whereas the span length on the gernal marine section is 50m generally and the PC box girder type is applied, the span length on land is 30m generally and the PC box girder bridge is also applied, considering the current Indian practice. In this sub-chapter, the results of the preliminary design of PC box girder type are summarized below.

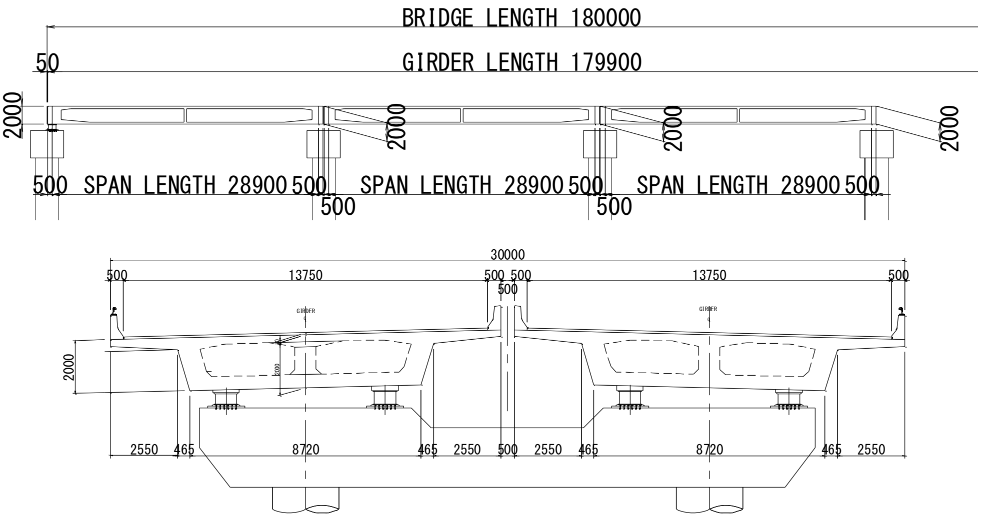
On the general marine section, the bridge width is 14.75m generally therefore two cell box girder type is applied. For the superstructure height, its height is 3.2m according to the continuously optimal girder height span ratio is 1/15 to 1/20 for this superstructure type. On the general land section, the bridge width is 14.75m generally therefore one box type is applied. For the height is 2.0m according to the simply optimal girder height.

The profile and cross section of superstructure is shown in Figure 6.5.22 and Figure 6.5.23.



Source: JICA Study Team

Figure 6.5.22 Profile and Cross Section of Superstructure on Marine Section for General Section (PC box Girder)



Source: JICA Study Team

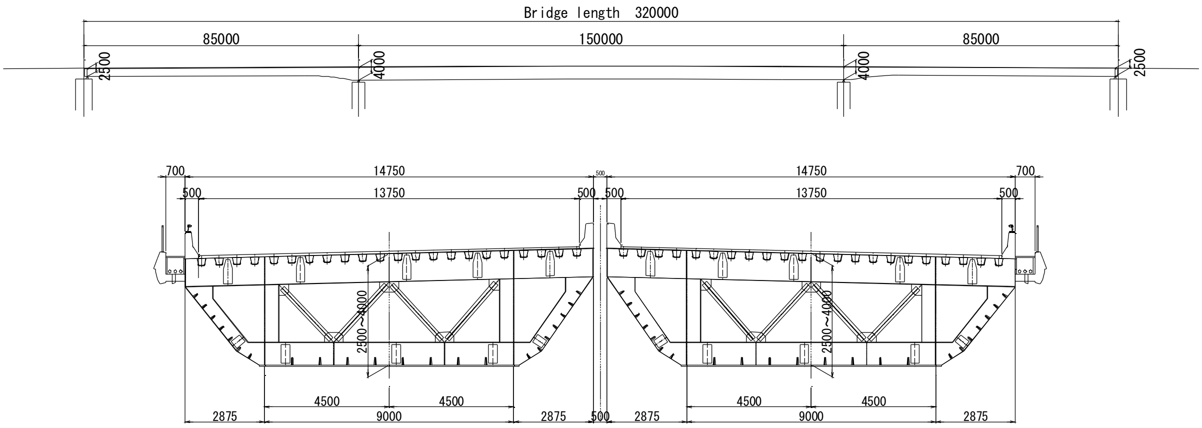
Figure 6.5.23 Profile and Cross Section of Superstructure on Land Section for General Section (PC box Girder)

(2) Obstacle Sections on Marine

The span length ranges from 150m and 180m on the section and the steel box girder with steel deck type is applied. The result of preliminary design for steel box girder with steel deck shall be described in the following

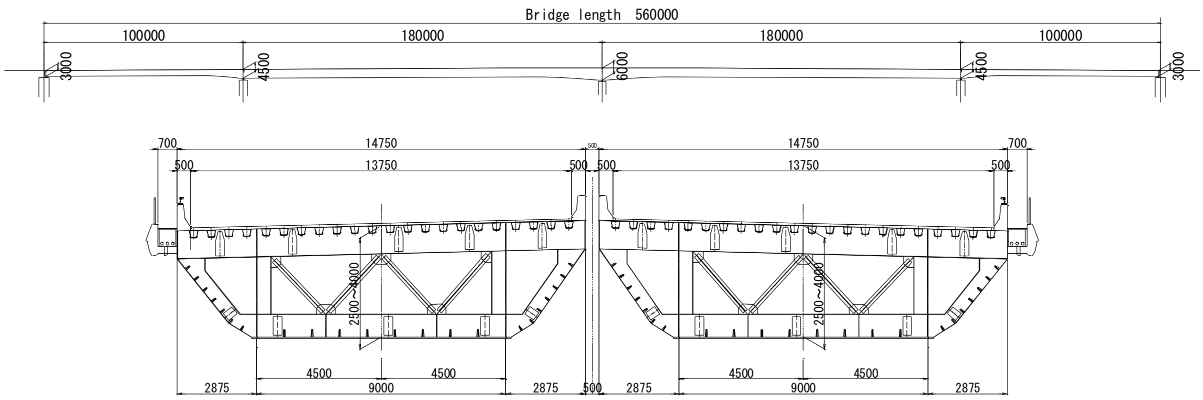
For obstacle section on marine, the bridge width is 14.75m generally therefore one cell box girder type is applied. For the superstructure height, the height is applied the variable cross section because span length is long in order to reduce the load of superstructure. .

The profile and cross section of superstructure is shown in Figure 6.5.24 and Figure 6.5.25.



Source: JICA Study Team

Figure 6.5.24 Profile and Cross Section of Superstructure for Special Section (Span Length 150m) (Steel Box Girder with Steel Deck)



Source: JICA Study Team

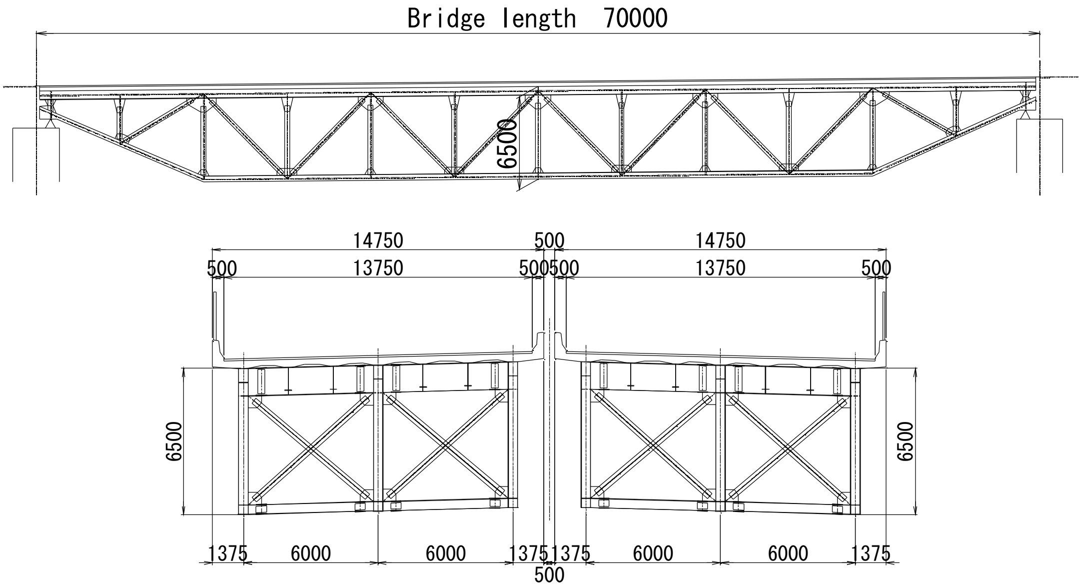
Figure 6.5.25 Profile and Cross Section of Superstructure for Special Section (Span Length 180m) (Steel Box Girder with Steel Deck)

(3) Mangrove Part (Navi Mumbai Side)

The PC box girder bridge is applied because the span length is 50m and 30m. The profile and cross section of superstructure is same as the ones for the general sections on both marine and land.

(4) Railway Crossing Part

The steel truss bridge is applied because the span length is 65m and 68m. The profile and cross section of superstructure is shown in Figure 6.5.26.



Source: JICA Study Team

Figure 6.5.26 Profile and Cross Section of Superstructure for Railway Crossing Section (Steel Truss Bridge)

(5) Road Crossing Part

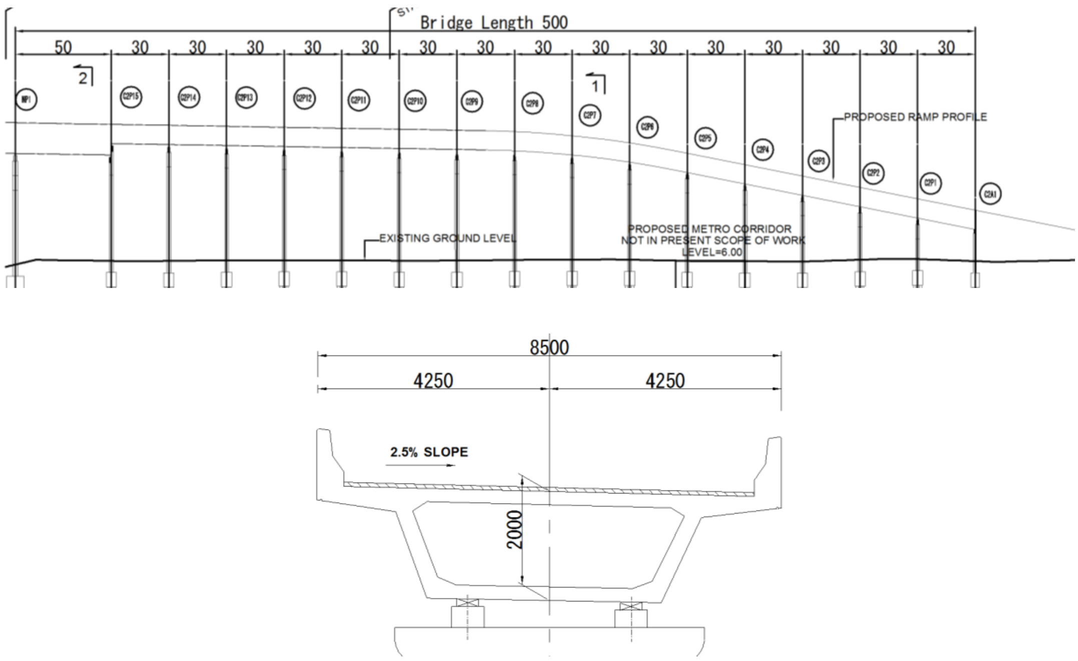
The PC box girder bridge is applied because the span length is 50m generally. The profile and cross section of superstructure is same as ones for the general sections on both marine and land.

(6) Interchanges

A PC box girder for superstructur is selected as same as one for both general sections on both marine and land because the span length is 50m generally

1) Sewri IC

A PC box girder for superstructur is selected because the span length is 30m generally. The profile and cross section of superstructure are shown in Figure 6.5.27 as a result of the preliminary design.

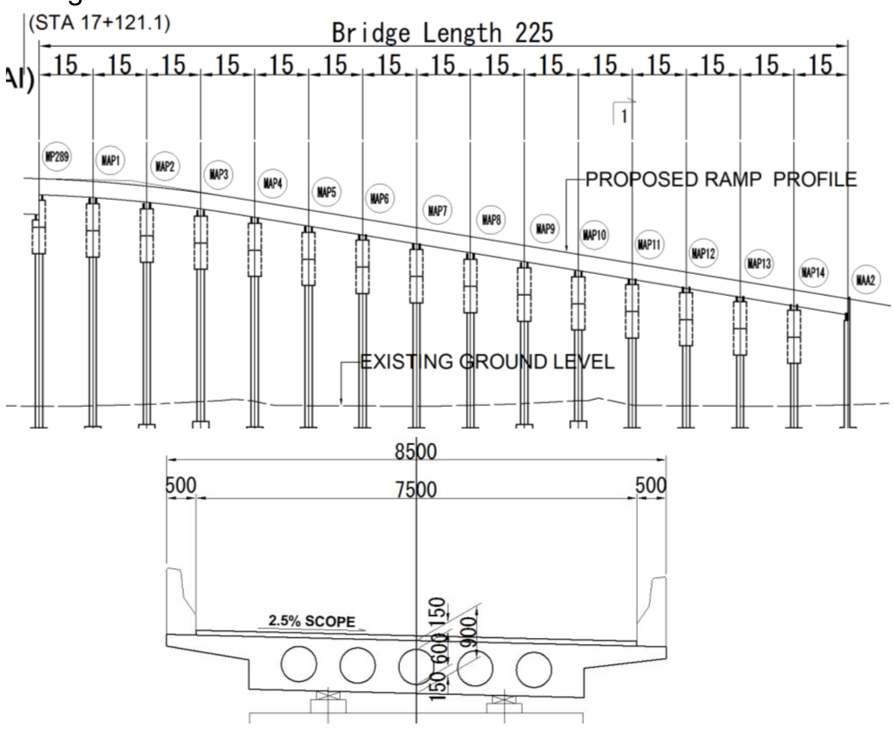


Source: JICA Study Team

Figure 6.5.27 Profile and Cross Section of Superstructure for Sewri IC (PC Box Girder)

2) Shivaji Nagar IC

A PC hollow slab for superstructur is selected because the span length is 15m generally. The profile and cross section of superstructure are shown in Figure 6.5.28 as a result of the preliminary design.

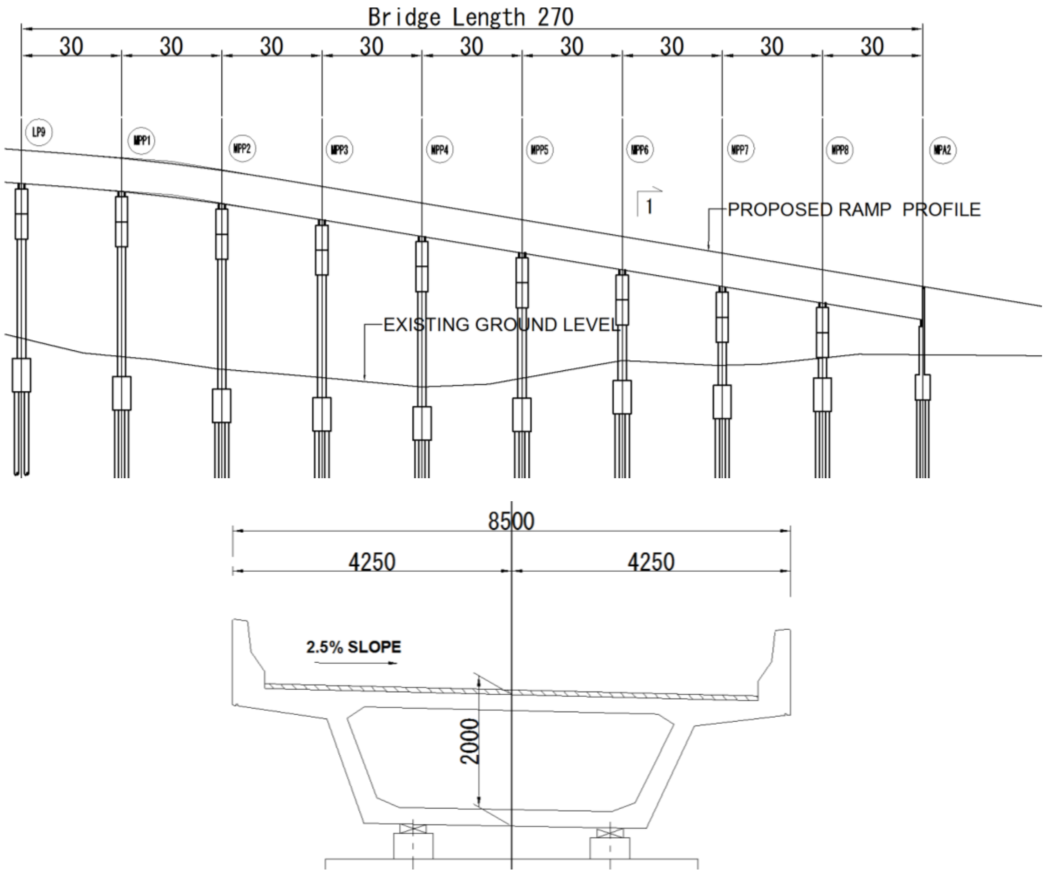


Source: JICA Study Team

Figure 6.5.28 Profile and Cross Section of Superstructure for Shivaji Nagar IC (PC hollow slab)

3) SH54 IC

A PC box girder for superstructur is selected because the span length is 30m generally. The profile and cross section of superstructure are shown in Figure 6.5.29 as a result of the preliminary design.

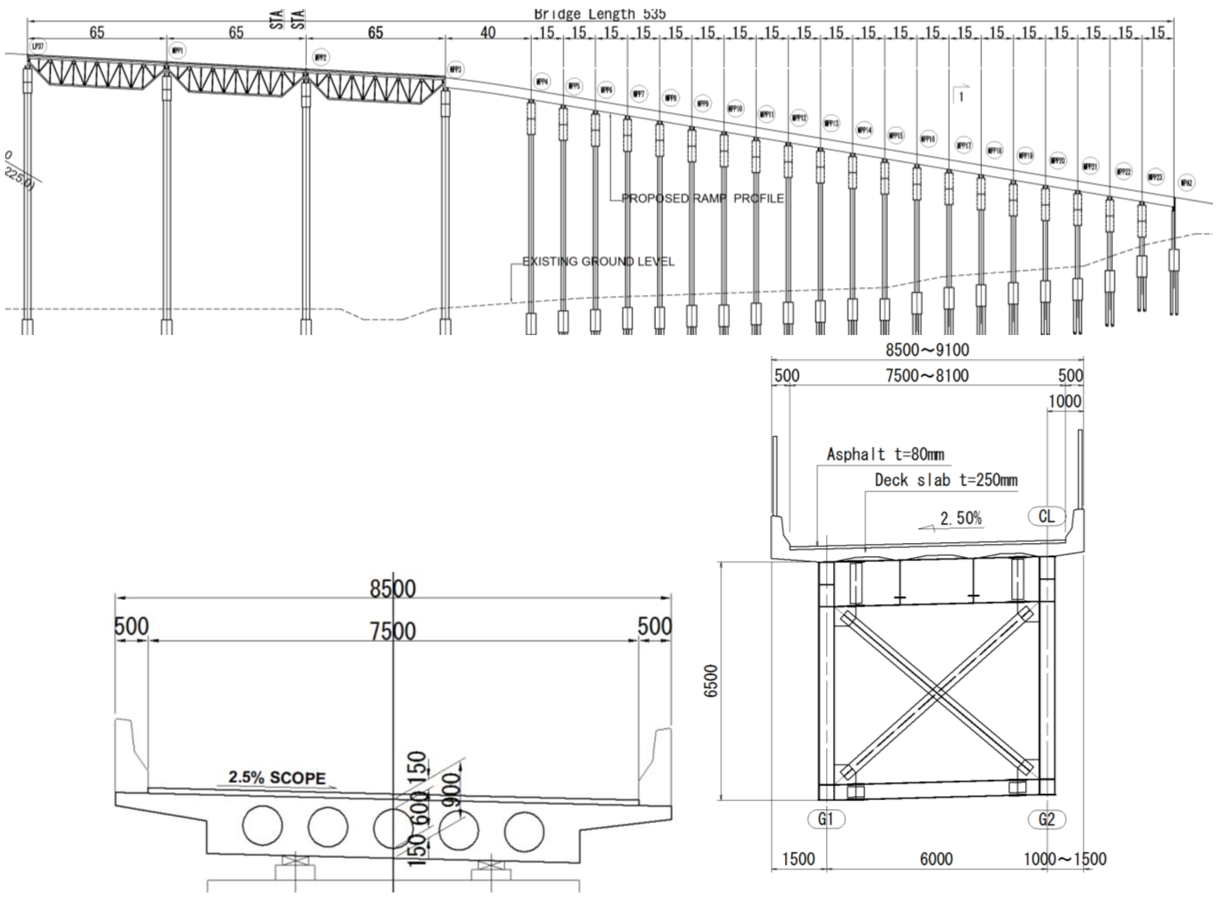


Source: JICA Study Team

Figure 6.5.29 Profile and Cross Section of Superstructure for SH54 IC (PC Box Girder)

4) ChirleIC

A steel box girder is appled for superstructure across over the railway because the span length is 65 m in general. For the remaining section, a RC hollow slab is applied for superstructure because the span length is 15 m generally. The profile and cross section of superstructure are shown in Figure 6.5.30 as a result of the preliminary design.



Source: JICA Study Team

Figure 6.5.30 Profile and Cross Section of Superstructure for Chirle IC (PC Hollow Slab and Steel Box Girder)

6.6 ITS

6.6.1 Introduction

In this section, the introduction of ITS (Intelligent Transportation System) in MTHL is considerd. MTHL will be access controled toll road, so MTHL should be considered based on the situation of introduction of ITS in similar roads of MMR. Accordingly, the appropriate Toll Management System and Traffic Management System of MTHL shall be planned, in consideration of the special features of the road and the organizational structure of MTHL.

6.6.2 Situation of ITS Introduction in Peripheral Toll Roads

The situation of ITS introduction in “Bandra Worli Sea Link” and “Mumbai Pune Expressway” are mentioned as the example of toll road around MTHL. In addition, the situation of ITS introduction of roads in Mumbai city is mentioned as well.

Source: MSRDC

Figure 6.6.1 Location of the Toll Roads

(1) Bandra Worli Sea Link (BWSL)

1) Outline of BWSL

This project aimed to reduce the traffic congestion of North - South traffic corridor from the island city to western suburbs. This project is to construct toll road bridges in marine erea between Bandra and Worle, and BWSL also forms a part of the proposed western freeway. BWSL of 5.6 km in length was opened in March, 2010. BWSL, exclusive mortor-vehicle way was designed to support eight traffic lanes.

The implementing agency of this project is “Maharashtra State Road Development Corporation Ltd.” (MSRDC), and the Operation and Maintenance Company is “MEP Infrastructure Developers Ltd.”. The contract of Operation and Maintenance is phase 2 now for three years.

BWSL has the similar conditions to MTHL, which are marine, longspan and access controlled toll road.

Source: JICA Study Team

Figure 6.6.2 Bandra Worli Sea Link

2) Toll Management System

The toll plaza of BWSL is only one place of main carriageway tollgate of the Bandra side. The toll plaza which is equipped with an electronic toll collection system (ETC) has 16 approach lanes including two lanes of exclusive ETC. The ETC system uses (Radio Frequency Identification) RFID TAG.

The EFKON Toll Management System (ETMS) was installed as the toll management system of BWSL. The system is devided into two parts, namely Lane side and Control room side. The systems or equipment in lane are connected with lane controller, with help of lane engine software application executes all toll collection transactions and other lane monitoring tasks. The control room consists of workstations which execute point of sale operation, cash up operations, lane equipment monitoring and toll collector monitoring etc.

The payment options for the toll are manually by cash in manual lane and purchasing of RFID TAG by ETC in ETC lane. The tolls Tariff for every classification are shown in Table 6.6.1

Table 6.6.1 Toll Rates (BWSL)

Vehicle Type	Single Journey	Return Journey	Daily Pass	Monthly Pass	Discount Card (50 trip) 10%	Discount Card (100 trip) 20%
Car / LMV	60	90	150	3,000 / -	2,700 / -	4,800 / -
Tempo / LCV	95	140	235	4,750 / -	4,275 / -	7,600 / -
Truck / Bus	125	185	310	6,250 / -	5,625 / -	10,000 / -

Source: Study Team

Figure 6.6.3 Toll Plaza (BWSL)

3) Traffic Management System

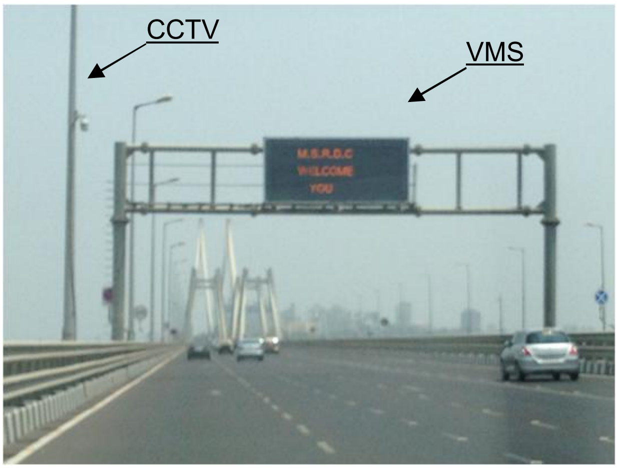
Road side facilities on BWSL are shown in Table 6.6.1.

CCTV cameras were installed every around 250m on the both sides of main route, and every around 400 m under the girder for the security. Operators always monitor in a traffic control room.

EFKON's Highway Traffic Management System was installed as the road traffic management system of BWSL. Field side systems and control room side systems are connected with each other through Fiber optic network.

Table 6.6.2 Road Side Facilities (BWSL)

Item	Quantity	Interval	Location
CCTV (road side)	57	Approx. 250m	Road side
CCTV (under girder)	15	Approx.400m	Under slub of median
Emergency Call Box (ECB)	11	Approx.1km	Road side
Variable Message Signs (VMS)	3	—	Entrance of toll plaza After getting on toll road /each direction
Automatic Traffic Counter -cum – Classifier (ATCC)	2	—	Toll Plaza /each direction



Source: JICA Study Team

Figure 6.6.4 Road Side Facilities (BWSL)

Source: Study Team

Figure 6.6.5 Traffic Control Room (BWSL)

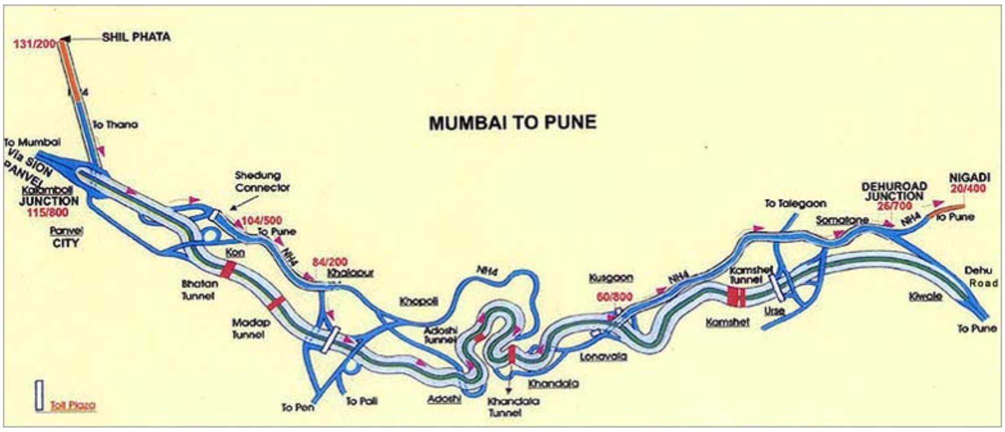
(2) Mumbai Pune Expressway (Yashwantrao Chavan Expressway)

1) Outline of Mumbai Pune Expressway

The Mumbai Pune Expressway officially the “Yashwantrao Chavan Expressway” is India's first access controlled tolled expressway. The expressway is a stretch of 94.5 km, six-lane concrete, connecting Mumbai, the administrative capital of Maharashtra, with Pune, an industrial hub and cultural capital of the state. The expressway starts at Kalamboli (near Panvel), and ends at Dehu Rd. (near Pune).

The expressway is the project of BOT scheme, including improvement (expansion to 4 lanes) of NH4, and it was opened in 2002.

The implementing agency of this project is MSRDC, and the concessionaire is IRB Infrastructure Developers Ltd. The period of concession is for 15 years (2004 through 2019).



Source: MSRDC

Figure 6.6.6 Route Map of Mumbai Pune Expressway

Source: JICA Study Team

Figure 6.6.7 Mumbai Pune Expressway

2) Toll Management System

The Mumbai Pune Expressway has four toll plazas, which consist of two toll plaza on the main carriageway (Khalapur and Telagaon) and two of interchanges (Kusgaon and Lonavala).

The Khlapur toll plaza in Mumbai side has 17 approach lanes including two lanes of exclusive ETC and the Telegaon toll plaza in Pune side also has 16 approach lanes including two lanes of exclusive ETC. The ETC system uses RFID TAG.

The payment options for the toll are the touch & go pre-paid IC card, cash by manual and the purchasing of RFID TAG.

The payment options for the toll are cash by manual in manual lane and purchasing of RFID TAG by ETC in ETC lane. But there is no compatibility with RFID TAG of BWSL.

The tolls Tariff for the journey from Mumbai towards Pune paid at Khalapur Interchange are shown in Table 6.6.3.

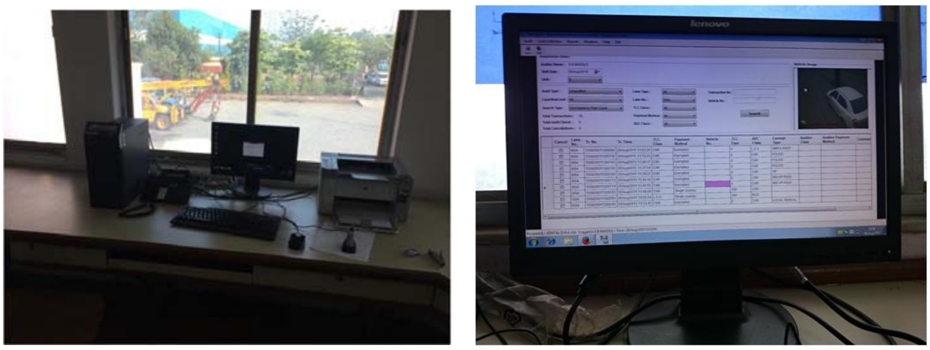
Table 6.6.3 Toll Rates (Mumbai Pune Expressway at Khalapur)

Vehicle Type	Dehu Road / Pune	Kusgaon / Lonavala
Car	195	117
Tempo	300	180
Truck / Bus	418	251
Bus	572	343
3 Axle	990	594
M Axle	1,317	790

All toll collection transactions in the toll booth are monitored by the systems in the control room. The operators in the control room check the vehicle types identified by toll collectors and vehicle type identifiers installed at the tollgates, and the processing data such as vehicle types and toll rates is accumulated.

Source: JICA Study

Figure 6.6.8 Toll Plaza (Mumbai Pune Expressway)



Source: Study Team

Figure 6.6.9 Control Room (Mumbai Pune Expressway)

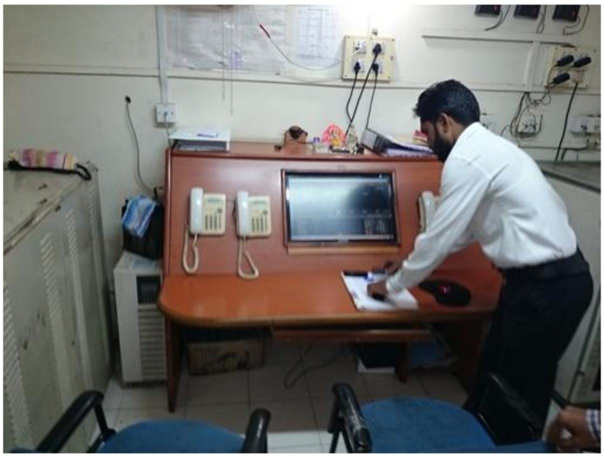
3) Traffic Management System

The road side facilities installed on Mumbai Pune Expressway are shown in Table 6.6.3.

Traffic Management System for the monitoring of traffic condition is not installed, and the operators in the call centre receive the emergency calls and make required initial responses such as a notification to relevant organizations including the police.

Table 6.6.4 Road Side Facilities (Mumbai Pune Expressway)

Item	Quantity	Interval	Location
ECB	Approx.100	Approx.2km	Road side
ATCC	4		Toll Plaza /each direction



Source: Study Team

Figure 6.6.10 Call Centre (Mumbai Pune Expressway)

(3) Roads in Mumbai District

1) Traffic Management System

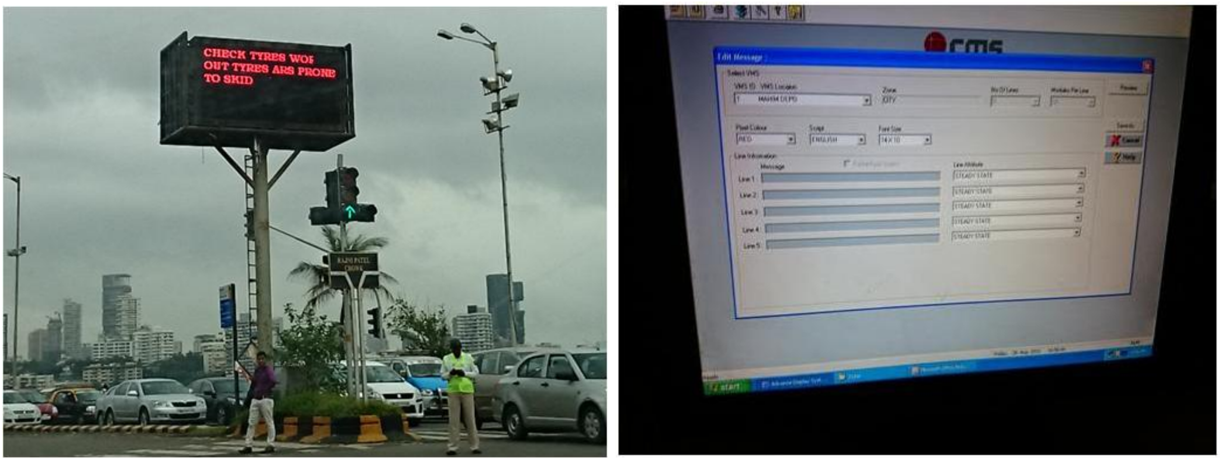
In Mumbai city, a traffic control centre is installed in Mumbai Traffic Police. 229 CCTV cameras, ATC (Area Traffic Control) signals and 250 non ATC signals are installed in Mumbai city, and monitored in the traffic control centre. The signal indications are adjusted based on the confirmation of the congestion situation with images and the communication from traffic policeplaced at main intersections. The officers of Traffic Police and the staff of Technical Consultant which Municipal Corporation of Greater Mumbai (MCGM) contracted are operating in the traffic control center. The staff of the consultant conducts various operations following the instructions of Traffic Police. The traffic management system made in Spanish Televent company was installed in Mumbai Urban Transport Project (MUTP) with a support of World Bank.

48 VMSs are installed in Mumbai urban area, and the messages to display in VMS are set individually using VMS system in the traffic control centre. However, the provided

information is limited to static and enlightening messages such as warnings on speed limit and wearing of helmets. The dynamic road and traffic information such as expected travel time, congestion level and route guidance is not available. In addition, the enlightening messages are decided twice a month by Joint Commissioner of Traffic Police.

Source: JICA Study Team

Figure 6.6.11 Traffic Control Centre (Mumbai Traffic Police)



Source: JICA Study Team

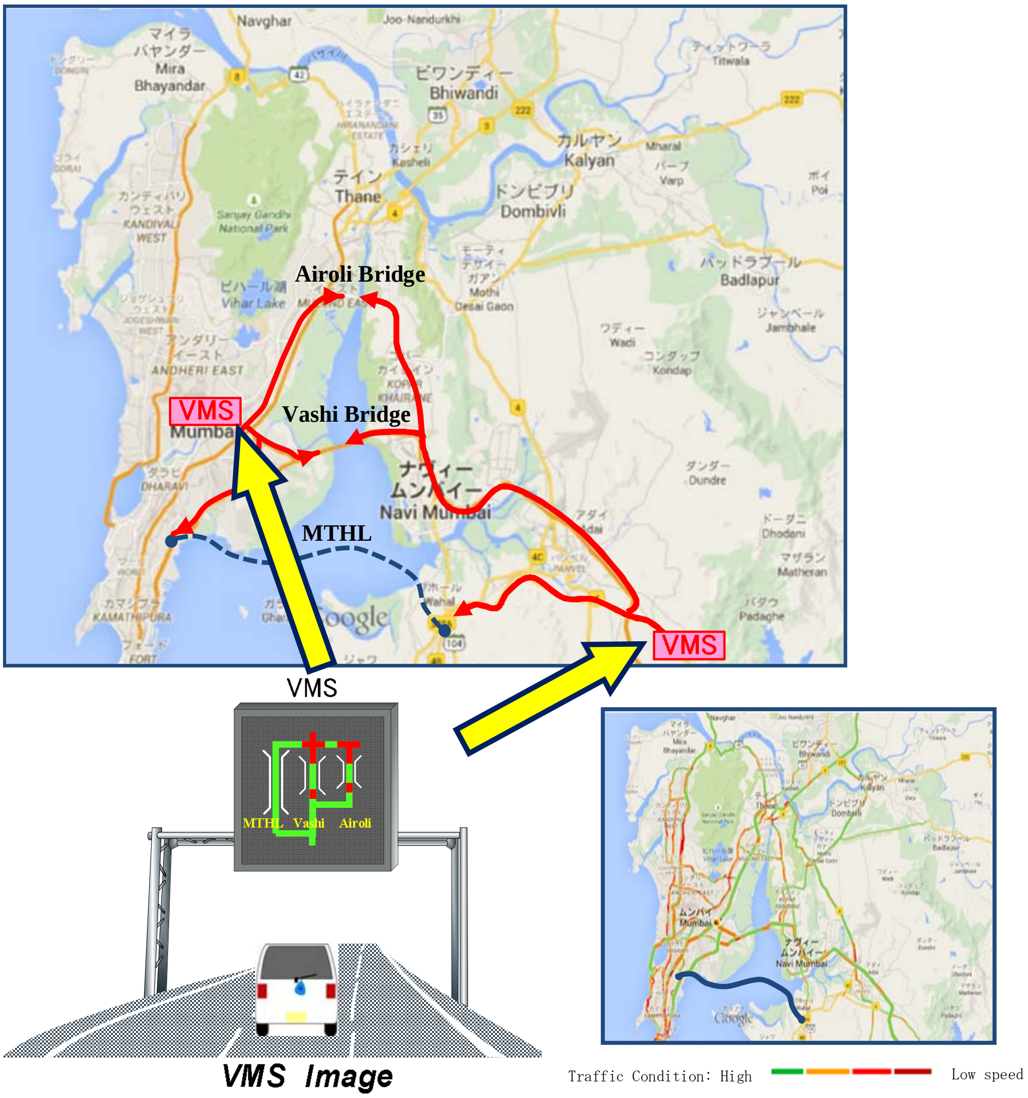
Figure 6.6.12 VMS System (Mumbai)

2) Conception of ITS in Mumbai Metropolitan Region (Recommended)

Access routes between Mumbai and Navi Mumbai will be strengthened by the development of MTHL. Providing traffic information to enable the selection of suitable route by road users shall be indispensable to enhance the effect of development. To achieve it, VMSs should be installed in Mumbai and Navi Mumbai sides respectively, and it is desirable to promote the road users' selections of routes corresponding to their destinations by providing traffic information of congestion level and expected travel time.

The conception of ITS is summarized as follow;

- To Provide road traffic information in Mumbai to road users
- To plan the dispersion of inflow traffic to Mumbai district by installation of VMSs at main intersections
- To Display the traffic condition to VMSs (Traffic information such as prove data of commercial vehicles can be purchased from suppliers)



Source: JICA Study Team

Figure 6.6.13 Image of the Conception of ITS in MMR

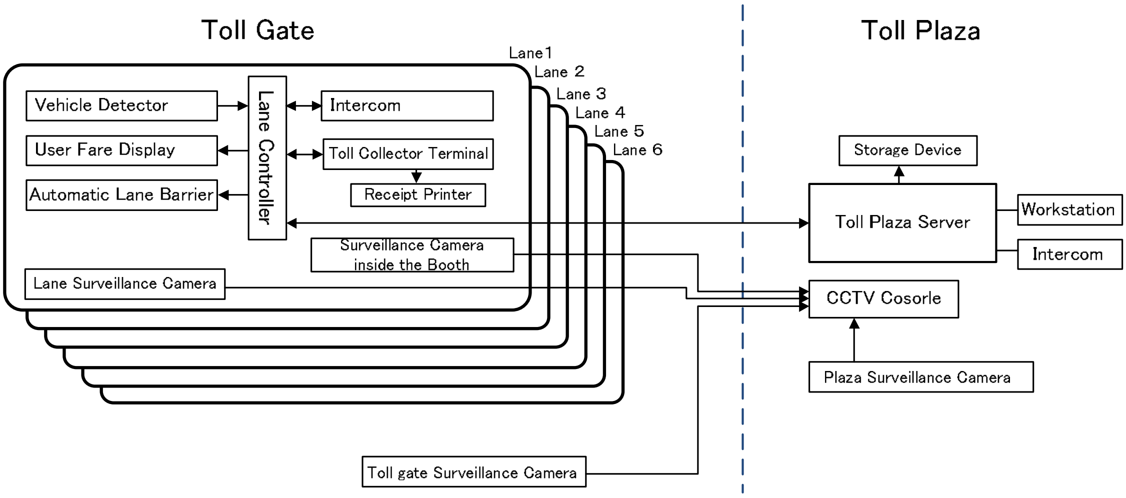
6.6.3 Toll Management System

(1) System Configuration of Toll Management System

The toll management system introduced into MTHL which is a toll road shall collect tolls from all road users of MTHL basically. Two types of toll collection method will be adopted; Electronic Toll Collection (ETC) and Manual (paying by cash).

The lanes corresponding to these toll collection methods are dedicated ETC lanes and Manual lanes, and the Manual lane equipment (cash collection) shall be installed to ETC lanes for backup to be able to cope at the time of the trouble of ETC equipment failure.

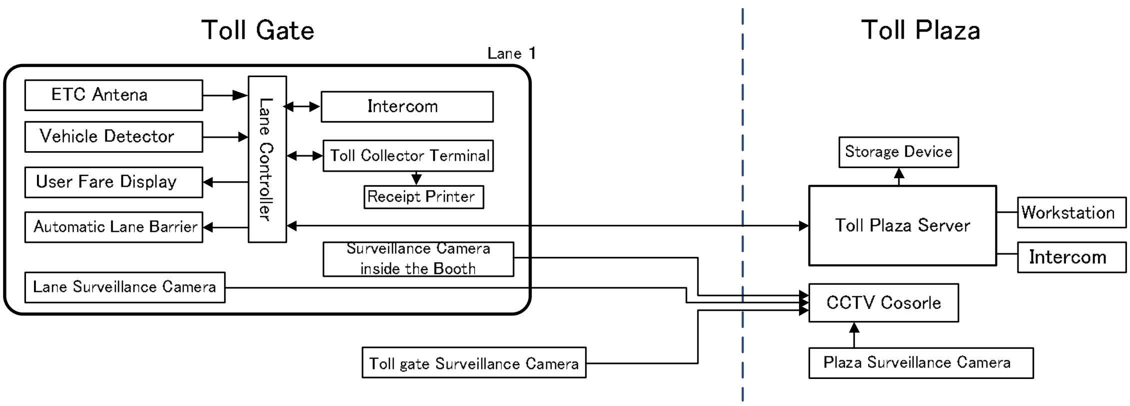
1) Manual Lane System Configuration



Source: JICA Study Team

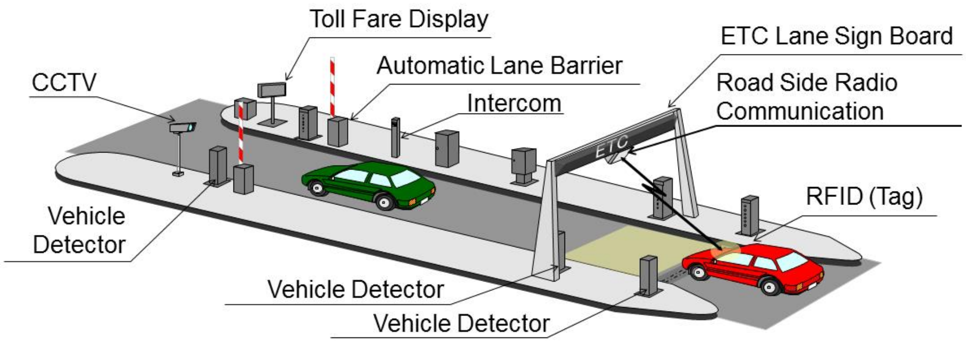
Figure 6.6.14 Manual Lane System Configuration

2) ETC Lane System Configuration



Source: JICA Study Team

Figure 6.6.15 ETC Lane System Configuration



Source: JICA Study Team

Figure 6.6.16 ETC Lane

(2) Lane Equipment

1) Manual Lane Equipment

Table 6.6.5 Manual Lane Equipment

Equipment	Function / Objective
Lane controller	Toll processing in the lane
Toll collector terminal	POS to be controlled by a toll collector
Receipt printer	Issuance of receipt of toll
Intercom	Communication with Toll office
Vehicle detector	Vehicle detection and vehicle classification
User fare display	Display of the passage propriety and the amount of toll
Automatic lane barrier	Controlling of the departure of a vehicle with movable gate bar
Lane surveillance camera	Monitoring of a lane
Booth surveillance camera	Monitoring of a toll collector

2) ETC Lane Equipment

Table 6.6.6 ETC Lane Equipment

Equipment	Function / Objective
Lane controller	Toll processing in the lane
ETC antenna	An Antenna to communicate with on-vehicle equipment for ETC
Toll collector terminal	POS to be controlled by a toll collector
Receipt printer	Issuance of receipt of toll
Intercom	Communication with Toll office
Vehicle detector	Vehicle detection and vehicle classification
User fare display	Display of the passage propriety and the amount of toll
Automatic lane barrier	Controlling of the departure of a vehicle with movable gate bar
Lane surveillance camera	Monitoring of a lane
Booth surveillance camera	Monitoring of a toll collector

3) Toll Plaza Computer System

Table 6.6.7 Toll Plaza Computer System

Equipment	Function / Objective
Toll plaza server	Calculation of the data of each lane
Workstation	A console to operate the above-mentioned server
Intercom	Communication with each lane
Storage device	Storage of data, status and operation logs
CCTV console	Controlling cameras, storage of images
Tollgate surveillance camera	Monitoring of Toll plaza

(3) Number of Required Lanes

The required number of lanes is calculated by considering the traffic volume (the average distance between in-coming vehicles), average service time and the level of the service (expressed as the average number of vehicles in a queue) at the recommended location of the tollgate.

1) Numbers of Vehicles to be processed

Table 6.6.8 shows the maximum numbers of vehicles to be processed by Manual (cash collection) in an hour with given numbers of lanes based on Service Time and Service Level.

- Service Time is eight seconds as the standard service time for the manual toll collection adopting the flat rate system.
- Service Level is defined as the average number of vehicles waiting in a queue at a tollgate. While the service level of one vehicle per queue is generally used as the standard in Japan, the average number of vehicles waiting in a queue of three shall be adopted for MTHL in consideration of a margin for the processing time and the numbers of vehicles waiting in queues of tollgates in the peripheral toll roads.

Table 6.6.8 Maximum Numbers of Vehicles to be Processed in an Hour with Given Numbers of Lanes

(Unit: Vehicles/hour)

	1 lane	2 lanes	3 lanes	4 lanes	5 lanes
Flat-rate toll/ toll collection in cash	340	780	1,230	1,670	2,120

(Service Time: 8 seconds, Average Number of Waiting Vehicles: 3)
Source: Design Standard of East Nippon Expressway Co, Ltd.

Numbers of vehicles to be processed by ETC shall be 1,200 vehicles/hour based on the IRC Standard (SP99-2013).

2) Utilization Rate of ETC

According to the interviews of the Concessionaires of peripheral toll roads, the utilization rate of ETC is less than 10 % in 2015, and has a tendency to increase. In consideration of this situation, 1% of increase is anticipated every year. The utilization rate of ETC shall be set at 10% in 2022, 20% in 2032 and 30% in 2042.

3) Number of Required Lanes

The required number of lanes is usually calculated from the hourly traffic volume in the peak hours.

(Design hourly traffic volume) = (Annual average daily traffic volume (AADT)) x (Peak Ratio)

The number of the required lanes of each tollgate calculated using traffic at a peak hour in the pricing Case 2 of 2042 is shown in Table 6.6.9.

Table 6.6.9 Number of Reqired Lanes by Type at Interchange

IC	Toward	Entry /Exit	Required No. of ETC Lane	Required No. of Manual Lane	Total No. of required lane	Remarks
Toll Plaza	Sewri	Entry	1	3	4	Ch19+370
	Chirle	Exit	1	3	4	
Shivaji Nagar	Airport→Sewri	Entry1	1	5	6	Ch17+400
	JNPT→Sewri	Entry2	1	2	3	
	Airport→Chirle	Entry3	1	2	3	
	Sewri→Airport	Exit1	1	5	6	
	Sewri→JNPT	Exit2	1	2	3	
	Chirle→Airport	Exit3	1	2	3	

4) Concern of the Black Spot in the Interchange

The type of Shivajinagar IC (CH:17+400) is modified clover leaf type. There is a weaving spot (crossing at short distance) at the confluence of ramp traffic, and it is concerned about becoming the black spot. There is a point that the traffic flow from planned road (from new airport) to MTHL (toward Mumbai) overlaps with the traffic flow from MTHL (from Mumbai) to planned road (toward JNPT). Arrangement Plan of Shivejinagar IC with the weaving spot is shown in Figure 6.6.17.

Other diverging/merging sections have the enough distance to diverge/merge.

And in “a” section (between Sewri and Shivajinagar) and “b” section (between Shivajinagar and Main Toll Plaza), it is thought that the accounting process has some problems.

- Problem ①: It is impossible to discriminate driver's destination which is toward Chirle or Sewri at the Toll Plaza of existing design.
    - ➢ Measure: Toll plaza (Entry) of existing design should be moved to the section of diversion, and the Entry1 (toward Chirle) and the Entry3 (toward Sewri) should be established.
- Problem②③: Weaving Spot occurs.
- Problem④: After the Entry2 passage, drivers can go straight on without flowing into the ramp.
    - ➢ Measure: The route going straight direction after the Entry2 passage should be closed.
- Problem⑤: It is impossible to collect tolls of the section (from Sewri to Airport) at the Toll Plaza (Exit2) of existing design.
    - ➢ The Exit1 (from Sewri to Airport) should be established.
- Problem⑥: It is impossible to discriminate driver's destination which is Shivajinagar or Sewri coming from Chirle at the Main Toll Plaza.
    - ➢ Measure: The Exit3 (from Chirle to Airport) should be established. The toll for all sections (from Chirle to Sewri) shall be collected at Main Toll Plaza, and the balance should be refunded in Exit3.
- Problem⑦: It is necessary to prepare for cash to refund in Exit3 and is difficult in operation.
- Problem⑧: The location of Toll Office and the passages for Toll collectors at Shivajinagar IC need to be considered.
- Supplementary: Manual lane of the Entry3 issues entry ticket, and the toll shall be collected at Main Toll Plaza.

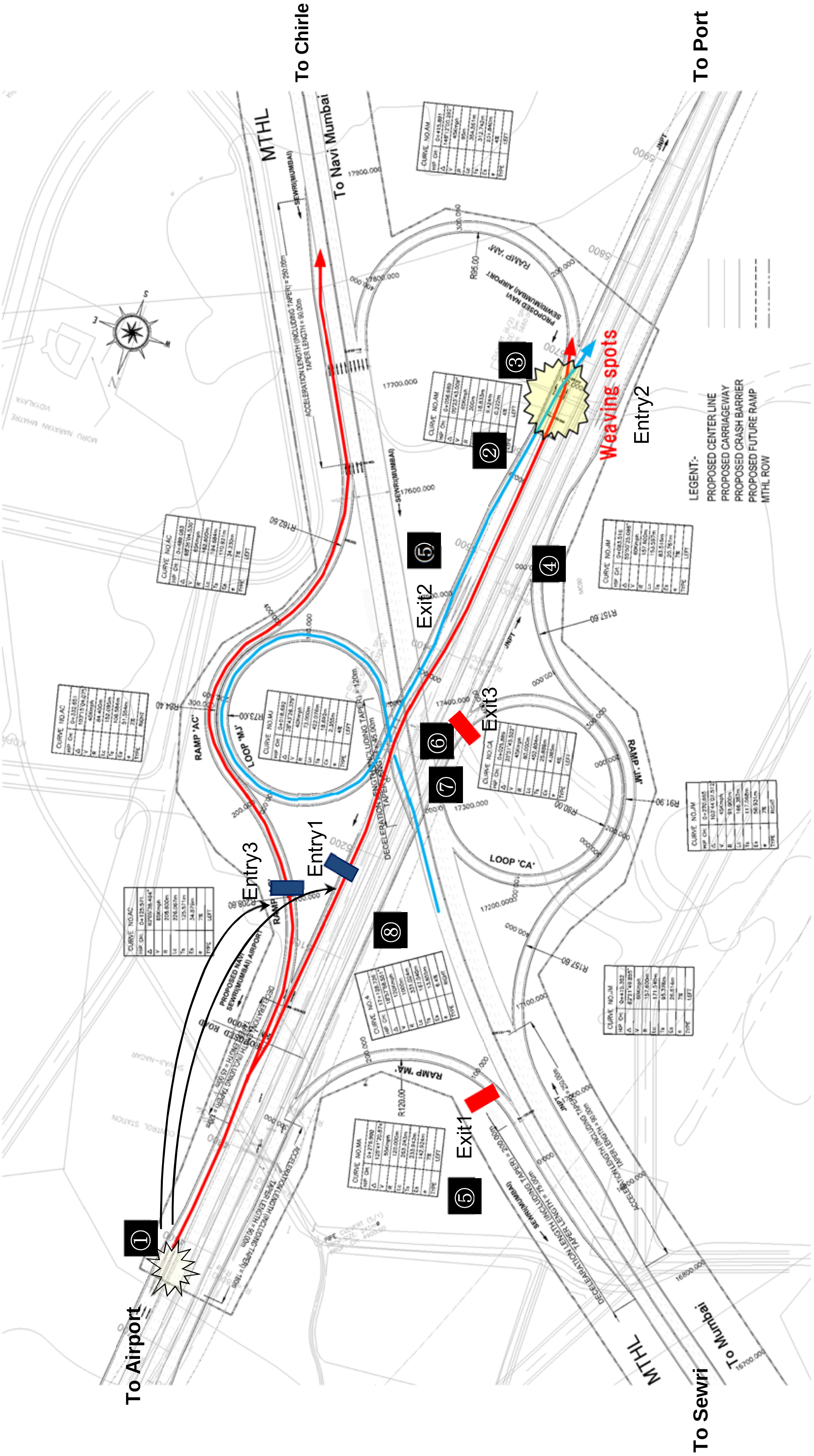


Figure 6.6.17 Arrangement Plan at Shivajinagar IC (Reference)

Source: Study Team

(4) Toll Management System Cost Estimation

Table 6.6.10 shows the rough estimated cost of Toll Management System.

Table 6.6.10 Rough Estimated Cost of Toll Management System

	Item	Estimated amount (in million INR)	Year of expenditure
1	Toll Management System	204	The completion year of the construction and every 10 years thereafter for renewal

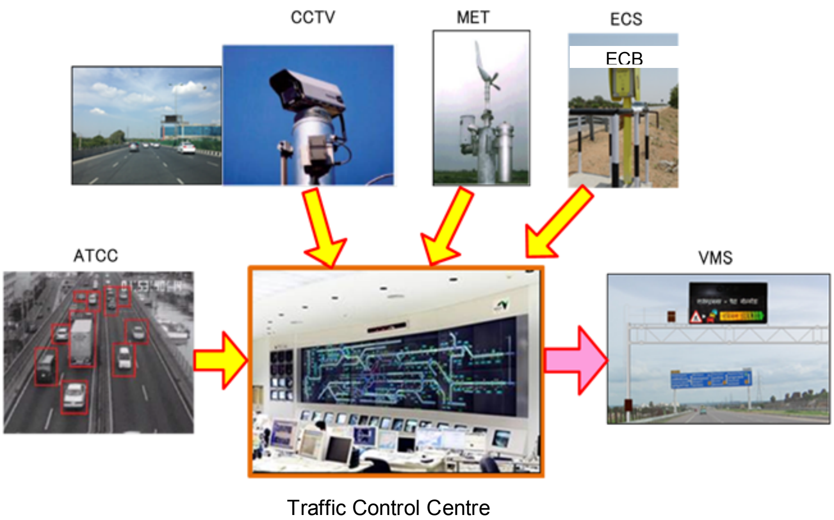
Source: JICA Study Team

6.6.4 Traffic Management System

(1) Outline of Traffic Management System

Traffic Management System is a support system to manage the traffic on MTHL safely and efficiently. The conceptual system configuration is shown in Figure 6.6.18. 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 the dissemination system including Variable Message Sign (WMS).

CCTV cameras shall be installed at around three places per 1km, on both sides of main route, and the monitoring of the traffic condition of the whole stretch of MTHL will be almost enabled in the Traffic Control Centre. In addition, the information of ECB, MET and ATCC is also collected in the Traffic Control Centre and VMS displays the appropriate information for road users based on the collected information. The information collected by these devices is transmitted to the Traffic Control Centre through the medium of an optical fiber cable laid in MTHL.



Source: JICA Study Team

Figure 6.6.18 Conceptual System Configuration

(2) Facility for Traffic Control

1) Information Collection System and Information Dissemination System

Table 6.6.11 Information Collection System and Information Dissemination System

Facility	Objective / Function
CCTV : on-road (Closed Circuit Television)	- Monitoring of traffic condition, traffic congestion and accident, etc. - Operation such as zoom, the turning by the remote control function 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)	- Report support system to the traffic control center at the time of the first aid in a disaster, trouble and accident, etc.
ATCC (Automatic Traffic Counter-cum-Classifier)	- Measurement of traffic volume - Classification of vehicle type
VMS (Variable Message Sign)	- Dissemination of the information such as road condition and weather condition

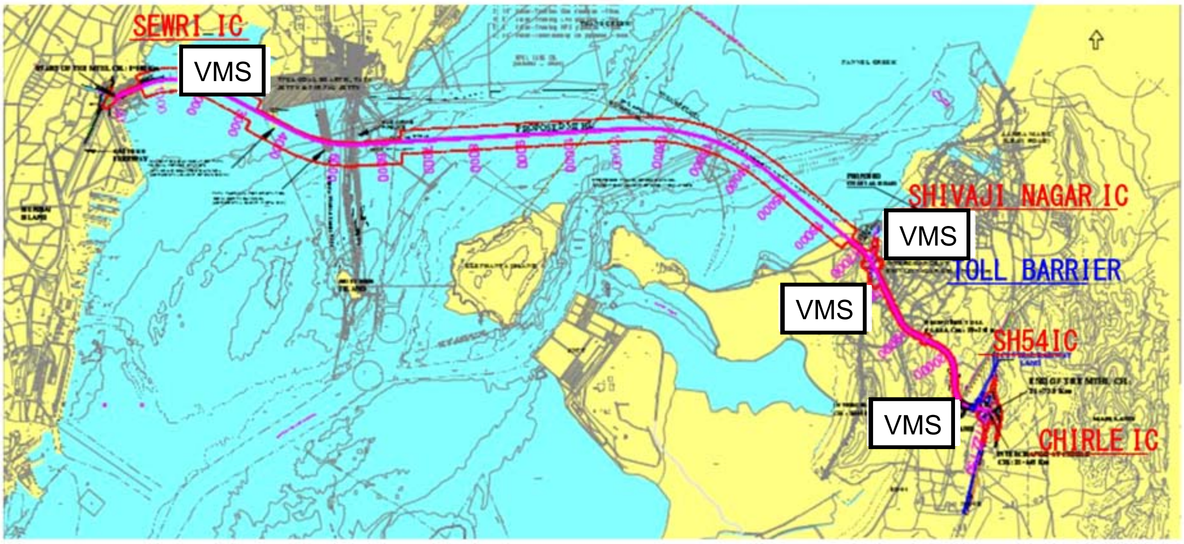
2) Facility Deployment Plan

The deployment plan of the road side facility shall be planned based on the situation of the similar roads mentioned in 6.6.2 and the discussion with MMRDA.

Table 6.6.12 Deployment Plan of Road Side Facility

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

VMSs shall be installed in the inflow section from Sewri side, Chirle side and Shivajinagar IC according to Figure 6.6.19, and disseminate the road information of MTHL. VMSs shall be planned not to be installed in the bridge intermediate section and the direction leaving outward from MTHL. This is because the information dissemination in the bridge intermediate section is attention enlightenment degree, and there is no information capable of appropriately enlightening the drivers leaving outward from MTHL.

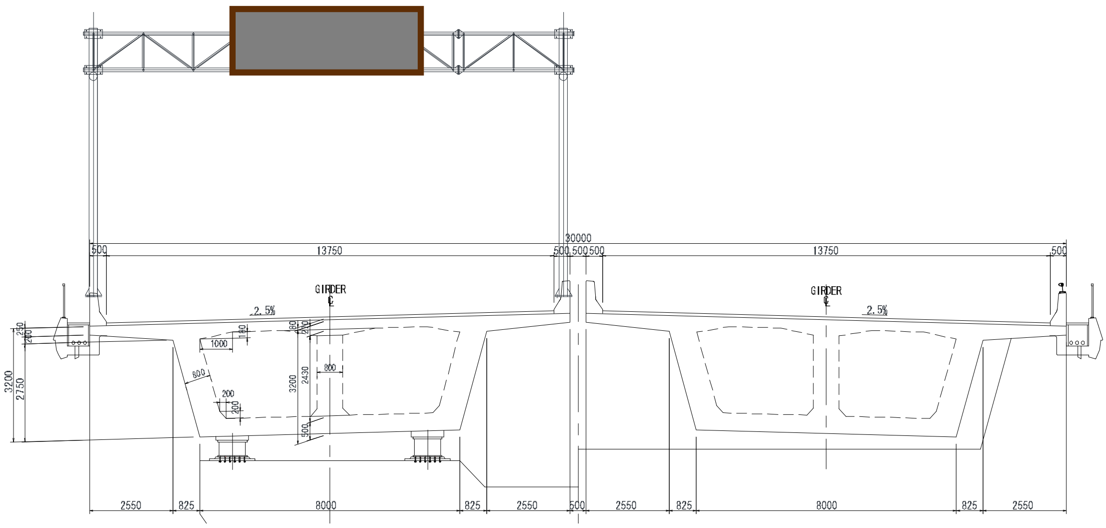


Source: JICA Study Team

Figure 6.6.19 Locations for the Installation of VMS (Recommended)

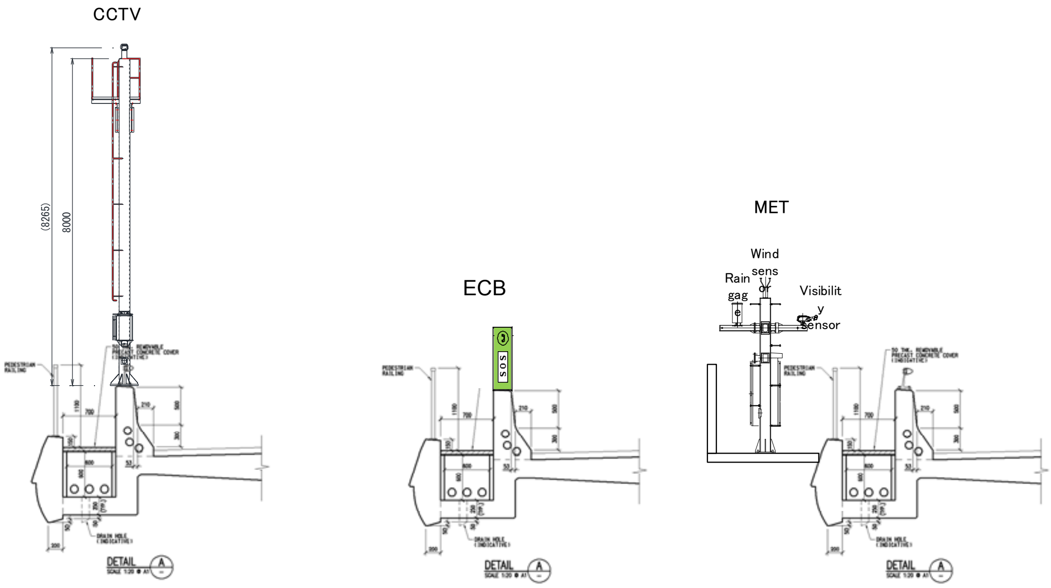
3) Installation

The installation images of each facility in the bridge part are shown below.



Source: JICA Study Team

Figure 6.6.20 Installation Image of VMS (Recommended)



Source: JICA Study Team

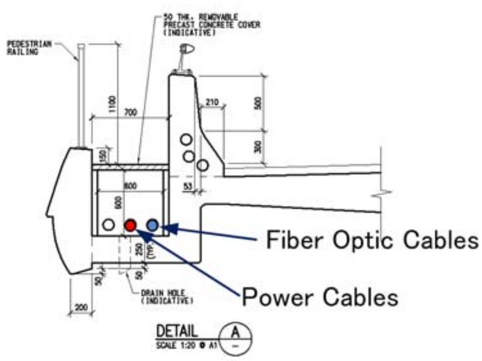
Figure 6.6.21 Installation Image of CCTV, ECB, MET (Recommended)

4) Optical Fiber Cable

MTHL's original communication line shall be installed by laying optical fiber cables on both sides of the road without using the communication carrier for the communication between the road side facilities and Traffic Control Centre, because nearly the entire line of MTHL consists of bridge structure over the Mumbai Bay.

5) Power Cable

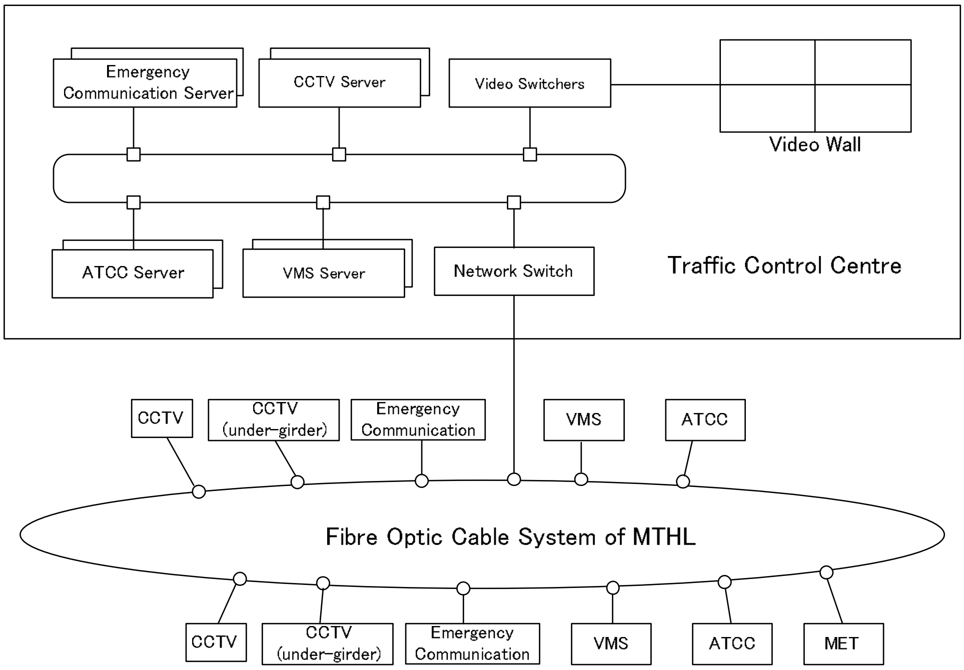
Electric power for the road facilities shall be supplied from Mumbai side and the Navi Mumbai side because nearly the entire line of MTHL is bridge section as mentioned above. In addition, it is necessary to install generators in both Mumbai side and Navi Mumbai side as the back up power source at the time of power failure.



Source: JICA Study Team

Figure 6.6.22 Laying Location of Cables (Recommended)

(3) System Configuration of Toll Management System



Source: JICA Study Team

Figure 6.6.23 Toll Management System Configuration

(4) Traffic Management System Cost Estimation

Table 6.6.13 shows the rough estimated cost of Traffic Management System.

Table 6.6.13 Rough Estimated Cost of Traffic Management System

	Item	Estimated amount (in million INR)	Year of expenditure
1	Traffic Management System	475	The completion year of the construction and every 10 years thereafter for renewal

Source: JICA Study Team

6.7 Safety and security Considerations

6.7.1 Introduction

The purpose is to review the vulnerability of the MTHL to threats, to consider how to provide a reasonable level of resilience and to give recommendations for inclusion within the MTHL contract documents.

This chapter consider the physical and operational vulnerability and risk mitigation measures to three types of threat such as terrorism, crime and civil disruption.

The chapter consists of the following three parts:

- Identify the likely threat to the project by carrying out a threat assessment.
- Review the resilience measures required to counteract the potential threat.
- Safety and Security measures to be installed in MTHL.

6.7.2 Threats assessment

(1) Terrorism

There is a high possibility for terrorist attack in India with several incidents occurring in the past. Although there is no evidence that bridges are being targeted for terrorist attacks in India, the past international experience suggest that bridges are targeted for reasons of symbolism, disruption and significant impact to the national and local economy.

MTHL is strategic linkage and plays important role to connect to the new international airport and its importance for the future prosperity of greater Mumbai makes it a potential target. Any act of terrorism made against the bridge structure, buildings, operational systems and staff represent a high impact threat to the operation of the bridge. Countermeasures should be adopted to avoid the threat or militate against any consequences of an action.

(2) Crime

Bridges tend to be exposed to criminal threats. Those criminal threats likely to generate the highest levels of risk are indicated in the following table:

Table 6.7.1 Main Criminal Threats for MTHL

Criminal Threat	Threat Analysis
Graffiti / Petty Vandalism	Graffiti / Petty Vandalism represent a low-impact criminal threat but may place a continual management and maintenance burden on the bridge operators. Failure to rapidly repair the damage caused by graffiti and petty vandalism has been shown to act as a catalyst for further criminal damage and is likely to identify the MTHL as an attractive target or location for more serious criminal activities. Graffiti and petty vandalism may target the bridge structure and / or personal or commercial property located in and around the structure. Depending on the nature of the criminal damage, the health and safety of the offenders -as well as bridge users- may be threatened (e.g. an individual on the carriageway may present a danger to traffic)
Arson	It has the potential to represent a significant threat to the MTHL
Sabotage	It is possible that an individual intent on disrupting bridge security and safety operations could sabotage security and safety systems.
Theft	The MTHL will be exposed to a threat of acquisitive crime perpetrated by both opportunist and more organised offenders due to its potential accommodation of valuable items (including personal property, parked motor vehicles, office and IT equipment). The MTHL is likely to accommodate (in, for example, the substation compounds and maintenance zones) building and maintenance materials, metals, plant equipment and machinery. Such items are increasingly being targeted by criminals due to their residual value on the black market. While MTHL management may be able to transfer some of the financial implications of these threats through, for example, insurance, or by making contractors responsible for their own property, it is likely to retain a degree of management burden, indirect cost and operational disruption (e.g. delay in maintenance works)
Violence/ Against the Person	Although it is not envisaged that MTHL staff, visitors or contractors will be involved in any activities that would be likely to raise their exposure to violence above ambient levels, best practice measures commensurate with the local threat environment and those deployed at similar facilities are recommended to mitigate this threat.
Trespass	Trespass has the potential to represent an important threat to the MTHL and its operations. Trespass may be the precursor to more serious criminal offences, such as criminal damage or theft, or it may be the result of individuals loitering or attempting to, for example, walk across the bridge. Individuals trespassing on the carriageway may present a significant safety risk to passing traffic as well as themselves. Preventing trespass through access control and intruder detection and surveillance systems represents one of the principal mechanisms for mitigating criminal and terrorist threats.
Drug and Alcohol Abuse	Although drug and alcohol abuse either within the MTHL environs may not present a direct threat to the bridge and its operations, it may result in a management burden (e.g. the requirement to dispose of drug paraphernalia). If the potential for drug and alcohol abuse in the environs of the MTHL is not responded to, then the MTHL may attract a greater risk of more serious criminality or anti-social behaviour including. The toleration of drug and alcohol abuse within the MTHL environs may also serve to increase the fear of crime and negatively impact on the quality of the environment for MTHL employees, visitors and users.
Vagrancy	Although vagrancy does not present a direct threat to the MTHL and its operations, it may result in a management burden, act as a catalyst for

	other forms of criminality and negatively impact on the ambience of the development and perceptions of criminal threat.
Prostitution and Related Offences	Although prostitution and related offences may not present a direct threat to the bridge and its operations, it may result in a management burden. In addition, if prostitution and related offences are not responded to, then the MTHL may attract a greater risk of more serious criminality or anti-social behaviour. The toleration of prostitution and related offences within the MTHL demise or environs may also serve to increase the fear of crime and negatively impact on the quality of the environment for MTHL employees, visitors and users.
Suicide / Attempted Suicide	Prominent bridges are commonly used as places where individuals attempt or commit suicide. Suicide attempts may have an adverse impact on bridge operations - for example leading to traffic disruption as emergency services respond to such incidents. Suicidal individuals may also present a danger to traffic by trespassing on the carriageway.

Source: JICA Study Team

(3) Civil Disruption

There have been a number of cases of protests and civil unrest in India such as demonstration. However, it have not been identified that specifically target bridge structures. Nevertheless the following forms of civil disruption are possible.

Table 6.7.2 Civil Disruption for MTHL

Criminal Threat	Threat Analysis
Grandstanding	'Grandstanding' protest activities typically involve a relatively small number of individuals who attempt to achieve significant publicity and a large audience for their cause through the extreme nature or audacity of their protest activities rather than by mobilising a large number of people. Protests targeting bridges can be of the grandstanding type - involving, for example, protestors scaling bridge structures, hanging banners advertising their cause from them and 'locking' themselves to bridge structures Such protests have the potential to cause significant disruption to traffic flows and bridge operations (e.g. through forcing the closure of the carriageway) for an extended duration.
Demonstration	Demonstrations typically involve a relatively large number of individuals who attempt to achieve significant publicity and a large audience for their cause through mobilising a large number of people rather than engaging in extreme or audacious forms of protest activity. Such protest activities are unlikely to target the MTHL, although they would have the potential to cause significant disruption to traffic flows and bridge operations.

Source: JICA Study Team

6.7.3 Requirements for Threats

The followings show the general requirements for threats.

(1) Terrorism

Robust structure with solid piers shall be provided. Provide barriers to vehicle entry at abutment and substations. CCTV entry recorded.

(2) Crime

Deter entry and provide barriers to entry at toll plaza buildings, abutments and substations.

(3) Civil Disruption

Measures to prevent access to attractive areas of occupation for protests

6.7.4 Safety and Security measures to be installed

The Security Plan (safety and security measures) has been developed to mitigate the threats and risks identified in front sections in order to define and coordinate the individual mitigation measures identified in the latter. The plan consists of five elements:

- Access management
- Surveillance
- Target hardening
- Active security
- Command & control

The combination of these elements will deter, detect and delay intrusions and attacks and provide verified alarms in order to initiate a security force and/or police response.

(1) Access Management

Access management will be achieved by a combination of the following elements:

- Zoning of the site
- Access control
- Physical security measures
- Electronic access control

① Zoning of the Site

The following zoning strategy will be adopted:

- **Zone 1 Public Areas**

Public accessible area on foot or vehicle where no or minimal measures are taken to control access.

- **Zone 1a Pedestrian Public Areas**

Public accessible area on foot where physical measures are taken to control vehicle access.

- **Zone 2 Semi Public Areas**

Open areas not normally on public rights of way and enclosed escape routes considered normally private with controlled access that may be breached by the public in cases of emergency.

- **Zone 3 Private Areas**

Private areas where visitors are permitted access only with permission and which will normally be occupied by maintenance staff. The areas themselves are not critical but may give access to security critical elements of the structure.

- **Zone 4 Restricted Areas**

Critical areas of the MTHL which are fundamental and of critical importance to the crossings operation.

This zoning described above is applied to the following table:

Table 6.7.3 Civil Disruption for MTHL

Area	Zone Classification
Road carriageway deck	1
Access to substations	1 a
Access to the abutments	1 a
Access to toll plaza buildings	1 a
Approach piers(low level)	2
Deck level maintenance walkway	2
Rescue Stations	3
Substation compounds	3
Abutments	3
Toll Plaza Buildings	4
Control room	4
The deck maintenance zone	4
Approach pier tops	4

② Access Control

Access control shall be achieved by a combination of physical and electronic measures to manage both pedestrian and vehicular access

a) Staff Access

- Management staff

Management staff will have the authority to move around the MTHL across all security zones upon authentication of an identity token.

- Security staff

Security staff whilst having generally permissive access based on authentication of identity must be subject to robust tracking and monitoring in critical areas.

- Maintenance staff

Maintenance staff should ideally be permanent members of MTHL staff. They will only have access to the areas they are required to visit for task completion. Areas which have been graded as critical that require access should be accessed under a permit condition.

- Approved contractors

Approved contractors should be accompanied at all times. Areas which have been graded as critical that require access should be accessed under a permit condition.

- Cleaning staff

It is assumed that cleaning staff are only permitted to the office areas under supervision. Their access across zones must be very carefully controlled.

- Utility employees

These will be treated as visitors and will have to access the MTHL substations through the staff access points and be accompanied at all times.

b) Vehicle Access

- Zone 1

Unimpeded vehicle access is provided on the deck carriageways.

- Zone 1a

The access roads have vehicle controls this is achieved using a combination of landscaping and road bollards.

- Zone 3

The access road to substations and toll plaza buildings has a demarcation vehicle control barrier. The substation compound has vehicle access gates. There is no vehicle access into the individual buildings.

③ Physical Security Measures

a) General

Physical measures shall be used to establish controlled perimeters and layers of security that relate to the security zones and boundaries as previously outlined in this plan. Physical standards of doors, shutters and access hatches have been chosen to deter and delay unauthorised entry to secure areas, effectively segregating Staff, maintenance, power production/distribution and plant areas from public areas. With associated fencing around compounds, the physical systems provide the necessary barriers to prevent uncontrolled entry, with the electronic systems providing verified intrusion alarms via appropriate sequential sensor technology or visual verification of breaches in those barriers such that a Police response may be initiated.

The operational response strategy and timings will be matched to the delay times offered by the physical measures installed.

The physical measures include the following:

- Key locking
- Doors
- Physical construction of buildings
- Back filling of trenches to prevent access to cables/control equipment
- Shutters
- Barsets
- Access hatches
- Fences
- Rising Blockers and Static Bollards — Impact rated

Specific measures at the zone boundaries are outlined in the following sections.

b) Zones 1— 2 boundary

For vehicles it will be the static bollards/rising blockers on access roadways and the associated curtilidge around the substations and abutments. A 10m stand-off from the abutment for vehicles shall be achieved using landscaping, retaining walls, ditches, bermes etc.

c) Boundary of Zone 1/2 and Zone 3

The second physical layer is the construction of the building envelopes which comprises the wall, roof, door and openings.

For pedestrians this boundary will be the outer demarcation lines through the use of fencing around the substations and operational buildings.

- Substations, Abutments, Toll Plaza Buildings:

Doors shall take two forms, where an internal lobby can be created then the outer facing door shall be constructed to SR1 classification or similar. This will provide a sacrificial barrier in security terms which is used as a deterrence to would be trespasses, arsonists, and graffiti artists alike. Immediately inside after a lobby shall be a second door rated SR3 or similar. This will provide the delay barrier until the security response attends site to investigate the alarm generated when the first outer barrier is breached. Where a sacrificial barrier cannot be installed then the outer door/shutter shall be classified to SR3 rating or similar.

- Deck Maintenance Zone:

Access hatches from roadway level into the deck interior are to be lockable hinged/sliding access points of steel construction and are to satisfy LPS 1175 SR3 or equivalent, with equivalent BS EN 12320 padlock standard for forced entry from deck level.

d) Boundary of Zone 3 and Zone 4

Zone 3 leads into the deck maintenance zone and control room. Doors accessing this area from the abutments shall be rated SR3 or similar. Control rooms shall be provided with SR3 rated doors or similar.

e) Standards

- Doors, shutters & barsets

Wherever possible, all security-rated doors, shutters and barsets shall be security rated as specified and independently certified. Where custom physical measures are required, they shall be equivalent to the required rating and subject to approval by MMRDA's adviser prior to use.

- Key Suiting

All door keys shall be subjected to a key suiting regime suitable for operation across abutments and doors on the bridge itself. Shutters and hatches throughout the MTHL shall be subject to a similar suiting regime for any padlocks used.

- Locks

When not part of a security-rated doorset, locks provided shall comply with BS 3621 or better and be part of the key suiting regime.

- Padlocks

Any padlocks used shall comply with BS EN 12320 Grade 3 or better and chosen to suit the local environment in terms of corrosion resistance. The form of the padlock and its associated Hasp and Staple (where applicable) shall be chosen to suit the local locking requirements.

- Fences

Perimeter fencing and gates shall be to (weldmesh or weldmesh panels) of 3000mm height (excluding any topping). Topping shall be provided if detection system effective capture area does not extend above fence height.

This welded mesh product shall be manufactured from hard drawn 4mm wire and welded at every intersection of 76.2mm by12.7mm so that the apertures are finger and toe proof.

- Electronic Access Control

An electronic access control is required to provide convenient and secure passage through the security zone boundaries previously described from public areas to Staff, maintenance areas and higher control areas. The access control system (ACS) will be supplemented by appropriate key locks, padlocks and suitable doors (as previously), with impact-rated static and rising barriers being provided for hostile vehicle mitigation.

The system shall be compatible with any existing access control sites. As a minimum this shall entail the use of common ACS credentials facilitated by the use of compatible MTHL readers.

The ACS system shall comprise a centralised PC based server with distributed controllers for local door control.

ACS shall be used as follows:

Location	Reader Type	Direction
Abutment	Proximity	In only
Control room	Proximity	In only
Toll Plaza Buldings	Proximity	In/out

(2) Surveillance

① General

Electronic surveillance systems comprising intruder detection devices and video surveillance/recording shall provide the means of establishing a breach in the security to critical areas and subsequent monitoring of the incident either in real time, and/or from recordings for forensic review.

The surveillance system shall comprise elements of both standard analogue and Thermal Imaging cameras. The thermal imaging cameras shall be used to aid traffic management throughout the length of the bridge deck in all weathers and investigating deck security alerts.

② Intruder Detection

A fundamental element of the layered security strategy is the provision of an intruder detection system. This shall be used across the MTHL site to provide indication to the local and remote control locations that a potential intrusion has occurred or an unauthorised event that needs investigating.

The system shall be compliant PD6662 or better with additional sensors/CCTV as necessary to provide alarm verification integrated with the access control and CCTV systems and to provide a verified alarm state to the Operator.

PD6662 places a responsibility on security alarm system installers to carry out a risk assessment, establish a system grade and to then design a system based on the grade and to design the installation of the system according to the installation environment. Whilst the grading of the system is the responsibility of the Installer, the strategy is based on a Grade 3 system being installed.

A panel “Red Care Ready” shall be provided at each of the abutments to monitor the IDS devices from the local abutment, sub-station and its compound. A PC shall be provided in the control room to manage the entire system.

Additionally, each IDS panel shall monitor the status of roadway access hatches along the bridge to its mid-point and the alarm status of the Perimeter Intruder Detection System (PIDS).

An alarm key pad shall be installed, adjacent to the Alarm Panel(s) and wall mounted at site locations where necessary for Staff to set or part-set the system for their normal site activities. These are considered to be:

- The entrance to the substation compound
- The entrance to the abutments compound

Each vulnerable compound shall be provided with a detection system, connected to the local abutment panel, to detect the presence of intruders moving between the fence and the building or from the sacrificial lobby into the operational areas of the crossing.

Where the detection system monitors lengths of fencing the Perimeter Intruder Detection System (PIDS) shall be divided into appropriate sector lengths coordinated with the CCTV coverage to give full sector length video display on alarm initiation via one or more cameras.

③ CCTV

CCTV cameras shall be installed at around three places per 1km, on both side of main alignment and the monitoring traffic condition including the invasion of suspicious person and unidentified objects of whole stretch of MTHL shall be carry out in the Traffic Control Centre. And also, it will be installed under bridge every 1km. In addition, patrol car and boat will be provided to MTHL. Details of those facilities are shown in chapter 6.6.4 Traffic management System.

The CCTV system shall be flexible to allow for future changes in technology such as the adoption of IP/HD cameras. A requirement for the use of thermal imaging cameras has been identified and the system shall be capable of managing, monitoring and recording images as an integral part of the system. They shall comprise dual head technology using an analogue CCTV camera and a thermal imaging camera both being fully functional unit for long distance bridge deck surveillance.

The system shall provide matrix display and management of video images for use by the operators in live and record modes of operation.

The Operational Requirement (OR) of each camera shall be stated in terms of its surveillance task, these being monitor and control, detect, observe, recognise or identify categories as defined by the Home Office Scientific Development Branch (HOSDB) CCTV Operational Requirements Manual (Publication No. 28/09). Each category has an associated requirement for image size based on a nominal 1.7m high figure. In HOSDB terminology, where the image of the figure fills the monitor screen from top to bottom, the image is said to be 100%. Recommendations from HOSDB used are:

- Alarm verification: greater than or equal to 10% R
- Observe: greater than or equal to 25% R
- Recognise: greater than or equal to 50% R
- Identify: greater than or equal to 100% R

The system shall incorporate a means of camera switching and control to enable the Operator(s) to display any camera onto any screen and provide sequencing of defined pictures. It shall have all common features and facilities to enable the efficient control of variable speed fully functional (PTZ) cameras (whether standard or incorporating a thermal element), and respond to alarm inputs from the IDS and ACS to provide automatic display of a relevant picture (or pictures) in response to an alarm activation.

Serial alarm input capability shall be suited to the input/output requirements of the MTHL initial system deployment and the number of required control/display locations, but shall also be capable of expansion in terms of camera and alarm inputs, display facilities and Operators to accommodate future additions to the MTHL system.

Images shall be displayed on Operator screens capable of a variety of display formats to allow versatility of information display as follows:

- Full screen view (single camera)

- Split-Screen Views e.g. 4, 8, 16
- Sequencing of full/split-screen views

The system shall incorporate privacy zoning capabilities to ensure any neighbouring properties cannot be overlooked. It shall be able to configure and manage 3D spatial masking.

Pre- and Post-Event recording shall be supported with playback automatically commencing on the operator's screen in response to an alarm occurrence.

The system storage capacity supplied shall be adequate to record and store video from ALL cameras continuously at the following parameters, the storage comprising multiples of hard-disk drives configured in RAID format:

- Resolution - full 4CIF
- Low compression - less than 30%
- Image capture - 12.5ips
- Length of storage before overwrite - 28 days

All standard cameras shall support high-resolution (460HTVL) Day/Night CCD units that are substantially sensitive in the IR region for the security task. The camera/lens combination shall ensure adequate pictures under ambient lighting conditions. Where necessary, supplementary illumination in the form of LED IR illuminators shall be provided. Where IP cameras are used they shall support MPEG4 Pt 10 or H264 transmission and Power over Ethernet.

As required for the installation vandal resistant camera housing shall be provided. The intention is that these shall be used for the external coverage of the substation, abutment and toll plaza buildings.

④ Traffic Management Systems

There shall be an intelligent traffic management system that shall be able to monitor the flow of traffic, which will be able to provide information to the management team that vehicles have stopped not on an individual vehicle by vehicle basis but in adequate detail to alert them and allow the CCTV system to be used to establish the cause of any blockage and confirm the likelihood of it being associated with either criminal or terrorist activities.

⑤ Security lighting to Sub-Station, compounds and buildings

Security lighting to be co-ordinated with sensitivity of CCTV surveillance system to provide 24 hour surveillance capability and where niches are created additional lighting shall be provided to deter the presence of unauthorised persons.

⑥ Guarding Support Systems

The Main Crossing shall have a common private mobile radio system that allows security and bridge maintenance to communicate throughout the entirety of the bridge.

⑦ Security Signage

This will comprise statutory health and safety and CCTV for monitoring purposes and those required to inform the public of semi-private and private areas. These will match the zones highlighted in the zoning drawings. Typically they shall say "No public Access Except in Emergency" or similar as such signs may conflict with signs indicating emergency exit routes.

(3) Target Hardening

In a direct response to the issues raised in the threat and risk assessment and subsequent resilience review, the following additional structural measures form a fundamental element of the security strategy.

① Structure

The substation and abutment walls and roofs shall be constructed of solid in situ reinforced concrete not less than 150mm thick.

Openings for windows, vents, etc. shall have bar sets installed on the secure inner side to deter and delay any attempt entry.

② Viaduct Base

For Vehicle access below the viaduct:

- Access by unauthorised vehicles below the viaducts at spans shall be prevented by the use of landscaping, retaining walls, ditches, bermes etc.
- Similar measures shall be used to prevent unauthorised vehicle access within 10m of the base of on-land viaduct piers.
- Impact rated barriers for hostile vehicle mitigations measures shall ensure no clear gap of more than 1.2m (1200mm).

③ Voids

Voids are of a significant concern in respect of security and the searching of voids is a time consuming task.

The term "voids" covers a wide range of spaces: the internal cavity of a stud wall, for example, is a void as it is a space which is never legitimately accessed for any reason once constructed, risers which are rarely accessed could be considered a void if located next to a critical element of the structure.

For the purpose of this document, therefore, a void is considered to be any space that is either never accessed or is inaccessible to which section a) below applies, or is rarely accessed that could be exploited by terrorist or other criminals and that will need to be searched, certified as clear and then sealed.

The major issue with voids is the secretion of items or possibly persons in preparation for some form of criminal or terrorist attack. In respect of items of almost any form the time period within which items could be secreted extends well into the construction phase.

This section sets out the requirement to manage voids.

a) Void Certification

A process of identification and certification of voids shall be implemented as part of the design and build process to the satisfaction of the Overseeing Organisation. This shall include; identifying, classifying, maintaining a register and finally certifying that any voids are clear of concealed or embedded explosive devices.

b) Service Voids

In order to reduce the number of service voids to a minimum, common access panels are preferable to individual service chambers. In practice, therefore, this requirement means that instead of individual access panels for each major component of a piece of equipment, a service room to the rear of the equipment's public façade giving access to all the internal components and which is accessed via a single door secured to LPS 1175 SR2 or better shall be used. In addition, access to a service void should not be from any unobserved public space and ideally should be in a non-public area.

The equipment and services within service voids should be set out to facilitate the ease if search and where possible floors should be kept clear. Service voids must be kept clear of construction and installation debris.

c) Design Safety

Some of the accessible voids that will be searched may be in areas where personnel are not expected to go. Therefore, individuals responsible for designing areas that could require searching should take due cognisance of the local health and safety regulations and bear in mind that if a person can access a void it will be accessed (possibly regularly) and will need to be safe enough for those who will carrying out the search. Health and Safety regulations require that risks arising out of the design are documented and eliminated; but, as a fundamental design principal the interior of all voids shall be designed on the basis that although access to them will be very limited it can be expected under certain circumstances and should be allowed for in any design.

(4) Active Security

Active Security is the process by which human resources, working to defined operational practices and procedures, complement the physical and electronic security measures. Active Security is necessary where physical and/or electronic measures alone would either be inappropriate, inadequate or impractical to maintain the required level of security whilst allowing the normal function of the area to continue.

① Policies and Procedures

The MTHL Maintenance Organisation will be responsible for all elements of active security including the following:

- The development and maintenance of security policies
- The development of a security culture amongst the employees and ensure all staff display ID at all times to allow a "challenge" mentality to be adopted
- Daily operational procedures linked to the time of day and operational readiness of the MTHL
- Regular and appropriate threat analysis and risk assessment
- Incident reaction plans including bomb threat and abandoned vehicle procedures
- Crisis management plans
- Continuity planning
- Disaster recovery plans
- Liaison with Police authorities
- Security staff training
- Security staff vetting

6.7.5 Contractual Requirements

The proposed items for inclusion within the Specific Employer's Requirements are:

(1) Security Requirements

① General

The Contractor shall ensure that resilient and robust security provisions are provided in the Crossing which shall include the requirements set out below.

The Contractor shall submit his proposals to satisfy this Section to MMRDA and their representative for approval.

The MTHL security and surveillance system shall be formed from both electronic and physical aspects designed to afford risk mitigation whilst aiding management of the operation and maintenance of the bridge, its associated buildings and compounds.

Security and surveillance measures applicable to the MTHL shall be commensurate with a medium to high threat and risk assessment, the 'high' rating being applicable to those aspects of the site that concern the supply or control of the power source and distribution of the Essential Supply System (ESS) that provides power to such critical services as traffic management systems.

Physical standards of doors, shutters and access hatches shall be chosen to deter and delay unauthorised entry to secure areas, effectively segregating Staff, maintenance, power production/distribution and plant areas from public areas. With associated fencing around compounds, the physical systems shall provide the necessary barriers to prevent uncontrolled entry, the electronic systems providing verified intrusion alarms via appropriate sequential sensor technology or visual verification of breaches in those barriers such that a Police response may be initiated.

Electronic systems comprising intruder detection devices and video surveillance/recording shall provide the means of establishing a breach in the security to critical areas and subsequent monitoring of the incident either in real time, and/or from recordings for forensic review. As a sub-set of the surveillance regime, standard CCTV cameras shall be supplemented by thermal imaging cameras for the particular task of aiding traffic management throughout the length of the bridge deck in all weathers and investigating deck security alerts.

② Substations, Abutments and Buildings

Internal and external entry / exit doors between public and staff areas shall be greater than or equal to LPS1175 SR3 or equivalent rated; doors for public use on escape routes shall be greater than or equal to LPS 1175 SR1 or equivalent rated. Roller shutters and associated wicket gate shall be greater than or equal to LPS1175 SR3 or equivalent rated and fitted with vibration detectors.

Staff and service entry / exit points shall be protected by intruder detection system ("IDS") sensors with access control on primary staff area entry door from corridor via proximity card / token. Locks on access controlled doors shall fail secure with a means of emergency egress and key override entry. Differing technology IDS sensors shall be required to complement contact sets to provide verified alarm from IDS.

Each monitored / controlled door leaf shall have a contact set on each leaf for remote status monitoring via IDS or access control system.

Window assemblies shall be greater than or equal to LPS 1175 SR3 or equivalent rated for forced entry which shall be achieved by incorporation of suitable internal barsets if necessary. Glass in windows shall be laminated with a pvb interlayer of a thickness of not less than 0.76 millimetres. Opening windows shall be fitted with contact sets for IDS monitoring, all windows shall be fitted with vibration detectors.

Vulnerable louvers (fixed or removable) shall be fitted with barsets and removable louvers shall be fitted with contact sets for IDS monitoring. Barsets to louvers shall also be fitted with vibration detectors for IDS monitoring.

③ Entry to deck

Access hatches from roadway level into the deck interior shall be lockable hinged / sliding access points of steel construction and shall satisfy LPS 1175 SR3 or equivalent with an equivalent BS EN 12320 padlock standard for forced entry from deck level.

④ Vehicle Access to Abutment Environs

Vehicle access to abutment environs shall be designed to ensure that unauthorised vehicles cannot approach within 10 metres of the abutment structure and within 15 metres of the bridge bearings. This shall be achieved by use of landscaping, retaining walls, ditches, bermes etc.

Operable impact rated vehicle barriers shall be provided on the relevant access road at the authorised vehicle approach limits. These shall take the form of hydraulically operated bollards that can be lowered so as to be flush with the adjacent road surface. The barriers shall incorporate a secure lockable access control system.

Operable and static barriers shall be provided. The design impact rating shall be determined by evaluating the speeds at which a range of potential hostile vehicles could approach the abutments taking account of road geometry and local topography.

Impact rated barriers for hostile vehicle mitigations measures shall ensure no clear gap of more than 1.2 metres.

⑤ Perimeter fencing and gates to sub-station compounds

Perimeter fencing and gates shall be to BS1722 Part 14 (weldmesh or weldmesh panels) to 3000 millimetre height (excluding any topping). Topping shall be provided if the detection system effective area does not extend above the fence height.

The welded mesh product shall be manufactured from hard drawn 4 millimetre diameter wire and welded at every intersection of 76.2 millimetres by 12.7 millimetres so that the apertures are finger and toe proof.

⑥ Sub-station compound perimeter security

Perimeter intrusion detection system ("PIDS") shall be provided to detect intruders moving between the outer fence and the sub-station building. Alarms from the PIDS shall be monitored by the IDS.

Entrance gates to compounds shall be status monitored by the IDS (for open / closed status). The entrance gate used by the Electricity Supply Company shall be a separate

PIDS sector (if required by the Contractor's provided PIDS technology) and be provided with a means of authorised isolation that shall not cause an alarm but shall be registered on the IDS display. Padlocks utilised for gate locking shall be to BS EN 12320 with a grade to suit the application and with co-ordinated key suiting.

CCTV shall provide day and night general and particular surveillance of compound fence lines and sub-station building in prevailing lighting conditions for the purposes of alarm verification and incident management. Digital recording shall be an integral part of the CCTV system for pre / post alarm video recording and incident review. The CCTV system and intruder detection system shall be integrated such that the alarm condition brings one or more relevant camera pictures to the operator's monitor and initiates recording system as programmed.

⑦ Substation Buildings

Substation buildings shall be constructed with solid in situ reinforced concrete walls and roofs not less than 150 millimetres thick.

⑧ Substation Building Access Doors

Doors to substations shall be greater than or equal to LPS1175 SR3 or equivalent rated.

⑨ Substation Security

Substation buildings shall be protected with IDS devices and UPS rooms shall be protected with IDS devices of differing technologies to provide a verified alarm condition.

Each door leaf or de-mountable louver shall have a contact set for remote status monitoring via IDS. Where it is not practical to protect each louver then Barsets shall be provided to protect unmonitored vulnerable areas

Barsets shall be provided to protect unmonitored vulnerable louvers.

⑩ Security Lighting to Substation and Compounds

Security lighting shall be co-ordinated with the sensitivity of the CCTV surveillance system to provide 24 hour surveillance capability.

⑪ General Locking Requirements

All doors, gates and hatches throughout the Main Crossing shall have as a minimum requirement padlocks to BS EN 12320 with a grade to suit application with co-ordinated key suiting and key locking to be to BS3621, also with coordinated key suiting. This includes internal doors to the Main Crossing deck. Access doors from the deck box to piers only require an opening and closing handle from both inside and outside.

⑫ Vehicle access below Main Crossing

Access by unauthorised vehicles below the deck shall be prevented by the use of landscaping, retaining walls, ditches, bermes, security fencing etc.

Similar measures shall be used to prevent unauthorised vehicle access within 10 metres of the base of on land piers.

Impact rated barriers for hostile vehicle mitigation measures shall ensure no clear gap of more than 1.2 metres.

⑬ CCTV and Digital Recording ("CCTVR") System —abutments and substations

The CCTVR system shall comprise a mixture of fixed and fully functional cameras to fulfil the surveillance requirement for buildings and compounds.

The CCTVR system shall remain operable in the prevailing lighting conditions for both internal and external cameras to allow alarm verification and incident management.

The CCTVR system shall be monitored from the Bridge Control Room or remote locations via TS IT network where one or more operator positions will allow for the control and display of both live and recorded images, and for the management and programming of operational parameters.

⑭ Bridge Deck Surveillance System

The bridge deck surveillance system shall also form part of, and be recorded by, the CCTVR system.

The full length and width of the bridge deck shall be provided with day / night surveillance for the purpose of security monitoring and beneficial use for traffic and incident management.

Surveillance shall be by combined dual head surveillance units comprising a high resolution uncooled thermal image unit with a separate colour charge coupled device ("CCD") camera enclosed in a single body and mounted on a pan / tilt head. These combined thermal / CCD units shall be complemented by additional PTZ CCD (only) units to complete the above surveillance task. Deployments shall ensure that all areas covering the length and width of the bridge deck are under surveillance by the thermal and colour cameras to a minimum image size that provides the equivalent of the Observe category for a 1.6 metre high target.

Thermal imagers shall provide a minimum resolution of 320 by 240 pixels and daytime colour cameras shall provide a resolution greater than or equal to 460HTVL.

Pan and tilt heads shall provide sufficient pan and tilt range to meet the surveillance requirements and shall provide a preset PTZ facility for alarm response.

The performance of the post shall meet the following tolerances, which are the accepted industry standards applied to external CCTV camera mountings, i.e.

- BS CP3 Chapter V Part 2 (1972) for wind speeds up to 40 m/s to BS6399 Part 2 (1997)
- The maximum deflection at the camera location for wind speeds of 40 m/s is 10 mm.

Ideally, there should be no post deflection at the camera location for wind speeds up to 15 m/s.

Note: Although BS CP3 is obsolescent and has been superseded, it is still accepted as the security industry norm.

The most important parameter is the amount the post will be deflected by the wind and, in particular, any wind induced resonant vibration/oscillation of the post, as it is this problem which affects the picture quality the most.

⑮ Security and Surveillance System Control and Monitoring

The entire CCTV / IDS / access control and video recording system shall be suitable for remote and local monitoring, relevant main control / display equipment being provided. IDS / access control displays shall include both textual and graphical warnings of system violations, with graphics maps including dynamic alarm icons being complemented by a suitably descriptive text description of the nature of the alarm. The access control system shall be provided with the local and remote capability (software and hardware) to create and enrol credentials onto the system, including the ability to print photographs and text onto suitable card credentials to make the Employer's staff photo-ID badges.

⑯ Inspection way

The inspection way for bridge inspection and maintenance shall be installed only around pier to prevent the invasion of the suspicious person. And the inspection and maintenance for other section except around piers shall be carried out by using the special bridge inspection vehicle. Details of the special inspection vehicle are shown in chapter 9.4.1 Proposed Operation and Maintenance Organization.

⑰ View Barrier

View barrier shall be installed on north side of main alignment from Ch.4km to Ch. 10km (total 6km) along Bhabha Atomic Research Centre.

⑱ Safety Fence

Safety fences of 3m in height shall be installed on both side of main alignment above the navigation channel and railway and highway crossing in order to protect illegal disposal from bridge and to keep safety for vessels.

⑲ Measures to Emergency Vehicles

Medium opening shall be installed every 2km in consideration of the passing of the emergency vehicles.

⑳ Structural Consideration

As for the bridge structure of MTHL, separated structure type is adopted in an up and down line to minimize the influence from explosion terrorism in particular.

As for the structure type, PC Box Girder and Steel Box Girder are adopted. PC structure is more firm and stronger than steel structure for the damage by the small explosion. However, when PC cable was broken or cut, the whole superstructure becomes a target of the repair or replacement because partial repair is almost impossible. On the other hand, as for the steel structure, partial repair is possible. Therefore, in the structure type of the bridge, it is difficult to discuss the advantageous and disadvantage for explosion terrorism unconditionally.

In addition, the continuous girder type is adapted to superstructure in MTHL. When some damages for superstructure by explosion terrorism is considered, the simple girder type is preferable. However, after consideration of runability, earthquake resistance and construction cost and maintenance cost, the continuous girder type is adopted.

7. CONSTRUCTION PLANNING

7.1 Introduction

In this chapter, construction method, procurement plan, contract package, rough construction schedule are described. The point unlike the previous construction plan in 2012 is application of the large-block election of the steel girders. The following advantages come up by applying the large-block erection of the steel girders that is lighter than concrete girder.

- Construction period can be shortening.
- Site safety can be improved. (It can decrease the period of construction at site.)
- Quality control can be improved. (Steel girders will be fabricated at factory.)

As for the construction period, it can shorten for approximately 1.5 years in comparison with the previous study in 2012 by applying the steel box girder with steel slab for long span sections and reviewing the whole construction schedule.

The construction schedule is tight. Therefore, after the commencement of the construction it is necessary to carry out the followings in parallel promptly.

- Detailed design
- Preparation work (material order, leveling and additional purchasing of construction yards, etc.)
- Obtainment of construction permissions from related authorities
- Establishment of construction plan
- Soil investigation at each pier location (confirmation of bearing layer)
- Confirmation of natural conditions
- Confirmation and obtainment of permission for the crossing structures such as pipelines and ship navigations
- Detour plan during the construction on land
- Grasp of environmental impact on surroundings

As for the contract package, it will be recommended in consideration of various kinds of conditions to secure the smooth and effective construction and construction supervision.

7.2 Construction Methodology

7.2.1 Construction Overview

Summary of the construction are shown below.

Table 7.2.1 Summary of the Construction - 1/6: 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+517L	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+517R		MP294 (17+341)R MP297 (17+482)R	
Mangrove Section	17+517L	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+517R	18+087R		MP298(17+517)R MP317(18+062)R	

Source: JICA Study Team

Table 7.2.2 Summary of the Construction - 2/6: 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) MP321 (18+187)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	18+187	18+217	PC Box Girder (Crane Full Span)	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+424	PC Box Girder (Full Staging)	MP328 (18+387)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Railway Overbridge	18+424	18+492	Steel Truss (Crane Full Span)	MP329 (18+424) MP330 (18+492)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	18+492L	18+574L	PC Box Girder (Full Staging)	MP331 (18+530)L MP332 (18+574)L	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
	18+492R	18+554R		MP331 (18+530)R MP332 (18+554)R	
Road Overbridge	18+574L	18+644L	PC Box Girder (Full Staging)	MP333 (18+610)L MP334 (18+644)L	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
	18+554R	18+644R		MP333 (18+595)R MP334 (18+644)R	
Typical Land Section	18+644	18+884	PC Box Girder (Crane Full Span)	MP335 (18+675) MP342 (18+884)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	18+884	18+929	PC Box Girder (Full Staging)	MA2(18+930)	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+009	PC Box Girder (Crane Full Span)	LP7(20+295) LP30(20+085)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	21+009	21+079	PC Box Girder (Crane Full Span)	LP31(21+009) LP33(21+079)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	21+079	21+228	PC Box Girder (Crane Full Span)	LP34(21+109) LP37(21+199)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Railway Overbridge	21+228	21+423	Steel Truss (Crane Full Span)	LP38(21+228) LP41(21+423)	Column Pier: ϕ3,250 Pile: ϕ1,500 (in situ)
Typical Land Section	21+423	21+659	PC Box Girder (Crane Full Span)	LP42(21+449) LP49(21+659)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Road Overbridge	21+659	21+729	PC Box Girder (Crane Full Span)	LP50(21+695) LP51(21+729)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)
Typical Land Section	21+729	21+834	PC Box Girder (Crane Full Span)	LP52(21+764) LP54(21+834)	Column Pier: ϕ2,500 Pile: ϕ1,200 (in situ)

Source: JICA Study Team

Table 7.2.3 Summary of the Construction - 3/6: Sewri IC

Sewri Interchange	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Substructure Type	Foundation Type
	Start	End			
Ramp A	Sewri	0+495	PC Box Girder (Crane Full Span / Full Staging)	Hammer Head Pier	Pile: ϕ1,200; ϕ1,500 (in situ)
Ramp B				Hammer Head Pier	Pile: ϕ1,200 (in situ)
Ramp C1				Wall Pier	Pile: ϕ1,000; ϕ1,200 (in situ)
				Straddle Bent	Pile: ϕ1,200 (in situ)
Ramp E				Hammer Head Pier	Pile: ϕ1,200 (in situ)
Ramp C2					
Ramp F					
Ramp EW					

Source: JICA Study Team

Table 7.2.4 Summary of the Construction - 4/6: Shivaji Nagar IC

Shivaji Nagar Interchange	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Substructure Type	Foundation Type
	Start	End			
Ramp JM	17+105	---	RC Voided Slab (Full Staging)	Inverted T Abutment Column Pier: ϕ2,000	Pile: ϕ1,000 (in situ)
Ramp MA	17+125	---			
Ramp CA	17+320	---			
Ramp MJ	17+471	---			
Ramp AM	17+797	---			
Ramp AC	17+617	---			

Source: JICA Study Team

Table 7.2.5 Summary of the Construction - 5/6: SH54 IC

SH 54 Interchange	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Substructure Type	Foundation Type
	Start	End			
Ramp MP	20+355	---	PC Box Girder (Crane Full Span)	Inverted T Abutment Column Pier: ϕ2,500	Pile: ϕ1,000; ϕ1,200 (in situ)
Ramp JM	20+355	---			

Source: JICA Study Team

Table 7.2.6 Summary of the Construction - 6/6: Chirle IC

Chirle Interchange	Construction Overview				
	Chainage		Superstructure Type (Construction Method)	Substructure Type	Foundation Type
	Start	End			
Ramp MP	21+228	---	Steel Truss (Crane+Bent Constr.)	Column Pier: ϕ3,250	Pile: ϕ1,500 (in situ)
			RC Voided Slab (Full Staging)	Inverted T Abutment Column Pier: ϕ2,000	Pile: ϕ1,000 (in situ)
Ramp JM	21+228	---	Steel Truss (Crane+Bent Constr.)	Column Pier: ϕ3,250	Pile: ϕ1,500 (in situ)
			RC Voided Slab (Full Staging)	Inverted T Abutment Column Pier: ϕ2,000	Pile: ϕ1,000 (in situ)
Ramp MJ	21+834	---	RC Voided Slab (Full Staging)	Inverted T Abutment Column Pier: ϕ2,000	Pile: ϕ1,000 (in situ)
Ramp PM	21+834	---	RC Voided Slab (Full Staging)	Inverted T Abutment Column Pier: ϕ2,000	Pile: ϕ1,000 (in situ)

Source: JICA Study Team

7.2.2 Construction Method

For this project, general construction method for earthworks, pavement and road facilities were considered. In this section, special construction methods are described briefly.

(1) Foundation

Cast in situ piles will be used on the bridges foundation. The geological strata in the project region can be rough described as: cohesive soil in the surface, sand, gravel, weathered basalt and hard basalt (or breccia). In some regions the basalt layer thickness is greater than 10 m. For cast in situ pile construction is recommended an all-casing method.

1) Land Portion

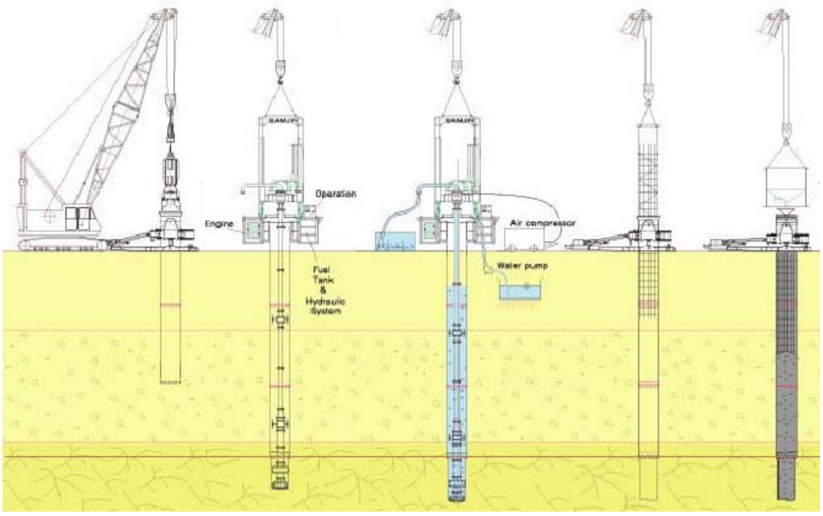


Figure 7.2.1 Steps for Cast in Situ Pile Construction on the Land Portion

For the land portion, the piles will be constructed using an all-casing method with a rock bit drilling equipment, according to the following steps:

- Set the casing oscillator in the horizontal position ensuring that the centre of the steel casing matches the pile centre.
- Excavate the cohesive, sand and gravel layer inside the casing pipe using a hammer grab, rotators shall press down the steel casing during the excavation to avoid hole collapse.
- Hammer grab is replaced by a rock bit drilling equipment. Fresh water is used as drilling fluid, while rock cuttings are bring to the surface using vacuum pump system.
- After achieving the bearing layer capacity, socketing in rock according to the specified length.
- Lowering the reinforcement cage.
- Insert the tremie pipe.
- Pump the concrete while slowly removing the casing and the tremie pipe.

2) Marine Portion (over Temporary Jetty)

Figure 7.2.2 Example of Cast in Situ Pile Using a Temporary Jetty

For the temporary jetty portion, the piles will be constructed using an all-casing method with a rock bit drilling equipment, according to the following steps:

- On the temporary jetty, set in horizontal position the crane with the installed vibro hammer, ensuring that the centre of the steel casing matches the pile centre.
- Install the steel casing.
- Excavate the soft layers using a hammer grab.
- The next steps are equal as the land portion.

3) Marine Portion (over Barge)

Figure 7.2.3 Example of Cast in Situ Pile in the Marine Portion

For the marine portion, the piles will be constructed using an all-casing method with a rock bit drilling equipment, according to the following steps:

- On a spud barge, set in horizontal position the crane with the installed vibro hammer, ensuring that the centre of the steel casing matches the pile centre.
- Install the steel casing.
- Excavate the soft layers using a hammer grab.
- The next steps are the same as the land portion.

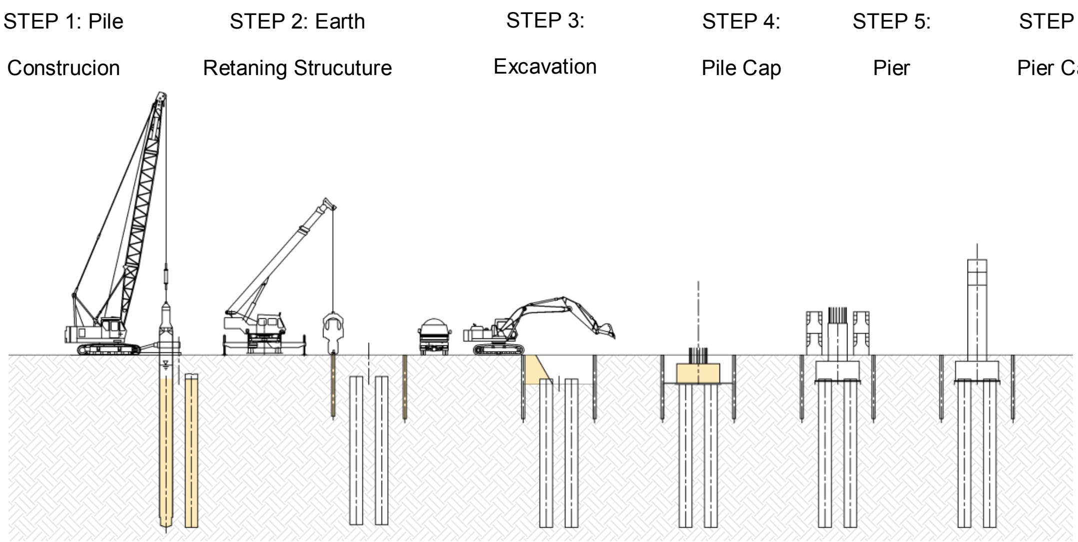
(2) Substructure

After completing the pile construction, the substructure will be constructed in the following order: pile cap (in the temporary jetty and marine portion will be used a precast shell), scaffolding, formwork & reinforcement assembling, fresh concrete casting. After the concreting, remove the formwork. For abutments, the last step is backfill.

Ground improvement treatment is necessary in weak and compressible soil areas, the implemented method should be based on ground settlement measures and boring investigations. The abutment construction should only start after the checking if the residual ground settlement and the ground strength measurements are according to the design specifications.

1) Land Portion

Manly, the open excavation method will be used in the land portion for building the pile cap. In Serwi Interchange area will be necessary to use sheet pile for excavation due the proximity with the existing road and others structures. Struts may be necessary if the excavation is deeper than 3 meters. The construction steps in the areas where earth retaining structures are necessary are shown in Figure 7.2.4.

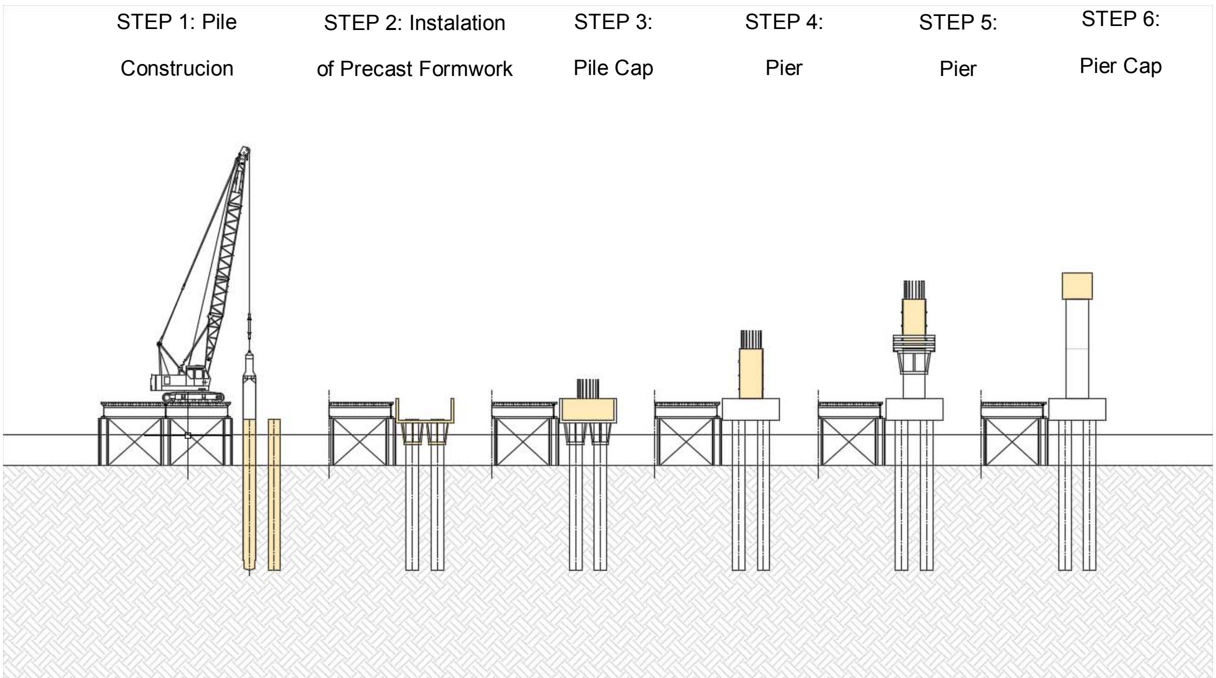


Source: JICA Study Team

Figure 7.2.4 Steps for Substructure Construction on the Land Portion

2) Marine Portion (over Temporary Jetty)

Material necessary for construction of the substructure can be supplied from the land side (by trucks) or from the marine side (by barges). After the construction of the piles, the pile cap is constructed using a precast formwork. Then the scaffold is installed and the pier and pier cap are erected. Construction in the marine portion over the temporary jetty is shown in Figure 7.2.5.

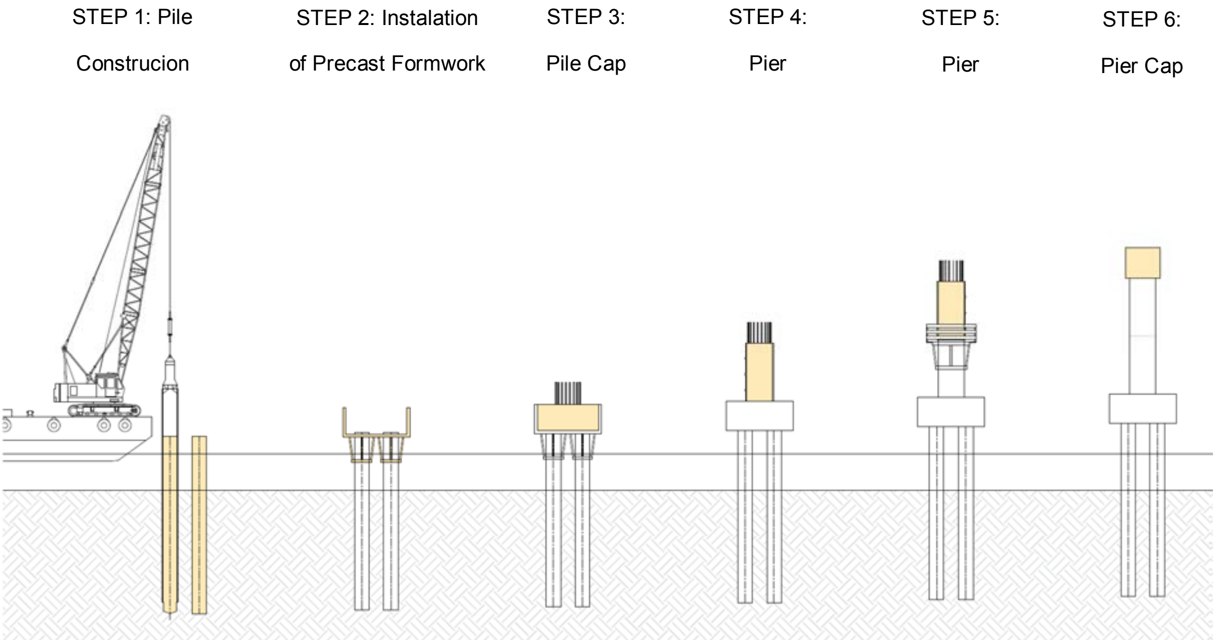


Source: JICA Study Team

Figure 7.2.5 Substructure Construction Step over Temporary Jetty (Pile Bent)

3) Marine Portion (over Barge)

In the marine portion, the construction will be executed mainly over barges. The construction steps are basically same as the construction over temporary jetty. The construction using concrete floating plant and barges to transport material need to be evaluated specially in the monsoon period. Construction in the marine portion over the barge is shown in Figure 7.2.6.



Source: JICA Study Team

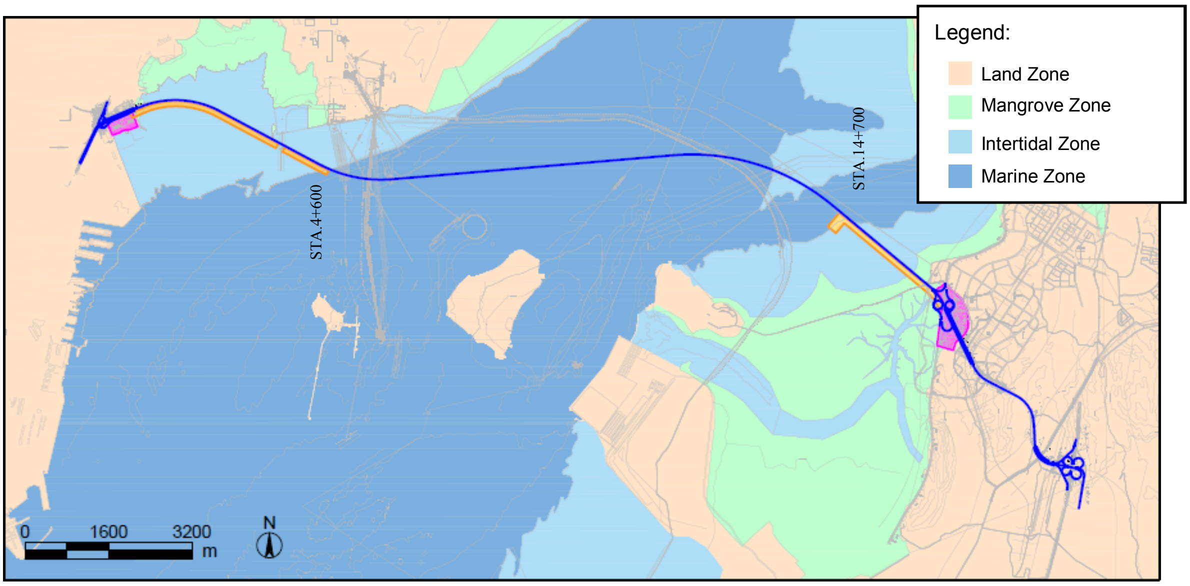
Figure 7.2.6 Substructure Construction Step over Barge (Pile Cap)

7.2.3 Temporary Jetty Plan

(1) Overall Plan

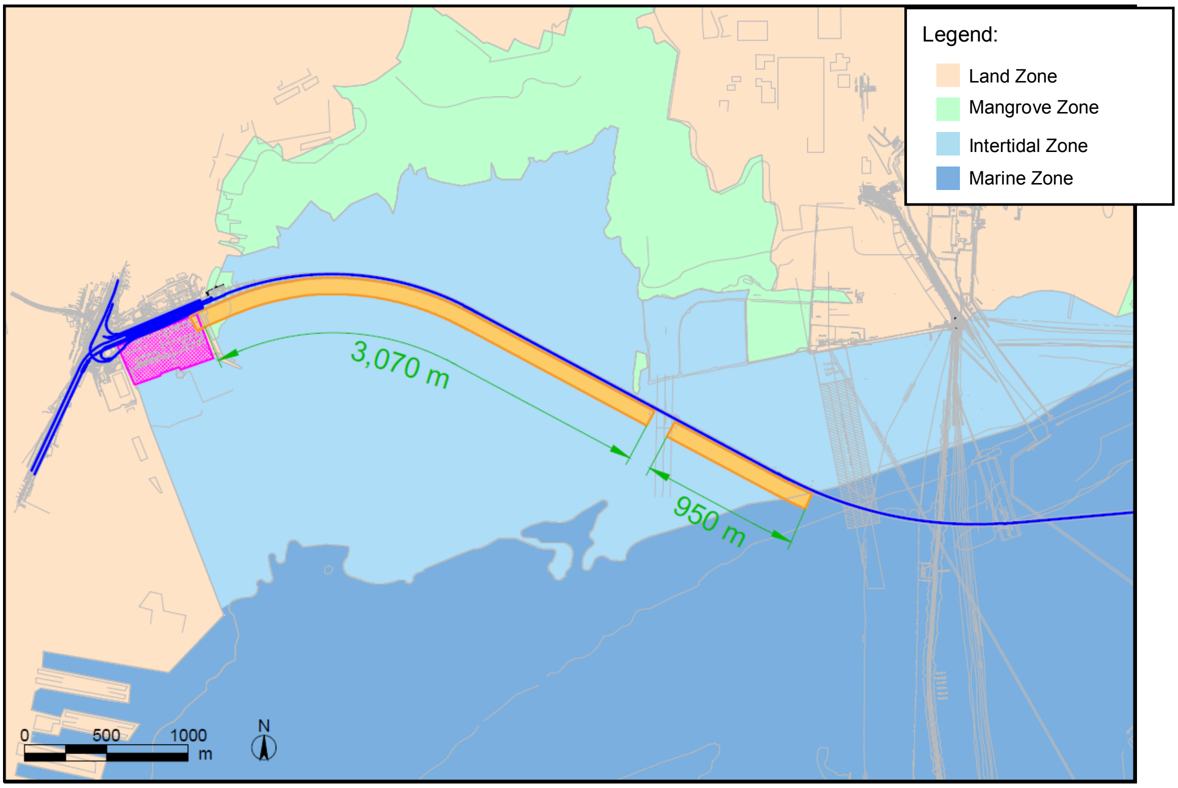
1) Outline

A temporary road shall be considered for the intertidal section on Mumbai and Navi Mumbai side. In Mumbai side, the temporary jetty with approximate 4.0 km from Sewri shore up to STA.4+600; in Navi Mumbai side, the temporary jetty with approximate 2.5 km from STA.14+200 to Shivaji Nagar Interchange (STA.17+200). Considering financial and construction time aspects is recommended the construction of temporary road on embankment. However, the area habited by flamingos is a sensitive mangrove ecosystem, so temporary jetty is a more suitable alternative. Furthermore, the position of the jetty pile foundation should be carefully considered to allow the passage of small fishing boats. The temporary jetty outline plan is shown in the Figure 7.2.7 to Figure 7.2.9.



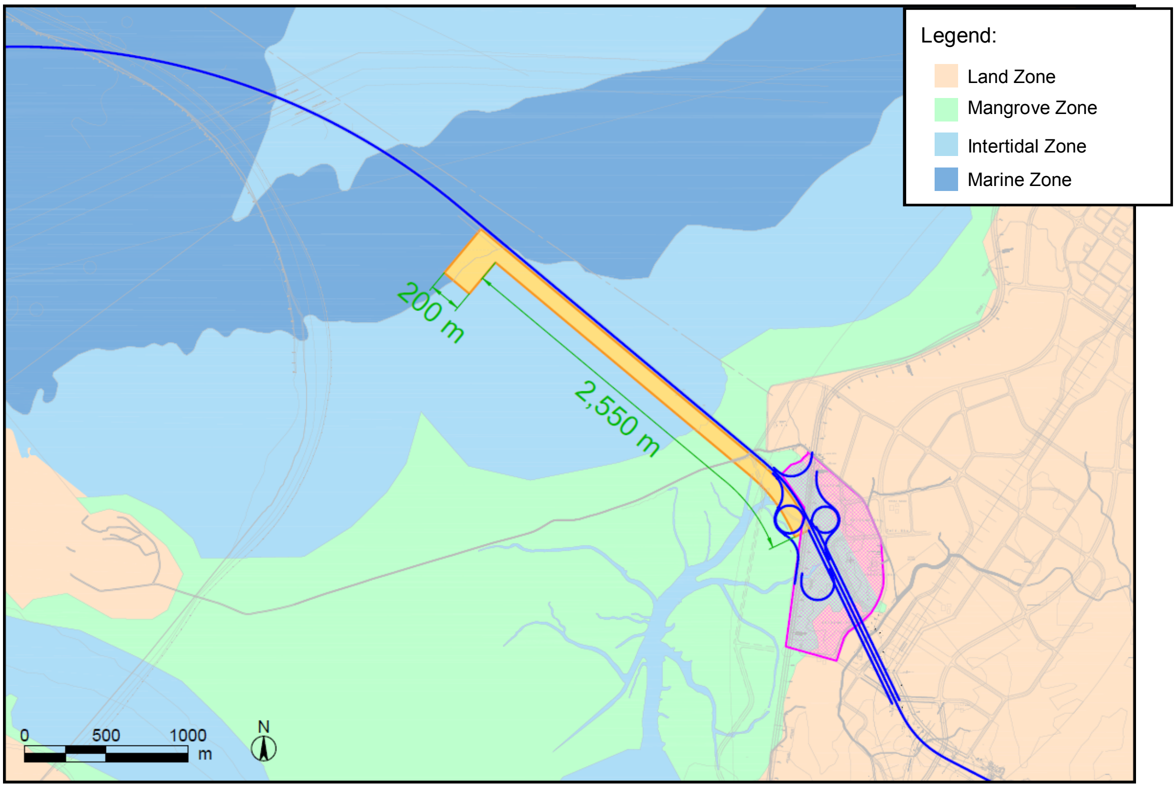
Source: JICA Study Team

Figure 7.2.7 Temporary Jetty (General View)



Source: JICA Study Team

Figure 7.2.8 Temporary Jetty (General View at Mumbai Side)

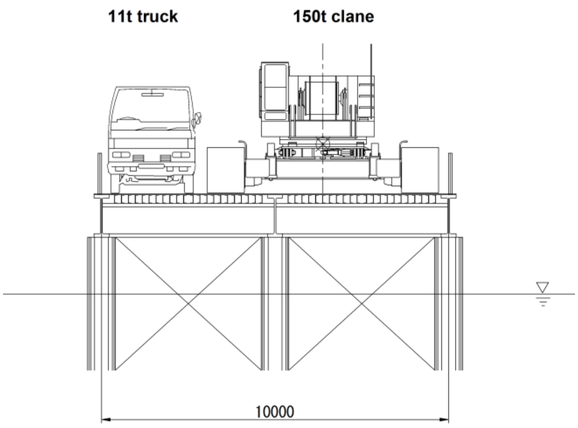


Source: JICA Study Team

Figure 7.2.9 Temporary Jetty (General View at Navi Mumbai Side)

2) Temporary Jetty Width

Considering that the temporary jetty will be used for wide ranging activities, the proposed width is 10 m allowing the simultaneous passage of a 150 tons crawler crane and a large size truck. The temporary jetty width is shown in Figure 7.2.10.



Source: JICA Study Team

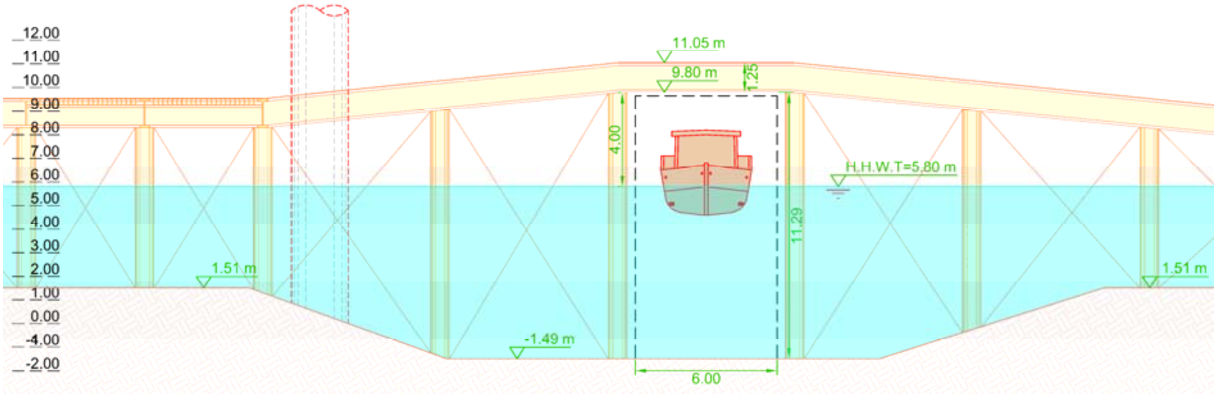
Figure 7.2.10 Temporary Jetty (Cross Section)

3) Passage for Small Boats

For general sections the temporary jetty surface level is proposed at H.H.W.L +1.00 m based on simulations of the sea level from Jan/2015 to 2023 (Max: 5.07 m / Min: -0.24 m). Also, an appropriate clearance was considered for the passage of small fishing boats.

Mumbai Side

There is a navigation route near STA.3+500 mainly used by fishing boats in Mumbai side. The temporary jetty foundations piles shall be located preserving the passage of small fishing boats. On the fishing boat navegation section a freebord of 4m above the H.H.W.L was considered to allow the passage of those fishing boats. The cross section is shown in Figure 7.2.11.

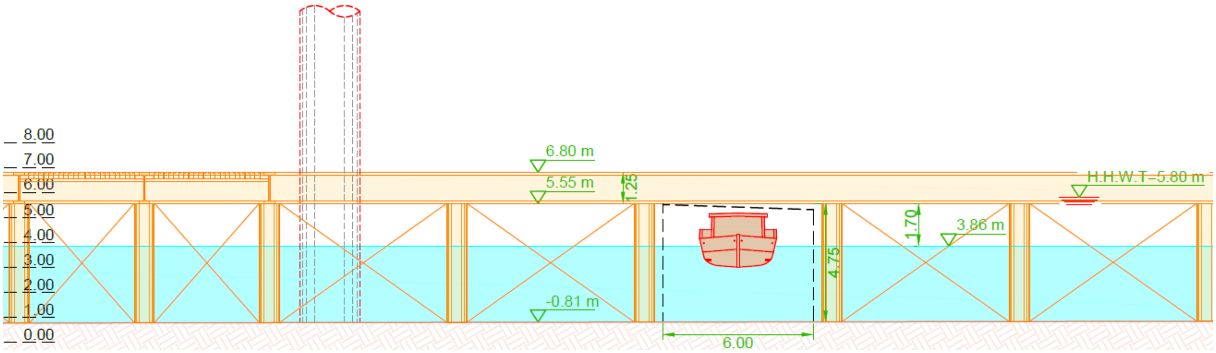


Source: JICA Study Team

Figure 7.2.11 Temporary Jetty (Fishing Boat Passage at Mumbai Side)

Navi Mumbai Side

The temporary jetty surface level is proposed at H.H.W.L +1.00 m, same as Mumbai side. Is possible to guarantee an average tidal window of 18.0 hours per day considering that a typical boat can only cross if the sea level is higher than 0.5m and there is minimum freeboard of 1.5m. If the jetty surface is raised 1.0 m (H.H.W.L +2.00 m), is possible to increase the tidal window for 20.0 hours per day. In this case, the temporary jetty will need a 3% gradient (~33 m length ramp), which is not a problem considering structural or constructive aspects. The fishing boat navigation channel cross section is shown in Figure 7.2.12.



Source: JICA Study Team

Figure 7.2.12 Temporary Jetty (Fishing Boat Passage at Navi Mumbai Side)

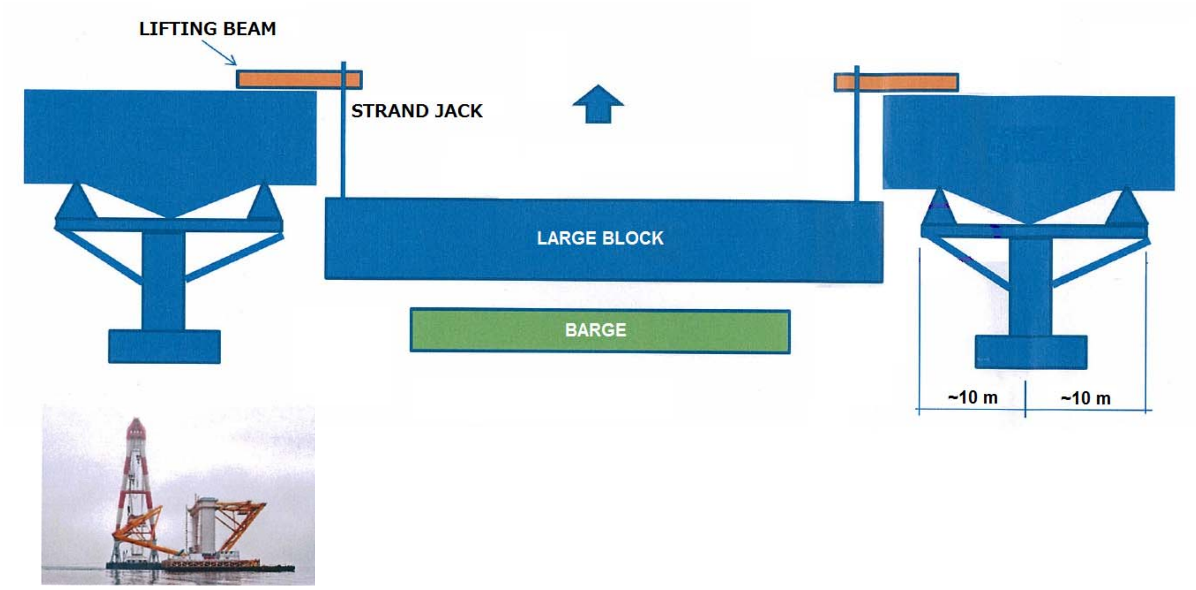
7.2.4 Superstructure

(1) Steel Slab Box Girder (Large Block Erection Method)

For construction of the steel slab box girder (4 sections) is proposed the large block erection method. In particular, transport the large block in a barge and jack up to the final position is one advantage alternative for the 3 sections located in the marine portion. For the remaining section located on a swallow area (STA.3+395 to STA.3+715), crane erection over the temporary jetty using temporary bent is proposed for construction of the side portion; gantry crane erection is proposed for construction of the central portion. Also, floating crane erection can be considered, if leasing from overseas, mobilization costs, etc. can be solved.

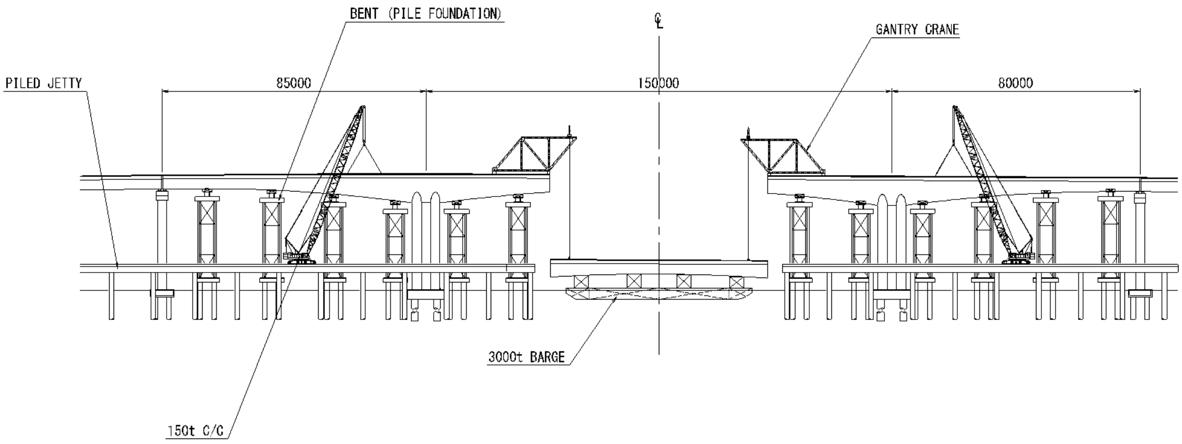
The steps of jack up erection method are described below:

- Fabricating girder segments at the fabrication yard.
- Transporting the girder segment from the fabrication yard to the assembling yard by multi-wheeled trailer or barge.
- Assembling girder segments into a large block.
- Transporting the large block girder from the assembling yard to the site by barge.
- Lifting up the main girder (large block) with a floating crane.



Source: JICA Study Team

Figure 7.2.13 Large Block Erection Method Using Floating Crane



Source: JICA Study Team

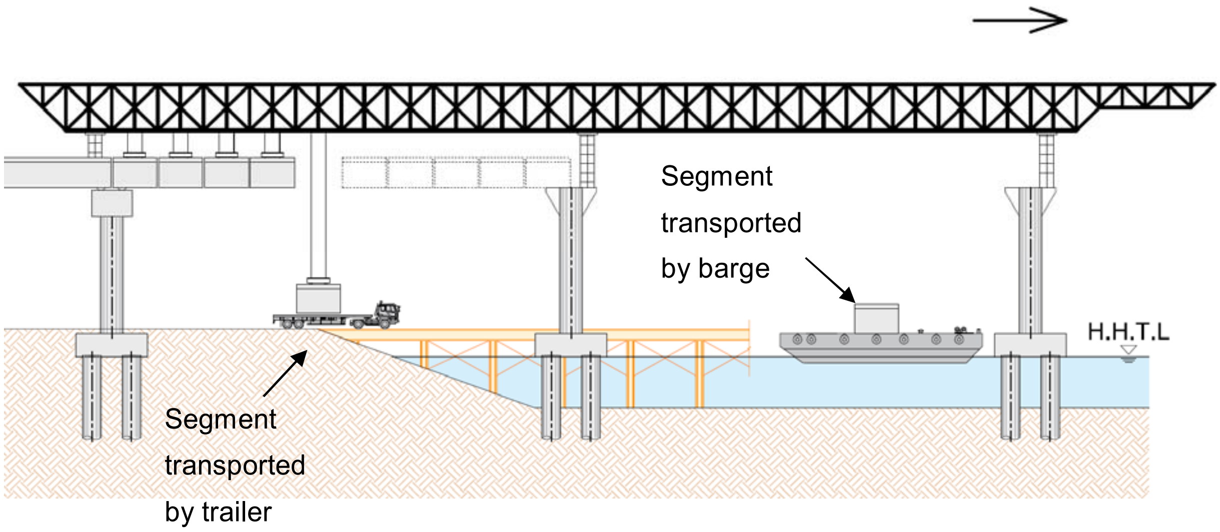
Figure 7.2.14 Central Span Erection Using Gantry Crane

Figure 7.2.15 Large Block Erection Method Using Floating Crane

(2) Span-By-Span Erection Method

The span-by-span erection method has being proposed by others studies aiming to reduce the construction period of the typical PC Box Girder (50 m span) section. The Study Team also recommends this alternative. Cranes used for the installation of the bent in the steel slab box girder sections can be also used for installation of the launching girder. The constructions steps are described below:

- Placing the launching girder over two piers.
- Transporting the girder segments from the precast yard to the site by multi-wheeled trailer (land and temporary jetty portion) or barge (marine portion).
- Placing each segment on the sliding pads and sliding into position.
- Appling epoxy in the joints, inserting the longitudinal prestressing tendons and prestressing the entire span.
- Moving the launching girder to the next span and repeat the cycle until the bridge is completed.



Source: JICA Study Team

Figure 7.2.16 Span-By-Span Erection Method

(3) Full Span Erection Method

Full Span Erection Method is proposed for construction of PC Box Girder 30 m span section in Navi Mumbai side. The basic construction sequence is described below:

- Placing the gantry cranes in position.
- Transporting the girder from the precast yard to the site by multi-wheeled trailer.
- Lifting the main girder into position.

Moving the gantry cranes to the next span and repeat the cycle until the bridge is completed.

Figure 7.2.17 Full Span Erection Method (Using Gantry Crane)

7.3 Procurement Plan

7.3.1 Procurement Plan for Major Materials

The procurement sources of major materials bridge and road works are given in Table 7.3.1. Raw materials, such as cement, aggregate, sand, rebar, strand, etc. can be procured in the domestic market. Steel material, special bearing pad and expansion joint need to be procured on overseas market.

Table 7.3.1 Procurement Source for Major Materials

Materials	Source		Remarks
	Domestic	Overseas	
Earth Works			
Borrow pit	○		
Aggregate	○		
Concrete			
Cement	○		
Course Aggregate	○		
Fine Aggregate	○		
Sand	○		
Fresh Concrete	○		
Rebar	○		
Epoxy rebar	○		
Steel Works			
Steel plate		○	Steel Box Girder with Steel Slab
H shape steel	○		
Bolt & Nut	○	○	
Welding materials	○	○	
Coating		○	Anti-corrosion Coating
Temporary Works			
Deck panel	○		
H shaped steel	○		
Steel bent	○		
Bridge Accessories			
Bearing pad	○		P < 600 t
		○	P ≥ 600 t
Expansion joint	○		e < 300 mm
		○	e ≥ 300 mm
Anchor bar	○		
Waterproof sheet	○		
PC strand	○		
Road Accessories			
Light	○		
Guard rail	○		
Traffic light	○		

Materials	Source		Remarks
	Domestic	Overseas	
Drainage	○		
Ground improvement			
Drain materials	○		
Oil and Emulsion			
Fuel	○		
Asphalt	○		

Source: JICA Study Team

7.3.2 Procurement Plan for Major Equipment

General equipment for civil works can be procured in India domestic market. However, large floating cranes need to be procured on overseas market. The procurement sources for major equipment are shown in Table 7.3.2.

Table 7.3.2 Procurement Source for Major Equipment

Equipment	Procurement Source		Remarks
	Domestic	Overseas	
Backhoe	○		
Bulldozer	○		
Rough terrain crane	○		
Truck crane	○		
Crawler crane	○		
Tower crane	○		
Floating crane		○	
Jack up	○	○	In India: Max 250 t available
Concrete pump machine	○		
Concrete pump vehicle	○		
All casing powered jack rig	○		
Vibration hummer	○		
Vertical drain equipment	○		
Tire roller	○		
Vibration roller	○		
Road roller	○		
Asphalt paver	○		
Vibration compactor	○		
Form traveller	○		
Dump truck	○		
Semi-trailer	○		
Concrete Floating Plant	○		
Asphalt Floating Plant	○		

Source: JICA Study Team

7.3.3 Source of Materials

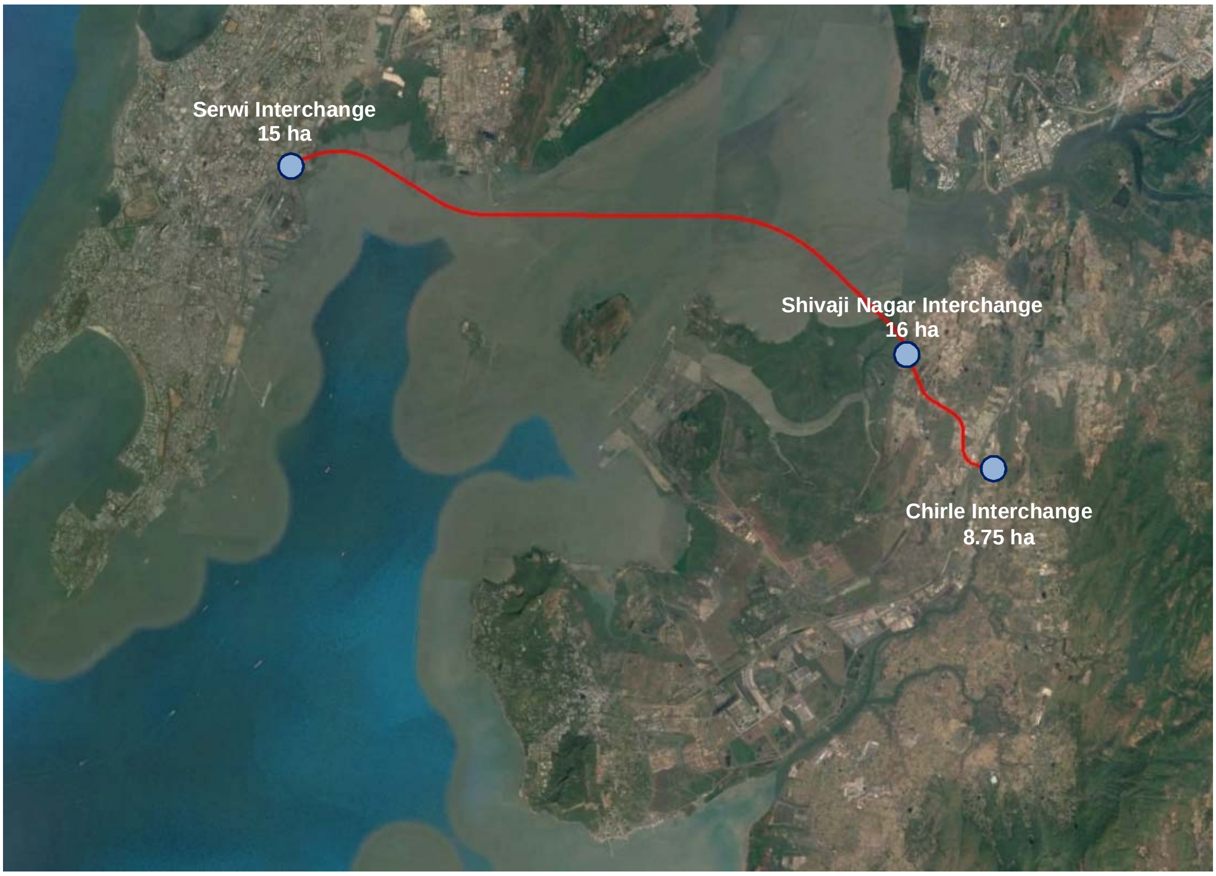
There are stone quarries in the project area and in the vicinities that can guarantee the enough aggregate quantity for this project as shown in Figure 7.3.1. Also, basalt stone from cutting sections in the land section could be used as aggregate. Regarding concrete and asphalt there are many plants in the project area that could provide the necessary quantities. Natural river sand is banned in Maharashtra State (replaced by crushed sand) and trucks transporting aggregate can only enter in Mumbai City at night.

Source: JICA Study Team

Figure 7.3.1 Quarry Location

7.3.4 Construction Yard

This project has approximate 22 km total length and approximately 17 km are located in the marine portion. Considering construction logistics, constructions yards in both Mumbai and Navi Mumbai side are necessary. The near Sewri IC in Mumbai side has 15 ha of the construction yard. The near Shivaji IC has 16 ha and the near Chirle IC has 8.75 ha of the construction yard. The detail of the construction yard is shown in Figure 7.3.2.



＊The casting yard with approximately 15 Ha near Serwi IC is guaranteed, however the others points indicated in the above figure are possible locations identified by JICA Study Team.

Source: JICA Study Team

Figure 7.3.2 Yard Location

7.4 Contract Package

7.4.1 Civil Works

The project can be categorized by the characteristic of the topography. In addition, the project consists of construction of concrete bridge and steel bridge except for earth work section in section 5 of table below.

Table 7.4.1 Topographic Classification in MTHL

Section	Topographic Classification	Depth of the Sea
Section-1 (Sta.0-0.5km)	Land	—
Section-2 (Sta.0.5-5.6km)	Mudflat	0.0 ～ 3.0m
Section-3(Sta.5.6-10.75km)	Sea	4.5 ～ 7.0m
Section-4 (Sta.10.75-16.75km)	Sea (partially Mudflat)	0.0 ～ 4.0m
Section-5 (Sta.16.75-21.84km)	Land	—

Source: JICA Study Team

The package of the project components should be carefully considered. The limitation by the construction contract scale does not exist. However, it shall be decided in consideration of the contract scale of the civil work in past JICA's projects and the contract price which the bidder can prepare a performance bond.

Although the bidder becomes able to prepare the large-scale performance bond by forming the joint venture consisting of several companies, this leads to many construction sections in a package and cooperation and adjustment between the construction sections may become difficult.

In another method, it can be divided by the construction work items. The work items that require high technique in the project are fabrication and large-block erection of steel girders. However, the marine section is dotted with the steel bridges so that it is difficult to divide the contract package by the construction work item (concrete bridge and steel bridge).

Other considerable factor for dividing the contract package is topographic classification and securable construction yard. As for the construction yard, it will be secured by MMRDA with approximately 14 ha at Sewri and more than 15 ha at around Shivaji Nagar IC. However, these faces the shallow marine portion so that temporary jetty and assembly base shall be provided up to deep marine portion and precast segments of PC girder and assembled steel girders can be carried out.

From the above, one or two contract packages become realistic in consideration of the availability of the construction yards. In case of three contract packages, another large construction yard inside ROW of 120m shall be provided on Navi Mumbai side.

The comparative analysis for packaging of the contract is shown in Table 7.4.2.

As a result of analysis for each optional packaging, it is recommended that the project should be implemented with three (3) contract packages in consideration of the contract scale, secured construction yards, increase of the bid participation opportunity and securing of smooth project implementation.

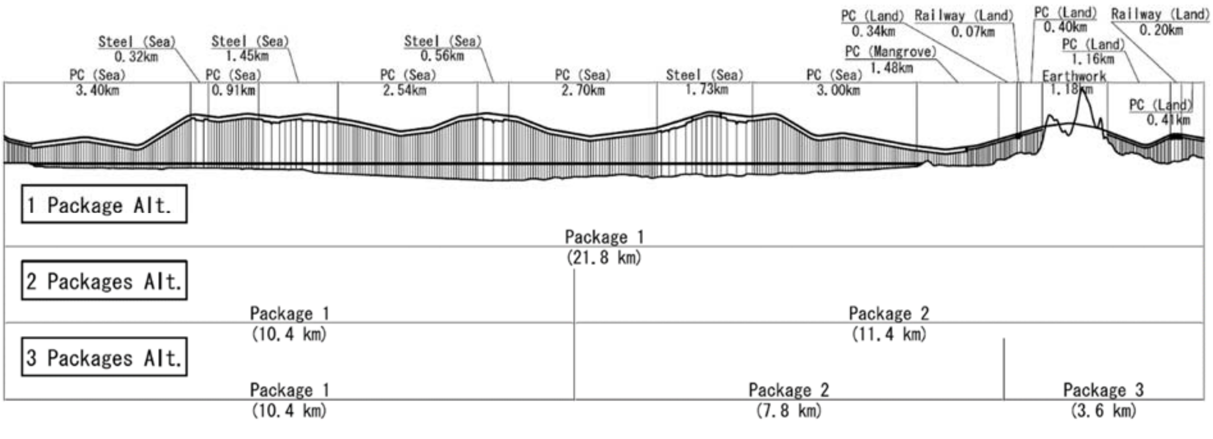


Figure 7.4.1 Options of Contract Package

Table 7.4.2 Analysis for Each Optional Packaging

Item	1 Package Alternative	2 Packages Alternative	3 Packages Alternative
Section	21.8km	Package 1 : 10.4km Package 2 : 11.4km	Package 1 : 10.4km Package 2 : 7.8km Package 3 : 3.6km
Features	- Integrated control is possible. - The largest scale in JICA funded bridge projects.	- Divided two packages to become the same scale each - Large scale in JICA funded bridge projects	- One package is land section on Navi-Mumbai, and marine section is divided in two packages. - Large scale in JICA funded bridge projects
Procurement of Contract	- Construction risks will be increased as the contract scale is large. - Shortest procurement period	- Opportunity of bid participation will be increased. - Longer procurement period than one package.	- Opportunity of bid participation will be increased. - Longest procurement period than others.
Construction Yard	Assumed construction yards will be available.	Assumed construction yards will be available.	Although an Additional construction yard will be required, it can be secured inside ROW.
Work Management	Quality control is easier than others.	Coordination and unification of quality between packages will be required.	Coordination and unification of quality between packages will be required.
Evaluation	Bidder will be limited and the risks of the bidder will be higher than others since the contract scale is large.	Opportunity of bid participation will be increased. Work management will not be complicated.	-The variation of bid will be increased by making a package for land portion. -Opportunity of bid participation will be increased. -Work management will not be complicated. **“Recommended Alternative”**

Source: JICA Study Team

7.4.2 ITS

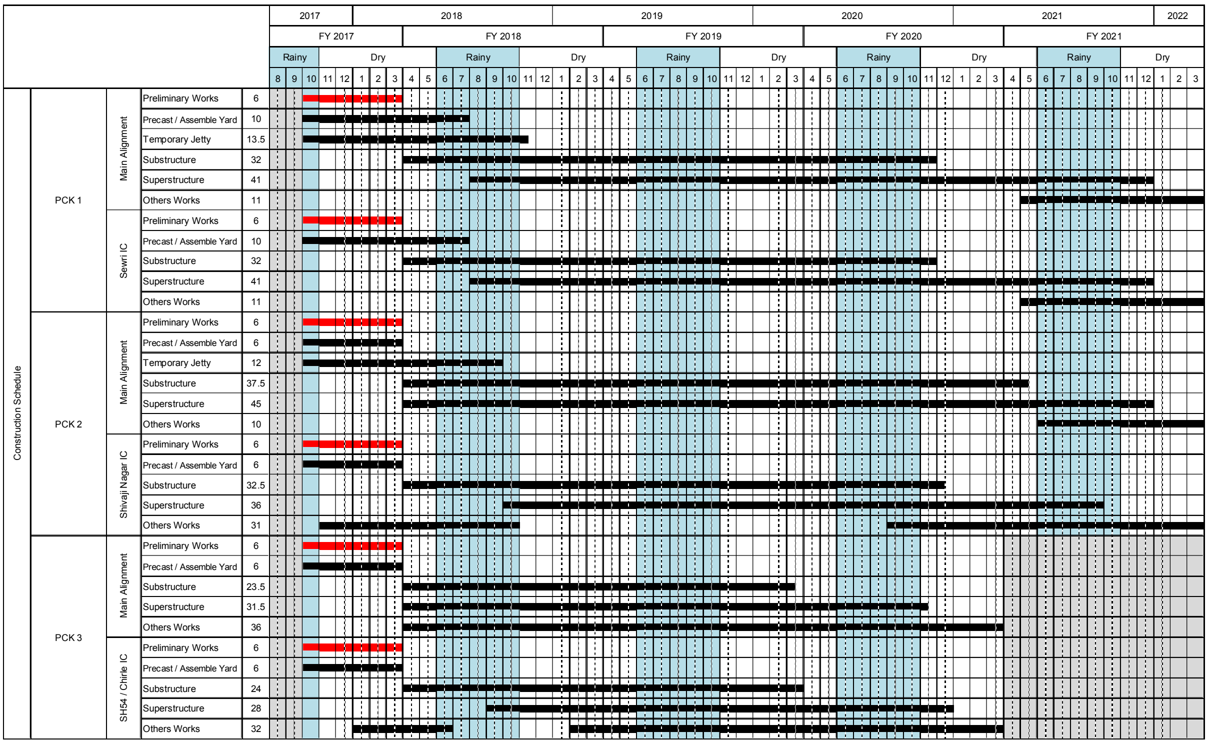
ITS compornent is mainly to procure and install the ITS machinery and materials. Therefor the ITS is separated the package of the project compornent (refer to 6.6).

7.5 Construction Schedule

7.5.1 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 few days that is not possible to work due continuous rains. However, the operation of barge 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 below:

(1) Construction Schedule Resume

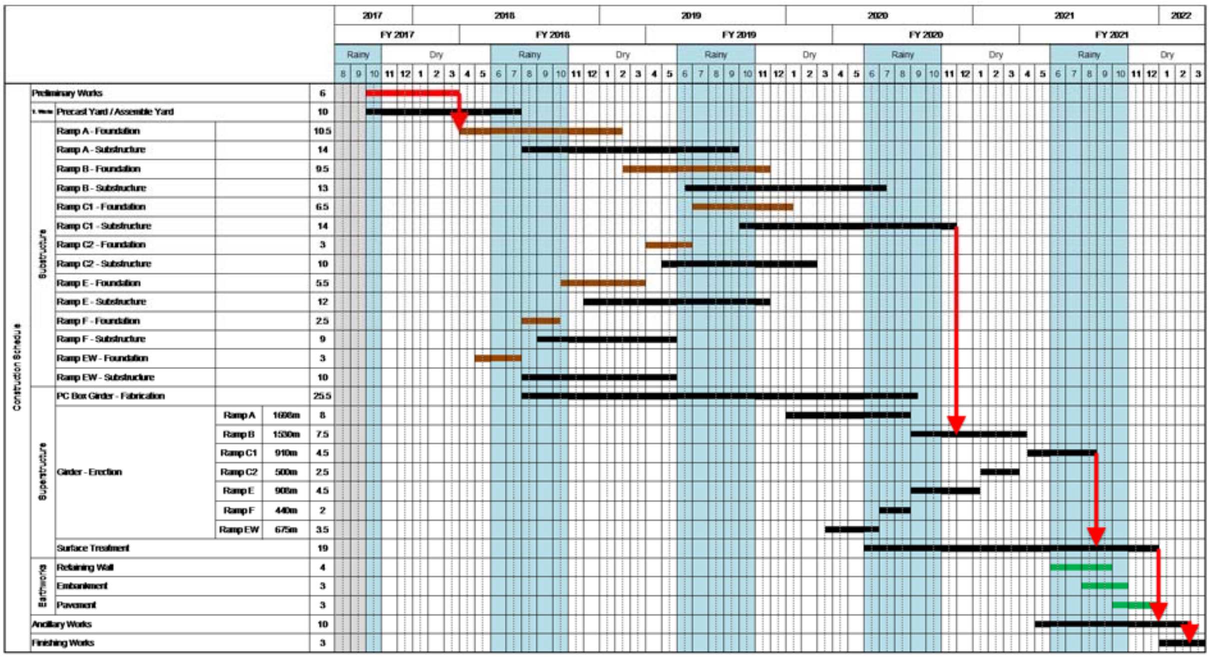


Source: JICA Study Team

Figure 7.5.1 Construction Schedule – Resume

(2) Package 1

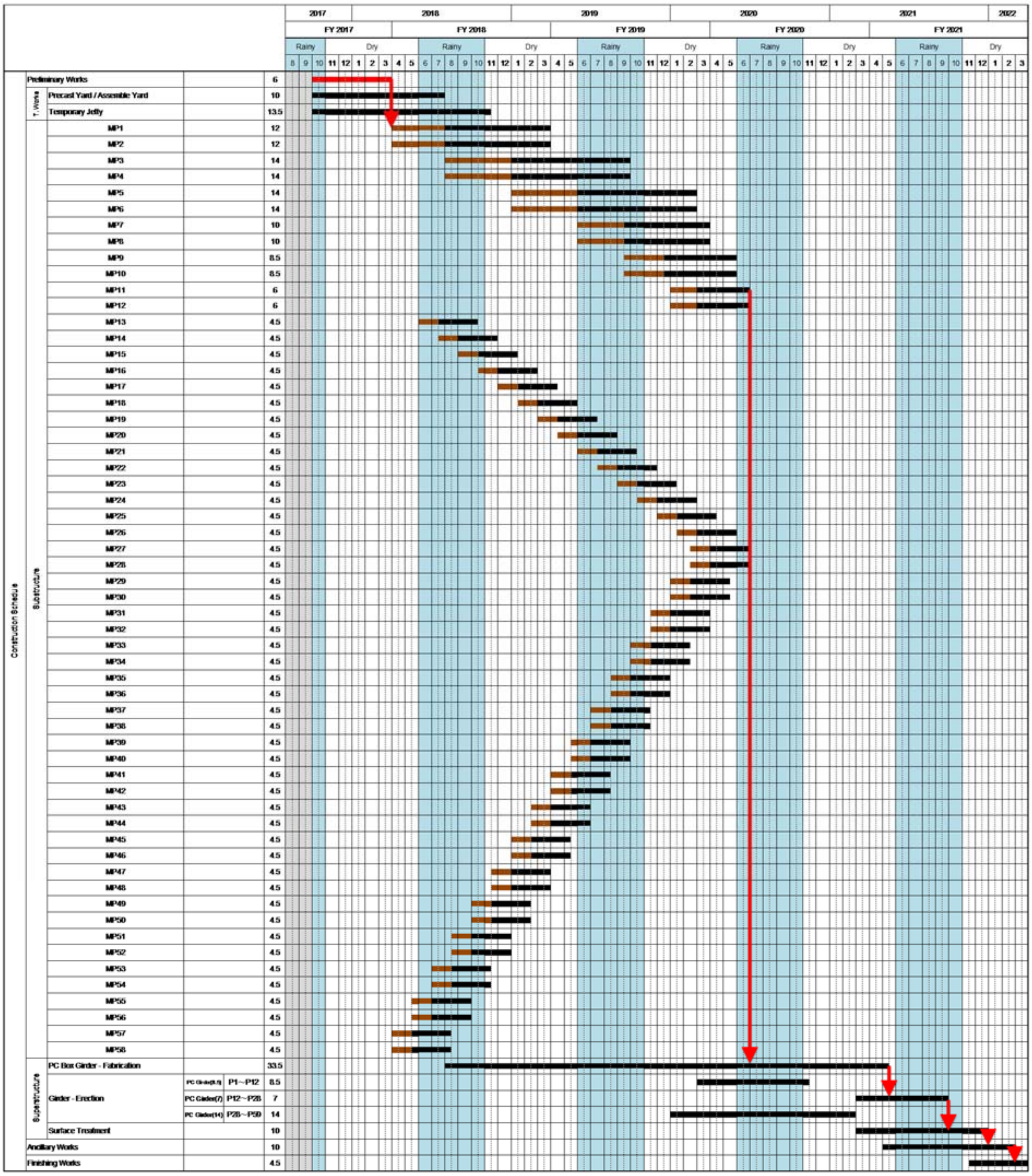
1) Sewri IC



Source: JICA Study Team

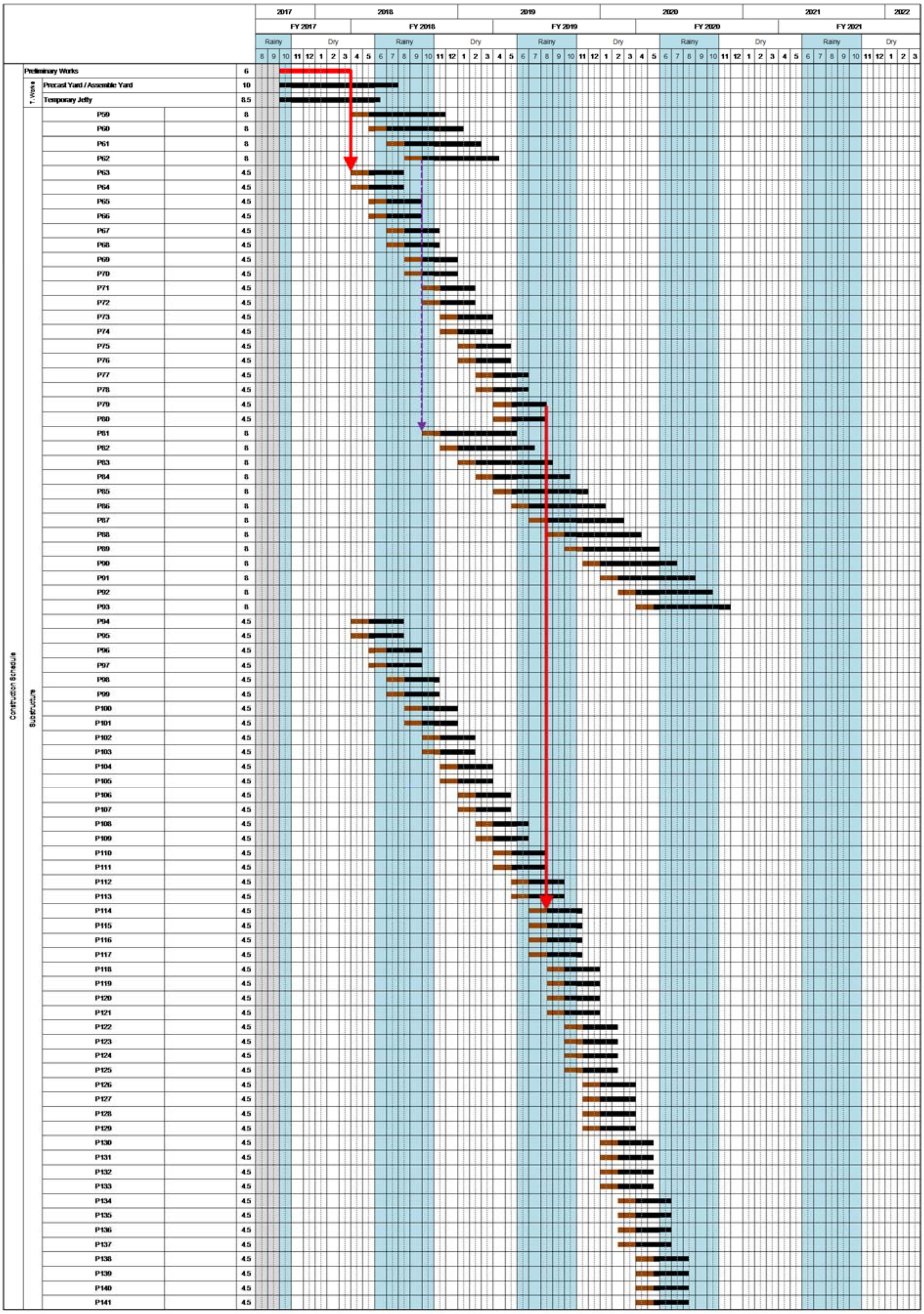
Figure 7.5.2 Construction Schedule – Sewri IC

2) Main Alignment (0+450~10+380)



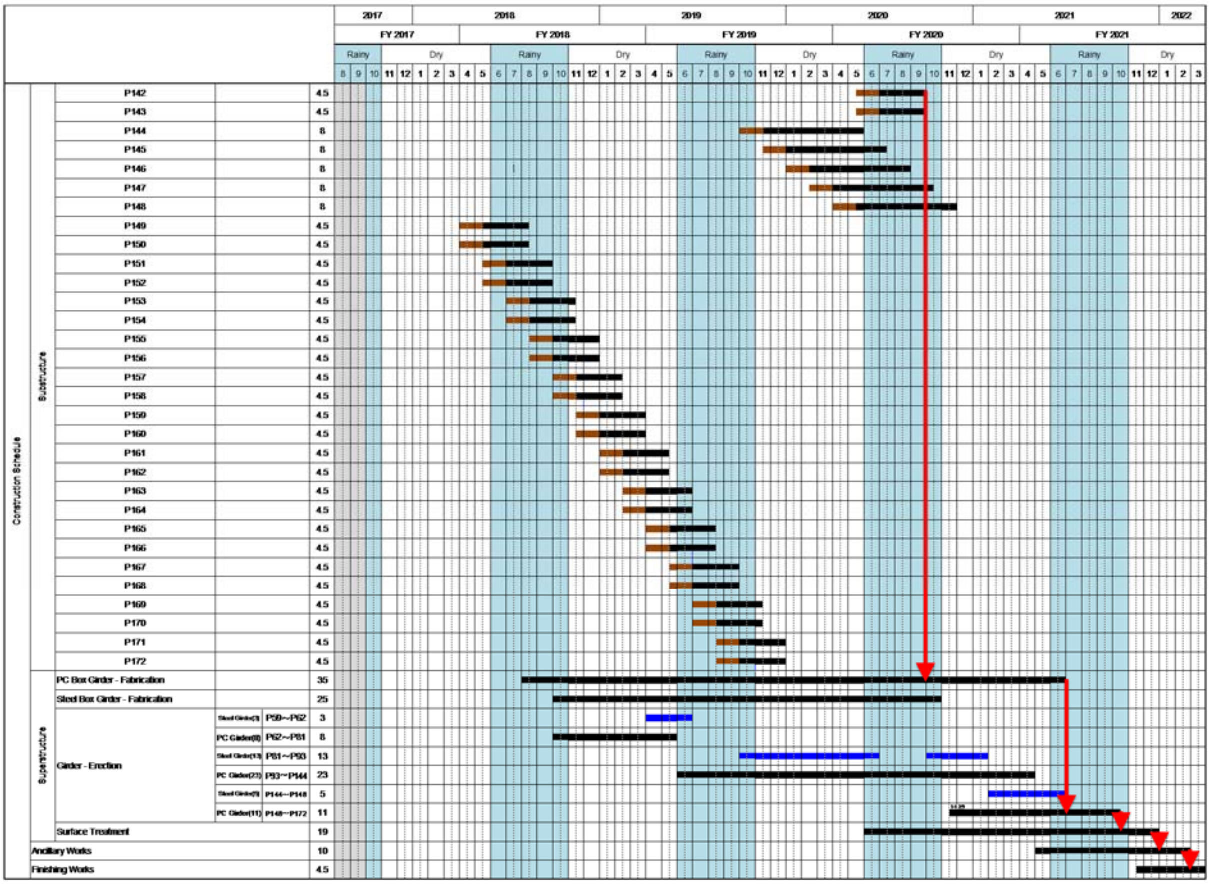
Source: JICA Study Team

Figure 7.5.3 Construction Schedule – Main Alignment (0+450~3+345)



Source: JICA Study Team

Figure 7.5.4 Construction Schedule – Main Alignment (3+345~8+474)

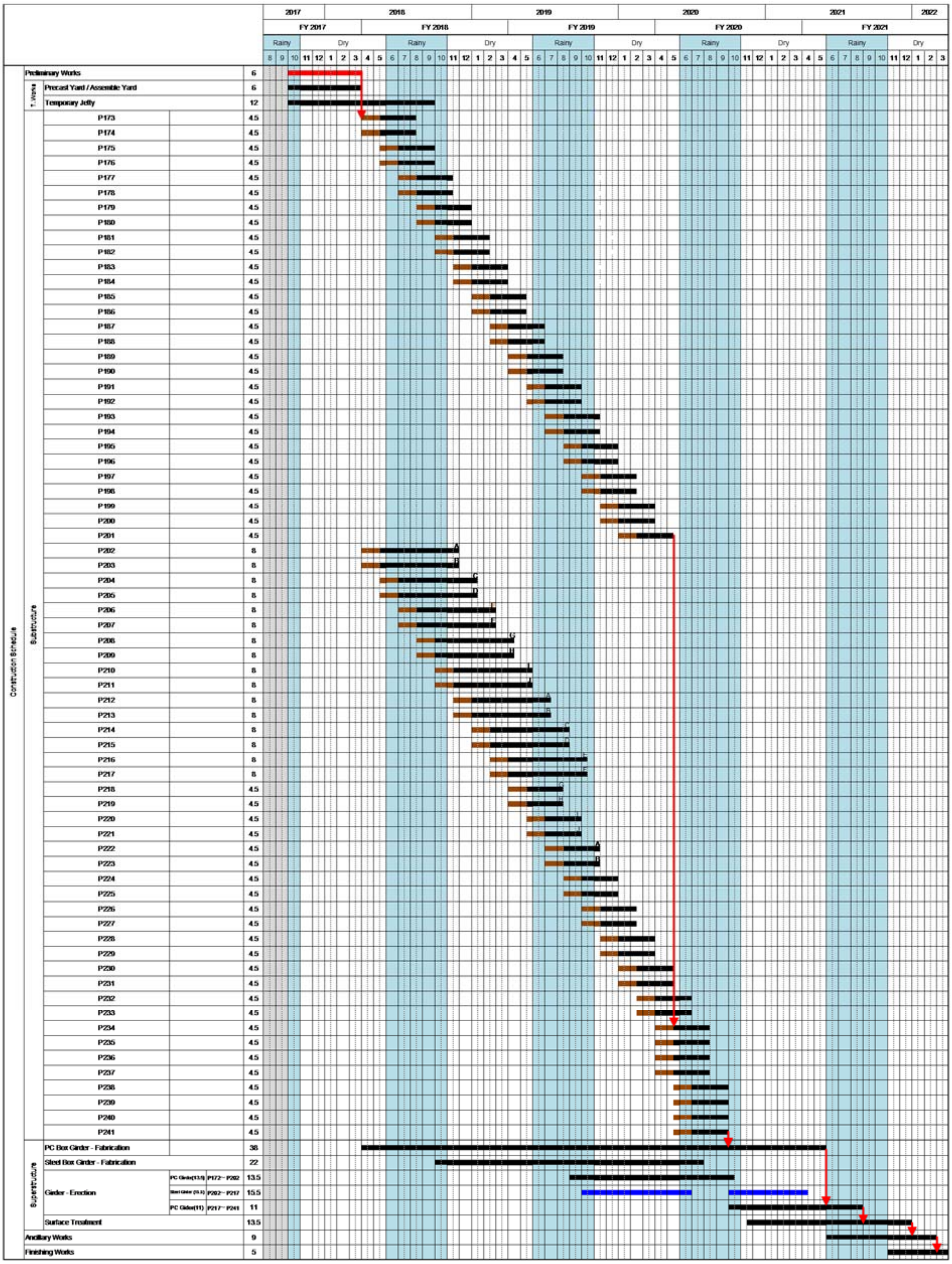


Source: JICA Study Team

Figure 7.5.5 Construction Schedule – Main Alignment (8+474~10+380)

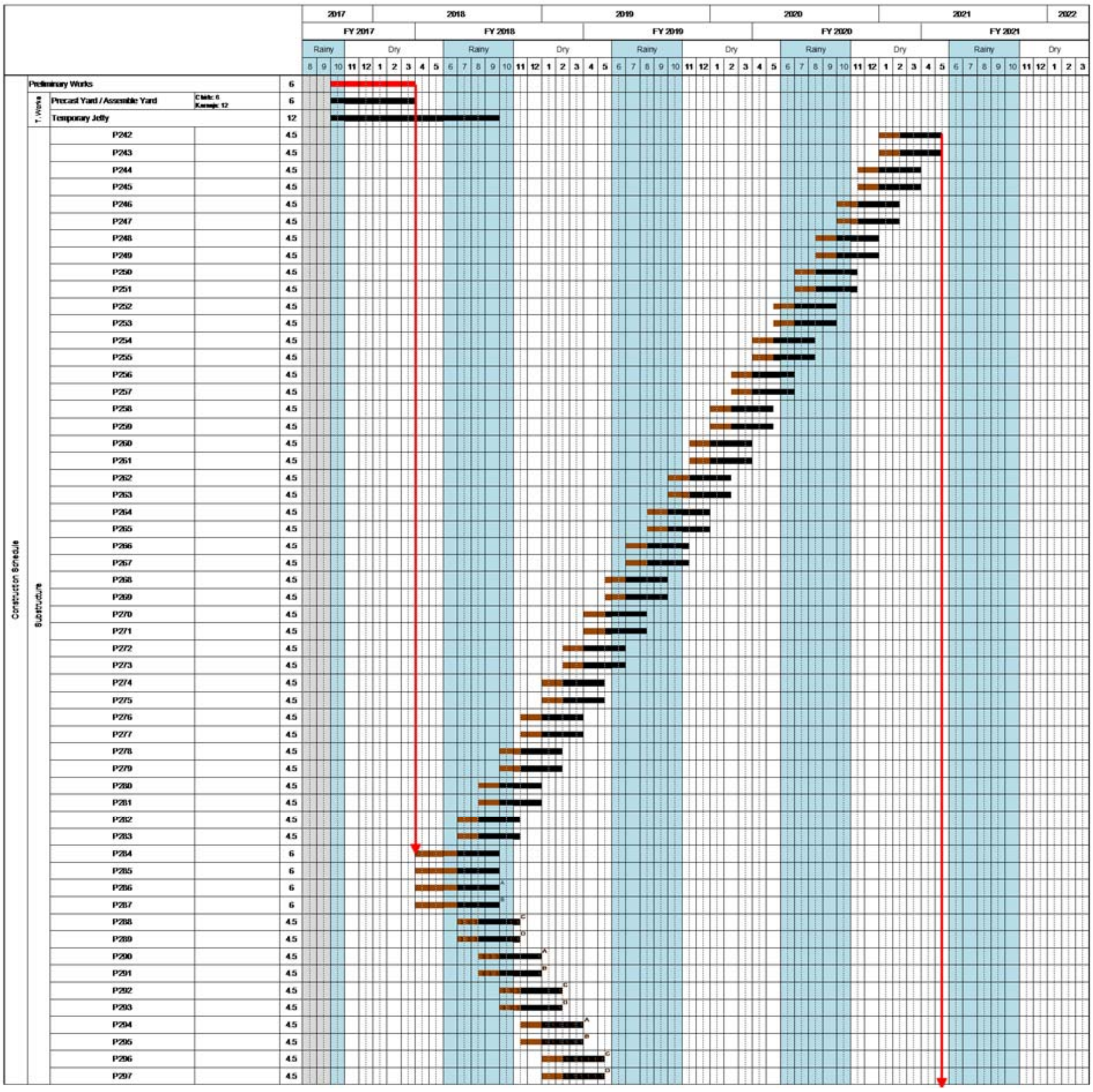
(3) Package 2

1) Main Alignment (10+380~18+187)



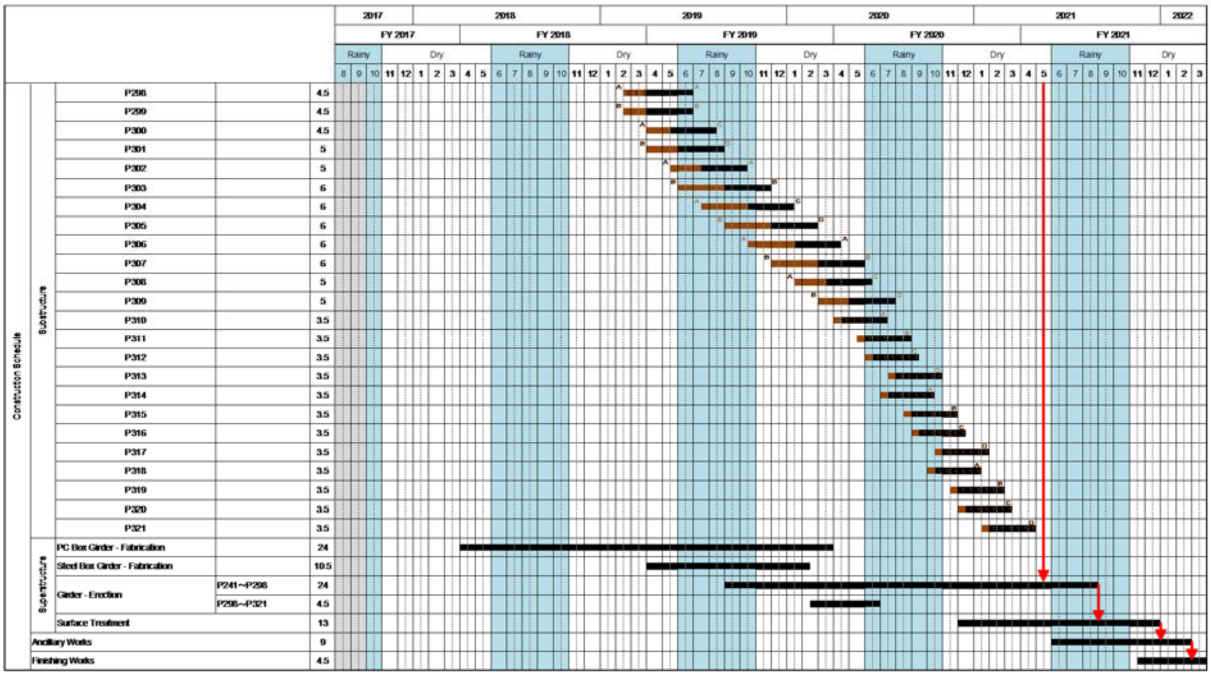
Source: JICA Study Team

Figure 7.5.6 Construction Schedule – Main Alignment (10+380~14+810)



Source: JICA Study Team

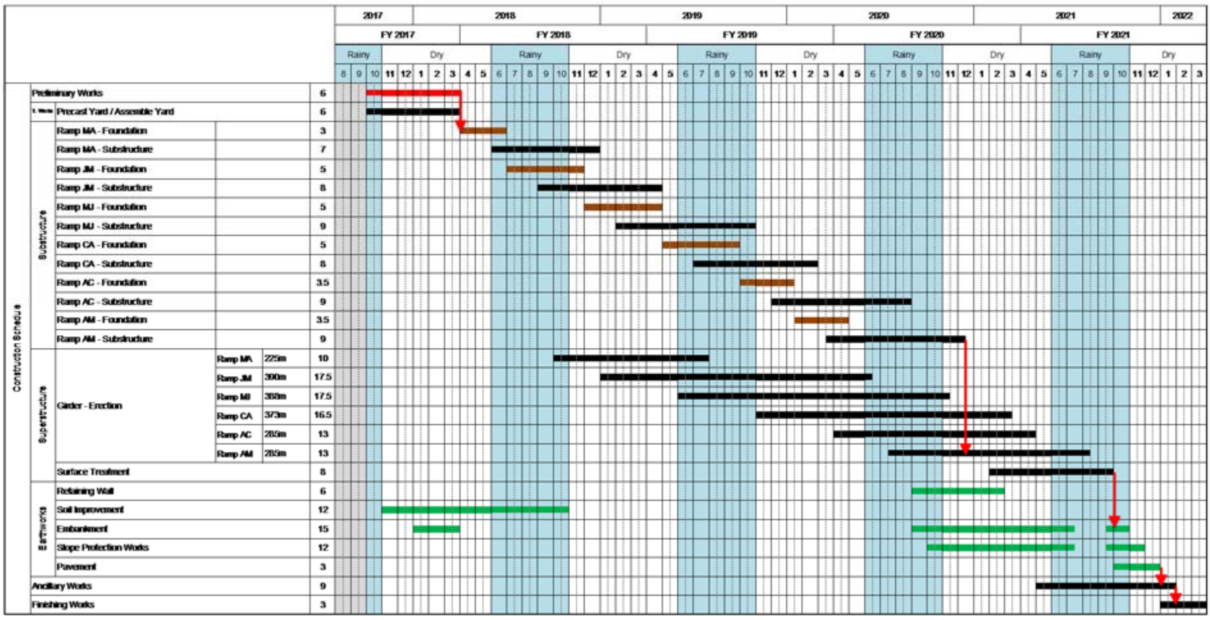
Figure 7.5.7 Construction Schedule – Main Alignment (14+810~17+482)



Source: JICA Study Team

Figure 7.5.8 Construction Schedule – Main Alignment (17+482~18+187)

2) Shivaji Nagar IC

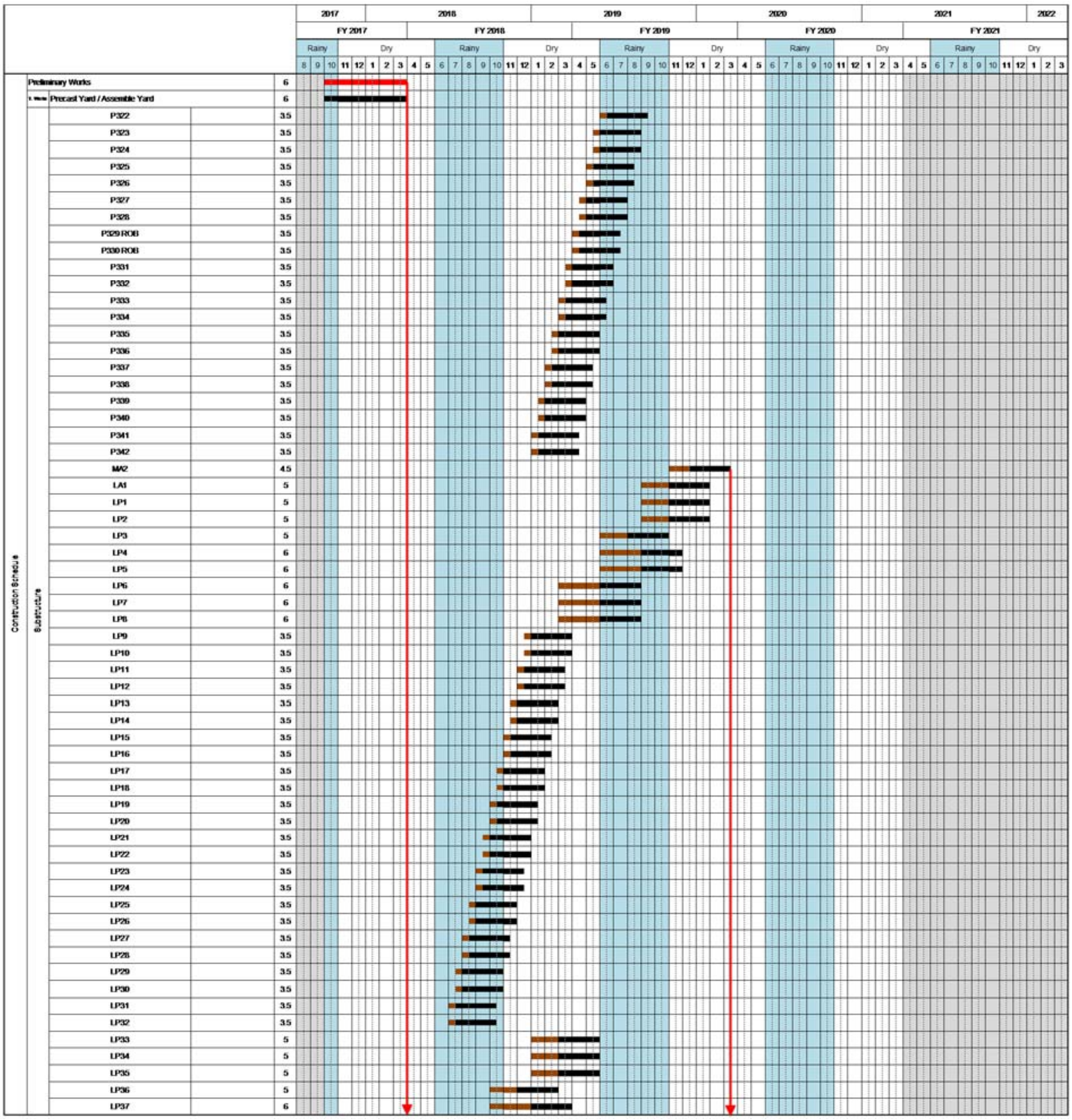


Source: JICA Study Team

Figure 7.5.9 Construction Schedule – Shivaji Nagar IC

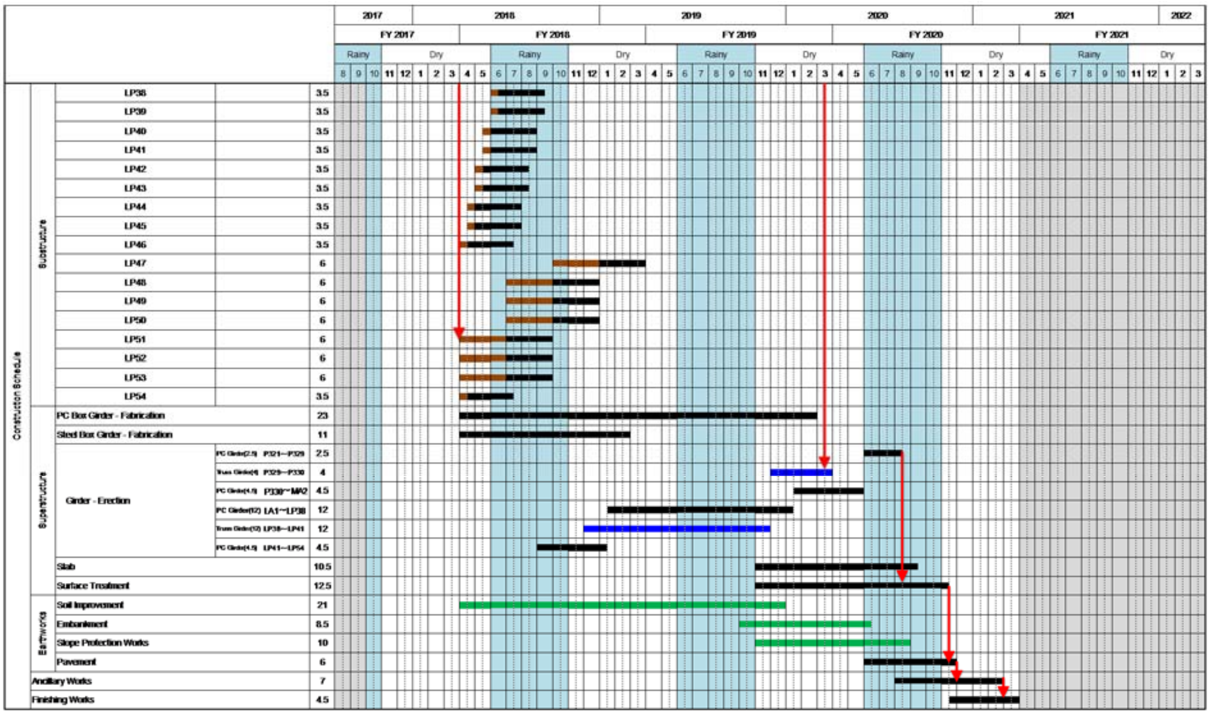
(4) Package 3

1) Main Alignment (18+187~21+834)



Source: JICA Study Team

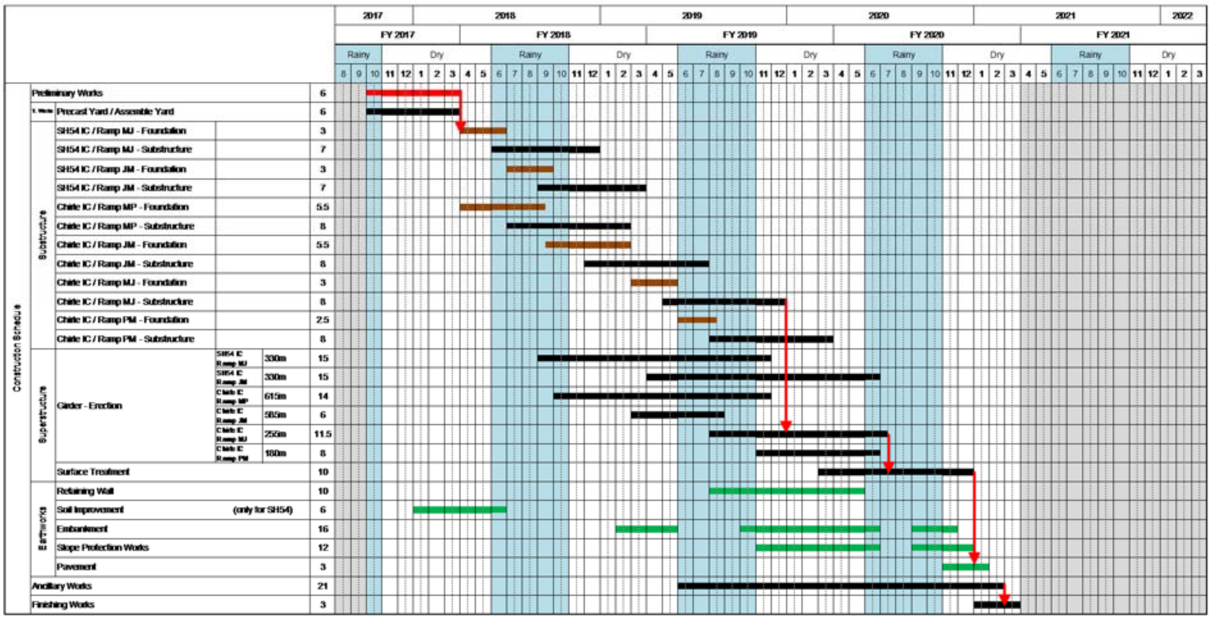
Figure 7.5.10 Construction Schedule – Main Alignment (18+187~21+199)



Source: JICA Study Team

Figure 7.5.11 Construction Schedule – Main Alignment (21+199~21+834)

2) SH54 / Chirle IC



Source: JICA Study Team

Figure 7.5.12 Construction Schedule – SH54 / Chirle IC

8. PROJECT COST ESTIMATE

8.1 Introduction

The project cost estimation is based on the rough quantities obtained from preliminary design for each subproject. The eligible portions of this project are assumed to be funded through the JICA loan scheme. For others expenses, it is assumed that the government of India will allocate funds from the federal budget (also from the state budget) thought MMRDA for the non-eligible portions of the project.

8.2 Condition for Cost Estimation

The conditions for cost estimation are shown in Table 8.2.1

Table 8.2.1 Conditions for Cost Estimation (Draft)

Item	Condition
Date of Estimate	Jan, 2016
Exchange Rate	1 US Dollar (USD) = 121.8 Japanese Yen (JPY) 1 US Dollar (USD) = 66.6 Indian Rupee (INR)
Price Escalation Rate	Foreign Currency Portion: 1.8% Local Currency Portion: 1.3%
Physical Contingency	10% of Construction Cost / 5% of Consultant Fee
Interest During Construction	0.30% of Construction Cost 0.01% of Consultant Fee
Administration Cost	3% of Total Cost
Import Tax	30%
Commercial Tax	6%

Source: JICA Study Team

8.3 Result of Cost Estimates

8.3.1 Construction Cost (Base Cost)

Base construction cost is shown in Table 8.3.1.

Table 8.3.1 Construction Cost (Base Cost)

Packages	Subtotal		Total
	JPY (Million)	INR (Million)	JPY (Million)
Package 1	1,685	65,116	
Package 2	923	48,556	
Package 3	127	13,005	237,405
Package 4	- -	1,444	
Package 5	- -	196	

Source: JICA Study Team

8.3.2 Total Project Cost

The estimated total project cost is shown in Table 8.3.2.

Table 8.3.2 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

8.3.3 Cost Breakdown

(1) Construction Cost

The breakdown of the project costs is shown in Table 8.3.3 and Table 8.3.4.

Table 8.3.3 Breakdown of Project Cost (Package-1)

Item	Unit	Quantity	Unit Price		Total
			Foreign	Local	
			JPY '000	INR '000	JPY '000
Investigation & Tests	L.Sum	1		554,254.8	1,013,637.1
Detailed Design	L.Sum	1		326,292.0	596,732.2
Existing Utilities Relocation	L.Sum	1		838,688.2	1,533,817.1
Temporary Jetty	m²	72,625		63.8	8,473,035.7
Earthworks		1			
Foundation	m	57,412		173.6	18,231,959.6
Substructure	m³	176,851		38.2	12,360,413.9
Superstructure (Concrete)	m²	235,920	7.1	64.0	29,293,613.0
Superstructure (Steel)	t	58,792	764.3		44,932,223.6
Dolphins	No	36		32,434.7	2,135,433.0
Pavement	m²	751,526		0.6	841,140.8
Road Furniture	L.Sum	1		743,648.2	1,360,005.3
Total					120,772,011.5

Source: JICA Study Team

Table 8.3.4 Breakdown of Project Cost (Package-2)

Item	Unit	Quantity	Unit Price		Total
			Foreign	Local	
			JPY '000	INR '000	JPY '000
Investigation & Tests	L.Sum	1		401,665.4	734,577.2
Detailed Design	L.Sum	1		234,190.5	428,294.4
Existing Utilities Relocation	L.Sum	1		607,100.0	1,110,282.0
Temporary Jetty	m²	65,761		88.1	10,591,552.0
Earthworks	L.Sum	1		3,590,652.9	6,566,689.5
Foundation	m	28,537		192.8	10,064,495.2
Substructure	m³	103,984		38.1	7,239,744.3
Superstructure (Concrete)	m²	140,798	6.6	61.4	16,730,351.1
Superstructure (Steel)	t	43,596	768.6		33,507,312.7
Dolphins	No	16		57,129.6	1,671,683.5
Pavement	m²	494,964		0.6	556,700.7
Road Furniture	L.Sum	1		285,261.1	521,693.7
Total					89,723,376.3

Source: JICA Study Team

(2) Quantity

The breakdown of the quantities is shown in Table 8.3.5 and Table 8.3.6.

Table 8.3.5 Breakdown of Quantities (Package-1)

Package 1 (CH. 0+000 to CH. 10+380)

Foundation (Pile)

Diameter of Piles *1	Number of Piers (A)	Number of Piles per Pier (B)	Average Length per Pile (m) (C)	Total Pile Length (m) (=AxBxC)
φ1000	14	8	17.848	1,999
φ1200	174	4	18.869	13,133
φ1500	34	2	19.397	1,319
φ2000	319	4	28.120	35,881
φ2400	44	4	28.864	5,080
				57,412

*1 Pile diameters according to the preliminary design: 1000/1200/1500mm (Sewri IC) and 2000/2400mm (marine area).

Substructure

Number of Pier (A)	Average Concrete Volume/Pier (m3) (B)	Total Concrete Volume (m3) (=AxB)
585	302.309	176,851

Superstructure (Concrete)

Bridge Length of Concrete (m) (A)	Average Area of Cross Section (m2) (B)	Number of Bridge (C) *1	Total Concrete Volume (m3) (=AxBxC)	
7,552	12.175	2	183,885	* Main Alignment
6,441	8.079	1	52,035	* Ramps
			235,920	

*1 There are 2 bridges in the main alignment: inbound lane (Chirle to Sewri) and outbound lane (Sewri to Chirle).

Superstructure (Steel Box Girder Bridge)

Bridge Length of Steel (m) (A)	Average Weight of Steel (kg/m) (B)	Number of Bridge (C) *1	Total Steel Weight (kg) (=AxBxC)	
2,333	12,600	2	58,792,000	* Main Alignment

*1 There are 2 bridges in the main alignment: inbound lane (Chirle to Sewri) and outbound lane (Sewri to Chirle).

Dolphins (Ship collision protection)

Number of Dolphin/Pier (A)	Number of Pier (B)	Total Dolphin Number (=AxB)
4	4	16
5	4	20
		36

Dolphins were considered only on piers adjacent to navegation channel.

Pavement

Pavement Length along Bridge (m) (A) *1	Average Pavement Width (m) (B) *2	Layers (C) *3	Total Pavement Area (m2) (=AxBxC)
16,326	23.016	2	751,526

*1 Total pavement length considering main alignment and ramps.
*2 Average pavement width considering main alignmnet and ramps.
*3 The pavement shall be executed in 2 layers (2 stages)

Noise Barrier

Noise Barrier Length along Bridge (m) (A) *1	Barrier Height (m) (B)	Number of Noise Barrier (C) *2	Total Noise Barrier Area (m2) (=AxBxC)
1,700	2	2	6,800

*1 Considered in the intertidal area to protect Flamingo in Mumbai side.
*2 Considered on both sides of the structure (north and south).

Concrete Barrier

Concrete Barrier Length along Bridge (m) (A)	Average Number of Concrete Barrier (B) *1	Total Concrete Barrier Length (m) (=AxB)
16,326	3.21	52,422

*1 The number shown is an average considerering 4 barriers in the main alignment and 2 barriers in the ramps.

Source: JICA Study Team

Table 8.3.6 Breakdown of Quantities (Package-2)

Package 2 (CH. 10+380 to CH. 18+187)

Earthworks

	Cross Section Area (m2) (A)	Average Height (m) (B)	Length (m) (C)	Total Volume (m3) (=AxB, AxC)
Excavation	69.90		1,490	104,151
Soft Soil Improvement	35,015.14	3.5		122,553

Values based on a typical cross section

	Height (m) (A)	Length (m) (B)	Total Area (m2) (=AxB)
Retaining Wall	6.00	308	1,848

Values based on a typical cross section

Foundation (Pile)

Diameter of Piles *1	Number of Piers (A)	Number of Piles per Pier (B)	Average Length per Pile (m) (C)	Total Pile Length (m) (=AxBxC)
φ1000	133	4	7.141	3,799
φ1200	62	6	7.357	2,737
φ2000	217	4	22.502	19,532
φ2400	32	4	19.289	2,469
				28,537

*1 Pile diameters according to the preliminary design: 1000/1200mm (Shivajinagar IC) and 1200/2000/2400mm (main alignment).

Substructure

Number of Pier (A)	Average Concrete Volume/Pier (m3) (B)	Total Concrete Volume (m3) (=AxB)
444	234.198	103,984

Superstructure (Concrete)

Bridge Length of Concrete (m) (A)	Average Area of Cross Section (m2) (B)	Number of Bridge (C) *1	Total Concrete Volume (m3) (=AxBxC)	
6,077	10.609	2	128,942	* Main Alignment
1,383	8.576	1	11,856	* Ramps
			140,798	

*1 There are 2 bridges in the main alignment: inbound lane (Chirle to Sewri) and outbound lane (Sewri to Chirle).

Superstructure (Steel Box Girder Bridge)

Bridge Length of Steel (m) (A)	Average Weight of Steel (kg/m) (B)	Number of Bridge (C) *1	Total Steel Weight (kg) (=AxBxC)	
1,730	12,600	2	43,596,000	* Main Alignment

*1 There are 2 bridges in the main alignment: inbound lane (Chirle to Sewri) and outbound lane (Sewri to Chirle).

Dolphins (Ship collision protection)

Number of Dolphin/Pier (A)	Number of Pier (B)	Total Dolphin Number (=AxB)
4	4	16

Dolphins were considered only on piers adjacent to navegation channel.

Pavement

Pavement Length along Bridge (m) (A) *1	Average Pavement Width (m) (B) *2	Layers (C) *3	Total Pavement Area (m2) (=AxBxC)
9,190	26.929	2	494,964

*1 Total pavement length considering main alignment and ramps.

*2 Average pavement width considering main alignmnet and ramps.

*3 The pavement shall be executed in 2 layers (2 stages)

Noise Barrier

Noise Barrier Length along Bridge (m) (A) *1	Barrier Height (m) (B)	Number of Noise Barrier (C) *2	Total Noise Barrier Area (m2) (=AxBxC)
627	2	2	2,508

*1 Considered in the intertidal area to protect Flamingo in Navi Mumbai side.

*2 Considered on both sides of the structure (north and south).

Concrete Barrier

Concrete Barrier Length along Bridge (m) (A)	Average Number of Concrete Barrier (B) *1	Total Concrete Barrier Length (m) (=AxB)
9,190	3.673	33,757

*1 The number shown is an average considerering 4 barriers in the main alignment and 2 barriers in the ramps.

Source: JICA Study Team

9. OPERATION AND MAINTENANCE OF MTHL

9.1 Introduction

The Government of Maharashtra appointed the Mumbai Metropolitan Region Development Authority (MMRDA) as the implementing agency of MTHL based on Resolution dated 4 Feb, 2009 and decided that necessary funds will be raised by MMRDA.

In Chapter 9, the existing implementation structure and capability of MMRDA as the implementation agency of MTHL is confirmed, and effective Operation & Maintenance plan is prepared. And Technical cooperation for the capacity development of Operation & Maintenance of MTHL is proposed, as necessary.

9.2 Organization and Capacity of Agencies Responsible for Road, Bridge Maintenance and Operation

9.2.1 The Organization and Responsibilities of MMRDA

MMRDA was established on 26th January, 1975 in accordance with the Mumbai Metropolitan Development Act, 1974 to make Mumbai Metropolitan Region (MMR) a destination for economic activity by promoting infrastructure.

Since the establishment, MMRDA is engaged in long term planning, promotion of new growth centres, implementation of strategic projects and financing infrastructure development.

The following are responsibilities of MMRDA,

Preparation of Regional Development Plans

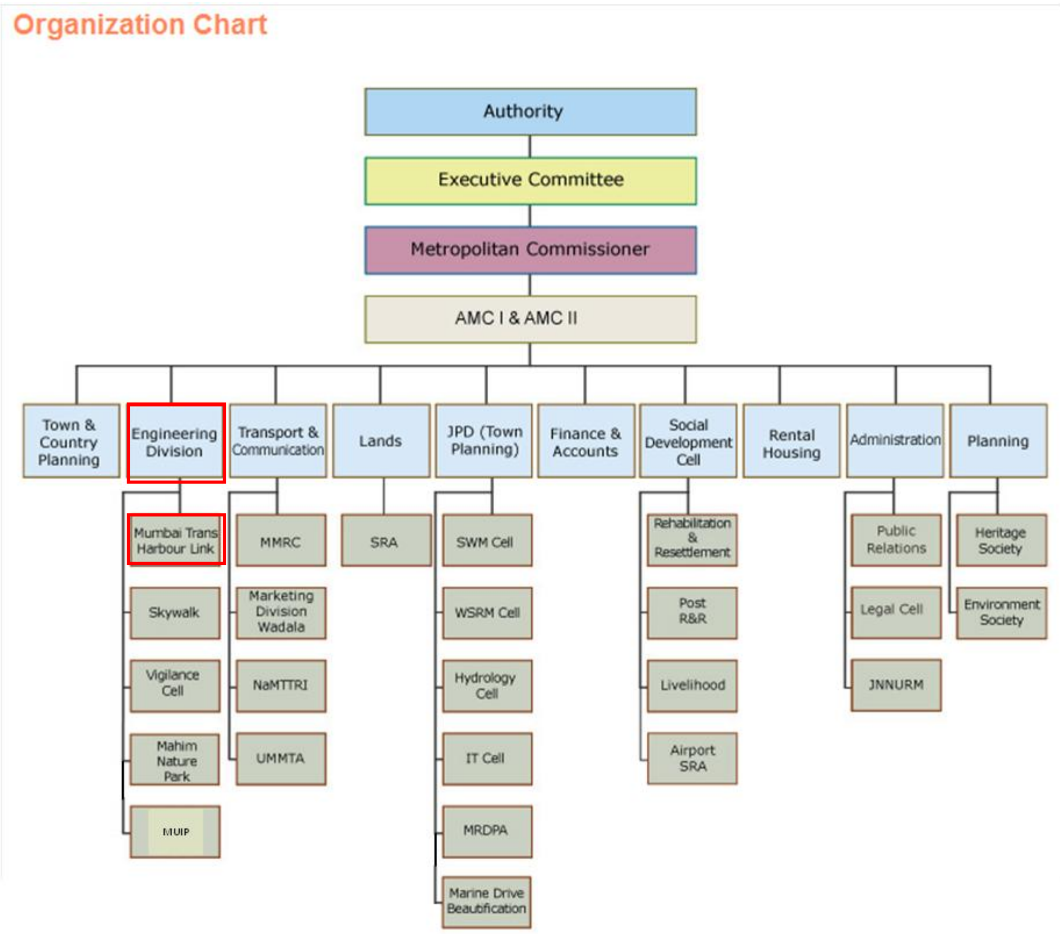
Providing financial assistance for significant regional projects

Providing help to local authorities and their infrastructure projects

Coordinating execution of projects and/or schemes in MMR

Restricting any activity that could adversely affect appropriate development of MMR, etc.In particular, it conceives, promotes and monitors the key projects for developing new growth centres and brings about improvement in sectors like transport, housing, water supply and environment in the Region. MTHL contributes for the improvement of connectivity in MMR to deal with the geographical limitation that is a big obstacle for continuing development of new growth centres. And MMRDA takes responsibility for MTHL directly, and carries it out.

Organization Chart of MMRDA is shown in Figure 9.2.1. Authority, headed by Chief Minister, Government of Maharashtra is the highest policy making body of MMRDA which supervises and controls all the activities of MMRDA. Executive Committee, headed by the Chief Secretary, Government of Maharashtra provides technical guidance to MMRDA. The implementation structure consists of ten (10) Divisions under the Metropolitan Commissioner. The project section of MTHL is established in the Engineering Division. The number of the engineers of the whole MMRDA, Engineering Division who are in charge of MTHL are shown in Table 9.2.1. The implementation structure in the Construction phase of MTHL, which is proposed by MMRDA, is shown in Table 9.2.2, and the officers class and numbers of engineers in Engineering Division in the Construction phase and the Operation and Maintenance phase of MTHL, which is proposed by MMRDA, is shown in Table 9.2.3 respectively.



Source: MMRDA

Figure 9.2.1 Organization Chart of MMRDA

Table 9.2.1 Number of Engineers

Organization/Division/Unit	Number (Person)	
	Engineers	Outsourced engineers
MMRDA (Total)	66	0
Engineering Division (Total)	54	0
MTHL Unit	5	0

Source: MMRDA

Table 9.2.2 Number of Officer of Project Implementation Unit (Proposed by MMRDA)

Division	Number (Person)	
	Key personnel	Support Staff
Engineering	26	4
Finance & Accounts	4	2
Social Development Cell	2	2
Lands	3	1
Administration	3	9
Environmental	2	0
Total	40	18

Source: MMRDA

Table 9.2.3 Officers Class and Numbers of Engineers in Engineer Division (Proposed by MMRDA)

Position Name	Number of Engineers (person)	
	Construction Stage	O / M Stage
Chief Engineer	1	1
Superintending Engineer	2	1
Executive Engineer	6 (civil), 2 (electric)	2
Deputy Engineer	6 (civil), 2 (electric)	4
Assistant Engineer	6 (civil), 2 (electric)	4
Total	27	12

Source: MMRDA

9.2.2 Financial Situation of MMRDA

The trend of allocated budget and expenditure for MMRDA Roads for the past 5 years are shown in Table 9.2.4.

Table 9.2.4 Allocated Budget and Expenditure for MMRDA Roads (Million INR)

Items	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Budget	8,250	9,900	4,380	6,700	7,230
Expenditure	6,280	9,040	7,760	7,020	7,000

Source: MMRDA

9.2.3 Implementation Capability of MMRDA

Engineering division of MMRDA which is responsible for MTHL undertakes various projects to provide better urban infrastructure and improve traffic and transportation scenario in MMR. The following are the major projects implemented by Engineering Division.

Mumbai Urban Infrastructure Project：MUIP

In consideration of the increasing population in Mumbai and future travel demand, this project is aimed at improving road network over 450 km in length consisting of elevated roads, flyovers, subways and footpaths. MUIP is estimated to cost approximately 37,400 million INR. This project period was 2005 through 2011.

Mumbai Urban Transport Project：MUTP

This project aimed to improve the transport infrastructure and services in Mumbai through investment in suburban railway projects, local bus transport, new roads, bridges, pedestrian subways and traffic management activities. MUTP is estimated to cost approximately 8,620 million INR. This project period is 2005 through 2015.

Eastern Freeway

In consideration of the present situation, future traffic and other transportation demands, this project aims to help smoothen traffic and reduction of traffic congestion in Mumbai. This project is to construct a freeway of 16km in length consisting of elevated corridor, bridges, flyovers, over bridge and twin tunnel which is first of its kind in Mumbai. This project is estimated to cost approximately 8,690 million INR. In addition, MTHL shall be connected to the freeway in Mumbai side.

Source: MMRDA

Figure 9.2.2 Mumbai Urban Infrastructure Project (MUIP)

Source: MMRDA

Figure 9.2.3 Mumbai Urban Tranceport Project（MUTP）

Source: MMRDA, Study Team

Figure 9.2.4 Eastern Freeway

MMRDA has various experiences of major road projects, and it is considered that MMRDA can perform the appropriate correspondence as the implementation agency in the implementation of MTHL. However, MMRDA does not have the experience of Operation and Maintenance of roads so far, because MMRDA handed over the roads developed by them to Municipal Corporations. It is necessary to examine the appropriate organization structure to maintain the marine bridge and operate the toll road, in consideration of the special features of MTHL, which are marine, long span bridge and access controlled toll road. An appropriate plan for Operation and Maintenance structure of MMRDA should be examined based on the organization of MSRDC which is an implementing agency of the toll road business in Maharashtra.

9.2.4 Maharashtra State Road Development Corporation Ltd. (MSRDC)

MSRDC is a corporation established and fully owned by the Government of Maharashtra and has been incorporated as a limited company under the Companies Act 1956 on 2nd August 1996. MSRDC mainly deals with the properties and assets comprising movables and immovables including land, road projects, flyover projects, toll collection rights and works under construction which vested with the State Government and were under the control of the Public Works Department.

MSRDC was the contracting agency of MTHL at the time of the bid before and responsible for the study of MTHL in 2004. According to the interview survey, MSRDC has jurisdiction over road projects of the BOT method, and MMRDA has juridiction over projects not involving BOT. Therefore MSRDC does not seem to have possibilities to operate MTHL in the future, due to the change of the project scheme from BOT method to EPC method.

One of the achievements of MSRDC is “Bandra Worli Sea Link (BWSL)” which is the link road connecting the western suburbs with the island city of Mumbai. This project is similar to MTHL containing marine bridges and toll road. Hence the administration of BWSL will be useful for the examination of the Operation & Maintenance Plan of MTHL. For the description of BWSL, see section 6.6.2.

9.3 Operation and Maintenance Plan

9.3.1 General Situation of Operation and Maintenance

(1) Divisions in Charge of Operation and Maintenance

The Engineering Division, MMRDA, will be in charge of Operation and Maintenance of MTHL after the completion of its construction. In the interviews with MMRDA, MMRDA intends to outsource the Operation and Maintenance of MTHL. In addition, Concessionaires generally under take Operation and Maintenance of toll roads in MMR.

(2) General Situation of Operation and Maintenance Works

As the general situation of Operation and Maintenance works of toll roads in MMR, the situations of MSRDC's Project, "Bandra Worli Sea Link (BWSL)" and "Mumbai Pune Expressway" are mentioned below. For the description of these projects, see section 6.6.2.

1) Inspection and Maintenance

In the interviews with MSRDC and MEP Infrastructure Developers Ltd. (the Concessionaire) which are operating and maintaining BWSL, the inspection and maintenance of road structures are conducted following the Operation and Maintenance Manuals of BWSL made by the Concessionaire based on relevant laws and regulations of India and the IRC guidelines.

In the Operation and Maintenance Manual of BWSL which has similar conditions with MTHL as marine bridge, inspection can be categorized into three classes: Routine, Extended and Special inspection. Beside these categorized inspections there are casual and cursory observations made by users of structure or by people who happen to be in the vicinity. This information can be of major importance, when reporting accidents and acts of vandalism.

(a) Routine Inspection

Routine Inspection should be carried out methodically at regular intervals (1 year, 3 years, 5 years: middle intervals of Extended Inspection). The inspector should work through a checklist prepared, based on this maintenance manual and take into account the local operating and environmental conditions of the bridge, by the concerned Bridge Maintenance Department.

The inspection should be carried out by a trained inspector under the supervision of an experienced bridge engineer. The result should be compared with the results of previous inspections. A written report should be made of the condition of the structure and various parts. The inspection is primarily a visual inspection and, in general, special access, plant or equipment other than those already provided in design should not be necessary.

(b) Extended Inspection

Extended Inspection should be carried out in place of second routine inspection (regular intervals: 2 years, 6 years, 10 years). The aim of Extended Inspection is to carry out a close and more intensive examination of all elements of the structure. This may require special access platforms or mounted vehicles such as cherry pickers, remote viewing techniques, taking core and samples, and in-situ non-destructive testing. In addition to the Checklist of Routine Inspection, special instructions applicable to the different parts of the bridge should be considered.

(c) Special Inspection

A number of circumstances may arise in between Routine Inspection and Extended Inspection that warrant additional inspections to be carried out. These include:

- Exceptional high wind or storms that may have caused bridge damage, including vibration of the stay cables.
- Abnormally heavy loads passing over the bridge.
- Collision with bridge piers, parapets, pylons, stay cables and abutments by errant vehicles or marine vessels.
- Accidents on the bridge involving spillage of toxic, flammable or corrosive material.
- An earthquake of sufficient magnitude to have caused damage to parts of the bridge.
- Acts of vandalism or unlawful violence serious enough to have damaged parts of the bridge.
- Exceptional high waves that may have caused damage to bridge piers.

As Maintenance works, measures of Correction and Prevention for the assumed Problems of each component (Piles, Pile Cap, Piers, Pylons, Bridge Bearings, Bridge Deck, Stay Cables, Stay Anchorages, Abutments, Concrete Kerb, Metal crash barrier, Hand Rail, Bituminous wearing course, Bridge Drainage System, etc.) are covered in Operation and Maintenance Manual. In addition, the improvement works are not included in the concession agreement, and MSRDC places an order for these works to specialized companies separately.

In the case of Mumbai Pune Expressway, 94.5km in total length is divided into 3 sections (about 30km/ section), and Inspection and Maintenance works are carried out in each Maintenance Office.

2) Traffic Management

(a) Traffic Patrol

In the case of BWSL, the road patrol by motorcycle is always conducted for 24 hours in 3 shifts by 2 people. In addition, it is not aimed for traffic management, but security guards are arranged every 500 m in median.

In the case of Mumbai Pune Expressway, Accident Management Team, Incident Management Team, Medical Team and Recovery Team are placed for the 24 hours in 3 shifts in each Maintenance Office of 3 sections like the inspection and maintenance works.

(b) Road side facilities and Traffic Control Centre

In the case of BWSL, the road side facilities such as CCTV (Closed-Circuit Television), ECB (Emergency Call Box), ATCC (Automatic Traffic Counter‑cum-Classifier Detection Systems) and VMS (Variable Message Signs) are installed, and 2 operators always monitor the road facilities of BWSL for the 24 hours by 3 shifts in a traffic control room.

In the case of Mumbai Pune Expressway, ECB and ATCC are installed, and an operator always arranged for the 24 hours by 3 shifts in a call centre.

For the description of Road side facilities and Traffic Control Centre of BWSL and Mumbai Pune Expressway, see section 6.6.2.

(c) Vehicles for Traffic Management

It is common in toll roads in India that following the concession agreement, the Concessionaire should assign 1) road patrol vehicles, 2) ambulances and 3) towing vehicles to a section of road that it manages and operate them. In fact, IRB Infrastructure Developers Ltd., the Concessionaire of Mumbai Pune Expressway, has assigned these vehicles to the sections and other crane trucks used together with other sections, and they manage and have been operating them there.

In the case of BWSL, the ambulance is not assigned because there are emergency facilities near.

Source: JICA Study Team

Figure 9.3.1 Vehicles for Traffic Management (Mumbai Pune Expressway)

3) Toll Management

For the Toll Management, Electronic Toll Collection system (ETC) is installed together with the manual toll collection by toll collectors at each toll plaza. For the description of Toll Management System, see section 6.6.2.

At the toll plaza of BWSL, 4 lanes are only for ETC among 16 lanes in total, and 12 remainder lanes are the manual toll collection. In each toll booth, the members are comprised of a Toll collector in the toll booth, a Lane assistant who delivering the receipt of the rate and the change out of the toll booth and a Security guard. Under the instruction of a Supervisor, the members conduct the manual toll collection for the 24 hours by 3 shifts. In addition, the placement system of the staff in the toll plaza is similar in Mumbai-Pune Expressway, too.

9.3.2 Operation and Maintenance Plan

(1) Outline of Operation and Maintenance

An appropriate plan for the Operation and Maintenance of MTHL after the completion of its construction is prepared. 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. Table 9.3.1 shows the outline of each of the four components mentioned above and the general supervision.

Table 9.3.1 Overview of Road Operation and Maintenance

Component	Outline of the work
General supervision	- Preparation of an overall project plan and a budgetary management plan - Supervision of budget allocation and work execution - Preparation of required standards and manuals - Supervision of the contracts on the maintenance work - Coordination with relevant organizations - Supervision and monitoring of the execution of the Inspection, Maintenance, Toll Management and Traffic Management
Inspection	- Preparation of an inspection plan - Execution of the inspection work (including emergency inspections) - Compilation of results of inspections and evaluation of structural soundness - Prioritization of the need for repair of damage - Preparation of a medium- to long-term maintenance plan - Preparation of a road improvement plan and a disaster management plan - Monitoring and evaluation of completed repair and improvement works
Maintenance	- Preparation of a maintenance plan - Execution of the maintenance work - Emergency work (repairing of road surface, accident restoration and disaster restoration, etc.) - Execution of improvement and maintenance works - Monitoring and evaluation of completed maintenance and repair works
Toll Management	- Preparation of a plan required for the toll collection including the number of lanes (toll booths) at the tollgate, assignment and work shifts of toll collectors, toll collection method and toll collection facilities - Toll collection - Counting, verification, storing and depositing of collected tolls - Responses to inquiries from road users
Traffic Management	- Collection of traffic information from relevant organizations and road users - Regular road patrols and road patrols at the time of emergency - Collection of traffic and road information from the road patrols and the roadside facilities (including CCTV cameras and emergency telephones etc.) - Provision of road and traffic information on variable-message signs (VMS), radio and the Internet - Initial responses (including traffic regulation and notification to the traffic police and fire services) to incidents (including accidents, objects on roads and stalled vehicles) - Warning and enforcement of regulations to traffic violators in cooperation with the traffic police

(2) Inspection and Maintenance Plan

1) Inspection Plan

MTHL will be characterized by a large proportion of bridge structures. In order to maintain MTHL in the condition which ensures safe and comfortable driving for a long term, damage to the structures shall have to be detected at an early stage with regular inspection and repaired.

The types and frequency of the inspection works are planned in Table 9.3.2, in reference to Operation and Maintenance Manual of BWSL and inspection works conducted on expressways in Japan.

Table 9.3.2 Types of Inspection for MTHL (recommended)

Items	Interval	Type of inspection
Initial Inspection	After completion of the construction and /or Before opening the road	Short range visual
Regular Inspection	5 / 2 weeks *	On board visual
Routine Inspection	1 / year	Distant visual Short range visual, if necessary
Detailed Inspection	1 / 5 year	Short range visual Examination by touch Hammering inspection Non-destructive inspection
Special Inspection	As needed	Short range visual

* In the case traffic volume is more than 25,000 /day and less than 50,000 /day

(a) Initial Inspection

Initial Inspection is the inspection by short range visual and hammering, etc to grasp the initial situation after the completion of the structure. The inspection is conducted before commencing services. The records such as defects, disasters and repairs under construction are gathered and it is necessary to arrange basic data about the initial situation of the structure to utilize it for the later maintenance.

(b) Regular Inspection

Regular Inspection is to detect the conditions of the structure on a daily basis to secure safe road traffic, and to prevent the damage to third parties. And to detect damages and changes in the conditions at an early stage and decide whether or not it is necessary to take appropriate measures against the damages and changes to maintain roads in the ordinary sound conditions.

The inspection is conducted in the range capable of confirmation from carriage way mainly by looking from the car and feeling while driving, and the condition is identified getting off the car as needed.

(c) Routine Inspection

Routine Inspection is to examine general conditions of structures in the entire section on a regular basis concerned with focus on damages at locations such as intersections and road sides where damage to third parties is expected to occur.

The inspection is conducted in the entire section mainly by distant visual observation from the outside of carriage way and short range visual observation as needed.

(d) Detailed Inspection

Detailed Inspection is to examine each member of structures in detail on a regular basis, and evaluate/diagnose the condition of structures with occurrence or progress of damages, to grasp structural soundness, to ensure safe road traffic and to prevent damage to third parties.

The inspection is conducted basically by short range visual observation with palpation, hammering and nondestructive inspection as needed.

(e) Special Inspection

Special Inspection is conducted when the need for the inspection arises, e.g. when a problem which cannot be solved with the regular inspection has been detected, when an severe damage has been detected on a structure, at the time of an extreme wheather condition or a traffic accident or a naural calamity.

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 demanded. For reference, Maintenance Requirements are shown in Table 9.3.3 and Table 9.3.4.

Table 9.3.3 Maintenance Requirements for Roads (Reference)

Nature of defect or deficiency	Time limit for repair / rectification
■Carriageway and paved shoulders	
Breach and blockade	Temporary restoration of traffic within 24 hours Permanent restoration within 15 days
Roughness value exceeding 2,750 mm in a stretch of 1 km	180 days
Pot holes	48 hours
Cracking in more than 5% of road surface in a stretch of 1 km	30 days
Rutting exceeding 10 mm in more than 2% of road surface in a stretch of 1 km	30 days
Bleeding / Skidding	7 days
Raveling / Stripping of bitumen surface exceeding 10 m^2	15 days
Damage to pavement edges exceeding 10 cm	15 days
Removal of debris	6 hours
■Hard / earth shoulders, side slopes, drains and culverts	
Variation by more than 2% in the prescribed slope of camber / cross fall	30 days
Edge drop at shoulders exceeding 40 mm	7 days
Variation by more than 15% in the prescribed side (embankment) slopes	30 days
Rain cuts / gullies in slopes	7 days
Damage to or silting of culverts and side drains during and immediately preceding the rainy season	7 days
Desilting of drains in urban / semi-urban areas	48 hours
■Road side furniture including road signs and pavement marking	
Damage to shape or position; poor visibility or less of retro-reflectivity	48 hours
■Street lighting and telecom (ATMS)	
Any major failure of the system	24 hours
Faults and minor failures	8 hours
■Trees and plantation	
Obstruction in a minimum head-room of 5 m above carriageway or obstruction in visibility of road signs	24 hours
Deterioration in health of trees and bushes	Timely watering and treatment
Replacement of trees and bushes	90 days
Removal of vegetation affecting sight line and road structures	15 days
■Rest areas	
Cleaning of toilets	Every 4 hours
Defects in electrical, water and sanitary installations	24 hours
■Toll plaza(s)	
Failure of toll collection equipment or lighting	8 hours
Damage to toll plaza	7 days
■Other Project Facilities and Approach roads	
Damage or deterioration in Approach Roads, (pedestrian facilities, truck lay-bys, bus-bays, bus-schelters, cattle crossings, traffic aid posts, medical aid posts and other works)	15 days

Table 9.3.4 Maintenance Requirements for Bridge (Reference)

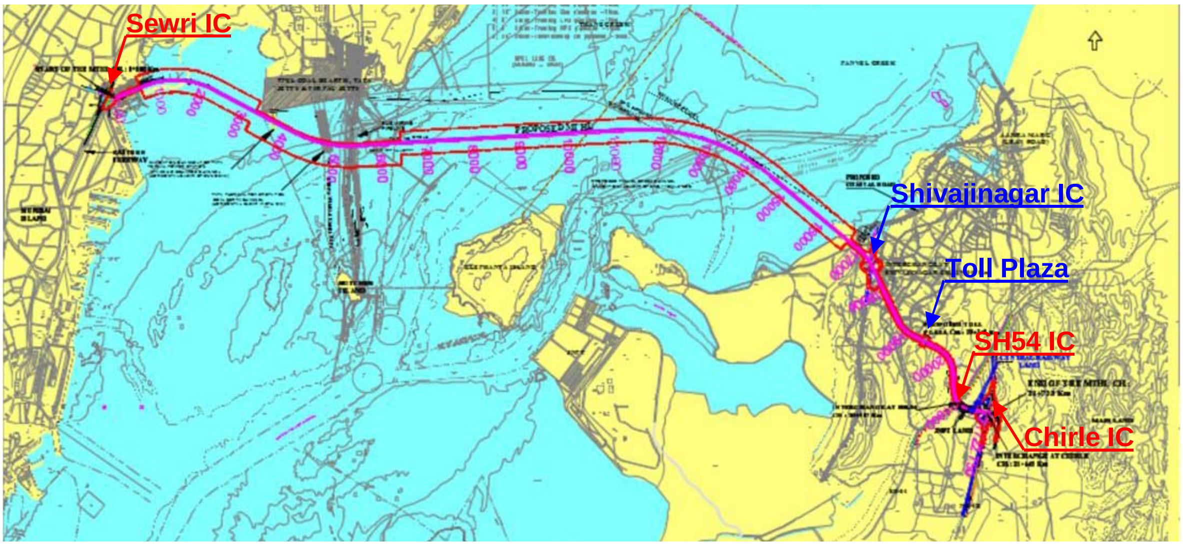
Nature of defect or deficiency	Time limit for repair / rectification
■Super structure of bridges	
Cracks	Temporary measures within 48 hours Permanent measures within 45 days
Spalling / scaling	15 days
■Foundations of bridges	
Scouring and/or cavitation	15 days
■Piers, abutments, return walls and wing walls of bridges	
Cracks and damages including settlement and tilting	30 days
■Bearings (metallic) of bridges	
Deformation	15 days
■Joints in bridges	
Loosening and malfunctioning of joints	15 days
■Other items relating to bridges	
Deformation of pads in elastomeric bearing	7 days
Gathering of dirt in bearings and joints; or clogging of spouts, weep holes and vent-holes	3 days
Damage or deterioration in parapets and handrails	3 days
Rain-cuts or erosion of banks of side slopes of approaches	15 days
Damage to wearing coat	15 days
Damage or deterioration in approach slabs, pitching, apron, toes, floor or guide bunds	30 days
Growth of vegetation affecting the structure or obstructing the waterway	15 days

(3) Toll Management Plan

1) Location of Toll Plaza

The interchanges connecting with MTHL are planned in one place (Sewri IC) of Mumbai side and three places (Shivajinagar IC, SH54 IC, Chirle IC) of Navi Mumbai side, so four places in total.

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



Source: JICA Study Team

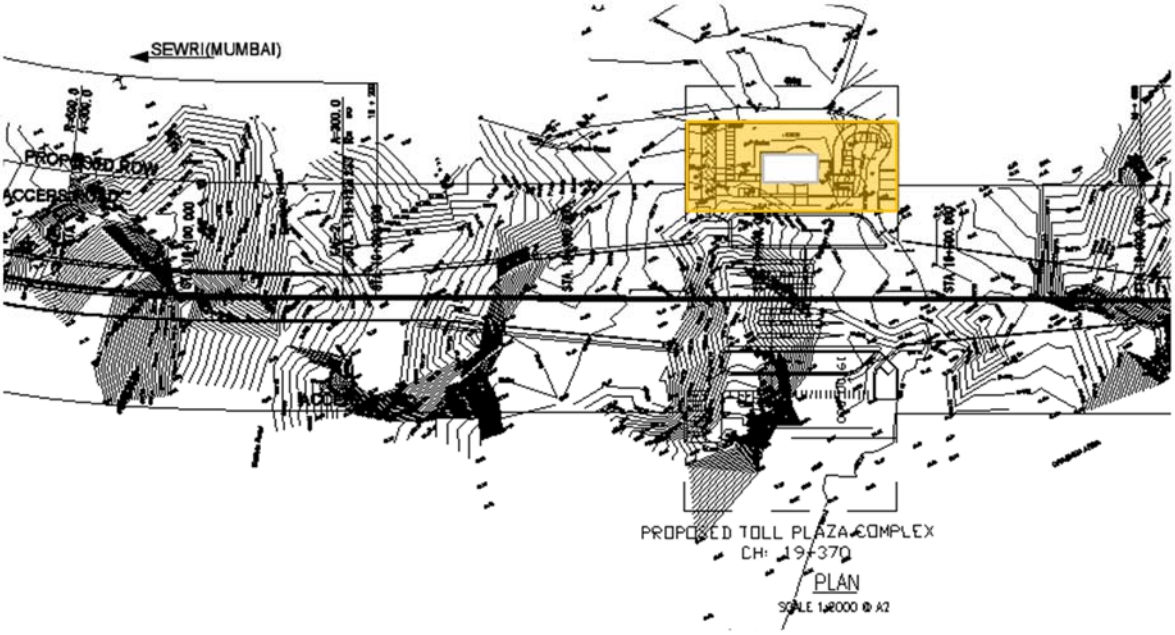
Figure 9.3.2 Location of IC and Toll Plaza

2) Layout Plan for the Toll Plaza

Main Toll Plaza shall be located in main line (CH:19+370). And the layout plan and points of concern of Shivajinagar IC Toll Plaza are shown in 6.6.3.

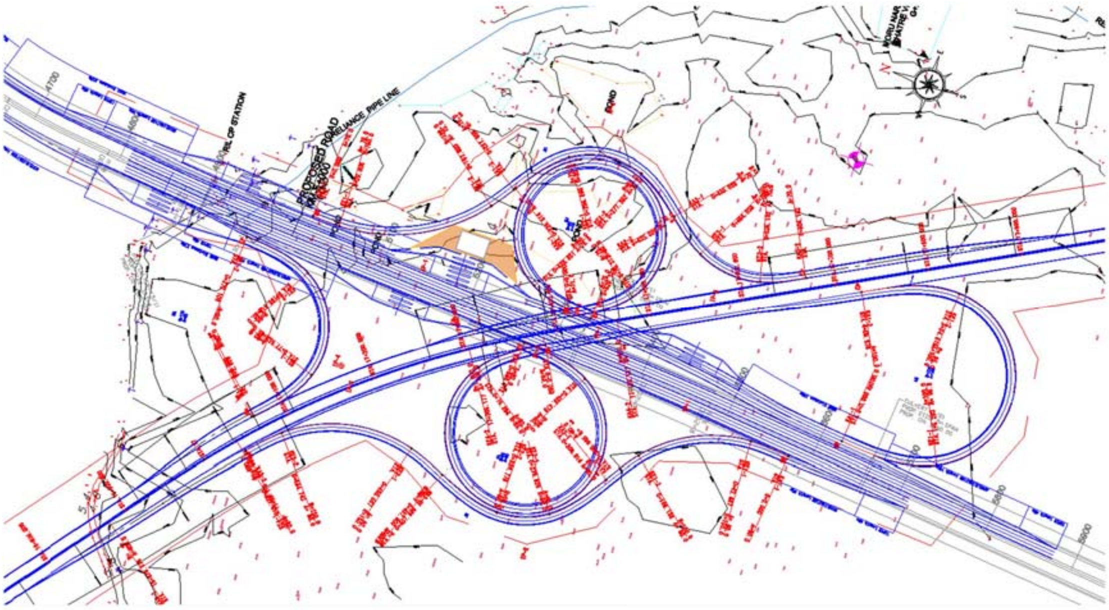
Facilities in the Toll Office are mainly for its functions of the monitoring of the toll collection, the management of the collected toll and as a rest place for toll collectors and as a place for customer care. As these functions do not require a large-scale facility, the operation office of the MTHL is designed to be established at the same location and in the same building as the toll office. The recommended layout plan of Main Toll Office is shown in 9.4.1 with Maintenance Office.

The Shivajinagar IC Toll Office should be located near Shivajinagar IC Toll Plaza within ROW considering accessibility to Toll Plaza, conditions in CRZ clearance and mangrove area. Therefor detailed location plan and drawings of Toll Office need to be prepared in next stage. The recommended layout plan of Shivajinagar IC Toll Office is shown in Figure 9.3.5.



Source: JICA Study Team

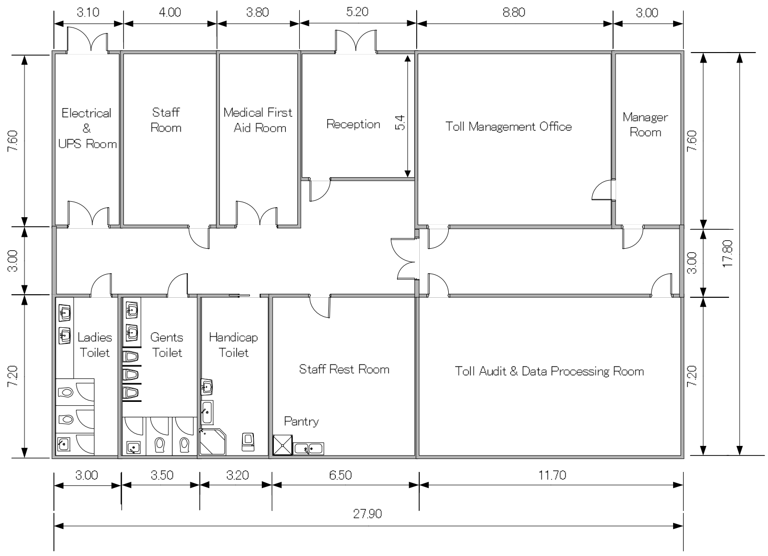
Figure 9.3.3 Location of IC and Main Toll Office (in Operation Office) (Reference)



Source: JICA Study Team

Figure 9.3.4 Location of Shivejinagar IC Toll Office (Reference)

TOLL PLAZA BUILDING FLOOR PLAN : REFERNCE
(SHIVAJI NAGAR INTERCHANGE)
CONCEPTUAL GRORUND FLOOR PLAN



Source: JICA Study Team

Figure 9.3.5 Layout Plan for the Toll Plaza (Recomended)

3) Facilities and Equipment in Toll Plaza

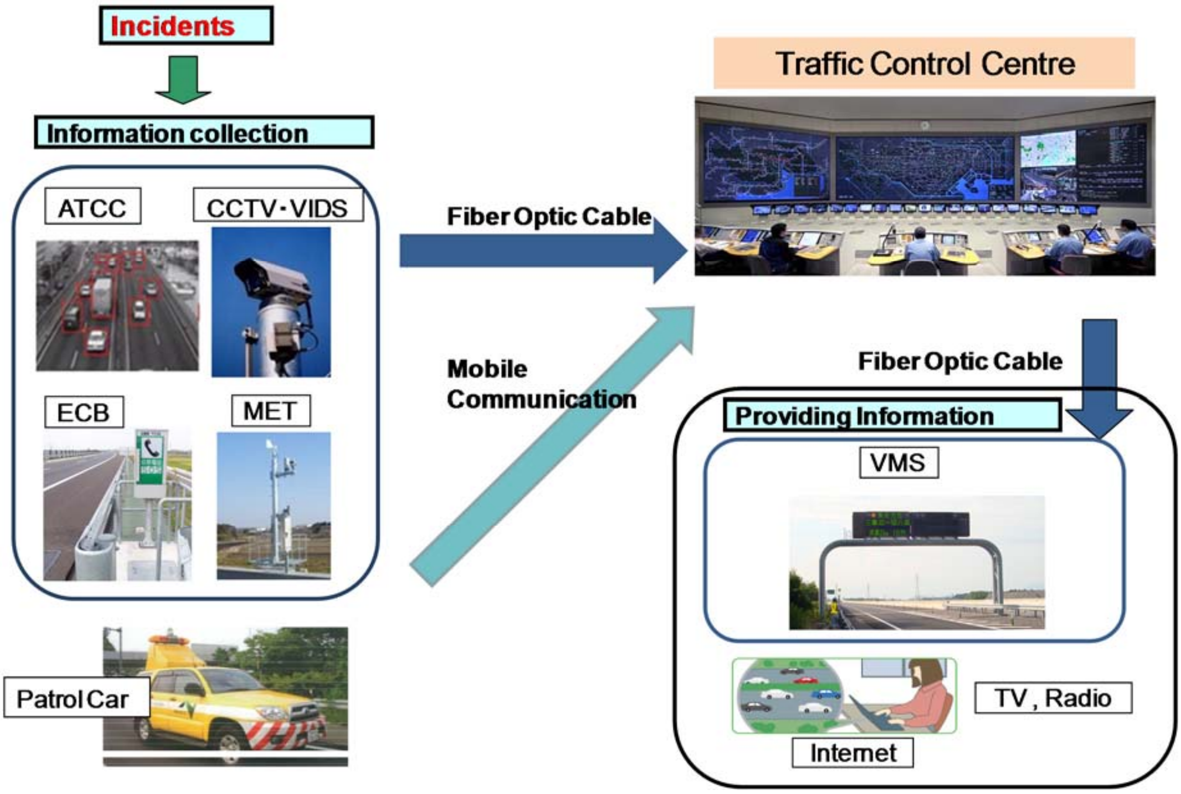
CCTV cameras shall be installed at each lane in the Toll Plaza and CCTV images shall be monitored in the Toll Office in order to monitor the situations of traffic and toll collection at tollgates. Vehicle types shall be identified and checked by toll collectors and vehicle type identifiers installed at the tollgates. Toll Management System configuration, Manual lane equipment, ETC lane equipment and Toll Plaza Computer System are shown in 6.6.4.

(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 roads 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.

The outline of workflow of the Traffic Management is shown in Figure 9.3.6 as reference.



Source: JICA Study Team

Figure 9.3.6 Outline of the Workflow of the Traffic Control (Reference)

1) Field Work (including Road Patrols)

In order to secure the level of services as the toll road to be maintained on MTHL, services such as regular road patrols and assignment and emergency dispatch of an ambulance and a tow vehicle will have to be provided on it.

2) Collection of the Road Traffic Information

Road information and traffic information will be collected from the road patrols, the data of traffic volumes at the toll plaza and from Road side facilities including Automatic Traffic Counter–cum-Classifiers (ATCC), CCTV and Emergency Call Boxes (ECB). The weather information will be obtained from Meteorological Sensors (MET) including rain gauges anemometers and visibility meters, in addition to TV programmes and other information sources. Information collection systems are shown in 6.6.4.

3) Provision of the Road Traffic Information

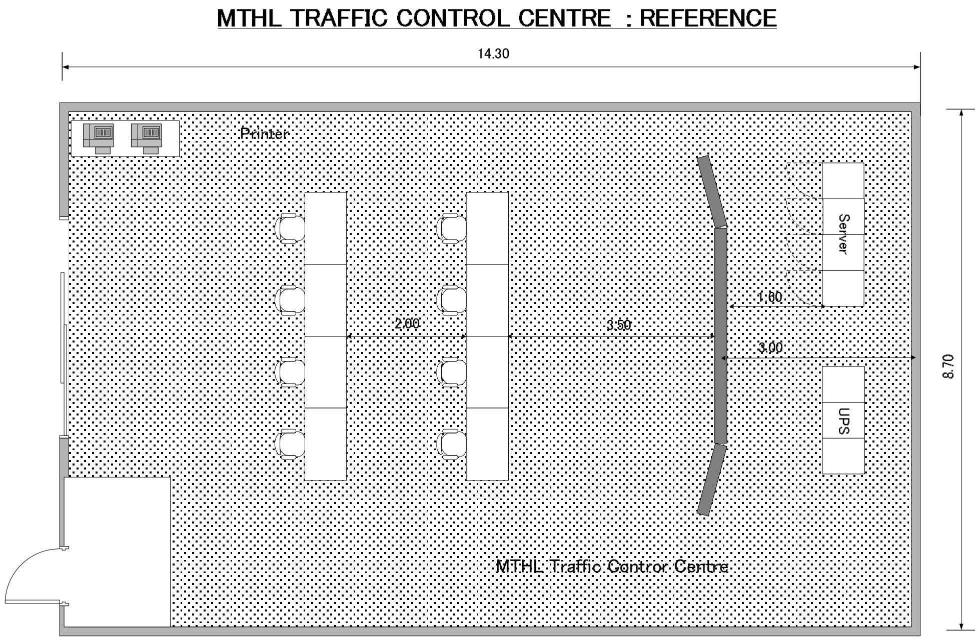
VMSs shall be installed for the provision of road information, traffic information and whether information to road users. The recommended location of VMSs is shown in 6.6.4.

4) Traffic Control Centre

Traffic control centre shall be planned to secure the safe and smooth traffic of MTHL and to operate the road facilities appropriately. The main roles of Traffic control centre are as follows;

- Collection of the Road Traffic Information from the roadside equipment and traffic patrols
- Analysis and accumulation of the Road Traffic Information
- Provision of the Road Traffic Information to road users
- Monitoring of the road and traffic conditions and responses to abnormal and emergency situations

Traffic Management System configuration is shown in 6.6.4. And the layout plan of Traffic control centre is shown in Figure 9.3.7 as reference.



Source: JICA Study Team

Figure 9.3.7 Traffic Control Center

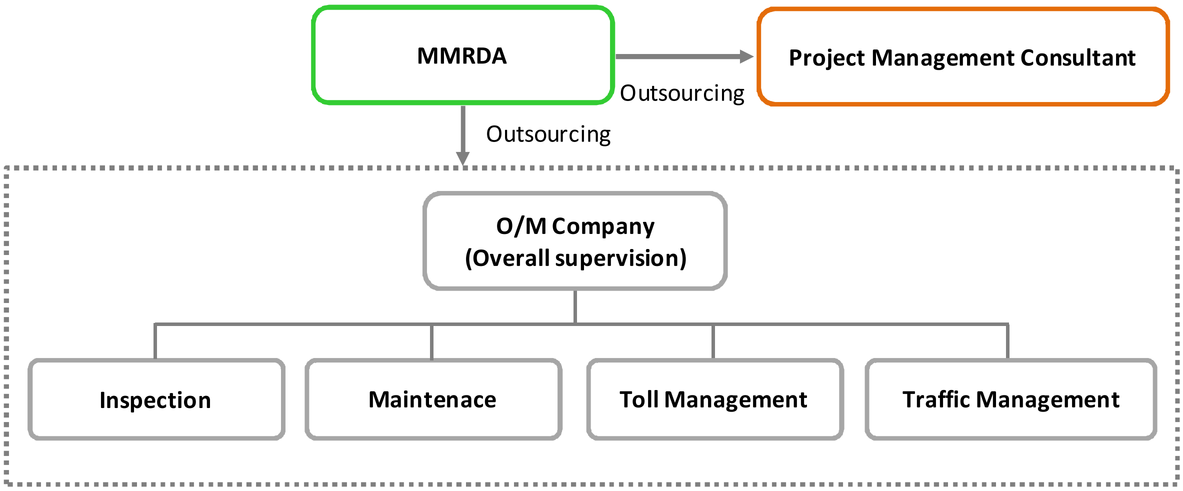
9.4 Operation and Maintenance Organization

9.4.1 Proposed 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. In the case of tolled roads of BOT scheme implemented by MSRDC, Independent Engineer supervises Operation and Maintenance works in place of MSRDC.

Efficient and effective road maintenance requires not only the functions and the works mentioned in Table 9.3.1, but also coordinated implementation of the works. The coordinated implementation requires establishment of an organizational structure which enables efficient and effective performance of individual functions and works under the supervision of a superior organization of the O/M Company (parent company). Figure 9.4.1 shows the recommended overall organizational structure for O/M for MTHL.



Source: JICA Study Team

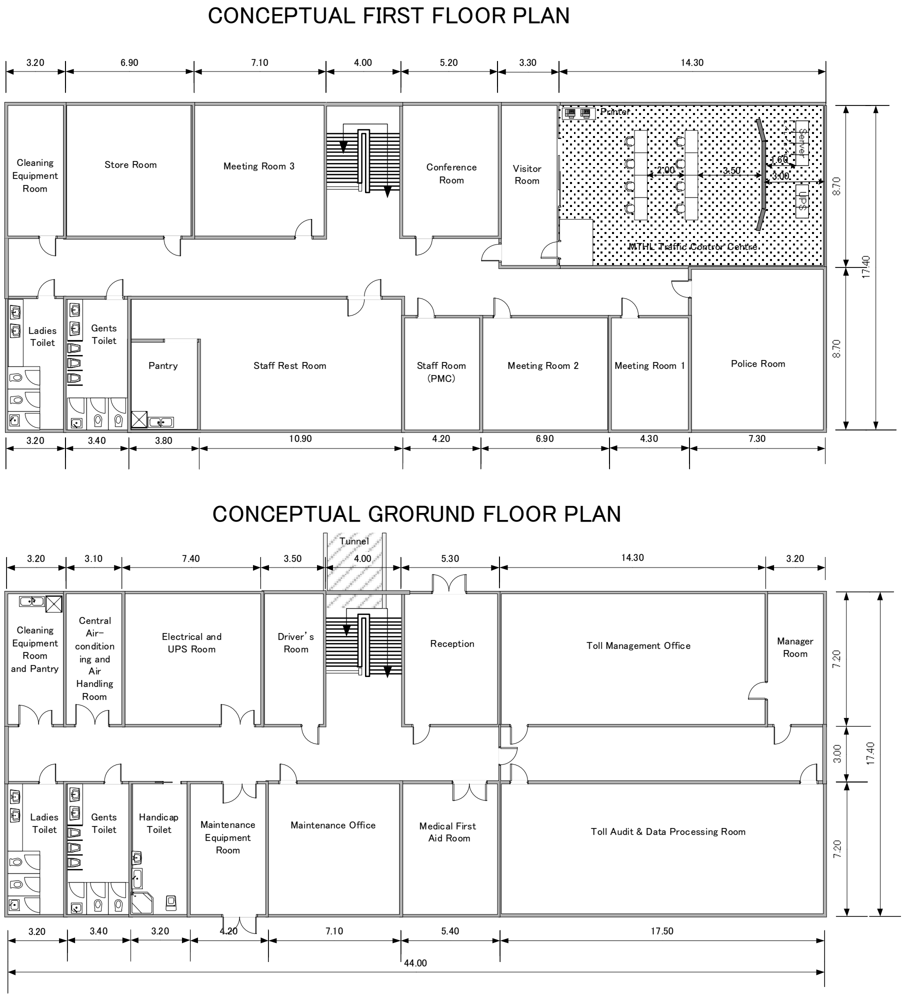
Figure 9.4.1 Overall Organizational Structure for O / M (Recommended)

(2) Overall Facility Plan

Appropriate road Operation and Maintenance requires a Maintenance Office for its implementation. Maintenance Offices are located in each toll road in MMR. Considering the management length per one Maintenance Office of Mumbai Pune Expressway being an average of around 30 km and the management length of MTHL, a main Maintenance Office is planned at a location facing main Toll Plaza on MTHL. The office includes Toll Office, Traffic Control Centre, Medical room and Police room, etc. The proposed floor plan of the main Maintenance Office is shown in Figure 9.4.2 as reference.

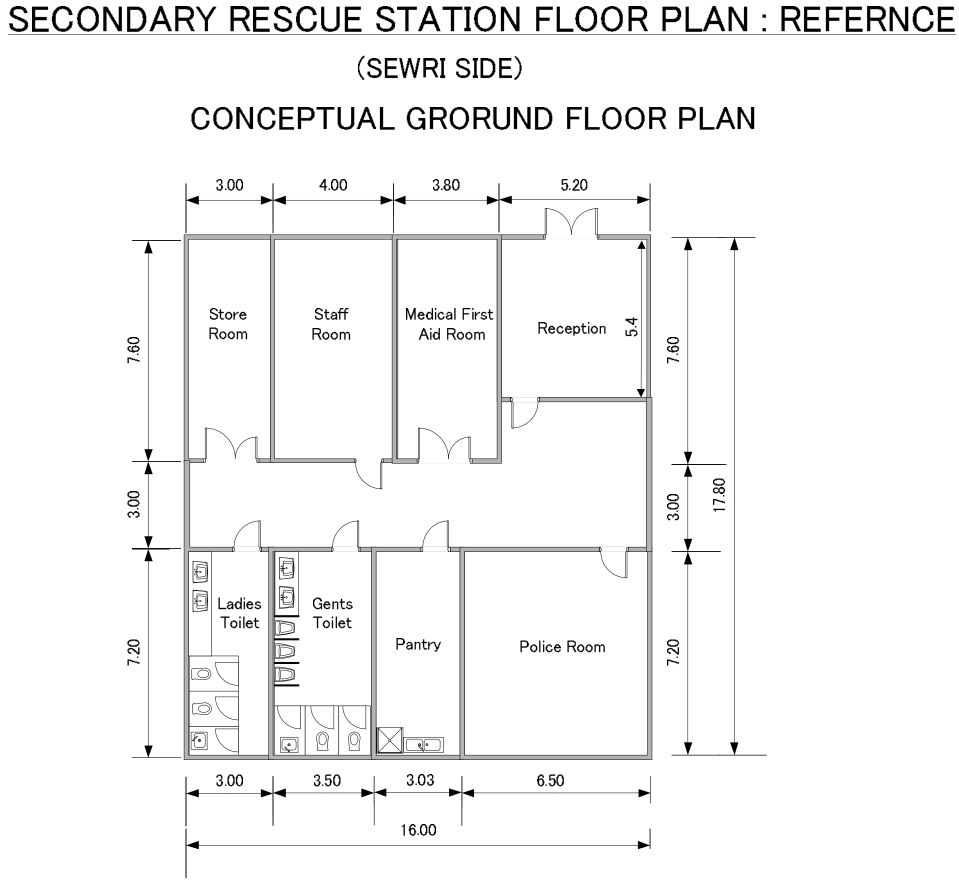
And considering requests from traffic police, a Secondary Office including Staff room, Medical room and Police room is planned at a location of Mumbai side within ROW. The proposed floor plan of the Secondary Office is shown in Figure 9.4.3 as reference.

TOLL PLAZA BUILDING FLOOR PLAN (Ch19+360) : REFERENCE



Source: JICA Study Team

Figure 9.4.2 Floor Plan of the Main Maintenance Office (Reference)

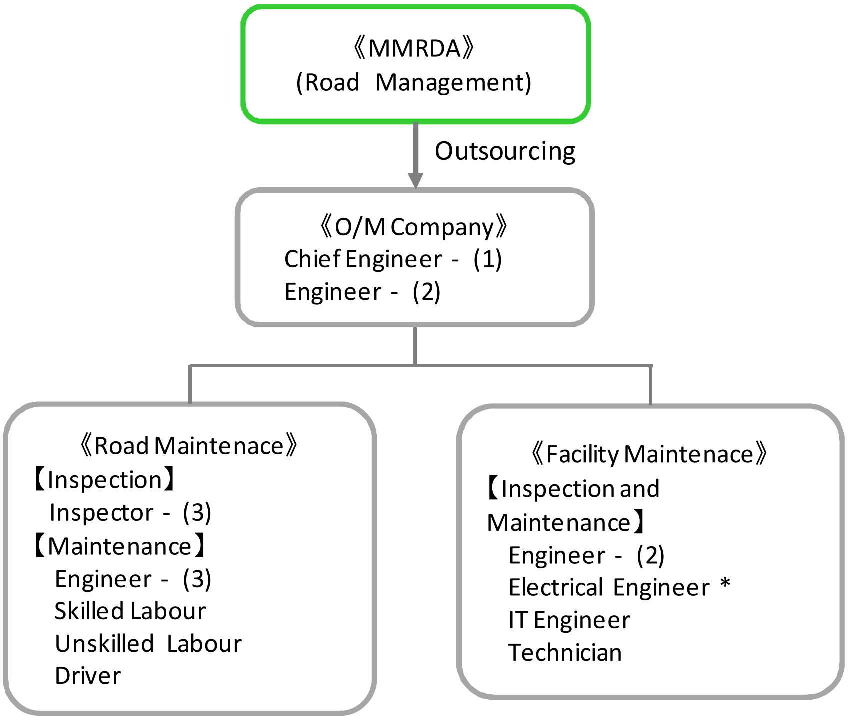


Source: JICA Study Team

Figure 9.4.3 Floor Plan of the Secondary Office (Reference)

(3) Organizational Structure for Inspection and Maintenance

Figure 9.4.4 and Table 9.4.1 show the recommended organizational structure and the main duties by job type, respectively, for the inspection and maintenance of MTHL. As seen in Figure 9.4.4, engineers shall be appointed to develop plans and supervise the inspection and maintenance and the actual inspection and maintenance services shall be conducted by Road maintenance team and Facility maintenance team. The number of labors changes depending on the work contents.



* 8 hours a day in 3 shifts

Source: JICA Study Team

Figure 9.4.4 Organizational Structure for Inspection and Maintenance (Recommended)

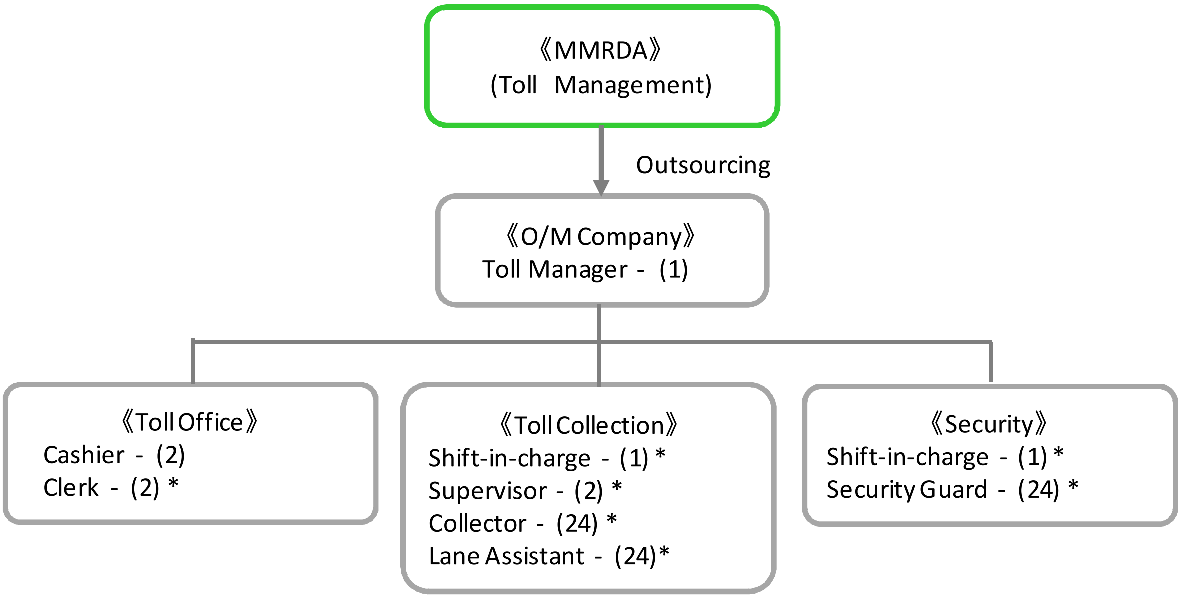
Table 9.4.1 Main Duties in the Inspection and Maintenance by Job Type (Recommended)

Job title	Main duties
Chief Engineer	- Head of the department responsible for the road inspection and maintenance - Responsible for all the inspection and maintenance work, coordinator of the overall operation - Reporting to and coordination with the relevant organizations on the results of the inspection and maintenance - Special inspection when serious damage has been detected on road structures - Education and training of the engineers
Engineer	- Supervision of the inspection and maintenance works - Preparation of a maintenance/repair plan - Reporting to and coordination with the chief engineer on the results of the inspection - Special inspection when serious damage has been detected on road structures, preparation of special inspection reports
Inspector (Road Maintenance)	- Implementation of the regular, routine, detailed and special inspections - Preparation of inspection reports - Compilation of and creation of databases of the inspection results - Preparation of inspection reports - Reporting to and coordination with the engineer on the results of the inspection
Engineer (Road Maintenance)	- Supervision of the actual road maintenance works - Labor management of the actual road maintenance works - Safety management of the actual road maintenance works - Reporting to and coordination with the engineers
Engineer (Facility Maintenance)	- Implementation of the inspection for facilities (Road side facitities, Toll plaza facilities and Traffic contorol centre facilites, etc) - Suervision of the actual facility maintenance works - Labor management of the actual facility maintenance works - Safety management of the actual facility maintenance works - Reporting to and coordination with the engineers

Source: JICA Study Team

(4) Organizational Structure for Toll Management

The recommended organizational structure and the details of the duties by job type are shown in Figure 9.4.4 and Table 9.4.2 designed by reference to other toll roads in India, respectively. As shown in Figure 9.4.4, the toll management is to be implemented with a structure consisting of eight job types. As the toll collection has to be performed 24 hours a day/365 days a year, a design of four teams taking 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 9.4.5 Organization Structure for Toll Collection (Recommended)

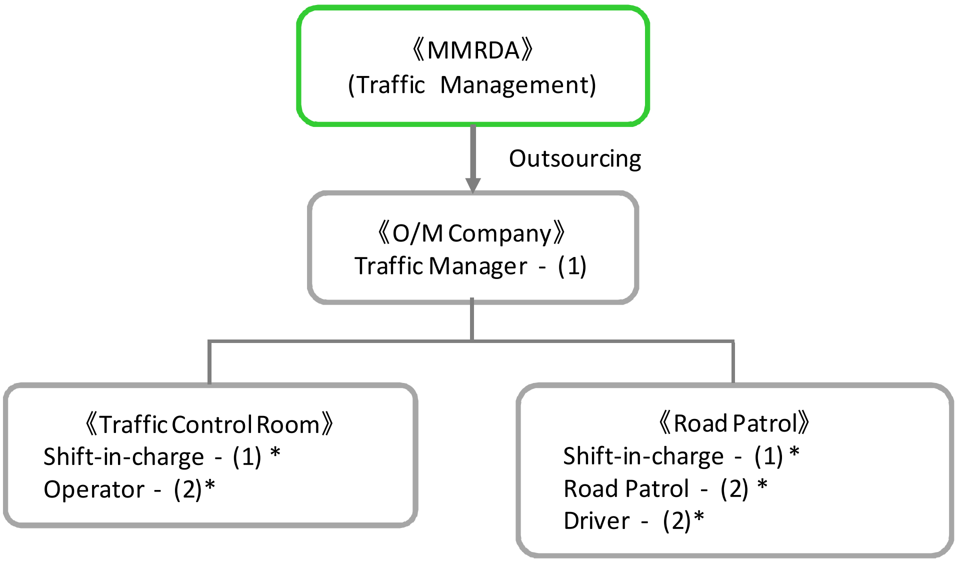
Table 9.4.2 Main Duties in the Toll Management by Job Type (Recommended)

Job title	Main duties
Toll Manager	- Supervision of the overall toll management - Coordination with the client and the relevant organizations
Cashier	- Counting the amount of the collected tolls and comparing the counted and calculated amounts - Verification of the amount of tolls collected in a day and depositing of the collected tolls in a bank account - Ensuring availability of small change and transporting it to the toll booths
Clerk	- Clerical works including attendance management and management of consumables and office supplies - Entry of management data in the system - Sales of special passes including season passes - Reception of reports on the collected and calculated amounts of the tolls (during the night) - On duty 24 hours a day/365 days a year
Shift in charge	- Head of the toll collection section - Preparation of work shift schedules - Monitoring of the performance and responses of the toll collectors and supervisors - Verification of vehicle type when a toll collector and a vehicle type identifier have identified the same vehicle differently - Education and training of the toll collectors and supervisors - On duty 24 hours a day/365 days a year
Supervisor	- Supervision of the performance of the toll collectors - Reception of a reports of a toll collector when a special incident, such as passing of an emergency vehicle - Reponses to non-payment of the toll - Responses to inquiries from road users - Verification of the amount of tolls collected by a toll collector after her/his shift - On duty 24 hours a day/365 days a year
Collector	- Stationed in a booth to identify types of vehicles and collect tolls from road users - Reporting of occurrence of a special incident such as passing of an emergency vehicle to the supervisor - Calculation of the amount of the collected tolls and reporting of the amount to the Head Cashier Banking (or the clerk on duty during the night) at the end of the shift - Closing of the tollgates and notification to road users in the case of a road closure - On duty 24 hours a day/365 days a year
Lane Assistant	- Stationed out of a booth to assist delivering tolls/changes between road users and collectors - On duty 24 hours a day/365 days a year
Security Shift In charge	- Head of the security section and in charge of the security - Preparation of work shift schedules of the security guards - On duty 24 hours a day/365 days a year
Security Guards	Monitoring and protection of the tollgate, lanes, staff members, collected money and facilities On duty 24 hours a day/365 days a year

Source: JICA Study Team

(5) Organizational Structure for Traffic Management

Figure 9.4.5 and Table 9.4.3 show the recommended organizational structure and main duties by job type, respectively, for the implementation of the traffic management of MTHL. As shown in Figure 9.4.5, the traffic management is to be implemented with a structure consisting of six job types. As the traffic control has to be performed 24 hours a day/365 days a year, a design of four teams taking 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 9.4.6 Organizational Structure for Traffic Management (Recommended)

Table 9.4.3 Main Duties in the Traffic Management by Job Type (Recommended)

Job title	Main duties
Traffic Manager	- Head of the traffic management - Coordinator of the overall operation of the traffic management with the responsibility for the whole operation - Education and training of the operators and the road patrol officers
Operator shift in charge	- Preparation of work shift schedules of Operators - Monitoring and management of the performance of the Operators - Making decisions on appropriate measures to be taken, including a road closure and provision of information to road users, after receiving information on occurrence of an extraordinary incident, such as a fire, an accident or an abnormal weather condition, from an Operator - Responses to inquiries from road users - Cooperation and coordination with public organizations including the police and fire services and relevant organizations including the state government - Handover of the duties to the Operator Shift in Charge of the next shift, preparation of daily reports - On duty 24 hours a day/365 days a year
Operators	- Collection of the Road Traffic Information - Collection of information required for the traffic control, including road construction work, from relevant organizations - Reporting incidents occurred and measures taken against them to the Operator shift in charge and making required initial responses (including a request for dispatch of the patrol team and notification to relevant organizations including the police) - Provision of the information on incidents occurred and measures taken against them on the VMSs to road users - Verifying the state of a roadside facility when its abnormality or breakdown has been detected and taking a measure, such as sending a request for the dispatch of the maintenance team - Preparation of daily reports on incidents, road conditions and measures taken - Making required responses in accordance with the instruction of the Operator shift in charge - On duty 24 hours a day/365 days a year
Patrol shift in charge	- Preparation of work shift schedules of the Road Patrols - Monitoring and management of the performance of the Road Patrols - Reporting to and coordination with the Traffic Control Centre - Instruction of an emergency dispatch and initial responses (including road closures and preventive measures against rear-end collision) to Road Patrols against an extraordinary/emergency situation - Handover of the duties to the Patrol shift in charge of the next shift, preparation of daily reports - On duty 24 hours a day/365 days a year
Road Patrol	- Regular road patrols - Driving an ambulance and/or a towing vehicle quickly to a scene of an extraordinary/emergency situation - Reporting such an incident as a fire, an accident or an abnormal weather condition to the Traffic Control Centre and making initial responses (including road closures, preventive measures against rear-end collision) at the scene of the incident - Preparation of daily reports on the patrol and reporting to the Patrol shift in charge - Notification of an abnormality or breakdown of a road facility to the Traffic Control Centre - On duty 24 hours a day/365 days a year
Driver	- Driving the patrol cars and emergency vehicles - On duty 24 hours a day/365 days a year

Source: JICA Study Team

(6) Operation of the Maintenance Office

In the Maintenance Office, it is necessary to perform general affairs so that the staffs can carry out their duties smoothly. For the main types of job, Office Manager, Accountants, Clerks, Office boys, Cleaners, Security guards are necessary.

(7) Vehicles for Operation and Maintenance

Table 9.4.4 shows the recommended vehicles for Operation and Maintenance of MTHL.

In addition to the vehicles deployed normally in the maintenance company of toll roads, a Bridge inspection vehicle and a Motorized patrol boat shall be deployed in consideration of characteristics of MTHL.

Table 9.4.4 Vehicles for O/M (Recommended)

Type	Quantity	Remarks
Road ptrol vehicle	8	Road / Facility Maintenance Traffic Management
Towing vehicle	2	Traffic Management
Vehicle mounted crane	1	Traffic Management
Ambulance	1	Traffic Management
Bridge inspection vehicle	1	Road Maintenance
Motorized patorol boat	1	Road Maintenance
Road sweeper	1	Road Maintenance

Source: JICA Study Team

Source: JICA Study Team

Figure 9.4.7 Bridge Inspection Vehicle

9.4.2 Operation and Maintenance Cost Estimation

The Operation and Maintenance Cost for MTHL shall be estimated based on the recommended Operation and Maintenance Plan in 9.3.2 and recommended Operation and Maintenance Organizational Structure in 9.4.1. And the Periodic Maintenance Cost shall be estimated as well.

(1) Routine Operation and Maintenance

Table 9.4.5 shows the rough estimated cost of Routine Operation and Maintenance.

Table 9.4.5 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 9.4.6 shows the rough estiated cost of Periodic Maintenance.

Table 9.4.6 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

9.5 Proposal for Technical and Institutional Support to O/M Agency

As mentioned in 9.4, MMRDA will outsource the supervision of outsourced Operation and Maintenance works, planned to be conducted by Project Management Consultants because they have no experience of Operation and Maintenance of roads.

MMRDA has an adequate capacity of contract management in consideration of their achievements of major projects.

Therefore, MMRDA can be assumed to be able to carry out Operation and Maintenace of MTHL with utilization of the outsourcing, after the completion of its construction.

In the business frame mentioned above, the items of technical cooperation for MMRDA are proposed as follows;

9.5.1 To Support the development of Operation and Maintenance Manuals of MTHL

Manuals for Operation and Maintenance will be required to implement Operation and Maintenance works adequately in MTHL by Project Management Consultant and Operation and Maintenance Company. In the stage of Detailed Design and Construction, Manuals should be developed depending on structures and facilities to be adopted.

The examples of Manuals supposed to be required are given as follow;

- Inspection and maintenance manual
- Traffic management manual
- Toll management manual
- Toraffic control system maintenance manual
- Toll collection system maintenance manual
- Training in Japan / Third country (Operation and Maintenance of expressway)

9.5.2 Training in Japan/Third Contry

The objective of the training in Japan/Third country is that MMRDA deepens the understanding of the Operation and Maintenance works for marine bridge and toll road before the commencement of Operation and Maintenance of MTHL. And MMRDA will come to be able to utilize the knowledges to the O/M of MTHL.

10. PROJECT IMPLEMENTATION PLAN

10.1 Implementation Organization

The project organization will be organized so that the MMRDA can implement the Project smoothly and effectively as well as coordinate with project stakeholders.It is recommended that the Project Management Office (PMO) for the Project will be organized under MMRDA. The PMO will be established before the commencement of tender. All tasks to be carried out for the Project will be managed by PMO. The Project is divided into following two stages.

- Tender stage (1st stage)
- Detailed design and construction stage (2nd stage)

Tender procedure and compensation work including the relocation will be carried out in the 1st stage. Construction management will be carried out in the 2nd stage.

10.2 Implementation Scheme

Navi-Mumbai airport connected to MTHL is going to open partially in 2019. In addition, scattering the city function of Mumbai in Navi-Mumbai and relaxation of traffic congestion in Mumbai and Vashi Bridge are urgent issues to be solved. From the above, MMRDA strongly hoped early commencement of construction work. Therefore JICA decided the adoption of the Design Built (DB) scheme unlike traditional scheme (separation ordering of detailed design and construction) under Japan ODA civil work project. DB is the implementation scheme to utilize the know-how of the contractor. Advantages of DB are as follows:

<u>Advantages</u>

➢ Efficient and rational design and construction can be carried out.

- The rational detailed design that utilized the contractor's prudent construction technology is enabled.
- Tendering procedure is reduced and preparation for construction is enabled while designing.

➢ Construction quality is increased.

- Reliable construction method by the contractor is utilized and its quality is also increased.

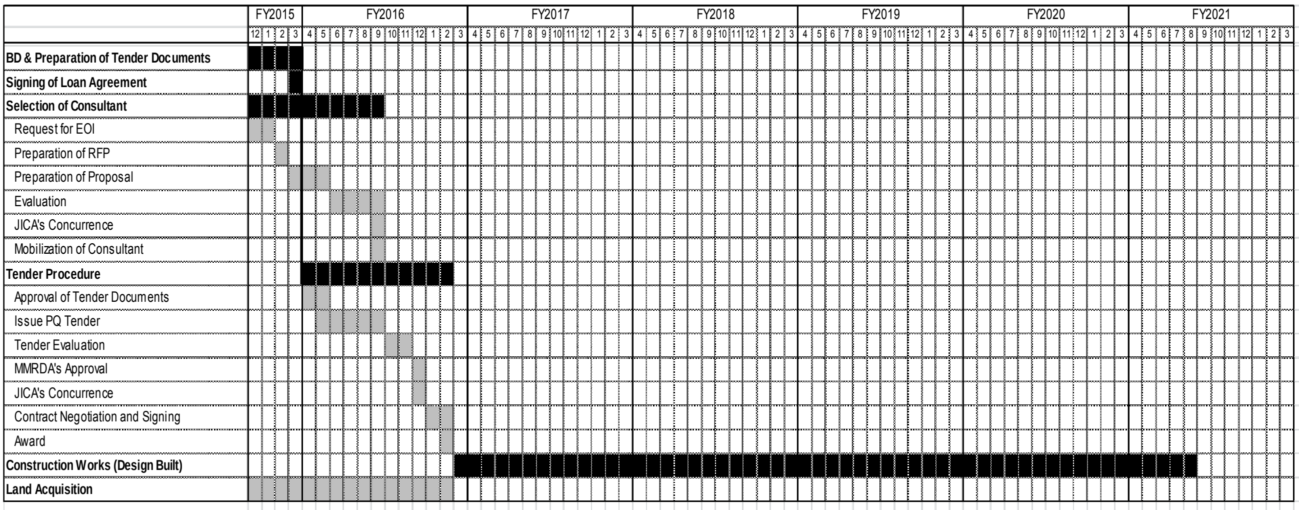
Basic conditions such as bridge span length, cross section, bridge form (substructure and superstructure) and pavement structure are decided in preliminary design. Therefore, the contractor shall carry out detailed design based on the preliminary design results which were shown by the client, while construction plan and required temporary facilities for the construction shall be proposed by the contractor. Contractor may increase the span lengths while maintaining the statutory vertical and horizontal clearances required.

10.3 Implementation Schedule

The implementation plan is established based on the month/year for the milestones of key events of the project. DB scheme has been already planned by discussion MMRDA with JICA. The plan includes the stage of tender procedure, detailed design and construction work. The construction period is estimated as 4.5 years. It is assumed that International Competitive Bidding (ICB) is applied for procurement of the contractor and the consultant for the project.The time required for the procurement is assumed based on the procedures for a financial scheme of Japanese ODA Loan. The milestones for the implementation of the project undertaken by Japanese ODA Loan are formulated as follows:
This implementation schedule was decided by discussion of MMRDA with JICA on 6 August 2015.

- Loan Agreement (L/A) will be signed in March 2016.
- 7 months will be required for the selection of the consultant for tender assistance and construction supervision.
- 9 months will be required for the procurement of the contractor.
- Construction period will be 54 months in DB scheme.

The total implementation schedule will begin with L/A in March 2016, and the construction will be completed in September 2021. In addition, Right of Way (ROW) for the project has already been conducted in this study and 70% of it has already completed. MMRDA will be able to commence the remaining land acquisition and compensation procedure soon, and the procedure will be completed by the commencement of the construction. The implementation schedule for the project is shown in Figure 10.3.1



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

Figure 10.3.1 Implementation Schedule

11. ECONOMIC AND FINANCIAL ANALYSIS

11.1 Financial Analysis

11.1.1 Purpose and Methodology

This section examines whether the project is financially feasible. As this project is formed as a toll road project, at least financial requirement on operation and maintenance should be satisfied, mainly financial feasibility on the following aspects are analysed.

- The soundness and profitability of the project cash flow will be verified by the project IRR. An analysis will be conducted in order to examine to what extent the project cash flow can cover OPEX, as well as CAPEX.

  For evaluating financial feasibility, the NHAI's "Guideline for Investment in Road Sector" will be referred. It states that (although the project is not PPP any more) for the case of the BOT Toll Model, which is exposed to traffic demand risk, the expected Project IRR should meet 14-16%.

- A DSCR analysis will be conducted in order determine whether the project cash flow will withstand the repayment of Yen loans provided by JICA. In each year of the loan term, the cash flow will be checked whether it is sufficient for the repayment of principle and interest of the loan.

  In terms of the DSCR threshold, in general, 1.0 or higher indicates that the project has a sufficient cash flow to repay the debt services (in contrast, a DSCR less than 1.0 indicates that the project cannot replay the full amount of the debt service).

11.1.2 Assumptions for financial analysis

(1) General Assumptions and Conditions

1) Project scheme

MMRDA is responsible for construction and its finance, and a concessionaire implements operation and maintenance. MMRDA takes the ridership risk and collects fares during a whole project period to recover O&M cost.

2) Project period

The project period shall be 35 years (construction for 7 years, operation for 28 years) in consideration with the repayment period of Yen loan Tranche 1 and Tranche 2.

- Yen loan Tranche 1: the repayment period 30 years from 2015 to 2044
- Yen loan Tranche 2: the repayment period 30 years from 2020 to 2049

3) Project schedule]

Period of construction is from 2015 to 2021. Commercial Operation Day is 2022 and the end of project period is 2049.

4) Terms of Yen loan

It is assumed Interest rate 1.4%, grace period 10 years, and repayment period 30 years. The loan is provided for two phases, Tranche 1 and Tranche 2. Interest during construction is born by MMRDA, and Yen loan don't additionally provide with this.

5) Inflation rate

Inflation rate is assumed at 5%. It is estimated based on IMF World Economic Outlook (WEO), April 2015 and others.

(2) Assumption for Cash inflow

1) Traffic volume

Traffic volume (vehicle volume, traffic growth ration, etc) in Chapter 4 is used for financial analysis.

2) Toll rates

Toll rates are assumed as 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 "willingness to pay survey in 2011", and it is escalated up to 2022 as the year of commercial operation day.
- Case 3：It is the amount of 50% increase of Case 2

Table 11.1.1 Toll rate setting on each case

Mode	Case 1		Case 2		Case 3	
	Chirle IC - Shivaji Nagar IC	Chirle IC - Sewri IC	Chirle IC - Shivaji Nagar IC	Chirle IC - Sewri IC	Chirle IC - Shivaji Nagar IC	Chirle IC - Sewri IC
	5 km	16.5 km	5 km	16.5 km	5 km	16.5 km
Car	30	90.00	55	180.00	80	270.00
Bus	60	210.00	130	420.00	190	630.00
LCV	40	120.00	70	240.00	110	360.00
HCV	60	210.00	130	420.00	190	630.00
MAV	90	300.00	180	600.00	270	900.00

Source: JICA Study Team

Revision of toll rates is annually made by applying the following formula, according to the National Highways Fee (Determination of rates and collection) rules, 2008.

$$\text{Applicable rate of fee} = \text{base rate} + \text{base rate} \times \left\{\frac{\text{WPI A} - \text{WPI B}}{\text{WPI B}}\right\} \times 0.30$$

(3) Assumption for Cash outflow

1) Initial Investment cost

Total project cost consists of initial investment costs (road construction costs, fee collection system and control systems, vehicles and consulting fees, price escalation, physical contingency, interest during construction, land acquisition and compensation, and tax) is used as 2015 cost. Total investment cost is assumed as 180,707 million INR.

Table 11.1.2 Initial Investment Cost

Breakdown of Cost	Total (million INR)		
	JICA Portion (INR)	Others (INR)	Total (INR)
Package-1	66,038	0	66,038
Package-2	49,061	0	49,061
Package-3	13,074	0	13,074
Package-4	1,444	0	1,444
Package-5	0	196	196
Dispute Boads for Pkg-1/2/3/4	183	0	183
Price Escalation	5,368	0	5,368
Physical Contingency	13,517	20	13,537
Consulting Services	4,568	0	4,568
Land Acquisition	0	10,060	10,060
Administration Cost	0	4,906	4,906
VAT	0	9,208	9,208
Import Tax	0	586	586
Interest during Construction	0	2,171	2,171
Front End Fee	0	307	307
Total	153,253	27,454	180,707

Source: JICA Study Team

2) Allocation of Construction Works

The phasing for construction works (excluding land acquisition cost) is shown in the following table.

Table 11.1.3 Phasing of construction works

	Total	JICA Portion		GOI Portion
		Tranche-I	Tranche-II	
2015	3,917	0		3,917
2016	7,523	497		7,025
2017	31,461	28,684		2,777
2018	32,098	29,191		2,907
2019	32,460	29,442		3,018
2020	34,147		30,904	3,244
2021	33,821		30,518	3,303
2022	924		444	480
2023	4,329		3,548	781
2024	25		23	2
Total	180,707	87,815	65,438	27,454

Source: JICA Study Team

3) Operation & maintenance expense, and large scale rehabilitation

OPEX is divided into routine maintenance cost and large scale rehabilitation cost. The detail is shown in the following table.

Table 11.1.4 Operation and Maintenance Cost

Unit: million INR

Year	MMRDA	Project Management Consultant	Inspection & Maintenance	Toll Management	Traffic Management	Others (Electricity)	Routin O/M Total	Pavement	Road marking	Touch-up painting	Repainting	Expansion device	Bearing	Bridge inspection passage	Noise barrier	Traffic Management system	Toll Management system	Periodic Maintenance	O/M Total
1	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
2	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
3	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
4	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
5	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
6	16	15	95	101	40	10	276	0	8	0	0	0	0	0	0	0	0	8	285
7	16	15	95	101	40	10	276	0	8	0	0	0	0	0	0	0	0	8	285
8	16	15	95	101	40	10	276	0	8	0	0	0	0	0	0	0	0	8	285
9	16	15	95	101	40	10	276	0	8	0	0	0	0	0	0	0	0	8	285
10	16	15	95	101	40	10	276	0	8	0	0	0	0	0	0	448	200	657	933
11	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
12	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
13	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
14	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
15	16	15	95	101	40	10	276	0	0	0	0	0	0	0	0	0	0	0	276
16	16	15	95	101	40	10	276	85	8	12	0	0	0	0	0	0	0	106	382
17	16	15	95	101	40	10	276	85	8	12	0	0	0	0	0	0	0	106	382
18	16	15	95	101	40	10	276	85	8	12	0	0	0	0	0	0	0	106	382
19	16	15	95	101	40	10	276	85	8	12	0	0	0	0	0	0	0	106	382
20	16	15	95	101	40	10	276	85	8	12	0	0	0	0	128	448	200	883	1159
21	16	15	95	101	40	10	276	0	0	12	0	33	0	24	0	0	0	69	345
22	16	15	95	101	40	10	276	0	0	12	0	33	0	24	0	0	0	69	345
23	16	15	95	101	40	10	276	0	0	12	0	33	0	24	0	0	0	69	345
24	16	15	95	101	40	10	276	0	0	12	0	33	0	24	0	0	0	69	345
25	16	15	95	101	40	10	276	0	0	12	0	33	0	24	0	0	0	69	345
26	16	15	95	101	40	10	276	0	8	0	30	0	0	0	0	0	0	39	315
27	16	15	95	101	40	10	276	0	8	0	30	0	0	0	0	0	0	39	315
28	16	15	95	101	40	10	276	0	8	0	30	0	0	0	0	0	0	39	315

Source: JICA Study Team

(4) Tax

Import tax and VAT imposed for construction are included in initial investment cost. Income tax and service tax is not taken into account in the financial analysis since MMRDA is exempted from such taxes because MMRDA is deemed the local official authority.

11.1.3 The result of financial analysis

(1) Financial results

The table below shows the result of financial analysis for Case 1. While revenues from toll during 28 years operation period can cover OPEX on the same period, cost recovery for the total investment cost including CAPEX cannot be realised. Project IRR accounts low rate, minus 1.13%. Average DSCR is 0.96, but minimum DSCR is 0.34. Repayment for the yen loan cannot be made in 23 years of the whole project period.

Table 11.1.5 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

Source: JICA Study Team

The table below shows the result of financial analysis for Case 2. Revenues from toll during 28 years operation period can cover OPEX, as well as CAPEX. Project IRR accounts still low rate, 1.77%. Average DSCR is 1.73, but minimum DSCR is 0.51. Repayment for the yen loan cannot be made in 10 years of the whole project period.

Table 11.1.6 The result of financial analysis (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

Source: JICA Study Team

The table below shows the result of financial analysis for Case 3. Like Case 2, revenues from toll during 28 years operation period can cover OPEX, as well as CAPEX. Project IRR accounts still low rate 3.36%. Average DSCR is 2.39, but minimum DSCR is 0.58. Repayment for the yen loan cannot be made in initial 8 years of the whole project period.

Table 11.1.7 The result of financial analysis (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

(2) Cash flow

The table below is a cash flow for Case 2 as bases case. In addition, this section provides the table which shows toll rate, traffic (per day) and revenew (per day) in each year.

Table 11.1.8 Cash Flow (Case 2)

Mumbai Trans Harbour Link (MTHL) Project - Cash flow

IDR in million

		Cash Outflow									Cash Inflow				
	Year	CAPEX	OPEX	Principal Repayment for Tranche I	Interest for Tranche I	IDC for Tranche I (paid by MMRDA)	Principal Repayment for Tranche II	Interest for Tranche II	IDC for Tranche II (paid by MMRDA)	Total Cash Outflow	Toll revenue	Principle Borrwoing from Tranche I	Principle Borrwoing from Tranche II	Total Cash Inflow	Net Cash Flow
1	2015	3917	0		0	0	0	0	0	3917	0	0		0	-3917
2	2016	7522	0		3	-3	0	0	0	7522	0	497		497	-7025
3	2017	31461	0		208	-208	0	0	0	31461	0	28684		28684	-2777
4	2018	32098	0		613	-613	0	0	0	32098	0	29191		29191	-2907
5	2019	32460	0		1023	-1023	0	0	0	32460	0	29442		29442	-3018
6	2020	34148	0	0	1229		0	216	-216	35377	0		30904	30904	-4473
7	2021	33821	0	0	1229		0	646	-646	35050	0		30518	30518	-4532
8	2022	924	276	0	1229		0	863	-863	2430	2579		444	3023	593
9	2023	4356	290	0	1229		0	891	-891	5875	2885		3573	6458	582
10	2024		305	0	1229		0	916		2450	3229			3229	779
11	2025		320	4391	1199		0	916		6825	3617			3617	-3209
12	2026		336	4391	1137		0	916		6780	4053			4053	-2727
13	2027		363	4391	1076		0	916		6746	4545			4545	-2201
14	2028		382	4391	1014		0	916		6703	5100			5100	-1603
15	2029		401	4391	953		0	916		6660	5725			5725	-935
16	2030		421	4391	891		3272	893		9868	6431			6431	-3437
17	2031		1448	4391	830		3272	847		10788	7228			7228	-3560
18	2032		450	4391	768		3272	802		9683	8127			8127	-1556
19	2033		473	4391	707		3272	756		9598	8545			8545	-1053
20	2034		496	4391	645		3272	710		9514	8985			8985	-529
21	2035		521	4391	584		3272	664		9432	9450			9450	18
22	2036		547	4391	522		3272	618		9351	9941			9941	590
23	2037		795	4391	461		3272	573		9491	10458			10458	968
24	2038		834	4391	400		3272	527		9423	11005			11005	1582
25	2039		876	4391	338		3272	481		9358	11582			11582	2224
26	2040		920	4391	277		3272	435		9294	12191			12191	2897
27	2041		2928	4391	215		3272	389		11196	12834			12834	1639
28	2042		915	4391	154		3272	344		9075	13514			13514	4439
29	2043		961	4391	92		3272	298		9013	14233			14233	5219
30	2044		1009	4391	31		3272	252		8954	14992			14992	6037
31	2045		1059	0	0		3272	206		4537	15794			15794	11257
32	2046		1112	0	0		3272	160		4545	16643			16643	12098
33	2047		1067	0	0		3272	115		4453	17540			17540	13087
34	2048		1120	0	0		3272	69		4461	18490			18490	14029
35	2049		1176	0	0		3272	23		4471	19495			19495	15023
	Total	180707	21801	87814	20288	-1847	65439	17275	-2617	388860	279211	87814	65439	432464	43603

Assumptions

1 The project period is set for 35 years (construction for 7 years, operation for 28 years) in consideration with the repayment period of Yen loan Tranche 1 and Tranche 2.
Yen loan Tranche 1: the repayment period 30 years from 2015 to 2044
Yen loan Tranche 2: the repayment period 30 years from 2020 to 2049

2 It is assumed Interest rate 1.4%, grace period 10 years, and repayment period 30 years. The loan is provided for two phases, Tranche 1 and Tranche 2. Interest during construction is born by MMRDA, and Yen loan don't additionally provide with this.

3 Inflation rate is assumed at 5%.

4 Toll rates is set based on "willingness to pay survey in 2011"
Revision of toll rates is annually made by applying the formula of the National Highways Fee (Determination of rates and collection) rules, 2008.

5 Import tax and VAT imposed for construction are included in initial investment cost.

Source: Study Team

Table 11.1.9 Toll rate, Traffic (per day), Revenue (per day) in each year

Toll rate

Chirle IC - Sewri IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	180.00	182.57	185.18	187.83	190.51	193.23	195.99	198.79	201.63	204.51	207.43	210.40	213.40	216.45	219.54	222.68	225.86	229.09	232.36	235.68	239.04	242.46	245.92	249.44	253.00	256.61	260.28	264.00
Bus	420.00	426.00	432.09	438.26	444.52	450.87	457.31	463.84	470.47	477.19	484.01	490.92	497.94	505.05	512.26	519.58	527.00	534.53	542.17	549.91	557.77	565.74	573.82	582.02	590.33	598.77	607.32	616.00
LCV	240.00	243.43	246.91	250.43	254.01	257.64	261.32	265.05	268.84	272.68	276.58	280.53	284.53	288.60	292.72	296.90	301.15	305.45	309.81	314.24	318.73	323.28	327.90	332.58	337.33	342.15	347.04	352.00
HCV	420.00	426.00	432.09	438.26	444.52	450.87	457.31	463.84	470.47	477.19	484.01	490.92	497.94	505.05	512.26	519.58	527.00	534.53	542.17	549.91	557.77	565.74	573.82	582.02	590.33	598.77	607.32	616.00
MAV	600.00	608.57	617.27	626.08	635.03	644.10	653.30	662.63	672.10	681.70	691.44	701.32	711.34	721.50	731.81	742.26	752.86	763.62	774.53	785.59	796.81	808.20	819.74	831.45	843.33	855.38	867.60	879.99

Chirle IC - Shivaji Nagar IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	55.00	55.79	56.58	57.39	58.21	59.04	59.89	60.74	61.61	62.49	63.38	64.29	65.21	66.14	67.08	68.04	69.01	70.00	71.00	72.01	73.04	74.08	75.14	76.22	77.31	78.41	79.53	80.67
Bus	130.00	131.86	133.74	135.65	137.59	139.55	141.55	143.57	145.62	147.70	149.81	151.95	154.12	156.32	158.56	160.82	163.12	165.45	167.81	170.21	172.64	175.11	177.61	180.15	182.72	185.33	187.98	190.67
LCV	70.00	71.00	72.01	73.04	74.09	75.14	76.22	77.31	78.41	79.53	80.67	81.82	82.99	84.17	85.38	86.60	87.83	89.09	90.36	91.65	92.96	94.29	95.64	97.00	98.39	99.79	101.22	102.67
HCV	130.00	131.86	133.74	135.65	137.59	139.55	141.55	143.57	145.62	147.70	149.81	151.95	154.12	156.32	158.56	160.82	163.12	165.45	167.81	170.21	172.64	175.11	177.61	180.15	182.72	185.33	187.98	190.67
MAV	180.00	182.57	185.18	187.83	190.51	193.23	195.99	198.79	201.63	204.51	207.43	210.40	213.40	216.45	219.54	222.68	225.86	229.09	232.36	235.68	239.04	242.46	245.92	249.44	253.00	256.61	260.28	264.00

Traffic (per day)

Chirle IC - Sewri IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	26,772	29,885	33,360	37,239	41,569	46,403	51,798	57,821	64,545	72,050	80,428	83,306	86,287	89,375	92,573	95,886	99,317	102,871	106,552	110,365	114,314	118,405	122,642	127,030	131,576	136,284	141,161	146,212
Bus	881	912	945	978	1,013	1,049	1,086	1,124	1,164	1,205	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248
LCV	1,460	1,555	1,657	1,765	1,880	2,002	2,133	2,272	2,420	2,578	2,746	2,830	2,917	3,006	3,099	3,194	3,291	3,392	3,496	3,604	3,714	3,828	3,945	4,066	4,191	4,319	4,452	4,588
HCV	1,016	1,096	1,183	1,277	1,378	1,487	1,604	1,731	1,868	2,016	2,175	2,222	2,269	2,318	2,368	2,419	2,471	2,524	2,578	2,633	2,690	2,748	2,807	2,867	2,929	2,992	3,056	3,121
MAV	1,026	1,098	1,174	1,256	1,344	1,438	1,539	1,646	1,761	1,884	2,016	2,103	2,193	2,287	2,385	2,487	2,594	2,705	2,822	2,943	3,069	3,201	3,338	3,481	3,631	3,787	3,949	4,119

Chirle IC - Shivaji Nagar IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	5,000	5,791	6,706	7,766	8,994	10,416	12,063	13,971	16,179	18,737	21,700	23,371	25,171	27,110	29,198	31,447	33,869	36,478	39,287	42,313	45,572	49,082	52,862	56,934	61,319	66,042	71,128	76,606
Bus	881	912	945	978	1,013	1,049	1,086	1,124	1,164	1,205	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248	1,248
LCV	460	490	521	554	590	628	668	711	757	805	857	886	915	946	978	1,010	1,044	1,079	1,115	1,152	1,191	1,231	1,272	1,315	1,359	1,404	1,451	1,500
HCV	349	371	395	421	448	477	507	540	575	612	651	660	669	678	687	697	706	716	726	736	746	756	767	777	788	799	810	821
MAV	90	98	106	115	125	136	148	161	175	190	206	219	232	247	262	278	296	314	333	354	376	399	424	450	478	508	539	573

Revenue (per day)

Chirle IC - Sewri IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	4,818,960	5,456,150	6,177,592	6,994,428	7,919,270	8,966,400	10,151,987	11,494,339	13,014,184	14,734,992	16,683,335	17,527,194	18,413,736	19,345,120	20,323,615	21,351,603	22,431,587	23,566,198	24,758,199	26,010,493	27,326,128	28,708,310	30,160,404	31,685,946	33,288,651	34,972,423	36,741,361	38,599,775
Bus	370,020	388,606	408,125	428,625	450,155	472,766	496,513	521,452	547,644	575,152	604,042	612,671	621,423	630,301	639,305	648,438	657,701	667,097	676,627	686,293	696,097	706,042	716,128	726,358	736,735	747,260	757,935	768,763
LCV	350,400	378,581	409,029	441,926	477,468	515,869	557,358	602,185	650,616	702,942	759,477	793,943	829,973	867,637	907,011	948,172	991,201	1,036,182	1,083,204	1,132,361	1,183,748	1,237,467	1,293,624	1,352,330	1,413,699	1,477,854	1,544,920	1,615,029
Truck	426,720	467,046	511,183	559,492	612,365	670,235	733,574	802,899	878,775	961,822	1,052,717	1,090,690	1,130,032	1,170,794	1,213,026	1,256,781	1,302,115	1,349,084	1,397,747	1,448,165	1,500,402	1,554,524	1,610,597	1,668,694	1,728,885	1,791,248	1,855,861	1,922,804
MAV	615,600	668,026	724,916	786,652	853,645	926,343	1,005,232	1,090,840	1,183,738	1,284,548	1,393,943	1,474,537	1,559,792	1,649,976	1,745,375	1,846,289	1,953,037	2,065,958	2,185,407	2,311,763	2,445,425	2,586,814	2,736,379	2,894,591	3,061,950	3,238,986	3,426,257	3,624,357
Total	**6,581,700**	**7,358,409**	**8,230,846**	**9,211,122**	**10,312,902**	**11,551,613**	**12,944,664**	**14,511,715**	**16,274,958**	**18,259,457**	**20,493,513**	**21,499,035**	**22,554,956**	**23,663,829**	**24,828,332**	**26,051,283**	**27,335,641**	**28,684,519**	**30,101,185**	**31,589,075**	**33,151,801**	**34,793,157**	**36,517,132**	**38,327,918**	**40,229,921**	**42,227,771**	**44,326,334**	**46,530,727**

Chirle IC - Shivaji Nagar IC

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Car	275,000	323,029	379,447	445,718	523,564	615,006	722,418	848,590	996,798	1,170,890	1,375,389	1,502,483	1,641,322	1,792,990	1,958,674	2,139,667	2,337,386	2,553,375	2,789,322	3,047,073	3,328,641	3,636,228	3,972,238	4,339,297	4,740,275	5,178,306	5,656,813	6,179,537
Bus	114,530	120,283	126,325	132,670	139,334	146,332	153,682	161,402	169,509	178,023	186,965	189,636	192,345	195,093	197,880	200,707	203,574	206,482	209,432	212,424	215,459	218,537	221,659	224,825	228,037	231,295	234,599	237,950
LCV	32,200	34,757	37,516	40,495	43,711	47,181	50,927	54,971	59,336	64,047	69,132	72,466	75,961	79,624	83,463	87,488	91,707	96,129	100,765	105,624	110,717	116,056	121,653	127,519	133,669	140,114	146,871	153,954
Truck	45,370	48,978	52,874	57,079	61,619	66,519	71,810	77,521	83,687	90,342	97,528	100,278	103,105	106,012	109,001	112,075	115,235	118,484	121,825	125,260	128,792	132,423	136,157	139,996	143,944	148,002	152,176	156,466
MAV	16,200	17,850	19,668	21,671	23,878	26,310	28,990	31,943	35,196	38,781	42,731	46,029	49,582	53,410	57,532	61,973	66,757	71,910	77,461	83,440	89,881	96,819	104,292	112,342	121,014	130,355	140,417	151,256
Total	**483,300**	**544,897**	**615,830**	**697,634**	**792,105**	**901,349**	**1,027,828**	**1,174,426**	**1,344,525**	**1,542,084**	**1,771,745**	**1,910,893**	**2,062,315**	**2,227,129**	**2,406,551**	**2,601,910**	**2,814,659**	**3,046,380**	**3,298,805**	**3,573,821**	**3,873,490**	**4,200,063**	**4,555,999**	**4,943,980**	**5,366,938**	**5,828,072**	**6,330,876**	**6,879,164**

Total (Case 2)	7,065,000	7,903,306	8,846,676	9,908,756	11,105,008	12,452,962	13,972,492	15,686,141	17,619,483	19,801,541	22,265,259	23,409,927	24,617,272	25,890,958	27,234,883	28,653,193	30,150,300	31,730,900	33,399,990	35,162,896	37,025,291	38,993,220	41,073,131	43,271,898	45,596,859	48,055,843	50,657,210	53,409,891

Source: Study Team

11.2 Economic Analysis

11.2.1 Purpose and methodology of economic analysis

(1) Methodology

Economic analysis aims to examine the effects of the project in terms of social and economic aspects, and evaluate the economic relevance of the project. Economic indicators such as the Economic Internal Rate of Return (EIRR), Net Present Value (NPV) and Cost Benefit Ratio (B/C ratio) are applied for the analysis.

Economic analysis in this study adopts one of the standard methods of cost benefit analysis, the discounted cash flow method. Cost benefit analysis is carried out by comparing economic benefit and economic cost.

(2) Basic Condition

In order to work out economic benefit, two cases are compared in this study: i.e. the “With Project” case and the “Without Project” case. Therefore, the economic benefit to be achieved by this project is defined as the gap of vehicle travel costs (e.g. VOC: vehicle operation costs and VOTT: travel time cost) between “With Project” and “Without Project” cases.

Calculation in the economic analysis in this study is carried out by a method of discounting economic benefit and project cost at a present value. The economic benefit in this study is determined by multiplying balance between traffic demands in both “With Project” and “Without Project” cases by unit vehicle operation cost and travel time cost.

11.2.2 Project Costs

(1) Initial investment cost

In this economic analysis, the annual amount of investment is calculated based on the total amount of initial investment, 161,743 million INR (excluding price escalation, administration cost. Including in 5% physical contingency) in proportion to the phasing of the project. 0.80 of the conversion rate is applied so that financial cost is converted into economic cost. The table below shows investment cost (financial cost and economic cost) and annual initial investment.

Table 11.2.1 Investment cost (financial cost and economic cost)

Financal cost

	Year	Investment	O & M,
1	2015	3628	
2	2016	6996	
3	2017	28,855	
4	2018	29,083	
5	2019	29,029	
6	2020	30,141	
7	2021	29,468	
1	2022	820	276
2	2023	3,723	276
3	2024		276
4	2025		276
5	2026		276
6	2027		285
7	2028		285
8	2029		285
9	2030		285
10	2031		933
11	2032		276
12	2033		276
13	2034		276
14	2035		276
15	2036		276
16	2037		373
17	2038		373
18	2039		373
19	2040		373
20	2041		1,149
21	2042		335
22	2043		335
23	2044		335
24	2045		335
25	2046		335

Economic cost
Conversion factor 0.8

	Year	Investment	O & M,
1	2015	2,902	
2	2016	5,597	
3	2017	23,084	0
4	2018	23,266	0
5	2019	23,223	0
6	2020	24,113	0
7	2021	23,574	0
1	2022	656	221
2	2023	2,978	221
3	2024	0	221
4	2025	0	221
5	2026	0	221
6	2027	0	228
7	2028	0	228
8	2029	0	228
9	2030	0	228
10	2031	0	746
11	2032	0	221
12	2033	0	221
13	2034	0	221
14	2035	0	221
15	2036	0	221
16	2037	0	298
17	2038	0	298
18	2039	0	298
19	2040	0	298
20	2041	0	919
21	2042	0	268
22	2043	0	268
23	2044	0	268
24	2045	0	268
25	2046	0	268

Source: JICA Study Team

(2) O&M cost and Rehabilitation cost

OPEX is divided into routine maintenance cost and large scale rehabilitation cost. The detail is shown in the table in the above section of financial analysis.

11.2.3 Benefit calculation

Benefit to be expected through implementation of the project is as follows:

- Reduction in vehicle operation cost (VOC)
- Reduction in travel time cost (TTC)
- Abatement of emission by mitigating traffic congestion

In this economic analysis, among the above mentioned benefits, (i) benefit to reduce Vehicle Operation Cost (VOC) and (ii) benefit to reduce Travel Time Cost (TTC) are treated as quantitative benefit.

Since traffic on MTHL to be constructed under this project is classified by 7 vehicle types, i.e. Motor Cycle, Car, Auto Rickshaw, Taxi, Bus, LCV and HCV in calculating the traffic demand forecasts, this economic analysis also adopts such classification. Unit value of vehicle operation cost and unit value of travel time cost on the CTS report of MMRDA (2008) are converted to 2022 price by adjusting inflation. As for unit value of travel time cost, unit value is annually increased by the ratio 7.29% from commercial operational year based on real GDSP growth 7.97% in Maharashtra which is adjusted population growth 0.68% in Maharashtra.

GDSP forecast in Maharashtra

Forecast of GDSP in Maharashtra is calculated by; average ratio in the past 9 years between actual GDSP in Maharashtra and in the whole India multiply forecast of GDP in 2019 in India. As a result, GDSP forecast in Maharashtra is 7.97%.

Table 11.2.2 GDSP Forecast in Maharashtra

		Actual (source: The Ministry of Statistics and Programme Implementation)										Forecast (source: IMF Article IV)					Source
		2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013	2014	2015	2016	2017	2018	2019	
(a)	Maharashtra	13.35	13.53	11.26	2.58	9.3	11.26	4.52	7.78	7.28	5.66	N/A	N/A	N/A	N/A	**7.97**	The Ministry of Statistics and Programme Implementation
(b)	(b)=(a)/(c)	1.40823	1.41379	1.20815	0.38393	1.08265	1.26375	0.67564	1.74049	1.53586						1.19028	
(c)	India	9.48	9.57	9.32	6.72	8.59	8.91	6.69	4.47	4.74	N/A	N/A	N/A	N/A	N/A	N/A	The Ministry of Statistics and Programme Implementation
																	http://mospi.nic.in/Mospi_New/site/inner.aspx?status=3&menu_id=82
	India	8.2							4.7	5	5.8	6.3	6.5	6.6	6.7	6.7	IMF Article IV
																	https://www.imf.org/external/pubs/ft/scr/2015/cr1561.pdf

Source: Actual ratio refer to The Ministry of Statistics and Programme Implementation, forecast refer to IMF Article IV.

Forecast of population growth in Maharashtra

Forecast of population growth in Maharashtra is calculated by; actual population growth ratio in Maharashtra multiply population growth forecast in the whole India. As a result, the average of annual population growth in Maharashtra from 2020 to 2045 is 0.68%.

Table 11.2.3 Forecast of Population Growth in Maharashtra

	Average annual rate of population change (percentage)									
	Actual				Forecast (Medium Variant)					
	Source: Ministr of Home Affair, Office of the register general & cescus commissioner India			Source: United Nations, Population Division, Department of Economic and Social Affairs						
	http://censusindia.gov.in/2011-prov-results/data_files/india/Final_PPT_2011_chapter3.pdf			http://esa.un.org/unpd/wpp/DVD/						
country or area	**1981-1991**	**1991-2001**	**2001-2011**	**2010-2015**	**2015-2020**	**2020-2025**	**2025-2030**	**2030-2035**	**2035-2040**	**2040-2045**
India		1.97	1.64	1.26	1.15	1.02	0.88	0.74	0.60	0.48
percentage of the previous decade			83%	77%	92%	89%	87%	84%	81%	80%
Avarage percentage from 2020 to 2045										0.75
Maharashtra		2.07	1.49	1.14	1.05	0.93	0.80	0.67	0.55	0.44
percentage of the previous decade			72%	77%	92%	89%	87%	84%	81%	80%
Avarage percentage from 2020 to 2045										**0.68**

Source: Actual ratio is refer to Minister of Home Affair, Office of the register general & census commissioner India, Forecast refers to United Nations, Population Division.

11.2.4 Cost-benefit analysis

Cost-benefit analysis is conducted on the basis of economic cost and benefit estimated in the above sections. The results are shown in the table below. Project life is assumed as thirty two (32) years (construction period 7years + operation period 25 years)[36].

The table below shows the result of financial analysis for Case 1. EIRR is 13.70%, which exceeds 12% as evaluation standards on the infrastructure project in India. B/C and NPV are also over 1.3 and positive, respectively. This indicates that implementation of the project is relevant from the viewpoints of national economy as well as from regional economy.

Table 11.2.4 Results of cost-benefit analysis in Case 1

(Unit: million INR)

Year	Investment Cost	O & M, Rehabilitation	Annual Total Cost	Benefit (VOC)	Benefit (TTC)	Total Benefit	Annual Net Benefit	Accumulated Net Benefit
2015	2,902	0	2,902			0	(2,902)	(2,902)
2016	5,597	0	5,597			0	(5,597)	(5,597)
2017	23,084	0	23,084			0	(23,084)	(23,084)
2018	23,266	0	23,266			0	(23,266)	(23,266)
2019	23,223	0	23,223			0	(23,223)	(23,223)
2020	24,113	0	24,113			0	(24,113)	(24,113)
2021	23,574	0	23,574			0	(23,574)	(23,574)
2022	656	221	877	2,405	2,664	5,069	4,192	4,192
2023	2,978	221	3,199	2,446	3,541	5,987	2,788	2,788
2024	0	221	221	2,488	4,618	7,106	6,885	9,673
2025	0	221	221	2,531	5,936	8,467	8,246	17,919
2026	0	221	221	2,575	7,541	10,116	9,896	27,814
2027	0	228	228	2,620	9,492	12,111	11,883	39,698
2028	0	228	228	2,666	11,853	14,519	14,291	53,989
2029	0	228	228	2,713	14,705	17,418	17,190	71,179
2030	0	228	228	2,761	18,141	20,903	20,675	91,854
2031	0	746	746	2,810	22,272	25,083	24,336	116,190
2032	0	221	221	8,916	27,228	36,144	35,923	152,113
2033	0	221	221	9,351	31,069	40,420	40,200	192,313
2034	0	221	221	9,803	35,449	45,252	45,031	237,343
2035	0	221	221	10,272	40,441	50,712	50,492	287,835
2036	0	221	221	10,758	46,131	56,889	56,668	344,503
2037	0	298	298	11,262	52,617	63,879	63,580	408,084
2038	0	298	298	11,785	60,009	71,793	71,495	479,579
2039	0	298	298	12,327	68,432	80,758	80,460	560,038
2040	0	298	298	12,888	78,030	90,918	90,620	650,658
2041	0	919	919	13,471	88,965	102,436	101,517	752,175
2042	0	268	268	12,901	101,424	114,324	114,056	866,231
2043	0	268	268	13,501	115,616	129,117	128,849	995,081
2044	0	268	268	14,123	131,782	145,906	145,638	1,140,718
2045	0	268	268	14,767	150,196	164,963	164,695	1,305,414
2046	0	268	268	15,434	171,167	186,601	186,333	1,491,747
		Present Value	76,592			99,134	22,541	

EIRR =	13.7%
NPV =	22,541
B/C =	1.3
Discount Rate =	12%

Source: JICA Study Team

[36] A period of 1 5-20 years beyond the completion of the project is generally considered for highway projects whereas in the case of expressway projects, the analysis period is considered up to 25 years. "MANUAL ON ECONOMIC EVALUATION OF HIGHWAY PROJECTS IN INDIA", INDIAN ROADS CONGRESS (2009)

The table below shows the result of financial analysis for Case 2. EIRR is 13.7%, which exceeds 12% as evaluation standards on the infrastructure project in India. B/C and NPV are also over 1.3 and positive, respectively. This indicates that implementation of the project is relevant from the viewpoints of national economy as well as from regional economy.

Table 11.2.5 Results of cost-benefit analysis in Case 2

(Unit: Million INR)

Year	Investment Cost	O & M, Rehabilitation	Annual Total Cost	Benefit (VOC)	Benefit (TTC)	Total Benefit	Annual Net Benefit	Accumulated Net Benefit
2015	2,902	0	2,902			0	(2,902)	(2,902)
2016	5,597	0	5,597			0	(5,597)	(5,597)
2017	23,084	0	23,084			0	(23,084)	(23,084)
2018	23,266	0	23,266			0	(23,266)	(23,266)
2019	23,223	0	23,223			0	(23,223)	(23,223)
2020	24,113	0	24,113			0	(24,113)	(24,113)
2021	23,574	0	23,574			0	(23,574)	(23,574)
2022	656	221	877	1,783	2,246	4,029	3,152	3,152
2023	2,978	221	3,199	1,908	3,158	5,066	1,867	1,867
2024	0	221	221	2,040	4,287	6,327	6,106	7,973
2025	0	221	221	2,179	5,678	7,857	7,636	15,609
2026	0	221	221	2,325	7,383	9,708	9,487	25,096
2027	0	228	228	2,478	9,465	11,943	11,715	36,811
2028	0	228	228	2,639	11,998	14,637	14,409	51,220
2029	0	228	228	2,808	15,068	17,877	17,649	68,868
2030	0	228	228	2,986	18,781	21,767	21,539	90,408
2031	0	746	746	3,173	23,258	26,431	25,685	116,092
2032	0	221	221	9,853	28,644	38,498	38,277	154,369
2033	0	221	221	10,116	32,445	42,561	42,340	196,710
2034	0	221	221	10,386	36,751	47,136	46,916	243,625
2035	0	221	221	10,663	41,627	52,290	52,069	295,694
2036	0	221	221	10,948	47,150	58,098	57,878	353,572
2037	0	298	298	11,241	53,406	64,647	64,349	417,921
2038	0	298	298	11,542	60,492	72,033	71,735	489,656
2039	0	298	298	11,852	68,516	80,368	80,069	569,725
2040	0	298	298	12,170	77,605	89,775	89,477	659,202
2041	0	919	919	12,498	87,898	100,396	99,477	758,678
2042	0	268	268	12,390	99,556	111,947	111,679	870,357
2043	0	268	268	12,686	112,759	125,445	125,177	995,534
2044	0	268	268	12,988	127,711	140,699	140,431	1,135,965
2045	0	268	268	13,298	144,644	157,942	157,674	1,293,639
2046	0	268	268	13,614	163,820	177,434	177,166	1,470,805
		Present Value	76,592			98,283	21,691	

EIRR =	13.7%
NPV =	21,691
B/C =	1.3
Discount Rate =	12%

Source: JICA Study Team

The table below shows the result of financial analysis for Case 3. EIRR is 13.3%, which exceeds 12% as evaluation standards on the infrastructure project in India. B/C and NPV are also over 1.2 and positive, respectively. This indicates that implementation of the project is relevant from the viewpoints of national economy as well as from regional economy.

Table 11.2.6 Results of cost-benefit analysis in Case 3

(Unit: Million INR)

Year	Investment Cost	O & M, Rehabilitation	Annual Total Cost	Benefit (VOC)	Benefit (TTC)	Total Benefit	Annual Net Benefit	Accumulated Net Benefit
2015	2,902	0	2,902			0	(2,902)	(2,902)
2016	5,597	0	5,597			0	(5,597)	(5,597)
2017	23,084	0	23,084			0	(23,084)	(23,084)
2018	23,266	0	23,266			0	(23,266)	(23,266)
2019	23,223	0	23,223			0	(23,223)	(23,223)
2020	24,113	0	24,113			0	(24,113)	(24,113)
2021	23,574	0	23,574			0	(23,574)	(23,574)
2022	656	221	877	1,547	1,969	3,516	2,639	2,639
2023	2,978	221	3,199	1,611	2,814	4,424	1,225	1,225
2024	0	221	221	1,678	3,864	5,542	5,321	6,547
2025	0	221	221	1,749	5,163	6,911	6,691	13,237
2026	0	221	221	1,824	6,759	8,583	8,362	21,599
2027	0	228	228	1,903	8,713	10,616	10,388	31,987
2028	0	228	228	1,986	11,096	13,082	12,854	44,841
2029	0	228	228	2,074	13,991	16,065	15,837	60,678
2030	0	228	228	2,167	17,499	19,666	19,438	80,116
2031	0	746	746	2,265	21,737	24,001	23,255	103,371
2032	0	221	221	8,998	26,843	35,841	35,620	138,991
2033	0	221	221	9,289	30,564	39,853	39,632	178,623
2034	0	221	221	9,591	34,800	44,391	44,170	222,793
2035	0	221	221	9,904	39,621	49,525	49,304	272,097
2036	0	221	221	10,230	45,107	55,337	55,116	327,213
2037	0	298	298	10,568	51,352	61,920	61,621	388,835
2038	0	298	298	10,918	58,459	69,378	69,079	457,914
2039	0	298	298	11,283	66,548	77,831	77,532	535,446
2040	0	298	298	11,662	75,752	87,414	87,115	622,562
2041	0	919	919	12,056	86,226	98,282	97,362	719,924
2042	0	268	268	12,219	98,145	110,363	110,095	830,019
2043	0	268	268	12,622	111,706	124,328	124,060	954,079
2044	0	268	268	13,042	127,136	140,178	139,910	1,093,990
2045	0	268	268	13,478	144,692	158,170	157,902	1,251,892
2046	0	268	268	13,931	164,666	178,598	178,330	1,430,221
		Present Value	76,592			93,116	16,524	

EIRR =	13.3%
NPV =	16,524
B/C =	1.2
Discount Rate =	12%

Source: JICA Study Team

11.2.5 Sensitivity Analysis

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

The worst scenario is a case of 10% increase of initial investment cost and 10% decrease of benefit. In this case, EIRR decreases to 12.3%, but it is more than 12% as evaluation standards on the infrastructure project in India, Net Present Value become minus, and B/C is 1.1. In another scenario, EIRR indicates also more than 12%. Therefore, impact from uncertainty is not significant.

Table 11.2.7 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

Table 11.2.8 Summery of sensitivity analysis (NPV)

		Benefit		
		-10%	Base case	+10%
Cost	-10%	19,429	29,257	39,085
	Base case	11,862	21,691	31,519
	+10%	4,296	14,124	23,952

Source: JICA Study Team

Table 11.2.9 Summery of sensitivity analysis (B/C)

		Benefit		
		-10%	Base case	+10%
Cost	-10%	1.3	1.4	1.6
	Base case	1.2	1.3	1.4
	+10%	1.1	1.2	1.3

Source: JICA Study Team

11.2.6 Qualitative effects for the Project

There are many kinds of expected benefits other than VOC and TTC savings that are considered in economic evaluation of this study. The followings are major qualitative effects.

Reduction of traffic accidents

The improvement of travel speed and road condition due to the completion of the project leads to reduce congestion. This results to decrease a number of accidents on the alternative roads.

Integrating the regional economy

Through the project implementation, it is expected to contribute expand economic interchange between great metropolitan area of Mumbai and surrounding area, not only between Mumbai area and Navi Mumbai area. Currently important large scale infrastructure project, such as Navi Mumbai new air port, SEZ, have been planed, and the project is expected to play a role as a part of infrastructure network.

11.2.7 Operation and Effect Indicators

The followings are Operation and Effect Indicators for the project.

Table 11.2.10 Operation and Effect Indicators

Indicator	Baseline Value in 2015	Baseline Value in 2024	Note
Travel Time	61 minutes	16.1 minutes	Section on Sewri～Chirle
Annual Average Daily Traffic (PCU/ peak hour)	8,748 PCU/peak hour	11,204 PCU/peak hour	Vashi Toll Plaza on Vashi Bridge
	-	42,647 PCU/peak hour	MTHL (Sewri IC- Shivaji Nagar IC)

Source: CONCEPT DESIGN REPORT, GHATKOPAR KOPARKHAIRNE BRIDGE, REWAS KARANJA SEA LINK (2014)

12. ENVIRONMENTAL IMPACT ASSESSMENT

12.1 Project Description

The project outline and location is shown in the Table 12.1.1 and Figure 12.1.1.

All specifications are still tentative due to under review and inspection based on the Final Feasibility Report in 2012.

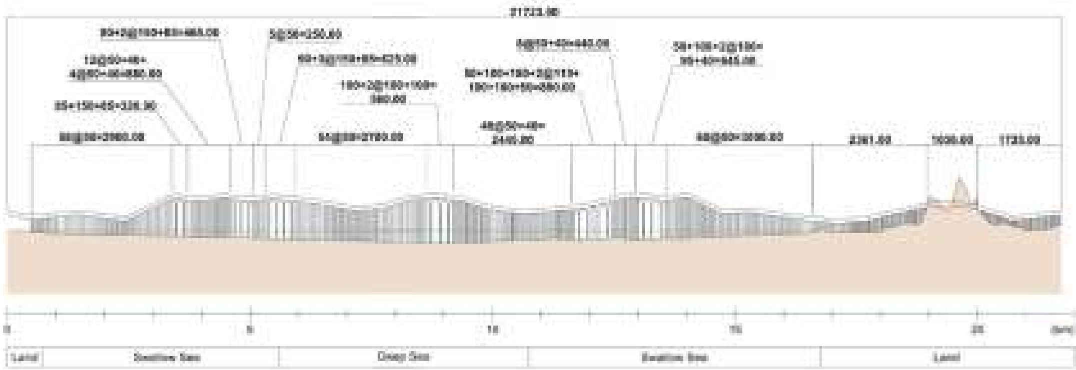
Table 12.1.1 Project Outline

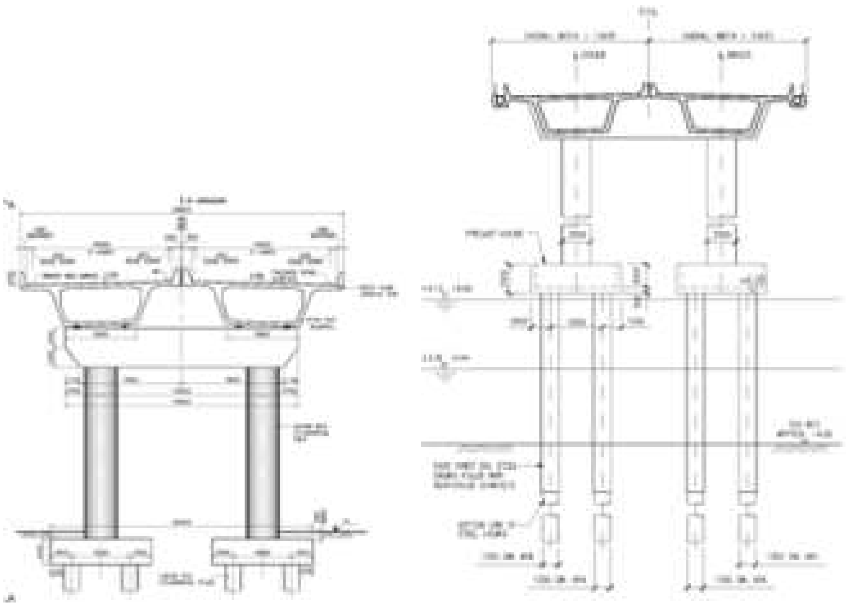
Item	Description
Project Name	Construction of Mumbai Trans Harbour Link
Type of construction Structure	- Road Type: Urban arterial road in MM Region - Type of Structure : Bridge across Mumbai bay & viaduct on land - Length: 22.5 km (App.17 km bridge on the sea) - Number of lanes: 6 lanes with paved shoulder
Location	- Starting point(Mumbai side): Sewri in Mumbai City - End Point: Chirle area in Raigad District
Road Width	- Clear width of each carriageway (viaduct portion) : 13.75m - Width of Right of Way (Navi Mumbai side): 120m - Width of Right of Way (Creek): 500m

Source: JICA Study Team

Source: JICA Study Team

Figure 12.1.1 Project Location Map





Typical Cross Section (On the Land)   Typical Cross Section (On the Sea)

Source: JICA Study Team

Figure 12.1.2 Typical Structure of the Bridge and Viaduct

12.2 Current Natural and Social Environmental Condition

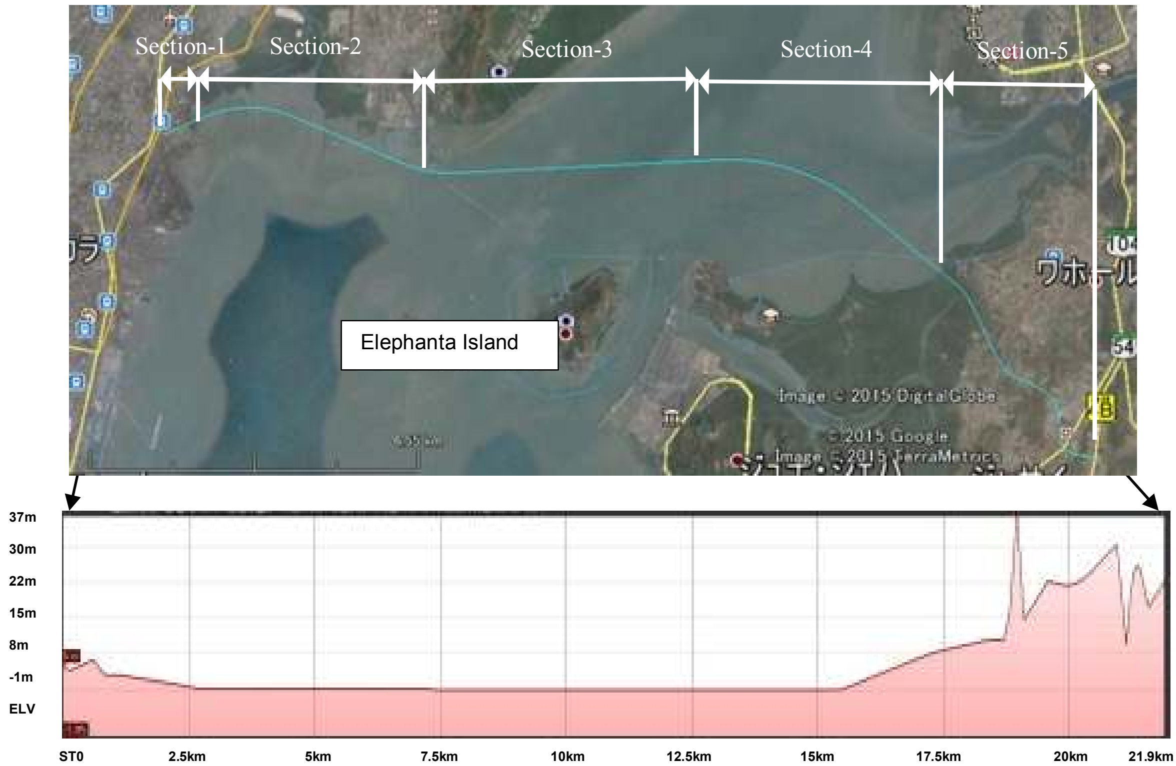
12.2.1 Topography, Geography and Hydrology

The elevation from the sea level is around 5 m from ST 0km Sewri side in Mumbai to CH(Chainage) 16km at the east side Navi Mumbai, and then the elevation increase up to approximately 40m gradually at the end point Chirle area. The area is classified in 5 sections based on topographic feature on site.

Table 12.2.1 Topographical and Geographical Features

Section	Topographic Classification	Depth of the Sea	Topographic Feature
Section-1 (CH 0 - 0.72km)	Land (Partially Tidal Area)	-	Flat
Section-2 (CH 0.72 - 5.60km)	Tidal area	0.0m～3.0m	Flat (Partially mangrove area)
Section-3 (CH 5.60 - 10.75km)	Sea area	4.5m～7.0m	Deepest area in the creek (crossing old & New Pir Pau jetties)
Section-4 (CH 10.75 - 16.75km)	Sea area (Partially Tidal Area)	0.0m～4.0m	Flat (Partially mangrove area)
Section-5 (CH 16.75 - 21.84km)	Land	-	Hilly area (exposed basaltic rock)

Source: JICA Study Team



Source: JICA Study Team

Figure 12.2.1 Topographic and Hydrological Feature

With regard to geographic feature, a sediment clay layer with 3 to 20 m thickness is located above the basalt layer in the sea section near Sewri area. The basalt layer is exposed in the Navi Mumbai Section.

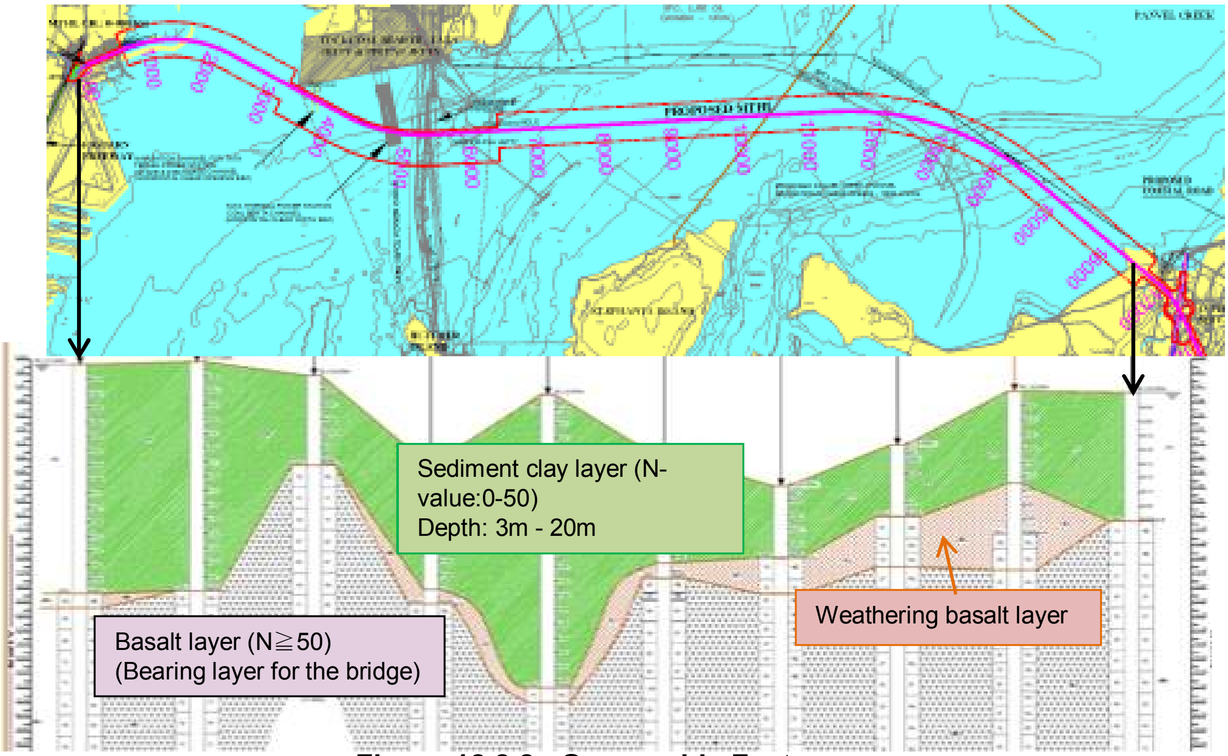
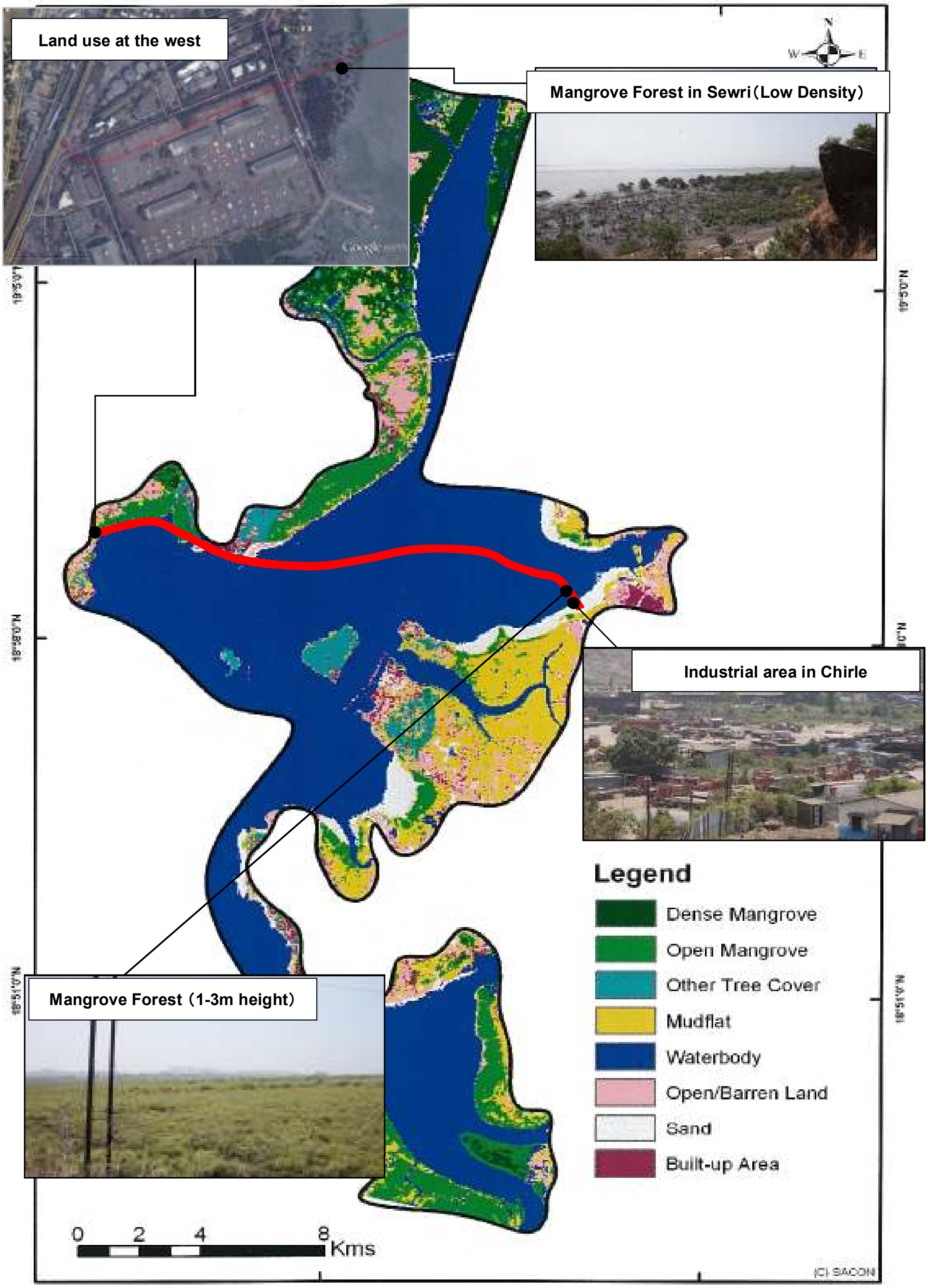


Figure 12.2.2 Geographic Feature

12.2.2 Land Use

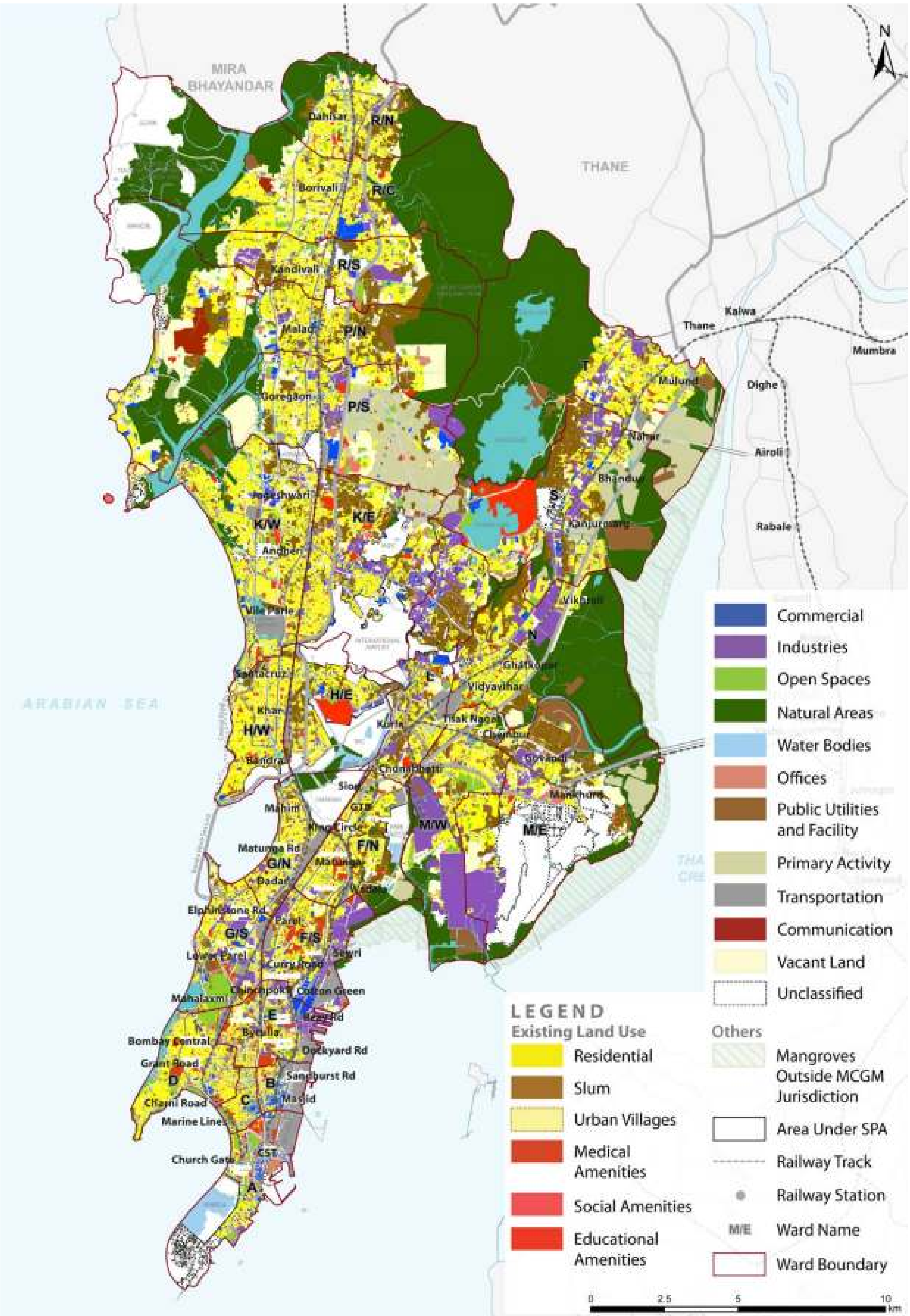
The authorities for the Development Plans are Municipal Corporation of Greater Mumbai (MCGM) in Mumbai and the City and Industrial Development Corporation (CIDCO) on Navi Mumbai side. The land use in the project area as of 2008 is shown in the Figure 12.2.3, and future's land use is shown in Figure 12.2.4 & Figure 12.2.5 respectively.

The starting point of the project alignment is the interchange with the Eastern Freeway. Then the alignment passes through the Mumbai Port Trust (MbPT) area on Mumbai side. The alignment in Navi Mumbai side passes through small residential area, quarry area, container yard area and then connects with the National Highway 4B.



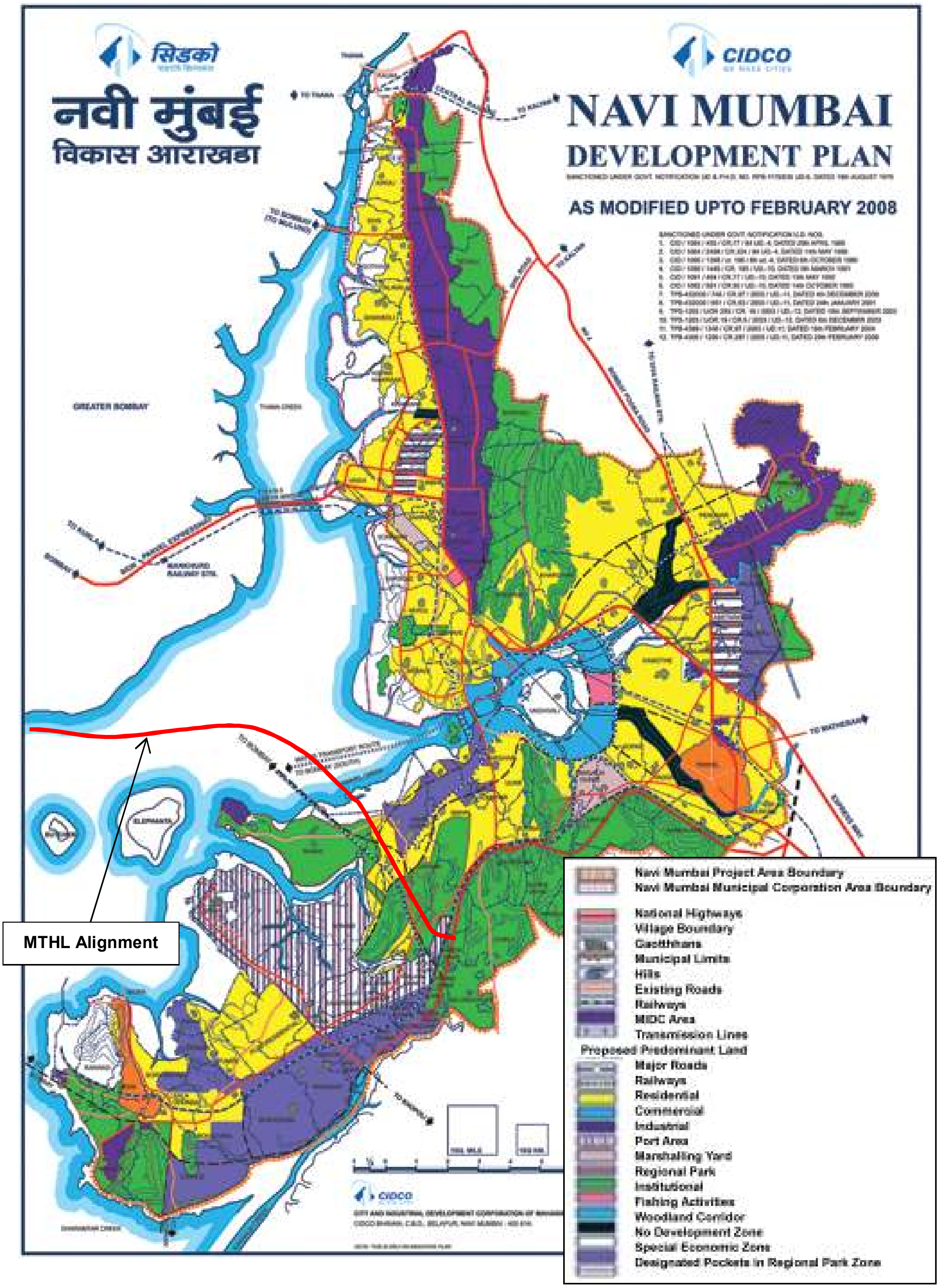
Source: Mumbai Trans Harbour Link Project Study of Flamingo and Migratory Birds Final Report 2008 December (Salim Ali Centre for Ornithology and Natural History)

Figure 12.2.3 Land Use in the Project Area



Source: Land Use Plan (draft: 2014－2034)

Figure 12.2.4 Proposed Land Use Plan in the Project Area (Mumbai Area 2014-2034)



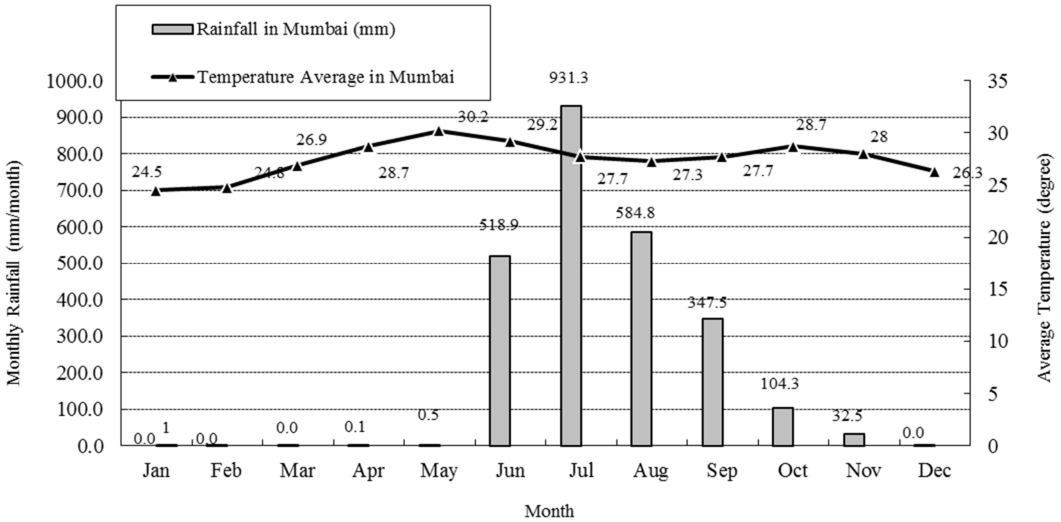
Source: Navi Mumbai Land Use Plan (CIDOCO 2008/Website)

Figure 12.2.5 Land in the Project Area in Navi Mumbai (2008)

12.2.3 Climate

The project area is categorized as the tropical monsoon climate. The Average Daily temperature varies from 24 degrees in January to 30 degree in May (dry season). On the other hand, the monsoon season starts from June and lasts till October.

Average monthly rainfall and temperature is shown in Figure 12.2.6.



Source: India Metrological Department, Ministry of Earth Sciences (website)

Figure 12.2.6 Annual Rainfall in Mumbai (2008-2013 Average)

12.2.4 Protected Area

(1) National Park

The Sanjay Gandhi National Park is located approximately 15km away on the north of the project starting point at Sewri. The project alignment falls outside the eco-sensitive zone of the Karnala Bird Sanctuary. The locations of the National Park and sanctuary are shown in Figure 12.2.7.

(2) Coastal Regulation Zone (CRZ)

The alignment passes through the Coastal Regulation Zone (CRZ). The Ministry of Environment, Forests & Climate Change (MOEF&CC) has issued CRZ Clearance for the project has been issued on 25th January 2016.

The Coastal Zone Management Plans near the project locations are shownin Figure 12.2.9.

(3) Important Birds and Biodiversity Areas (IBAs)

The IBAs are proposed program by Birdlife International and designates the areas to be conserved and managed. The criteria of the area shown below in accordance with Birdlife International;

- Places of international significance for the conservation of birds and other biodiversity
- Recognised world-wide as practical tools for conservation
- Distinct areas amenable to practical conservation action
- Identified using robust, standardised criteria
- Sites that together form part of a wider integrated approach to the conservation and sustainable use of the natural environment

3 sites are located in the project area and surrounding area as shown in Figure 12.2.8.

Table 12.2.2 Outline of the IBAs in the Project Area

Site Name / Item	1. Mahul- Sewri	2. Thane Creek	3. Sanjay Gandhi National Park
Distance from the Project Site	On the alighment (app, 5km length passing)	App. 7.8km	App. 15km
Location	72^{o} 53.00' East 19^{o} 1.00' North	72^{o} 57.50' East 19^{o} 7.50' North	72^{o} 57.80' East 19^{o} 18.58' North
IBA Criteria	A1, A4i, A4iii	A1, A4ii	A1, A2, A3
Area (ha)	1,000 ha	12,200 ha	10,308 ha
Assessment Year	2004	2004	2004

Source: Birdlife International website as of 26th Nov. 2015

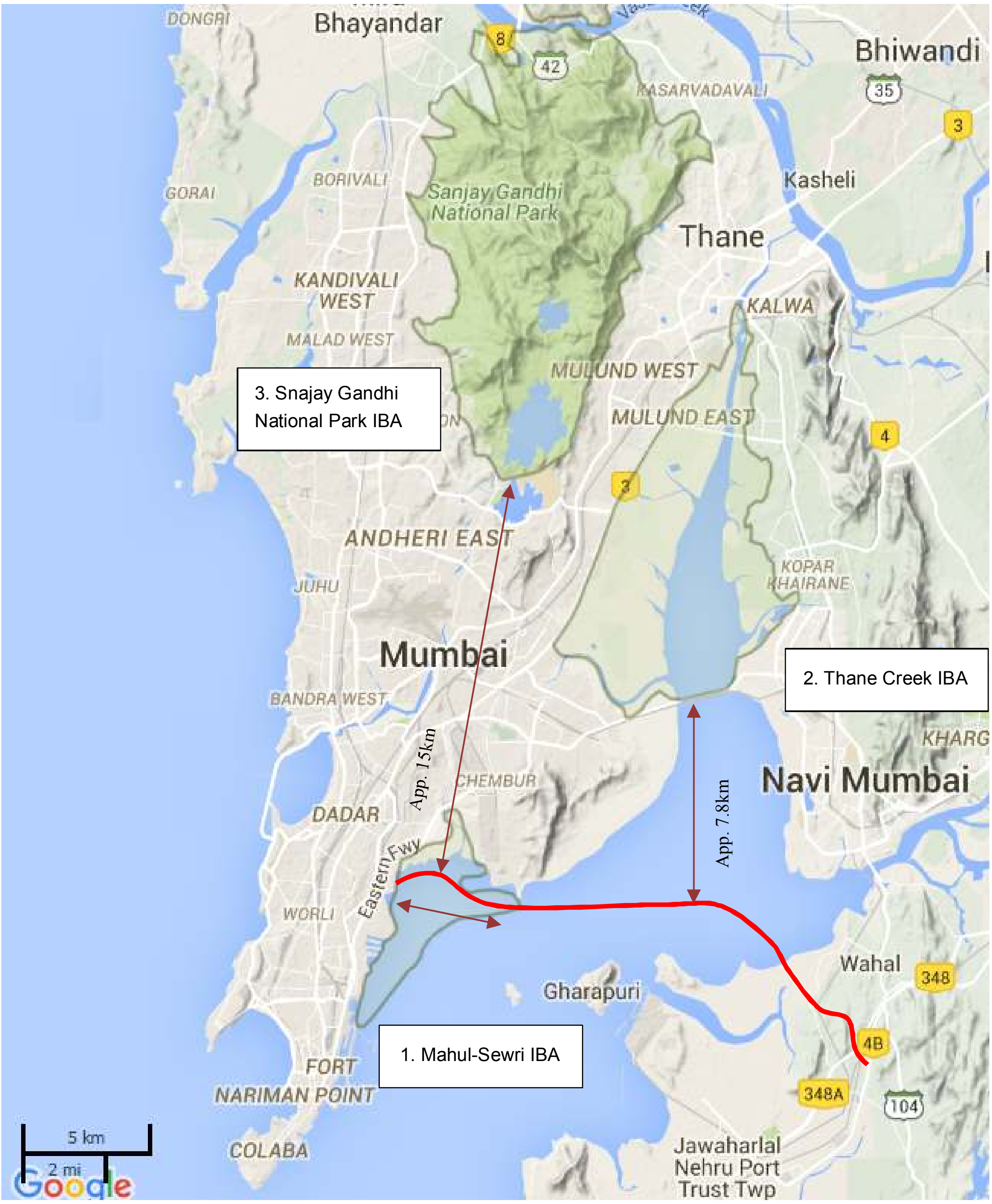
Table 12.2.3 Criteria of IBAs

Criteria	Description
A1. Globally threatened species	The site is known or thought regularly to hold significant numbers of a globally threatened species, or other species of global conservation concern.
A2. Restricted-range species	The site is known or thought to hold a significant component of a group of species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).
A3. Biome-restricted species	The site is known or thought to hold a significant component of the group of species whose distributions are largely or wholly confined to one biome.
A4. Congregations	A site may qualify on any one or more of the four criteria listed below: i). Site known or thought to hold, on a regular basis, >1% of a biogeographic population of a congregatory water bird species. ii). Site known or thought to hold, on a regular basis, >1% of the global population of a congregatory seabird or terrestrial species. iii). Site known or thought to hold, on a regular basis, > 20,000 waterbirds or >10,000 pairs of seabirds of one or more species. iv). Site known or thought to exceed thresholds set for migratory species at bottleneck sites.

Source: Birdlife International website as of 26th Nov. 2015

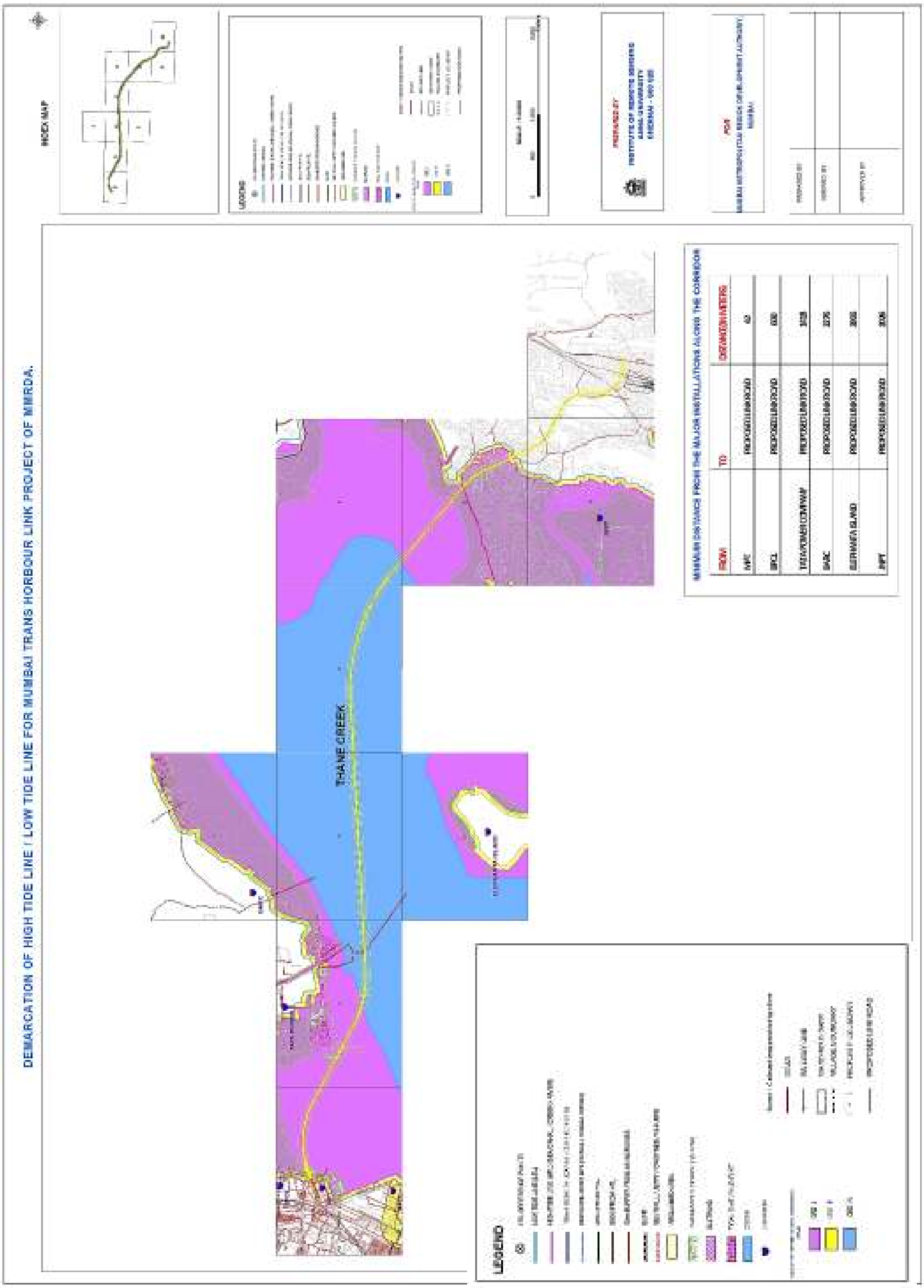
Source: JICA Study Team

Figure 12.2.7 Location map showing the of Sanjay Gandhi National Park and Karnala Bird Sanctuary



Source: Birdlife International as of June 2016

Figure 12.2.8 Location of Important Birds Areas (Mahul - Sewri Creek)



Source: MMRDA

Figure 12.2.9 Coastal Zone Management Plan (Mumbai and Navi Mumbai side)

12.2.5 Fauna and Flora

According to the past surveys[37] , 81 bird species has been observed in the project area. Most of observed species are categorized as the Least Concern (LC) class, but 5 species were categorized NT species such as Black Headed Ibs, Painted Stork, Black Tailed Godwit, Eurasian Curlew and Lessor Flamingo, and one species was VU species Greater Spotted Eagle. Additionally as per the latest bird's survey in Feb. – May 2016, 147 bird species has been observed in the project area. 12 species (Lesser Flamingo, Woolly-necked stork, Painted Stork, Black-headed Ibis, Greater Spotted Eagle, Indian Spotted Eagle, Pallid Harrier, Great Knot, Black-tailed Godwit, Bar-tailed Godwit, Eurasian Curlew and Alexandrine Parakeet) of 147 species of birds identified in the field observations have been classified as NT or higher categories (EN: 1 sp., VU: 3 sp., NT: 8 sp.) in the IUCN Red List . The other 135 species have been classified LC or NE which concerned degree of conservation is low.

According to local bird specialist, the migrated Flamingos have been observed since 1994. It is supposed that one of the reasons is due to increasing of the mudflat area and feeds such as plankton and algae under organic polluted environment in the basin. However Sewri are in Mumbai side is widely known as industrial area, however Lessor Flamingos and Greater Flamingos have been coming from Gujarat State in November since 1994 and staying there until June.

According to the study report conducted by MMRDA in 2008, counted number of the flamingos is approximately 10,000 to 15,000 a day. These flamingos eat algae and/or plankton during low tidal.

With regard to mangrove in Sewri and Navi Mumbai side, although the dominant specie is Avicennia marina, the surveyed density is quite low and small.

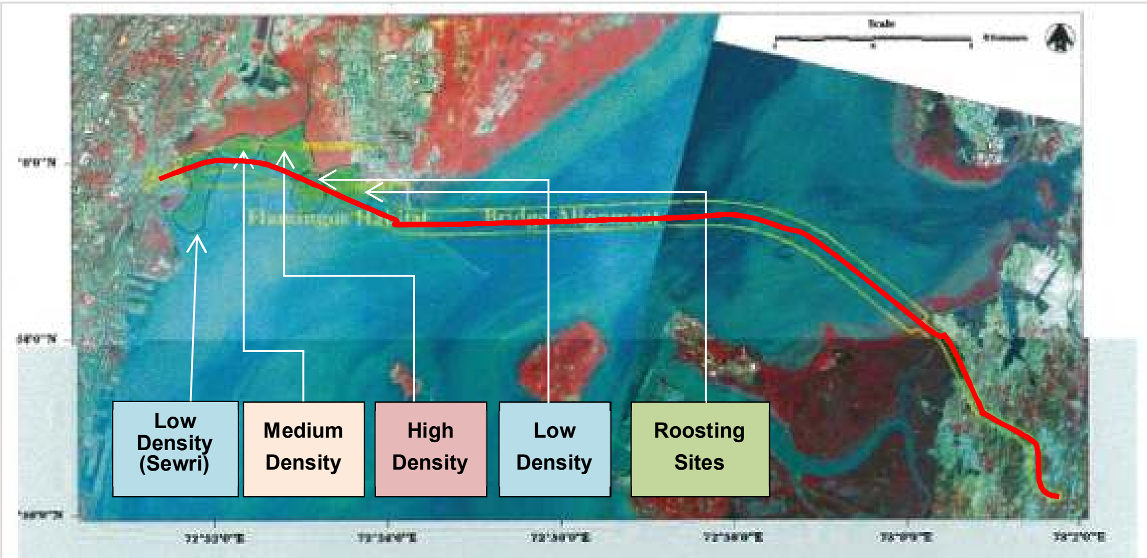
Source: JICA Study Team

Figure 12.2.10 Vegetation Community at Sewri and Navi Mumbai Site (April 2015)

[37] 1) Mumbai Trans Harbour Link Project Study of Flamingo and Migratory Birds Final Report 2008 December (Salim Ali Centre for Ornithology and Natural History) 2) Rapid EIA (MMRDA 2012)

Source: JICA Study Team

Figure 12.2.11 Observed Migratory Bird (Lessor Flamingo) in Sewri Mudflat Site



Source: Mumbai Trans Harbour Link Project Study of Flamingo and Migratory Birds Final Report 2008 December (Salim Ali Centre for Ornithology and Natural History)

Figure 12.2.12 Surveyed Flamingo's Distribution (2008)

12.2.6 Cultural Heritage

The Sewri Fort is located in the north approximately 180m away from Chainage 700m on the alignment. The Gateway of India is at 9 km distance from the alignment whereas the Elephanta Caves are 3km away from the alignment. No Objection Certificate (NOC) has been issued from the Archaeological Survey of India for the project alignment.

Source: JICA Study Team

Figure 12.2.13 Location of Registered Cultural Heritages

12.2.7 Socio-Economic

(1) Population

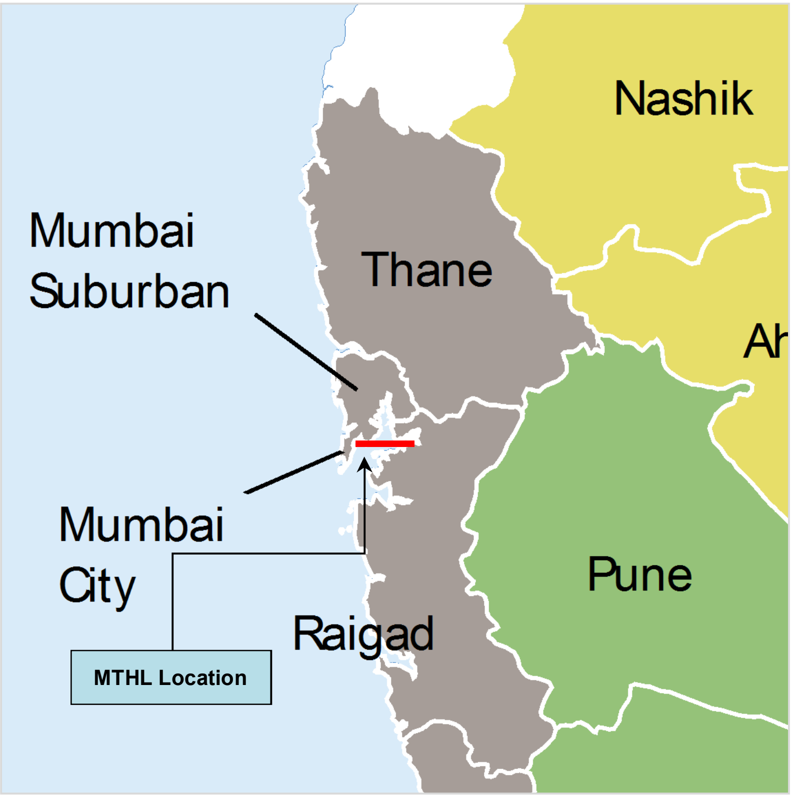
The project area is located in Konkan Division, State of Maharashtra. The starting point of the Mumbai Harbour Trans Link is in Sewri area Mumbai City, and the route is crossing Mumbai Bay and connects with National Highway 4B in Raigad District.

Total area of Mumbai and Raigad District is approximately 7,750 km^2 and its total population is app. 5.8 million on the census in 2011. Population increase for 10 years from 2001 to 2011 is 4.56 % in Mumbai and app. 19% in Raigad District.

Table 12.2.4 Socio-Economic Situation in the Project Area

Name of Area	Area (km^2)	% Area	Population (2011) (Person)	Grouth Rate (for 10 years)	Population Density (Person/km^2)
India	3,287,263	100.00%	1,210,193,422	14.99%	368
Maharashtra State	307,713	9.36%	112,372,972	15.99%	365
Konkan Division	30,746	0.94%	28,739,397	-	935
Mumbai City	603.4	0.02%	3,145,966	4.56%	25,851
Raigad District	7,152	0.22%	2,635,200	19.36%	368

Source: Indian Statistical Census (2011)



Source: JICA Study Team

Figure 12.2.14 Project Location on District Map

(2) Economy

GDP in India by state is indicated in Table 12.2.5. The GDP in Maharashtra is ranked the top state in India, and the GDP indicates 4,155 billion INR about 1.5 times of Uttar Pradesh.

On the other hand, GDP per capita in Maharashtra is 114,000 INR and ranked 7th in India as shown in Table 12.2.6. Additionally GDP and GDP per capita in Mumbai, Raigad and Thane are shown in Table 12.2.7.

Table 12.2.5 GDP in India (FY2013-2014)

Unit: Billion INR.	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
1 Maharashtra	4,155	4,868	5,845	6,848	7,540	8,558	10,492	11,754	13,238	14,762
2 Uttar Pradesh	2,608	2,932	3,363	3,830	4,447	5,234	6,003	6,855	7,804	8,627
3 Tamil Nadu	2,190	2,578	3,105	3,508	4,013	4,797	5,849	6,672	7,449	8,542
4 Gujarat	2,034	2,447	2,837	3,293	3,679	4,313	5,215	5,988	6,585	7,656
5 West Bengal	2,087	2,302	2,617	2,995	3,419	3,989	4,610	5,283	6,033	7,066
29 Manipur	51	57	61	68	74	83	91	111	127	143
30 Arunachal Pradesh	35	38	41	48	57	75	90	108	118	135
31 Sikkim	17	20	22	25	32	61	74	89	105	124
32 Mizoram	27	30	33	38	46	53	64	69	84	103
33 Andaman & Nicobar Islands	18	20	25	30	35	41	43	50	56	62

Source: Census of India (2015)

Table 12.2.6 GDP PER CAPITA in India (FY2013-2014)

Unit: x 1,000 INR	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
1 Goa	77	85	95	109	136	149	168	212	201	224
2 Delhi	64	72	83	95	112	126	145	167	193	220
3 Sikkim	27	30	32	36	47	91	109	130	151	176
4 Chandigarh	74	85	98	103	108	117	127	137	142	157
5 Puducherry	48	67	69	74	79	97	101	103	114	144
6 Haryana	38	42	49	57	67	82	94	106	120	133
7 Maharashtra	36	42	50	58	62	70	85	94	104	114
8 Tamil Nadu	30	35	42	48	54	64	78	89	99	113
9 Andaman & Nicobar Islands	41	45	54	61	69	79	81	90	98	107
10 Gujarat	32	38	43	50	55	64	77	86	93	107
31 Jharkhand	19	18	20	25	25	28	35	37	40	46
32 Assam	17	18	20	21	24	28	33	36	39	44
33 Manipur	19	20	21	23	24	27	28	34	38	42

Source: Census of India (2015)

Table 12.2.7 GDP PER CAPITA in the Project Area (FY2013-2014)

	GDP (billion INR)		GDP per capita (1,000 INR)	
	2012-2013	2013-2014	2012-2013	2013-2014
1 Mumbai	28.8	33.4	166	189
2 Thane	17.8	20.0	156	173
3 Raigad	3.5	3.8	120	132

Source: Maharashtra state plan division (2015)

(3) Industry

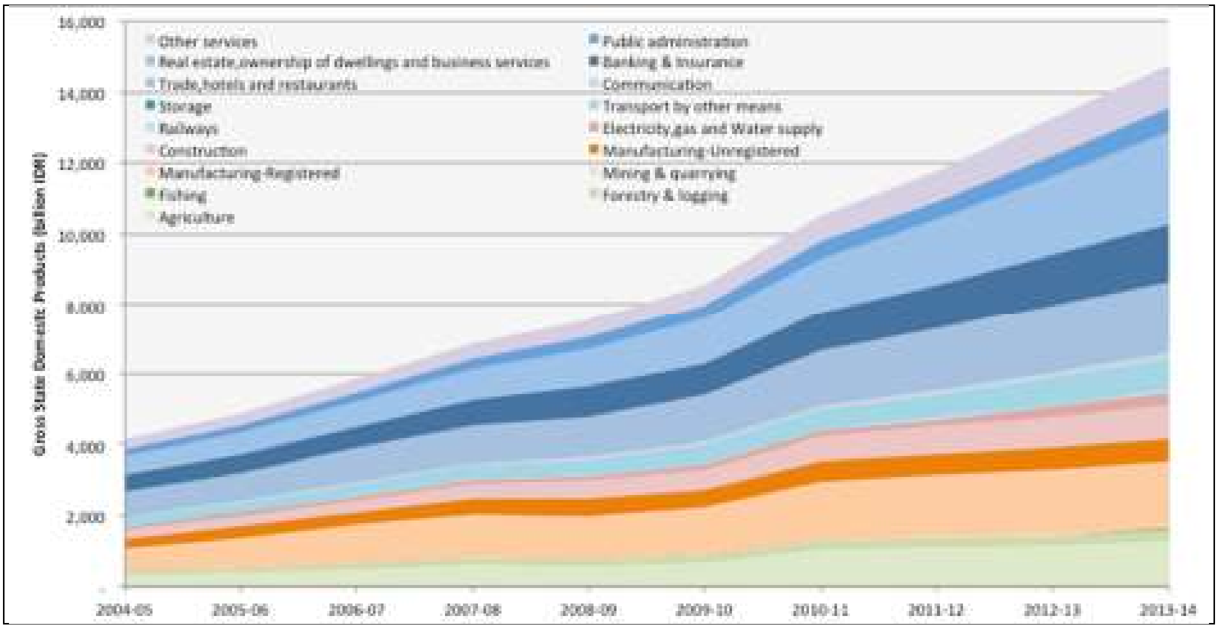
The key industries and sectors top three are shown in Table 12.2.8. The major industry in Maharashtra state is a service industry and it indicates around 63% and has been increasing.

On the other hand, the industrial production is about 26% in 2013-2014, and it has been decreasing. The agricultural production is stabilized around 11-12 %.

Table 12.2.8 GDP on Major Industry in Maharashtra State

Unit: % (Billion INR)	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Primary Industry	10.8 (449)	10.8 (528)	11.5 (672)	11.8 (807)	10.1 (758)	10.4 (886)	12.3 (1,293)	11.8 (1,387)	10.9 (1,442)	11.1 (1,636)
1 Agriculture	8.3	8.2	8.7	9.4	7.9	8.0	10.2	9.6	8.7	8.8
2 Forestry	2.2	2.3	2.5	2.1	2.0	2.1	1.9	1.9	1.9	2.0
3 Fishery	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3
Secondary Industry	29.6 (1,230)	31.8 (1,547)	32.0 (1,869)	32.4 (2,216)	31.3 (2,361)	29.8 (2,551)	29.7 (3,116)	28.2 (3,317)	27.4 (3,622)	26.0 (3,845)
1 Registered manufacturing	14.1	16.8	17.7	17.3	16.0	15.1	15.4	14.3	13.5	12.4
2 Construction	6.3	6.2	5.9	6.5	7.0	6.5	6.5	6.8	6.5	6.5
3 Not registered manufacturing	6.5	6.4	6.3	6.4	6.2	6.0	5.7	5.1	4.8	4.3
Tertiary industries	59.6 (2,475)	57.4 (2,793)	56.5 (3,303)	55.9 (3,826)	58.6 (4,420)	59.8 (5,121)	58.0 (6,082)	60.0 (7,050)	61.7 (8,173)	62.9 (9,282)
1 Real Estate	12.8	12.9	12.7	13.0	14.1	14.9	14.9	15.9	16.7	17.8
2 Trading/Hotel/ Restaurant	16.2	15.6	15.9	15.4	15.0	15.1	14.6	14.6	14.6	13.8
3 Insurance and financial	11.4	10.5	10.2	10.2	11.1	10.4	10.4	10.8	10.8	11.0

Source: Census of India (2015)



Source: Census of India (2015)

Figure 12.2.15 GDP by Industry in Maharashtra State

(4) Poverty Line

The criteria for poverty have been revising by the central government non-periodically. Thus the poverty line and the number under the poverty line are not accurate under the same criteria. According to poverty line in 2011-2012 based on the criteria determined by the

India Planning Committee in 2014, the poverty line is 1,078 INR in agricultural area Maharashtra and 1,560 INR in urban area respectively.

Table 12.2.9 Poverty Line in Maharashtra State

	Poverty Line (INR/month-capita)		Poverty Ratio (%)			Number of Poor (million)		
	Rural	Urban	Rural	Urban	Total	Rural	Urban	Total
Lakdawala Methodology								
1973-74	50.47	59.48	57.71	43.87	53.24	21.1	7.7	28.7
1977-78	58.07	73.99	63.97	40.09	55.88	25.0	8.0	33.0
1983-84	88.24	126.47	45.23	40.26	43.44	19.4	9.7	29.1
1987-88	115.61	189.17	40.78	39.78	40.41	18.6	10.9	29.6
1993-94	194.94	328.56	37.93	35.15	36.86	19.3	11.2	30.5
1999-00	318.63	539.71	23.72	26.81	25.02	12.5	10.3	22.8
2004-05	362.25	665.90	29.6	32.2	30.7	17.1	14.6	31.7
Tendulkar Methodology								
2004-05	485	632	47.9	25.6	38.1	27.7	11.6	39.3
2009-10	744	961	29.5	18.3	24.5	18.0	9.1	27.1
2011-12	967	1,126	24.2	9.1	17.4	15.1	4.7	19.8
C.Rangarajan Methodology								
2011-12	1,078.34	1,560.38	22.5	17.0	20.0	14.0	8.8	22.8

Source: India Planning Committee (2014)

12.3 Environmental Legislation

12.3.1 Environmental Impact Assessment (EIA Notification 2006)

The necessity of environmental impact assessment is stipulated on the Environmental Protection Law in 1986, and concrete rules are described on the Environmental Impact Assessment Notification in 2006 (EIA Notification). According to the notification, prescript projects are required to obtain an Environmental Clearance before implementation of the actual construction.

Category A projects in accordance with EIA notification are required to obtain the Environmental Clearance from Ministry of Environment and Forests (MOEF) of the central government, on the other hand, Category B project shall have the clearance from State Government.

The Sr. No. 7(f) schedule of the EIA Notification 2006 is reproduced in Table 12.3.2 below. The MTHL being an urban arterial road is not covered under category A or B defined under 7(f). Hence the project does not attract provisions of EIA Notification 2006.

Thus MMRDA has obtained only CRZ clearance from MOEF in 2013 and 2016 through approprirate process under reviwing by state and central relevant organizatios after preparation of Rapid EIA in 2012 in accordance with CRZ Notification 2011.

Contents and summary of Rapid EIA 2012 is shown in Table 12.3.1 and detailed surveyed data is indicated in article 12.4.5 Baseline survey result.

Table 12.3.1 Summary and Contents of Rapid EIA 2012

Chapter	Contents	Page	Detailed Item
Executive Sammary	―	37	
Chap. 1 Project background	Necessity of the project and study, legal framework, project positive impacts etc.	6	
Chap.2 Project description	Project background, alternative alignment analysis, road structure, interchange plan, traffic analysis, topographic analysis, resettlement, land acquisition, toll gate, quarry, schedule and cost	25	
Chap.3 Baseline survey	Topo-geo survey result, land use plan, air, water, noise, heritage, ecosystem, migratory birds and CRZ(Coastal Regulation zone)	45	✓ Air quality on site measuerment ✓ Water quality on site measurement ✓ Noise level on site measurement ✓ Biorology survey in 1 season (benthos, bottom sediment quality, migratory birds, mangrove etc.) ✓ Note) Detailed data is indicated in article 12.4.5 Baseline survey
Chap. 4 Analysis and mitigation measures	Impact analysis during and after construction (including adverse impacts on mudflat)	35	✓ Quantitative forecast analysis on air, noise level ✓ Note) Detailed data is indicated in article 12.4.5 Baseline survey ✓ Qualitative analysis on biorology
Chap. Environmental Management Plan	Environmental Management Plan, Monitoring Plan and Institutional framework	12	-
Chap. Disaster Management Plan	Risk Management Plan, Disaster management plan, risk analysis	10	-
Appendix	CRZ Permission letter and condition		

Source: Rapid EIA 2012 sumarrized by JICA Study Team

Table 12.3.2 Part of Schedule of EIA Notification 2006

Project or Activity		Category	
		Category A	Category B
7f	Highway	i) New National Highways; and ii) Expansion of National High ways greater than 30 KM, involving additional right of way greater than 20m involving land acquisition and passing through more than one State.	i) New State High ways; and ii) Expansion of National / State Highways greater than 30 km involving additional right of way greater than 20m involving land acquisition.

Source: EIA Notification (MOEF 2006)

12.3.2 Coastal Regulation Zone (CRZ Notification 2011)

According to CRZ notification 2011, following objectives for establishment of regulation are described;

"Now, therefore, in exercise of the powers conferred by sub-section (1) and clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government, with a view to ensure livelihood security to the fisher communities and other local communities, living in the coastal areas, to conserve and protect coastal stretches, its unique environment and its marine area and to promote development through sustainable manner based on scientific principles taking into account the dangers of natural hazards in the coastal areas, sea level rise due to global warming, does hereby, declare the coastal stretches of the country and the water area upto its territorial water limit, excluding the islands of Andaman and Nicobar and Lakshadweep and the marine areas surrounding these islands upto its territorial limit, as Coastal Regulation Zone (hereinafter referred to as the CRZ) and restricts the setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances as specified in the Hazardous Substances (Handling, Management and Transboundary Movement) Rules, 2009 in the aforesaid CRZ."

In the designated CRZ, the permitted and regulated activities are stipulated.

The Mumbai Harbour Trans Link being a trans harbour link, is permitted in CRZ. Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India has issued a CRZ clearance on 25th Jan 2016.

Relevant description regarding MHTL project on CRZ notification 2011 is show below.

Table 12.3.3 Relevant Description on CRZ Notification 2011

No.	Name of Article	Contents
Clause "3 (iv) (Page 2).	Prohibited activities within CRZ	The activities such as Land reclamation, bunding or disturbing the natural course of seawater are declared as prohibited activities within the CRZ except those,- (a) required for setting up, construction or modernisation or expansion of foreshore facilities like ports, harbours, jetties, wharves, quays, slipways, bridges, sealink, road on stilts, and such as meant for defence and security purpose and for other facilities that are essential for activities permissible under the notification;"
Clause "7 (Pg 8)	Classification of the CRZ	- For the purpose of conserving and protecting the coastal areas and marine waters, the CRZ area shall be classified as follows, namely:- (i) CRZ-I,– A. The areas that are ecologically sensitive and the geomorphological features which play a role in the maintaining the integrity of the coast,- (a) Mangroves, in case mangrove area is more than 1000 sq mts, a buffer of 50meters along the mangroves shall be provided; (b) Corals and coral reefs and associated biodiversity; (c) Sand Dunes; (d) Mudflats which are biologically active; (e) National parks, marine parks, sanctuaries, reserve forests, wildlife habitats and other protected areas under the provisions of Wild Life (Protection) Act, 1972 (53 of 1972), the Forest (Conservation) Act, 1980 (69 of 1980) or Environment (Protection) Act, 1986 (29 of 1986); including Biosphere Reserves; (f) Salt Marshes; (g) Turtle nesting grounds; (h) Horse shoe crabs habitats; (i) Sea grass beds; (j) Nesting grounds of birds; (k) Areas or structures of archaeological importance and heritage sites. B. The area between Low Tide Line and High Tide Line; (ii) CRZ-II,- The areas that have been developed upto or close to the shoreline.
Clause "8 (Pg 9)	Norms for regulation of activities permissible under this notification,-	(i) The development or construction activities in different categories of CRZ shall be regulated by the concerned CZMA in accordance with the following norms, namely:- I. CRZ-I,- (i) no new construction shall be permitted in CRZ-I except,- (e) Construction of trans harbour sea link and without affecting the tidal flow of water, between LTL and HTL." "(ii) Areas between LTL and HTL which are not ecologically sensitive, necessary safety measures will be incorporated while permitting the following, namely:- (g) Construction of trans harbour sea links, roads on stilts or pillars without affecting the tidal flow of water."

Source: Coastal Regulation Zone Notification (MOEF 2011)

Table 12.3.4 Specific Conditions in the CRZ issues to the MTHL project (2016)

No.	Conditions
(i)	All the terms and conditions stipulated by the MCZMA in their letter No.CRZ 2015/CR236/TC4 dated 26th November, 2015, shall be strictly complied with.
(ii)	All the terms and conditions as mentioned in the earlier CRZ Clearance dated 19th July,2013, shall also be compliec with in letter and spirit.
(iii)	The Environment Management Plan as presented during the meeting shall be implemented in consultation with all the stakeholders.
(iv)	The project/activity shall be carried out strictly be in accordance with the provisions of CRZ Notification, 2011, and shall not affect the coastal ecology of the area including flora and fauna.
(v)	The project proponent shall obtain all permissions from concerned authorities prior to commencement of the project, and shall observe all safety requirements onshore and offshore
(vi)	The project proponent shall not undertake any blasting/construction activities during night hours.
(vii)	The proposal indicates the diversion of 47.417 ha forest land for which the proponent shall obtain the requisite Forest Clearance. The project may be executed in the entire stretch in non-forest land, and while making application to get the Forest Clearance, the execution of work on non-forest land shall not be cited as a reason for grant of FC and in case FC is declined, the forest land shall be maintained at its existing condition. The PP shall submit an undertaking to this effect at the earliest to the concerned Regional Office to this Ministry.
(viii)	All the wildlife mitigation measures as proposed by BNHS in their report dated 23.09.2015 for original alignment shall be implemented with the following modification: (a) construction of jetty on both the ends passing through mud flats and mangroves must not exceed 30months and construction ofactual spans must notexceed more that futher 12 months (b) the distance between the supporting pillars shall remain 50 m as currently proposed by the MMRDA (c) MMRDA will party bear the cost of setting of effluent treatment plant in the region as suggested by BNHS.
(ix)	The project proponent shall not undertake any blasting / construction activities during night hours

Source: CRZ Environmental Clearance (MOEF 25th Jan. 2016)

Table 12.3.5 CRZ clearance related conditions (Jan. 25 2016)

No.	Conditions
1	The project/activity shall be carried out strictly be in accordance with the provisions of CRZ Notification, 2011, and shall not affect the coastal ecology of the area including flora and fauna.
2	The project proponent shall obtain all permissions from concerned authorities prior to commencement of the project, and shall observe all safety requirements onshore and offshore.
3	The project proponent shall not undertake any blasting/construction activities during night hours.
4	Adequate provision for infrastructure facilities including water supply, fuel and sanitation must be ensured for construction workers during the construction phase of the project to avoid any damage to the environment.
5	The project proponents shall inform to the Regional Office as well as the Ministry, the date of financial closure and final approval of the project by the concerned authorities and the date start of land development work.
6	All other statutory clearances such as the approvals for storage of diesel from Chief Controller of Explosives, Fire Department, Civil Aviation Department, and clearances under the Forest Conservation Act, 1980 and Wildlife (Protection) Act,1972 etc. shall be obtained, as applicable by project proponents from the respective competent authorities.
7	The Sewri End of the Jetty should be used for transportation of construction material to avoid disturbance to the mudflats
8	MMRDA to install noise barriers of 3 m height on both side of the Sealink passing through CRZ I (mudflat & mang.roves area) and CRZ IV area.
9	MMRDA to ensure that all construction equipments are fully fitted with mufflers and exhaust silencers to contain the noise levels. Machinery used during construction should be properly maintained to minimize the air and noise emissions.
10	MMRDA to ensure that minimum damage is caused to mangroves ecosystem.
11	MMRDA to ensure that operations in the mudflats or intertidal zone will be done by using temporary jetty which will be parallel to permanent structure in the Right of way for the transportation of labour, construction material, precast elements, machinery ect. On the either ends.
12	All the construction equipment's shall be provided with exhaust silencers as committed
13	Noise containment barriers shall be provided on both sides of the birds in mudflat areas (CRZ-IA) so as to minimize the likely impacts to the migratory birds as committed.
14	There shall be no dredging and reclamation for the project.
15	Pre-stressed super structure shall be used in the mud flat area for construction as committed
16	The muck material shall be analysed prior to dumping/ disposal in the identified location with the approval of the competent authority to ensure that it do not cause any impact to the environment.
17	There shall be no water drawal in CRZ area
18	There shall be no disposal of soild or liquid wastes on coastal area. Solid waste Management shall be as per Municipal Solid (Management and Handing) Rules, 2000.
19	Sewage shall be treated and the Treatment Facility shall be provided in accordance with the Coastal Regulation Zone Notification, 2011. The disposal of treated water shall conform to the regulations of State Pollution Control Board

Source: UMBAI TRANS HARBOUR LINK PROJECT/ MoEF's CONDITIONS: TO BE INCORPORATED IN BID DOCUMENT

Table 12.3.6 The conditions related to Forest clearance; (Jan. 22 2016)

No.	Conditions
1	No labour camp shall be established on the forest land.
2	The Contractor shall provide fuels preferably alternate fuels to the labourers and the staff working at the site so as to avoid any damage and pressure on the nearby forest areas.
3	The layout plan of the proposal shall not be changed without the prior approval of the Central Government.
4	The forest land shall not be used for any purpose other than that specified in the proposal.
5	No damage to the flora and fauna of the adjoining area shall be caused.
6	Felling of trees on the forest land being diverted shall be reduced to the bare minimum and the trees should be felled under strict supervision of the State Forest Department.
7	The reclamation of quarry should be done under the supervision of the State Forest Department. The quarry shall be reclaimed and afforested completely before the project is closed.
8	Overburden shall not be dumped outside the width of the road. The muck generated in the earth cutting will be disposed off at the designate dumping sites and in no case the muck/debris shall be allowed to roll down the hill slopes.
9	The User Agency will provide retaining walls, breast wall, breast wall and drainage as per requirement to make the slope stable.
10	The Contractor will undertake comprehensive soil conservation measures at the project cost in consultation with the State Forest Department.
11	The designing of culverts/bridges. If any, over the natural streams/rivers/ canals should be done in such a manner that it does not hamper the natural course of water, does not give rise to water-logging, and also does not hamper movement of wild animals
12	Any other condition that the concerned Regional Office of this Ministry may stipulate, from time to time in the interest of conservation, protection and development of forests & wildlife.
13	The Contractor shall ensure compliance to provisions of the all Acts, Rules, Regulations and Guidelines, for the time being in force, as applicable to the project.
14	Mitigation Measures implemented by Contractor MoEF implied following mitigating measures to ameliorate any adverse environmental impact due to the construction/ execution of the MTHL project:
15	Construction in mud flat areas will involve use of temporary steel bridge/jetty parallel to the permanent structure for transportation of personnel, construction materials, pre cast elements, machinery, etc on either ends so as to cause minimal disturbance to eco sensitive mud flats and mangroves.
16	No embankment to be used in the construction of the bridge alignment; the bridge is proposed as a sea link with viaducts. Therefore, only the foot print area occupied by the piers/piles/ramps would be affected.
17	Assist MMRDA in compensatory mangrove plantation to be carried out through the Forest Department at the cost of the project proponent/MMRDA
18	Use of pre cast/fabricated units for superstructure to avoid effect on mudflats by minimizing construction activity on mud flats and also to avoid supporting system from sea bed.
19	As far as possible during construction, construction machinery movement (barges, etc) to bypass locations having migratory birds.
20	Construction machinery/equipment to be fitted with mufflers/exhaust silencers to contain noise produced along with provision of enclosures and intake silencers.
21	DG sets, if used, to adhere to noise standards as laid down by the MoEF.
22	Illumination of bridge carriage way in the mudflat stretches is proposed at low level (inner side of railing/noise barrier) to avoid disturbance to bird habitat at night.
23	Excavated soil to be disposed off at designated/approved dumping sites located far from the mud flat areas
24	No burning of waste in open air to be allowed during construction.
25	Implementation of surveillance management and monitoring program during construction to prevent

	any adverse impact on migratory birds.
26	No cable stayed bridge proposed to allow free and unhindered movement of birds.
27	Appointment of bird monitors during construction and even after completion of the project till the baseline levels are achieved.
28	Creation of an Environment Monitoring Cell comprising MMRDA officials and experts to monitor the impact on environment during construction as well as operation.
29	Debris in any form should not be dumped in mudflat and mangrove areas of Sewri, Thane creek and Nhava and other parts of Sewri Bay under any circumstances.
30	Debris disposal plan to be developed in which debris disposal sites to be clearly demarcated.
31	As far as possible the transportation of construction material to be facilitated from Sewri Jetty to avoid disturbance to mudflats.
32	A clear plan for construction to be provided before the work begins.
33	As far as possible, the spans to be pre fabricated at sites which are away from ecologically sensitive zones and brought in by barges
34	Utmost care to be taken to ensure that mangroves and mudflats on either side of the bridge are not disturbed.
35	Though it is recognized that it may be beyond the mandate of MMRDA under the current project, the Maharashtra state must facilitate establishment of a mechanism to clean up the Sewri Mudflats (and Thane Creek) through integrated effluent treatment plant/plants.
36	Habitat quality assessment and monitoring of the conservation/mitigation measures during construction are to be continued till 5 years after completion so as to ascertain the impact of MTHL on flamingo and roosting areas.
37	Construction of jetty on both the ends passing through mudflats and mangroves must not exceed 30 months and construction of actual span must not exceed more than further 12 months.
38	The distance between the supporting pillars in mudflat areas shall remain minimum 50 m as currently proposed by MMRDA

Source: UMBAI TRANS HARBOUR LINK PROJECT/ MoEF's CONDITIONS: TO BE INCORPORATED IN BID DOCUMENT

12.3.3 Other Relevant Environmental Laws and Regulations

Other relevant environmental laws and regulations are shown in the next table.

Table 12.3.7 Other Relevant Environmental Laws and Regulations

No.	Name	Year
1	Environmental (Protection) Act	1986
2	Environment Impact Assessment Notification	2006, 2009, 2012
3	Forest Conservation Act	1927, 1980
4	National Forest Policy	1952, 1988
5	Coastal Regulation Zone Notification	2011
6	Wildlife (Protection) Act	1972
7	Land Acquisition Act	1894, 1989
8	Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act	2013
9	Air (Prevention and Control of Pollution Act)	1981
10	Hazardous Waste (Management and Handling Rules)	1989, 2003
11	Municipal Solid Waste (Management and Handling Rules)	2000
12	Noise Pollution Regulation and Control Rule	2000
13	Water (Prevention and Control of Pollution Act)	1974

Source: JICA Study Team

Table 12.3.8 Other Relevant Environmental Ratification Treaty

No.	Name	Effected Year
1	United Nations Framework Convention on Climate Change	1994
2	Kyoto Protocol	2001
3	Convention on Biological Diversity	1993
4	Cartagena Protocol on Biosafety	2003
5	Vienna Convention for the Protection of the Ozone Layer	1988
6	Montreal Protocol on Substances that Deplete the Ozone Layer	2002
7	Basel Convention	1992
8	The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	2004
9	Stockholm Convention on Persistent Organic Pollutants	2004
10	United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa	1996
11	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1975
12	The Convention on Wetlands of International Importance especially as Waterfowl Habitat	1975
13	Antarctic Treaty / Protocol on Environmental Protection to the Antarctic Treaty	1961
14	Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol)	1998

Source: Ministry of Foreign Affairs in Japan (website)

12.3.4 Gaps between Rapid EIA study and JICA's Guidelines

As per the JICA's guidelines the project is categorized as Category A. Following preliminary comparative analysis has been conducted between JICA Guidelines and "Rapid EIA in 2012" prepared by MMRDA.

According to the gap analysis, the identified gaps are Social Impact Survey, Vibration Survey and holding Public Consultation.

Table 12.3.9 Result of Preliminary Gap Analysis between JICA Guidelines and Rapid EIA

JICA Guideline (Appendix 2. EIA Reports for Category A Projects)	Rapid EIA (2012 prepared by MMRDA)	Gaps	Policy to fill up gaps in this Study
When assessment procedures already exist in host countries, and projects are subject to such procedures, project proponents etc. must officially finish those procedures and obtain the approval of the government of the host country.	At first, the project is not required to prepare the EIA in accordance with EIA Notification 2006. However necessary environmental clearance for CRZ is obtained from MOEF by MMRDA in 2016.	- (no difference)	Not required
EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them.	Rapid EIA 2012 has been prepared in only English.	At least English and Hindi version shall be prepared. Marathi is also considered.	Supplemental EIA in English and summary version in Marathi shall be disclosed after approval of Final Supplemental EIA.
EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted.	Rapid EIA in 2012 is disclosed when any persons request in accrodace with the right to information Act 2005	Rapid EIA shall be disclosed upon request	Supplemental EIA in English and summary version in Marathi shall be disclosed after approval of Final Supplemental EIA.
In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared.	A public consultation has not been conducted on the process of Rapid EIA 2012	Either local Stakeholder meeting and public consultation has been conducted on the process of Raid EIA 2012	Twice public consultation is held at scoping and draft supplemental EIA stage respectively
Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared.	Any consultation has not been conducted on the process of Rapid EIA 2012	ditto	ditto

Source: JICA Study Team

12.4 Environmental and Social Impact Assessment

In this article, alternative analysis, scoping and expected mitigation measures are described for the MTHL project.

12.4.1 Analysis of Alternatives

(1) Alternative Analysis

As explained in previous chapter 3, the route and fundamental structure have concluded and approved by central government from the view of natural & social environment, security and adjustment with other projects in 1984. In 2015, a NGO (BNHS) has recommended to change alignment in the Sewri Section and MMRDA has considered and analysed it from the view of natural & social environment with other relevant government organizations, however the recommended route in the Sewri was not adopted due to significant impacts on the other relevant government plans.

Thus factor on alternative analysis is limited as follows. As shown in Table 12.4.1, Span length and location of IC is listed up as factor of alternative analysis, however, in general, the location of IC is planned at actual connected trunk road, and hence, there are not any options to shift other area so long as the connected road plan does not change.

Table 12.4.1 Selected Factors on Alternative Analysis

Factor/ Condition	Reason for adoption
Location of Interchange	As the MTHL needs to have effective connectivity with the Eastern Freeway and the Sewri-Worli connector, the location of the interchange cannot be shifted to other points. Thus "location of interchange" is not appropriate factor on the analysis.
Span length (steel girder bridge)	Increasing the span length may reduce footprint of the structure in the mudflat and mangrove area. Adoption of steel girder for superstructure enables adopting longer spans and reduction of number of piers. Thus this factor is selected as an appropriate factor on the analysis.

Source: JICA Study Team

"Span length" is selected as a factor on the alternative analysis and evaluated from the view of natural environment and economy & cost as shown in Table 12.4.2.

According to the result of analysis, although option 1 with 60m span length can reduce the number of piers, the size of piers becomes bigger as a result of the structural analysis. Thus option-2 with 50m span length has slight advantage as regards the impact area on mudflat and mangroves. Additionally 50m spans have advantages such as easier constructability, lesser construction period and lower construction cost. Thus Option-2 (50m) should be selected from above point of view.

Table 12.4.2 Alternative Analysis (Span Length)

Item \ Option		Option-1			Option-2 (adopted)			
		60m Spans			50m Spans			
Specification	Superstructure	PC Box Girder (girder depth: 2.0m to 4.0m)			PC Box Girder (girder depth: 3.2m)			
	Substructure	62 Piers (pilecap type)			42 Piers (pilecap type)	34 Piers (pile bent type)		
		Pier: φ2,500mm-2nos			Pier: φ2,500mm-2nos	Pier: φ2,400mm-2nos		
		Pilecap: 9.0m×9.0m			Pilecap: 9.0m×9.0m	Bored pile: φ2,000mm-4nos		
		Bored pile: φ2,000mm-4nos			Bored pile: φ2,000mm-4nos			
Structural performance		High record of usage		◎	High record of usage			◎
Constructability	Construction method	Cantilever method (more difficult than span by span method)	○	○	Span by Span method (easier than cantilever method)		◎	◎
	Quality control	Normal (Cantilever method)	○		Easy (Span by span method)		◎	
Construction period		Longer than Option-2 (superstructure: cantilever method, all 62 piers: pilecap type)		△	Shorter than Option-1 (superstructure: span by span method, 42 piers: pilecap type, 34 piers: pile bent type)			◎
Environmental impact (Impact on mudflat habitat, mangrove cutting area)		Area occupied by pier inside mud flat area: **10,000m^2** (all 62 piers: pilecap type)		○	Area occupied by pier inside mud flat area: **7,000m^2** (42 piers: pilecap type, 34 piers: pile bent type)			◎
Construction cost (Approx. 4.1km within mud flat area)	Amount (crore INR)	2,560		△	2,000			◎
	Ratio	1.28			1.00			
Evaluation		Not recommended			**Recommended ○**			

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

Source: JICA Study Team

(2) Zero Option

In case of "Zero Option" which does not implement the project, following adverse negative and positive impacts are expected. Some positive impacts are expected, however, since the expected negative impacts are serious from the view of economic and environment, "With project case" is desirable comprehensively;

[Negative Impacts]

- The congested situation must be accelerated and prevent from sound urban development. Furthermore, this “without case” will not give a synergy effect on other development plan such as a construction of Navi Mumbai Air Port.
- The accelerated congestion must make all of vehicles decrease travelling speed, and then volume of greenhouse gases increase from vehicles.

[Positive Impacts]

- Mangrove and mud flat is conserved
- Resettlement and land acquisition is not caused

12.4.2 Screening

As described in 12.3, obtaining the Environmental Clearance is not required in accordance with EIA Notification 2006, however CRZ clearance in accordance with CRZ Notification 2011 is required. The MoEF&CC has granted CRZ Clearance to the project on 25th January 2016. JICA feels that the project may have significant impacts on natural and social environment. Thus the project has been classified as “Category A” as per JICA’s guidelines. This requires conducting EIA study.

12.4.3 Scoping

Scope of the EIA study for the project is discussed in this section. The environmental scoping is conducted based on an environmental reconnaissance by the JICA Study Team in April 2015.

The result of scoping is indicated on the Leopold scoping matrix and reason tables. First of all, impact factors, impacted item and impact degree are shown on the following scoping matrix based on JICA’s Guidelines.

(1) Scoping Matrix for MTHL

As the result of Scoping Analysis, 15 items such as Air, Water, Waste, Noise & Vibration, Biology & protected area, Hydrology, Topography and Geography, Existing Infrastructures, Misdistribution of benefit and damage, land scape, infection diseases and accident are selected as item of the Rating B which has some negative impacts.

Additionally mainly social items such as “involuntary resettlement” are evaluated as “Rating C” which has unknown impacts.

Table 12.4.3 Draft Scoping Matrix for MTHL

	No	Impacted Item (JICA Guidelines)	Impacted Item (Items of the Rapid EIA 2012)	During Construction	Pre/ During Construction Phase: Land acquisition and Loss of properties and Change of Land use plan, Control of various activities by regulations for the construction	Pre/ During Construction Phase: Reclamation of Wetland, etc.	Pre/ During Construction Phase: Deforestation(including Mangrove)	Pre/ During Construction Phase: Alteration to ground by cut land, filling, drilling, tunnel, etc.	Pre/ During Construction Phase: Operation of Construction Equipment and Vehicles	Pre/ During Construction Phase: Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Pre/ During Construction Phase: Traffic Restriction in construction area	Pre/ During Construction Phase: Influx of construction workers, construction of base camp	After Construction	Operation Phase: Increase of Through Traffic and traveling speed	Operation Phase: Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Operation Phase: Increasing influx of settlers
Pollution	1	Air Pollution	Air quality/ Siting of borrow and quarry material areas	B-	D-	D-	D-	D-	B-	D-	D-	D-	B-	B-	D-	D-
Pollution	2	Water pollution	Water Quality/ Construction of labour camp/ Siting of borrow and quarry material areas	B-	D-	B-	D-	B-	D-	D-	D-	B-	D-	D-	D-	D-
Pollution	3	Waste	Solid waste management/ Construction of labor camp/ Topography, Soil and Geology	B-	D-	D-	B-	B-	D-	D-	D-	B-	D-	D-	D-	D-
Pollution	4	Soil contamination	Topography, Soil and Geology/ Siting of borrow and quarry material areas	C-	D-	D-	D-	B-	D-	D-	D-	D-	D-	D-	D-	D-
Pollution	5	Noise and Vibration	Ambient Noise	B-	D-	D-	D-	D-	B-	D-	D-	D-	B-	B-	D-	D-
Pollution	6	Ground Subsidence		D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Pollution	7	Odor		D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Pollution	8	Sediment quality	Topography, Soil and Geology(No.4)	C-	D-	D-	D-	C-	D-	D-	D-	D-	D-	D-	D-	D-
Natural Environment	9	Protected Area	Reserved Forest and Fauna	B-	D-	D-	B-	B-	B-	D-	D-	C-	B-	B-	B-	D-
Natural Environment	10	Ecosystem	Ecology and Biodiversity/ Ecology/Construction of labor camp	B-	D-	D-	B-	B-	B-	D-	D-	C-	B-	B-	B-	D-
Natural Environment	11	Hydrology		B-	D-	D-	D-	B-	D-	D-	D-	D-	B-	D-	B-	D-
Natural Environment	12	Topography and geology	Topography, Soil and Geology	B-	D-	D-	D-	B-	D-	D-	D-	D-	B-	D-	B-	D-

	No	Impacted Item (JICA Guidelines)	Impacted Item (Items of the Rapid EIA 2012)	During Construction	Pre/ During Construction Phase: Land acquisition and Loss of properties and Change of Land use plan, Control of various activities by regulations for the construction	Reclamation of Wetland, etc.	Deforestation(including Mangrove)	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	After Construction	Operation Phase: Increase of Through Traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Increasing influx of settlers
Social	13	Involuntary resettlement		B-	B-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social	14	The poor		C-	C-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social	15	Indigenous and ethnic people		D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social	16	Local economy such as employment and livelihood	Quality of Life/Fisheries	C-	C-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social	17	Land use and utilization of local resources	Land use/Fisheries	C-	C-	D-	C-	D-	D-	D-	D-	D-	C-	D-	C-	D-
Social	18	Waste Usage	Water Quality	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social	19	Existing social infrastructures and services	Utility services and community severance	B-	B-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social Environment	20	Social institutions such as local decision making institutions		D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social Environment	21	Misdistribution of benefit and damage	Quality of life	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social Environment	22	Local conflict of interests		B-	D-	D-	D-	D-	D-	D-	D-	B-	D-	D-	D-	D-
Social Environment	23	Cultural Heritage	Archaeological /Heritage	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
Social Environment	24	Landscape	Aesthetics and landscape	B-	D-	D-	D-	D-	D-	B-	D-	D-	B-	D-	B-	D-
Social Environment	25	Gender		C-	C-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-

	No	Affected Activities / Impacted Item (JICA Guidelines)	(Items of the Rapid EIA 2012)	During Construction	Pre/ During Construction Phase: Land acquisition and Loss of properties and Change of Land use plan, Control of various activities by regulations for the construction	Reclamation of Wetland, etc.	Deforestation(including Mangrove)	Alteration to ground by cut land, filling, drilling, tunnel, etc.	Operation of Construction Equipment and Vehicles	Construction of Roads, tollgates, parking lots, Access roads for bridges and other related facilities	Traffic Restriction in construction area	Influx of construction workers, construction of base camp	After Construction	Operation Phase: Increase of Through Traffic and traveling speed	Appearance/ Occupancy of Roads and related building structures including tunnel and embankment	Increasing influx of settlers
Social Environment	26	Right of Children		D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
	27	Infectious diseases such as HIV/AIDS		B-	D-	D-	D-	D-	D-	D-	D-	B	D-	D-	D-	D-
	28	Labor environment (including work safety)		B-	D-	D-	D-	D-	D-	D-	D-	B-	D-	D-	D-	D-
Other	29	Accidents	Accident hazards and safety	B-	D-	D-	D-	D-	B-	D-	D-	D-	B-	B-	D-	D-
	30	Cross Boundary impacts and climate change		B-	D-	D-	B-	D-	B-	B-	D-	D-	C-	C-	D-	D-

Note) Rating:

A: Serious impact is expected. B: Some impact is expected. C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done) No mark: Few impacts are expected. Detailed quantitative survey is not necessary. (+: Positive impacts, - : Negative impacts)

Source: JICA Study Team

Table 12.4.4 Reasons for Draft Scoping on MTHL

Area	No.	Impacted Item (Item on the Rapid EIA 2012)	Rating (Scoping stage) Pre/During Const	Rating (Scoping stage) After Const	Reasons of the Rating
Pollution	1	Air Pollution (Air quality/ Siting of borrow and quarry material areas)	B-	B-	**Construction phase:** Temporary negative impacts are expected on air quality due to construction machines and equipment. **Operation phase:** Negative impact is expected due to the increase in traffic number.
	2	Water Pollution (Water Quality/ Construction of labor camp/ Siting of borrow and quarry material areas)	B-	D-	**Construction phase:** Turbid water may be generated by earth works and excavation in the water where bridges are planned. Additionally Organic polluted water may be discharged from base camp. **Operation phase:** No serious impacts are expected(The service area is not planned on this project)
	3	Waste (Solid waste management/ Construction of labor camp/ Topography, Soil and Geology)	B-	D-	**Construction phase:** Construction waste such as waste soil and cutting trees are expected. Additionally domestic waste and night soil may be generated from construction base camp. **Operation phase:** No serious impacts are expected(The service area is not planned on this project)
	4	Soil Contamination (Topography, Soil and Geology/ Siting of borrow and quarry material areas)	C-	D-	**Construction phase:** Excavated soil in the mudflat and mining area may contain polluted soil such as heavy metals. **Operation phase:** No impacts are expected
	5	Noise and Vibration (Ambient Noise)	B-	B-	**Construction phase:** Noise generation is expected due to works of construction machines and equipment. **Operation phase:** Traffic Noise and Vibration is expected because of the increase in traffic number and travelling speed.
	6	Ground subsidence	D-	D-	**Construction and operation phase:** No impacts are expected since activities which cause ground subsidence not expected.
	7	Odor	D-	D-	**Construction and operation phase:** No impacts are expected since activities which cause odor are not expected.
	8	Sediment quality (Topography, Soil and Geology(No.4))	C-	D-	**Construction phase:** Excavated soil in the mudflat and may contain polluted soil such as heavy metals. **Operation phase:** No impacts are expected
Natural Environment	9	Protected Area (Reserved Forest and Fauna)	B-	B-	**Construction and operation phase:** There are not any national parks on the alignment, however, the alignment is passing through a part of coastal regulation zone (CRZ) and Important Bird Area (IBA). Although an environmental clearance (EC) of CRZ has been given from MOEF in 2013 and 2016, the degree of impact should be confirmed.
	10	Ecosystem (Ecology and Biodiversity/ Ecology/Construction of labor camp)	B-	B-	**Construction and Operation phase:** Some considerable species are observed in the project area. The degree of impacts will be evaluated based on literature surveys and interview survey with specialists.
	11	Hydrology	B-	B-	**Construction and Operation phase:** Construction of bridge may change hydrological situation of the rivers.
	12	Topography and geology (Topography, Soil and Geology)	B-	B-	**Construction and operation phase:** Considerable topography and geological sites are not located in the project area, thus no impact is expected. However embankment section may have risks of land slide.

Area	No.	Impacted Item (Item on the Rapid EIA 2012)	Rating (Scoping stage)		Reasons of the Rating
			Pre/During Const	After Const	
Social Environment	13	Involuntary resettlement	B-	D-	**Pre-Construction phase:** Illegal occupants are observed in Sewri area, and number of affected persons will be identified on the SIA Survey. **Operation phase:** No impact is expected
Social Environment	14	The Poor	C-	D-	**Pre-Construction phase:** Impacts will be assessed based on the SIA Survey. **Operation phase:** No impact is expected
Social Environment	15	Indigenous and ethnic people	D-	D-	**Pre-Construction and Operation phase:** Few impacts are expected
	16	Local economy such as employment and livelihood	C-	D-	**Pre-construction phase:** Livelihood of residents and shopkeepers may be affected by land clearance. The degree of impacts will be assessed on the SIA Surveys. **Operation phase:** Few impacts are expected
	17	Land use and utilization of local resources (Quality of Life/Fisheries)	C-	C-	**Pre-construction phase:** No agriculture land is observed, but quarry sites are located on Navi Mumbai side. Additionally construction of bridge may affect to fishermen in the sea. Thus the degree of impacts to fishermen will be assessed by the SIA Surveys. **Operation phase:** It is not likely to give adverse impacts since appropriate land management along the road in Navi Mumbai side is planned by CIDCO. w impacts are expected However construction of bridge may affect to fishermen in the sea. Thus the degree of impacts to fishermen will be assessed by the SIA Surveys.
	18	Water Usage (Water Quality)	D-	D-	**Construction phase:** Few impacts are expected since major structure is viaduct and earthwork is limited in the project area. Furthermore, there are any residential area in the earth work area, thus it is not likely to give any impacts on this item. **Operation phase:** Few impacts are expected.
	19	Existing social infrastructures and services	B-	D-	**Pre-Construction and Construction phase:** Some schools, temples and public facilities may be affected by land acquisition for the road construction. Thus the degree of impacts will be assessed on the SIA Surveys. **Operation phase:** Few impacts are expected because major structure is viaduct.
	20	Social institutions such as local decision making institutions	D-	D-	**Construction and operation phase:** Impacts are not expected, since local decision making institute will continue after the road construction.
	21	Misdistribution of benefit and damage (Quality of life)	D-	D-	**Construction and operation phase:** Misdistribution of benefit and damage caused by the road & bridge construction is not expected.
	22	Local conflict of interests	B-	D-	**Construction phase:** Local inhabitants and local authorities may request to ensure job opportunities as construction workers. **Operation phase:** No impact is expected
	23	Cultural Heritage (Archeological /Heritage)	D-	D-	**Pre-Construction and Construction Phase:** No registered cultural heritage on the alignment. **Operation phase:** No impact is expected
	24	Landscape (Aesthetics and landscape)	B-	B-	**Construction and operation phase:** Sewri Fort and Elephanta Island (World Cultural Heritage) is located near the alignment, thus landscape from each site may change after construction of bridges and road.

Area	No.	Impacted Item (Item on the Rapid EIA 2012)	Rating (Scoping stage)		Reasons of the Rating
			Pre/During Const	After Const	
Social Environment	25	Gender	C-	D-	**Pre-Construction and Construction phase:** Male head of the household may seize the initiative in India, thus actual situation should be confirmed on SIA Survey. **Operation phase:** Few impact is expected
	26	Right of children	D-	D-	**Construction and operation phase:** Few impact is expected
	27	Infectious diseases such as HIV/AIDS	B-	D-	**Construction phase:** Infectious diseases such as STD are possible to be spread due to inflow of construction workers. Furthermore, alteration to ground by cut land and filling may provoke to provide habitats of mosquito that possibly transmits dengue fever. **Operation phase:** Road operation which causes infectious diseases is not expected.
	28	Labor environment	B-	D-	**Construction phase:** Construction work environment needs to be considered in accordance with relevant laws and regulations. **Operation phase:** No impact is expected.
Other	29	Accidents (Accident hazards and safety)	B-	B-	**Construction phase:** Construction vehicles may use existing local road near residential areas, thus number of traffic accident may increase. **Operation phase:** Risks of traffic accidents on the new road is expected due to increase of traveling speed.
	30	Cross boundary impacts and climate change	B-	C-	**Construction phase:** Deforestation and operation of construction machines may increase greenhouse gases such as CO2. **Operation phase:** Reduction of distance between Navi Mumbai and Mumbai area will cut amount of greenhouse gases such as CO2. Furthermore, replantation 5 times of cutting tree will be done, thus such replantation will give positive impacts. However construction of the sealink may generate additional traffic flow from developed area, thus the impact should be estimated by quantitative forecast.

Note) Rating:

A: Serious impact is expected. B: Some impact is expected. C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done) No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

12.4.4 Baseline Survey and Analysis Methodology

The expected baseline and survey and analysis methodologies are shown below.

Mainly 1) measurement of vibration, 2) updating of statistical data and current secondly data and 3) quantitative forecast on air, noise, vibration and water quality based on the latest traffic condition will be done based on the Rapid EIA 2012, and then the EIA will be modified and approved by MMRDA.

Methodologies of baseline survey and analysis are shown in the following table.

Table 12.4.5 Draft Baseline Survey and Analysis Methodology on MTHL

Area	No.	Item (on Rapid EIA 2012)	Rating		Survey Methodology	Forecast Methodology
			Pre and during Const.	Operation		
Pollution	1	Air pollution (Air quality/ Siting of borrow and quarry material areas)	B-	B-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any	**During Construction Phase:** Qualitative analysis **Operation Phase:** - Quantitative analysis (Puf model : calm wind model)
	2	Water pollution (Water Quality/ Construction of labor camp/ Siting of borrow and quarry material areas)	B-	D-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any	**During Construction Phase:** Qualitative analysis and quantitative analysis based on other cases
	3	Waste (Solid waste management/ Construction of labor camp/ Topography, Soil and Geology)	B-	D-	Refer to Rapid EIA in 2012 and the preparatory survey by JICA	**During Construction Phase:** Quantitative forecast of cutting trees and excavated soil based on construction plan
	4	Soil Contamination (Topography, Soil and Geology/ Siting of borrow and quarry material areas)	C-	D-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any	**During Construction Phase:** Qualitative forecast based on the Rapid EIA 2012
	5	Noise and Vibration (Ambient Noise)	B-	B-	-Site Survey: Noise : Not conducted Vibration: measurement at 2 points for 24 hours -Literature Survey: Refer to Rapid EIA in 2012 and the latest monitoring data	**During Construction Phase:** Quantitative or qualitative analysis based on other cases. **Operation Phase:** - Quantitative analysis (ASJ CN-Model 2008)
	6	Ground Subsidence (Topography, Soil and Geology(No.4))	D-	D-	－(surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	7	Odor	D-	D-	－(surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	8	Sediment Quality (Topography, Soil and Geology(No.4))	C-	D-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any	**During Construction:** Qualitative analysis based on the Rapid EIA in 2012
Natural Environment	9	Protected Area (Reserved Forest and Fauna)	B-	B-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any	**During Construction and Operation Phase:** Qualitative analysis based on the Rapid EIA in 2012 and relevant monitoring data, if any
	10	Ecosystem (Ecology and Biodiversity/ Ecology/Construction of labor camp)	B-	B-	-Site Survey：Not conducted -Literature Survey : Refer to Rapid EIA in 2012 and the latest monitoring data, if any Interview survey with specialist and other project study cases in Japan is referred.	**During Construction and Operation Phase:** Qualitative analysis based on the Rapid EIA in 2012, interview survey with specialists and relevant monitoring data, if any

Area	No.	Item (on Rapid EIA 2012)	Rating		Survey Methodology	Forecast Methodology
			Pre and during Const.	Operation		
Natural Environment	11	Hydrology	B-	B-	- Site Survey: Not conducted - Literature Survey: Refer to secondary data the latest monitoring data and results on this JICA Survey, if any	**During construction and operation phase:** Refer to other quantitative analysis
	12	Topography and geology (Topography, Soil and Geology)	B-	B-	-Site Survey：Not conducted -Literature Survey： Refer to Rapid EIA in 2012, the latest monitoring data and topo. & geo. survey result on this JICA Survey	**During construction and operation phase:** Qualittive analysis
Social Environment	13	Involuntary resettlement	B-	D-	Refer to SIA survey	**During construction phase:** Quantitative analysis based on SIA surveys
	14	The poor	C-	D-	Refer to SIA survey	**During construction phase:** Quantitative analysis based on SIA surveys
	15	Indigenous and ethnic people	C-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	16	Local economy such as employment and livelihood (Quality of Life/Fisheries)	C-	D-	Refer to SIA survey	**During construction phase:** Quantitative or qualitative analysis based on SIA surveys
	17	Land use and utilization of local resources (Land use/Fisheries)	C-	C-	Refer to SIA survey	**During construction phase:** Quantitative or qualitative analysis based on SIA surveys
	18	Water Usage (Water Quality)	D-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	19	Existing social infrastructures and services (Utility services and community severance)	B-	D-	Refer to SIA survey	**During construction phase:** Qualitative analysis based on SIA surveys
	20	Social institutions such as local decision making institutions	D-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	21	Misdistribution of benefit and damage (Quality of life)	D-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	22	Local conflict of interests	B-	D-	Refer to SIA survey	**During construction phase:** Qualitative analysis based on SIA surveys
	23	Cultural Heritage (Archeological /Heritage)	D-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	24	Landscape (Aesthetics and landscape)	B-	B-	-Site Survey: Visual Survey at Sewri and Elphanta Island (April 2015)	**During Construction and Operation Phase:** Qualitative analysis or preparation of Photo montage
	25	Gender	C-	D-	Refer to SIA survey	**During construction phase:** Quantitative or qualitative analysis based on SIA surveys

Area	No.	Item (on Rapid EIA 2012)	Rating		Survey Methodology	Forecast Methodology
			Pre and during Const.	Operation		
Social Environment	26	Right of Children	D-	D-	- (surveys on this item is not required due to no impacts)	Not required because few impacts are expected
	27	Infectious diseases such as HIV/AIDS	B-	D-	Refer to SIA survey	**During construction phase:** Qualitative analysis based on SIA surveys
	28	Labor environment including work safety	B-	D-	Legal framework regarding labor environment and safety shall be clarified and the safety shall be secured. Relevant laws and actual situation shall be interviewed with relevant organizations.	Qualitative and quantitative analysis based on the construction plan
Other	29	Accident (Accident hazards and safety)	B-	B-	Literature Survey: Statistical data from police department, if any	**During Construction and Operation Phase:** Quantitative analysis based on statistical data
	30	Cross Boundary impacts and climate change	B-	C-	Site Survey: Not conducted Literature Survey: Refer to the drawing and SIA survey results (number of cut trees)	**During Construction and Operation Phase:** Quantitative analysis based on generation of CO2

Note) Rating:

A: Serious impact is expected. B: Some impact is expected. C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done) No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

12.4.5 Summary of Baseline Survey and Forecast

(1) Summary of Baseline Survey, Forecast and Evaluation

The Result of Baseline and Forecast are shown in Table 12.4.6.

Major measured and analysed data on the Rapid EIA and Supplemental EIA is shown below of Table 12.4.6.

Table 12.4.6 Result of Baseline and Forecast on Main Items

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage): Pre and during Const.	Rating (Scoping Stage): Operation	Summary of Result: Baseline	Summary of Result: Forecast	Summary of Result: Mitigation Measures and Evaluation
Pollution	1	Air pollution (Air quality/ Siting of borrow and quarry material areas)	B-	B-	The value of SPM is high and above the Indian standards and IFC standards. Other items such as CO, NO2 and SO2 are low and below the standards. Note) SPM is between 92 (Elephanta Island) to 393 $\mu g/m^3$ (Sewri) on Rapid EIA 2012 (monitored in 2011)	[During construction] Exhaust gases including CO, NO2, SO2 and SPM are discharged from construction machines and may impact to the near residential area. However this adverse impact is not serious because operation time is limited and most of the construction area is on the ocean. [After Construction] Forecasted impacts with background density meet Indian standard and IFC.	[During const.] Exhaust gases and dusts are produced by the construction activities. However the adverse impact is not serious because of far distance from residential area, bridge structure, underwater construction etc., and the impacts can be minimized by mitigation measures such as water sprinkling. [After const.] Air quality such as PM10, CO, NO2 and SO2 density increases along the road during operation phase. However the density-increasing area is very limited, and road-contributed density is very small, and the total density at roadside point is below standard values, thus it is not likely to give significant impacts on air quality.
	2	Water pollution (Water Quality/ Construction of labor camp/ Siting of borrow and quarry material areas)	B-	D-	DO at all Zone in high tide Zone II and III in low tide is exceeding standard values. pH range and BOD values are within the range of the standard. The highest COD value was found to be 105mg/L and within acceptable limits of 250mg/L.	[During const.] Turbid water is generated by earth works and excavation. Spillage of oil and grease from machines and storage is avoided or mitigated by appropriate management and maintenance.	[During const.] The impacted time, duration and area is limited. And the impacts are minimized by planned mitigation measures such as sedimentation pond, the casing. Thus, the degree of impacts is acceptable level.
	3	Waste (Solid waste management/ Construction of labor camp/ Topography, Soil and Geology)	B-	D-	Domestic waste from household is disposed to designated dumping site. Night soil in the city area is treated in sewerage plant. Construction waste such as concrete and cutting trees are used for construction material. Muck soil is tested, treated and disposed at designated site.	[During const.] Excavated muck soil from the sea section is estimated around 99,000 m^3. General waste soil on the land section is 2,400m^3. Cutting mangrove volume is approximately 13.9m^3. Domestic waste and night soil is generated at base camp for workers, estimated volume is around 760kg/day.	[During const.] All generated construction waste and domestic waste are reused and/or disposed under adequate mitigation measures, thus it is not likely to give significant impacts on this item.

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage)		Summary of Result		
			Pre and during Const.	Operation	Baseline	Forecast	Mitigation Measures and Evaluation
Pollution	4	Soil Contamination (Topography, Soil and Geology/ Siting of borrow and quarry material areas)	C-	D-	According to Rapid EIA 2012, only density of Lead is exceeding standard level.	[During const.] Excavated muck soil from the sea section is estimated around 99,000 m^3. General waste soil on the land section is 2,400m^3.	[During const.] All generated construction waste soil are reused and/or disposed after soil analysis under adequate mitigation measures, thus it is not likely to give significant impacts on this item.
	5	Noise and Vibration (Ambient Noise)	B-	B-	The existing noise levels are exceeding the permissible limit excepting Mahul near powerplant industrial area. All vibration level meets traffic vibration standard of Japan. Note) daytime : Night time Noise dB(A) Leq Sewri: 75-76 : 60-62 Shivaji Nagar: 62-65 : 54-60 Vibration: dB Sewri: 48-49 : 48-49 Shivaji Nagar: 48-49 : 48-49	[During const.] Estimated construction noise is less than 85dB(A). With regard to construction vibration, it is estimated less than 75dB. The noise and vibration during the construction of MTHL can be expected to be less than the Japanese standard. [After const.] The all forecasted noise and vibration level meet Indian standard and Japanese standard respectively. Note) Noise Standard along road: 75 dB(A) for daytime and 70 dB(A) for night time, Vibration Standard : 65dB for daytime and 60 dB for night time along the road	[During const.] In the daytime, it is expected that impacts from construction activities is reduced by mitigation measures such as selecting low-noise equipment, informing the construction schedule and meet standard values, thus it is not likely to give serious impacts to surrounding area. In the night time, the construction activities will give a degree of impacts to the nearest residential area, however, implementation of the mitigation measures minimize the impacts and the degree of impacts will be acceptable level for inhabitants. [After const.] The forecasted noise and vibration level meets standard values, thus it is not likely significant impact on this item. Since the noise-reducing effect of noise barrier is not very high, it is not necessary to build a noise barrier.
	8	Sediment Quality (Topography, Soil and Geology(No.4))	C-	D-	According to Rapid EIA 2012, only density of Lead is exceeding standard level.	[During const.] Excavated muck soil from the sea section is estimated around 99,000 m^3.	[During const.] All generated construction waste soil are reused and/or disposed after soil analysis under adequate mitigation measures, thus it is not likely to give significant impacts.
Natural Environment	9	Protected Area (Reserved Forest and Fauna)	B-	C-	The proposed alignment passes through Coastal Regulation Zone and Important Birds Area.	Totally 2.25km of the alignment has been classified as CRZ. CRZ-I : 2.0km CRZ-II: 0.25km The alignment is passing trough Important Bird Areas along app. 5km in Sewr side, and expected some impacts.	It is not likely to give serious impacts under implementation of appropriate mitigation measures. With regard to IBA, it is confirmed that the Article 17 of IFC Performance standard 6 is complied in accordance with JICA Guidelines. (see; （2） Detailed description regarding Ecosystem and Protected area)

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage)		Summary of Result		
			Pre and during Const.	Operation	Baseline	Forecast	Mitigation Measures and Evaluation
Natural Environment	10	Ecosystem (Ecology and Biodiversity/ Ecology/ Construction of labor camp)	B-	C-	On Rapid EIA 2012, 17 bird species, 4 butterflies, 7 fauna species in benthos have been recorded. On migratory birds survey on 2008, totally 78 bird species have been observed. Out of 78 bird species on the survey 2008 and 2012, 15 species are categorized as migratory birds, only 1 species Lessor Flamingo is categorized as NT level (Nearly Threatened). In other 66 species, 5 species are categorized as NT and VU (Vulnerable) However it is supposed that such 6 species are using the project area as feeding area, not nesting area. Note) NT: 1) Black Headed Ibs, 2) Painted Stork, 3) Black Tailed Godwit and 4) Eurasian Curlew VU: Greater Spotted Eagle	[During const.] Fauna Turbid water due to activities in the river and inflowing from construction area may impact on aquatic fauna. Part of the mudflat ecosystem is lost by the implementation of development projects. The drying of the mudflat may impact on food resources of migratory birds. If the base camp and construction yard are installed near the feeding grounds of migratory birds, migratory birds may avoid and fly away to other mudflat in Mumbai harbour temporarily. However, in general, such birds may come back same place throughout a period of time. Flora Deforestation may impact on mangrove area. However, the drying of the mudflat may increase the mangrove area in some limited area around piles. It is expected that mangrove cut area is 0.1176 ha in CRZ and 200m^2 out of CRZ respectively. The surrounding area of the piles may be dried, and it may give condition for increase of mangrove. [After const.] Fauna Some migratory birds are accidentally killed on the road and bridge due to increase of traffic volume. The presence of elevated road, there is a risk of inhibiting the flight path of the Flamingo. Impact on the Flamingo roost is concerned by the irradiation of road lighting. According to the result of forecast on hydrology, existence of piers does not give significant impacts on entire of tidal flow and physical condition of mudflat, thus it is expected that such insignificant impacts on tidal	[During const.] Construction activities of MTHL may cause noise during construction stage, thus some group of migratory birds may avoid the adjacent area and flyaway to other area in Mumbai basin temporarily. However since several mitigation measures will be conducted, the migratory birds may get back again gradually. Additionally turbidity from excavated area in the sea and cutting mangrove area will be minimized by appropriate mitigation measures. [After const.] Vehicle travelling, making noise and existence of viaduct may give adverse impacts for migratory birds. For minimization of these impacts, not only CRZ specification conditions, but also additional measures such as consideration of lighting system not to give impacts on Flamingo's roosting area are planned. With regard to mangrove, dried are around piles may give condition for mangrove growing, and 5 times of cutting mangrove shall be planted in the designated area under CRZ specific condition and permission of Maharashtra High-court. When unexpected events and phenomena has been confirmed after construction and during construction, appropriate to take action in consultation with relevant organizations. Thus, it is not likely to give serious impacts on project including mudflat ecosystem under implementation of appropriate mitigation measures.

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage) Pre and during Const.	Operation	Summary of Result Baseline	Forecast	Mitigation Measures and Evaluation
Natural Environment						flow and physical condition of mudflat does not give adverse impacts on ecosystem in the mudflat. Flora The drying of the mudflat may be caused by existence of bridge piers, however, such area is limited around piers and may provide possible environment which mangrove grows. With regard to distribution of mangrove seeds, since the construction of bridge does not give impacts on tidal flow in Mumbai basin significantly, thus this situation means that project does not give adverse impacts on distribution and provision of mangrove seeds in the basin.	
	11	Hydrology	B-	B-	The project area belongs to Savana Climate and dry-rainy seasons are distinguished clearly. Mumbai basin has 1,358 ha with some rivers and Thane creek. Tidal flow varies with location, time and depth. Nautical chart indicates near MTHL alignment from 1.03 to 1.54 m/s.	According to hydraulic analysis by using FEM (Finite Element Method) on the report of the Central Water and Power Research Station (CWPRS), at the nearest point of the project alignment No.3 named Pir-Pau, there is negligible increase and decrease in current strength during ebb and flood tide (the difference is 0.05-0.15m/s). It was also reported that it will not have any hydraulic impact on functioning of other points.	Although Hydraulic impacts are negligible, the monitoring of the tidal level and current should be conducted at the bridge sites by installing water alarm system during and after the construction of the bridge. Furthermore, the bathymetric survey around the MTHL should be conducted periodically, and will be confirmed that the sea bed level is higher than the design scour depth. When the sea bed gets closer to the design scour depth, the surrounding of pier around the sea bed will be protected by appropriate material such as the riprap or geobag.
	12	Topography and geology (Topography, Soil and Geology)	B-	B-	The area is classified in 5 sections based on topographic feature on site. 1: flat land 2: tidal area (partially mangrove area) 3: sea area 4: sea and tidal area (partially mangrove area) 5: hills and rock mountainous area	Any considerable topography and geological sites are not located in the project area, thus no impact is expected. However embankment section may have risks of land slide.	Implementation of appropriate designing and mitigation measures such as slope protection and periodical monitoring & maintenance will mitigate the expected impacts. Thus it is not likely to give significant impacts on stability of earthwork section.

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage)		Summary of Result		
			Pre and during Const.	Operation	Baseline	Forecast	Mitigation Measures and Evaluation
Social Environment	13	Involuntary resettlement	B-	D-	A total of 282 project affected families and 1,272 project affected persons are recorded.	[During const.] Total Number of PAFs and relocated persons is 282 and 1,272 to be displaced are identified based on SIA survey.	[During const.] Implementation of appropriate compensation, resettlement and social assistance will mitigate expected adverse impacts, thus it is not likely to give serious impacts on this item.
	14	The poor	C-	D-	In the Sewri area, 146 (58.9 %) of PAHs earn income ranging from 50,000 to 100,000 INR while yearly expenditure less than 300,000 INR indicates 96.3%. 4 PAPs are categorized as under-poverty line in the survey area Sewri Section.	[During const.] 4 PAPs under poverty line to be displaced are identified. Such displaced PAPs may have income reduction due to increase of commuting time and loss of job temporarily.	[During const.] Although the displaced house heads may have risks of income reduction, implementation of appropriate compensation and social assistance will mitigate expected adverse impacts, thus it is not likely to give serious impacts on this item.
	16	Local economy such as employment and livelihood (Quality of Life/Fisheries)	C-	D-	More than half of household heads are private service workers, and approximately 23.7% belongs to business and trade activities.	[During const.] According to census and economic surrey on SIA, loss of income is expected on private sector workers and Non fishing labours mainly.	[During const.] Although 447 PAPs and their properties are impacted by the project, implementation of appropriate compensation and social assistance will mitigate expected adverse impacts, thus it is not likely to give serious impacts on this item.
	17	Land use and utilization of local resources (Land use/Fisheries)	C-	C-	Some areas are used for residential and commercial shops. Some house heads and shop owners have a lease contract with MPT in Sewri Section. Additionally, in the sea section, traditional fishermen have own customary fishing ground. Detailed data is shown in SIA report.	[During const.] Approximately 8.6 ha commercial and housing land will be used for construction site and yard. In the sea section, customary fishing ground will be reduced by the construction. [After const.] Surrounding area of the MTHL may be used for commercial area and small factory compound without any permission from authorities.	[During const.] Although totally 8.6ha compound in Sewri area, and customary fishing area in sea section is affected by the project, implementation of appropriate compensation and social assistance will mitigate expected adverse impacts, thus it is not likely to give serious impacts on this item. [After const.] Appropriate land use management will give positive impacts in the affected area from the view of economic and natural environment considerations.
	19	Existing social infrastructures and services (Utility services and community severance)	B-	D-	According to SIA survey, no sensitive receptors such as school and hospital and local meeting places are observed in the affected area. However community level temple, mosques and women's group accommodation are recorded in the project area.	[During const.] Traffic restriction area in the project area, inhabitants and commuting people including students will spend much time than usual for passing such construction area. Additionally displacement of community level temples & mosques and women's group facilities may give adverse impacts on prayers and group members.	[During const.] Construction activities will give adverse impact on access to public facilities and commuting time, additionally displacement of community level temples and mosque will be caused. However implementation of mitigation measures will minimize the impacts. Thus it is not likely to give serious impacts on this item.

Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage) Pre and during Const.	Rating (Scoping Stage) Operation	Summary of Result: Baseline	Summary of Result: Forecast	Summary of Result: Mitigation Measures and Evaluation
Social Environment	22	Local conflict of interests	B-	D-	According to comments in the local level stakeholder meetings and socialization meetings on SIA, local inhabitants and local authorities requested to ensure job opportunities as construction workers.	[During const.] Conflicts or disputes between communities may be raised if imbalance in hiring workers is caused.	[During const.] The hired workers from other areas may have conflicts with inhabitants however implementation of mitigation measures will minimize the impacts. Thus it is not likely to give serious impacts on this item.
	24	Landscape (Aesthetics and landscape)	B-	B-	Sewri fort as registered heritage and Elephant Caves designated as the World Cultural Heritage is located within 5 km from the project area. However entrance of Elephanta cave cannot see project area, thus Sewri Fort is selected as main view point.	The landscape elements are mainly mangrove trees, mudflat and skyline of opposite hilly area. A part of mangrove and mudflat are obstructed by the construction of MTHL.	The changes before and after construction of sealink are unavoidable. However the structure does not give serious impact on skyline of opposite hilly area. Additionally, Non Objection Certificate regarding passing through near heritage sites had been issued from relevant authority in 2003. Thus it is evaluated that the project does not give serious impacts on this item.
	25	Gender	C-	D-	--	[During const.] According to result of basic economic survey on SIA, any gender gaps and risks caused by the project on this item are not identified.	--
	27	Infectious diseases such as HIV/AIDS	B-	D-	According to interview survey with inhabitants, major infection diseases are dengue fever, malaria and diarrhea. However such statistical data is not recorded in this area.	[During const.] Hired construction workers and skilled equipment operators may contact with inhabitants and spread infection diseases. Additionally puddles in the construction area and insufficient drainage will provide a habitat of carrier mosquito for dengue fever and malaria. [After const.] Insufficient maintenance of drainage and bridges may provide some puddles and small pond, such environment may be habitat of mosquito larva.	Inflow of workers during construction may provide opportunity for spreading infection disease. Additionally insufficient and inappropriate drainage and maintenance during and after construction may also provide habitats of mosquito larvae. However implementation of mitigation must prevent and minimize these adverse impacts. Thus it is not likely to give serious impacts on this item.
	28	Labor environment including work safety	B-	D-		[During const.] Working without considering labor laws and regulations in the construction area may cause accident. For instance, working without out helmet and working boots have risks to injure head and foot.	[During const.] The labour environment is secured when the contractor under observation of general consultant follows Indian laws and international standards.

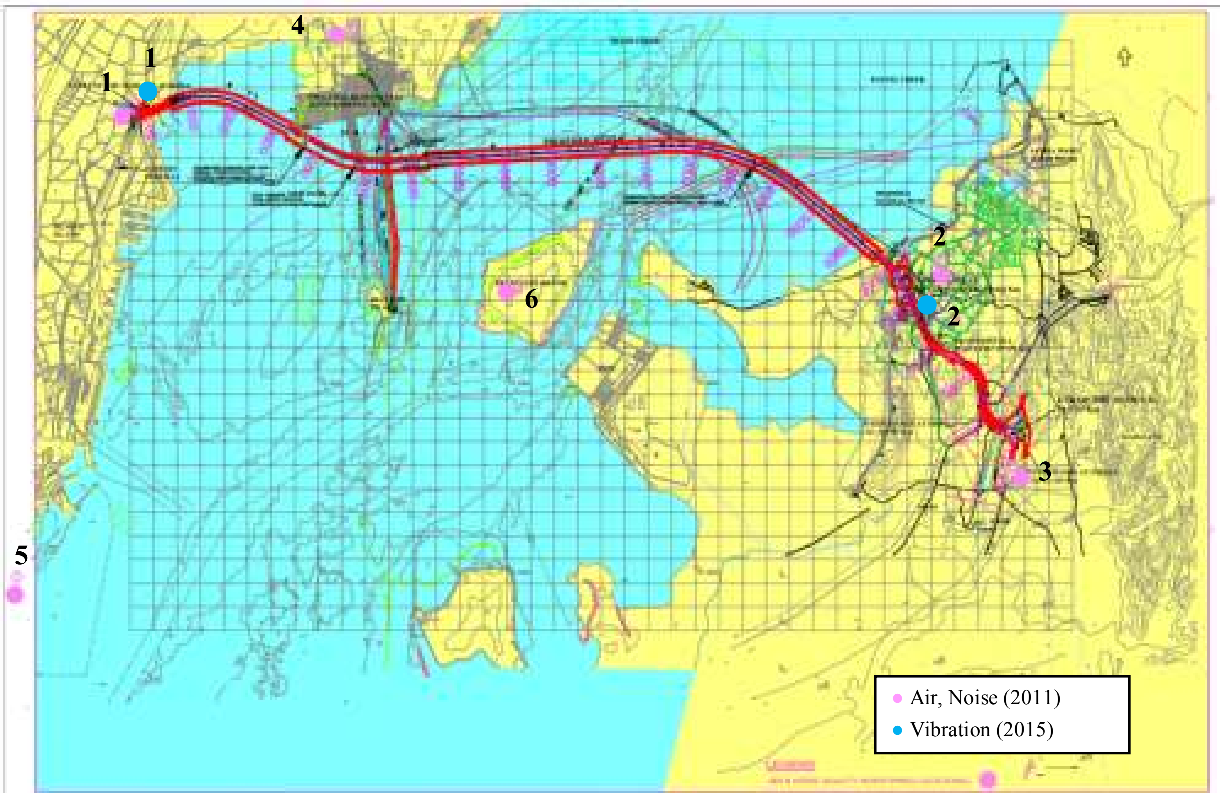
Area	No.	Item (on Rapid EIA 2012)	Rating (Scoping Stage)		Summary of Result		
			Pre and during Const.	Operation	Baseline	Forecast	Mitigation Measures and Evaluation
Other	29	Accident (Accident hazards and safety)	B-	B-	According to statistical Mumbai Police Department, number of fatal and injured case in 2014 is 350 and 14,684 persons respectively.	[During const.] Construction machines and trucks will be operated for 4.5 years. Thus risks of traffic accident increase on the commuting roads. [After const.] Number of traffic accident may increase due to increase of traffic number and travelling speed after construction of MTHL.	Traffic volume must increase during and after construction of MTHL, hence, number of accident increase in conjunction with traffic volume. However implementation of mitigation must prevent and minimize these adverse impacts. Thus it is not likely to give serious impacts.
	30	Cross Boundary impacts and climate change	B-	C-	--	Total generated CO2 volume is analysed with and without MTHL respectively. 1. Current Condition in 2015 With Project: ---- Without Project: 454,386 t/year 2. During Construction in 2018 With Project: 602,173 t/y Without Project: 591,914 t/year 3. During Operation Phase in 2032 With Project: 984,813 t/y Without Project: 986,574 t/year With project case, CO2 volume during construction is higher than without project case, however, this volume during operation in 2032 and 2042 gives positive impacts.	[During const.] Compensatory mangrove replanting is required in accordance with CRZ clearance on 19th July 2013. [After const.] Not required

Note) A: Serious impact is expected. B: Some impact is expected. C: Extent of impact is unknown (serious impacts are not expected, but survey and analysis shall be done) No mark: Few impacts are expected. Detailed quantitative survey is not necessary.

Source: JICA Study Team

(2) Major measured data and result of analysis

Measured and quantitative analysis data based on the Rapid EIA and Supplemental EIA 2015 is shown below.



Source: Rapid EIA 2012 by MMRDA and Supplemental EIA 2015 by JICA

Figure 12.4.1 Monitoring Points for Air, Noise and Vibration

Table 12.4.7 Monitored Ambient Air Quality (Rapid EIA 2012)

Location / Item	Chirle	Shivaji Nagar	Mahul	Sewri	Gate Way of India	Elephanta Island	UNIT	Indian Standards		(reference) IFC Standards	
								Industrial and Residential	Sensi-tive area	Mid Term	Standard Value
SPM	266.33 (exceeding)	135.58 (exceeding)	153.33 (exceeding)	393.58 (exceeding)	220 (exceeding)	92	μg/m³	$60^{1)}$ $100^{2)}$	$60^{1)}$ $100^{2)}$	$70^{1)}$ $150^{2)}$	$20^{1)}$ $50^{2)}$
RSPM	79.92	42.83	48.42	141.00	48.5	24	μg/m³				
SO2	53.67	31.33	32.02	66.85	37.1	12.6	μg/m³	$50^{1)}$ $80^{2)}$	$20^{1)}$ $80^{2)}$	$125^{2)}$	$20^{2)}$
NO2	61.83	39.25	38.18	74.82	53.4	13.8	μg/m³	$40^{1)}$ $80^{2)}$	$30^{1)}$ $80^{2)}$		$40^{1)}$ $200^{2)}$
NH3	21.97	10.15	16.70	31.32	26.2	28.5	μg/m³	$100^{1)}$ $400^{2)}$	$100^{1)}$ $400^{2)}$		
Pb	0.61	0.33	0.47	0.82	BDL	BDL	μg/m³	$0.5^{1)}$ $1.0^{2)}$	$0.5^{1)}$ $1.0^{2)}$		
CO	2.04	1.08	1.52	2.54	1.8	2.27	mg/m³	$2^{3)}$ $4^{4)}$	$2^{3)}$ $4^{4)}$		
HC	1086.27	973.92	1090.42	1348.92	861	1083	μg/m³				
O3	16.00	9.77	11.66	19.68	17.8	10.5	μg/m³	$100^{3)}$ $180^{4)}$	$100^{3)}$ $180^{4)}$	$160^{3)}$	$100^{3)}$
C6H6	BDL	BDL	BDL	BDL	BDL	BDL	μg/m³	$5^{1)}$	$5^{1)}$		
BaP	BDL	BDL	BDL	BDL	BDL	BDL	ng/m³	$1^{1)}$	$1^{1)}$		
As	BDL	BDL	BDL	BDL	BDL	BDL	ng/m³	$6^{1)}$	$6^{1)}$		
Ni	2.12	1.32	1.81	3.43	BDL	BDL	ng/m³	$20^{1)}$	$20^{1)}$		

Note) 1)= Annual, 2)=24hours, 3)= 8hours, 4)=1hour, BDL: Below Detected Level
Source: Rapid EIA 2012 by MMRDA

Table 12.4.8 Ambient Air Standard in India

Pollutant	Time Weighted Average	Industrial, Residential Rural and Other Areas	Sensitive Areas
SO_2 ($\mu g/m^3$)	Annual * 24 hours**	50 80	20 80
NO_2 ($\mu g/m^3$)	Annual * 24 hours**	40 80	30 80
PM_{10} ($\mu g/m^3$)	Annual * 24 hours**	60 100	60 100
$PM_{2.5}$ ($\mu g/m^3$)	Annual * 24 hours**	40 60	40 60
O_3 ($\mu g/m^3$)	8 hours** 1 hour	100 180	100 180
Pb ($\mu g/m^3$)	Annual * 24 hours**	0.50 1.0	0.50 1.0
CO (mg/m^3)	8 hours** 1 hour**	2 4	2 4
NH_3 ($\mu g/m^3$)	Annual * 24 hours**	100 400	100 400
C_6H_6 ($\mu g/m^3$)	Annual *	05	05
BaP (ng/m^3)	Annual *	01	01
As (ng/m^3)	Annual *	06	06
Ni (ng/m^3)	Annual *	20	20

Source: Indian Pollution Control Board

Table 12.4.9 Monitored Ambient Air Quality by MPCB and CPCB (2015)

Location / Item	Mumbai side		Navi Mumbai Side	UNIT	Indian Standards		(reference) IFC Standards	
	Bandra 24hrs; 17th Aug. 2015 by CPCB	Sion 24hrs; 17th Aug. 2015 by MPCB	Airoli 24hrs; 17th Aug. 2015 by CPCB		Industrial and Residential	Sensitive Area	Middle term objective	Guideline value
SPM	45.19 (meet standard)	-	50.88 (meet standard)	$\mu g/m^3$	100	$100^{2)}$	150	50
RSPM		135.0	-	$\mu g/m^3$				
SO_2	16.33 (meet standard)	20.0 (meet standard)	14.37 (meet standard)	$\mu g/m^3$	80	80	125	20
NO_2	26.62	88.0	-	$\mu g/m^3$				200
CO	BDL	-	0.50 (meet standard)	mg/m^3	4	4		

Source: Rapid EIA 2012 by MMRDA

Source: Maharashtra State Pollution Control Board / Central Pollution Control Board

Figure 12.4.2 Air Quality Monitoring Locations by MPCB and CPCB

Source: JICA Study Team

Figure 12.4.3 The prediction points of Air and Noise & Vibration

Table 12.4.10 Result of Comprehensive Quantitative Forecast on Air Quality

	Point	ST-1			ST-2			ST-3			Standard
	Distance from the road	0m	10m	200m	0m	10m	200m	0m	10m	200m	
Indicator	Forecasted Point										
SPM ($\mu g/m^3$)	Road surface	92.3	92.2	92.0	92.6	92.4	92.0	92.2	92.2	92.0	100 1)
	Ground	92.3	92.2	92.0	92.2	92.2	92.0	92.2	92.1	92.0	
SO_2 ($\mu g/m^3$)	Road surface	12.9	12.9	12.6	13.5	13.2	12.7	12.9	12.8	12.6	80 1)
	Ground	12.9	12.9	12.6	12.9	12.9	12.7	12.8	12.8	12.6	
NO_2 ($\mu g/m^3$)	Road surface	16.4	16.1	14.2	19.4	17.9	14.2	16.0	15.5	13.9	200 2)
	Ground	16.5	16.2	14.2	16.1	15.9	14.2	15.4	15.2	13.9	
CO (mg/m^3)	Road surface	2.36	2.35	2.28	2.47	2.41	2.28	2.34	2.32	2.27	10 3)
	Ground	2.36	2.36	2.28	2.35	2.34	2.28	2.32	2.31	2.27	

Note: 1)= Indian standard 2)=IFC standard, 3)= Japan Standard
Source: JICA Study Team

Source: Prepared by JICA Study Team based on Rapid EIA 2012

Figure 12.4.4 Water and Bottom Sedimentation Soil Quality Survey Points (Rapid EIA 2012)

Table 12.4.11 Physical & Chemical Attributes in Aquatic medium (Rapid EIA 2012)

Sites	Tide	pH [6.5-9]	Temp ºC	Salinity ‰	Alkalinity ppm	Hardness mg/L	DO (mg/L) [3.0]	BOD (mg/L) [3 or 5]	COD mg/L
Zone II	High	7.5	28	32.95	14	46	1.20 **(exceeding)**	0.97	100
	Low	7.5	24.5	32.95	14	47	1.48 **(exceeding)**	1.32	105
Zone III	High	7	23.5	32.95	12	32	3.10	0.42	105
	Low	7	28	32.95	14.5	34	2.40 **(exceeding)**	0.42	76
Zone IV	High	7	26	32.95	10	36	3.03	0.83	100
	Low	7	28	32.95	9.5	30	2.05 **(exceeding)**	0.12	85

Note: [*****] standard values for Primary Water Quality Criteria for Class SW-IV Waters (For Harbour Waters)
Source: Rapid EIA 2012 by MMRDA

Table 12.4.12 Soil Quality Survey Results (Rapid EIA 2012)

Site	Monitored Item (Standard Values)						
	Zn mg/l (No Standard)	Cu µg/l (No Standard)	Total Manganese mg/l (No Standard)	Pb mg/l (0.01mg/l)	Cd mg/l (0.01mg/l)	Fe µg/l (No Standard)	Cobalt mg/l (No Standard)
Zone I (Sewri: Land)	1,800					Absence	Absence
Zone II (Sewri: Sea)	-	2,000		**0.483** (Exceeding)	0.00084 (Not exceed)	Absence	Absence
Zone III (Sea)	-		0.000053			Absence	Absence
Zone IV(Shivaji Nagar)	250	1,500	Absence	**0.498** (Exceeding)	0.0006 (Not exceed)	Absence	Absence
Zone V	-					Absence	Absence

Note: this table was made based on the description of Rapid EIA 2012
Source: Rapid EIA 2012 by MMRDA

Table 12.4.13 Ambient Noise Level (Rapid EIA 2012)

Location (Area Code)	Measured Date	Noise Levels in dB(A)							Standard
		Leq (Day)	Leq (Night)	Lmax	Lmin	L90	L50	L10	L_{eq}: day/night
1. Sewri (A)	03/10/11 to 05/10/11	76 (Exceeding)	61.1	80	50	54	72	78	75/70
	10/10/11 to 12/10/11	75.4 (Exceeding)	60.5	80	50	53	72	78	75/70
	20/10/11 to 22/10/11	75.4 (Exceeding)	61.6	80	50	53	72	78	75/70
	29/10/11 to 31/10/11	76 (Exceeding)	62.6	80	50	54	72	79	75/70
	1/12/11 to 03/12/11	75.8 (Exceeding)	61.8	80	50	53	72	79	75/70
	07/12/11 to 09/12/11	76 (Exceeding)	61.9	80	50	52	73	79	75/70
	14/12/11 to 16/12/11	75.8 (Exceeding)	61.8	80	50	52	73	79	75/70
	21/12/11 to 23/12/11	76 (Exceeding)	61.9	80	50	52	73	79	75/70
2. Shivaji Nagar (C)	03/10/11 to 05/10/11	62.6 (Exceeding)	54.6 (Exceeding)	69	44	46	59	65	55/45
	10/10/11 to 12/10/11	62.1 (Exceeding)	56.2 (Exceeding)	69	44	47	59	64	55/45
	20/10/11 to 22/10/11	62.1 (Exceeding)	56.4 (Exceeding)	69	44	48	59	64	55/45
	29/10/11 to 31/10/11	62.3 (Exceeding)	54.4 (Exceeding)	69	44	58	63	53	55/45
	1/12/11 to 03/12/11	62.2 (Exceeding)	55.3 (Exceeding)	69	44	46	59	65	55/45
	07/12/11 to 09/12/11	62.3 (Exceeding)	55.6 (Exceeding)	69	44	45	60	65	55/45
	14/12/11 to 16/12/11	65.3 (Exceeding)	59 (Exceeding)	72	47	51	62	68	55/45
	21/12/11 to 23/12/11	65.2 (Exceeding)	60 (Exceeding)	72	47	50	62	68	55/45

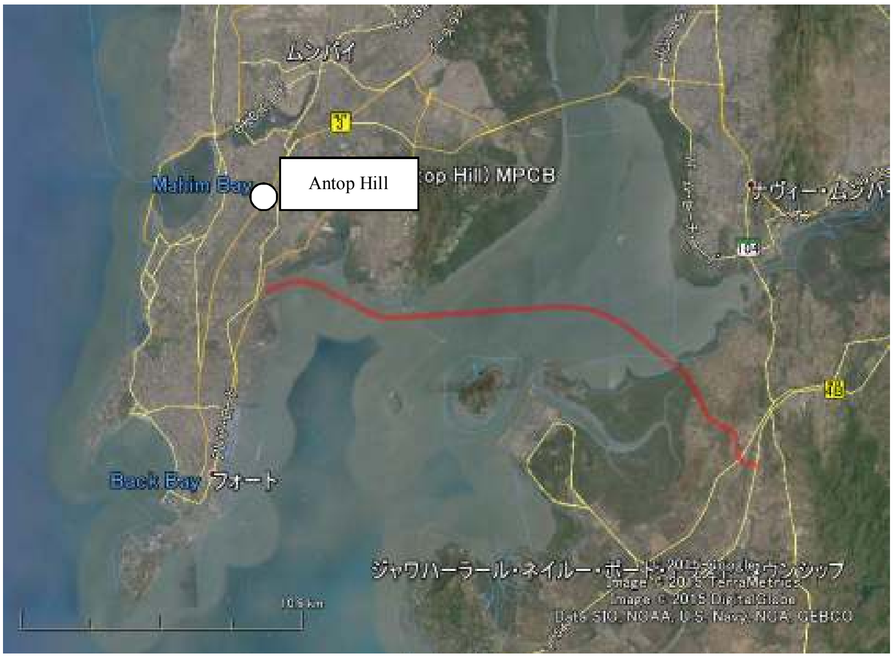
Location (Area Code)	Measured Date	Noise Levels in dB(A)							Standard
		Leq (Day)	Leq (Night)	Lmax	Lmin	L90	L50	L10	L_{eq}: day/night
3. Chirle (C)	03/10/11 to 05/10/11	67 (Exceeding)	60.4 (Exceeding)	72	49	50	63	70	55/45
	10/10/11 to 12/10/11	68 (Exceeding)	61.3 (Exceeding)	74	50	53	65	71	55/45
	20/10/11 to 22/10/11	68 (Exceeding)	61.2 (Exceeding)	75	50	53	65	70	55/45
	29/10/11 to 31/10/11	67.7 (Exceeding)	62 (Exceeding)	85	57	61	78	82	55/45
	1/12/11 to 03/12/11	68.5 (Exceeding)	62.2 (Exceeding)	75	50	52	65	71	55/45
	07/12/11 to 09/12/11	68.3 (Exceeding)	62.3 (Exceeding)	75	50	52	64	71	55/45
	14/12/11 to 16/12/11	68.7 (Exceeding)	60.8 (Exceeding)	75	50	52	62	72	55/45
	21/12/11 to 23/12/11	68.5 (Exceeding)	62.5 (Exceeding)	75	50	53	65	71	55/45
4.Mahul (I) (near power plant)	03/10/11 to 05/10/11	66.6	59.2	72	48	49	63	69	75/70
	10/10/11 to 12/10/11	67.2	59.9	74	49	51	64	70	75/70
	20/10/11 to 22/10/11	67.3	61	74	49	50	64	70	75/70
	29/10/11 to 31/10/11	67.2	59	74	49	52	64	70	75/70
	1/12/11 to 03/12/11	67.1	60.4	73	49	51	64	70	75/70
	07/12/11 to 09/12/11	67.1	61.5	74	49	52	64	69	75/70
	14/12/11 to 16/12/11	67.4	60.3	74	49	51	64	70	75/70
	21/12/11 to 23/12/11	67.7	61.6	74	49	53	64	70	75/70
5. Gate Way of India (B)	14/12/11 to 16/12/11	66.2 (Exceeding)	60.2 (Exceeding)	73	48	50	63	69	65/55
	21/12/11 to 23/12/11	66.3 (Exceeding)	59.3 (Exceeding)	73	48	52	62	69	65/55
6.Gavan (C)	14/12/11 to 16/12/11	68.8 (Exceeding)	60.4 (Exceeding)	75	50	52	65	71	65/55
	21/12/11 to 23/12/11	68.3 (Exceeding)	60.4 (Exceeding)	75	50	53	65	70	65/55

Source: Rapid EIA 2012 by MMRDA

Table 12.4.14 Ambient Noise Level (Rapid EIA 2012)

Location (Area Code)	Date and Time		Noise Levels in dB(A)						Indian Standard
			Leq	Lmax	Lmin	L90	L50	L10	L_{eq}
Antop Hills (Residential)	14th Dec. 2014 6 AM- 10 PM:	Daytime	**67.1** **(exceeding)**	82.1	51.0	78.0	69.5	59.6	55
	14th Dec. 2014 10 PM- 6 AM:	Night Time	**63.4** **(exceeding)**	82.2	51.7	73.2	61.9	54.1	45
	15th Dec. 2014 6 AM- 10 PM:	Daytime	**63.6** **(exceeding)**	72.6	59.0	51.3	70.5	64.7	55
	15th Dec. 2014 10 PM- 6 AM	Night Time	**60.1** **(exceeding)**	75.4	51.3	71.6	57.6	52.1	45

Source: Report on Ambient Noise Monitoring of Metropolitan Cities in Maharashtra 2014 (Maharashtra Pollution Control Board)



Source: JICA Study Team (Supplemental EIA 2015)

Figure 12.4.5 Ambient Noise Monitoring Location by MPCB (2014)

Table 12.4.15 Vibration Monitoring Result at Sewri (No.1:Sewri)

Year/Date/Time 2015	Measured values	Converted values	Standard Value (Japanese Standard in dB)	Evaluation (Meet or Exceeds standard)
	Vibration velocity (mm/s)	Vibration level (dB)		
3rd May 7:00	0.080	49.1	7:00-20:00 Day Time 70	Meet Japanese Standard
8:00	0.080	49.1		
9:00	0.079	49.0		
10:00	0.077	48.7		
11:00	0.080	49.1		
12:00	0.0807	49.1		
13:00	0.080	49.1		
14:00	0.076	48.6		
15:00	0.074	48.4		
16:00	0.075	48.5		
17:00	0.080	49.1		
18:00	0.078	48.8		
19:00	0.075	48.5		
20:00	0.077	48.7		
21:00	0.078	48.8	20:00-7:00 Night Time 65	Meet Japanese Standard
22:00	0.071	48.0		
23:00	0.079	49.0		
2nd May 24:00	0.0763	48.7		
1:00	0.076	48.6		
2:00	0.077	48.7		
3:00	0.080	49.1		
4:00	0.077	48.7		
5:00	0.083	49.4		
6:00	0.076	48.6		

Source: JICA Study Team (Supplemental EIA 2015)

Table 12.4.16 Vibration Monitoring Result at Sewri (No.2:Shivaji Nagar)

Year/Date/Time 2015	Measured values: Vibration velocity (mm/s)	Converted values: Vibration level (dB)	Standard Value (Japanese Standard in dB)	Evaluation (Meet or Exceeds standard)
3rd May 7:00	0.079	49.0	7:00-20:00 Day Time 70	Meet Japanese Standard
8:00	0.075	48.5		
9:00	0.076	48.6		
10:00	0.0747	48.5		
11:00	0.074	48.4		
12:00	0.0805	49.1		
13:00	0.0773	48.8		
14:00	0.0728	48.2		
15:00	0.0782	48.9		
16:00	0.0744	48.4		
17:00	0.0757	48.6		
18:00	0.076	48.6		
19:00	0.077	48.7		
20:00	0.078	48.8		
21:00	0.075	48.5	20:00-7:00 Night Time 65	Meet Japanese Standard
22:00	0.072	48.1		
23:00	0.077	48.7		
2nd May 24:00	0.079	49.0		
1:00	0.0833	49.4		
2:00	0.074	48.4		
3:00	0.078	48.8		
4:00	0.081	49.2		
5:00	0.080	49.1		
6:00	0.082	49.3		

Source: JICA Study Team (Supplemental EIA 2015)

Table 12.4.17 Forecasted Traffic Noise at the Station Points (with background level)

Point (landuse)		ST1 Sewri (0-200m: Industry)			ST2 Elaphanta (0-200m: Right of way)			ST3 Shivaji Nagar (0-50m: Right of way 50-200m: Commercial)			Indian Standard dB(A) (Industrial and Commercial) ** IFC Standards
Distance from road		0m	10m	200m	0m	10m	200m	0m	10m	200m	
Day	Road surface	64	66	60	66	68	60	62	63	56	75 (Industrial) *65 (Commercial) ** IFC: 70 Industrial and Commercial)
	Ground (evaluated values)	56	56	57	56	56	57	55	56	*55	
Night	Road surface	60	62	57	62	64	57	58	59	54	70 (Industrial) *55 (Commercial) ** IFC: 70 (Industrial and Commercial)
	Ground (evaluated values)	54	54	55	54	54	55	54	54	*54	

Source: JICA Study Team (Supplemental EIA 2015)

Table 12.4.18 Forecasted Traffic Vibration at the Station Points

Point		ST1 Sewri			ST2 Elaphanta			ST3 Shivaji Nagar			Japanese standard
Distance from road		0m	10m	200m	0m	10m	200m	0m	10m	200m	
Vibration Level (dB)	Day	48	47	45	50	48	45	46	45	42	65
	Night	48	47	45	50	49	45	46	45	42	60

Source: JICA Study Team (Supplemental EIA 2015)

(3) Detailed Description on the Ecosystem and Protected Area

Ecosystem and Protected Area is listed as considerable items on the Supplemental EIA, the detailed description regarding evaluation is as follows.

1) Ecosystem (Fauna-Flora)

The existing information on the project area suggests that the project area does not have rich environment due to pollution and poor mangrove, however mangrove vegetation is existing partly and a plenty of migratory birds mainly Flamingos are feeding on the mudflat between from November to June.

[During Construction]

Construction activities of MTHL may cause noise during construction stage, thus some group of migratory birds may avoid the adjacent area and flyaway to other area such as Thane creek and JNPT in Mumbai basin temporarily. Actually it was observed that the flamingos have avoided during construction of Vashi Bridge and continue to feed same place.

However since several mitigation measures will be conducted, the migratory birds may again get back to same habitat gradually. Additionally turbidity from excavated area in the sea and cutting mangrove area will be minimized by appropriate mitigation measures such as adoption of bored piling methodology and installation of temporary jetty in the mudflat.

[Post Construction]

On the other hand, during operation phase, travelling vehicles generate noise and existence of viaduct may give adverse impacts for migratory birds in CRZ and IBA. However, in case of Vasi and Ilori Bridge construction, Flamingos are feeding before and after construction. It is supposed that any adverse impacts are not caused in the feeding area from the view of biota and topographic view. It is assumed that Flamingo has adapted to such noisy environment.

With regard to distribution of mangrove seeds, since the construction of bridge does not give serious impacts on tidal flow in Mumbai basin in accordance with quantitative analysis by the Central Water and Power Research Station (CWPRS), this situation means that it is supposed project does not give adverse impacts on distribution and provision of mangrove seeds in the basin.

However, for minimization of these impacts, not only CRZ specific conditions, but also additional measures such as consideration of lighting system not to give impacts on Flamingo's roosting area are planned.

When unexpected events and phenomena has been confirmed after construction and during construction, appropriate to take action in consultation with relevant organizations such as MMRDA with general consultant and contractor, environmental department of Maharshtra and MoEF.

Thus, it is not likely to give serious impacts on project area including mudflat ecosystem under implementation of appropriate mitigation measures.

2) Protected Area

The project alignment is passing through Coastal Regulation Zone (CRZ) totally 2.25km and Important Bird Area proposed by Birdlife International totally 5km. With regard to CRZ, the permission has been granted by MoEF in 2013.

On the other hand, JICA Guidelines stipulates that IBA the Sewri Mudfalt is one of the critical habitats, and JICA has confirmed that significant impact is not given by the project in accordance with following conditions in the article 17 of IFC Performance Standard 6.

- The alignment has been concluded in consideration of natural environment and relevant government facilities. (see Chapter 3 of main report) According to description in the Chapter 3, there are no viable alternatives to the proposed alignment.
- As described above article "1) Ecosystem (Fauna-Flora)", the planned structure has selected not to give significant adverse impacts to wildlife such as birds on mudflat with mitigation measures, thus the Project does not involve significant conversion or significant degradation of critical natural habitat.
- Observed bird species in the past surveys which classified as CR or EN identified in Sewri mud flats as described above article " 1) Ecosystem (Fauna-Flora)" may avoid construction area and fly away to the nearest mud flat such as Thane Creek and sanctuaries. Thus it is not predicted that significant impacts such as net reduction of the number of individuals.
- Several mitigation measures shall be taken with the aim of minimizing the impact on fauna and flora living in the mud-flats. MTHL is designed by giving consideration for migrating birds such as adoption of girder bridge type instead of cable-stayed bridge, as well as installation of lighting system in the handrail/noise barrier/view barrier.

During construction phase, the construction plan considering with lifecycle of migratory birds shall be established, and contractor shall take measures such as adoption of excavation methodology for turbid water prevention.

- The implementation of mitigation measures for migratory birds and the baseline survey of migratory birds & habitats will be conducted during migration peak period in 2016 under observation of India and Japanese specialists. In addition, a long-term monitoring and evaluation program for migratory birds & habitats till the baseline status is achieved shall be established by MMRDA and integrated into its environmental management program.

3) Major Mitigation Measures for Ecosystem

Followings are major mitigation measures;

[During Construction]

- Adoption of excavation methodology for the minimal turbid water prevention (i.e. bore casing and excavation)

Source: JICA Study Team

Figure 12.4.6 Bored Piling Methodology for Prevention of Turbid Water

- Minimization of affected area on mangrove area and mudflat by adoption of temporary jetty construction road

Source: JICA Study Team

Figure 12.4.7 Temporary Jetty during Construction

- Implementation of the compensatory mangrove plantation in accordance with CRZ clearance specific condition on July 2013 (5 times of cutting mangrove)

[After Construction]

- Sound barriers shall be installed on both sides of the road in CRZ area and Flaming distributed area so as to minimize the adverse impacts to the migratory birds in accordance with CRZ clearance specific conditions.
- Lighting which does not give significant adverse impacts to roosting area of Flamingos should be installed in accordance with CRZ clearance specific condition.

Source: Panasonic Eco-solutions (Project name: Shin Meishin Expressway Asuka IC- Nabeta IC in Japan)

Figure 12.4.8 Noise Barrier with Lighting System in the handrail/noise barrier/view barrier

- Adoption of bridge type not to give significant impacts on migratory bird flying course in mudflat area. Distribution area and flying course for such as Flamingo should be identified through baseline survey prior to construction stage.
- Pre-stressed super structure shall be used in the mud flat area for construction as committed on CRZ clearance.

Source: JICA Study Team

Figure 12.4.9 Adopted Bridge Structure and Landscape from Sewri Fort (Photomontage)

12.4.6 General Environmental Management Plan

An Environmental Management Plan (EMP) has been recommended in this chapter. This EMP takes into account all the environmental impacts identified for MTHL and the corresponding mitigation measures to ameliorate the same. The EMP presented below includes:

- Specific actions to be taken vis-à-vis site-specific issues;
- Mitigation measures for abatement of the undesirable impacts caused during construction and operation stages
- Agencies responsible for its implementation & supervision;
- Post project Environmental Monitoring Program to be undertaken after commissioning of the project
- Environmental status reporting frequency; and
- Institutional arrangement, Strengthening of their capabilities, and role.
- Mitigation measure and monitoring plan is merged from Rapid EIA 2012 prepared by MMRDA, CRZ clearance specific condition and JICA Scoping report commented by JICA Advisory Committee.
- The cost for all mitigation measures is including a part of construction cost except replanting mangrove. The cost of replanting mangrove in accordance with CRZ clearance will be borne by MMRDA.
- Detailed mitigation measures and monitoring plan should be establish in the future under MMRDA and General Consultant

Environmental management plan during construction phase and operation phase is listed below.

Table 12.4.19 Draft Major Environmental Management Plan on MTHL

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Pollution	1	Air pollution (Air quality/ Siting of borrow and quarry material areas)	- All vehicles and machineries shall obtain & maintain the 'Pollution under Control Certificate (PUC)'. These vehicles will be maintained so that emissions conform to the standards prescribed in the certificate. - Vehicles carrying construction material shall be covered to avoid spilling. - Asphalt mixing plant (Hot mix and batching plants) shall be over 500 m away from any communities and 300 m from the road as far as possible to avoid any air emissions from these plants. - Water sprinkling shall be carried out twice or thrice each day on earth road/unpaved sections of road and construction yard near residential area to avoid dust generation. - The exhaust of DG set will be released at the height prescribed by MPCB (Maharashtra Pollution Control Board) so that it does not affect nearby population.	- Appropriate land use management along the road (commercial and industrial area). - Monitor periodically ambient air quality at suggested locations. - Enforcing different control measures to minimize the air pollution.	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	2	Water pollution (Water Quality/ Construction of labor camp/ Siting of borrow and quarry material areas)	- Turbid waste water from earthwork area on the land shall be mitigated and treated in sedimentation pond, if required. - In the sea section, the casing and excavation methodology shall be adopted not to generate significant turbid water. - There shall be no water drawl in CRZ area - Waste oil shall be store and dispose to designated site. - Provision of sanitation facilities at the labor camps, also the location of camps will be at least 200 m away from any water sources. - Domestic waste water and night soil from base camp shall be treated and discharged. - Septic tanks will be provided in accordance with Coastal Regulation	- In the mudflat section, storm water should be collected by every pier and discharged on pile caps not to excavate mudflat area by the falling water. - Turbid water from road surface shall be collected through drainage and treated by sedimentation trench.	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Pollution			Zone Notification, 2011. The disposal of treated water shall conform to the regulations of MPCB (Maharashtra Pollution Control Board). - Uncontrolled digging of borrow pits will be avoided to prevent water accumulation, which results in breeding of vector disease. - Providing adequate drainage structure - Avoiding obstruction of existing drainage during filling.			
	3	Waste (Solid waste management/ Construction of labor camp/ Topography, Soil and Geology)	- After considering the possibility of reuse, construction waste shall be disposed at designated disposal site after treating. - Garbage at workers camp and waste oil shall be brought to designated disposal site or facility. - Water treatment facility such as septic tank shall be introduced to the workers camp. - There will be no disposal of solid or liquid wastes on coastal area. Solid waste Management will be as per Municipal Solid (Management and Handling) Rules, 2000.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	4	Soil Contamination (Topography, Soil and Geology/ Siting of borrow and quarry material areas)	- Polluted excavated soil including muck soil shall be treated, and then reused and/or disposed at designated site in accordance relevant laws and regulations.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	5	Noise and Vibration (Ambient Noise)	- Selecting low-noise equipment. - Avoiding works of heavy equipment during night time. - Informing the construction schedule to surrounding communities to obtain their consensus. - All the construction equipment's shall be provided with exhaust silencers as committed. - Provision of using ear plugs by workers exposed to high noise levels.	- Proponent will propose appropriate land use plan such as commercial area along the road - Noise barrier shall be installed as required. However, the effect of noise barrier is very limited for the ground height. - Periodic monitoring of ambient noise levels at suggested locations - Erecting signboards at sensitive and residential locations prohibiting use of horns - Growing road side plantation to prevent the noise levels.	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Pollution	8	Sediment Quality (Topography, Soil and Geology(No.4))	- Polluted excavated soil including muck soil shall be treated, and then reused and/or disposed at designated site in accordance relevant laws and regulations.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
Natural Environment	9	Protected Area (Reserved Forest and Fauna)	- Adoption of excavation methodology for the turbid water prevention (i.e. bore casing and excavation) . - Temporary jetty would be constructed in the mudflats for movement of vehicles and machinery to avoid the disturbance to mudflats/mangroves. - Establishment of construction plan in consideration with lifecycle of migratory birds such as Flamingos, if possible. - Installation of silencer with construction machines in accordance with CRZ clearance. - Implementation of monitoring for migratory birds such as Flamingos in accordance with CRZ clearance general condition. - Implementation of the compensatory mangrove plantation in accordance with CRZ clearance specific condition (5 times of cutting mangrove: 0.1776 ha x 5 = 0.888 ha). - It is recommended that implementation of detailed baseline survey for fauna & flora and preparation of monitoring plan in the project area before design-build stage.	- Installation of noise barrier for not to cause “Fly-Kill” on the viaduct as required. - Sound barriers shall be installed on both sides of the road in CRZ area and Flaming distributed area in accordance with CRZ clearance specific conditions. - Adoption of bridge type which does not give significant impacts on migratory bird flying course in mudflat area. note) Distribution area and flying course should be identified through baseline survey prior to construction stage. - Pre-stressed super structure shall be used in the mud flat area for construction as committed on CRZ clearance. - Lighting which does not give significant adverse impacts to roosting area of Flamingos should be installed in accordance with CRZ clearance specific condition. - Prohibit using vehicle horn in mudflat section (Installation of sign boards). - Implementation of monitoring for migratory birds such as Flamingos in accordance with CRZ clearance general condition. - Implementation of appropriate management and maintenance of mangrove plantation area.	MMRDA & Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	10	Ecosystem (Ecology and Biodiversity/ Ecology/ Construction of labor camp)				

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Natural Environment	11	Hydrology	- The monitoring of the tidal level and current should be conducted at the bridge sites by installing water alarm system during and after the construction. - The bathymetric survey around the MTHL should be conducted periodically, and will be confirmed that the sea bed level is higher than the design scour depth. - Designing of bridges with sufficient capacity not to give impacts on tidal conditions. - There shall be no water drawl in CRZ area.	-Same monitoring and mitigation measures during construction shall be done	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	12	Topography and geology (Topography, Soil and Geology)	- These slope gradients are stabilized in accordance with Guideline of earthwork (Japan Road Association). - Appropriate slope protection measures are adopted, as required.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
Social Environment	13	Involuntary resettlement	- Implementation of SIA (Holding consultation meetings for understanding of compensation policy, Implementation of adequate compensation on JICA Guidelines and Implementation of livelihood restoration program based on SIA)	- Monitoring and evaluation based on SIA policy	MMRDA	MMRDA
	14	The poor	- Implementation of SIA	- Monitoring and evaluation based on SIA policy	MMRDA	MMRDA
	16	Local economy such as employment and livelihood (Quality of Life/Fisheries)	- Implementation of SIA	- Monitoring and evaluation based on SIA policy	MMRDA	MMRDA
	17	Land use and utilization of local resources (Land use/Fisheries)	- Implementation of SIA	- Management of appropriate land use in accordance with approved land use plan along the road.	MMRDA	MMRDA (propose to MCGM and CIDCO)
	19	Existing social infrastructures and services (Utility services and community severance)	- Implementation of SIA	- Monitoring and evaluation based on SIA policy	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Social Environment	22	Local conflict of interests	- Local workforce is prioritized for construction. - Implementation of appropriate education for hired workers from other area and countries.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	24	Landscape (Aesthetics and landscape)	- The monotone color harmonized with surrounding current landscape has been adopted. - Landscaping of borrow pits.	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	27	Infectious diseases such as HIV/AIDS	- Installation of sufficient drainage facilities not to provide habitat for vector mosquito. - Provision of adequate temporary sanitation facilities. - Enforcement of medical screening and periodical medical check-up. - In order to prevent spread of infectious diseases such as HIV/AIDS, awareness of the labors and local inhabitants is promoted.	- Installation of sufficient drainage facilities not to provide habitat for vector mosquito. - Implementation of periodical maintenance for drainages and bridges.	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)
	28		- Implementation and follow relevant laws and regulations “Building And Other Construction Workers (Regulation of Employment and Conditions of Service) Act,1996” and “The building and other construction worker’s welfare cess Act, 1996” and IFC Performance Standard 2 Labor and Working Conditions	Not required	Contractor (Construction Company)	MMRDA & General Consultant (PMC & EC)

Area	No.	Item (on Rapid EIA 2012)	Mitigation Measures		Responsibility	
			During Construction	Operation	Implementation Agency	Responsible Agency
Other	29	Accident (Accident hazards and safety)	- Secure assistance from local police for traffic control during construction phase. - Safety measures will also be undertaken by installing road signs and marking for safe and smooth movement of traffic. - Setting up of appropriate detours. - Restricting mobilization speed in the construction site. - Installation of parking for idling construction machines. - Installing gate structure at the entrance of the construction site to set up restricted area - Deploying flagman at the gate and crossing points of the construction vehicles. - Installing fence around the construction site to keep out local people such as children. - Installation of lightning in the night time near construction area. - Labourers will be equipped with proper safety gears like helmets gloves and gumboot. - Periodic health check-up of construction worker. - Safety training for the workers and safety patrol at the construction site by supervisors. - Monthly safety meeting	- Implementation of advertisement for traffic safety campaign. - Prepare and administer a monitoring system on road accidents. - Installation of sign board and road making for speed limit. - Enforcement of traffic controls by police.	Contractor (Construction Company) in consultation with Traffic Police Department	MMRDA Traffic Police
	30	Cross Boundary impacts and climate change	- Replanting mangrove and street trees same amount of cutting trees (5 times of cutting mangrove shall be replanted in CRZ in accordance with CRZ clearance specific condition)	- Maintenance of planted trees and mangroves through periodical inspection	MMRDA	MMRDA

Source: JICA Study Team

Additionally all committed specific conditions on CRZ clearance on 2013 will be conducted by MMDA as shown in the next table.

Table 12.4.20 Mitigation Measures on CRZ Clearance for MTHL

No	Conditions	Response on Mitigation Measures
1	As per the CRZ notification, 2011, at least five times the number of mangroves destroyed/cut during the construction process shall be replanted. Mangrove plantation in an area of 30 ha shall be carried out as committed against loss of 0.1776 ha of mudflats/mangroves. Permission from the High Court of Bombay shall be obtained with respect to mangrove cutting.	MMRDA will replant 5 times of cutting mangrove in the appointed area by MoEF.
2	Proponent shall provide lighting in consulting in consulting with the Bombay Natural History Society so as to minimize the likely impacts to the migratory birds.	MMRDA will setup traffic light inside of bridge handrail especially in CRZ and flamingo roosting area.
3	All the construction equipment's shall be provided with exhaust silencers as committed.	Low noise construction machines and with exhaust silencer is installed during construction.
4	Noise containment barriers shall be provided on both sides of the bridge in mudflat areas (CRZ-IA) so as to minimize the likely impacts to the migratory birds.	Noise barrier is installed in CRZ and roosting /feeding are of migratory birds such as flamingo.
5	There shall be no dreading and reclamation for the project.	Dreading and reclamation is not planned on this project in the CRZ.
6	Pre-stressed super structure shall be used in the mud flat area for construction as committed.	Pre-stressed super structure will be used in the mud flat area CRZ.
7	The muck materials shall be analyzed prior to dumping / disposal in the identified locations with the approval of competent authority to ensure that it do not cause any impact to the environment.	The muck soil is generated from excavated points of piles. The excavated soil is analyzed and disposed at designated and authorized dumping site.
8	Proponent informed that there is no fishing activity in the area since it is a navigation channel for the nearby ports. However, navigation channel is provided with 25m for ships and 9.1 m for fishing boats.	Sufficient prescript vertical clearance under discussion with relevant authorities.
9	All the recommendations of the MCZMA shall be strictly compiled with.	All recommendation of the Maharashtra Coastal Zone Management Authority will be reflected to mitigation measures, if any.
10	There shall be no building construction beyond 20,000 sqm.	No building is planned in CRZ. Only toll gate is planned out of CRZ in Navi Mumbai side.
11	There shall be no water drawal in CRZ area.	No polluted water from project in CRZ. However storm water will be flow down from the road in monsoon season.
12	There shall be no disposal of solid or liquid wastes on coastal area. Solid waste Management shall be as per Municipal Solid (Management and Handling) Rules, 2000.	There is no activities to discharge and dispose solid and liquid waste from project activities in CRZ.
13	Sewage shall be treated and the Treatment Facility shall be provided in accordance with the Coastal Regulation Zone Notification, 2011. The disposal of treated water shall conform to the regulations of State Pollution Control Board.	Sewage including polluted water and night soil does not generate from project activities in CRZ.
14	The project proponent shall set up a separate environmental management cell for effective implementation of the stipulated environmental safeguard under the supervision of a Senior Executive.	MMRDA will setup environmental management cell for MTHLin MMRDA.
15	The funds earmarked for environment management plan shall be included in the budget and this shall not be diverted for any other purposes.	MMRDA will secure budge for MTHL.

Source: CRZ Environmental Clearance (MOEF 19th July 2913)

12.4.7 Environmental Monitoring Plan

Environmental Monitoring shall be done by the construction contractor. The contractor shall conduct prescript monitoring and report to the construction supervision consultant monthly.

The expected environmental monitoring plans are shown below.

Table 12.4.21 Environmental Monitoring Plan Pre and During Construction Phase

Area	No.	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Pollution	1	Air pollution	SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, Pb, CO, NH_3, C_6H_6, BaP, As, Ni, CH_4 and CO_2 (14 Items)	Same method as baseline survey Or Establis fixed monitoring station at 2 locations	**2 Locations** where baseline monitoring was carried out. (2 locations: Sewri and Shivaji Nagar)	**4 times / year x 4.5 years** (Once every quarter – Summer, Winter, post-monsoon) (24 hr/day for 2 consecutive working days per week for 2 weeks except CO which is 8 hr/day)	1,800,000	National Ambient Air Quality Standards (NAAQS) by Central Pollution Control Board (CPCB) (Standard for 24hrs: Industrial and Residential) • SO_2: 80μg/m^3 • NO_2: 80μg/m^3 • PM_{10}: 100μg/m^3 • $PM_{2.5:}$: 60μg/m^3 • O_3: 180μg/m^3 • Pb: 1.0μg/m^3 • CO: 0.4mg/m^3 • $NH_{3:}$: 400μg/m^3 Following standards are for Annual • C_6H_6: 0.5μg/m^3 • BaP: 0.1μg/m^3 • As: 0.6mg/m^3 • Ni: 20mg/m^3
	2	Water pollution	pH, BOD, DO, Turbidity and O&G	Same method as baseline survey	3 Locations Near excavated area in Zone II (Sewri mudflat), Zone III and Zone IV where baseline monitoring was carried out.	4 times / year x 4.5 years Once every quarter – Summer, Winter and post-monsoon	810,000	**Marine water quality Standards – Class SW-IV Harbour Waters (MPCB)** pH : 6.5-9 DO: 3 mg/l Turbidity: 30 NTU BOD: 5 mg/l O & G: 10 mg/l
	3	Waste	Volume of waste soil, cutting tree and domestic garbage	Record volume of generated waste	3 Locations (1. Sewri camp site 2. Mangrove cutting area 3. Navi Mumbai camp site))	4 times / year x 4.5 years	324,000	**Municipal Soild Waste Management Rules, 2013** Generated waste shall be reused or disposed at designated site. (The construction waste can be dumped in legally authorized dumping grounds in Navi Mumbai by CIDCO with association of Navi Mumbai Municipal Corporation (NMMC) which is located in Taloja. Remaining i.e. from Mumbai side, MMRDA can be taken care of and dumped the construction waste in association with Municipal Corporation of Greater Mumbai (MCGM) on authorised sites i.e. Deonar, Mulund and Gorai.

Area	No.	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Pollution	4 And 8	Soil Contamination/sedimentation	Heavy Metals & Oil & Grease (5-10 items shall be selected from Soil pollution standards)	Same method as baseline survey	2 Locations 1. Excavated muck soil and 2. stocked soil in the yard from cutting area	1 times / year x 4.5 years	108,000	**Soil Pollution Standard in India (MOEF)** Cd: 0.01mg/l Lead: 0.01mg/l Chromium (VI): 0.05mg/l Arsenic: 0.01mg/l T-Mercury: 0.0005mg/l Copper: 125mg/kg (some items shall be selected from totally 25 standards items)
	5	Noise and vibration	Ambient and road side noise (dB(A)LAeq)	Same method as baseline survey (continuous 24 hrs)	3 Locations (1. Sewri, 2. ST migratory bird distribution area ST500-5500, 3. Shivaji Ngagar) Note) No2 and 3 locations where baseline monitoring was carried out.	2 times / year x 4.5 years	108,000	-Construction Noise; 85dB(A) -**Ambient Noise Standards in India (dB (A) Leq)** 1.Industrial Area Day Time: 75 (6-22hr) Night Time: 70 (22-6hr) 2.Commercial Area: Day Time: 65 (6-22hr) Night Time: 55 (22-6hr) 3.Residential Area: Day Time: 55 (6-22hr) Night Time: 45 (22-6hr) 4.Silence Zone Day Time: 50 (6-22hr) Night Time: 40 (22-6hr)
			Vibration (dB L10 or mm/sec)	Same method as baseline survey (continuous 24 hrs)	↑ ditto	2 times / year x 4.5 years	54,000	- Construction vibration 75dB -**Vibration Standards** roadside 1. Commercial /Industrial Area Day Time: 70 (7-20hr) Night Time: 65 (20-7hr) 2. Residential Area: Day Time: 65 (7-20hr) Night Time: 60 (20-7hr)
Natural Environment	9	Protected Area	1.Monitoring of mudflat conditions including fauna-flora 2. Monitoring of Cutting Tree and replantation/ transplanting area 3.Monitoring of Mangrove Plantation area appointed by MoEF 4. Monitoring of sedimentation soil and ecological parameter (18items on EIA main text Table 6.1.15 for soil and 7 items	Ocular inspection and quantitative survey 1-1. Fauna-Flora Line-Point census and record number and appeared species 1-2: Mangrove density and community survey 1-3: Benthos Survey 2-1: Cutting trees confirmation	Along MTHL alignment and mangrove replant area	**4 times / year x 4.5 years**	6,480,000	Significant impacts are not caused by the project **Note)** **Detailed monitoring plan will be setup during basic design stage** Standard for Soil; Table 6.1.15 Sandar for Ecological Parameter: • Net primary Productivity <1,500 mgC/m^3/day at surface • Chlorophyll-a <4mg/m^3 • Phosphate: 0.1-90μg/l • Nitrate: 1.0-500μg/l • Nitrite: <125μg/l • Particulate Organic Carbon: 10-100mg/m^3
	10	Ecosystem						

Area	No.	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Natural Environment			such as 1)Net primary productivity, 2)Chlorophyll-a, 3)Phosphate, 4)Nitrate, 5)Nitrite, 6)Particulate Organic Carbon, 7) SiO_2)	3-1: Mangrove survey in the replanted area				• SiO2: 10-5,000μg/l
	11	Hydrology	Flooding situation	Flood level measurement during high precipitation periods	2 Locations (CRZ at Sewri and Shivaji Nagar)	4 times / year x 4.5 years	540,000	Project activities and structures does not cause flooding and impacts on tidal conditions
	12	Topography and Geology	Conditions in embankment area	Visual survey about Stability of embankment	2 Locations (1. Embankment of Inter Change in Shibaji Nagar and 2 Cutting area at toll gate in Chirle)	4 times / year x 4.5 years	The cost is including with No 17 Land use	Embankment shall be stabilized without any landslide and cracks
Social Environment	13	Involuntary resettlement	Payment and implementation of social assistance in accordance with SIA	Consultation Meeting and/or Survey with the project affected persons (PAPs)	Affected area	Refer to SIA monitoring plan	Refer to SIA monitoring plan	Compensation shall be completed prior to actual construction activities and secure livelihood standards
	14	The poor						
	16	Local economy such as employment and livelihood						
	17	Land use and utilization of local resources	Situation of establishment of land use map	Confirmation of land use map	2 Locations (Sewri and Navi Mumbai side in the Affected area)	2 times / year x 4.5 years	180,000	Designated land use shall be secured without any unplanned development by local people and developers
	19	Existing social infrastructures and services	Condition of facilities to be displaced	Ocular inspection	Affected area	Refer to SIA monitoring plan	Refer to SIA monitoring plan	Compensation shall be completed prior to actual construction activities and secure livelihood standards
	22	Local conflict of interests	Construction worker's township	Confirmation of workers list from contractor	2 Locations (camp site in Sewri and Shivaji Nagar)	4 times / year x 4.5 years	180,000	Employment opportunity shall be provided fairly
	24	Landscape	Condition of landscape	Visual inspection	1 Location (View from Sewri Fort)	1 time / year x 4.5 year (Dry season)	22,500	Color of structure shall be adopted monotone color harmonized with surrounding landscape
	27	Infectious diseases such as HIV/AIDS	Number of infected patient	Confirmation of health check list from contractor	2 Locations (camp site in Sewri and Shivaji Nagar)	4 times / year x 4.5 years	180,000	Infection disease rate shall not be caused by the project

Area	No.	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Social Environment	28	Labour Environment	Construction worker's condition	Confirmation of safety devices and conditions via interviews	2 Location (camp site in Sewri and Shivaji Nagar)	2 times / year x 4.5 years	90,000	"Building And Other Construction Workers (Regulation of Employment and Conditions of Service) Act,1996", "The building and other construction worker's welfare cess Act, 1996" and international standards such as "IFC Performance Standard 2 Labor and Working Conditions"
Other	29	Accident	Number of accidents	Confirmation of accidents list from local government and State Traffic Police Department	2 Locations (camp site in Sewri and Shivaji Nagar)	4 times / year x 4.5 years	180,000	Any accidents are not caused by construction
	30	Cross Boundary impacts and climate change	Monitoring of replanting and transplanting trees and mangrove	Refer to No.9 and 10				
Total Cost during Construction : *8,145,000* for 4.5 years (during construction)								

Source: JICA Study Team

Environmental monitoring survey plan for operation phase is proposed as follows. Proposed monitoring period is at least three (3) years.

Table 12.4.22 Environmental Monitoring Plan during Operation Phase

Area	No	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Pollution	1	Air pollution	SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, Pb, CO, NH_3, C_6H_6, BaP, As, Ni, CH_4 and CO_2 (14 Items)	Same method as baseline survey Or Establis fixed monitoring station at 2 locations	**2 Locations** where baseline monitoring was carried out. (2 locations: Sewri and Shivaji Nagar)	**4 times / year x 4.5 years** (Once every quarter –Summer, Winter, post-monsoon) (24 hr/day for 2 consecutive working days per week for 2 weeks except CO which is 8 hr/day)	600,000	National Ambient Air Quality Standards (NAAQS) by Central Pollution Control Board (CPCB) (Standard for 24hrs: Industrial and Residential) • SO_2: 80μg/m^3 • NO_2: 80μg/m^3 • PM_{10}: 100μg/m^3 • $PM_{2.5:}$: 60μg/m^3 • O_3: 180μg/m^3 • Pb: 1.0μg/m^3 • CO: 0.4mg/m^3 • $NH_{3:}$: 400μg/m^3 Following standards are for Annual • C_6H_6: 0.5μg/m^3 • BaP: 0.1μg/m^3 • As: 0.6mg/m^3 • Ni: 20mg/m^3
	2	Water pollution	pH, BOD, DO, Turbidity and O&G	Same method as baseline survey	3 Locations Zone II (Sewri mudflat), Zone III and Zone IV where baseline monitoring was carried out.	4 times / year x 3 years Once every quarter – Summer, Winter and post-monsoon	540,000	Marine water quality Standards – Class SW-IV Harbour Waters (MPCB) pH : 6.5-9 DO: 3 mg/l Turbidity: 30 NTU BOD: 5 mg/l O & G: 10 mg/l
	4 & 8	Soil Contamination / sedimentation	Heavy Metals & Oil & Grease (5-10 items shall be selected from Soil pollution standards)	Same method as baseline survey	3 Locations (Zone II, III and III)	1 time / year x 3 years	108,000	Soil Pollution Standard in India (MOEF) Cd: 0.01mg/l Lead: 0.01mg/l Chromium (VI): 0.05mg/l Arsenic: 0.01mg/l T-Mercury: 0.0005mg/l Copper: 125mg/kg (some items shall be selected from totally 25 standards items)
	5	Noise and vibration	Ambient and road side noise (dB(A)LAeq)	Same method as baseline survey	2 Locations Sewri and Shivaji Nagar where baseline monitoring was carried out.	2 times / year x 3 years	48,000	Ambient Noise Standards in India (dB (A) Leq) 1.Industrial Area Day Time: 75 (6-22hr) Night Time: 70 (22-6hr) 2.Commercial Area: Day Time: 65 (6-22hr) Night Time: 55 (22-6hr) 3.Residential Area: Day Time: 55 (6-22hr) Night Time: 45 (22-6hr) 4.Silence Zone Day Time: 50 (6-22hr) Night Time: 40 (22-6hr) Vibration Standards (refer to Japanese
			Vibration (dB L10 or mm/sec)	Same method as baseline survey		2 times / year x 3 years	24,000	

Area	No	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
								standards along the road) 1. Commercial /Industrial Area Day Time: 70 (7-20hr) Night Time: 65 (20-7hr) 2. Residential Area: Day Time: 65 (7-20hr) Night Time: 60 (20-7hr)
Natural Environment	9 & 10	Protected Area / Ecosystem	1.Monitoring of mudflat conditions including fauna-flora 2. Monitoring of Cutting Tree and replantation/ transplanting area 3.Monitoring of Mangrove Plantation area appointed by MoEF 4. Monitoring of sedimentation soil and ecological parameter (18items on EIA main text Table 6.1.15 for soil and 7 items such as 1)Netprimary productivitye, 2)Chlorophyll-a, 3)Phosphate, 4)Nitrate, 5)Nitrite, 6)Particulate Organic Carbon, 7) SiO_2)	Ocular inspection and quantitative survey 1-1. Fauna-Flora Line-Point census and record number and appeared species 1-2: Mangrove density and community survey 1-3: Benthos Survey 2-1: Cutting trees confirmation 3-1: Mangrove survey in the replanted area	Along MTHL alignment and mangrove replant area	**2 times / year x 3 years**	2,160,000	Significant impacts are not caused by the project **Note) Detailed monitoring plan will be setup during basic design stage** Standard for Soil; EIA main text Table 6.1.15 Standards for Ecological Parameter: • Netprimary Productivity <1,500 $mgC/m^3/day$ at surface • Chlorophyll-a <4mg/m^3 • Phosphate: 0.1-90μg/l • Nitrate: 1.0-500μg/l • Nitrite: <125μg/l • Particulate Organic Carbon: 10-100mg/m^3 • SiO2: 10-5,000μg/l
	11	Hydrology	Flooding situation	Flood level measurement during high precipitation periods	2 Locations (CRZ at Sewri and Shivaji Nagar)	4 times / year x 3 years	360,000	Project activities and structures does not cause flooding and impacts on tidal conditions
	12	Topography and Geology	Conditions in embankment area	Visual survey about Stability of embankment	2 Locations (1. Embankment of Inter Change in Shibaji Nagar and 2 Cutting area at toll gate in Chirle)	2 times / year x 3 years	Refer to item No17	Embankment shall be stabilized without any landslide and cracks

Area	No	Item (on Rapid EIA 2012)	Parameter	Method	Location	Frequency a year	Cost (INR)	Standard
Social Environment	13	Involuntary resettlement	Payment and implementation of social assistance in accordance with SIA	Consultation Meeting and/or Survey with the project affected persons (PAPs)	Affected area	Refer to SIA Monitoring plan	Refer to SIA monitoring plan	Compensation shall be completed prior to actual construction activities and secure livelihood standards
	14	The poor						
	16	Local economy such as employment and livelihood						
	17	Land use and utilization of local resources	Situation of establishment of land use map	Confirmation of land use map	2 Locations (Sewri and Navi Mumbai side in the Affected area)	2 times / year x 3 years	60,000	Designated land use shall be secured without any unplanned development by local people and developers
	24	Landscape	Condition of landscape	Visual inspection	1 Location (View from Sewri Fort)	1 time / year x 3 year (Dry season)	15,000	Color of structure shall be adopted monotone color harmonized with surrounding landscape
Other	29	Accident	Number of traffic accidents	Confirmation of accidents list from local government and State Traffic Police Department	On Mumbai Trans Harbour Link	2 times / year x 3 years	30,000	Any accidents are not caused by construction
	30	Cross Boundary impacts and climate change	Monitoring of replanting and transplanting trees and mangrove	Refer to No.9 and 10				
Total Cost: *3,945,000* INR for 3 years (after construction)								

Source: JICA Study Team

12.4.8 Monitoring Organization

The objectives and design of the EMP and Environmental Monitoring Plan was described in earlier sections of this chapter. There is a necessity to form a proper ‘Institutional Framework’ for the effective implementation of the formulated environmental management & monitoring plan. The elements of this ‘Institutional Framework’ will co-ordinate and work with each other throughout the project, i.e. during pre-construction, construction & operation stage. The implementation of formulated environmental mitigation measures comes with a cost so the budgeting of EMP is necessary and also the financial source that will provide this budget, are discussed in this section.

The suggested elements of ‘Institutional Framework’ for implementing EMP of MTHL project will be as follows:

a) MMRDA - Project Implementing Agency (PIA) and Environmental Cell

b) Financial Source – JICA & MMRDA

c) Project Contractor – Construction Company (PC)

d) General Consultant

- Project Management Consultant (PMC)
- Environmental Consultant (EC)

e) Environmental Authorized Agency - Statutory Bodies (Authorities)

- Maharashtra State Pollution Control Board (MPCB)
- Ministry of Environment Forests

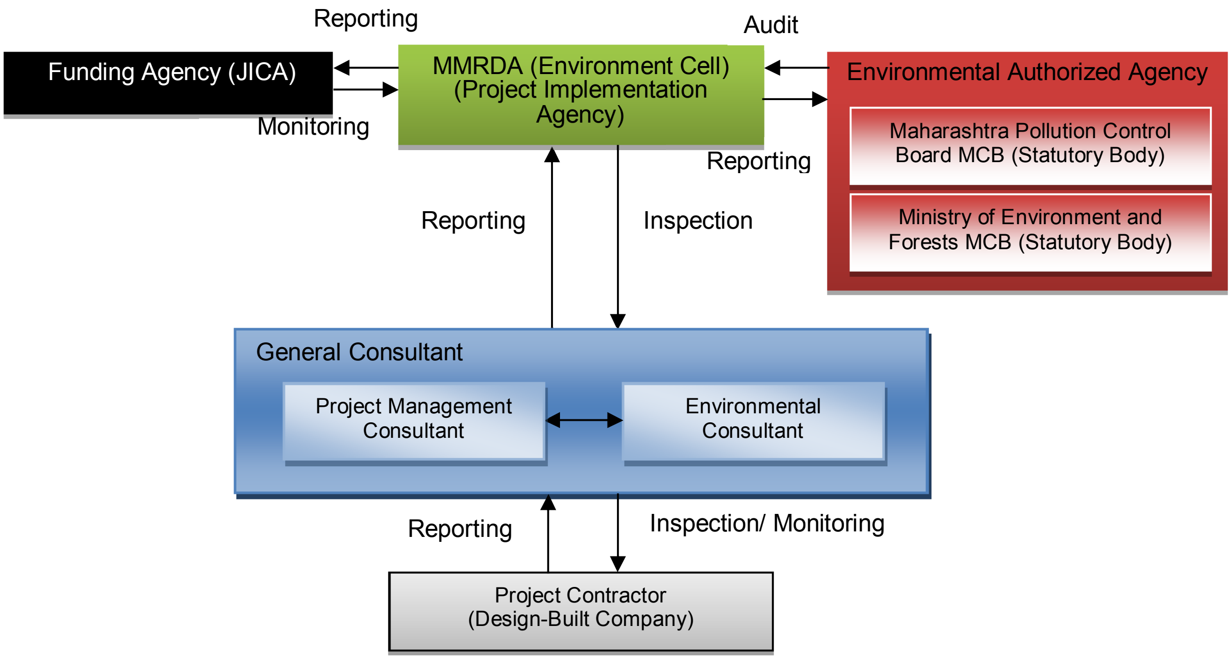
The Environmental Authorized Agency will not be a direct part of ‘Institutional framework’ but it will hold controlling authorities on it. It will review and approve the reports submitted by the PIA and can take necessary further actions, if any.

The above stated elements are part of the ‘Institutional Framework’ who will work together to effectively implement the formulated ‘Environmental Management Plan’. The roles & responsibilities of these elements are given in Table 7.3.1 Roles & Responsibilities of Institutional Framework.

Table 12.4.23 Environmental Management and Monitoring Organization

Stage	Name of Organization	Roles and Responsibilities
Pre- Construction & Construction	Project Implementing Agency and Environmental cell - PIA	
	MMRDA	Initiate the co-ordinate process among the concerned organizations (Elements of Institutional Framework) for EMP implementation. Overseeing the implementation of the EMP by the PMC Approval of '6 monthly - Environmental Compliance Report' submitted by the EC and respond necessary action. After Approval sending the report to the MPCB. Finalization of the SIA during detailed design. Facilitate relocation of people & monitoring actual payments of compensation to affected stakeholders such as landowners, Structure owners etc.
	General Consultant	
	Project Management Consultant (PMC)	PIA will get the EMP implanted through PMC. PMC will work in association with Project Contractor (Construction Company) & the Environmental Consultant (EC) on a full time basis at the project site office. PMC will mainly look after managing engineering & construction related activities.
	Environmental Consultant (EC)	EC will look after implementation of approved environment measures on site. EC will be in constant touch with PMC & Project Contractor. EC will facilitate PIA to obtain mandatory 'Consent to Establish' certificate from Maharashtra State Pollution Control Board (MPCB) before start of the Construction on site. EC will get the 6 monthly environmental monitoring done from the MoEF approved laboratory. EC will prepare an 'Environmental Compliance Report (ECR)' describing Status of approved Environmental Mitigation measures on site (submitted by PC) and Monitoring of Environmental Attributes (submitted by MoEF Approved Laboratory) on a six monthly basis and will submit it to the PIA for their approval. PIA will then submit the approved ECR to the MPCB.
	Project Contractor - PC	
	Construction Company	PC will implement approved EMP (mitigation measures) as directed by PMC & Environmental Consultant. The PC will submit the report for all conducted mitigation measures on site to the EC on a six monthly basis.
Operation (Twice in a year x 3 years)	Project Implementing Agency – PIA	
	MMRDA	PIA will oversee the compliance status of all environmental measures through their appointed consultants.
	Appointed Consultant by MMRDA	Periodical inspection & maintenance of the MTHL. EC will facilitate PIA to obtain mandatory 'Consent to Operate' certificate from Maharashtra State Pollution Control Board (MPCB) before start of operation of the project. EC will prepare annual 'Environmental Statement (Form V)' as mandated in CRZ clearance and submit to PIA for their approval. PIA after reviewing the same will submit to the MPCB.

Source: JICA Study Team



Source: JICA Study Team

Figure 12.4.10 Proposed Environmental Management and Monitoring Implementation Organization

All cost for environmental management plan such as mitigation measures are including in the physical contingency of project construction cost. On the other hands, cost for project management such as Environmental Cell in MMRDA will be secured on MMRDA annual budget.

12.5 Stakeholder Meeting

12.5.1 Objectives of the Meeting

It is mandatory to conduct local level stakeholder meeting twice for this EIA based on draft EIA process as per JICA Guidelines for Environmental and Social Consideration (2010).

Main objectives for holding local stakeholder meeting are shown below;

- ✓ To make aware stakeholders about the proposed MTHL project and project related proposed actions both before and after development decisions are made.
- ✓ To understand the concerns of local project affected people and others who have plausible stake in the environmental impacts of the project.
- ✓ To inform stakeholders about the environmental and social adverse and positive impacts of the project.
- ✓ To exchange opinions regarding project and environmental issues.

- ✓ To minimize probable adverse impacts of the project and to achieve speedy implementation of the project through bringing in awareness among the stakeholders about the benefits of the project.

12.5.2 Meeting Notification and Language

(1) Scoping Stage

In case of “First Public Consultation”, the publicity of meeting was carried out by sending separate “Invitation Letters” to the experts in various fields (as per JICA categorization requirement) while the stakeholders were invited through telephonic as well as personal invitation. The presentation material was indicated in English by MMRDA, explanation of the material was done in in local “Marathi” language upon request of the participants.

(2) Draft Supplemental EIA Stage

In case of “Second Public Consultation”, the publication was carried out by putting an advertisement in two local newspapers about three weeks prior to the date of the public consultation meeting. The Marathi advertisement was put up in “SAKAAL” and English advertisement was put up in “HINDUSTAN TIMES” newspapers. This presentation was also given in “Marathi” language.

12.5.3 Schedule of the Meeting

Following local stakeholder meetings are scheduled in July & August-September 2015. A schedule and agenda for stakeholder meetings are shown below;

Table 12.5.1 Schedule Stakeholder Meetings on EIA and SIA

Date & Venue	Objectives of the meeting	Major Agenda	Participants
7th July, 2015 Shakha office, Near Shri Krishna Hindu Hotel, Sewri Gadi Adda, Haji-bundar road, Sewri (E), Mumbai - 400 015	To discuss the social impacts of the project with the key Stakeholders (Project affected people)	Project outline, necessity of social survey and survey items, basic compensation policy and declaration of cut off data	MMRDA JICA Team Project Affected Persons
29th July, 2015 Committee Room, 6th Floor, MMRDA Office, B.K.C, Mumbai	To inform stakeholders about the proposed MTHL project & Explanation of draft modified Rapid EIA and formulation of basic consensus	Project outline, Benefits of the project, Predicted environmental impacts, practical mitigation measures, monitoring plan and project schedule	MMRDA JICA Team Relevant local government (CIDCO, MPT & JNPT, ASI, NEERI) Project affected persons Experts from various fields as per JICA requirement
25th August (SIA 2nd PC) Sewri Koli Samaj Hall, 22/1 Koli Samaj Co.Op.Society, Sewri, Koliwada (E), Mumbai - 400015	To intimate to the stakeholders about the result of BSES and Resettlement & Rehabilitation Policy of MTHL.	Background, 1st SIA Stakeholder meeting (SSM), Result of BSES, Resettlement & Rehabilitation Policy of MTHL, Resettlement Site, Requesting opinions from PAPs.	MMRDA JICA Team Project Affected Persons
15th September, 2015 Sewri Koli Samaj Hall, 22/1 Koli Samaj Co.Op.Society, Sewri, Koliwada (E), Mumbai - 400015	To inform/communicate to the stakeholders and public at large about the findings of the draft supplemental EIA. To discuss about the mitigation measures as suggested in the draft EIA.	Opening Remarks, Project in Brief, Objectives & schedule of public consultation meetings, details of first public consultation of EIA, result of reformed studies, Environmental Management Plan, Environment Monitoring Plan, Project Implementation Schedule, Exchange Opinions, Remarks	MMRDA Team JICA Team Relevant local government (CIDCO, MPT & JNPT) Experts from various fields as per JICA requirement NGOs Project affected persons

Source: JICA Study Team

12.5.4 Objectives of the Meeting

(1) Scoping Stage

1) Participants of the Meeting

Table 12.5.2 Major Participants of Public Consultation on Scoping Stage

Date & States	Major Participants	
Mumbai, Maharashtra State 29th July 2015 2.00-4.00pm (at Committee Room, 6th Floor, MMRDA office, B.K.C, Mumbai)	MMRDA	Chief Engineer, Superintending Engineer, Ex. Engineer, Chief, Social Development Cell, Deputy Engineer, Deputy Engineer
	Other Government	Scientist- NEERI, IFS- Head Mangrove Cell, Superintending Archaeologist – Archaeological Survey of India, Dy.Chief Engineer- Mumbai Port Trust, Ex.Engineer – CIDCO, Manager (EC)- JNPT
	NGO and/or Community specific group	Project Manager –Social Specialist- CEED, Representative of Teacher's Group, Representative of Women;s Group
	PAPs	Local Medical Practitioner, Social Activist, Resident
	JICA Team	JICA study team and local consultant
Number of Total Participants	Government: 12, PAPs: 13, NGOs and Community Specific Group: 3, JICA Team: 6 Total: 34 (Male: 26, Female: 8)	

Source: JICA Study Team

2) Agenda

- ✓ Explanation of the objective of the meeting by JICA Team
- ✓ Explanation of project background & project features by JICA Study Team
- ✓ Explanation of MTHL alignment by JICA Study Team
- ✓ Explanation on need of Environmental & Social consideration in this project
- ✓ Explanation on supplemental EIA and RAP outline (process, extent of impact and study schedule) by JICA Study Team
- ✓ Explanation on Study Schedule (Timeline)
- ✓ Exchange of opinions

(Note): Contents above was explained in "Marathi" language based on the materials prepared for SHM and RAP Socialization at scoping stage

3) Major Opinion and Summary of Discussion

JICA Study Team initiated the proceedings and welcomed the gathering and explained about the project in brief and EIA studies carried out. He presented the project and EIA findings in Marathi language to the participants. The meeting then opened for Questions & Answers session. The major opinions and discussions held in the meeting are given below:

Table 12.5.3 Major Opinions and Discussions of the Stakeholder Meeting

No	Major opinion and Answer			
	Question/Comment		Answer	
	Name/Position	Question	Name/Position	Answer
1	Scientist- NEERI Female	Who will do the funding to the project?	Mr. Kolatkar (EIA Specialist -JICA Study Team)	It is expected that the funding to the project is from "Japan International Cooperation Agency" (JICA).
2	Scientist- NEERI Female	In which season the environmental monitoring is carried out? Whether Marine water & Air quality monitoring is covered in this Reformed Rapid EIA?	Mr. Kolatkar (EIA Specialist -JICA Study Team)	Post monsoon season monitoring was carried out in the year 2012. JICA Study Team will use the secondary data from Pollution Control Board, if any.
3	Scientist- NEERI Female	What activities are planned in the supplementary EIA?	Mr. Kolatkar (EIA Specialist	JICA Study Team has checked the old Rapid EIA Report 2012 based on the JICA guidelines, and will fill out the gaps. Vibration Study and Social Impact Assessment will be covered in the Supplemental EIA.
4	EC- JNPT & Scientist- NEERI Female	Whether Mangrove Management Plan & Ecology Impacts are considered?	Mr. Kolatkar (EIA Specialist	All these will be covered in the EIA finalized in the September 2015.
5	Archaeological Survey of India male	How much is the distance between alignment and Elephanta caves? Elephanta Caves has no electric connection. If project is passing at 1 km from Elephanta Caves then electricity should be converted.	Mr. Kolatkar (EIA Specialist)	Around 2km from the alignment to Elephanta cave. With regard to provision of power, this is a good advice and will be taken into account in the future.
6	PAP Male	Long back, Mangrove Park was declared in Sewri. Is this taken into account?	Mr. Kolatkar (EIA Specialist)	JICA Study Team will check on this. (After the meeting, It was confirmed that there are any plans such as mangrove park)
7	PAP Male	Give details of Slum Rehabilitation Plan.	Mr. Kolatkar (EIA Specialist)	MMRDA carried out 100 household surveys earlier and now 380 households survey is been carried out on SIA survey. MMRDA will study these survey results and follow MMRDA's Compensation Policy for Rehabilitation.
8	PAP Male	The PAP said this is a good project and we want such project. But the rehabilitation should be in the near area or in the same area. As per new law, should get new and good homes and commercial units.	Mr. Vishram Patil (Chief-Social Development Cell, MMRDA)	MMRDA will take into account these points. But they cannot commit that they can shift the PAPs in the same area at the moment. But they will see the situation and try to shift the PAPs in the nearby area. MMRDA will not build the houses but will give the compensation. As the land is of Mumbai Port Trust and hence the revision will be done in terms of place.
9	PAP Male	What about the houses which are not in impact zones?	Mr. Vishram Patil (Chief-Social Development Cell, MMRDA)	Those who are interested to shift, MMRDA will think positively regarding the same. MMRDA will follow the policy in view of JICA R & R policy. House in lieu of house will be as per new policy. As per rule, 225 Sq.ft space will get per house. If more than 225 Sq.m then MUTP policy will be followed.
10	PAP Male	What about commercial area? Because these are not taken into account.	Mr. Vishram Patil (Chief-Social Development Cell, MMRDA)	As per Government of India Act, commercial in lieu of commercial area policy is not there. Business may get lost, but MMRDA will take into account the number of business affected persons and will think on compensation.

No	Major opinion and Answer			
	Question/Comment		Answer	
	Name/Position	Question	Name/Position	Answer
11	PAP Male	Are worship/religious places taken into account?	Mr. Vishram Patil (Chief Social Development Cell, MMRDA)	MMRDA will think on shifting of these places out of project ROW (Right of Way). OR MMRDA will think on land compensation with discussion with the locals.
12	PAP Male	What if commercial area is above 3000 Sq.ft & has more than two or three properties?	Mr. Vishram Patil (Chief Social Development Cell, MMRDA)	If more than 1 shop is there, then same area will be given like 225 Sq.ft. Above that, if required then it has to be purchased. If 900 Sq.ft area is there, then 750 Sq.ft area will be given. Above this if required then PAP has to buy. If 700 Sq.ft area is there then 225 Sq,ft will be given free of cost and above that owner has to buy it. The cost to buy will be as per ready reckoner rate.
13	PAP male	If some people are not willing to shift then what will be the solution?	Mr. Vishram Patil (Chief Social Development Cell, MMRDA)	Government rules will be strictly followed during development. In many of the projects of MMRDA, it was observed that people want their homes in the same building. Temporary shifting will be given concerning with Mumbai Port Trust. It will be till building construction.

Source: JICA Study Team


Source: JICA Study Team

Figure 12.5.1 Photos of the 1st Public Consultation on EIA

(2) Draft EIA Stage

1) Participants of the Meeting

Table 12.5.4 Major Participants of Public Consultation on Scoping Stage

<table>
<tr><th>Date & States</th><th colspan="2">Major Participants</th></tr>
<tr><td rowspan="5">15th September 2015</td><td>MMRDA</td><td>Additional Metropolitan Commissioner, Joint Director-Environment, Chief Engineer, Dy. Collector, Tehsildar, Superintending Engineer, DMC Co-ordination, Deputy Engineer, Deputy Engineer, Executive Engineer</td></tr>
<tr><td>Other Government</td><td>JNPT (Chief Mamager-EC), CIDCO (Assistant Chief Engineer), MPT: (Executive Engineer) and</td></tr>
<tr><td>JICA Team</td><td>JICA study team and Local Consultants</td></tr>
<tr><td>PAPs</td><td>Local Medical Practitioner and other PAPs</td></tr>
<tr><td>NGO and/or Community specific group & others</td><td>Bombay Natural Historical Society , Conservation Action Trust, Architects, other groups</td></tr>
<tr><td>Number of Total Percipients</td><td colspan="2">Government: 13, Experts as per JICA Categorization: 1, PAPs: 66, NGOs and Community Specific Group: 17, JICA Team: 8
Total: 105 (Male: 91, Female: 14)</td></tr>
</table>

Source: JICA Study Team

2) Agenda

- ✓ Explanation of the objective of the meeting
- ✓ Explanation of project outline by JICA Study Team
- ✓ Intimation of result/findings of the supplemental draft EIA
- ✓ Intimation of proposed mitigation measures
- ✓ Exchange of opinions

3) Major Opinion and Summary of Discussion

JICA study team initiated the proceedings and welcomed the gathering and explained about the project in brief and EIA studies carried out. JICA study team presented the project and EIA findings in Marathi language to the participants. The meeting then opened for Questions & Answers session. The opinions and discussions held in the meeting are given below:

Table 12.5.5 Major Opinions and Discussions of the Stakeholder Meeting

<table>
<tr><th rowspan="3">No</th><th colspan="4">Major opinion and Answer</th></tr>
<tr><th colspan="2">Question/Comment</th><th colspan="2">Answer</th></tr>
<tr><th>Name/Position</th><th>Question</th><th>Name/Position</th><th>Answer</th></tr>
<tr><td>1</td><td>NGO
male</td><td>We want this bridge to come up as it is a good public facility, but the bridge should be realigned. Flamingos are coming here and they stay for 6 months. We should look at how we can save them. We should use latest technology monitoring programme. Restoration program for the mudflats so that flamingo habitation area can be kept secured and citizens can enjoy the nature.</td><td>MMRDA</td><td>Ok, we have noted these good suggestions.

Note)
Observation from MMRDA after the meeting.

MMRDA has obtained a permission of CRZ from MoEF, and adequate mitigation measures are prepared for fauna and flora. Thus MMRDA does not have intention to change alighment.</td></tr>
<tr><td>2</td><td>NGO
male</td><td>Bridge should start from MPT. What are the impacts of the project on:
• Marine life
• Migratory Birds
• Fisherman and fishing activities and its period
• Remedial Measures for the PAPs
• Earth strata impact for such 5 years long period
• In the event of accidental release of gases
• Aquatic life</td><td>JICA Study Team</td><td>The plan is to minimize the construction through construction of pillars with larger spans. Rain water & storm water will be discharged through the piles and not directly, in sea to avoid turbidity.
Noise & vibration impacts will be minimized by installation of noise barriers with edge treatment so that this will also mitigate the impact of street lights on the aquatic biota specially flamingos.
Piling/boring will be there for pillars and the outcomes will be disposed as per CRZ notification. Shorter spans will only be at interchanges in area at 50 mts.</td></tr>
<tr><td>3</td><td>PAP
(fishermen society)
male</td><td>Do all documents are open to public and are they in Marathi? What are the impacts on fishing activities and fisherman? What are mitigation measures?</td><td>JICA Study Team</td><td>Draft EIA will be submitted on 25th September and then it will be available on JICA website.
Committee will be formed in one week to decide the impacts and mitigation measures for Fisherman and Fishing activities.</td></tr>
<tr><td>4</td><td>NGO
male</td><td>What about draft EIA reports and current status and updates. Whether detailed studies on migratory birds and fauna are been carried out? 150 species are noted in this area. 15000 flamingoes for 6 to 7 months visit this place. Not only noise barriers but also trees should be planted. Project will lead to environment degradation due to upcoming traffic on proposed link bridge. Impacts on mangroves and its cutting. Modelling should be just like Bandra Worli Sea Link.</td><td>JICA Study Team</td><td>Draft EIA will be submitted on 25th September and then it will be available on JICA website. Here only piers will be coming. There is no erosion because of piers.
Flamingoes came in 1994. They are well noted still under Vashi & Airoli bridge without any mitigation measures. But in this proposed project except construction period no such impacts are anticipated. No erosion is expected. Mangroves generally increased due to siltation. Mangrove replantation will be carried out as per CRZ clearance.</td></tr>
<tr><td>5</td><td>PAP
male</td><td>What happens to public transport like trains? Traffic studies are done? What will be the toll cost? Will it cause financial burden?</td><td>MMRDA</td><td>No railway is part of the project. Navi Mumbai has already plan of development of an airport. Toll cost will be for all. Toll cost will be fixed in such a way that people will use the bridge.</td></tr>
<tr><td>6</td><td>PAP (institute)
male</td><td>Are trains included in this project?</td><td>MMRDA</td><td>No, Trains are not included in this project.</td></tr>
</table>

No	Major opinion and Answer			
	Question/Comment		Answer	
	Name/Position	Question	Name/Position	Answer
7	NGO male	In proposed project area sanctuary is declared. Dumping is going /operational at Kanjur & JNPT. What will be the impact if such a delineation will happen?	MMRDA	The distance between Thane creek and sanctuary is far. We have carried out traffic studies and reported in EIA. Flamingo study is carried out by the experts and only after this design is fixed.
8	PAP male	Being a member of IIE, this project is very important and is proposed from long time. How this project will help to cope with increasing traffic and speed level? The balance should be done for positive impacts for both humans and flamingoes.	MMRDA	The benefits and cost cannot be thought at this stage. But yes, balanced approached will be maintained in this project.
9	NGO male	Thane creek is far from sanctuary. But are necessary approvals obtained for the project and are these factors been considered?	JICA Study Team	Like no other projects, in this projects environmental impacts are considered. It is already explained that all necessary approvals are obtained. Now international and local experts are looking and studying about flamingoes. Hence all the points will be covered and reported in the supplemental EIA. New technology is proposed, but still we are open for good suggestions which will be discussed with JICA to ensure that this project will not create environmental disaster but for further projects it will be an example.
10	NGO male	Does this project impact tidal pattern? And do the pillars cause impact on environment? What are the mitigation measures?	MMRDA	CWPRS carried out studies on these issues. And it is noticed that no such impacts are anticipated.

Source: JICA Study Team

Source: JICA Study Team

Figure 12.5.2 Photos of the 2nd Public Consultation

12.6 Construction Schedule

It is expected that “the design-build system” is adopted from the view of saving cost and time for this project after feasibility study and basic study.

Almost 1 year is required for bidding and selection of contractor, and 4.5 years are necessary for detailed design and construction period.

The tentative construction schedule is shown as of March 2015 is given in Table 12.6.1.

Table 12.6.1 Construction Schedule (as of Feb, 2016)

Work Item/ Year	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year
1. Feasibility Study (under Japan International Cooperation Agency: JICA)							
2. Basic Design							
3. Procurement of Design-Build Contractor							
4. Implementtion of Design-Build							

Source: JICA Study Team

12.7 Other Necessary Permissions

12.7.1 Other Environmental Permission

Other necessary permission to be obtained by MMRDA before and during construction is shown below;

Table 12.7.1 Other Necessary Environmental Permissions

Name of Permission to be obtained		Necessity and Status as of Sep. 2015	Status / Reasons
1	Environmental Certificate (EC) for EIA by Ministry of Environment and Forests (MOEF)	Not Required	EC for EIA is not necessary on EIA notification in 2006 as of 2015. MSRDC had obtained EC for old EIA law in 2005 with 5 years validity. Although the EIA is not necessary after 2006, MMRDA has updated this EIA as Rapid EIA for mainly obtaining of CRZ-Environmental Certificate.
2	EC for Coastal Regulation Zone by MOEF	Not Required (Already obtained in 2013 and 2016)	The EC of CRZ had been obtained from MOEF based on law of 2011 CRZ in 2013 with 5 years validity. (Until 18th July 2018) and Jan. 2016. The EC is including mangrove cutting permission from MOEF. Law: Coastal Regulation Zone Notification 2011 Issued date of CRZ for MTHL: 18th July 2013 (valid until 17th July 2018) and 25th January 2016
3	Mangrove Cutting Tree Permission by MOEF	Not Required (Already obtained in 2013 and 2016)	According to interview with the person in charge environment in MMRDA, in general, a mangrove cutting permission shall be acquired by the proponent from the Forest Department of MOEF. However CRZ-EC was approved by MOEF and mangrove cutting permission was given on same CRZ-EC. As mentioned on CRZ-EF, MMRDA shall replant 5times of cutting mangrove trees (0.0176 x 5times = 0.888 ha) in appointed area of 30 ha in Nhava by MOEF before construction phase.
4	Maharashtra High Court Permission for Mangrove Cutting	Before Construction	The proponent shall have Maharashtra high-court permission for cutting mangrove after obtaining CRZ-EC from MOEF. MMRDA has not obtained this permission yet as of Sep. in 2015. This permission shall be obtained before actual cutting activities in construction stage based on CRZ-EC and Mangrove cutting permission. According to the person in charge environment in MMRDA, the process may take around 3 months after submission of application.
5	Tree Cutting Permission by Local Government	Before Construction	All permissions shall be obtained after identification of final affected area and number of trees based on detailed design and investigation of affected trees. The legal framework and process is show below (Table 12.7.2)
6	Non Objection Certificate from Maharashtra Pollution Control Board (MPCB)	Before Construction	The contractor shall submit construction plan including activities and plant before actual construction activities, and then MPCB reviews and issue Non Objection Certificate in accordance with following laws and regulations; The Water (Prevention & Control of Pollution) Act, 1974 The Air (Prevention & Control of Pollution) Act, 1981 The Hazardous Wastes (Management and Handling) Rules, 1989
7	Environmental Certificate under EIA Notification Law 2006	As required	The contractor shall have necessary an Environmental Certificate in accordance with EIA Notification 2006 from Maharashtra State and/or Central MOEF when the contractor develops new quarry, borrow pits and camp site, if required Additionally the contractor shall follow JICA Guideline for Environmental and Social Considerations 2010

Source: JICA Study Team based on interviews with MMRDA

Table 12.7.2 Cutting Tree Permission Process

Item \ Permission		Mumbai Side	Navi Mumbai Side
1	Name of Permission	Permission for Logging of Project Affected Trees	Ditto
2	Applicable law and regulation	Maharashtra Felling of Trees (Regulations Acts, 1964) Amended in 2006	Ditto
3	Approval Authority	MCGM (Municipal Corporation for Greater Mumbai)	MCNM (Municipal Corporation for Navi Mumbai) Note)The permission is given from affected authority
4	Due date to be approved	67 days before cutting trees	Ditto
5	Process for obtaining permission	(1) Marking on affected area after detailed design (2) Fix the affected area based on detailed design (3) Site survey affected species, location and numbers (4) Submission of application form and result of survey (5) Inspection and review (xx days) (6) Issue of permission	Ditto
6	Process period	(4)-(6): 3-6 months (depend on case)	Ditto

Source: JICA Study Team based on interviews with MMRDA

12.7.2 Other Necessary Development Plan

(1) Quarry Site and Borrow Pit

The designated registered quarry sites and borrow pits are shown in Figure 12.7.1.

The contractor should use these registered quarry sites as possible as they can. However the contractor can use other designated and registered quarry sites or develop new sites under obtaining permission from relevant authority prior to actual construction activities. Additionally the contractor shall follow JICA Guidelines for Environmental and Social Considerations 2010, if required.

(2) Construction Yard and Labor Camp

The planned construction yard and labor camp is located in Sewri side and Navi Mumbai side respectively as shown in Figure 12.7.2.

The Construction and Camp Site in Sewri is located in Mumbai Port Trust compound app. 18 ha, on the other hand, the site in Navi Mumbai side is located on Right of Way of MTHL. A Part of the camp site in Shivaji Nagar has been secured by MMRDA. It is estimated that approximately totally 3,000/day workers at construction peak day time, and 1,000 workers are staying temporary accommodation on sites.

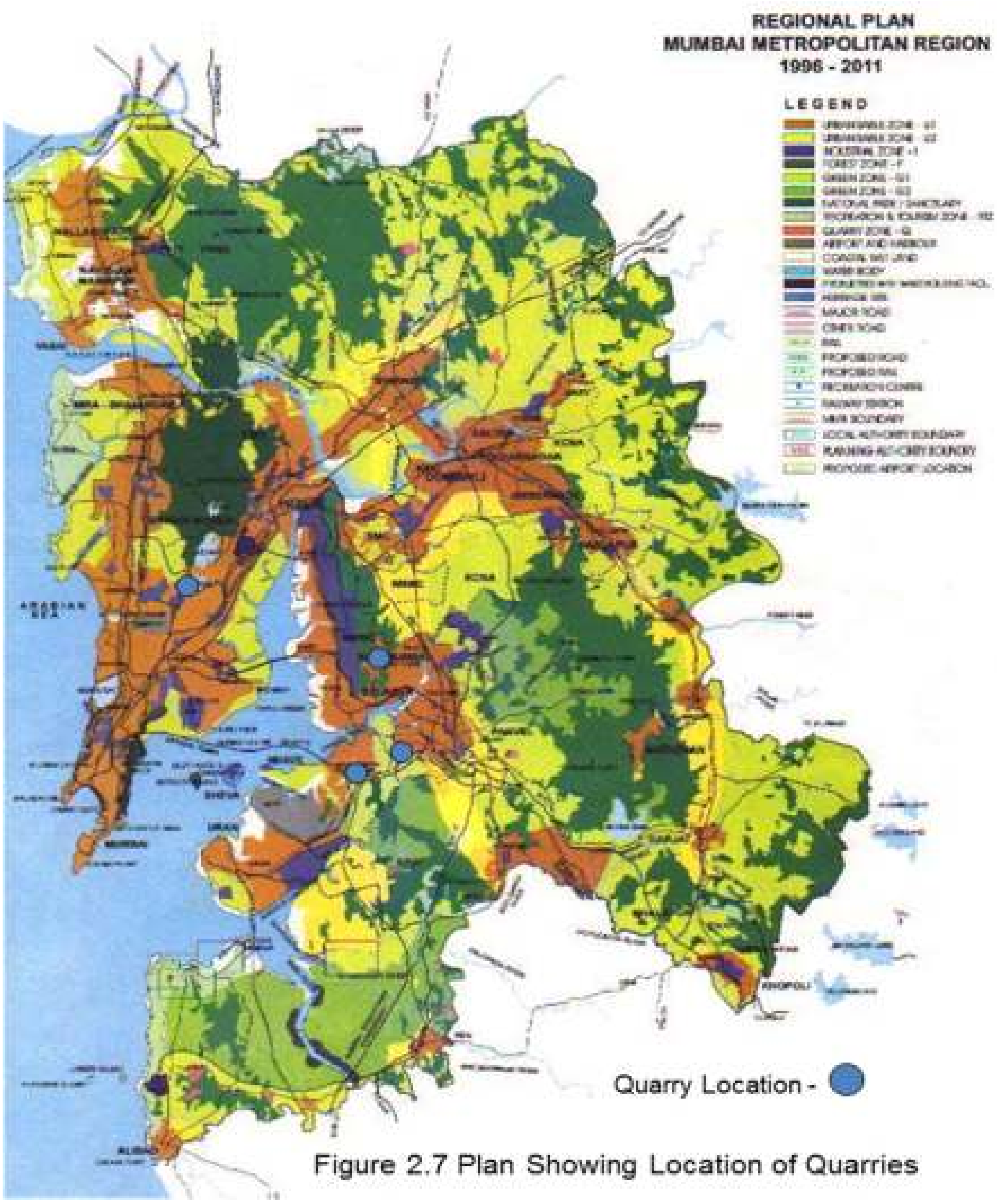
Table 12.7.3 Outline of Construction Yard

Item / Name of Site	Estimated Number of Workers (accommodated)	Function and Installed Plant
1. Sewri Construction Yard	1,540 (510)	Casting yard, material storage, workshop for construction machines and accommodation for workers
2. Shivaji Nagar Construction Yard	860 (290)	
3. Chirle Construction Yard	600 (200)	

Source: JICA Study Team

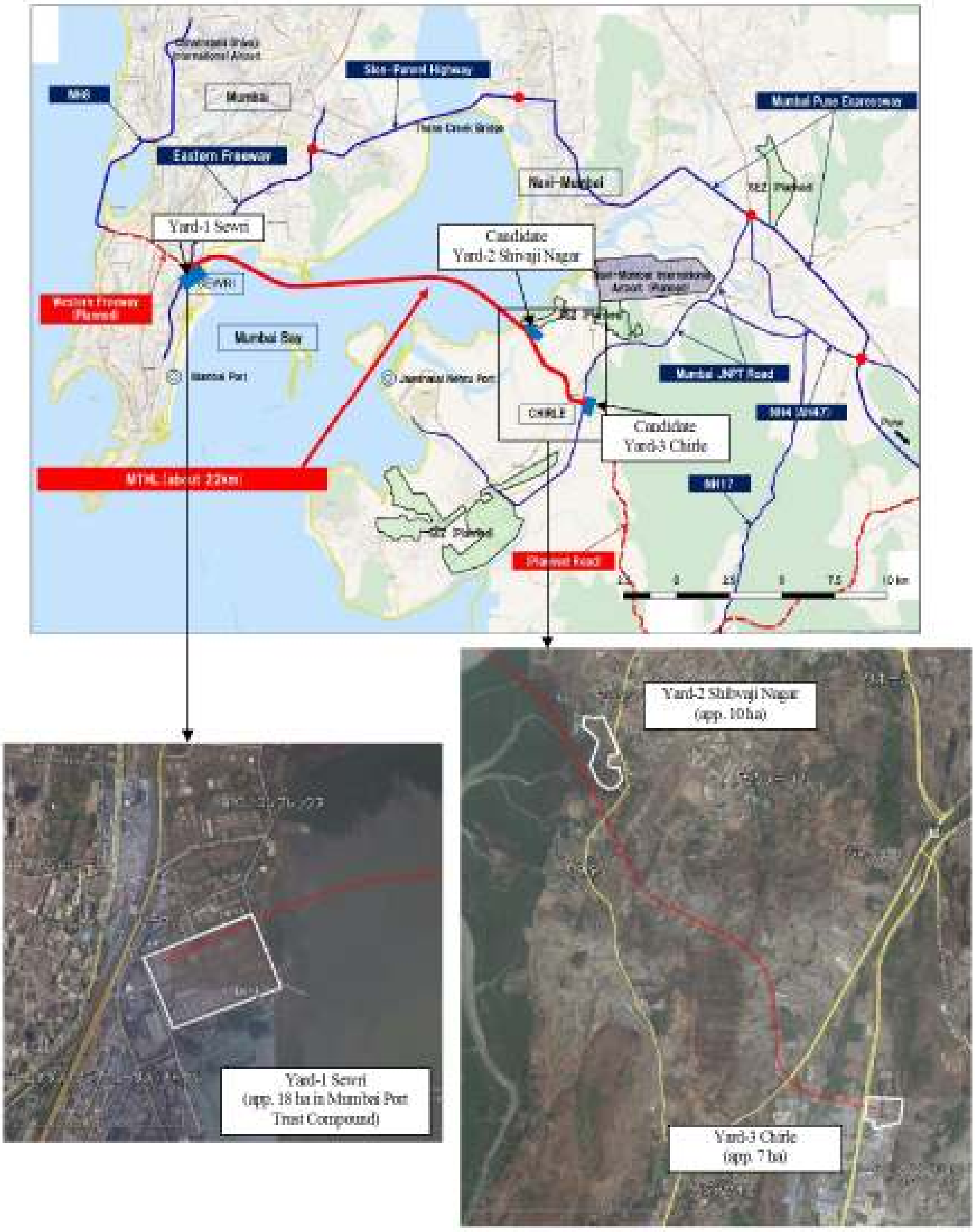
Although all construction yard is secured by contractor, the contractor shall refer following scoping and mitigation measures and obtain necessary permissions in accordance with relevant Indian laws.

Tentative draft scoping and mitigation measures are shown in the Supplemental EIA.



Source: Rapid EIA 2012

Figure 12.7.1 Designated Quarry Site near Project Area



Source: Rapid EIA 2012

Figure 12.7.2 Tentative Construction and Camp Site on MTHL

12.8 Recommendation on EIA

Following actions to be carried out are recommended from the view of natural and social environment considerations. The project proponent MMRDA should discuss and respond regarding following items under cooperation with other relevant organizations and agencies.

(1) Necessity of Local Environmental Management Plan including Coastal Area

Environmental and social considerations on each development project including MTHL are reviewed and discussed under the proponent, state and central governments generally. Public infrastructure developer such as MMRDA and CIDCO, Municipal Corporation and state government should establish a Environmental Management Plan from the view of sustainable development in regional level including coastal area harmonized with development and environment.

Major Relevant Agencies: MMRDA, CIDCO, MCGM, MCNM, Maharashtra State and MOEF

(2) Appropriate Land Use Management

Accumulation of unplanned development near interchange may give significant adverse impacts on natural and social environment. Thus MMRDA should encourage other relevant organizations such as MCGM, MCNM and CIDCO to manage the land use properly.

Major Relevant Agencies: MMRDA, CIDCO, MCGM, MCNM

(3) Construction Contractor's Responsibility

Following conditions should be subjected on bidding document for construction contractor

- The contractor shall comply with the stipulations in the Environmental Management Plan (EMP) in the Supplemental EIA and in the CRZ clearance & Clearance of diversion of Forest Land issued on January 2016
- The contractor shall comply with relevant Indian laws and JICA Guidelines for Environmental and Social Considerations (2010) when the contractor develop construction yard, and then conduct appropriate mitigation measures and monitoring.

Major Relevant Agencies: MMRDA, General Consultant, Contractor

(4) Compensatory Planting of Mangrove

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

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

(5) Implementation of Baseline Survey before Construction Stage

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

Items to be conducted surveys are migratory birds, benthos, fish, mangrove and mudflat

Major Relevant Agencies: MMRDA, GC, JICA

(6) Establishment of Information and Communication Centre

It is recommended to establish information & communication centre for disclose natural and social monitoring result and promote stakeholders to understand the project objectives and process before and during construction.

Major Relevant Agencies: MMRDA, MCGM

13. LAND ACQUISITION AND RESETTLEMENT

To Be Updated after Completion of Fishery Survey

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.

Following sections reconfirm 1) the legal frameworks in India, 2) JICA's policy on involuntary resettlement, 3) gap between legal frameworks and JICA policies, and define 4) applicable policies on involuntary resettlement for the MTHL project.

13.1.1 Indian Legal Frameworks on Involuntary Resettlement

Principle legal frameworks for land acquisition in Maharashtra is Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Rehabilitation and Resettlement Act 2013 (LARR2013) that repealed Land Acquisition Act 1894 (LA1894) and Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (Maharashtra) Rules 2014 (LARR_MH2014). As the MTHL project was awarded and started land acquisition in 1980's, past land acquisition in Navi Mumbai (57.6Ha) was completed before 2000 based on LA1894 with additional compensation packages by CIDCO 12.5% scheme. Now, the rest of all other land acquisition shall be conducted based on LARR_MH2014 with R&R/MUTP and other related laws and regulations in Maharashtra.

<u>SEWRI SECTION</u>

All Sewri section is owned and under the jurisdiction of Mumbai Port Trust (MPT). Since transfer of land ownership from MPT to MMRDA is required, negotiation has been conducted based on the Major Port Trusts Act (MP1963) and Policy Guidelines for Land Management by Major Ports (PGLM2014). In addition, in order to support none title holders within the project area on MPT land, a social impact assessment (resettlement and rehabilitation plan) is prepared as per R&R/MUTP. Based on the SIA, relocation and rehabilitation support will be implemented.

SEA-LINK SECTION

As all the sea-link section is inside the harbour limit of MPT and JNPT, in general, governing legal frameworks are defined by the port related legislations by the central government and enforced by MPT and JNPT in each port. Although the sea-link section is exclusive harbour area, relevant legislation does not prohibit fishing activities except large scale mechanical fishing. Considering the fishing rights and regulatory agency, Maharashtra Department of Fisheries (DoF) would be the most relevant authority among others.

For preceding project implementation, MMRDA set a special committee on MTHL fishery compensation policy development, which was composed of relevant authorities including DoF as well as representatives of fishing societies and communities potentially affected by the project. The committee has defined MMRDA's principal policy on fishermen compensation for MTHL and MMRDA approved the compensation policy. Detail description of the compensation policy is described in section 13.3.

NAVI MUMBAI SECTION

The town planning and development has been implemented based on CIDCO's general development plan in Navi Mumbai. For MTHL, a part of CIDCO's development land will be transferred to MMRDA. Roughly 70% (69Ha) of the right of way (ROW) had been acquired before 2000. Presently the rest of the land roughly 30% (27Ha) are on the process of the final negotiation between land owners and CIDCO. Applicable policies for land acquisition, resettlement and rehabilitation in the past before 200 and present have been separately enforced as follows:

- Past Land Acquisition 69Ha before 2000: LA1894 and CIDCO12.5% scheme, and
- On-Going Land Acquisition 27Ha: LARR_MH2014 and CIDCO12.5% scheme (Land to land and/or cash) or CIDCO22.5% scheme (Land to Land only).

The principal legal frameworks are summarized below.

(1) Key Legislation Relevant to Land Acquisition for MTHL

Table 13.1.1 Key Legislation Relevant to Land Acquisition

Land Acquisition Act (LA1894, amendment 1984)* <applied for past land acquisition before 2000 in Navi Mumbai section (69Ha)>	• Principally applicable for public projects and specifying the responsible authorities, process of land acquisition, means of land valuation and compensation • Market price as compensation price at the time of land acquisition • No compensation for impacts of occupational & livelihood • ONLY applicable for legal landowners
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 • LA1894 as the basis of the R&R/MUTP with some mitigation measures to fulfil the WB OP4.12. • Adapted policy for the JICA Mumbai Metro Phase III project
Major Port Trusts Act (MP1963)	• Determination of major port in India and its functions • Determination of the governing law as LA1894 in case of land acquisition for the port development
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 floor space 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
Mumbai Metropolitan Region Development Authority Act (MMRDA1974)	• Defining the setup of MMRDA and legal power including land acquisition for regional planning and other authorized projects • 100 times monthly productive financial values of the immediate 5years average as compensation price
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

* The LA1894 was repealed by LARR2013 on 1st of Jan. 2014. In case of approval/awarded rights by LA1894, validity remains up five(5) years excluding the period of court case suspension.

** 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

(2) Other Key Legislation Most Likely Relevant to Rehabilitation

Table 13.1.2 Other Key Legislation Relevant to Rehabilitation

MTHL– Fisher-Folks Compensation Policy 2015	• Defining the compensation and rehabilitation policy of MTHL as per JICA Guidelines on Environmental and Social Consideration 2010 Defining

Source: JICA Study Team

(3) Summary of Section-Wise Primary Legal Frameworks for Involuntary Resettlement

Table 13.1.3 Project Section Wise Primary Legal Frameworks of MTHL

Sections	Sewri	Sea-link	Navi Mumbai
Primary Laws and/or Compensation Policies	• Major Port Trust Act 1963 • PGLM2014 • R&R/MUTP • MMRDA Act, 1974	• Major Port Trust Act 1963 • PGLM2014 • Maharashtra Fisheries Act (1981) • MMRDA Act, 1974	<Past Land Acquisition> • LA1894 • And CIDCO 12.5% Scheme <New Land Acquisition> • LARR_MH2014 & CIDCO 12.5% Scheme • Or 22.5% Scheme only
Governing Authority	• MPT • (MMRDA)	• MPT • JNPT	• CIDCO • JNPT

Source: JICA Study Team

13.1.2 JICA Policies on Involuntary Resettlement

The key principle of JICA policies on involuntary resettlement is summarized below.

(1) Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.

(2) When, population displacement is unavoidable, effective measures to minimize the impact and to compensate for losses should be taken.

(3) People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.

(4) Compensation must be based on the full replacement cost[38] as much as possible.

(5) Compensation and other kinds of assistance must be provided prior to displacement.

(6) For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public. It is desirable that the resettlement action plan include elements laid out in the World Bank Safeguard Policy, OP 4.12, Annex A.

(7) In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance. When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.

(8) Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans.

(9) Appropriate and accessible grievance mechanisms must be established for the affected people and their communities.

(10) Above principles are complemented by World Bank OP 4.12, since it is stated in JICA Guideline that “JICA confirms that projects do not deviate significantly from the World Bank’s Safeguard Policies”. Additional key principle based on World Bank OP 4.12 is as follows.

(11) Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits.

(12) Eligibility of Benefits include, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying.

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[38] Description of “replacement cost” is as follows.

Land	Agricultural Land	The pre-project or pre-displacement, whichever is higher, market value of land of equal productive potential or use located in the vicinity of the affected land, plus the cost of preparing the land to levels similar to those of the affected land, plus the cost of any registration and transfer taxes.
	Land in Urban Areas	The pre-displacement market value of land of equal size and use, with similar or improved public infrastructure facilities and services and located in the vicinity of the affected land, plus the cost of any registration and transfer taxes.
Structure	Houses and Other Structures	The market cost of the materials to build a replacement structure with an area and quality similar or better than those of the affected structure, or to repair a partially affected structure, plus the cost of transporting building materials to the construction site, plus the cost of any labor and contractors’ fees, plus the cost of any registration and transfer taxes.

(13) Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based.

(14) Provide support for the transition period (between displacement and livelihood restoration.

(15) Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc.

(16) For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared.

In addition to the above core principles on the JICA policy, it also laid emphasis on a detailed resettlement policy inclusive of all the above points; project specific resettlement plan; institutional framework for implementation; monitoring and evaluation mechanism; time schedule for implementation; and, detailed Financial Plan etc.

13.1.3 Gap between Indian Legal Frameworks and JICA Policies

Gaps between applicable legal frameworks for each section and JICA Env.Guidlines2010 are summarised below. Details of the comparison are described in the Table 6.5 of the MTHL Social Impact Assessment (SIA) report.

(1) Sewri Section

Based on Table 6.5 of SIA, it is confirmed that all conditions of R&R/MUTP meet JICA Env.Guidelines2010. R&R/MUTP was originally prepared for the compensation policy for the involuntary resettlement for the word bank funded project “Mumbai Urban Transport Project.” R&R/MUTP conforms to the World Bank operational policy on involuntary resettlement (PO4.12), which JICA Env.Guidelines2010 refers to.

(2) Sea-Link Section

In October 2015, MMRDA organized an expert committee on defining the mitigation measures for the potentially affected fishermen along the MTHL alignment and started a new compensation policy development. The committee was held four times with the presence of not only relevant authorities but also representatives of nine project affected fishing societies. In addition, a separate consultation between DoF and fishermen was held. After such communication, the MTHL principal compensation policy for project affected fisherman was approved by MMRDA in December 2015, Based on the principal compensation policy, monetary compensation for expected impacts will be paid in advance and unforeseen impacts will be confirmed through monitoring and its compensation shall be defined by a grievance redress committee. The MMRDA fisherman compensation policy complies with JICA Env.Guidelines2010.

(3) Navi Mumbai Section

As it is described previously, applicable policies are different between past land acquisition for 69Ha and on-going acquisition for 27Ha. It is confirmed that both past and on-going land acquisition meet JICA Env.Guidelines2010. Detailed comparison tables are shown in the appendix 7.

13.1.4 Applicable Policies on Involuntary Resettlement for the MTHL Project

Applicable policies on land acquisition and involuntary resettlement are as follow.

Table 13.1.4 Principals of Involuntary Resettlement Policy for MTHL

I. MMRDA applies the involuntary resettlement policy of the Government of Maharashtra - "Mumbai Urban Transport Project (2000)" (R&R/MUTP) for MTHL. However, R&R/MUTP does not cover the potential impacts of fishing activities. Thus, MMRDA applies the principal policy of fisherman compensation for MHTL, which MMRDA set as per JICA Guidelines for Environmental and Social Considerations (2010). This section states the principles of the compensation policies, and the details of the entitlements of the PAPs are described in section 13.3 of entitle matrixes.

II. Land acquisition and involuntary resettlement will be avoided where feasible, or minimized, by identifying possible alternative project designs that have the least adverse impact on the communities in the project area.

III. Where displacement of households is unavoidable, all PAPs (including communities) losing assets, livelihoods or resources will be fully compensated and assisted so that they can improve, or at least restore, their former economic and social conditions.

IV. Compensation and rehabilitation support will be provided to any PAPs, that is, any person or household or business which on account of project implementation would have his, her or their:
- Standard of living adversely affected;
- Right, title or interest in any house, interest in, or right to use, any land (including premises, agricultural and grazing land, commercial properties, tenancy, or right in annual or perennial crops and trees or any other fixed or moveable assets, acquired or possessed, temporarily or permanently;
- Income earning opportunities, business, occupation, work or place of residence or habitat adversely affected temporarily or permanently; or
- Social and cultural activities and relationships affected or any other losses that may be identified during the process of resettlement planning.

V. All affected people will be eligible for compensation and rehabilitation assistance, irrespective of tenure status, social or economic standing and any such factors that may discriminate against achievement of the objectives outlined above. Lack of legal rights to the assets lost or adversely affected tenure status and social or economic status will not bar the PAPs from entitlements to such compensation and rehabilitation measures or resettlement objectives. All PAPs residing, working, doing business and/or cultivating land within the project impacted areas as of the date of the latest census and inventory of lost assets (IOL), are entitled to compensation for their lost assets (land and/or non-land assets), at replacement cost, if available and restoration of incomes and businesses, and will be provided with rehabilitation measures sufficient to assist them to improve or at least maintain their pre-project living standards, income-earning capacity and production levels.

VI. PAPs that lose only part of their physical assets will not be left with a portion that will be inadequate to sustain their current standard of living. The minimum size of remaining land and structures will be agreed during the resettlement planning process.

VII. People temporarily affected are to be considered PAPs and resettlement plans address the issue of temporary acquisition.

VIII. Where a host community is affected by the development of a resettlement site in that community, the host community shall be involved in any resettlement planning and decision-making. All attempts shall be made to minimize the adverse impacts of resettlement upon host communities.

IX. The resettlement plans will be designed in accordance with R&R/MUTP and LARR_MH2014 and JICA's Policy on Involuntary Resettlement.

X. The Resettlement Plan will be translated into local languages and disclosed for the reference of PAPs as well as other interested groups.

XI. Payment for land and/or non-land assets will be based on the principle of replacement cost.

XII. Compensation for PAPs dependent on agricultural activities will be land-based wherever possible. Land-based strategies may include provision of replacement land, ensuring greater security of tenure, and upgrading livelihoods of people without legal land titles. If replacement land is not available, other strategies may be built around opportunities for re-training, skill development, wage employment, or self-employment, including access to credit. Solely cash compensation will be avoided as an option if possible, as this may not address losses that are not easily quantified, such as access to services and traditional rights, and may eventually lead to those populations being worse off than without the project.

XIII. Replacement lands, if the preferred option of PAPs, should be within the immediate vicinity of the affected lands wherever possible and be of comparable productive capacity and potential39. As a second option, sites should be identified that minimize the social disruption of those affected; such lands should also have access to services and facilities similar to those available in the lands affected.

XIV. Resettlement assistance will be provided not only for immediate loss, but also for a transition period needed to restore livelihood and standards of living of PAPs. Such support could take the form of short-term jobs, subsistence support, salary maintenance, or similar arrangements.

XV. The resettlement plan must consider the needs of those most vulnerable to the adverse impacts of resettlement (including the poor, those without legal title to land, ethnic minorities, women, children, elderly and disabled) and ensure they are considered in resettlement planning and mitigation measures identified. Assistance should be provided to help them improve their socio-economic status.

XVI. PAPs will be involved in the process of developing and implementing resettlement plans.

XVII. PAPs and their communities will be consulted about the project, the rights and options available to them, and proposed mitigation measures for adverse effects, and to the extent possible be involved in the decisions that are made concerning their resettlement.

XVIII. Adequate budgetary support will be fully committed and made available to cover the costs of land acquisition (including compensation and income restoration measures) within the agreed implementation period. The funds for all resettlement activities will come from the MMRDA and/or Government of Maharashtra.

XIX. Displacement does not occur before provision of compensation and of other assistance required for relocation. Sufficient civic infrastructure must be provided in resettlement site prior to relocation. Acquisition of assets, payment of compensation, and the resettlement and start of the livelihood rehabilitation activities of PAPs, will be completed prior to any construction activities, except when a court of law orders so in expropriation cases. (Livelihood restoration measures must also be in place but not necessarily completed prior to construction activities, as these may be on-going activities.)

XX. Organization and administrative arrangements for the effective preparation and implementation of the resettlement plan will be identified and in place prior to the commencement of the process; this will include the provision of adequate human resources for supervision, consultation, and monitoring of land acquisition and rehabilitation activities.

XXI. Appropriate reporting (including auditing and redress functions), monitoring and evaluation mechanisms, will be identified and set in place as part of the resettlement management system. An external monitoring group will be hired by the project and will evaluate the resettlement process and final outcome. Such groups may include qualified NGOs, research institutions or universities.

Cut-off-date of Eligibility

The cut-off-date of eligibility refers to the date prior to which the occupation or use of the project area makes residents/users of the same eligible to be categorized as PAPs and be eligible to Project entitlements.

[39] Agricultural land for land of equal productive capacity means that the land provided as compensation should be able to produce the same or better yield the AP was producing on his/her land prior to the project. The production should be in the planting season immediately following the land acquisition. It can be for a future period if transitional allowance equal to the household's previous yield is provided to the AP household while waiting for the land to get back to the same productivity as the previous land.

FOR SEWRI SECTION in the Project, Cut-off dates for both titled and non-titled PAPs in "Sewri section" will be the beginning date of the population census, known as basic socio economic survey (BSES), on 10th July, 2015. The BSES date was disclosed in advance to the project affected families with the MMRDA notification as well as the time of BSES survey.

FOR SEA-LINK SECTION in the Project, to be completed.

FOR NAVI MUMBAI SECTION in the Project, present land use and no possession of none title holders including residential use were confirmed y JICA study team in June, 2015. Thus, ONLY the present title holders for the rest of the 27Ha will be eligible for MTHL compensation policies. Thus, no cut off date is set for Navi Mumbai section, but CIDCO as the town planning and development authority will assure the prevention of non title holders' possession within both past and on-going land acquisition areas.

The establishment of the eligibility cut-off date is intended to prevent the influx of ineligible non-residents who might take advantage of Project entitlements.

Principle of Replacement Cost

All compensation for land and non-land assets owned by households/shop owners who meet the cut-off-date will be based on the principle of replacement cost. Replacement cost is the amount calculated before displacement which is needed to replace an affected asset without depreciation and without deduction for taxes and/or costs of transaction as follows:

A *Productive Land (agricultural, aquaculture, garden and forest) based on actual current market prices that reflect recent land sales in the area, and in the absence of such recent sales, based on recent sales in comparable locations with comparable attributes, fees and taxes or in the absence of such sales, based on productive value;*

B. *Residential land based on actual current market prices that reflect recent land sales, and in the absence of such recent land sales, based on prices of recent sales in comparable locations with comparable attributes; fees and taxes.*

C *Existing local government regulations for compensation calculations for building, crops and trees will be used where ever available.*

D. *Houses and other related structures based on actual current market prices of affected materials;*

E. *Annual crops equivalent to current market value of crops at the time of compensation;*

F. *For perennial crops, cash compensation at replacement cost that should be in line with local government regulations, if available, is equivalent to current market value given the type and age at the time of compensation.*

G. *For timber trees, cash compensation at replacement cost that should be in line with local government regulations, if available, will be equivalent to current market value for each type, age and relevant productive value at the time of compensation based on the diameter at breast height of each tree.*

13.2 Scope of Land Acquisition and Resettlement Impact

13.2.1 Necessity of the Land Acquisition and Involuntary Resettlement

(1) Project Components and Project Affected Area

MTHL is divided by three different sections, namely Sewri, Sea-Link, and Navi Mumbai section, and applicable conditions and policies for land acquisition are different among three sections due to the physical and jurisdictional differences. Characteristics of each section and relevant information are summarized as follow.

Table 13.2.1 Major Characteristics of Each Section and Present Status

Section	Jurisdictional Authorities / Ownership of the Section	Land/Are Use Status	Acquisition Status
Mumbai/Sewri Section KM0+000-KM0+720 (8.6 Ha)	MPT, MMRDA / MPT	Exclusive/restricted port area, MPT related businesses, residence	• Principle agreement between MPT and MMRDA has been made. Legal process of land transfer has been on the process. • The resettlement & rehabilitation plan (SIA) for both legal title holders and none title holder is competed and approved by MMRDA.
Sea-Link Section KM0+720- KM16+750 (810 Ha)	MPT, JNPT , MMRDA / MPT, JNPT	Port and navigation channel, gas/oil pipelines, submarine cables, tidal zones (mud flat, river mouth, mangrove)	• Principle agreement with all authorities and entities including MPT & JNPT has been made. • MMRDA's principal policy on fishermen compensation for MTHL is set and approved by MMRDA. Detail survey for project affected fishermen has been conducted.
Navi Mumbai Section KM16+750- KM21+840 (96 Ha)	MMRDA, CIDCO, JNPT / CIDCO, JNPT, private, Indian Railways	Wetland, Unused land (already acquired by CIDCO), Mining (rock & sand), temporal storage, railway	• CIDCO has already acquired 69ha（70%）. The rest of 27Ha（30%） is on the process of final negotiation as of September 2015. • Approval of bridge over railway has already awarded by Indian railways.

Source: JICA Study Team

Table 13.2.2 Components of MTHL in Each Section

Section	General Description of Project Component
Mumbai/Sewri Section KM0+000-KM0+720	Interchange and ramps to connect existing roads and future planned roads Widest row with to bundle all connecting roads toward east and gradual reduction of row
Sea-Link Section KM0+720-KM16+750	Mechanical fishing by large fishing vessels is prohibited within MPT and JNPT harbour limits, but fishing by registered small boats and traditional fishing without engines are active in and around the ROW. Such status was confirmed by JICA study team as well as discussion with responsible officers of Maharashtra department of fisheries. (ref. Appendix 8 Fishing Survey Track and Photos) As active fishing activities were confirmed, necessary baseline information shall be collected through the support of Maharashtra department of fisheries and communication with representatives of project affected fishing societies mediated by the department of fisheries.

Section	General Description of Project Component
Navi Mumbai Section KM16+750-KM21+840	Through the satellite image with ROW provided by MMRDA and field survey along ROW, it is confirmed that there are no residents and PAPs required for livelihood recovery by MTHL. (ref. Appendix 9 Navi Mumbai Land Use Survey Track and Photos) Confirmation of adequate compensation in the past and on-going acquisition by CIDCO with applicable regal frameworks of Maharashtra and JICA Env.Guidelines2010. It is confirmed that no further socio economic surveys are necessary based on the field survey.

Source: JICA Study Team

Considering the ownership of the land throughout the Project, out of 104.9Ha land acquisition, only 27Ha is under private ownership and 77.9Ha is government possession. All sea-link section is either MPT or JNPT's possession.

Table 13.2.3 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></td><td></td><td>1,554</td></tr>
<tr><td>4.1</td><td>Households/ Businesses (No.)</td><td>282</td><td rowspan="2">surveying*</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>1,272</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>surveying*</td><td>58</td></tr>
</table>

NA – Not applicable

* For Sea-link section, detailed surveys for project affected fishermen are conducted now. Based on the MMRDA principal compensation policy for MTHL approved by MMRDA in December 2015, up to 474 project affected fishermen will be affected.

** 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

SEWRI SECTION

Based on a property survey by MMRDA in 2013, the basic socio economic survey (BSES) was conducted for all project affected households. Resettled households and businesses will be 282, and number of project affected persons will be 1,272. Among 282 project affected households, 58 households are recognized as vulnerable group.

Considering the project affected structures, number of the structures is 317 and majority of the affected structures is resident. Some religious and community facilities (community hall and toilet) will be also relocated.

Table 13.2.4 Acquired Property in Sewri Section

Type	Relocate Property (No.)	Responses by the owner during BSES
Resident	229	244
Businesses	53	47
Temple	5	5
Mosque	1	1
Female Community Hall (WSHG)	3	3
MPT Buildings/Warehouse/etc.	25	25
Public Toilet	1	1
Total	**317**	**306**

Source: JICA study team

Table 13.2.5 Number of Full or Partial Affected Properties

Type	Full Acquisition	Partial Acquisition	Total
Resident	210	19	229
Business	52	1	53
Other	34	1	35
Total	**296**	**21**	**317**

Source: JICA study team

SEA-LINK SECTION

Although the detailed survey to determine the eligible fishermen for the MMRDA's principle policy for fishermen compensation is conducted at this moment (February 2016), expected impacts of the Sea-link section is categorized as follow. Based on the principal compensation policy, there would be permanent and temporary impacts with expected numbers of eligible persons. Final number of eligible persons will be defined by the on-going detailed survey.

Table 13.2.6 Expected Project Affected Persons in Sea-Link Section

Impact Type	Expected Impacts	Expected Number
Permanent	Loss of fishing and livelihood due to removal of fishing stakes (‘sus’) and nets in the ROW	48 nets
Permanent	Permanent decrease of revenue due to decline in fish catches and changed seawater currents	34 nets
Permanent	Loss due to restricted movement of subsistence level fishermen for hand picking of fishery organisms	Subsistence 512 persons
Temporary	Loss of fishing time and increased operating cost (fuel) to reach fishing grounds from their hamlets due to MTHL during construction phase	Commercial 300 boats Artisanal 175 boats
Temporary	Loss of fish due to increased turbidity during construction phase	Artisanal150 boats Subsistence boats
Accident	Damage of fishing boats and nets due to construction activities and movements of barges, vessels, machinery materials & men along the ROW	200 times /5 years

Source: MMRDA Principal Compensation Policy for Fisherman

NAVI MUMBAI SECTION

Except the interchanges and construction yards, project components of the MTHL would be bridge structures in Navi Mumbai section. Due to the completion of 70% land acquisition and old stone quarries and non-farmland, the impacts are limited to the mangrove, wetland and unused land.

The Navi Mumbai section of the alignment is about 5.5 km in length. The project would require 96 hectare of land and CIDCO has already acquired 65Ha. CIDCO is presently on the process of acquiring remaining 27Ha, of which CIDCO has already acquired 8Ha as of November, 2015.

Table 13.2.7 MTHL Project Land Acquisition Details

Sr. No.	Village Name	Type of land in hectare					Total (Ha)
		Private	Govt.	Forest	JNPT	Central Railway	
1	Ghavan	49.080	2.298	0.87	-	-	52.248
2	Jasai	30.157	5.38	-	1.99	0.245	37.772
3	Chirle	6.155	0.173	-	-	-	6.328
4	Total	85.392	7.851	0.87	1.99	0.245	96.348

Source: CIDCO

Table 13.2.8 CIDCO's Land Acquisition Status for MTHL

Sr. No.	Village Name	Land in hectare		
		Private Land Acquired	Govt. Land Transferred	Total Land Acquired
1	Ghavan	41.42	2.136	43.556
2	Jasai	14.366	5.38	19.746
3	Chirle	1.825	0.173	1.998
	Total	**57.611**	**7.689**	**65.30**

Source: CIDCO

13.2.2 Population Census

As per JICA.Env.Guidelines2010, a census survey for all project affected households was conducted in Sewri section only. In Sea-link section, another census survey for all potentially affected households is conducted at this moment. In Navi Mumbai section, no census survey was conducted due to no need for rehabilitation.

Table 13.2.3 showed the general profile of project affected persons (PAPs) in Sewri section, following table shows the socio-demographic profile of the PAPs in Sewri section.

Table 13.2.9 Socio-Demographic Profile of Sewri Section

	Elements	Number PAF or PAPs	Percentage (%)
1	Sex ratio (550 females per 722 males)		
	Females	550	43
	Males	772	57
	Total	**1,272**	**100**
2	religious group		
	Hindu	177	63.9
	Muslim	93	33.5
	Others	7	2.5
3	Social Group		
	ST	2	0.7
	SC	6	2.2
	OBC	26	9.4
	General	83	30.1
	Others (Specify)	159	57.6
4	Mother Tongue/ Language spoken		
	Hindi	196	64.5
	Marathi	92	30.3
	English	5	1.6
	Guajarati	9	3.0
	Kokani	0	0.0
	Other	2	0.7
5	Age group		
	above 15 year	1045	82.2
	below 15 year	277	17.8
6	Education		
	Illiterate	211	17.3
	Primary (Class 5)	255	20.9
	Secondary (6-10)	502	41.1
	Higher (Graduate)	247	20.2
	Technical	7	0.6
	Vocational	0	0.0

Source: JICA Study Team

13.2.3 Livelihood and Economic Condition

SEWRI SECTION

Based on the BSES, majority of the PAPs are engaged in private services (58.8%) followed by small business/trade (23.6%) and Non Fishing Labour (9.4%). Each share of the other types is less than 3% in share. Considering the location of work, fixed work place account for 45.5% followed by no fixed place as per work requirement (34.9%), and home (19.7%). Considering the distance to the work, walking accounts for 45.5% followed by train (39.4%) and bus (15.1%).

Table 13.2.10 Employment Status of Sewri Section

	Element	No. of PAPs	Percentage (%)
1	**Nature of Employment**		
	Private Service	257	58.8
	Business /Trade	106	23.6
	Non Fishing Labour	42	9.4
	Govt. Service	10	2.3
	Maid Service	8	2.0
	Fishing	2	0.4
	Others	22	5.0
2	1) **Location for work**		
	Specific place	173	45.4
	All over	133	34.9
	At home	75	19.7
3	2) **Distance of work**		
	Walking	181	45.5
	Train	157	39.4
	Bus	60	15.1

Source: JICA Study Team

In total, 47 commercial establishments have been covered under the BSES. The type of commercial establishment and number of employees are shown in Table 13.2.11. The majority of the commercial activities are self-employed tea stall and small vender shops for consumer goods accounting for 53.2% of affected businesses. The proposed MTHL project shall have cumulative impacts on both the affected commercial establishments as well as 40 employees in such affected businesses. In terms of license from the competent authorities to run the business, merely 8.5% of commercial establishments have the licenses.

Table 13.2.11 Commercial & Self Employment Activities

	Types	Number	%	Employee (No.)
1	Tea Stall	5	10.6	6
2	Grocery (Kirana)/ General Store	8	17.0	6
3	Pan/ cigarette shop	7	14.9	1
4	Lubricant shop	5	10.6	0
5	Waste Recycler (Kabari) shop	1	2.1	0
6	Hotel/ Restaurant/ Motel	3	6.4	0
7	Handicrafts	1	2.1	4
8	Medical Shop	2	4.3	3
9	STD/PCO	1	2.1	0
10	Others	14	29.8	12
	Total	47	100	40

Source: JICA Study Team

The economic condition of PAPs is studied from the family annual income and expenditure. The income represents the sum of the all earning members and expenditure represents all family expenditure. The majority of the project affected families (PAFs) fall in the below INR100,000/y accounting for 70.2% followed by 100,000-500,000/y group (28.6) and over 500,0000/y group (1.2%). Despite more than 70% of PAFs earn less than INR100,000/y, only 46.8% of the PAFs spend less than INR100,000/y and the rest spend INR100,000-500,000/y (53.2%). Such deficient balance should be carefully monitored during the post resettlement monitoring.

Table 13.2.12 Annual Income Profile in Sewri Section

Annual Income (INR)	No. of PAPs	Percentage (%)
Less than 100,000	174	70.2
100,000 – 500,000	71	28.6
Over 500,000	3	1.2
Total	**248**	**100**

Source: JICA Study Team

Table 13.2.13 Annual Expenditure Profile in Sewri Section

Annual Expenditure (INR)	Number PAPs	Percentage (%)
Less than 1,00,000	105	46.8
1,00,000 to 5,00,000	119	53.2
Over 5,00,000	0	0
Total	**224**	**100**

Source: JICA Study Team

SEA-LINK SECTION

After the detailed fishing survey to determine the eligible fishermen for the MMRDA's principle policy for fishermen compensation, livelihood and economic condition of the project affected fishermen shall be updated in this section.

NAVI MUMBAI SECTION

Due to the no resettlement need in Navi Mumbai section, PAPs' livelihood and economic condition was not studied. However in general overview along the Navi Mumbai section, economic activities are limited to the old quarries, temporary container storage, and truck yards due to the hilly unproductive land.

13.2.4 Vulnerable Group of People

Based on the census survey in Sewri section, 58 (21%) out of 282 project affected households belong to the vulnerable group (scheduled cast (SC) or scheduled tribes (ST) set by either the Constitution or relevant policies, below poverty line[40], women headed, and family with handicap persons). Results of the census survey confirmed that the living standard and condition of the SC and ST are as same level as other PAPs.

Considering the gender issues in the Sewri section, it is also confirmed that there are no discrimination between male and female. Female family members have certain roles and equally participate decision making in the family and society.

Although R&R/MUTP does not give additional monetary benefits to such vulnerable groups, MMRDA has supported any PAP when confirming the necessity of the additional support during the post evaluation (Social Development Cell, MMRDA).

Table 13.2.14 Vulnerable Group Profile in Sewri Section

Category	No. of PAH	%
Scheduled Cast (SC)	6	10
Scheduled Tribes (ST)	2	4
Below Poverty Line (BPL)*	4	7
Widow Headed Household + Widows	28 (2 + 26)	48
Divorce Headed Household	5	9
Women Headed Household	10	17
Family with Handicap	3	5
Total	**58**	**100**

Source: JICA Study Team

40 India Planning Comission defined the BPLs in 2014. The BPL for the rural area is 1,078 INR/month and urben area is 1,560 INR/month.

13.3 Mitigation Measures for Project Affected Stakeholders

The rehabilitation/mitigation measures for PAPs and project affected businesses (PABs) shall be enforced based on R&R/MUTP in Sewri section, MMRDA principal compensation policy for MTHL in Sea-link section, and LA2013 with CIDCO 12.5% scheme or CIDCO 22.5% scheme in Navi Mumbai section.

13.3.1 Property Compensation

<u>SEWRI SECTION</u>

The R&R/MUTP offers two resettlement options to PAPs (i: township plot of 25 sq.m. with cash compensation for the existing housing structures, and ii: a tenement of 20.91 sq.m. in multi-storeyed buildings without cash compensation). However, there is no available land for township in metropolitan area. Thus, at this moment, MMRDA is planning to apply tenement option only at Bhakti Park, which has already constructed and distributed for other PAPs by MMRDA projects. The transport of the PAPs' properties in the existing houses will be either arranged by MMRDA or PAPs themselves for free of charge.

In case, a PAH belongs to the vulnerable group and meets some conditions, their preference shall be considered by MMRDA as shown below:

- Ground floor allotment for family with handicap members and/or
- Preference in sanctioning of loans from the "Community operated fund."

<u>SEA-LINK SECTION</u>

As there are no allotment of fishing rights and properties affected by MTHL, property compensation is not applicable.

<u>NAVI MUMBAI SECTION</u>

As there are no residential or farmland acquisition in Navi Mumbai, compensation for only land will be conducted. There two options for the land compensation:

1) 12.5％ Scheme: Land owner will receive benefits defined by new land law (LARR_MH2014) with monetary compensation (200% of authorized land value (Ready Reckoner Rate)) and CIDCO's developed land for residents and businesses (12.5% of acquired land). The CIDCO's developed land includes utilities, public facilities, school, and religious places. Such land for utilities and other facilities accounting for 30% will be deducted from the 12.5%. Thus, the actual possession of the development land will be 8.75% of the acquired land.

2) 22.5％ Scheme: Land owner will only receive CIDCO's developed land for residents and businesses (22.5% of acquired land) without monetary compensation. It also deducts the common and public area accounting for 30%. Thus, the actual possession of the development land will be 15.75% of the acquired land. Although

this scheme does not have advanced monetary compensation, majority of the land owners prefer 22.5% scheme due to the high expectation of value escalation in Navi Mumbai (CIDCO official).

13.3.2 Livelihood Recovery

SEWRI SECTION

As per R&R/MUTP, all PAPs will receive house, additional commute transport allowance. In case a PAP permanently loses the source of livelihood, one year income compensation with vocational training will be provided. For MTHL project, Social Development Cell (SDC), MMRDA will evaluate the status of the PAPs' livelihood recovery within 6months. If SDC confirms the necessity of the additional support, MMRDA and/or appropriate authorities of Maharashtra state will provide necessary assistances.

Especially in Maharashtra, many schemes for slum rehabilitation are actively operated by other agencies. The responsible officers of SDC will arrange such rehabilitation scheme through public channels. As a part of the state agency, almost all information on assistance scheme is available in MMRDA, it would be easy for PAPs to find the appropriate schemes for their needs. As MMRDA will also support PAPs to apply other agencies assistance schemes, preferable environment is available for PAPs seeking for additional support.

SEA-LINK SECTION

As Sea-link section is active fishing area, MMRDA set a special compensation development committee to define the appropriate compensation policy for the PAPs. Throughout the discussion among relevant authorities and representatives from all project affected fishing societies as well as inputs from the experienced experts in fishermen compensation in the region, the committee proposed the principal compensation policy and MMRDA approved the recommended principal policy in December 2015. Based on the principal compensation policy, fishermen are able to continue fishing after the completion of the project, only advanced monetary compensation will be given. If more than foreseen impacts are confirmed along with project implementation, MMRDA will provide necessary compensation and rehabilitation supports as same as Sewri section.

NAVI MUMBAI SECTION

There would be no need for livelihood recovery assistances as land owners do not live or conduct economic activities on their acquired land at this moment.

13.3.3 Development Plan on Resettlement Communities for PAPs

MMRDA has proposed the tenement compensation at Bhakti Park that is roughly 3km from the Sewri-section adjacent to commercial and recreational facilities and good access to the public transportation (monorails and buses). Since the Bhakti Park is the closest tenement community from the Sewri section, the expected impacts shall be minimum for the PAPs.

As MMRDA originally developed the Bhakti Park for other projects, PAPs from other projects have already lived in the park. There are still large numbers of tenements available so that all PAPs in Sewri section could move in the same area in the park. In addition, project affected businesses will receive business plots on the ground floor so that they could continue businesses in the Bhakti Park.

The general description of the Bhakti Park is summarised as follows.

Table 13.3.1 Available Resettlement Site, Bhakti Park Clooney for Sewri Section

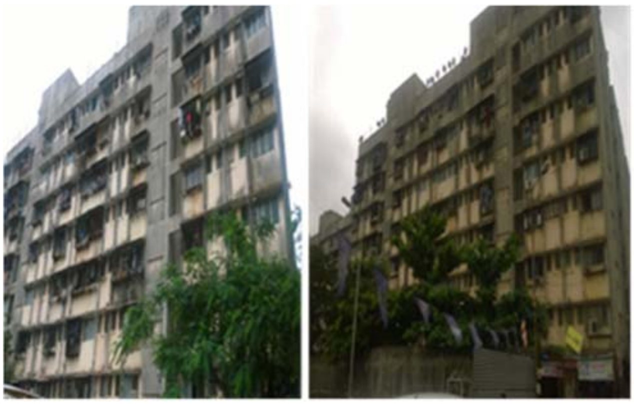
AFFECTED AREA & PAFS	PROPOSED RESETTLEMENT SITE				
Areas	Name of proposed Location	Area in Sq. ft. (m^2)	No. of Residential units /Carpet area/Cost per unit	No. of Commercial units/Carpet area/Cost per unit	R+C Units/carpet area/Cost per unit
Sewri East Section	Bhakti Park, Wadala	225 (20.9)	100-150/225 sq.ft (one room) /Per unit Rs.300,000	50/ as per the actual affect area limited to maximum 225 sq. ft./ Per unit Rs.300,000	Will be made available As per the requirement/ as per the actual affect area limited to maximum 225 sq. ft./ Per unit Rs.300,000

Source: MMRDA and R&R/MUTP

Resettlement Site at Bhakti Park, Wadala (Google map)

1	Total Area of the Plot	34249.60 Sq.m.
2	No. of Buildings constructed	11
3	Type of Construction	G+7
4	Total number of Residential Tenements	1540
5	Carpet area each of residential tenement	225 Sq.ft.
6	Cost per residential tenements	Land and buildings procured from Private Developer against TDR. Estimated Land + Building cost of tenement as per Ready Reckoner, 2012 is Rs. 19,46,721/- (Rs. 93,100/ sq. m.)
7	Total number of shops constructed	193
8	Cost per commercial tenements	Land and buildings procured from Private Developer against TDR. Estimated Land + Building cost of tenement as per Ready Reckoner, 2012 is Rs. 23,37,738/- (Rs.1,11,800/- sq. m.)
9	Social amenities	A Society Office, Balwadi and Welfare Centre for 100 tenements

Details of the Resettlement Buildings



Entry Gate & G + 7 Bldg. structures

Facilities of Commercial shops

Source: Google maps 2015 & JICA study team

Figure 13.3.1 Available Resettlement Site, Bhakti Park Clooney for Sewri Section

13.3.4 Entitle Matrix of MTHL

Since applicable compensation policies are different among three sections, the entitle matrix of each section is shown below.

Table 13.3.2 Entitle Matrix of Sewri Section

	Category of PAP	Monetary Compensation	House/Structure Compensation	Price to be Charged
1.	**Non-resident land owners or Lessee**			
	Non-resident land owners (Including farmers and horticulturists)	Market value of land and buildings as per LA1894	N/A	
	Non-resident lessees	Apportionment of compensation for the valid lease period as per LA1894	N/A	
2.	**Resident landlord or Lessee**			
	Resident landlord (land and building) (including farmers and horticulturists)	Market value of land and buildings as per LA1894	Cash supplement equivalent to cost of construction of floor space (subject to a max. of 20.91 sq.m.) occupied prior to resettlement. OR Floor space equal to self-occupied floor area, subject to maximum of 70 sq.m., irrespective of use of floor space	First 20.91 sq.m. of floor space free of cost and at actual cost for the area in excess thereof.
	Resident lessee of land and building	Apportionment of compensation for the valid lease period as per LA1894	Floor space equal to self-occupied floor area, subject to maximum of 70 sq.m., irrespective of use of floor space	
3.	**Resident lessees, tenants or sub-tenants of buildings**	Shifting charges as per LA1894	Floor space equal to self-occupied floor area, subject to a maximum of 70 sq., irrespective of use of floor space.	
4.	**Squatters (Non title holders)**			
	Non-Resident structure owners	Replacement Cost of structures	N/A	
	Resident structure owners	Replacement Cost of structures	**Township Option**: Residential: floor space of 20.91 sq.m.	Same as #2 (resident landlord or lessee)
	Resident structure owners or Tenants	N/A	**PH/HD/SRD Option**: Residential floor space of 20.91 sq.m.	Free of cost.
			Shops & Business Area equivalent to existing area with a maximum of 70 sq.m. out of which 20.91 sq.m. is free of cost.	Same as #2 (resident landlord or lessee)
5.	**Pavement dwellers (Non title holders)**			
	Pavement dwellers	N/A	Same as #4 Squatters (Township, PH/HD/SRD, Shops & Business)	
6.	**Employees and entrepreneurs**			
	(a) Employees residing in the affected community and working at some other place	Amount equivalent to the fare of twelve quarterly season tickets for excess distance by suburban railway	N/A	
	(b) Non-resident employees			
	(c) Employees and entrepreneurs who permanently lose	Lump sum compensation equivalent to one year's	The rehabilitation package shall include access to employment information through employment exchange, and	

	Category of PAP	Monetary Compensation	House/Structure Compensation	Price to be Charged
	their source of livelihood.	income, determined by the R & R Agency's valuation committee.	training facilities for appropriate skills to be provided through on-going government programs, and credit through, community operated fund.	

Source: R&R/MUTP

Table 13.3.3 Entitle Matrix of Sea-Link Section

Category &Type of loss		Nature of Loss	Expected # of PAPs	Compensation
C1	Perman ent	• Loss of livelihood (removal of fishing stakes and nets in the ROW) • Not possible to move to adjacent area due to overcrowded yet	48 nets within 500m width along ROW	Onetime payment of Rs. 5,84,000/- per net (ref. NGT order to JNPT, etc.)
C2	Perman ent	• Decline of fish catches and fish resources due to current change	34 nets	50% of the amount provided per Unit in Category C1
C3	Perman ent	• Loss of fishing/catching area due to permanent and construction yards • Particularly subsistence level fisher-folks for hand picking	512 subsistence fishermen	Onetime payment of Rs. 5,84,000/- per family (ref. NGT order to JNPT, etc.)
C4	Tempor ary	• Loss of fishing time and increased operating cost (fuel) to due to restricted entry of fishing ground and detour	300 Cargo boats & 175 Artisanal fishing boats	Assurance of present income level with monetary compensation for additional 3 hours and fuel
C5	Tempor ary	• Loss of fish due to increased turbidity during construction phase	150 Artisanal fishing boats 400 Substance fishermen	Up 5years of payment for losses
C6	Incident al	• Damage of fishing boats and nets due to construction activities	200 times over 5years	• Replacement/fix costs of boats and gears • Compensation for loss of fishing time • Compensation for loss of life

Source: MMRDA Fisher-folk Compensation Policy, 2015 (MMRDA Principal Compensation Policy)

Table 13.3.4 Entitle Matrix of Navi Mumbai Section

Type of loss	Monetary Compensation	Land Compensation
Non-resident land owners (Including farmers and horticulturists)	• N/A	**CIDCO 22.5% Scheme:** • CIDCO's developed land for residents and businesses (22.5% of acquired land) including the common area accounting for 30% • The actual possession of the development land: 15.75% of the acquired land
	• Resettlement allowances as per LARR_MH2014 • 200% of Ready Reckoner Rate	**CIDCO 12.5% Scheme:** • CIDCO's developed land for residents and businesses (12.5% of acquired land) including the common area accounting for 30% • The actual possession of the development land: 8.75% of the acquired land

Source: CIDCO

13.4 Grievance Mechanism

Grievance Redress Mechanism will be enforced three-phases as follows:

I) Responsible field officer in charge of PAPs, Social Development Cell (SDC) will try to solve the issues on demand bases,

II) If the SDC officers' solution is not satisfactory, MMRDA sets a Field Level Grievance Redress Committee (FLGRC) as the second phase mediation. FLGRC will be comprised of one committee member and independently set within MMRDA.

III) If the FLGRC's solution is not satisfactory, MMRDA sets a Senior Level Grievance Redress Committee (SLGRC) as the third phase mediation. SLGRC will be comprised of one committee member and independently set within MMRDA.

After the third phase without satisfactory, the case may be brought to the regional court. If a protesting PAP prefers to appeal in the court, the case can be brought to the court in any time. Considering the reason of one committee member in FLGRC and SLGRC, it is MMRDA's timely solution from past good practices. In the past, multi member committees took long time and could not reach the solutions in many cases.

For MTHL project, MMRDA will apply existing MMRDA grievance mechanism, except the 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 Fisher-folk Compensation Policy, 2015 (MMRDA Principal Compensation Policy)

13.5 Organization Structure of Land Acquisition and Resettlement Assistance

The implementation of Resettlement and Rehabilitation (R&R) requires involvement of various institutions at different stages of project cycle. The institutions to be involved in the process of R&R implementation are summarized in this section. Expected major organizations are as follows.

Primary Agencies	Project Management Unit (PMU) of MMRDA	Project Management in general
	SDC, MMRDA	Resettlement matters in general
Other	Grievance Redress Committee, MMRDA	FLGRC, SLGRC
	CIDCO	Land acquisition and monitoring in Navi Mumbai section
	MPT	Juridical authority of Sewri section and sea-link section
	JNPT	Juridical authority of the coast in Navi Mumbai section and sea-link section
	Department of Revenue	Payment of compensation
	Department of Fisheries	Fishing compensation (including GRC)

The implementation structure of R&R is based on the structure of the environmental management in chapter 12 with addition of management structure of land acquisition, resettlement and rehabilitation, and fishing compensation (figure 13.5.1). More detailed structure and components' relationship is shown in figure 13.5.2. Although all R&R components will be in MMRDA, each component's independency will be assured.

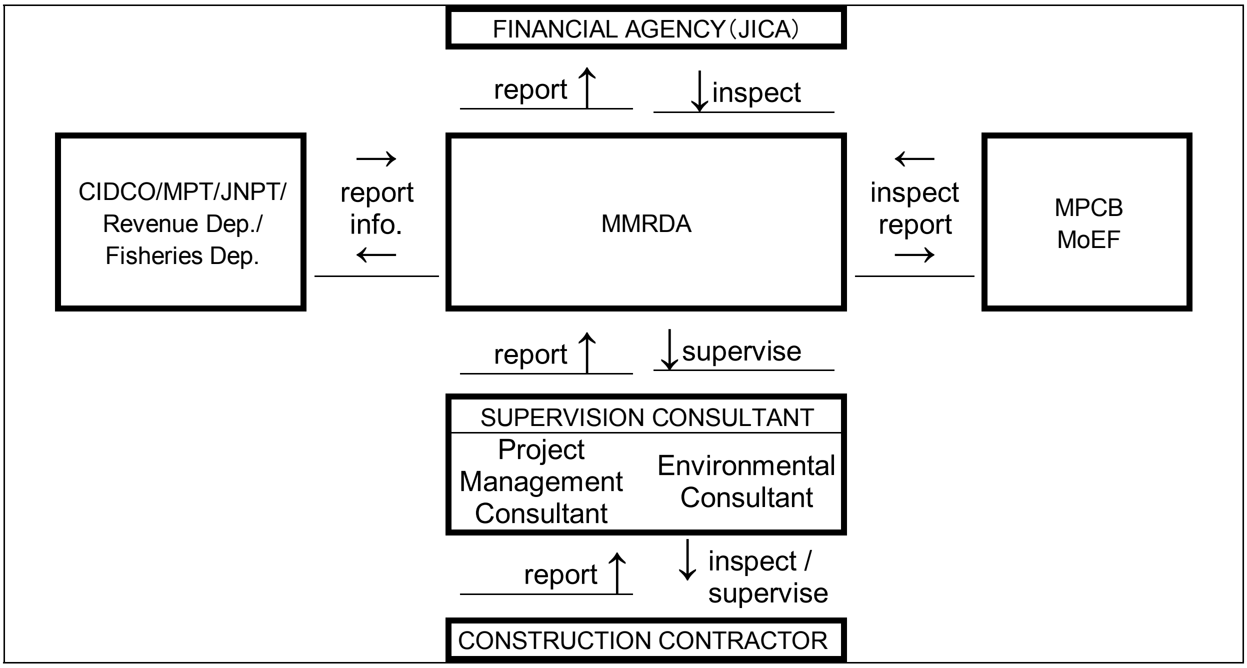


Figure 13.5.1 Organization Structure of Environmental Management and R&R

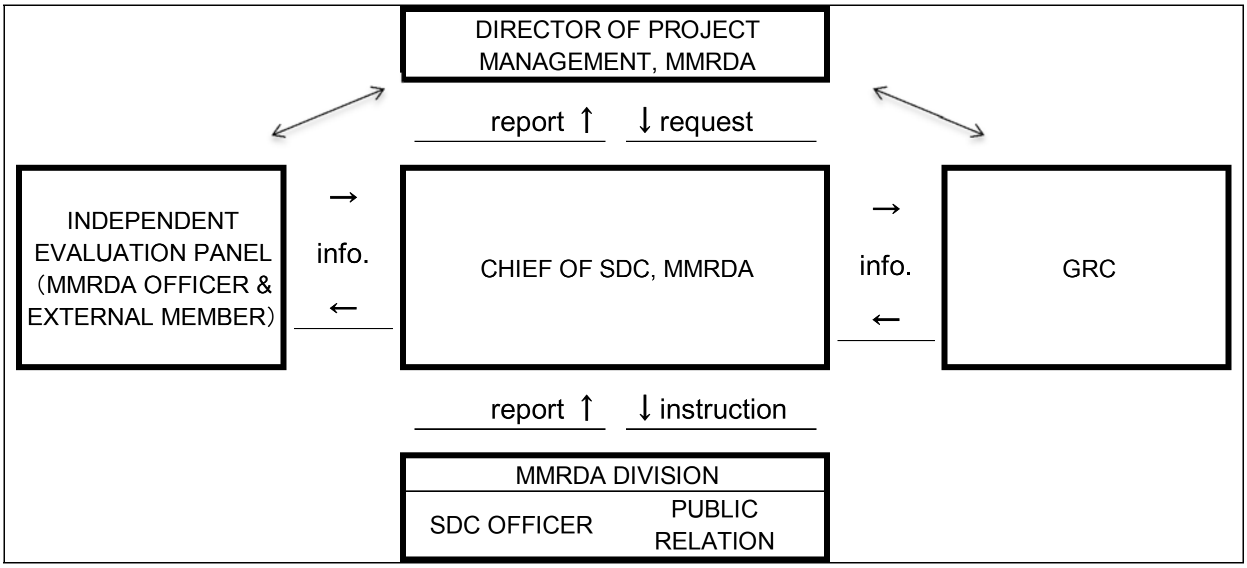


Figure 13.5.2 Organization Structure of Land Acquisition, R&R, Fishermen Compensation

Table 13.5.1 Role of Stakeholders for Implementation of R&R

Position	Responsibilities
Project Director- (PMU), MMRDA	• Overall planning and supervision of all project activities; • Exercise of administrative approval for finance & execution related activities; Supervision and control over responsible officers in PMU • Coordination with JICA, Govt. of India, Govt. of Maharashtra and other concerned agencies.
Social Development Cell, MMRDA	• Planning, supervision and implementation of R&R components; Report to Project Director, PMU; • Supervision and control over the Managers, Officers and support staff in SDC; • Liaison and coordination with PMU, Land and Estate Management Cell, Engineering Cell, NGOs, PAPs & other stakeholders; • Prepare and submit all reports and communication to Project Director; The administrative domain of Chief-SDC include: ✓ Approval of eligibility list ✓ Approval of Progress Reports ✓ Procurement of Consultancy services for R&R components; ✓ Disclosure of information to requesters and external agencies
Public Relation Unit	• Disclosure of R&R activities; • Assurance of information to PAPs and other stakeholders; • Publication of internal R&R monitoring report and home page updates.
Grievance Redress Committee	• FLGRC address grievances relating to individual eligibility and entitlement; • SLGRC review decisions of FLGRC on grievance petitions filed by PAPs,
Independent Evaluation Panel	• Mid-term and post evaluation (external evaluation) for livelihood recovery • Evaluate the implementation of the various provisions and activities planned in the SIA; • Review the internal monitoring report for evaluating progress of R&R implementation

Source: JICA Study Team

13.6 Schedule of Land Acquisition and Resettlement Assistance

Proposed implementation schedule for R&R activities for MTHL including various sub tasks and time line matching with civil work is shown below.

Table 13.6.1 Proposed Implementation Schedule for R&R

	Task Designation	Start Date	Completion Date
SEWRI SECTION			
1	**Preparation of Final SIA**	May 2016	February 2016
1.1	MMRDA Approval		December 2015
1.2	JICA Approval	December 2015	January 2016
1.3	Posting of project information on MMRDA web sites	December 2015	
1.4	Translation and disclosure of entitlement policy in local language to all APs	February 2016	Completion of post project evaluation
2	**Resettlement and Rehabilitation Implementation**		
2.1	Grievance redress mechanism established	Available in MMRDA	Completion of Construction
2.2	Recruitment of R&R evaluation consultant	Mid-term and post-completion	
2.3	Preparation and issue of PAP ID card	February 2016	March 2016
2.4	Notice to APs for shifting (Sewri Section)	February 2016	
2.5	Allotment of dwelling units to APs	March 2016	March 2016
2.6	Shifting of APs to resettlement Colony	April 2016	June 2016
2.7	Transfer of compensation/allowances/assistance to APs	March 2016	March 2016
2.8	Creation of Community Revolving fund (within 3 months post handing over)	July 2016	September 2016
2.9	Evaluation of livelihood recovery (within 6 months after handing over.	September 2016	December 2016
2.10	Registration of co-operative housing societies, transfer of maintenance funds. (6 months period).	April 2016	September 2016
2.11	Signing of Civil Contract		Summer 2016
2.12	Notice for Civil works to proceed		Autumn 2016
3	**Monitoring & Evaluation**		
3.1	Internal Monitoring – Monthly/Quarterly progress report	April 2016	December 2016
3.2	Independent Evaluation Mid-term and Final evaluation	Within 6 months after resettlement, Mid, and post evaluation	
SEA-LINK SECTION			
4	**Formulation of Fishermen Compensation Policy**		
4.1	Formulation of final principal compensation policy and MMRDA approval of the principal policy	December 2016	December 2016
4.2	Stakeholder meeting at all fishing societies	December 2016	February 2016
4.3	Detail survey and eligibility list	December 2016	February 2016
5	**Advanced Monetary Compensation**		
5.1	Grievance redress mechanism established	June 2016	June 2016
5.2	Recruitment of R&R evaluation consultant	Mid, and post evaluation	

	Task Designation	Start Date	Completion Date
5.3	Preparation and issue of PAP ID card	June 2016	July 2016
5.4	Payment of compensation	August 2016	September 2016
6	**Monitoring & Evaluation**		
6.1	MMRDA internal monitoring (confirming complaints monthly, and quarterly report)	February 2016	June 2016
6.2	Independent Evaluation	Mid, and post evaluation	
NAVI MUMBAI SECTION			
7	**Land Acquisition**		
7.1	Grievance redress mechanism established	Available in CIDCO / Available in MMRDA	Completion of acquisition
7.2	Payment of land acquisition	On going	August 2016
8	**Monitoring & Evaluation**		
8.1	MMRDA internal monitoring (prepared by CIDCO monthly, and quarterly report)	February 2016	Completion of acquisition
8.2	Independent Evaluation Mid-term and Final evaluation	Mid, and post evaluation	

Source: JICA Study Team

13.7 Cost and Source of Land Acquisition and Resettlement Assistance

Summary of the land acquisition, resettlement and rehabilitation cost is shown in this section. Due to the on-going process of negotiation between MMRDA and port authorities (MPT and JNPT) at the time of reporting, the most updated costs were taken from the MPT and JNPT's letters in 2015. Since the estimated cost for land and property is based on Ready Reckoner Rates 2015, some cost may increase based on the Ready Reckoner Rates at the time of the construction.

In addition, price escalation shall apply different rates on each item so that the budget should be considered as "Indicative." All costs shall be reconfirmed and updated at the time of project commencement. The costs may be also adjusted to address the inflation of costs and personnel expenses over the four years of construction period. Detailed description of the each cost shall be referred to Chapter 10 of Social Impact Assessment report (MMRDA, 2015).

13.7.1 Land Acquisition

SEWRI SECTION

Compensation for MPT; As all ROW in Sewri section is the jurisdiction of MPT, costs of land transfer will be paid to MPT. Based on the latest negotiation records between MMRDA (#MMRDA/MTHL/MbPT/Land charges/Rev/2015 dated 9/SEP/2015) and MPT

(#CE.MTHL/92/2460 (G) dated 27AUG/2015), some corrections and updates are still expected. As stated in MPT letter, we assumed the land acquisition (land & water area) cost is INR3,595.9 million for 30years plus some contract charge.

Compensation for Land Titleholders; As BSES did not identify any legal titleholders including official lessees of MPT properties in Sewri section, we assume no costs for titleholders.

Compensation for Non-Titleholders; Based on the BSES, all PAPs are categorised as non-titleholders. As per R&R/MUTP, no monetary compensation is given to PAPs.

Demolition/Land Clearing; All structure shall be cleared before handing over to the contractor, we assumed the cost of demolition and disposal based on the present market rates. Based on the rough estimation, volume of the debris for the existing structure would be 10,746m^3 costing roughly INR1.5 million.

SEA-LINK SECTION

No land acquisition is involved in the Sea-Link section. Thus, only cost for ROW on the water surface is considered.

Compensation for MPT and JNPT; The cost for the sea area within MPT jurisdiction is counted in Sewri section. Thus, we counted only JNPT's cost stated in JNPT letter (JNPT/PP&D/MMRDA/MTHL/2015/819 dated 14AUG/2015). The land acquisition (water area) cost is INR1,688.4 million for 99years plus some contract charge.

NAVI MUMBAI SECTION

Compensation for CIDCO; Based on the agreement between MMRDA and CIDCO in 2013, CIDCO will rent the previously acquired land (69Ha) for IND1/y, so we omitted the cost for the 69Ha in the total cost. The rest of the acquiring land (27Ha) will be acquired by CIDCO on behalf of MMRDA in advance. However, CIDCO has not completed the land acquisition and there were no assumption given by CIDCO. We conservatively assumed the cost of the 27Ha land as value of the CIDCO's developed land for CIDCO22.5% scheme. The calculation of the land value is shown as follow:

a) Area (Ha)	b) Net developed land* (m^2) /Ha	c) Total developed land (m^2) = a) x b)	d) Ready Reckoner/ m^2	Total Land Value (INR) = c) x d)
27.80	1,575	43,787	2,430	106,400,000

*as per CIDCO22.5% scheme

Demolition/Land Clearing; There is a possibility to acquire a part of public school on CIDCO's public land. Although small adjustment of the alignment could avoid the land acquisition and resettlement of a school, we tentatively assume the demolition and land clearing. As it is public land, cost of the land is not considered. Based on the rough estimation, the cost of land clearing would account for INR181,413.

13.7.2 Resettlement and Replacement of Property

SEWRI SECTION

Compensation for MPT; Based on the agreement between MMRDA and MPT, MMRDA is required to relocate some abandoned and presently used MPT buildings in ROW. As not all properties are used at this moment, we conservatively assumed the replacement cost of all structure. Detailed calculation shall be referred to the Annexure 10.4 of SIA report. The replacement cost of MPT structure is INR192,249,137.

Compensation for Non-Titleholders; Based on the BSES, all PAPs are categorised as non-titleholders. No monetary compensation is given to PAPs as per R&R/MUTP for public housing scheme. Due to the no availability of public land in metropolitan region, township option of R&R/MUTP is no longer valid.

SEA-LINK SECTION

No property is affected in the Sea-Link section.

NAVI MUMBAI SECTION

Compensation for CIDCO; There is a possibility to acquire a part of public school on CIDCO's public land. As stated above, we conservatively counted the cost of the public school relocation. Based on the rough estimation, the cost of the new school construction would be INR45,215,226.

13.7.3 Land Lease During Construction

SEWRI SECTION

Compensation for MPT; Based on MPT letter (#CE.MTHL/92/2460 (G) dated 27AUG/2015), annual cost for the temporary yard and jetty in Sewri section is INR332,336,835. We conservatively assumed the land lease period for 5years. The land lease cost would be INR1,800,043,497 for 5years. Annual escalation of lease is expected, but it is not considered at this time.

Compensation for Land Titleholders; As BSES did not identify any legal titleholders including official lessees of MPT properties in Sewri section, we assume no costs for titleholders.

SEA-LINK SECTION

Water surface lease is already considered in the section of land acquisition. No further lease is expected.

NAVI MUMBAI SECTION

Compensation for CIDCO; Based on the agreement between MMRDA and CIDCO in 2013, CIDCO will rent the 19Ha of construction yard for INR1/y, so we omitted the cost for the 19Ha lease in the total cost. No further cost for lease is expected.

13.7.4 Prior Compensation and Post Assistance for Livelihood Recovery

SEWRI SECTION

Compensation for PAPs; As per R&R/MUTP, PAPs will have choices to receive some benefits by monetary allowance or in kind. In addition, MMRDA will provide necessary assistance once MMRDA confirms the need of additional support for PAPs during post monitoring. Such undefined cost is not estimated (shown TBD in the summary table). Known costs are shown below:

- Commute allowance (additional travel cost assistance for 335 PAPs): INR3,859,200
- Community revolving fund (micro credit scheme for recovery assistance for 282 PAPs): 282,000

SEA-LINK SECTION

Due to the on-going process of detailed fishing survey to determine the eligible fishermen for compensation, we tentatively assumed the cost of the prior fishing compensation estimated in MMRDA fishing compensation policy (2015). Sum of the fishermen compensation would be INR797,420,160.

NAVI MUMBAI SECTION

Due to the land acquisition only, no livelihood recovery assistance is expected.

13.7.5 Monitoring and Post Resettlement Activities

Monitoring & Evaluation; Based on the past experiences in the region for similar scale resettlement projects, we assumed the total cost for monitoring including NGOs, administrative costs and consultants. The sum of the cost would be INR1,700,000.

Post Resettlement Support; As per R&R/MUTP, post resettlement support to initiate the property management by PAFs shall be provided by MMRDA. Post Resettlement Support (New community management account for 282 PAFs): INR5,640,000.

13.7.6 Summary of the Land Acquisition and Rehabilitation Support

The costs for implementation of Resettlement and Rehabilitation Plan are summarized as follow. The s total cost for R&R implementation plan is roughly INR.9,063 million.

Table 13.7.1 Costs for Land Acquisition and Resettlement & Rehabilitation

	Description	Quantity	(Unit)	Rate (INR)	Cost (INR)	Cost (INR/Year)*
1	**Land Acquisition (Total)**				**5,392,200,000**	**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
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	**Allowances (Total)**				**801,279,360**	
1	Sewri					
	Livelihood recovery assistance				TBD	
	Moving allowance				TBD	
	Commute allowance*****	335		11,520	3,859,200	
2	Sea-Link	lump sum			797,420,160	
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)**				**1,700,000**	
1	NGO Cost	lump sum			500,000	
2	Cost for Monitoring & Evaluation	lump sum			700,000	
3	Cost of Public Relation Consultant	lump sum			500,000	
7	**Post Resettlement Activity**	**282**		**20,000**	**5,640,000**	
	Sub-Total (1 to 7)				8,238,790,633	
	Miscellaneous items @ 10% of sub total				823,879,063	
	GRAND TOTAL (Round @1,000)				**9,062,669,696**	

* 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

13.8 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).

Internal monitoring will be conducted by the Project Management Unit (PMU) or Social Development Cell (SDC) off MMRDA while the independent evaluation will be conducted by independent evaluation unit of MMRDA or external experts. Especially independent evaluation is important since R&R/MUTP does not provide special benefits to vulnerable group of PAPs.

In case, monitoring activities and/or PAPs' requests recognize the need of additional assistance, SDC of MMRDA will take necessary actions. Such supporting structure has already been set and shown in the MMRDA's Citizen's Charger on its web site in both English and Marathi.

13.8.1 Internal Monitoring

The internal monitoring for R&R implementation will be carried out by MMRDA or appointed consultants on behalf of MMRDA with monthly basis till the completion of the land acquisition and resettlement in Sewri and Sea-link section. For the Navi Mumbai section, CIDCO will conduct the monitoring and MMRDA will monitor and organize the results. The main objectives of internal monitoring are to:

- measure and report progress against the SIA schedule;
- verify that agreed entitlements are delivered in full to affected people;
- identify issues and propose solution related to land acquisition and resettlement timely;
- monitor the effectiveness of the grievance system
- periodically measure the satisfaction of project affected people.

Table 13.8.1 Indicators for Internal Monitoring

Category	Parameters
Physical / Statistical	Number identity card prepared and distributed Number of structures dismantled Number of relocated PAHs and PABs Number of received tenement by PAHs and PABs Number of PAHs and PABs already receiving moving allowance/arrangement by MMRDA Number of provided commute allowance by PAPs Number of PAPs eligible for fishermen compensation
Financial	Amount of compensation paid for PAPs and other benefits such as railway passes Amount paid for training and capacity building of supporting staffs Transfer of community revolving fund by MMRDA
Social	Area and type of house and facility at resettlement site PAPs knowledge about their entitlements Communal harmony Morbidity & mortality rate Recovery status of vulnerable PAPs
Economic	Entitlement of PAPs-land/cash Number of business re-established Utilization of compensation Livelihood recovery schemes usage
Grievance	Number of community level meeting Number of GRC meetings Number of cases disposed by MMRDA to the satisfaction of PAPs Number of grievances referred and addressed by GRC

Source: JICA Study Team

The internal monitoring is expected to start from April 2016 (after the loan agreement or initiation of R&R, whichever sooner) till the completion of each resettlement activities and the advanced fishermen compensation. PMU of MMRDA will make a quarterly monitoring report and submit it to MMRDA and JICA. The format for the internal monitoring of R&R implementation is given in ANNEXURE 11.1 of Social Impact Assessment report.

13.8.2 Independent Evaluation

The independent evaluation shall be conducted for the purpose of confirming recovery of the PAPs' livelihood and necessity of additional assistances independently. The main objectives of external evaluation are to;

- Assess whether resettlement objectives have been met, specifically, whether livelihoods and living standards have been restored or enhanced,
- Assess resettlement efficiency, effectiveness, impact and sustainability, drawing lesions as a guide to future resettlement policy making and planning, and
- Ascertain whether the resettlement entitlements were appropriate to meeting the objectives, and whether the objectives were suited to affected persons' conditions,

- This comparison of living standards will be in relation to the baseline information available in the BSES. If some baseline information is not available then such information should be collected on recall basis during the evaluation.

The following aspects shall be considered in evaluation of R&R implementation in the project. The list of impact performance indicators is shown in the following table.

Table 13.8.2 Indicators for Qualitative Independent Evaluation

Objectives	Risk Factor	Outcomes and Impacts
− The negative impact on persons affected by the project will be minimized. − Persons losing assets to the project shall be compensated at replacement cost. − The project-affected persons will be assisted in improving or regaining their standard of living. − Vulnerable groups will be identified and assisted in improving their standard of living.	− Resettlement plan implementation may take longer time than anticipated − Institutional arrangement may not function as efficiently as expected − NGO may not perform the task as efficiently as expected − Unexpected number of grievances − Finding a suitable rehabilitation site for displaced population − PAPs falling below their existing standard of living	− Satisfaction of land owners with the compensation and assistance paid − Type of use of compensation and assistance by land owners − Satisfaction of structure owner with compensation and assistance − Type of use of compensation and assistance by structure owner − % of PAPs adopted the skill acquired through training as only economic activity − % of PAPs adopted the skill acquired through training as secondary economic activity − % of PAPs reported increase in income due to training − % PAPs got trained in the skill of their choice − Role of NGO in helping PAPs in selecting trade for skill improvement − Use of productive asset provided to PAPs under on time economic rehabilitation grant − Type of use of additional assistance money by vulnerable group − Types of grievances received − No. of grievances forwarded to GRC and time taken to solve the grievances − % of PAPs aware about the GRC mechanism − % of PAPs aware about the entitlement frame work mechanism − PAPs opinion about NGO approach and accessibility

Source: JICA Study Team

The independent evaluation will be conducted 6months after the completion of resettlement, middle of construction, and at the end of the construction. PMU of MMRDA will make the evaluation report each time and submit it to MMRDA and JICA. The format for the independent evaluation shall be the form of BSES, initially used for base line census survey (ANNEXURE 2.1 of Social Impact Assessment report).

13.9 Result of Stakeholder Meetings with Project Affected Households

13.9.1 Sewri Section

In order to adequately disclose the project information and encourage PAPs participation in the resettlement process, MMRDA conducted two stakeholder meetings with participation of representatives of Sewri community, PAPs, and JICA study team. Throughout the meetings, it is confirmed that PAPs generally accept the resettlement and desire to relocate as soon as possible.

(1) SIA - 1st Explanatory Meeting

The explanatory document was prepared in Marathi, the official language of Maharashtra to follow the government of Maharashtra's policy on official language at the public places and notifications. The content of the explanatory documents were originally prepared by JICA study team and authorised by the responsible officer of the MMRDA before the 1st meeting. The contents of the explanatory document are summarized as follows.

Table 13.9.1 Contents of the 1st SIA Explanatory Meeting

BACK GROUND	• Back ground information after the MMRDA's nomination as the MTHL implementation agency
PROJECT FEATURES	• General description of project scale and infrastructure
ALIGNMENT OF MTHL	• MMRDA's Determined ROW on the Map
Social Impact Assessment	• General description of SIA and process of determining the present status by Basis Social Economic Survey (BSES) • Eligibility of the compensation and livelihood recovery support including the effective date of cut off date • Contents of BSES
SIA Schedule	• Schedule and general description of the 1st explanatory meeting, the 2nd stakeholder meeting, and expected final
Opinions from PAPs	• Comments from key stakeholders for projects and BSES

Source: MMRDA and JICA Study Team

Roughly fifteen key stakeholders in the community of the Sewri section attended the first meeting including the two representatives from the women society. From the MMRDA, host side, two relevant officers from Social Development Cells of MMRDA, one environmental and social expert of JICA study team, and three local environmental consultants attended and organized the meeting (pictures bellow). Including the host's presentation and opinions from the key stakeholders, it was roughly one hour meeting and completed calmly with attendants general understanding.

Host & Venue

Key Stakeholders

Table 13.9.2 Summary of the Key Stakeholders' Comments 1st SIA Explanatory Meeting

Type of Comments	Summary of the Comments
Compensation	• Beneficial stakeholders should be ALL households and businesses in the Communities in the Sewri section on MPT instead of only ROW. • Some families have lived more than 50years in the project affected area. Such families should be able to claim the land ownership instead of only land lease and/or none title status for compensation package. • What would be the compensation packages for the PAPs? • What would be the compensation packages for the businesses? • Please confirm the property and BSES at the same time (assuming some difference from last survey in 2013). • Will PAPs get land/houses as same size as what the PAPs have now?
New Resettlement Site	• New resettlement site should be close to the present location. • New resettlement site(s) should accommodate a school and a hospital as it is now as well as close distance from railway station.
BSES	• Why BSES is necessary and what is the benefit of the BSES?
Schedule	• When the resettlement shall be started? • How long will PAPs have displacement time?

Source: MMRDA and JICA Study Team

(2) 2nd Consultation Meeting with Project Affected Households

The 2nd SIA consultation was conducted on August 25th with prior notices in the project affected communities and phone call invitations to the key stakeholders presented in the 1st consultation. In order to accommodate more PAPs rather than just key stakeholders, a conference room that is able to accommodate more than 400 persons were used for the 2nd consultation meeting. A short presentation was prepared in Marathi and oral explanation was given in Marathi by the local expert of the JICA study team. Contents of the presentation are as follows:

- Result of BSES[41],
- Compensation policies for properties' losses,
- Compensation policies for livelihood recovery, and
- Development plan or/and description of resettlement housing.

After the presentation, opinions from PAPs were raised and responsible representatives of MMRDA and JICA Study Team responded accordingly. In addition to the onsite verbal communication, written comment forms were given at the initial registration and accepted at the site. Summary of the comments and their responses are given in the following table.

Table 13.9.3 Summary of PAPs and Responses at 2nd SIA Consultation Meeting

Opinions from PAPs	Responses of MMRDA*
Compensation Policy and Conditions	
• Is JICA using Resettlement & Rehabilitation policy of the World Bank? • Is R&R/MUTP also complying the World Bank policy?	• Yes, JICA has its guidelines but referring to the World Bank OP 4.12 <JICA Study Team>. • Yes, the R&R/MUTP was originally formulated for the World Bank funded "Mumbai Urban Transport Project." Then, the present R&R/MUTP was formally approved by GoM in 2000 as compensation policy of Maharashtra.
• Some PAPs are official lessees of MPT structures in ROW. Will they be considered as legal title holders under the entitlement matrix? • What is the agreement between MPT and MMRDA?	• It is understood from the experience of the MMRDA/Eastern Freeway project that claimed lessees in structures on MPT land mostly did not have legally valid rights. However, the concerned PAPs should submit the relevant documents to prove the legal validity of claims. Entitlements in such cases will be considered. • The execution of the project will be carried out with the final approval of MPT.
• How will the occupants of partially affected structures resettled? • Can people staying in the same settlement but not affected by the project be resettled?	• In case of partially affected structures, the PAPs would have a choice of either shifting to resettlement site or remaining the rest of structures without any entitlement. • It is not responsibility of the MMRDA. However, if unaffected persons want to relocate with PAPs, such persons should formally request such desires to MMRDA. MMRDA will consider the possibility and make a decision after consultations.
New Resettlement Site	
• Is there any area for resettlement other than Bhakti Park? Preferably more close to the Sewri	• The Bhakti Park resettlement site was suggested due to the nearest site from Sewri. Other resettlement sites are located at farther locations. It will be possible to choose other resettlement sites if PAPs request MMRDA formally. • MMRDA does not own any land or other possible sites adjacent to Sewri.
• What are the details of other resettlement sites?	• All resettlement sites including Bhakti Park are developed in accordance with the applicable Development Control Regulations for Greater Mumbai and provided various amenities and facilities complying with such rules. • The other resettlement sites are at Mankhurd, Mahul, Govandi, Oshiware etc.

[41] Basic Socio Economic Survey required by MMRDA to set the cut off date

	• All resettlement sites are planned and developed under the same Regulations and most of the stock of tenements is of 225 sq.ft. carpet area.
Schedule	
• When is the project implementation likely to start?	• At present details of the project and its funding are studied and various arrangements are yet to be finalized. Thus, it is not possible to indicate accurate project schedule now.

* In case of specific questions for JICA Study Team, <JICA Study Team> is shown.

Source: MMRDA and JICA Study Team

	
2nd Consultation Notices in the PAP's Community (right column of building)	Consultation Room
	
Registration	PAPs
	
Presentation Given By JICA Study Team (BEIPL)	MMRDA/Local Representative/JICA Study Team/JICA Study Team (Local)

Questioned by Local Representative

Discussion After the Consultation

13.9.2 Sea-Link Section

Throughout the field observations (June and July, 2015) and communication with key officials in Department of Fisheries (DoF), Maharashtra, JICA study team confirmed that almost all alignment of MTHL (Sea-Link section) is active fishing area. As a part of the MMRDA's principal compensation development for fishermen, series of consultations were conducted. Summaries of the consultations are as follows.

Table 13.9.4 1st Consultation Meeting with Representatives of Fishing Societies

Place / Date	Aquarium Hall, DoF / 23rd November, 2015
Chairman	Commissioner (Marine) , DoF
Department of Fisheries	• JT. COMMISSIONER OF FISHERIES, (MARINE) MUMBAI • ASST. COMMISSIONER OF FISHERIES, MUMBAI CITY • ASST. COMMISSIONER OF FISHERIES, MUMBAI SUBURB DISTRICT. • ASST. COMMISSIONER OF FISHERIES, THANE & PALGHAR DISTRICT.
Representatives of Fishing Societies	Representatives of 9 potentially affected fishing communities
Observer	• MMRDA: Deputy Engineer • JICA study team: Local Expert

ITINERARY
- Objective of the meeting and role of the DoF in the process (DoF)
- Project description and summary of the potential impacts and its draft compensation policy (Local expert of JICA study team)
- Q & A

CONFIRMED TOPICS
- General understanding of objectives and draft compensation policy
- Acceptance and support of detailed fishermen survey requested for the MMRDA fishermen compensation policy development committee by JICA study team
- DoF's key roles to coordinate key stakeholders for the compensation development

Questions and opinions from representatives of fishermen	Responses by DoF (JICA study team local expert for some cases)
Fishermen compensation in general	
• Overall fishing businesses have been declined due to water pollution. Reduction of the fish resource productivities by MTHL should be compensated.	• As per JICA Env.Guideline2010, MMRDA's compensation policy ensures the living standard of project affected fishermen. The draft policy adapted the compensation level of the recent National Green

• Will the compensation given be sufficient to cover life-time losses?	Tribunal case, which is as same condition as the highest compensation case. • The compensation will be commensurate with the losses.
• Dredging activity may affect the spawning of fishes and other aquatic species.	• The technology for piling is not likely to create a lot of turbidity. However, adequate area will be covered as prime impact zone to cover the affected fishermen for the potential turbidity loss.
• Subsistence fishermen must be eligible for compensation.	• Subsistence fishermen will be adequately covered
• In some cases, fishing is prohibited around the bridge pillars. Is the fishing around piles restricted? How long is the restricted area in case of restriction?	• The MMRDA fishermen compensation policy committee comprises the safety experts. Safety regulation matter shall be discussed and defined in the following committee meetings.
• Illegal waste disposal may impact fishing.	• MTHL it self does not create such waste and illegal disposal is not expected from the passing vehicles and trucks.
Compensation Timing / Means	
• Advanced compensation must be done.	• Detailed procedure shall be defined later, but advanced compensation will be given.
• Are vocational training and new job arrangement for PAPs included?	• Only monetary compensation is considered at this moment.

Aquarium Hall, DoF


JICA study team local expert: draft policy explanation


DoF explanation


Representatives of fishing communities/societies

Table 13.9.5 3rd MMRDA Fishermen Compensation Policy Development Committee

Place / Date	MMRDA Board Room / 1st December, 2015
Chairman	• MMRDA: ADDITIONAL METROPOLITAN COMISSIONER – II
Committee members	• DOF: COMMISSIONER (MARINE) • MAHARASHTRA MARITIME BOARD: CHIEF EXECUTIVE OFFICER • MUMBAI DISTRICT: COLLECTOR • RAIGAD DISTRICT: COLLECTOR • POLICE: DEPUTY COMMISSIONER (COVERING SEWRI) • POLICE: DEPUTY COMMISSIONER (NAVI MUMBAI-SHIVAJI NAGAR) • EXTERNAL COMPENSATION EXPERT: PRINCIPAL RESEARCHER OF CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
Committee secretary	• MMRDA : ENGINEERING IN CHIEF
Representatives from fishing communities/societies (all 9 societies)	• MAHUL, TROMBAY, URAN KOLIWADA, BELPADA KOLIWADA, HANUMAN KOLIWADA, GAVHAN KOLIWADA, BELAPUR, SARSOLE, DIWALE
Observer	• DOF: JT. COMMISSIONER (MARINE) • MMRDA: OFFICERS OF ENGINERING DIVISION • JICA STUDY TEAM LOCAL EXPERT
ITINERARY • Objective of the meeting and MMRDA Fishermen Compensation Policy Committee • Potential impacts and its draft compensation policy (Local expert of JICA study team) • Q & A CONFIRMED TOPICS • Requests and opinions from fishing communities/societies (verbal and request letters) • Appreciation of fishermen's involvement in compensation policy development and support for detailed fishermen survey • General understanding of objectives and draft compensation policy • Methodologies of detailed fishermen survey and process of finalizing the compensation policy • Exclusion of the compensation from other project in the past within the MTHL project affected area	

During the third MMRDA Fishermen Compensation Policy Committee, general understanding of the draft MMRDA principal compensation policy of MTHL by fishing communities was confirmed. As the result, committee members approved the principal compensation policy at the fourth committee (10th December, 2015). Then, MMRDA approved the principal compensation policy of MTHL on 23rd of December, 2015. Upon the MMRDA's approval, detailed survey to identify the eligible PAPs in the 9 project affected communities as well as stakeholder meetings will be conducted by March 2016.

13.9.3 Navi Mumbai Section

As the planning and development authority of the Navi Mumbai, CIDCO had acquired land in and around MTHL since 1980s with CIDCO 12.5% scheme through district corrector. The negotiations of land acquisition had been individually conducted between the district corrector and the land owners or those two with CIDCO. With the CIDCO12.5% scheme, CIDCO completed around 70% of the land acquisition in Navi Mumbai before 2000.

The rest of the 30% land acquisition has been conducted based on individual negotiation as same manner as past land acquisition before 2000. During the fact finding mission #2 of JICA on 19 November 2015, it is confirmed that CIDCO has already acquired agreement from 8Ha of the rest of 27Ha. The rest of the land acquisition is on the process of negotiation and negotiation will be conducted individually as same manner as previous acquisition between the land owner and the district corrector with CIDCO.

14. CONSIDERATION FOR CLIMATE CHANGE

14.1 Vulnerability due to Climate Change

South Asia is believed to be highly vulnerable to climate change with India as one of the countries with the highest vulnerability. According to a research on the risks of climate change to development in South Asia which was commissioned by the World Bank to Potsdam Institute for Climate Impact Research and Climate Analytics, India is already experiencing a warming climate and Mumbai, which has large parts of the city built on reclaimed land below the high-tide mark, was confirmed as having the world's largest population exposed to coastal flooding. Moreover, its rapid and unplanned urbanization further increases the risks of sea water intrusion.

14.1.1 UN Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations in 1988 to IPCC produces reports that support the United Nations Framework Convention on Climate Change (UNFCCC), which is the main international treaty on climate change. The ultimate objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [i.e., human-induced] interference with the climate system". In a presentation made at the Sixth Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (COP-6), Robert T. Watson, Chair of the IPCC, defined vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained. In the case of the Mumbai Trans Harbor Link, vulnerability is considered from 2 aspects:

- Vulnerability of the structure itself
- Additional perturbation to the natural system due to change in the environment caused by the proposed bridges

14.1.2 India's National Action Plan on Climate Change (NAPCC)

In 2008, the Indian Government released India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies and programs addressing climate mitigation and adaptation. The plan identifies measures that promote India's development objectives while also yielding co-benefits for addressing climate change effectively.

14.1.3 Scenario of Climate Change

The IPCC has postulated global warming projections for various scenarios. The common scenarios are shown in Table 14.1.1.

Table 14.1.1 Scenarios of Global Warming postulated by IPCC

Scenarios	Assumptions	Temperature Change (degrees Celsius)		Sea Level Rise (cm)
		Most likely value	Most likely Range	Most likely Range
Scenario A1B (A balanced emphasis on all energy sources)	General Considerations: * Rapid economic growth. * A global population that reaches 9 billion in 2050 and then gradually declines. * The quick spread of new and efficient technologies. * A convergent world - income and way of life converge between regions. Extensive social and cultural interactions worldwide.	2.8 °C	1.7 to 4.4 °C	21 to 48 cm
Scenario A1F1 (An emphasis on fossil-fuels)		4.0 °C	2.4 to 6.4 °C	26 to 59 cm
Scenario A1T (Emphasis on non-fossil energy sources)		2.4 °C	1.4 to 3.8 °C	20 to 45 cm
Scenario A2	General Considerations: * A world of independently operating, self-reliant nations. * Continuously increasing population. * Regionally oriented economic development. * Slower and more fragmented technological changes and improvements to per capita income.	3.4 °C	2.0 to 5.4 °C	23 to 51 cm
Scenario B1	General Considerations: * Rapid economic growth as in A1, but with rapid changes towards a service and information economy. * Population rising to 9 billion in 2050 and then declining as in A1. * Reductions in material intensity and the introduction of clean and resource efficient technologies. * An emphasis on global solutions to economic, social and environmental stability	1.8 °C	1.1 to 2.9 °C	18 to 38 cm
Scenario B2	General Considerations: * Continuously increasing population, but at a slower rate than in A2. * Emphasis on local rather than global solutions to economic, social and environmental stability. * Intermediate levels of economic development. * Less rapid and more fragmented technological change than in A1 and B1.	2.4 °C	1.4 to 3.8 °C	20 to 43 cm

Source: JICA Study Team

14.2 Basic Concept

14.2.1 Need for Adaptation Options

The Project is to newly construct a road approximately 22km long on the sea across the Mumbai Bay between Sewari in Greater Mumbai and Chirle in Navi-Mumbai with the approach sections on land including interchanges and the other necessary facilities for full access-controlled motorway and marine bridges. Approximately 17km of the road will run on a PC box girder and steel box girder in the sea. It is therefore necessary to consider the safety of the road and all related structures so as to ensure traffic safety from the effects of climate change.

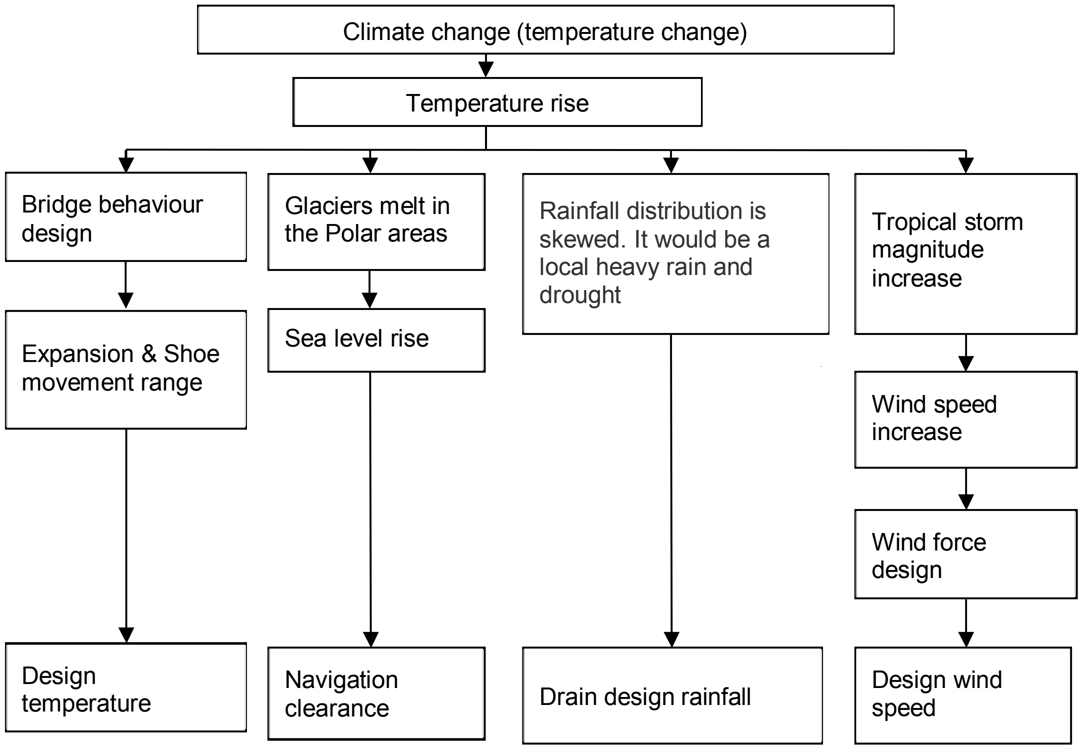
While there are various types of climate change in the global climate system, the most significant influence of global climate change for this Project which is located in India is global warming and its related changes. Of concern to us is temperature rise and its related sea level rise, rainfall rise, drought and tropical storm magnitude which are not independent climate phenomenon.

The influences of temperature change are as follows;

- The air temperature rises at the bridge site, which will raise the bridge temperature.
- The global temperature causes de-icing of the polar area. This leads a rise of sea level.
- The air temperature rise leads to an increase in rain fall due to the rise in humidity from the sea water temperature rise.
- The temperature rise leads to an increase in tropical storm magnitudes. This leads to a rise in wind speed.

The reasons for the consideration of the effects of climate change as they impact this project are as follows;

- The bridge shape can easily be deformed by temperature change.
- The clearance under the bridge must be secured for vessel passage.
- The bridge must bear the natural forces. A wind speed rise could be generated by climate change.
- The bridge must drain the deck surface for traffic.



Source: JICA Study Team

Figure 14.2.1 Scope of Consideration

14.2.2 Adaptation Options

Adaptation options are divided into two categories. One is design considerations and the other is operation considerations. The adaptation options for climate change in India due to the above mentioned causes are selected as follows;

- Temperature change due to bridge design
- Sea level rise due to temperature change
- Rain fall due to temperature change
- Wind speed increase due to the rise in cyclone magnitude due to the temperature rise

14.2.3 Target Year of Climate Change

The target year of climate change is based is to be based on the service life of the bridges. Based on the design criteria, the service life of the bridge is 100 years. Therefore the project target year will range between 2120 and 2122 depending on the completion date of construction.

14.3 Climate Change Data for This Project

Data is collected from existing reports and nearby weather stations maintained by the India Meteorological Department (IMD) while predicted data is also collected from various existing reports available from various sources including IPCC, UNFCCC, Ministry of Environment, Forest and Climate (MEFC), India's First National Communication on Climate Change (NATCOM) and Indian Institute of Tropical Meteorological (IITM).

14.3.1 Temperature

There are various kinds of predictions for temperature. According to the IPCC (2013), the global climate has shown warming of 0.89 [0.69 to 1.08] °C over the period 1901–2012 which is mainly attributed to anthropogenic activities. Temperature projections at the end of the 21st century are shown in Table 14.3.1.

Table 14.3.1 Projected Global Average Surface Warming at the End of the 21st Century by IPCC

Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]	
	Best estimate	*Likely* range
Constant year 2000 concentrations [b]	0.6	0.3 – 0.9
B1 scenario	1.8	1.1 – 2.9
A1T scenario	2.4	1.4 – 3.8
B2 scenario	2.4	1.4 – 3.8
A1B scenario	2.8	1.7 – 4.4
A2 scenario	3.4	2.0 – 5.4
A1FI scenario	4.0	2.4 – 6.4

Source: JICA Study Team

According to reports released by IMD (2012), increasing temperature trends of the order of 0.60°C during last 112 years have been observed over India. Changes temperatures have also been reported by Dash *et al.* (2009), Arora *et al.*(2005), De *et al.* (2005), Guhathakurta and Rajeevan (2008), MoEF (2010), Jones and Briffa (1992), Kothawale *et al.* (2010), Tyagi and Goswami (2009) and others. Long-term changes in surface temperature and precipitation in India were analyzed using observational records of IMD from 1951 to 2010. In this study, 282 stations shown in Figure 14.3.1 free from highly influence of urbanization and having continuous temperature records from 1951 onwards were selected to estimate long term temperature trends.

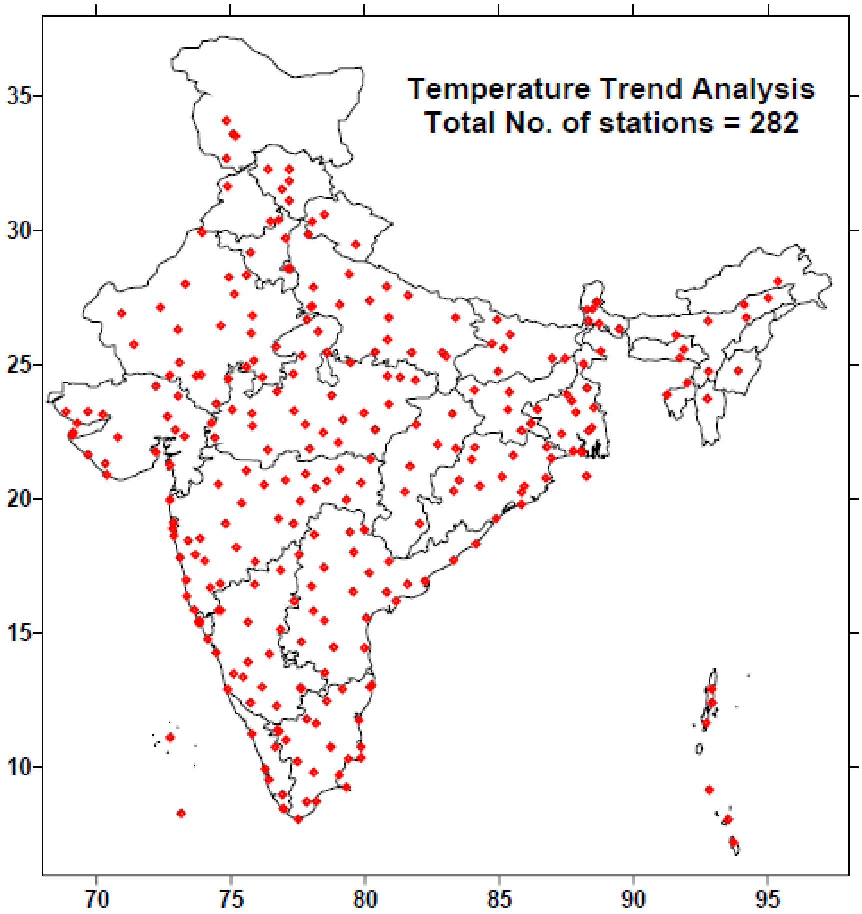


Figure 14.3.1 Distribution of 282 Surface Meteorological Stations used for State Level Temperature Trend Analysis for 1951-2010

The data collected from these stations was used to prepare the state level temperature time-series for 1951-2010. Based on this analysis, it was confirmed that annual mean temperatures have increased significantly over most states in India including the project location as shown in Figure 14.3.2.

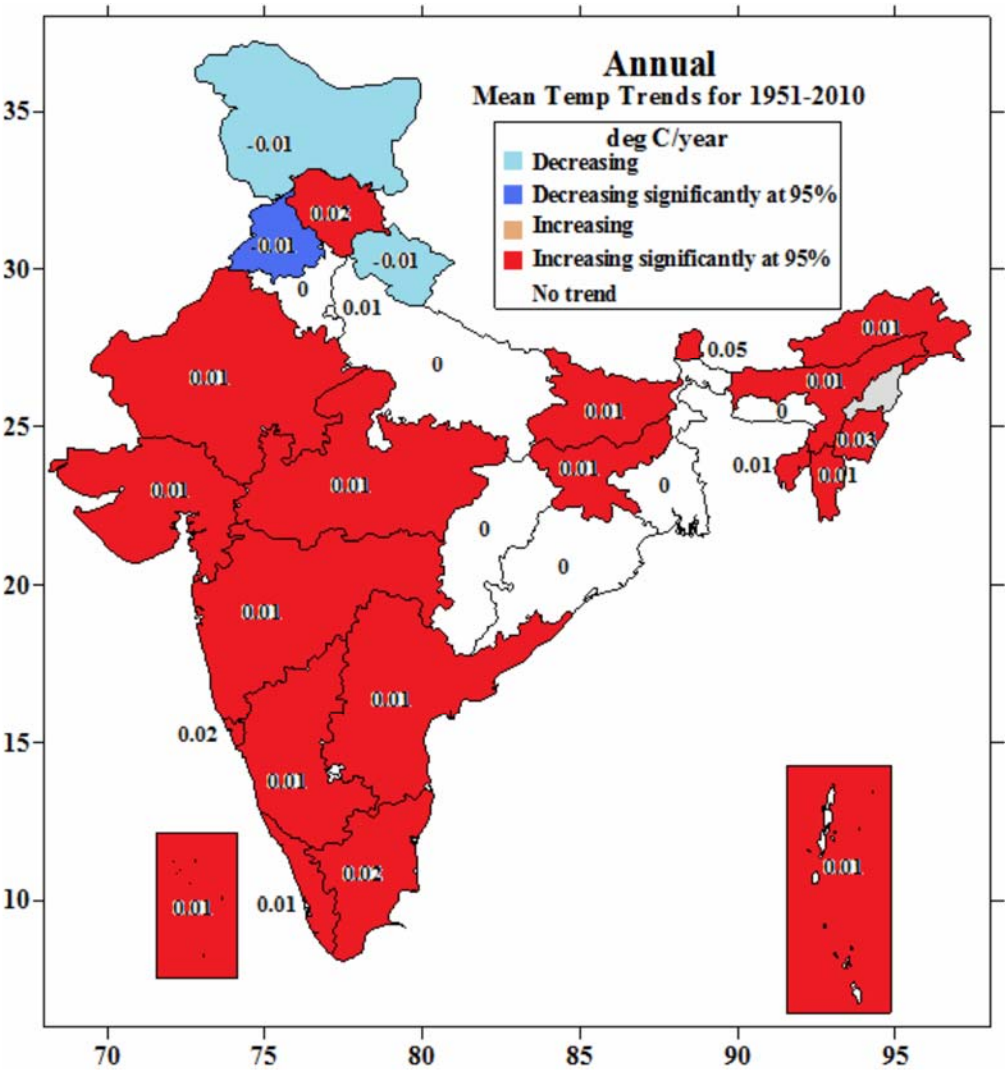


Figure 14.3.2 State Level Annual Mean Temperature Trends

As reported in India's Second National Communication to the United Nations Framework Convention on Climate Change, climate change scenarios have been developed using the second generation Hadley Centre Regional Model (HadRM2) and the IS92a future scenarios of increased GHG concentrations shown in Figure 14.3.3 The projections indicate that above 25°N latitude, the maximum temperature may rise by 2-4°C during the 2050s and in the northern region the increase in maximum temperature may exceed 4°C. The minimum temperature in the 2050s is expected to rise by 4°C all over India, with a further rise in temperature in the southern peninsula.

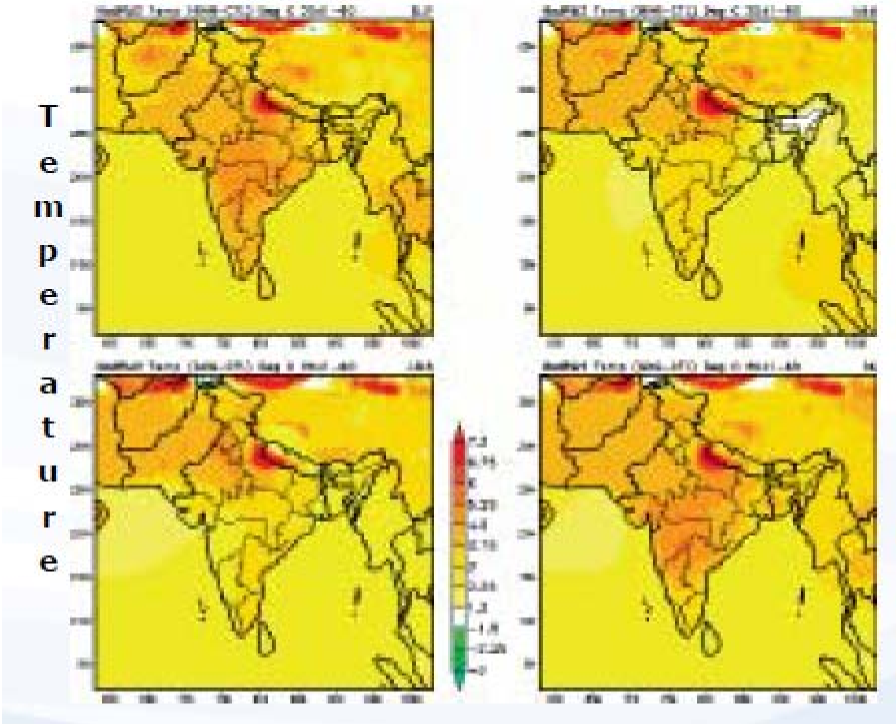


Figure 14.3.3 Seasonal Temperature Projections for the 2050s

Analysing the above, it is estimated that temperature will rise by 4^{o} in 50 years, Therefore , following the same trend, the temperature rise in 2120 (our target year) will be less than 10^{o}C.

14.3.2 Sea Level Rise

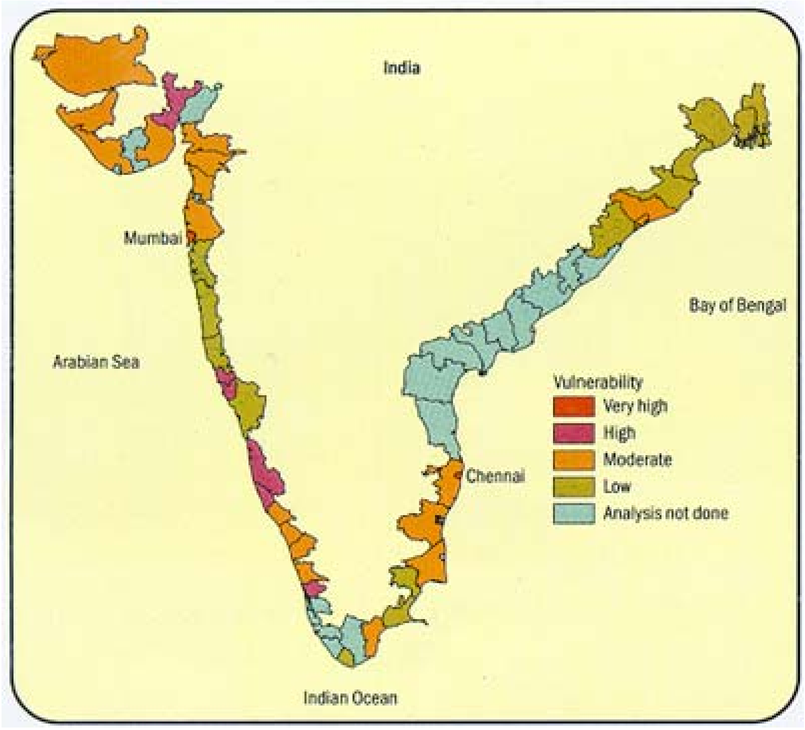
Sea level rise is also described by IPCC for 6 scenarios as shown in Table 14.3.2.

Table 14.3.2 Projected Global Average Sea Level Rise at the End of the 21st Century

Item	Scenarios					
	B1	A1T	B2	A1B	A2	A1FI
Sea Level Rise	0.18 – 0.38	0.20 – 0.45	0.20 – 0.43	0.21 – 0.48	0.23 – 0.51	0.26 – 0.59

According to the MoEF, the absence of protection, Asthana (1994) showed that a one metre rise in sea level will affect an area of 5763 km^2 and put 7.1 million people at risk. 83% of all damages will be because of land loss, but the extent of vulnerability will also depend upon physical exposure and the level of economic activity in the region. TERI (1996) developed a district-level ranking of vulnerability to one-metre sea level rise by constructing a weighted index shown in Figure 14.3.4. Based on this figure, the vulnerability to sea level rise of Mumbai in which our project is located is very high.

Vulnerability to one-metre sea level rise



Source: TERI 1996

Figure 14.3.4 Vulnerability to One-Meter Sea Level Rise

Based on the above, the sea level is expected to rise by 60cm in the most severe case.

14.3.3 Rainfall

According to the IMD, increase in heavy rainfall events and decrease in low and medium rainfall events (Goswami et al. 2006) over India have been observed while changes in rainfall and temperatures have also been reported by Dash et al. (2009), Arora et al. (2005), De et al. (2005), Guhathakurta and Rajeevan (2008), MoEF (2010), Jones and Briffa (1992), Kothawale et al. (2010), Tyagi and Goswami (2009) and others. Long-term changes in precipitation in India were analyzed using observational records of IMD from 1951 to 2010. In this study, 1451 stations (Figure 14.3.5) were selected to determine long term temperature trends.

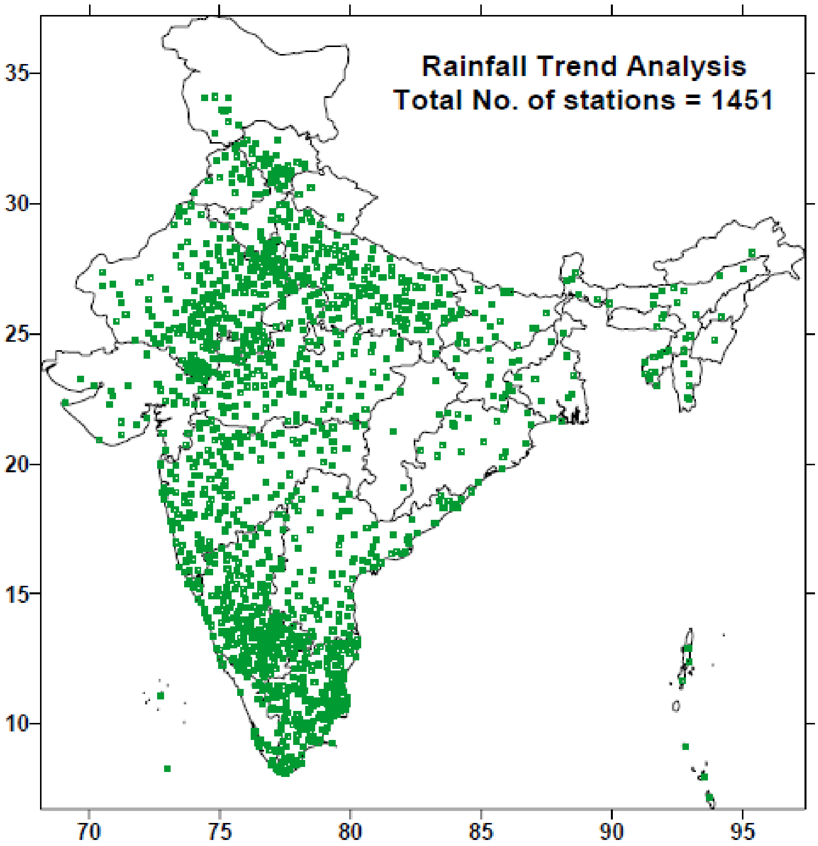


Figure 14.3.5 Distribution of 1451 Stations Used for State Level Rainfall Trend Analysis for 1951 -2010

The data collected from these stations was used to prepare the state level temperature time-series for 1951-2010 shown in Figure 14.3.6. Based on this analysis, it was confirmed that annual rainfall has decreased over some states in India including Maharashtra in which our project is located.

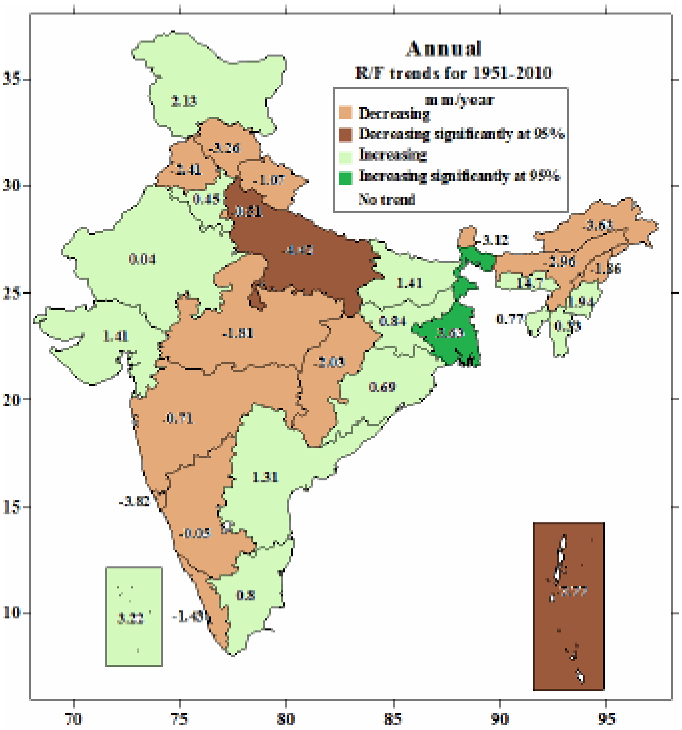


Figure 14.3.6 State Level Annual Trends

Climate change scenarios have also been developed using the second generation Hadley Centre Regional Model (HadRM2) and the IS92a future scenarios of increased GHG concentrations as shown in Figure 14.3.7. The projections indicate at an all-India level, little change in monsoon rainfall is projected up to the 2050s. However, there is an overall decrease in the number of rainy days over a major part of the country. This decrease is greater in the western and central parts (by more than 15 days), while near the Himalayan foothills (Uttaranchal) and in the Northeast the number of rainy days may increase by 5-10 days. Increase in rainy day intensity by 1-4 mm/day is expected all over India, except for small areas in the northwest where rainfall intensities are expected to decrease by 1 mm/day.

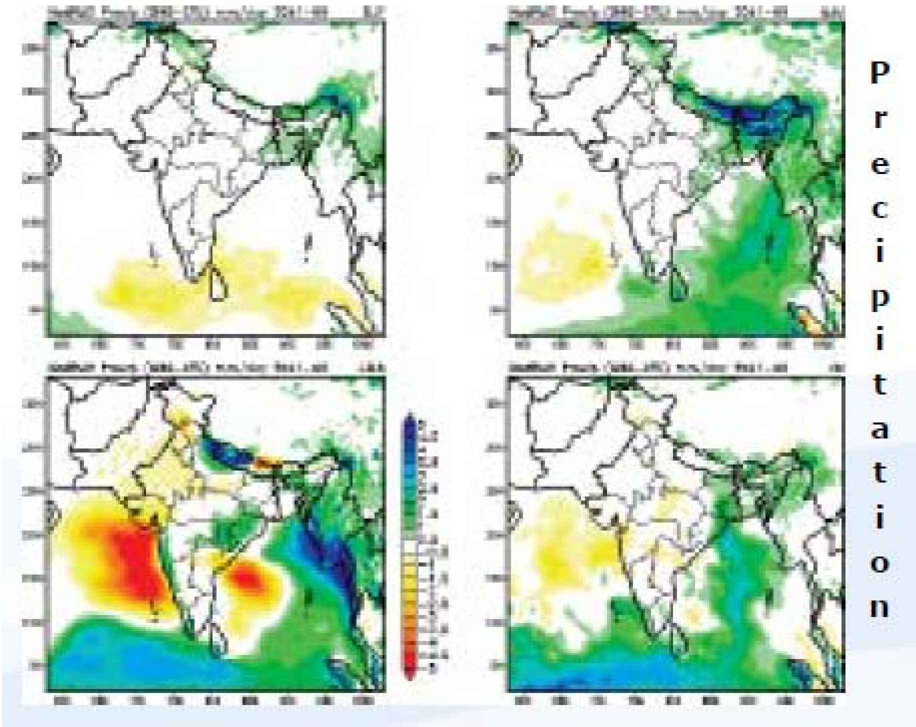


Figure 14.3.7 Seasonal Precipitation Projections for 2050s

Furthermore, hydrological modelling (using the SWAT model) of 12 river basins in India in combination with the outputs of the HadRM2 run on the IS92a scenario indicate that in the 2050s there is likely to be a general reduction in the quantity of available runoff with extreme water stress conditions in the western and south western river basins and rare water stress conditions in the river basins in central and eastern regions (Figure 14.3.8). The severity of droughts and intensity of floods in various parts of India are likely to increase by the 2050s.

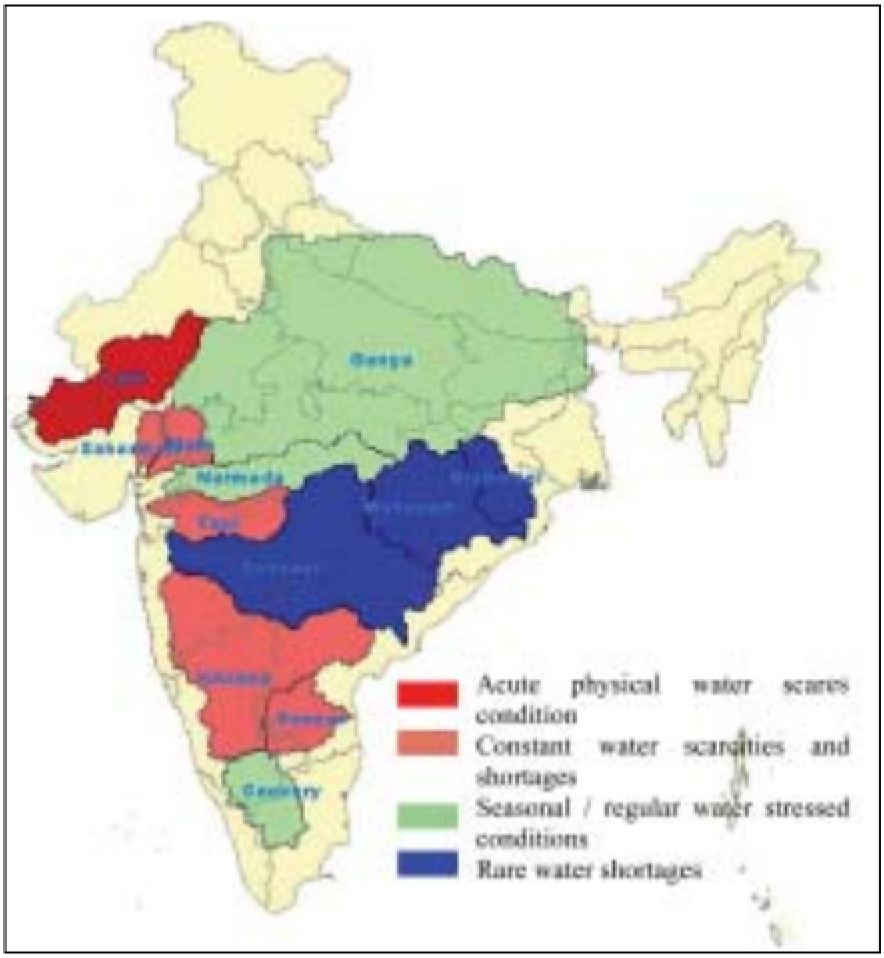


Figure 14.3.8 Projections of River Run Off in the 2050s for Major River Basins in India

Based on the above, it is projected that precipitation will decrease in the western side of India.

14.3.4 Wind Speed

The monsoon wind speed was used in the design of MTHL bridge. As discussed in section 14.3.3, little change in monsoon rainfall is projected up to the 1950s. Assuming this trend continues, it is unlikely that significant increase in monsoon wind speeds will occur. The likelihood of significant change in wind speed in the next 100 years is therefore extremely low.

14.3.5 Consideration of Mitigation Measures for Climate Change

(1) Contribution to Climate Change for MTHL

The affected area of sea level rise because of the climate changes and the large cyclones is the lowland area at the start point and the end point along the Vashi Bridge. This lowland area is the most vulnerable area in connecting Mumbai and Navi Mumbai.

The MTHL which is constructed on the sea between Mumbai and Navi Mumbai is the elevated road. The MTHL have enough navigation clearance to pass under the MTHL by the fishing boats and the large ships. The MTHL does not receive the affected sea level rise because of climate changes and large cyclones. Therefore the passengers can use the MTHL without affected sea level rise.

(2) Disadvantage and Mitigation Measure of Climate Change

There are two points of view of the vulnerable from climate change.

- The vulnerable of the viaducts by itself
- The vulnerable of the viaducts from changes in the natural environment

The MTHL is designed by design standard in which design life is 100 years. Therefore the viaducts by itself is not vulnerable. On the other hand, there are below factor of changes in the natural environment for the MTHL.

- Temperature rise
- Sea level rise
- Increase for rainfall and storm
- Increase for wind speed
- Storm surge, tsunami

1) Affected MTHL and Mitigation Measure by Temperature Rise

The maximum temperature rise between the design life of bridge is under 10 degrees Celsius. The almost of all viaduct part in MTHL is the concrete brigde. The concrete bridge is generally less susceptible to the effects from temperature. The steel bridges are applied some special part. The steel bridge is generally susceptible to the effects from temperature. Therefore the amount of movement of expansion joint is a little bit larger. The expansion joint is replaced if the temperature rised.

2) Affected MTHL and Mitigation Measure by Sea Level Rise

The sea level rise is affected through under the MTHL by fishing boats and large ships. It is assumed the sea level rise is 60 cm, however the navigation clearance has to pass under the MTHL by the fishing boats and large ship. For the conclusion, the mitigation measure in the MTHL does not need sea level rise.

3) Affected MTHL and Mitigation Measure by Increase for Rainfall and Storm

It is assumed the rainfall is decreased around Mumbai area. The mitigation measure in the MTHL does not need the increase for rainfall.

The MTHL is installed the CCTVs and the meteorological equipements because the MTHL which is high-standard road is controlled to access. When the rainfall is harder, the CCTVs and the meteorological tell the some information to the traffic control center. Then the traffic control center tells the passengers the information of speed limits and road closed etc. through the VMS. Therefore the MTHL can be made the countermeasures for harder rainfall.

4) Affected MTHL and Mitigation Measure by Increase for Wind Speed

It is assumed the wind speed is not increased around Munbai area because the rainfall is decreased around this area. The cyclones sometimes come to western Mumbai but the MTHL has the countermeasures to the passengers.

The steel bridges make the vibration cause of the wind. The countermeasure for hard wind is to installe the fairing at the end of girder and/or the vibration control devices in the girder.

(3) Mitigation Measure by Other Factor

- The exhaust gas is decreased because of shortening travel time from Sewri to Chilre
- The exhaust gas is decreased because the traffic jam is resolved in Mumbai indirectly

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15. CONCLUSION AND RECOMMENDATION

15.1 Conclusions

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 environment and social consideration. 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 adverse impacts of both environment and resettlement including the flamingos and the World Heritage site of the Elephanta Island. This is an only alignment that enables to avoid the land occupancy of MbPT port yard and facility with keeping, its function as highway at 100km/h of design speed.
- As per the result of the future traffic demand forecast, construction of 6 lane (three lanes each bound) MTHL shall be constructed in single phase is justified.
- While Pre-stressed Concrete box girder superstructure is suitable for 50 m spans in portion with no obligatory spans, 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 span. 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 Bridge portion 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.

15.2 Recommendations

The recommendations of the Survey are as follows;

- It is recommended that Project Management Office should be established within MMRDA before commencement of the Project implementation in order to clarify the responsibility of the Project implementation and deal with arrangement and coordination activities with a large number of various stakeholders.
- It is necessary for MMRDA to complete land acquisition within the ROW, compensation to the Project affected people and also acquiring the land required for casting yard before commencement of the construction works. This would enable MMRDA to hand over the lands within ROW to the contractor after conclusion of the work contract and to adhere to the designated construction schedule.
- It is recommended that the project be implemented on the Design-Built basis. The Design-Build method enables the contractor to carry out the detailed design and construction preparation simultaneously thus resulting into earlier commencement of the work. Secondly, MMRDA has experience of implementation of the projects on Design-Built method (including the metro project). However, it is necessary to consider the risk shares between the client and the contractor as the Design-Built method may result into higher bid price as no detailed design are available at the bidding stage.
- It is recommended to separate the Project into three packages, two on the marine section and one on the land section at the Navi Mumbai side, considering availability of construction yards, accessbility to the construction site on the sea and avoidance of inconsistency of the viaduct design.
- Various provisions against the severe-saline environment, through which the bridge passes, shall be made in the technical specifications in the bid documents. These would include use of anti-corrosive coating to the rebars and Prestressing Cables for prestressed concrete bridge, thick anti-corrosive coat for steel bridge etc. As the project implementation would involve Technology Transfer for maintenance method for steel bridge on the sea, it is recommended to provide for such scheme of Technology Transfer by JICA before starting the operation of MTHL.
- Pipelines carrying the fuel have been identified crossing the project alignment. It is very important for MMRDA and the Contractor to identify the exact location of the pipelines so as to avoid damages to the pipelines during the foundation work.
- According the traffic demand forecast, 6 booths are required to deal with toll collection at Shivaji Nagar IC in 2042. Since the present widths of ROW can only accommodate the space up to four booths, it is necessary to consider shifting the toll collection place according to the actual increase in traffic volume in future.

- As MTHL is expected to implement with the help of Japanese ODA loan, it is important to decide appropriate toll fees to attract vehicles on the link as well as to ensure adequate revenue towards repayment of loan and the necessary operation and maintenance expenses.
- Although operation and maintenance for MTHL is planned to be entrusted to concessionaire after completion, MMRDA is full responsibility of operation and maintenance of MTHL. Furthermore, in case that traffic demand is less than expected, the financial support should be considered from State Government.
- MTHL is expected to be a landmark project in Mumbai & India for its landscape. In order to develop the flamingo habitat, it is recommended to develop the coastal areas at both ends as park or bird-watching place.