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MMRDA
Mumbai, India

Techno-Economic Feasibility and Detailed Project Report for Thane-Bhiwandi-Kalyan

Final Detailed Project Report

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Final Detailed Project Report

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ABBREVIATIONS AND ACRONYMS

ADB: Asian Development Bank
ADB: Asian Development Bank
AFC: Automatic Fare Collection System
AFC: Automated Fare Collection
AGT: Automated Guideway Transit
AON: All: Or: Nothing Assignment
ASS: Auxiliary sub: stations
ATO: Automatic Train Operation
ATP: Automatic Train Protection
ATS: Automatic Train Supervision
BCR: Blast Containment Ring
BIS: Bureau of Indian Standards
BMC: Brihan-Mumbai Municipal Corporation
BMC: Brihan Mumbai Municipal Corporation
BNMC: Bhiwandi: Nizampur Municipal Corporation
BOD: Biochemical Oxygen Demand
BOT: Build Operate & Transfer
BPSM: Bullet Proof Steel Morcha
BRT: Bus Rapid Transit

BSB: Bomb Suppression Blanket
BSNA: Bhiwandi Surrounding Notified Area
CATC: Continuous Automatic Train Control System
CBI: Computer Based Interlocking
CBTC: Communication based Train Control System
CBTC: Communications Based Train Report
CCTV: Closed Circuit Television
CD: Custom Duty
CPCB: Central Pollution Control Board
CTS: Comprehensive Transportation Study
CWR: Continuous Welded Rails
DMRC: Delhi Metro Rail Corporation
DPR: Detail Project Report
DPR: Detailed Project Report
DTO: Driverless Train Operation
DUE: Deterministic User Equilibrium
ED: Excise Duty
EIA: Environmental Impact Assessment
EMC: Electromagnetic Compatibility
EMP: Environmental Management Plan
EPA: Environment Protection Act
FIRR: Financial Internal Rate of Return
FOTS: Fibre Optic System
G.C: General Consultant
GLT: Guided Light Transit
GoA: Grades of Automation
GOI: Government of India
HHMD: Hand Held Metal Detectors
HR: Hard Rock
IDBI: Industrial Development Bank of India
IIFCL: Infrastructure Funding Organizations
IMD: Indian Meteorological Department
JICA: Japan International Cooperation Agency
KDMC: Kalyan Dombivali Municipal Corporation
KDMT: Kalyan Dombivali Municipal Transport
LRT: Light Rail Transit
LWR: Long Welded Rails IRST:
MDFMD: Multi: zone Door Frame Metal Detector
MDFMD: Multi: zone Door Frame Metal Detector
MIDC: Maharashtra Industrial Development Corporation
MMC: Multi Modal Corridor
MMR: Mumbai Metropolitan Region
MMRC: Mumbai Metro Rail Corporation

MMRDA: Mumbai Metropolitan Region Development Authority
MMRDA: Mumbai Metropolitan Region Development Authority
MoEF: Ministry of Environment and Forest
MoUD: Ministry of Urban Development
MPCB: Maharashtra Pollution Control Board
MPCB: Maharashtra Pollution control board
MRTS: Mass Rapid Transit System
MRV: Medium Rail Vehicles
MSA: Method of Successive Averages
MSRTC: Maharashtra State Road Transport Corporation
MVA: Motor Vehicle Act
NMS: Network Management System
Nox: Oxides of Nitrogen
O&M: Operation & Maintenance
O&M: operation & maintenance
OCC: Operation Control Centre
OPC: Overhead Protection Cable
PCU: Passenger Car Unit (PCU)
PHPD: Projected Peak hour per direction
PM10: Respirable Particulated Matter
POM: Passenger Operated Machine
PRT: Personal Rapid Transit
ROD: Revenue Opening Date
ROD: Revenue opening Date
RPM: Respirable Particulate Matter
RRT: Rail Rapid Transit
SAR: Sodium Adsorption Ratio
SCADA: Supervisory Control and Data Acquisition
SO: System Optimum Assignment
SOx: Oxides of Sulphur
SPM: Suspended Particulated Matter
SPV: Special Purpose Vehicle
STEM: Shahad Temghar Water Authority
STO: Semi: Automatic Train Operation
SUE: Stochastic User Equilibrium
TAZ: Traffic Analysis Zone
TBK: Thane Bhiwandi Kalyan
TMC: Thane Municipal Corporation
TMT: Thane Municipal Transport
UE: User Equilibrium
UIC: Universal Item Code
ULB: Urban Local Bodies
UTO: Unattended Train Operation

VAG: Versova: Andheri: Ghatkopar
VAT: Value Added Tax
VGF: Viability Gap Funding
WR: Weathered Rock

REPORT
TECHNO-ECONOMIC FEASIBILITY AND DETAILED PROJECT REPORT FOR THANE-BHIWANDI-KALYAN
DETAILED PROJECT REPORT

1 INTRODUCTION

1.1 BACKGROUND

Government of Maharashtra (GoM) and Mumbai Metropolitan Region Development Authority (MMRDA) intend to improve transport scenario in the Mumbai Metropolitan Region (MMR). MMRDA has completed Comprehensive Transportation Study (CTS) for MMR that has identified transport infrastructure for horizon year 2031. There are various ideas of CTS which are recommended of which few are being implemented in phased manner.

MMRDA has carried out Technical Feasibility Study on Thane - Bhiwandi – Kalyan monorail (approx. 25 kms) corridor in December, 2011 which is displayed in Figure 1.1. The CTS data used for the estimating the ridership is more than a decade old. As per Feasibility study, Thane (Kapurbawdi) -Bhiwandi- Kalyan Monorail corridor may not turn out to be economically viable on fare box, advertisement and other revenues.

MMRDA entrusted D'Appolonia S.p.A. and TATA Consulting Engineers Limited to carryout fresh travel demand estimation for Thane (North), Bhiwandi, Kalyan sub region and to prepare Techno-Economic Feasibility and Detailed Project Report (DPR) for appropriate MRT system for the Thane-Bhiwandi-Kalyan sub region.

A joint site visit followed by kickoff meeting with MMRDA was held on 18th March 2015, based on which a general understanding of the assignment was developed which is being submitted in the form of this inception report. This inception report would form the basis of the techno-economic feasibility report.

1.2 SCOPE AND OBJECTIVE OF STUDY

Main objective of the study is to plan and conduct essential technical studies to establish techno-economic feasibility of a Mass Rapid Transit System on the Thane Bhiwandi Kalyan corridor. This objective is essential to prepare a techno-economic feasibility and Detailed Project Report for Thane-Bhiwandi-Kalyan for selected Mass Rapid Transit System. The scope of the services includes the following:

Collection of data from secondary sources from ULB's, TMC, BNMC, KDMC, MMRDA and other State Department;

Review the current Transport situation in order to establish the existing condition and capacity of the public transport system;

Identify various options of alignment taking into consideration the development of Thane-Bhiwandi-Kalyan sub-region in the last decade. The alignment details would be discussed and finalized in consultation with MMRDA;

Traffic surveys, OD survey, interview with potential transit users including Stated Preference Survey;

Travel demand model for sub-region considering, future population, land use, employment & transport infrastructure;

Topographic survey, Geo-technical investigation (@ 2 boreholes per km);

Preparation of geometric alignment and land requirement;

Alternative analysis and planning of feeder network including pedestrian, IPT, NMT and Parking in catchment area;

Recommend most suitable system based on worldwide experience, capacity, engineering aspects and technology (rolling stock, power supply system, signaling and telecom system and other systems), relative costs of alternative systems (capital, operating &maintenance), Right of way, stations, stabling and maintenance depots, and interchanges etc.;
Operation Plan & Service details;
Passenger dispersal and integration facilities with other modes of public transport;
Capital Cost estimates of the project and operation & maintenance cost, fixed and variable component & fare integration collection methodology;
Carryout Economic and financial analysis and recommend appropriate implementation strategies;
Environment Impact Assessment;
Transit Oriented Development (TOD) for the influence zone;
Any other aspect which require for the development of system.

1.3 PROFILE OF MUMBAI METROPOLITAN AREA

Mumbai, the capital city of Maharashtra also termed as the economic capital of India, is the ninth most populous city in India with an estimated Urban Agglomeration of 20.7 million (census 2011). With the promising multiple business opportunities and the potential to offer a higher standard of living, the city of Mumbai attract migrants from all over India; making Mumbai a common hub for many communities and cultures from all over the country.

Mumbai Metropolitan Region (MMR) is a metropolitan area consisting of the metropolitan area of Mumbai and its surrounding dependent towns in Maharashtra. It has an area of around 4,355 sq. km (census 2011), and is considered as one of the top ten most populated urban places in the world. Different public mode of transport like Mumbai Suburban Railway system and a large network of roads are used to link it with the city of Mumbai.

Developing over a period of about 20 years, MMR comprises Mumbai city district, Mumbai suburban district, parts of Thane district (Thane, Bhiwandi, Kalyan and Ulhasnagar tehsils, Vasai tehsil), and parts of Raigad district (Uran tehsil, Panvel, Karjat, Khalapur, Pen and Alibaug tehsil). It consists of 7 municipal corporations and 15 smaller municipal councils. The entire area is overseen by the Mumbai Metropolitan Region Development Authority (MMRDA), a Maharashtra State Government organization in charge of town planning, development, transportation and housing in the region. Though Mumbai Suburban Railway system has been supporting the emerging public transport needs, trains are overcrowded during peak hours, with trains of capacity 1,700 passengers, actually carrying around 4,500 passengers at peak hours (Environment and urbanization. v. 14, no. 1. International Institute for Environment and Development. April 2002.). With immensely increasing population in Mumbai, it still continues to struggle with traffic congestion even though 88% of its commuters travel by public transport.

In a brief during the studies conducted during CTS comprise of different surveys which are used to understand the travel characteristics in MMR. It mainly focused on internal and external travel pattern and demand, terminal studies, road network and public transport. Table 2 stipulates the trend followed during past few decades in the public transport ridership. It can be observed that there is an increase in the trips per day for Rail when compared to Bus in 2001. It is also found that there is a constant growth rate during the past decades for the Rail transport where as a drastic decline in growth rate for Bus transport was observed. This condition is because of many factors like fare, comfort, and ease of transport and availability.

Table 1.1: Public Transport Ridership Trend

Mode	Trips per Day				% Growth per year		
	1981	1991	2001	2014	1981-91	1991-01	2001-2014
Rail	39.76	47.73	57.24	75.00	1.8	1.8	2.4%
Bus	48.51	60.22	56.04	40.00	2.2	-0.7	-2.2%
	88.27	107.95	113.28	115	2	0.5	0.1

Source: TEFS Report

This clearly persists to still improve the suburban railway facilities and makes an initiative to implement MRTS like monorail/metro to facilitate the emerging public transport needs. This would not only favour the daily commuters but also reduce the likelihood to go for private ridership. This would further aid in reducing the air pollution due to fuel emission from various motorized vehicles.

Traffic demand and Assessment Report for the corridor was submitted in September 2015. During the meeting held on 2nd September 2015 along with MMRDA officials, the consultants had recommended to start the corridor from Thane Railway Station to Kalyan via Bhiwandi. However, during the meeting it was recommended to start the corridor from Kapurbawadi instead of Thane Railway Station since Thane – Kasarvadavali Metro is proposed on the same route alignment. Consequently, this report details the alignment between Kapurbawadi junction to Kalyan railway station. In the demand assessment report it was also concluded that, according to the simulated ridership levels provided by preliminary analysis (especially for 2031 scenarios), the most appropriate MRTS seems to be a metro system since it can carry traffic densities exceeding 30,000 PHPDT.

Three alignment corridors were recognized connecting the Thane – Bhiwandi- Kalyan regions. The final option-I was chosen based on different parameters considered (length, neighborhoods covered, land acquisition, Right of Way available and surrounding land use). The projected ridership from demand assessment report is ~ 20,000 PHPDT in horizon year 2021 and ~ 30,000 PHPDT in horizon year 2031.

1.4 STUDY AREA PROFILE

The study area is bounded by the administrative boundaries of Thane, Bhiwandi-Nizampur and Kalyan-Dombivali Municipal Corporations. The proposed MRTS corridor passes through these three municipal corporations and is 23.6 km in length. For the purposes of better understanding the project corridor and its uniqueness, the entire corridor has been split into six homogeneous sections:

Section 1: Kapurbawadi – Kasheli; majority of this section lies in Thane Municipal Corporation area and rest in Bhiwandi-Nizampur Municipal Corporation area

Section 2: Kasheli – Kalher – Purna; this section lies in Bhiwandi-Nizampur Municipal Corporation area

Section 3: Purna – Anjurphata – Narpoli; this section lies in Bhiwandi-Nizampur Municipal Corporation area

Section 4: Narpoli – Bhiwandi – Gopal Nagar – Shanti Nagar; this section lies in Bhiwandi-Nizampur Municipal Corporation area

Section 5: Shanti Nagar – Bhiwandi Bypass – Kongaon; this section lies in Bhiwandi-Nizampur Municipal Corporation area

Section 6: Kongaon – Durgadi – Shivaji Chowk: this section lies partly in Bhiwandi-Nizampur Municipal Corporation area while majority lies in Kalyan-Dombivali Municipal Corporation area.

The six sections of the proposed corridor for Thane-Bhiwandi-Kalyan are shown in Figure 1.1.

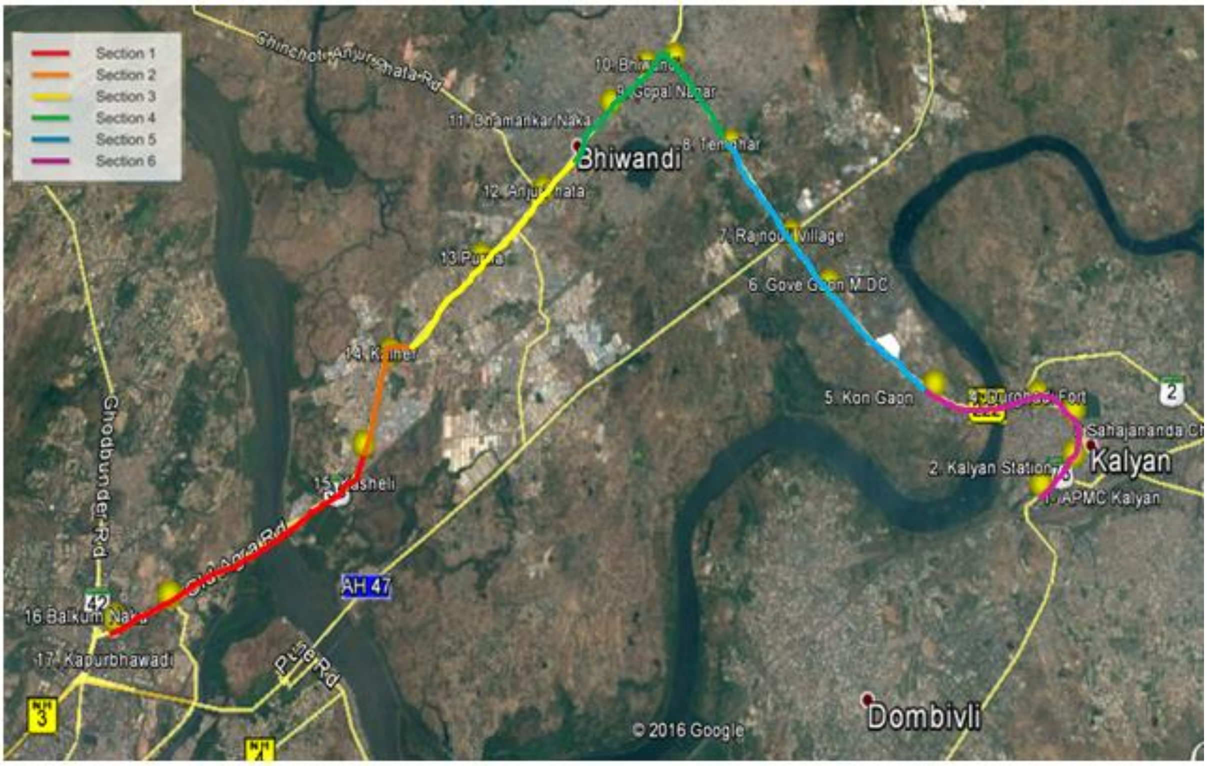

Figure 1.1: Six Sections of the proposed MRTS Corridor

The land use of the study area is shown in Figure 1.2. The figure depicts the land use of all the three municipal corporations namely Thane, Bhiwandi-Nizampur and Kalyan-Dombivali, through which the study corridor passes through.

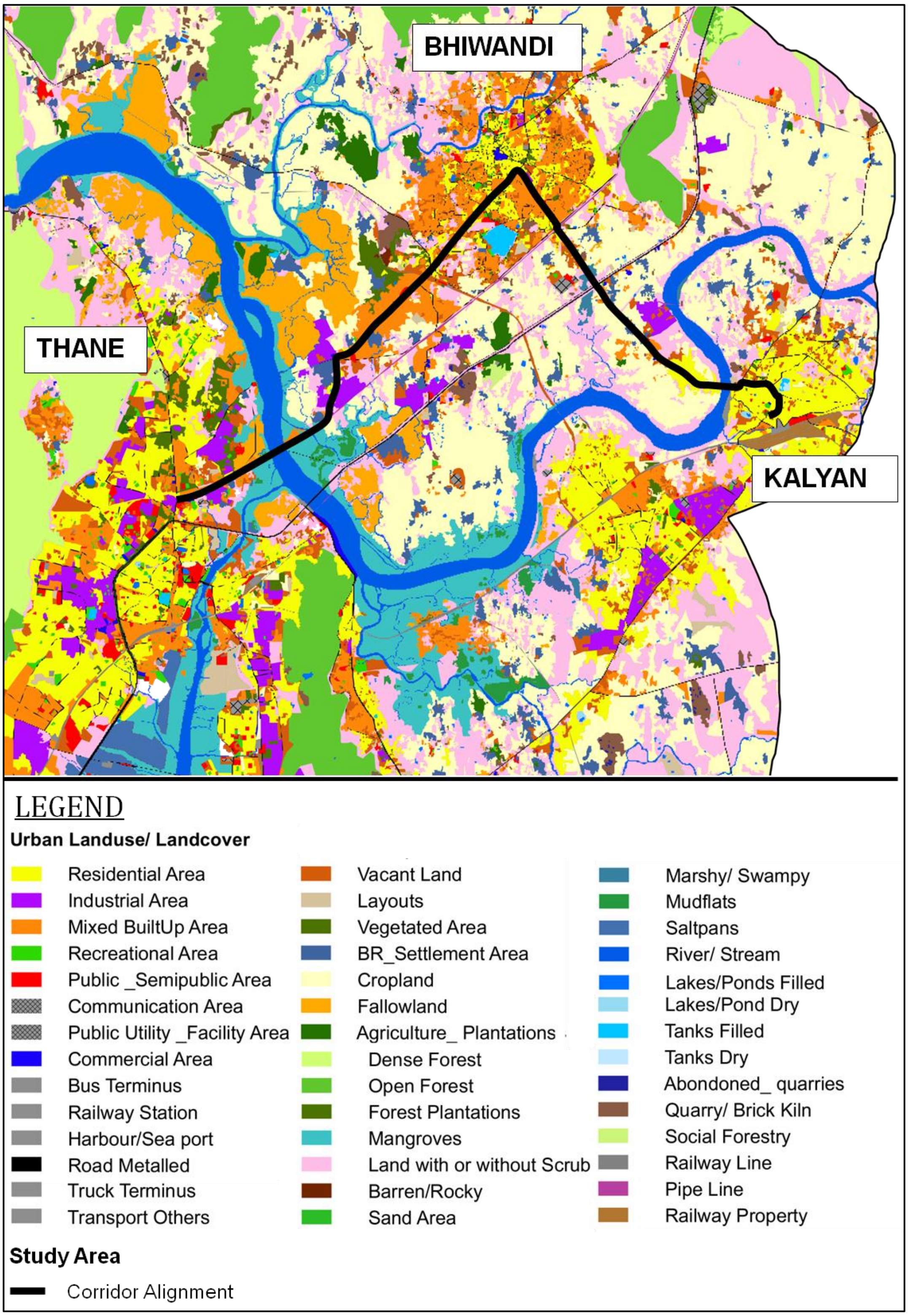

Figure 1.2: Study Area Land Use

The section of the corridor passing through Thane Municipal Corporation has mixed use development like Srinagar Colony & Ganesh Bawadi and industrial areas like Kolshet Industrial Area, Tolia Group of Industries, JIK Industries Ltd., Gayatri Industries, etc. lying on both sides of the corridor. There are also residential areas like Jawahar Nagar, Chirak Nagar, Sainath Nagar, Samata Nagar and Kapurbawdi in proximity to the starting chainage of the corridor. Lake City Mall and Viviana Mall also lie near to this section. Offices like Tata Motors Finance Ltd., Tata Consultancy Services Ltd., SSR Realty Ventures Pvt. Ltd., Thane One Corporate IT Park, Yashmaag Machines Works Pvt. Ltd., etc. also lie in the vicinity of this section of the corridor.

The section of the corridor passing through Bhiwandi-Nizampur Municipal Corporation has a lot of mixed use and residential areas in its proximity. Some of these areas are Kopar, Rahnal, Anjurphata, Oswalwadi, Balaji Nagar, Samad Nagar, Gopal Nagar, Nehru Nagar, Shastri Nagar, Ashok Nagar, Kaneri, etc. Since these areas are mostly mixed use development, so they attract many laborers from nearby places. Education institutions like Matoshri Ushatai Jadhav Institute of Management Studies & Research Centre, Samadiya College of Arts & Commerce, Mahendra Laxman Mhatre Degree College, Aqsa Women's Degree College and B.N.N. College also lies near to this section and will attract many student commuters. There are few industries lying nearby to this section like Madhu Tex Industries, BIDCO Industries, Dinesh Industries, Nutan Polyspin Industries, etc.

The section of the corridor passing through Kalyan-Dombivali Municipal Corporation has mostly residential areas lying in its proximity. These areas include Kalyan West, Swanand Nagar, Manik Colony, Surganda Society, Shubh Milan Society, Ekveera Nagar, Tilak Nagar, etc. There are also few institutional areas in the vicinity of the corridor like National Urdu Arts, Science & Commerce Junior College, Laxman Devram Sonawane College of Arts & Commerce, Kalyan High School & Junior College, Achievers College Arts & Commerce, Gurunanak Junior College of Commerce, etc. There are two industries namely KB Industries and Atlas Steel Industries lying near the corridor. One of the most important areas that this section connects to is the Kalyan Junction Railway Station. There are also shopping centres lying near this section like Bail Bazaar Shopping Centre, Zojwal Shopping Centre, Mahavir Shopping Complex, D Mart Kalyan, Panjwani Plaza, etc.

1.4.1 Thane

The city of thane, part of Mumbai Metropolitan Region, is one of the major industrial towns. It is one of the fast growing areas in the region. High industrialisation and its proximity to Mumbai led to this fast paced growth. It is bounded by Vasai Creek on the north and east side, while Sanjay Gandhi National Park limits it boundaries on the west side. The southern part of Thane is connected to Mumbai via NH 3. The city is located on latitude 720 50' North and longitude 19010' East. Thane is spread over an area of 147 km2. There are a total of 116 wards in Thane city. Large scale developments have also taken place in Kalwa and Mumbra, near to Thane; although much of it is unauthorised. These areas have been experiencing tremendous growth due to their proximity to rail and road corridors. The emergence of these areas as new centres of urban growth has already been recognised in the Draft Development Plan of Thane.

The demographic characteristics of thane city are presented in Table 1.2.

Table 1.2: Demographic Characteristics of Thane (2011)

Population	18,41,488
Households	4,35,341
Sex Ratio	888 per 1000 males
Literacy Rate	79%
Literacy Rate - Males	82%
Literacy Rate - Females	76%
Population (>6 years of age)	16,31,609
Sex Ratio (>6 years of age)	885 per 1000 males
Main Worker	6,49,128
Main Worker (Male)	5,15,048
Main Worker (Female)	1,34,080
Marginal Worker	50,107
Marginal Worker (Male)	31,138
Marginal Worker (Female)	18,969

The city is well connected by an extensive network of roads and railways. The Central Railway's main north -south corridor passes through the city providing daily commuter services to Mumbai as well as long distance train services. National Highway 3 and State Highway 42 & 35 pass through the city. Thane is accessible by buses of B.E.S.T, T.M.T, NMMT, KDMT, MBMT and MSRTC. Commuters can also avail options of some private buses, auto-rickshaws and taxis.

1.4.2 Bhiwandi-Nizampur

Bhiwandi, a suburb of Mumbai, is located at 19.29°N and 73.06°E. The Vasai creek / Ulhas River bound the city from the western and southern side. There are many hills which surround the city adding to its scenic beauty. It is connected to Thane and Mumbai via SH 35 and NH 3. The economy of Bhiwandi-Nizampur is mainly dependent on its power loom industry. It is the second largest power loom centre in the country after Surat city power loom. The bloom of cloth oil and looms attracts a lot of workers from various states to come and find suitable jobs. The power loom industry is the main reason for huge number of floating population. It is the richest city in Thane District and also has become city with the highest paid octroi with the largest godown in Asia.

The demographic characteristics of thane city are presented in Table 1.3.

Table 1.3: Demographic Characteristics of Bhiwandi-Nizampur (2011)

Population	7,09,665
Households	1,40,035
Sex Ratio	709 per 1000 males
Literacy Rate	69%
Literacy Rate - Males	73%
Literacy Rate - Females	64%
Population (>6 years of age)	6,17,840
Sex Ratio (>6 years of age)	678 per 1000 males
Main Worker	2,69,087
Main Worker (Male)	2,43,067
Main Worker (Female)	26,020
Marginal Worker	20,741
Marginal Worker (Male)	15,073
Marginal Worker (Female)	5,668

At present, there are no intra city bus services within Bhiwandi. Commuters travel within the city via auto rickshaws and taxis apart from private vehicles. TMT, KDMT and MSRTC runs bus services from the city to various other cities in the state as well as neighbouring states. The Bhiwandi Nizampur state transport depot is located on the NH 3. Buses run every half hour to nearby depots like Mumbai-Central, Thane, Kalyan, Vasai, Wada and Borivli, Nashik, Shirdi, Aurangabad, Pune etc. The city depends on Mumbai for all flight trips via Chhatrapati Shivaji International Airport, which is at a distance of approximately 40 km.

1.4.3 Kalyan-Dombivli

Kalyan, part of Thane district, is bounded on the north side by Ulhas river. Kalyan along with its neighbouring township of Dombivali, together, form the Kalyan Dombivali Municipal Corporation (KDMC). It is a part of the Konkan region in the state of Maharashtra. It lies approximately 48 km to the north-east of Mumbai. Overcrowding in Mumbai and incentives from the government to develop areas outside of Mumbai has attracted industrial business as well as industrial employees to Kalyan. Kalyan Junction is one of the important railway stations in Maharashtra for suburban travel as well as for long distance trains. There is a large industrial complex, on the eastern side of the city, where electrical equipment, rayon, and dyes and other chemicals are manufactured. There are also a large number of textile-based cottage industries.

The demographic characteristics of thane city are presented in Table 1.4.

Table 1.4: Demographic characteristics of Kalyan-Dombivali (2011)

Population	12,47,327
Households	3,02,735
Sex Ratio	920 per 1000 males
Literacy Rate	82%
Literacy Rate - Males	85%
Literacy Rate - Females	80%
Population (>6 years of age)	11,26,205
Sex Ratio (>6 years of age)	922 per 1000 males
Main Worker	4,40,991
Main Worker (Male)	3,45,060
Main Worker (Female)	95,931
Marginal Worker	28,315
Marginal Worker (Male)	16,850
Marginal Worker (Female)	11,465

Majority of commuters in Kalyan use auto-rickshaw for their daily travel needs. Kalyan Dombivali Municipal Transport (KDMT) runs its bus services within the city and to neighbouring villages. Significant traffic has increased in the past few years in the city. This has led to traffic congestion, mostly owing to large heavy vehicles passing through the city.

1.5 PREVIOUS STUDY

Based on the study conducted by the LEA International Limited, Canada in 2008.The study has been based on the extensive data collected by randomly selected 66,000 houses scattered through the MMR region, the OD Surveys and classified volume counts at outer cordon locations, suburban's rail passenger survey, IPT (intermediate public transport) auto and taxi survey, bus terminal surveys, parking survey, speed flow studies and workplace based survey. With the survey report the following proposal has been made for the development of the Mumbai metropolitan region (MMR). These are the modification of suburban railway station areas, new developments of the metro station areas and constructions of interchange of freeways have been proposed. About 107 stations are proposed for commercial developments in case of sub urban rail system from the period of 2016- 2031. The sub-urban railways station has been divided into category based on area, size, commuter volume and basic cost of station development. Extensive network of mass rapid transit system has been proposed in the region in the form of ground and elevated corridors including the Island city, Western and Eastern suburbs and the rest of the region. The Metro offers extensive potential for commercial developments along the corridors and over the stations. All the proposed corridors in the island city are of underground corridors type while the corridor in the suburbs and extended region are of elevated and at grade type. A number of freeways have also been proposed as a part of part of the transport network for the MMR. The freeways are green field projects. Three types of interchanges have been designed based on the types of links intersecting at each point. These are arterial to arterial intersection, arterial to freeway intersection and freeway to freeway intersection. The region is divided into six zones – south Mumbai, central Mumbai, Eastern Mumbai, Western Suburbs, Navi Mumbai and rest of MMR based of land availability for developments. A total of 157 interchange has been proposed for the development on the basis of land availability in the region.

1.6 NEED FOR STUDY

Thane and Kalyan are major trip generating locations in Mumbai Metropolitan Region (MMR). Considerable population of working class is living in Thane and Kalyan. Bhiwandi is a hub for warehouses and small industries, which leads into major trip attraction zone. Though in terms of time based mobility and accessibility, there is lack of connectivity between them. Secondly, besides having railway stations at Thane and Kalyan, most of the time suburban rails have passenger volume which is far more than the crush load and hence causes high level of discomfort to the commuters. In light of above, it is necessary to review the status of public transportation in Thane, Bhiwandi and Kalyan.

2 TRAFFIC DEMAND ANALYSIS

This chapter covers the transport demand projections of Thane Bhiwandi Kalyan corridor.

2.1 COLLECTION OF THE DATA

The starting data used for modelling the network of Thane, Bhiwandi and Kalyan region are drawn from the Comprehensive Transport Study (CTS, 2005) for Mumbai Metropolitan Region carried out by MMRDA. In particular, this study concerned a detailed analysis of travel demand in different alternatives scenarios of population, employment and network development for various horizon years. However, as will be shown in the following paragraphs, these data need to be updated taking into account the results of recent 2011 census and new planned development plans of the area.

2.2 THE CONSTRUCTION OF THE NETWORK

The MMRDA has provided the network model of the whole Mumbai Metropolitan Region developed for the CTS using EMME software.

However, as already stated in the inception report (14-1167-H1, 2015), the transport planning software chosen for this project is Transcad, which actually gives the possibility to import both network and demand files from EMME.

Therefore, the first task to perform before the calibration of the network is the conversion of previous model data into Transcad files.

It is worth highlighting that, even if EMME networks are compatible with Transcad (i.e. there is a specific procedure to import this kind of files), a lot of information regarding the supply model is lost during the conversion. It is therefore necessary to set up and fill out from the beginning all the missing data which are necessary for a macroscopic transport simulation. To this purpose, using previous reports carried out for the CTS, Nodes, Links and Function data are set up in Transcad (Figure 2.1).

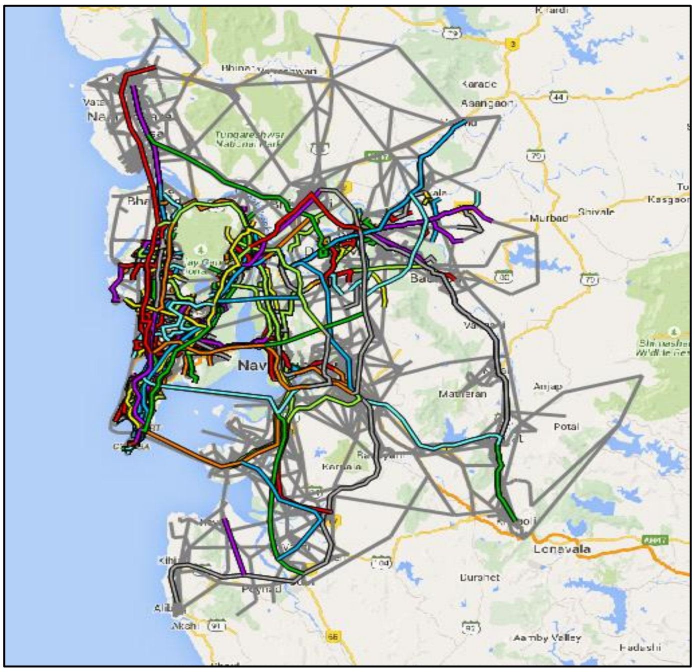

Figure 2.1: Network Model Imported in Transcad 6.0

2.3 THE CHARACTERISTICS OF THE NETWORK

The base network consists of nodes and links. The nodes are divided into centroids and regular nodes. A centroid is a node that is associated with a zone; all trips from and to the zone start and end in that zone. A regular node may correspond to an intersection or a transit stop.

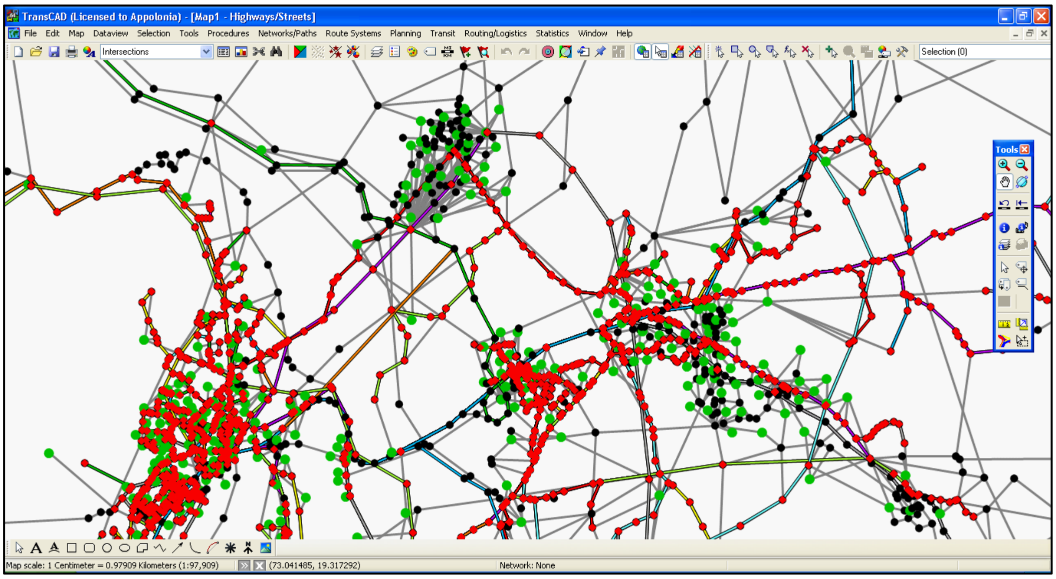

Figure 2.2: Different Node Representations in the Model Network

In Figure 2.2 the different node representation is shown. In particular, green nodes are centroids, red nodes are transit stops, while black nodes can represent common intersections or points where at least one attribute of the link changes.

A link is a directional connection between two nodes, by one or more nodes. A link that connects a centroid to a regular node is called a connector link. The initial node of a link is I-node, and the terminal node of a link is called J-node. Attributes such as number of lanes, volume delay functions, etc. are attached as attributes of a link. The links of the base network, which are defined by using ordered pairs of nodes, may carry more than one mode such as cars, two wheelers, buses, taxis, auto rickshaws and pedestrians. These are specified by including all the modes allowed on a particular link.

The Transit line itinerary is defined as the sequence of nodes (stops) encountered by the transit line on its route. The travel time of a transit line is specified by an average speed or with travel time functions. These functions are correlated to the travel time of the auto mode on the same link.Speed of various modes are incorporated in the model as it is one of the important parameter.

Transit line corresponds to regular transit service, fixed frequency and travel times, on a fixed itinerary. The itinerary is defined as a sequence of transit segments, each one of them corresponding to a link in the base network.

Pedestrian movements along sidewalks are represented as Auxiliary Transit modes which travel at constant speed (Figure 2.3).

Information about each kind of link is summarized in Table 2.1 and Table 2.2.

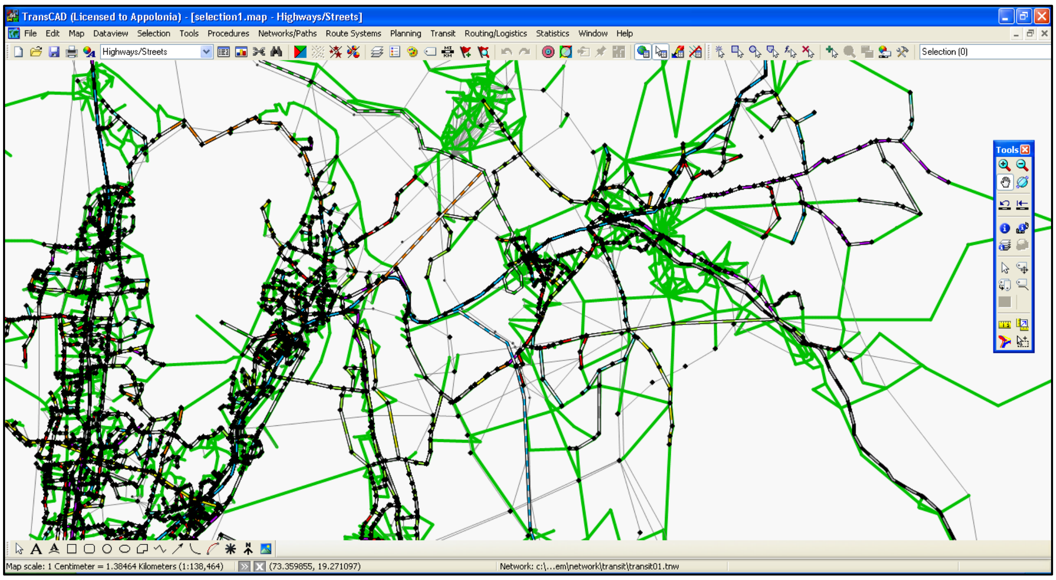

Figure 2.3: Representation of Pedestrian Links (green links)

Table 2.1: Modes Implemented in the Model

CODE	MODE	TYPE
w	Two-wheeler	Auxiliary auto
c	car	Auxiliary auto
r	Rickshaw	Auxiliary auto
x	Taxi	Auxiliary auto
l	LCV	Auxiliary auto
k	MAV, Trucks	Auxiliary auto
t	Train	Transit
b	Bus	Transit
m	Metro	Transit
e	Connector	Auxiliary
f	Transfers	Auxiliary transit
p	Pedestrian	Auxiliary transit
g	Train	Auxiliary transit

This information enables the construction of a "hyper" network where both private and public transport modes are considered. However, since the underlying assumptions, costs, and algorithms involved are very different, the two types of assignments (i.e. private and transit systems) in Transcad are performed separately but share information on congestion and travel times. For instance, when preparing the scenario for private car assignment, the road capacity used by transit vehicles can be taken into account specifying the auto equivalent of transit vehicles (i.e. "Preload") as additional volume; similarly, the dependence of the travel time of transit vehicles on the congestion on the road network can be considered in the transit assignment, in the line itinerary, as a transit time function which is a function of the auto time.

Table 2.2: Functional Classification of Roads in the Network

VDF	LANE CONFIGURATION	DIVIDED/UNDIVIDED	TRAFFIC MANAGEMENT
1	2/3 Lane	Undivided	One Way
2	2/3 Lane	Undivided	Two Way
3	2 Lane	Flyover	Undivided
4	4 Lane (Effective two lanes)	Divided	Two Way
5	4 Lane	Undivided	One Way
6	4 Lane	Divided	Two Way
7	6 Lane	Divided	Two Way
8	6 Lane	(Flyover)	Divided
9	8 Lane	Divided	Two Way
10	10 Lane	Divided	Two Way
11	10 Lane (Ser road)	Divided	Two Way
Regional	LANE CONFIGURATION	DIVIDED/UNDIVIDED	TRAFFIC MANAGEMENT
12	2/3 Lane	Undivided	Two Way
13	4 Lane	Divided	Two Way
14	4/6 Lane Bypass	Divided	Two Way
15	Expressway	Divided	Two Way
16	Long	Divided	Two Way

2.4 DESIGN OF THE ZONING SYSTEM

One of the most important steps in modelling transportation systems is the zoning design. Indeed, this activity is necessary to have a clear and spatial disaggregated idea of the origin and the destination of trips, population, land uses, etc.

As already stated, the model network provided by the MMRDA regards the whole MMR. In particular, for detailed analysis, previous study suggested to divide the whole metropolitan area in 1030 traffic zones.

As far as our study area is concerned (i.e. Thane, Bhiwandi and Kalyan sub-districts), the total number of traffic zones amounted to 227 (see Figure 2.4). For each of them, the data provided are:

- Population (base scenario and future projected scenarios);
- Area;
- Density;
- Employment split in office, industry and other sector fields (base scenario and future projected scenarios).

The base scenario refers to 2005, which corresponds to the year the CTS was carried out; the future scenarios concern the expected future levels of population and employment from 2011 up to 2031 (i.e. scenario identified as “P3E3” in CTS report).

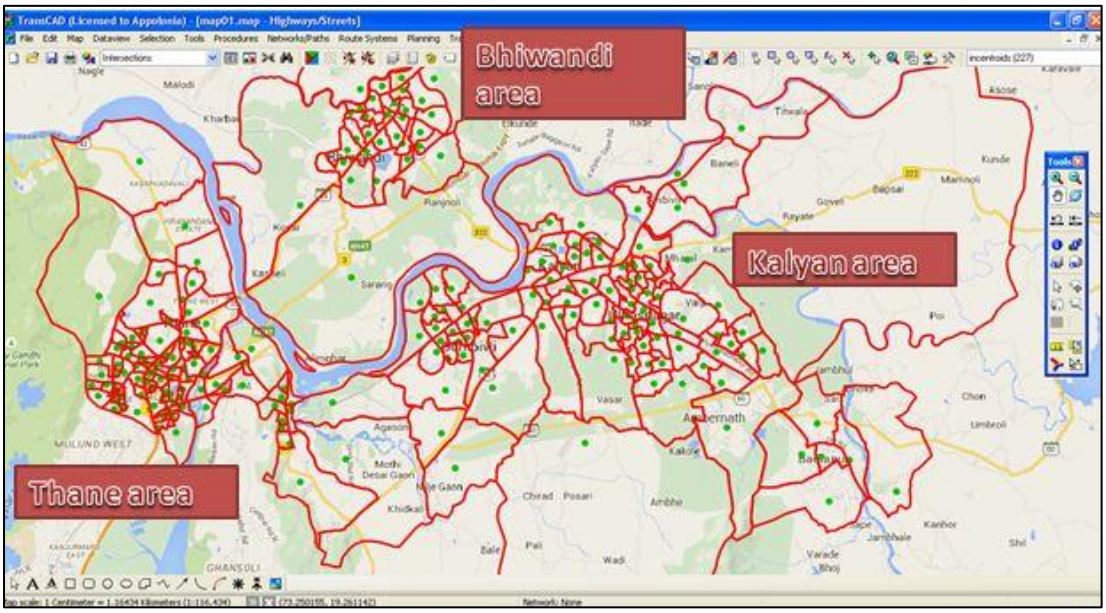

Figure 2.4: Zoning System of Thane, Bhiwandi and Kalyan Area

Available data regarding population projections are listed in Appendix A.

In order to keep a correspondence between previous CTS and the current feasibility study, the traffic zones have been left unchanged. The same zoning scheme has therefore been adopted for analyzing the transport mobility of Thane, Bhiwandi and Kalyan region considering both internal trips and relations with the outer part of the study area (i.e. internal-external crossing trips, external-internal crossing trips and crossing trips). However, it is worth nothing that two zones (whose TAZ code is “2009” and “2011”; see Appendix A for more references) belonging to Thane cluster in previous CTS, are considered now in Bhiwandi as part of Bhiwandi Surrounding Notified Area (BSNA) together with another zone, whose TAZ code is “2010”. This distinction is necessary to consider future development plans in Bhiwandi area (see chapter 3.7).

2.5 DATA RELATED TO BASE OD MATRICES

Previous CTS proposed an in-depth analysis for the estimation of traffic flows of MMR. The different activities performed to carry out OD matrices for each vehicle typology (car, taxi, rickshaw, LCV and trucks) and for each public transport systems were:

- development of trip end models and distribution models to estimate production and attractiveness of each traffic zone;
- development of a gravity model to generate the first OD matrix;
- development of a mode split model for the estimation of an OD matrix for each transport mode;
- assignment of the OD matrices using the simulation model;
- Correction of the OD matrices through comparing the observed traffic volumes with the simulated ones.

More details about these procedures are explained in CTS report.

According to the expected (i.e. future scenario indicated as “P3E3” in CTS) medium term transportation strategies, the MMRDA has provided the OD matrices regarding future scenario 2016 for each vehicle category. These constitute the base matrices of the current feasibility study.

The vehicle categories considered are:

- Car;
- Two Wheeler;
- Rickshaw;
- Taxi;
- Bus;
- Rail (train);
- LCV;
- Truck.

Each matrix (except from bus matrix which is expressed as passenger/trip) has been converted in Passenger Car Unit (PCU) adopting the following coefficients (CTS, 2005):

- Car: 1;
- Two Wheeler: 0.5;
- Rickshaw: 0.8;
- Taxi: 1.0;
- LCV: 2.0;
- Bus: 3;
- Truck: 3.

Matrices converted in PCU can thus be summed and then assigned to the road network.

Bus and train matrices are instead expressed as passengers and can be directly assigned to the transit system.

3 ASSIGNMENT OF THE BASE OD MATRICES TO THE ROAD AND TRANSIT NETWORKS

The assignment of the base projected matrices (i.e. 2016) aims to assess the effectiveness of forecasted flows obtained from CTS. Indeed, this study might be too old and provides results which are far from representing correctly actual traffic conditions of 2015.

Therefore, before making calibrations, it is important to check if previous projections produce results whose order of magnitude is similar to survey traffic flows.

In Transcad a full complement of traffic assignment procedures can be implemented. Basic traffic assignment methods available are:

- All-Or-Nothing Assignment (AON);
- STOCH Assignment;
- Incremental Assignment;
- Capacity Restraint;
- User Equilibrium (UE);
- Stochastic User Equilibrium (SUE);
- System Optimum Assignment (SO).

As already stated in Paragraph 2.3, the assignment procedures regarding road and transit networks are very different and are kept separated. However, the construction of a “hyper” network enables the analysis of the interaction between different transport modes.

In the following, all the details about the two assignment procedures will be explained.

3.1 ROAD TRANSPORT ASSIGNMENT

In previous CTS, the procedure adopted for performing the road transport assignment is the “User Equilibrium”.

The User Equilibrium assignment is based on the Wardrop first principle according to which:

“Each traveler chooses the path (or route) perceived as being the best; if there is a shorter path than the one being used, the traveler will choose it. At the equilibrium, no one can improve their travel time by changing the path” (Wardrop, 1952).

On the basis of Wardrop’s principle, it is assumed that all drivers perceive costs in an identical manner. Thus, a solution to this problem is an assignment such that no driver can reduce his journey cost by unilaterally changing route. In addition, considering that all users have perfect knowledge about travel costs on a network, this behavioral assumption leads to Deterministic User Equilibrium (DUE).

However, in this study, a Stochastic User Equilibrium (SUE) assignment is preferred. This implies assuming that drivers perception of costs on any given route are not identical and that the trips between each OD pair are divided among the routes with the cheapest route attracting most trips. In some circumstances, SUE assignments might produce more realistic results than deterministic UE model. Less attractive routes for instance, will have lower utilization but will not have zero flows as they do under UE assumptions.

The algorithm used by Transcad to solve a SUE assignment is the Method of Successive Averages (MSA), which is known to be a convergent method (see Cantarella 1997; Sheffi and Powell, 1981; 1982), although the rate of convergence may not be rapid. Due to the nature of this method, a large number of iterations should be used.

The assignment features available in Transcad are:

- Single class traffic assignment;
- Multi class traffic assignment.

The one chosen for this feasibility study is the Single Class Auto Assignment. This is the simplest form of equilibrium assignment; travel times are given by the volume delay functions associated with the links of the road network, and the turn penalty functions intersection delay functions associated with turns. The input required is the demand matrix expressed as PCU containing the demand of cars and the other kinds of vehicles (see Chapter 2.5).

3.1.1 Results of Road Traffic Assignment

The flows obtained by the road assignment are compared with the surveyed flows providing the following results (Table 3.1), where:

- ID is the identification number of each link;
- COUNT_AB and COUNT_BA correspond to survey flows in both directions;
- AB_FLOW and BA_FLOW represent the simulated flows;
- DIFF_AB and DIFF_BA is the percentage difference between surveyed and simulated flows.

Table 3.1: Difference between Surveyed and Simulated Flows

MORNING PEAK HOUR						
ID	COUNT_AB	COUNT_BA	AB_FLOW	BA_FLOW	DIFF_AB	DIFF_BA
6371	7151		6221	5114	-13,00%	
6372	2091	2645	2031	2247	-2,85%	-15,06%
6607	2311		24334	2771	5,32%	
7797	1944		1614	1579	-16,98%	
7798	3224		2085	2137	-35,33%	
7799	2513		6230	5957	147,90%	
7812	1676		1350	1286	-19,43%	
7813	1046		515	616	-50,77%	
8027	1506	1352	3650	3487	142,36%	157,94%
1742		1221	259	120		-90,16%
7335		1799	2241	2051		14,00%
7393		1604	1070	1398		-12,87%
7810		1302	1231	1288		-1,06%

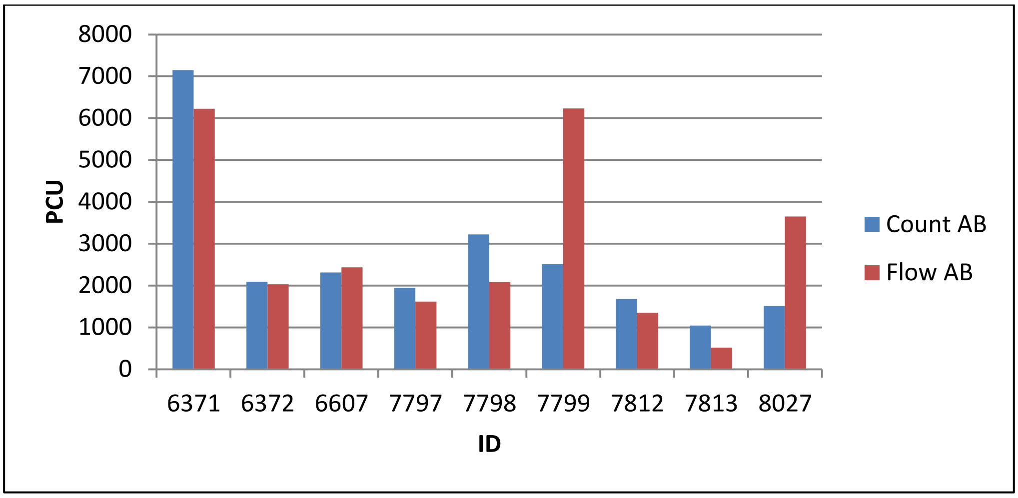

Figure 3.1: Histogram Showing the Differences between Surveyed and Simulated Flows (direction AB)

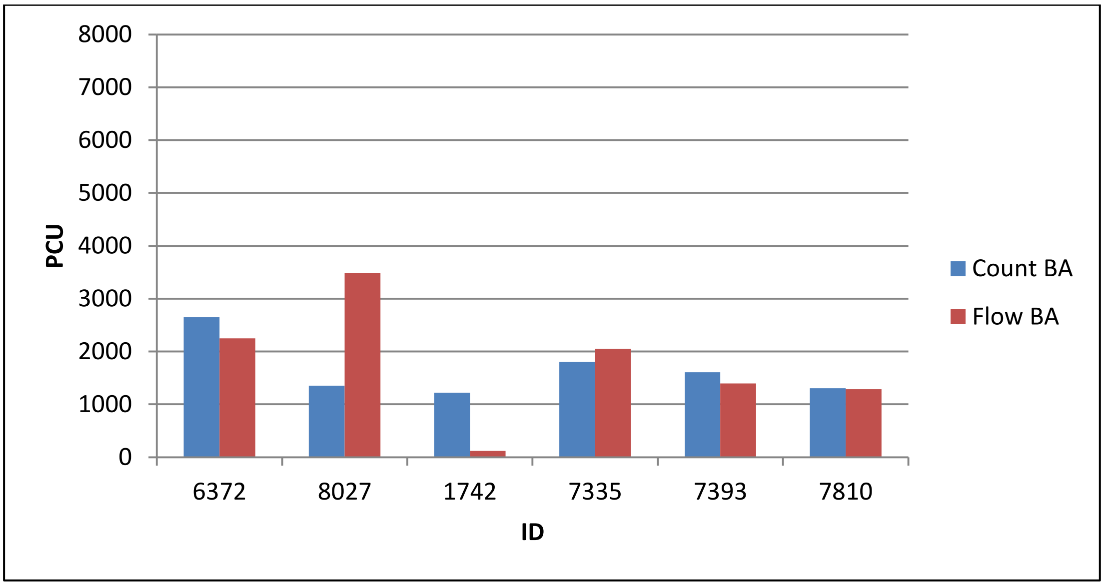

Figure 3.2: Histogram showing the differences between Surveyed and Simulated Flows (direction BA)

Table 3.2: Total Difference between Surveyed and Simulated Flows

	PCU
MORNING PEAK HOUR SURVEYED FLOWS	33385
MORNING PEAK HOUR SIMULATED FLOWS	36721
DIFFERENCE	+9,99%

What comes out from the analysis of Table 3.1 is that there is a huge difference between traffic flows simulated and the ones observed during surveys. In particular, as shown by Table 3.2, base OD matrices provided by MMRDA produce morning peak hour flows which are higher (+9,99%) than expected values. Obviously, it is worth highlighting that survey results represent a realization of a random variable and should be considered only as a term of reference.

However, it is necessary to implement some calibration procedures so as to estimate the base OD matrix for the simulation of the current scenario (i.e. 2015 scenario).

3.2 TRANSIT ASSIGNMENT

Transit assignment models enable the estimation of the number of passengers that use transit segments and routes in a transit network as a function of transit level of service and fare.

The methods implemented in Transcad for transit assignment are:

- All or Nothing;
- Pathfinder;
- Stochastic User Equilibrium;
- Equilibrium Pathfinder.

The procedure adopted in this feasibility study is the Stochastic User Equilibrium (SUE) method.

The SUE approach is the more advanced assignment method and it is similar to the one adopted for road assignment. In particular, for transit, travelers select paths from their origin to their destination based upon their overall attractiveness of the path computed from its constituent travel time components, transfer penalties and fares (i.e. user generalized cost perceived). The result is that paths receive flow as a function of their relative attractiveness. As for road assignment, the iterative procedure to reach the convergence and thus the equilibrium solution is based on the Method of Successive Averages (MSA). SUE assignment is particularly useful to predict route utilization when there are many alternatives for transit paths even when there are no capacity issues. That is why it will be adopted for the simulation of future transit scenarios in order to estimate the total ridership which would interest the new MRTS.

3.2.1 Results of Traffic Assignment on Transit Networks

The transit networks provided by MMRDA are based on 2021 and 2031 future scenarios respectively. In both of the cases, different metro lines are included which actually are not in operation yet. Therefore, before running transit assignments, it is necessary to reproduce correctly the supply model of public transport system. The list of all the bus routes included in our analysis is shown in Appendix B. Basically; in 2015 only one metro line is in operation, namely the Versova-Ghatkopar line (i.e. Line 1).

After this phase, the base OD matrices for train and buses are assigned to the transit network.

Table 3.3: Simulated and actual transit flows on Thane-Bhiwandi Bus Route

	MORNING PEAK HOUR	
Bus route	Simulated Passenger flows	Actual Passenger Flows
Thane-Bhiwandi via Kasheli	1227	923[1]

As for the road assignment, even for public transport, passenger flows are overestimated. Table 3.3 shows a comparison between transit travelers simulated in Transcad and the ones provided by State Transport authority of Thane for the route Thane-Bhiwandi via Kasheli.

3.3 UPDATING MATRICES USING 2011 CENSUS INFORMATION

In chapter 3, results highlighted the necessity to update forecasted projections carried out by CTS in 2005, since they overestimated traffic flows within our study area.

[1] Data provided by State Transport of Thane

In order to correct these projections and to scale the OD matrices compatibly to actual conditions, it is useful to adopt the last information about population growth provided by the 2011 census data[2] which can help figure out how the Indian demography has recently changed. Indeed, demographic data can be viewed as representative of the development of each district which, in turn, is strongly correlated to the mobility of the area.

Table 3.4 summarizes the total number of inhabitants of Thane, Bhiwandi (including BSNA zones) and Kalyan area. As it can be seen, the population has increased from 1991 to 2001 with an extremely high growth rate; in particular, in Thane the growth rate has been notably higher (+45.97%) than Bhiwandi (+18.53%) and Kalyan (+11.20%). In the following decade (i.e. from 2001 to 2011), the population has continued to increase with growth rates even higher than the previous ones. In this case Bhiwandi is the district with the higher rise of inhabitants, followed by Thane (+57.02) and then Kalyan (+24.45%). As far as the BSNA area is concerned, the population has notably increased in both considered decades (i.e. +47.05 and + 41.97% respectively). Presumably, it will increase even more due to expected development plans (DPBSNA, 2008).

Comparing 2011 projections of CTS with actual data from 2011 census (Table 3.5), it comes out that, except from BSNA (-30.53%), all the other projections are close to the actual values. Indeed, differences are included in a range of ±10%. As a results, the total number of actual inhabitants results to be higher of 5.36% than CTS estimation.

Table 3.4: Growth Rates of Thane, Bhiwandi (including BSNA Zones) and Kalyan Area

CENSUS DATA	1991	2001	2011	Growth rate	
SUB-DISTRICT	NUMBER OF INHABITANTS			1991-2001	2001-2011
Thane	803389	1261517	1841488	+45.97%	+57.02%
Bhiwandi	379070	598703	709665	+18.53%	+57.94%
Bhiwandi BSNA	114349	168151	238728	+47.05%	+41.97%
Kalyan area	1367121	1967921	2449129	+11.20%	+24.45%

Table 3.5: Differences between CTS Projection and Census Data for 2011

	NUMBER OF INHABITANTS 2011		
SUB-DISTRICT	**CTS PROJECTION**	**2011 CENSUS**	**DIFF CTS/census**
Thane	1688442	1841488	-9,06%
Bhiwandi	774801	709665	+8,41%
Bhiwandi BSNA	182893	238728	-30,53%

[2] www.censusindia.gov.in

Table 3.5: Differences between CTS Projection and Census Data for 2011

Kalyan area	2326460	2449129	-5,27%
Total population	**4972596**	**5239010**	**-5,36%**

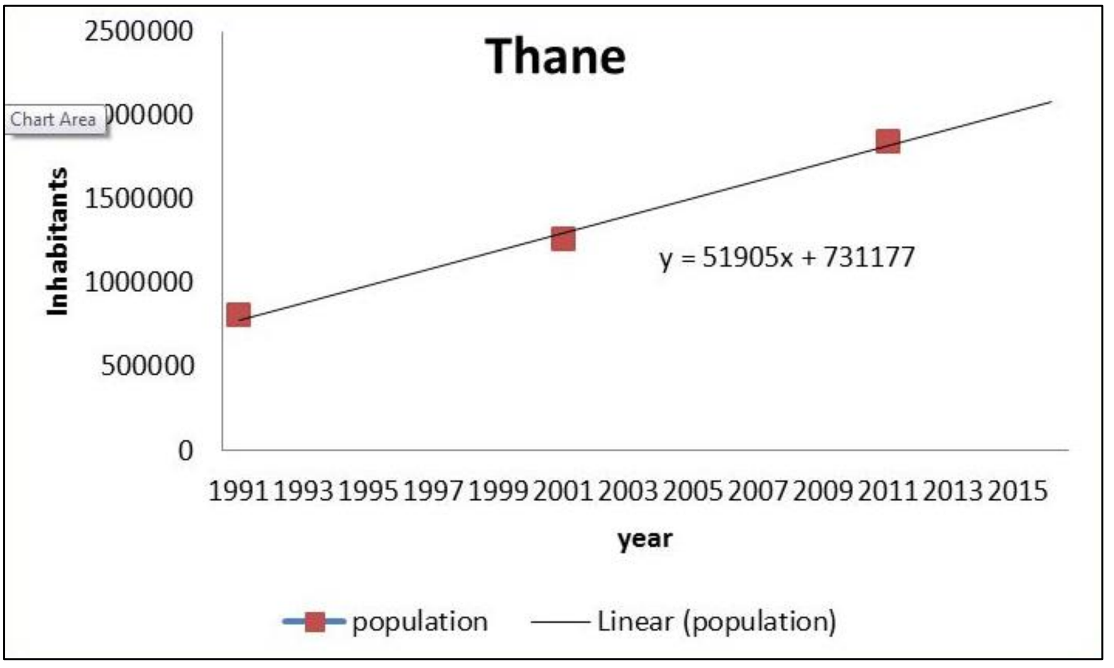

Figure 3.3: Trendline Function of Thane Area

Data of Table 3.5 give the possibility to calibrate new trendline functions for the estimation of population growth of the last years. In Figure 3.3, Figure 3.4, Figure 3.5 and Figure 3.6 the results of this calibration process are shown.

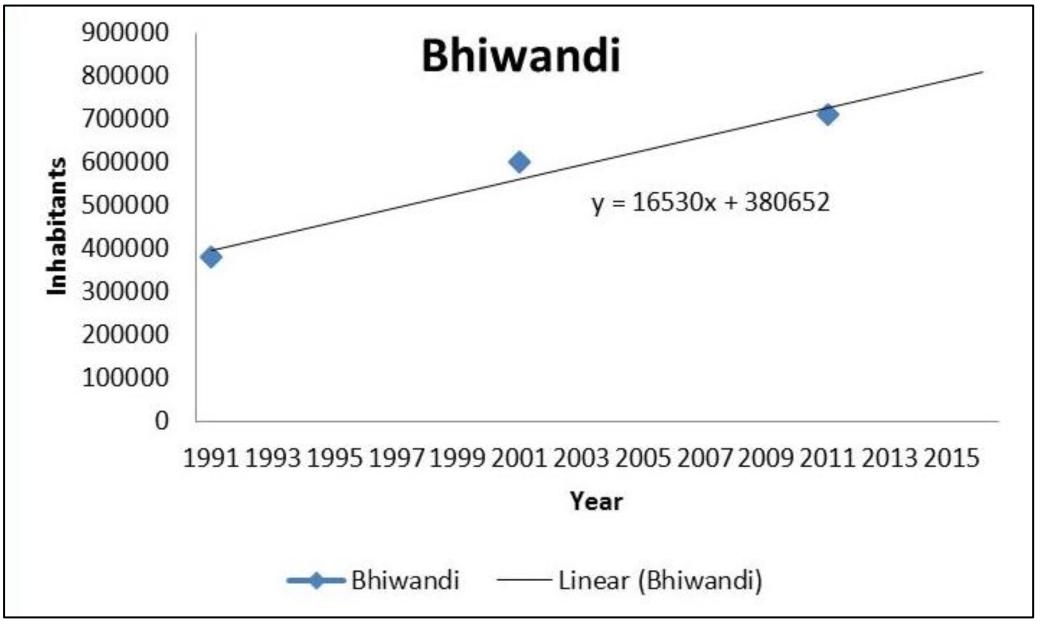

Figure 3.4: Trendline Function of Bhiwandi Area

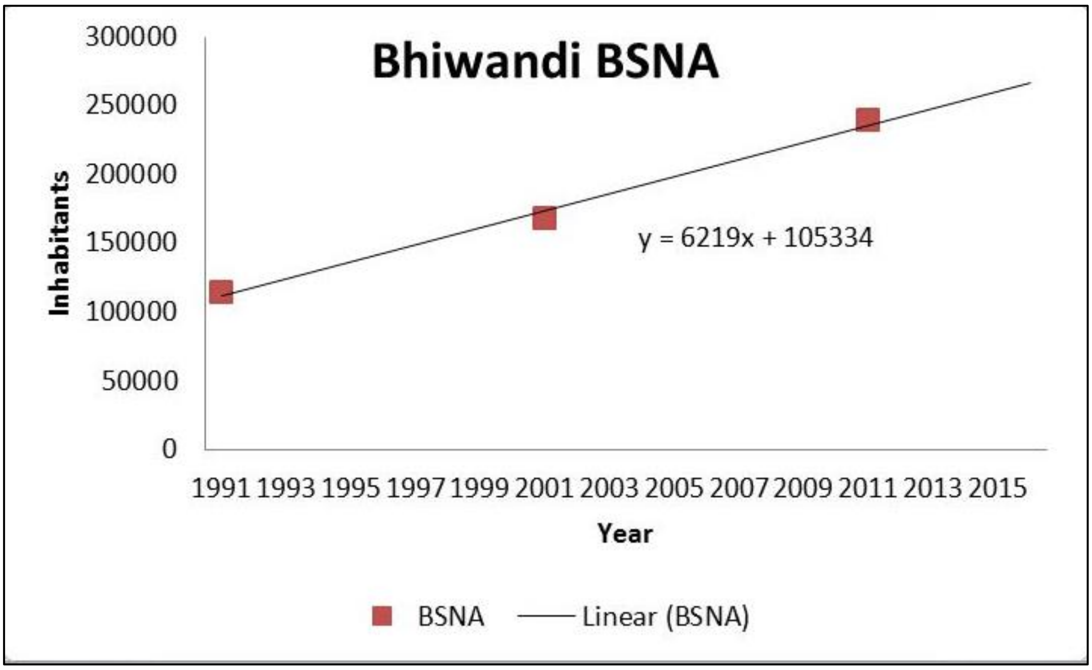

Figure 3.5: Trendline Function of Bhiwandi BSNA

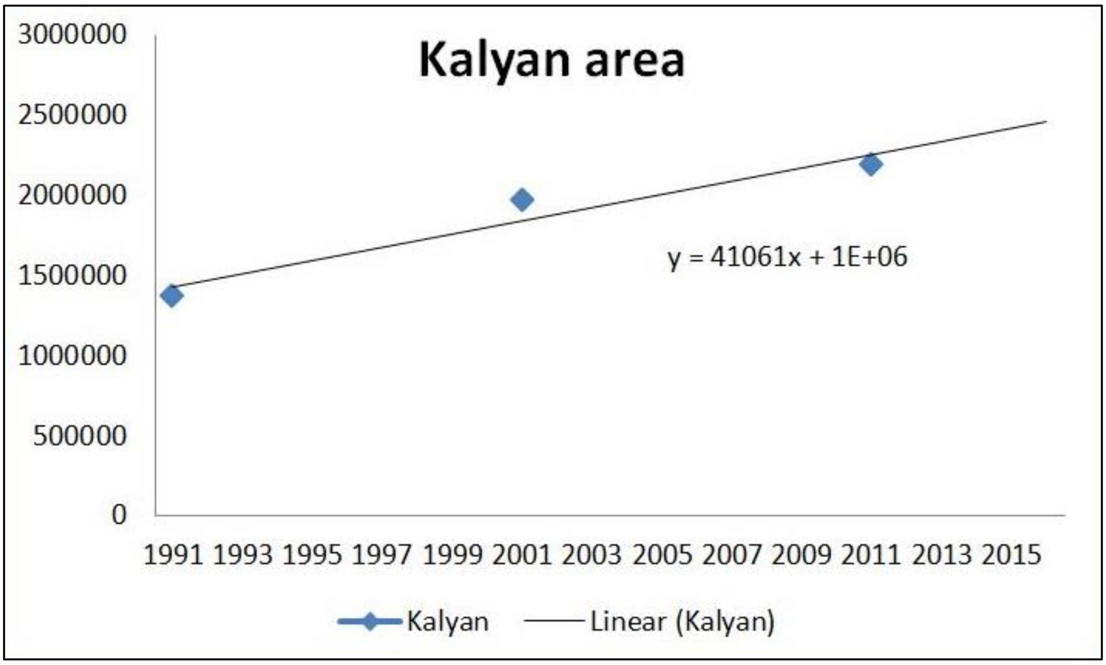

Figure 3.6: Trendline Function of Kalyan Area

The equation of each trendline can thus provide a new population projection regarding year 2016, which is our term of reference according to data given by MMRDA.

It is worth noting that, contrary to 2011 data, in this case CTS projections have overestimated the number of inhabitants. In particular, the total overestimation amounts to 6.27%. This value is therefore considered the scale factor for updating the OD matrices provided by MMRDA.

Table 3.6: Differences between CTS projection and Census Data for 2016

	NUMBER OF INHABITANTS 2016		
SUB-DISTRICT	**CTS PROJECTION**	**2011 CENSUS**	**DIFF CTS/Census**
Thane	1883835	2080707	-10.45%
Bhiwandi	902439	810432	+10.20%
Bhiwandi BSNA	255920	267028	-4.34%
Kalyan area	2895090	2406600	+16.87%
Total population	**5937284**	**5564767**	**+6.27%**

Once obtained the new 2016 matrices, it is necessary to bring them back to 2015 in order to calibrate the current scenario adopting results carried out from traffic surveys. As shown in Table 3.7, according to the estimated trendlines, the updated 2016 matrices have to be reduced of 2.37%.

Table 3.7: Differences between 2015 and 2016 Projected Data

SUB-DISTRICT	2015	2016	DIFF 2015/2016
Thane	2028802	2080707	2.56%
Bhiwandi	793902	810432	2.08%
Bhiwandi BSNA	260809	267028	2.38%
Kalyan area	2352500	2406600	2.30%
TOTAL POPULATION	**5436013**	**5564767**	**2.37%**

3.4 CALIBRATION AND SIMULATION OF THE CURRENT SCENARIO

Calibration of transportation planning models is arguably the most important step before applying a simulation model. It involves both demand and supply model which are generally calibrated separately even though some methodologies for joint demand-supply calibration have also been recently developed.

As far as this feasibility study is concerned, due to the accuracy and the extreme reliability of previous models provided by MMRDA (especially regarding the supply model), the calibration mainly concerns travel demand. The aim is that of producing a new OD matrix that is consistent with current traffic conditions. However, a specific “tuning” process about link capacity of our study area is performed so that actual congestion problems can be effectively reproduced.

In the following, a detailed description of both calibration processes is provided.

3.5 OD DEMAND ESTIMATION USING TRAFFIC COUNTS

Many approaches have been proposed to solve the OD estimation problem. They can be grouped into two main classes: direct estimation methods (surveys) and estimation methods using traffic counts. In general, the direct estimation methods are expensive and time consuming. In recent years, increasing attention has been devoted to more effective methods of OD demand estimation using traffic counts. These are easy to obtain and above all, are not expensive.

In Transcad, different OD estimation procedures can be performed and vary according to the network analyzed (i.e. road or transit network). Therefore, in the following paragraphs, as previously done for the assignment, calibrations of road and public transport demand are kept separated.

There are two basic O-D basic matrix estimation procedures in Transcad. The first one is based on Nielsen method (Nielsen, 1993) which is an iterative process that switches back and forth between a traffic assignment stage and a matrix estimation stage. Basically, starting from an initial estimate of the OD matrix, the procedure calibrates the assigned volumes for each OD pair according to the traffic counts. The second methodology is instead called the "gradient approach" and it is based on the work of Heinz Spiess (Spiess, 1987). Contrary to the previous process, the gradient method assesses the contribution of each OD flows to an overall objective function which must be minimized. Assignment and OD trips updates are repeated in an iterative loop until a convergence criterion is reached. The aim of Spiess procedure is that of providing an OD matrix which should resemble as closely as possible to the original one. In other words, the process to adjust should not only comply with the observed volumes but also ensure that the difference between original and resultant matrix is least. For this reason, this method is more appropriate when there is high confidence in the prior estimate for the OD matrix.

For this study, both procedures have been adopted and compared so as to assess the reliability of the results obtained.

It is worth noting that, in order to make a correspondence with previous traffic assignments, the OD matrix estimation has been performed using the SUE approach.

3.5.1 Analysis of the Results obtained by OD demand Calibration

As previously stated, OD demand calibration is performed twice considering both Nielsen and Spiess method. Only assessing the results obtained, it is possible to choose which method has to be actually preferred for the current case study.

Table 3.8: Results of OD Estimation Process

	COUNTS		SPIESS METHOD				NIELSEN METHOD			
ID	COUNT AB	COUNT BA	FLOW AB	FLOW BA	DIFF AB	DIFF BA	FLOW AB	FLOW BA	DIFF AB	DIFF BA
6371	7151		6973	4771	-2.49%		7146	4180	-0.07%	
6372	2091	2645	2038	1900			1839	2649	-12.05%	0.16%
6607	2311		1568	938	4.32%		1786	245	1.01%	
7797	1944		2153	1497	-19.33%		3078	1276	-8.15%	
7798	3224		3498	5615	-33.21%		2738	6642	-4.53%	
7799	2513		1308	965	39.21%		1666	671	8.96%	
7812	1676		384	333	-21.95%		1048	547	-0.57%	
7813	1046		2401	1824	-63.26%		2009	1345	0.21%	
8027	1506	1352	261	157	59.42%	34.88%	495	1213	33.43%	-0.50%
1742		1221	1694	1520		-87.18%	1883	1795		-0.62%
7335		1799	725	1184		-15.54%	808	1604		-0.23%
7393		1604	1180	902		-26.18%	1211	1286		-0.02%
7810		1302	6973	4771		-30.75%	7146	4180		-1.23%

Table 3.8 highlights the differences between surveyed and assigned flows provided by the two procedures. As it can be seen, Spiess method produces flows which are significantly far from the expected ones. This means that it is not possible to obtain good results remaining too close to the base OD matrix.

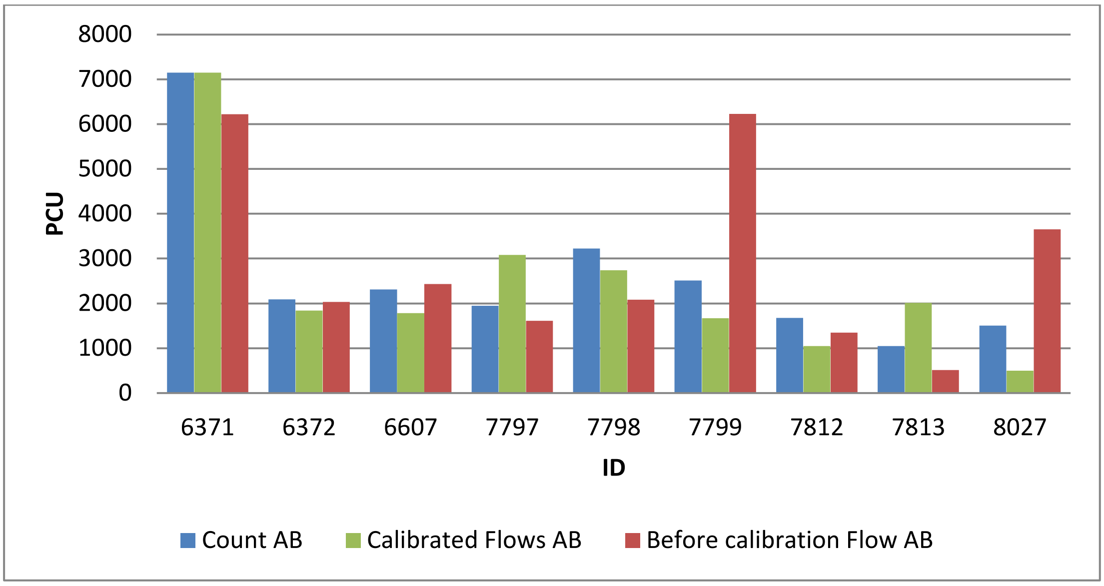

Figure 3.7: Histogram showing the Results of Calibration Process (direction AB)

The Nielsen method by contrast, having fewer constraints than the previous approach, in 40 iterations provides outputs which are very close to the observed flows. For this reason, the OD matrix obtained by means of this calibration procedure is chosen for the following analyses.

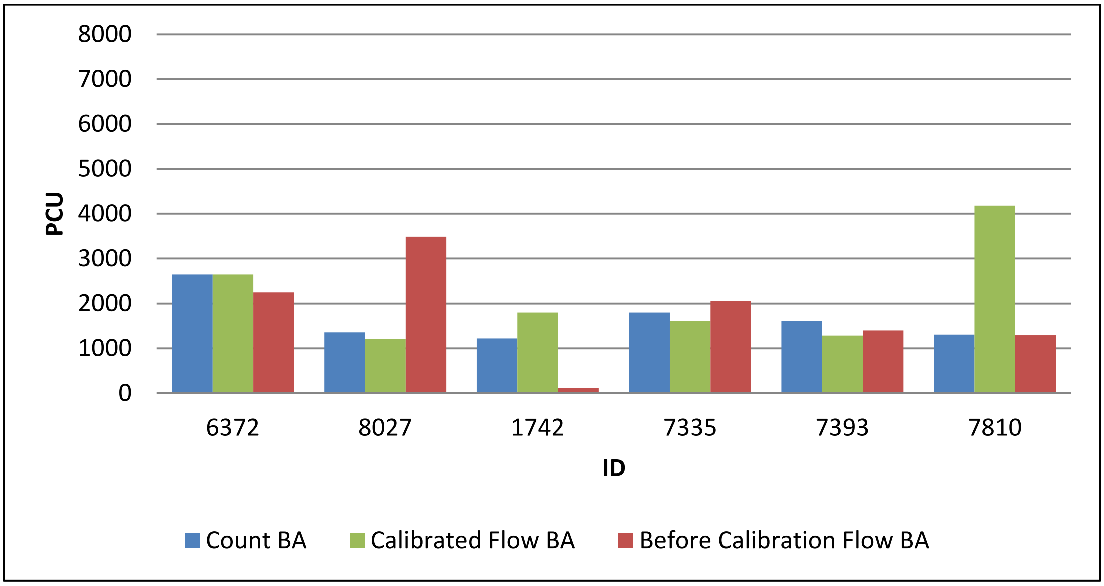

Figure 3.8: Histogram showing the Results of Calibration process (direction BA)

3.5.2 Supply Model Calibration of the Study Area

Due to the presence of highly congested intersections (equipped or not equipped with traffic lights), in many cases the capacity of road links is overestimated. Indeed, intersections generally produce a reduction of link capacity due to the fact that vehicle flows can be often interrupted.

In order to reproduce correctly traffic jams and congestion within our study area, the capacity value of each link has been carefully updated. In particular, this process consists of repeating iteratively traffic assignments until traffic conditions within the study area are correctly reproduced. As term of reference, traffic flow information provided by previous surveys is used.

In Figure 3.9 and Figure 3.10, it is shown the typical morning peak hour congestion during a common weekday of Thane, Bhiwandi and Kalyan main streets. In particular, the different link colors highlight the following conditions:

- Green links represent roads where there is a low level of congestion. Basically, all vehicles manage to keep their speed without interactions between each other;
- Orange links correspond to low level of congestion. There are few interactions between vehicles but the stream is generally not interrupted;
- Light red links are road sections with a high level of traffic flow and problems of congestion. The link capacity is in this case almost saturated;
- Dark red links correspond to condition of extremely high congestion level. The link capacity is completely saturated and vehicles are forced to queue (i.e. stop&go phenomenon).

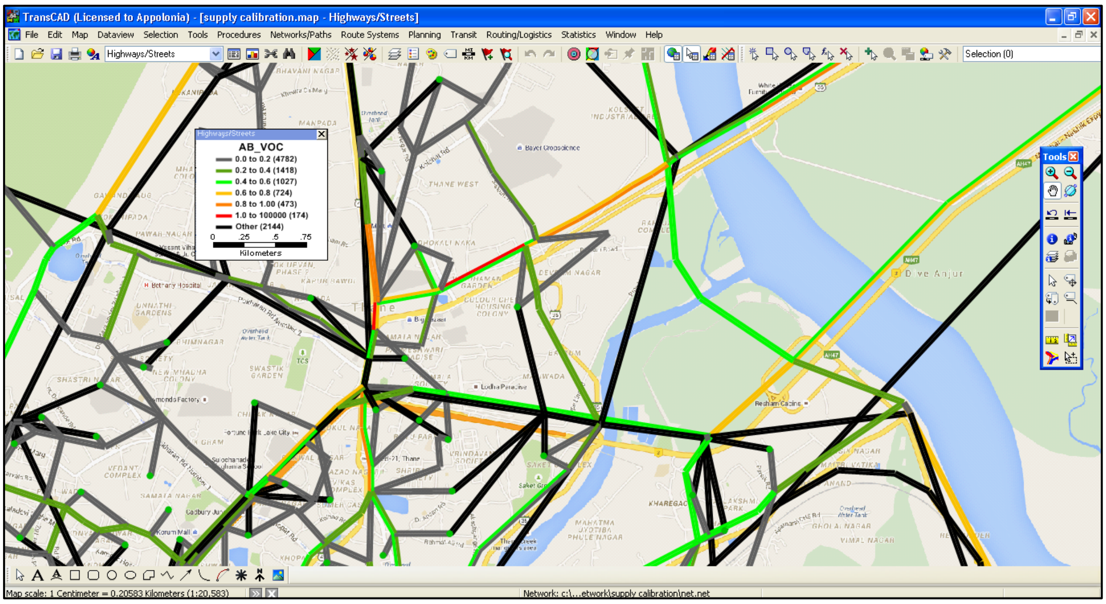

Figure 3.9: Results of Calibration Process of Thane Area

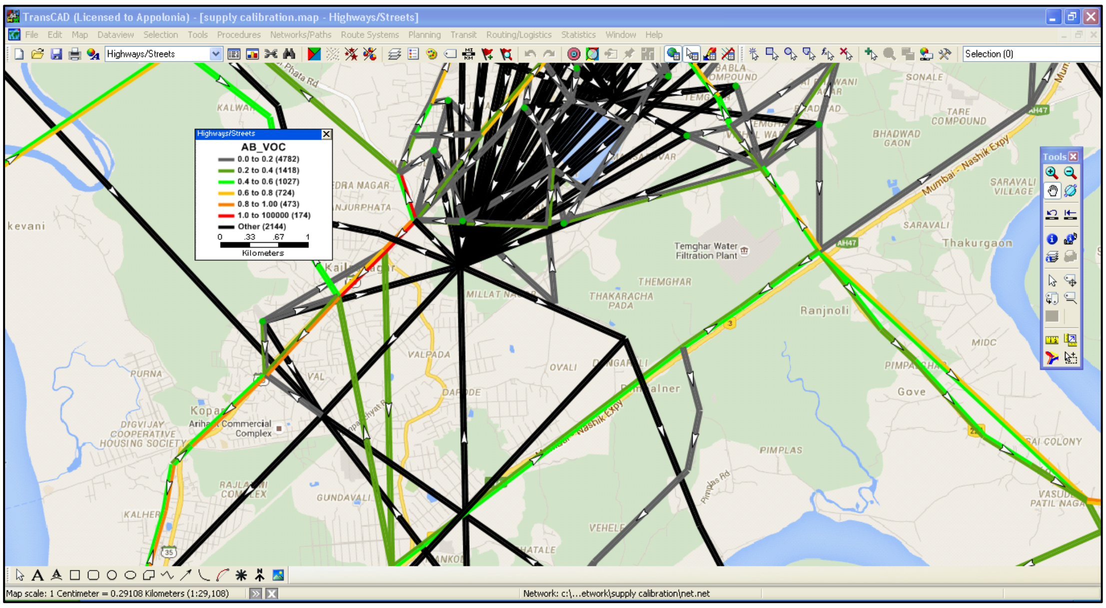

Figure 3.10: Results of Calibration Process of Bhiwandi Area

3.6 OD ESTIMATION FOR TRANSIT SYSTEM

As for road demand models, even transit demand models have to be calibrated. The OD matrix estimation procedure implemented in Transcad for dealing with public transport system is based upon the Nielsen's method (i.e. exactly the same described in the previous paragraph). In this case the correction process consists of assigning a base OD matrix to a transit network generating passenger flows; the latter, in turn, are compared with the counts and the OD matrix is modified one OD pair at time.

Table 3.9 Ridership Information Provided by ST (Thane) (outward and backward trips)

SR.NO	ROUTE NAME	BUS TYPE	AVG No. of DAILY COMMUTERS
1	THANE-BHIVANDI VIA KASHELI	STANDARD	5859
2	THANE-PURNA	STANDARD	1512
3	THANE-BHIVANDI VIA SAIBABA	STANDARD	3370
4	THANE-MANKOLI	STANDARD	660
5	BHIVANDI-MANKOLI	STANDARD	370
6	BHIVANDI-KASHELI	STANDARD	1224
7	BHIVANDI -KALYAN	STANDARD	16537

Table 3.10: Ridership Information provided by KDMT (outward and backward trips)

SR NO	ROUTE NAME	AVG No. of DAILY COMMUTERS
1	KALYAN TO KALYAN (DURGADI)	2718
2	KALYAN TO KALYAN (BIRLA COLLEGE)	2712
4	KALYAN TO DOMBIVALI	445
5	KALYAN TO YOGIDHAM (GOWRIPADA)	531
6	KALYAN TO MOHANA COLONY	2107
7	KALYAN TO VASHI (CBD)	4499
8	KALYAN STATION TO KOKAN BHAVAN	4432
9	KALYAN STATION TO UMBARDE GAON	408
10	KALYAN TO PANVEL	4412
11	KALYAN TO GHANDHARI AGARWAL COLLEGE (MADHA)	878
12	KALYAN TO GHANDHARI AGARWAL COLLEGE (HINA)	872
13	KALYAN TO BHIWANDI	4734
14	KALYAN TO JAMBUL VASAI	431
15	KALYAN TO VAKALAN	448
16	KALYAN TO BURDUL	556
17	KALYAN TO MALANGAD	2399
33	KLAYAN STATION TO BADALAPUR GAON/ K.N SCH	99
34	KLAYAN STATION TO AMBERNATH VIA CAMP	145
35	KLAYAN STATION TO AMBERNATH VIA NETTAWALI	136

Three types of counts can be accepted:

- boarding counts;
- ridership;
- node to node counts.

Boarding and alighting counts are taken at individual stops that record the total number of passengers boarding and alighting specified routes at that stop over a certain period of the day.

Ridership counts record the total number of passengers riding a specified route segment over a given period of time.

Node to Node counts track the transit flow between transits over a given period of time.

For this feasibility study, State Transport of Thane (ST) and Kalyan Dombivali Municipal Transport (KDMT) have provided daily ridership information about some bus routes belonging to our study area. This information is collected in Table 3.9 and

Considering the peak hour ridership as 10% of the whole day, the data provided in the previous tables are used for running the estimation procedures.

Regarding the assignment methodology, the SUE approach has been adopted so as to reproduce correctly the choice process made by each passenger.

After calibrations, the ridership values obtained for each bus route have an average error (i.e. difference between simulated flows and counted flows) included between a range of 15÷20%.

3.7 ESTIMATION OF FUTURE RIDERSHIP FOR DESIGNING THE MRTS

In order to estimate the future ridership on our corridor, it is necessary to analyse all the development plans which affect the study area. Indeed, the assessment of the upcoming developments becomes an important part of the traffic modelling study, since demography growth rate of each zone can be conditioned by changes due to settlements of new activities or residential areas. Furthermore, it is worth highlighting that the estimation of future ridership will influence the characteristics of the MRTS.

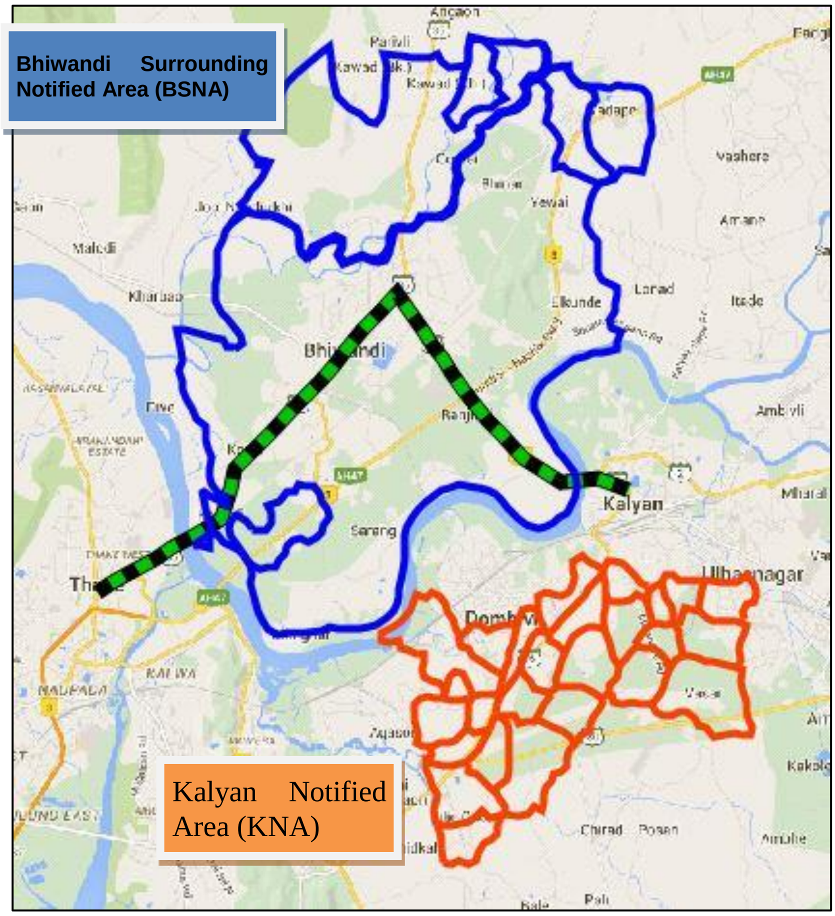

Figure 3.11:Zones expected to Grow Up in the following Years

According to MMRDA reports regarding development plans of Bhiwandi and Kalyan, the upcoming MRTS project in the Thane-Bhiwandi-Kalyan region passes through surrounding areas which are going to be affected by huge development (Figure 3.11).

In particular, it is expected that in Bhiwandi Surrounding Notified Area (BSNA) 60 villages will be developed; in Kalyan and Ambarnath Tehsils area other 27 villages will grow up.

In addition, another important factor that could contribute to huge developments in the considered study area is the proposed Multi Modal Corridor (MMC, 2011) from Virar to Alibaug which passes through Bhiwandi-Kalyan region. As it can be seen in Figure 3.12, section 2-3 and section 3-4 of the MMC are expected to pass through our study area.

Figure 3.12:Section 2-3 and 3-4 of MMC

Hence, in this report two different time horizons are considered, namely:

- 2021;
- 2031.

For each of them, more hypotheses are evaluated taking into account the expected population growth rates and the possibility that the development plans as well as the MMC could not be completed by the estimated horizons.

Indeed, by 2021 it is likely that the abovementioned development plans especially in BSNA are still in progress. In particular, reports provided by MMRDA (DPBSNA, 2008; DPKAT, 2011) give projections for 2021 only for Kalyan area; for the BSNA villages (i.e. 60 villages), projections are given only for 2031.

Furthermore, depending on the starting date of construction works, it could be that at least the MMC would be working. Another important factor to be considered is the opening of new metro lines, since the mobility within the MMR can notably change. According to MMRDA officials, the metro lines expected to be in operation by 2021 are:

- Line “Dahisar-Charkop-Bandra-Mankhurd” Metro (Flyover);
- Line “Colaba-Bandra-SEEPZ” Metro(Fully Underground);
- Line “Ghatkopar-Thane” Metro Corridor (Flyover).

It is worth noting that, except from Line "Ghatkopar-Thane", the other two lines are far from our study area. However, recent changes in their alignment are considered in our model[3] (Figure 3.13).

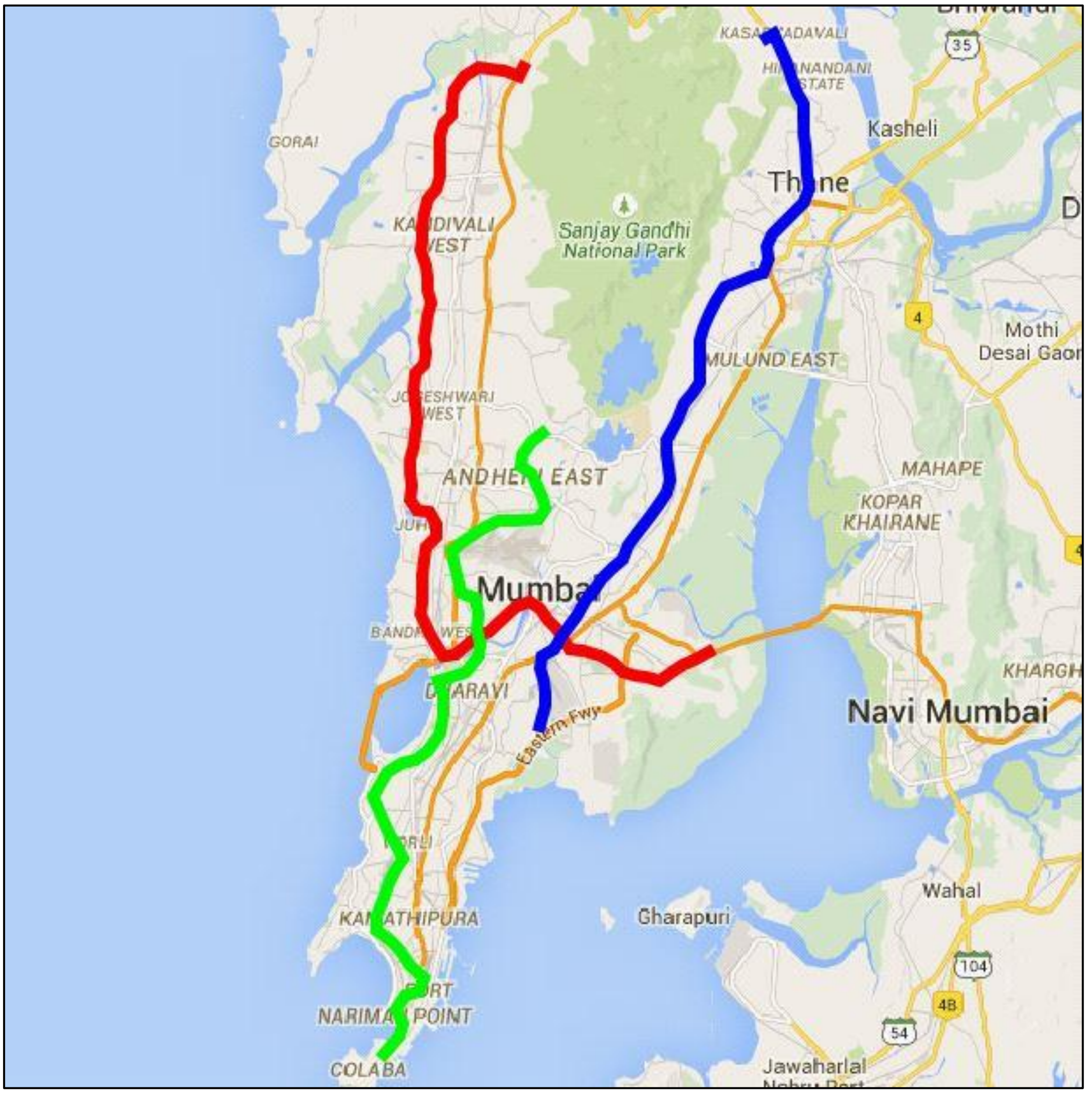

Figure 3.13: New alignments of Line "Dahisar-Charkop-Bandra-Mankhurd" (red line), Line "Colaba-Bandra-SEEPZ" (green line) and Line "Ghatkopar-Thane" (blue line)

Rest of the lines is under planning phase and is considered only in 2031 simulations.

As a consequence, for 2021 two possible scenarios can be expected:

- Scenario A: the MMC is not completed. The expected population growth rates (Chapter 3.3) are used to estimate the future ridership of the MRTS, taking into account the foreseen developments in Kalyan;
- Scenario B: the MMC is completed. The simulation considers the increase of traffic flows and passengers due to MMC as well as the developments in Kalyan.

[3] The new alignments of Line "Dahisar-Charkop-Bandra-Mankhurd" (red line), Line "Colaba-Bandra-SEEPZ" (green line) and Line "Ghatkopar-Thane" (blue line) have been provided by MMRDA.

More complex is the analysis of 2031 horizon. By that date, it is almost certain that both MMC and all metro lines will be working at full speed. The development plans expected for the outer areas of Bhiwandi and Kalyan may be completed as well, increasing the attractiveness of these zones. As a consequence, population is expected to rise and generate more traffic flows. However, as suggested by CTS, migration trends will likely change the population distribution within the MMR and this will directly affect the travel demand.

Therefore, in this case, three possible scenarios have to be assessed:

- Scenario A: both MMC and all metro lines are in operation (following CTS long term recommendations; CTS, 2005). Nevertheless, the increase of population within our study area (due to the above-mentioned new developments) is partially compensated by a small reduction in the other zones belonging to the MMR. Indeed, as it is projected in CTS, the population spread may continue concentration in the suburbs, due to constraints regarding developable and availability areas within Mumbai.
- Scenario B: both MMC and all metro lines in MMR are in operation. According to development plans (DPBSNA, 2008; DPKAT, 2011), new settlements expected in Kalyan and Bhiwandi will attract people mainly coming from other zones belonging to our study area. In this case, it makes sense to think that there will be a new population distribution and the growth rate of Thane, Bhiwandi and Kalyan regions will remain constant (i.e. the same growth rate estimated in Chapter 3.3 of this report can be used so as to consider the last census data). Transport mobility outside of the study area (i.e. the remain part of the OD matrix) is not affected by developments and it does not vary;
- Scenario C: both MMC and all metro lines in MMR are in operation. In addition, it is considered that, similarly to the study area, population (and thus transport mobility) will increase in all MMR due to strong migration phenomena coming from rural areas. Obviously, this scenario is extremely optimistic, but it is necessary to assess the capacity required to fulfil travel needs even in the worst case.

Before running the transit assignment, it is necessary to design the future MRTS in Transcad following a precise corridor. At this stage of the study, the alignment has not been discussed yet; therefore, it is decided to use the path suggested in previous Thane-Bhiwandi-Kalyan feasibility study (Figure 3.14) in order to assess the amount of ridership (see TEFS, 2011).

As indicated in the previous report, the proposed MRTS corridor is approximately 24 km.

Furthermore, in these preliminary simulations, 17 possible stations are considered, which are shown in Figure 3.15. Obviously, in following reports, after the new alignment design and the definition of station locations, simulations will be repeated so as to obtain more precise results in terms of zone accessibility.

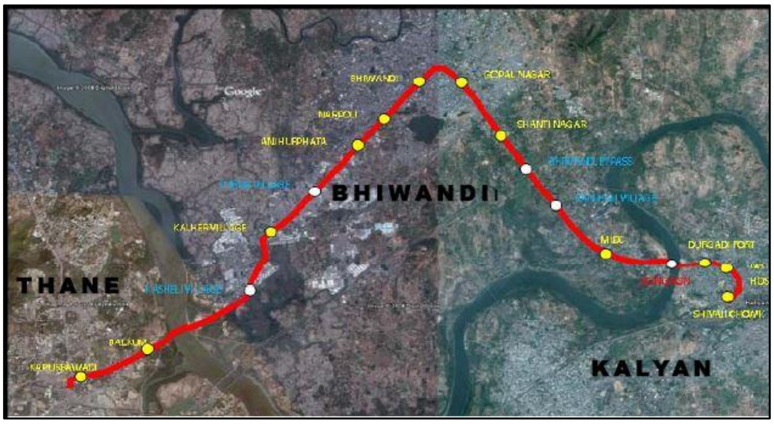

Figure 3.14: Alignment Proposed in Previous Feasibility Study

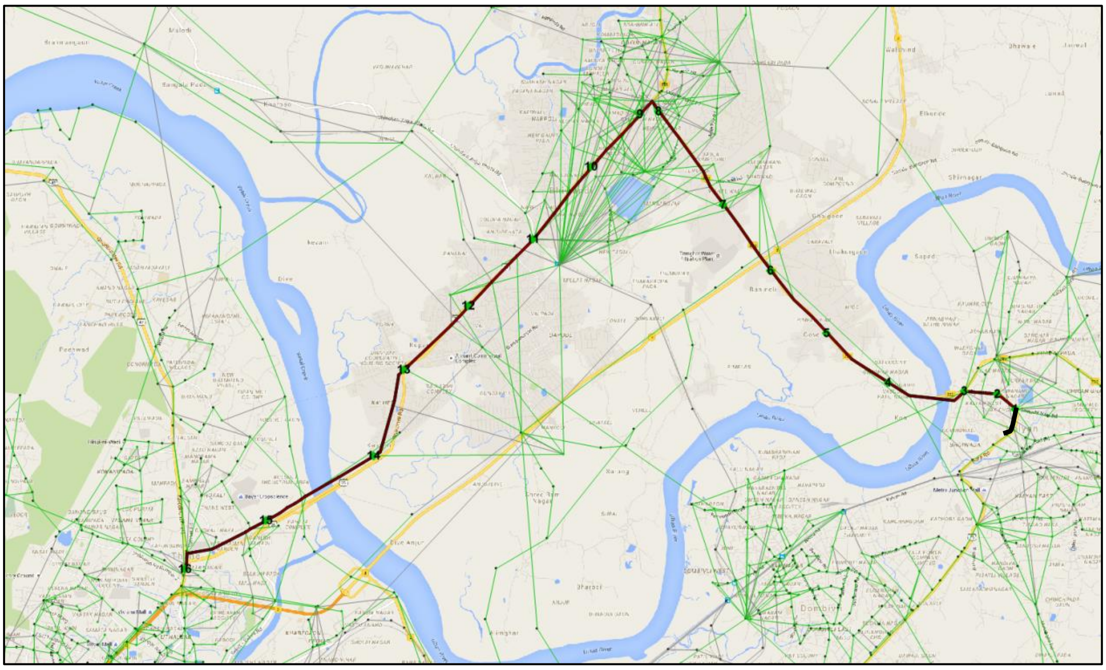

Figure 3.15: Proposed Stations of the MRTS

Another important remark is related to the characteristics of the MRTS adopted for simulating the future scenarios since they can affect the results. In particular, for 2021 scenario (both A and B cases), it is assumed that the MRTS service has a headway of 6 minutes during the morning peak hour. For the more distant scenarios (i.e. 2031A, B and C) by contrast, the headway is considered similar to that of the other metro lines, which is 2 minutes. Another important input data is the hourly capacity of the MRTS. Due to the high level of inhabitants within the study area, it is likely that the number of customers of the new service may be noteworthy. For this reason, for each run it is considered a maximum capacity of 1000 passengers (i.e. the same capacity of a metro train).

Obviously, only final results can provide a feedback about the hypothesized service characteristics.

Last significant consideration concerns the specification of performance variables and transportation costs used in the simulations. Basically, some variables perceived by users can be associated with individual trip phases. Examples of such variables are travel times (transversal and/or waiting), monetary cost, discomfort, etc. These variables are referred to as "*level-of-service*" or "*performance attributes*". Thus, the transportation link cost reflects the average users' disutility for carrying out the activity represented by the link and can be expressed in terms of generalized cost as follows:

$$c_l = \sum_n \beta_n \cdot r_{n,l} \quad (1)$$

where:

- c_l is the generalized link transportation cost;
- β_n is the generic "reciprocal substitution coefficient" which is necessary to homogenize the different performance variables and make the generalized cost a singular scalar quantity;
- $r_{n,l}$ is the generic link performance variables (e.g. waiting time, running time, etc.).

In addition, there are other performance variables and costs which cannot be associated to individual links but rather to the whole trip.

Therefore, the average generalized transportation cost of a path *k*, g_k, is defined as a scalar quantity homogenizing in disutility units the different performance variables perceived by the users (of a given category) in making trip-related choices and, in particular, path choices.

It is expressed as follows:

$$g_k = g_k^{ADD} + g_k^{NA} \tag{2}$$

where:

- g_k^{ADD} is the additive path cost;
- g_k^{NA} is the non-additive path cost which means that it cannot be obtained as sum of link specific values (an example is the monetary cost performance attribute when it is not proportional to the distance covered).

The additive path cost can be defined as the sum of the link-wise additive path performance variables, namely:

$$g_k^{ADD} = \sum_n \beta_n \cdot z_{n,k}^{ADD} \tag{3}$$

where $z_{n,k}^{ADD}$ is the generic path performance variable. Under the assumption that the generalized cost depends linearly from performance variables, the additive path cost can be expressed as the sum of generalized link cost c_l.

In order to perform the transit assignments described above, the following generalized cost specification is adopted:

$$g_k = \sum_{wal} \beta_{wal} \cdot t_{wal} + \sum_{w} \beta_w \cdot t_w + \sum_{r} \beta_r \cdot t_r + \beta_{mc} \cdot mc \tag{4}$$

where:

- t_{wal} is the time spent by the user on walking links (wal);
- t_w represents the waiting time at waiting links "w" (i.e. stations or stops);
- t_r is the running time spent on running links "r" such as on board the train, the metro or the bus;
- mc is the monetary cost expressed as "flat fare";
- β_{wal}, β_w, β_r, β_{mc} are the reciprocal substitution coefficients, whose values are summarized in Table 3.11.

Table 3.11: Values of Reciprocal Substitution Coefficients used for Transit Simulations

β_{wal}	β_w	β_r	β_{mc}
3	2	1	1

The amount of "flat fare" is calculated considering the different fare structure of each transport mode, which is shown in Appendix D.

In particular, by classifying the ticket fare for different distance ranges, it is possible to estimate the trendline functions which provide the cost that users have to pay for taking each transport mode (i.e. bus, metro or train) as depending on the distance travelled.

As it comes out from Table 3.12, where three hypotheses of travel distance are collected, trains are almost three times cheaper than both buses and metros. Specifically, it is estimated that on average the flat fares which express the monetary cost borne by bus and metro customers is respectively 2.72 and 2.73 higher (see Table 3.13). In addition, an extra cost equal to 0.4 is considered every time users change transport modality so as to represent the inconvenience they perceived in buying a new ticket (no fare integration is planned at the moment).

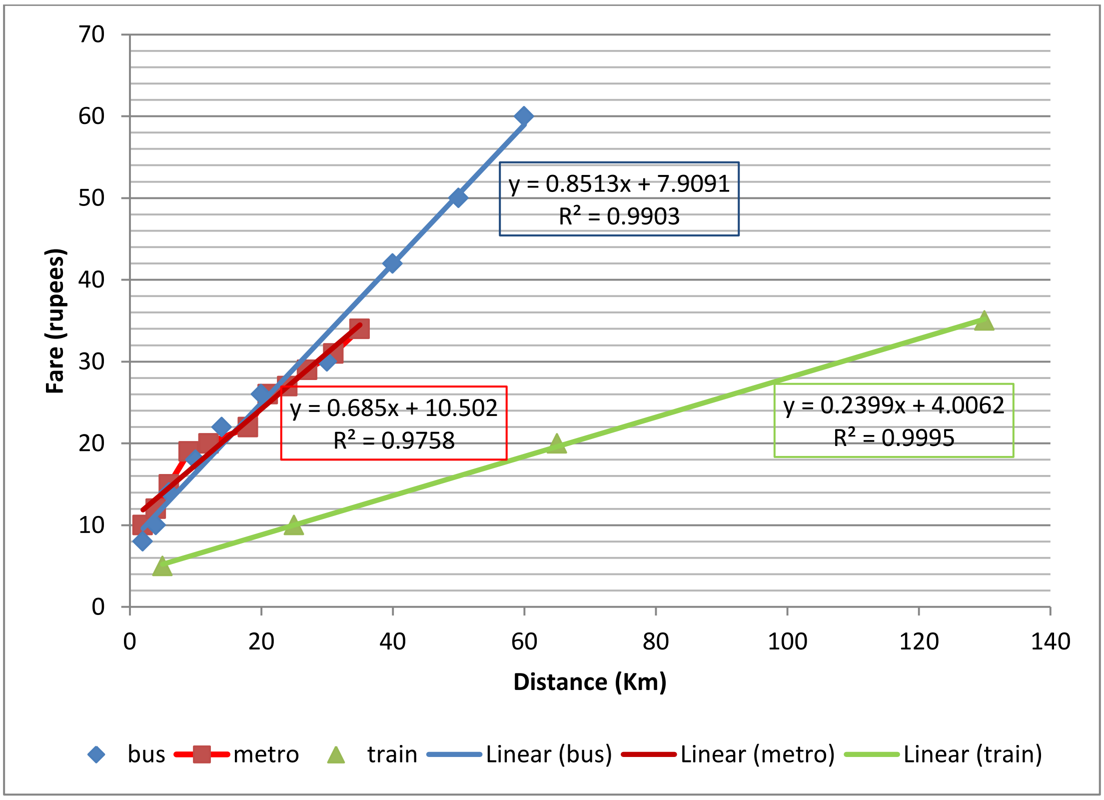

Figure 3.16: Fare Structure depending on the Distance travelled for bus, Metro and Train Network

Table 3.12: Different Fare Cost (rupees) for each Transport Mode in MMR

Transport mode	Travel distance = 15 km (Hp1)	Travel distance = 20 km (Hp2)	Travel distance = 20 km (Hp3)
Bus	20.68	24.94	29.19
Metro	20.78	24.20	27.63
Train	7.60	8.80	10.00

Table 3.13: Flat Fares (rupees) adopted in the Model for each Transport Mode in MMR

Transport mode	Travel distance = 15 km (Hp1)
Bus	2.72
Metro	2.73

Train	1

3.8 2021 SCENARIO A

As previously stated, in Scenario A it is supposed that the MMC will not be completed by 2021. It is therefore expected that population will rise according to the trendline functions previously estimated using 2011 census data. However, development plans provided by MMRDA foresee a slight growth for the new 27 villages in Kalyan. Therefore, in order to take into account this effect, a new demography projection for the whole Kalyan area has to be estimated.

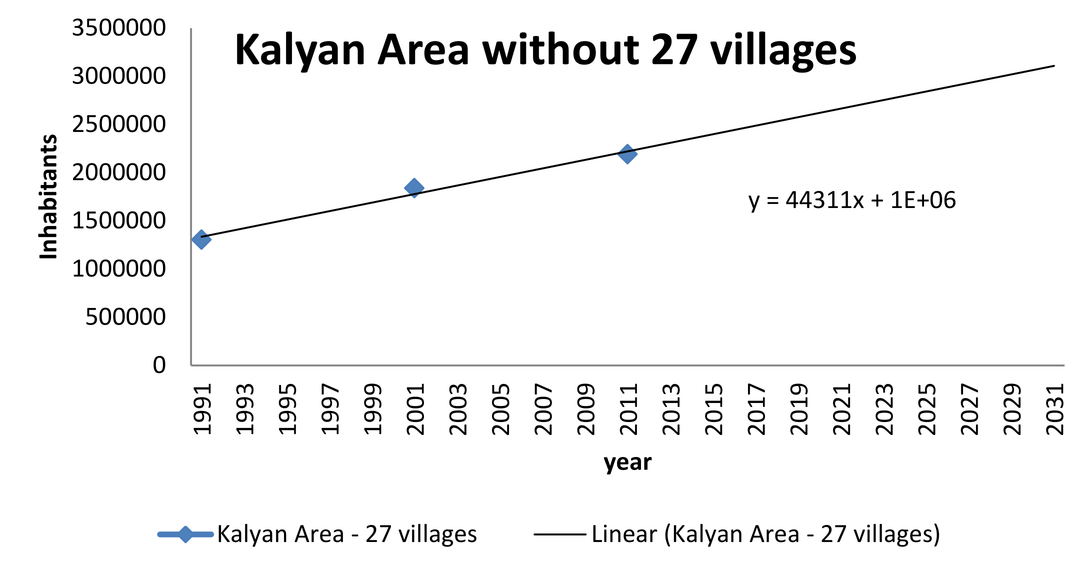

Figure 3.17: Trendline Function of Kalyan Area without Considering the Zones Affected by the Future Development Plans

To this purpose, data regarding population growth rate of the 27 villages are kept separated from the rest of the Kalyan area so that it could be possible to assess its contribution to the increase of inhabitants. In Figure 3.17, it is shown the new trendline function for Kalyan area excluding the zones affected by future developments. Table 3.14 instead, collects the results of this analysis including the other sub-districts.

Merging Bhiwandi and Kalyan values, it is possible to obtain the new growth rates expected for 2021.

As it can be seen, development plans for the 27 villages belonging to Kalyan sub-district have actually affected the growth rate of the entire study area. As a result, on an average basis, matrices have to be increased of 16.05%.

Performing SUE assignment as previously explained, the new transit matrix provides the amount of ridership of future MRTS.

Table 3.14: New Population Projections for 2021 (Scenario A)

	Number of Inhabitants				
Sub-District	1991	2001	2011	2016	2021
Thane	803389	1261517	1841488	2080707	2340232
Bhiwandi (BNMC)	379070	598703	709665	810432	893082
Bhiwandi (BSNA)	114349	168151	238728	267028	298123
kalyan AREA-27	1302121	1837512	2188336	2406600	2373641

Kalyan (27 villages)	65000*	130409*	260793		637537[4]

Table 3.15: Expected Population Growth Rate for 2021 (Scenario A)

	POPULATION 2021	DIFFERENCE 2016-2021
Thane	2340232	**12.47%**
Bhiwandi	1191205	**10.56%**
Kalyan area	3011178	**25.12%**
Average value		**16.05%**

3.9 2021 SCENARIO B

In Scenario B, besides the development in Kalyan villages, even the effect of the opening of the MMC is considered.

MMC feasibility study report (MMC, 2011) has assessed the increase of both traffic and transit flows on section 2-3 and section 3-4, namely the ones passing through our study area. According to these data (see Table 3.16 and Table 3.17), the MMC is expected to generate 48 thousands passengers per trip per day in 2020. Assuming flows during peak hour as 10% of the all day, it is possible to get an estimation of the amount of travelers who has to be distributed among the whole study area considering the attractiveness of each traffic zone.

Table 3.16: Highway Traffic Produced by MMC

HIGHWAY TRAFFIC FORECAST (LAKH VEHICLES PER DAY)				
Year	2015	2020	2025	2030
Section 2-3	34	67	101	135
Section 3-4	45	91	136	180
Generated by the Area	11	24	35	45
% Generated by the Area	**32.35%**	**35.82%**	**34.65%**	**33.33%**

Table 3.17: Public Transport Passenger Produced by MMC

PUBLIC TRANSPORT FORECAST (THOUSAND PASSENGERS PER TRIP PER DAY)				
Year	2015	2020	2025	2030
section 2-3	139	279	418	558
section 3-4	164	327	491	655
generated by the area	25	48	73	97
% generated by the area	**17.99%**	**17.20%**	**17.46%**	**17.38%**

3.10 2031 SCENARIO A

In 2031 Scenario A, it is supposed that population will rise following CTS projections (i.e. long term transportation strategy scenario “P3E3”). It is indeed likely that new areas under planned development; which may increase the number of inhabitants, will attract more people from other zones belonging to MMR. Therefore, starting from 2021 projections (see Table 3.14), in order to reach the population foreseen by CTS in our study area for the 2031

4 2021 population value suggested in Kalyan report development plan.

time horizon (i.e. 8595001 inhabitants), it is assumed an average growth rate of 31.37% (Table 3.18). This factor is adopted for updating the OD matrix as regards the internal trips while external-internal trips as well as exchange trips are not increased, since it is assumed that population in Mumbai will mostly remain the same.

Table 3.18: Expected Population Growth Rate for 2031 (Scenario A)

	POPULATION 2021	POPULATION 2031 (CTS projection)	DIFFERENCE 2021-2031
Study area	2340232	8595001	**31.37%**

In addition, the number of passengers generated by MMC is expected to be around 97 thousands passengers per trip per day (Table 3.17) and all metro lines are considered in operation as well (see Appendix C).

3.11 2031 SCENARIO B

In 2031 scenario B, on the basis of recent census data (Chapter 3.3), the growth rate is expected to be lower than CTS long term projection. Indeed, it is assumed that people living within our study area (especially people living in slums) will be easier attracted by the new planned settlements and they will relocate in these new areas. The population will thus distribute in the whole study area and the growth rate will increase following our estimated trendline functions.

As summarized in Table 3.20, the average growth rate is therefore assumed equal to +18.66%. The OD matrix is then updated considering the travel demand generated by the MMC.

Table 3.19: New Population Projections for 2031 (Scenario B)

	Number of Inhabitants	
Sub-District	2021	2031
Thane	2340232	2859282
Bhiwandi (BNMC)	893082	1058382
Bhiwandi (BSNA)	298123	360313
kalyan AREA-27	2373641	2816751
Kalyan (27 villages)	637537	637537

Table 3.20: Expected Population Growth Rate for 2031 (Scenario B)

	POPULATION 2031	DIFFERENCE 2016-2021
Thane	2340232	**22.18%**
Bhiwandi	1191205	**19.10%**
Kalyan area	3011178	**14.72%**
Average value		**+18.66%**

External-internal trips and exchange trips are left again unchanged.

3.12 2031 SCENARIO C

The 2031 scenario C follows the same assumptions introduced in the previous scenario. However, it is considered that the rising trend of demography does not concern only the study area but all MMR. As a consequence, the whole OD matrix is updated according to the expected population growth rate shown in Table 3.20.

3.13 ANALYSIS OF THE RESULTS

In Table 3.21 ridership values of the five simulated scenarios are collected. Basically, what comes out from the analysis of these results is that the construction of a new MRTS would be extremely attractive for a great amount of people.

Table 3.21: Maximum Ridership Levels for the different simulated Scenarios

HORIZON 2021	Maximum PHPD	Daily Ridership	Average Trip Length in KM
Scenario A	17957	229394	10.48
Scenario B	18044	231482	
HORIZON 2031			
Scenario A	26143	302558	11.16
Scenario B	25724	299525	
Scenario C	29906	335938	

*For Both 2021 and 2031, Scenario A is considered as final scenario.

In particular, in some cases, the ridership values exceed the maximum capacity of the MRTS which is considered equal to 10000 PHPD (10 trains/hour) for the 2021 scenarios and equal to 30000 PHPD (30 trains/hour) for 2031 scenarios. This is due to the fact that a macroscopic simulation, as the one performed, cannot simulate the dynamic of flow propagation and the formation of queues along the line. Therefore, during the morning peak hour, it is likely that the capacity of the MRTS does not fulfil travel demand requirements. However, because of higher congestion levels (especially for train lines) and running times (especially for bus routes) of the other public transport modes, a great amount of passengers would prefer to remain on the platform and wait more time for the first available train (i.e. train with enough capacity to board) since the extra cost they perceived would be lower than the one produced by other mode choices.

The main factors behind the outcomes illustrated in Table 3.21 are:

The MRTS seems to be a valuable alternative to local trains (i.e. Central Railway) for connecting Thane to Kalyan, whose train connection at the moment has an extremely high ridership. Many usual travelers would prefer the new MRTS, since it would give the possibility to reach their destinations in less time and with a high level of service quality (Figure 3.18);

Approximate Modal shift from other modes to Metro are as follows

- Two wheeler :11%
- Car/Taxi : 13%
- Auto :21%
- Bus: 31%

The MRTS enables a fast connection to the railway line passing through Bhiwandi area (i.e. Central Railways). Indeed, as confirmed by simulations, the interchange flow between station 6 of the MRTS and Bhiwandi Road Railway Station is significant (Figure 3.19);

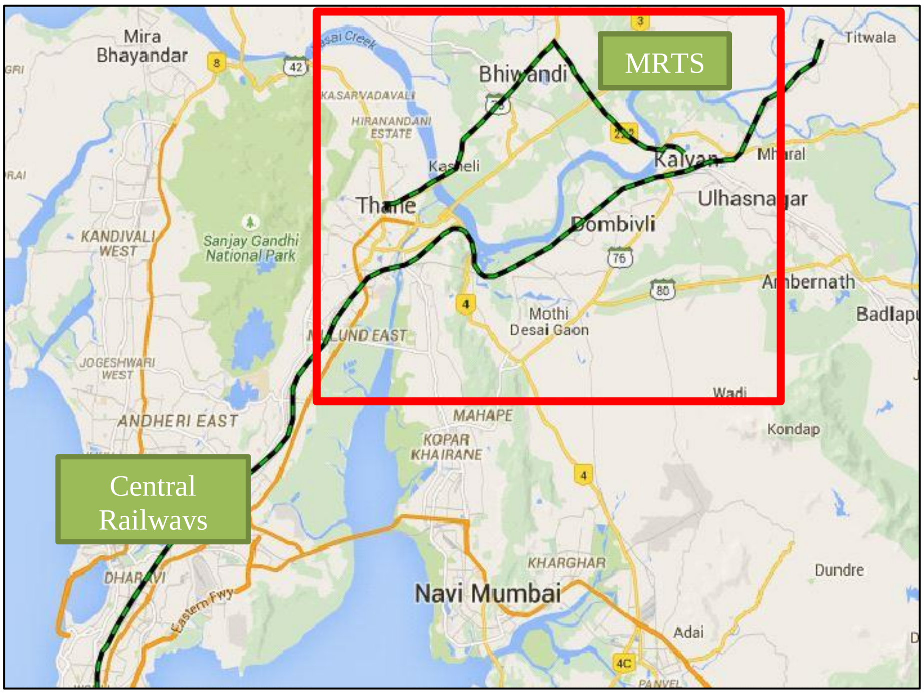

Figure 3.18:Representation of the MRTS and Central Railways Rail Line

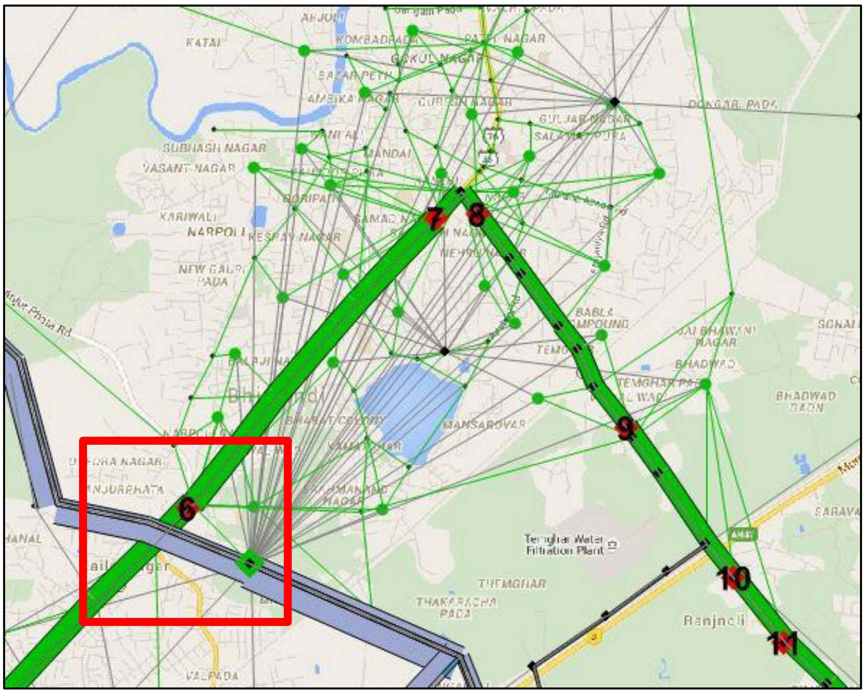

Figure 3.19:Flow Interchange between the MRTS and the Railway line passing through Bhiwandi Area

The possible opening of Line “Ghatkopar-Thane” would provide a fast metro connection to our study area reducing travelling time for people coming from other zones of the MMR. In particular, Line 1 "Versova-Andheri-Ghatkopar" (already in operation), Line "Ghatkopar-Thane" and the new MRTS would create an important metro corridor (Figure 3.20);

In following years, traffic congestion is expected to increase due to the big developments of transport infrastructure (e.g. MMC) and population growth. For this reason, in the simulation of future scenarios bus routes result to be less attractive than a fast MRTS.

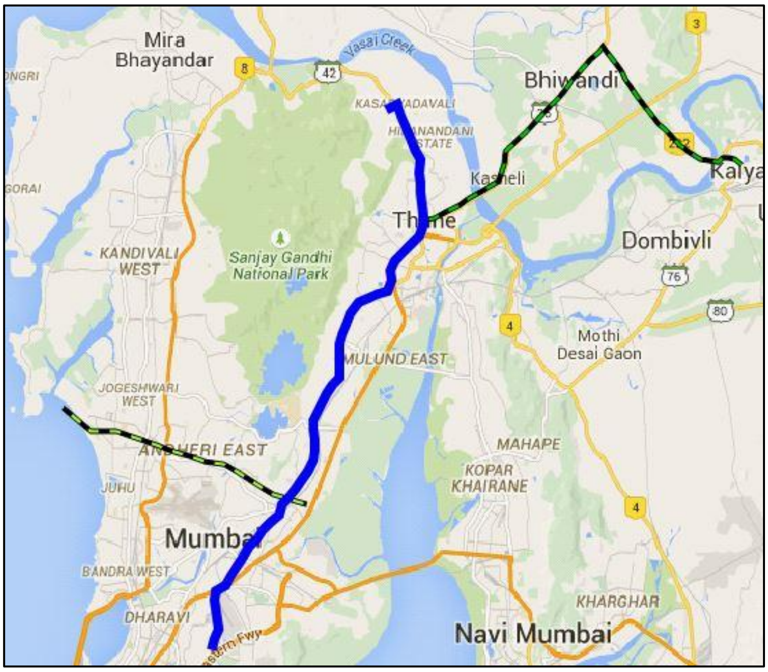

Figure 3.20: Representation of Line "Versova-Ghatkopar"- Line "Ghatkopar-Thane" - new MRTS Metro Corridor

The analysis of load diagrams demonstrates that the highest ridership levels affect the section connecting Kalyan to Thane passing by Bhiwandi.

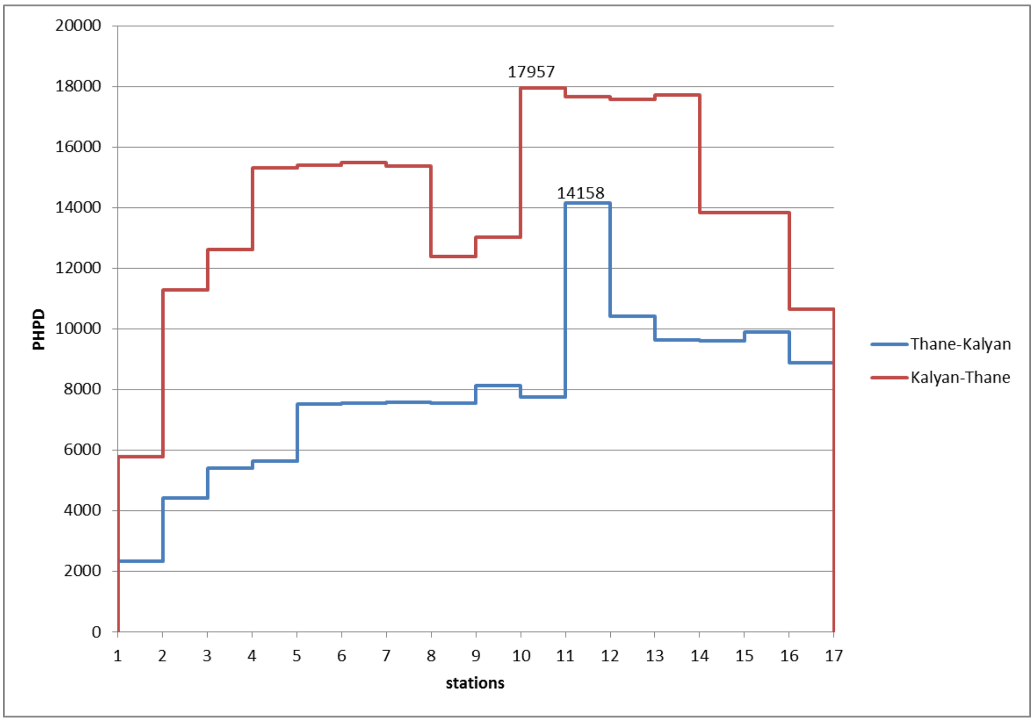

Figure 3.21:Load Diagrams regarding simulation of 2021 Scenario A

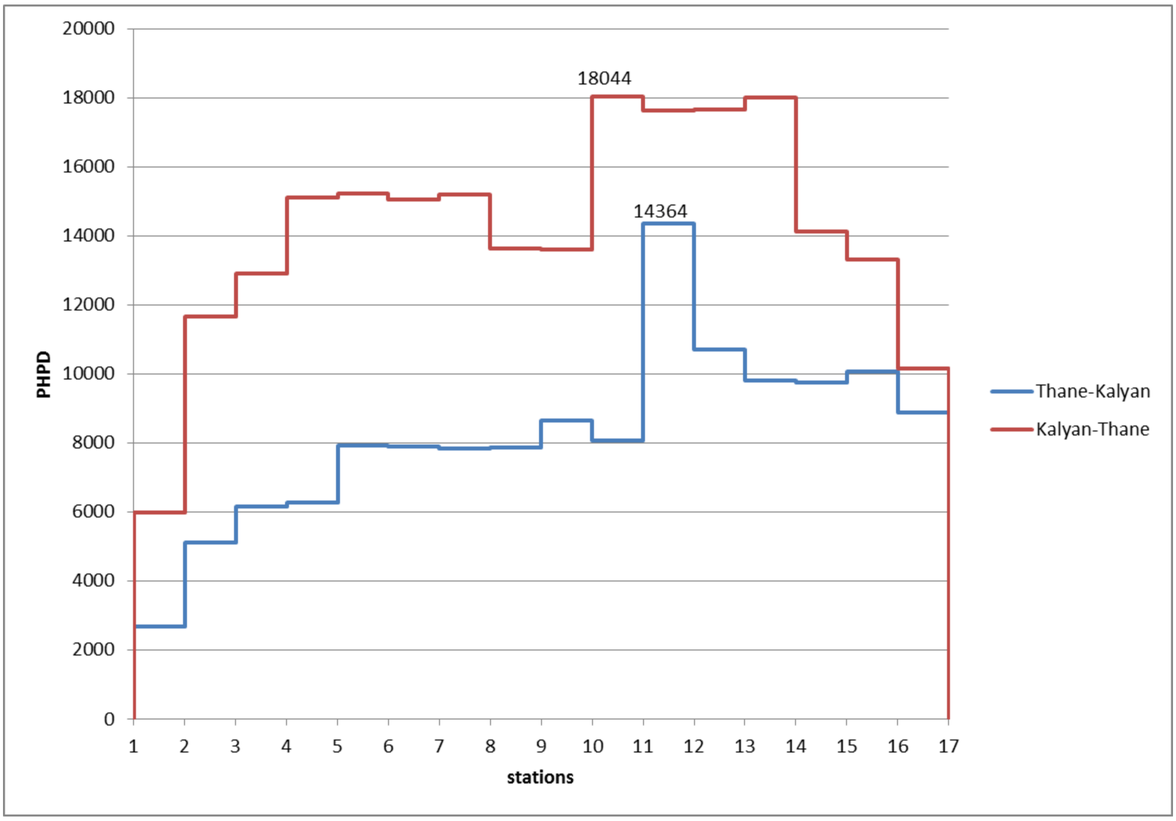

Figure 3.22:Load Diagrams regarding simulation of 2021 Scenario B

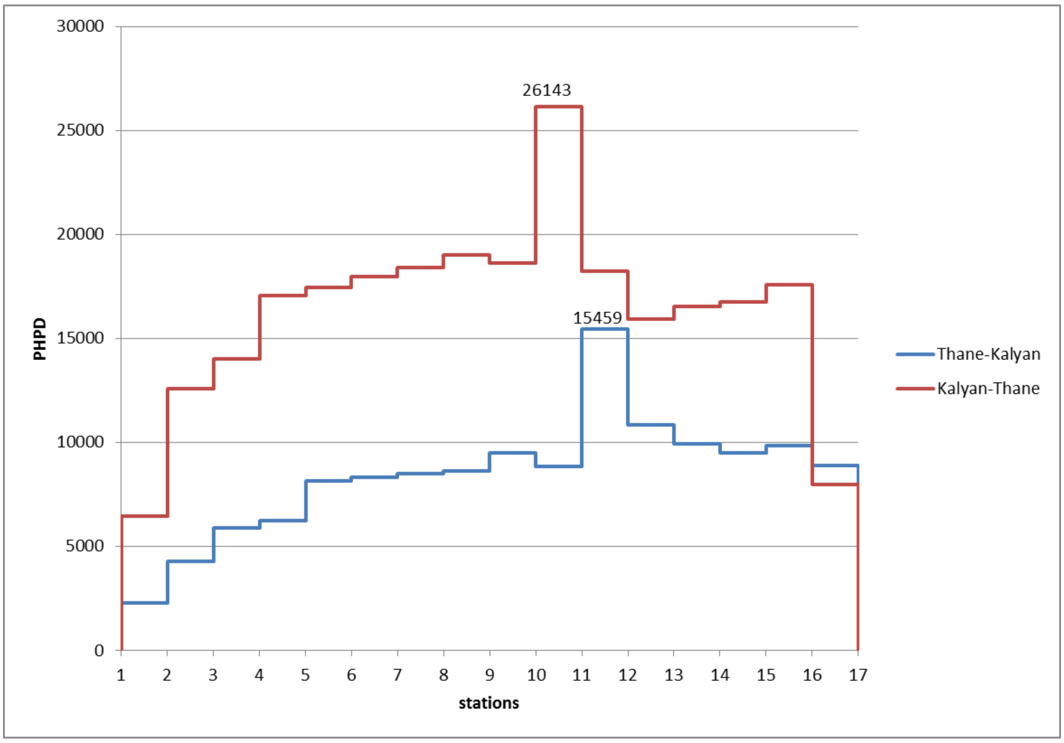

Figure 3.23: Load Diagrams regarding Simulation of 2031 Scenario A

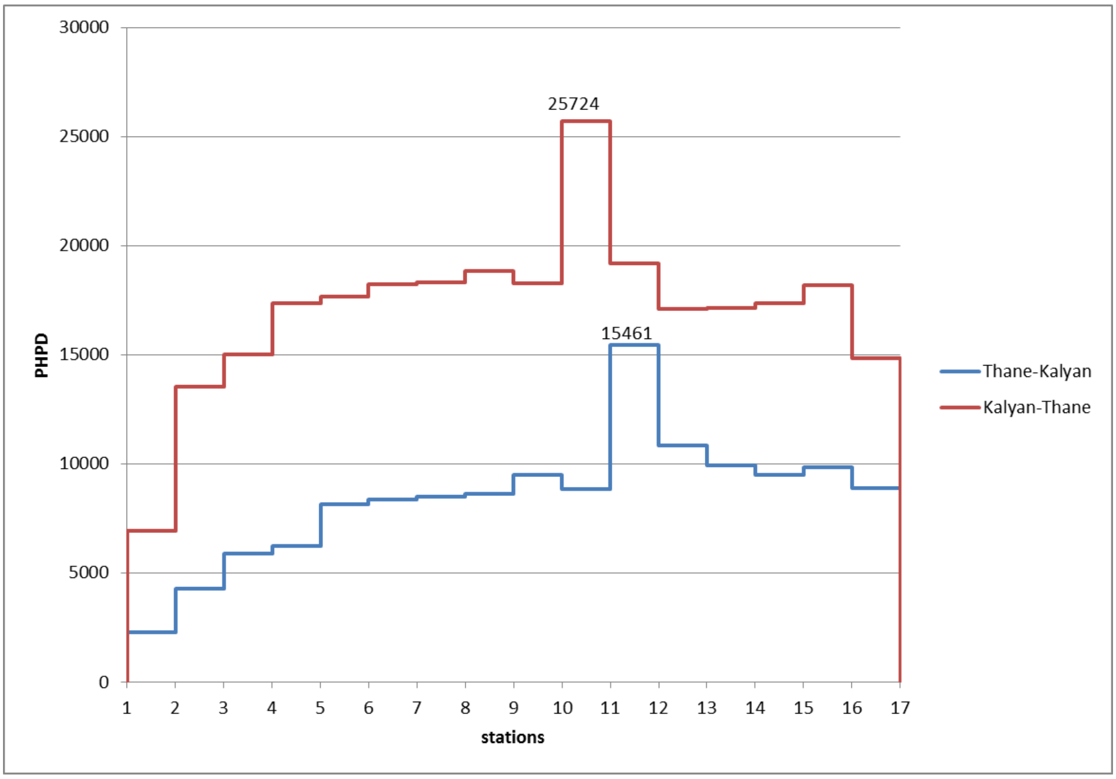

Figure 3.24:Load Diagrams regarding Simulation of 2031 Scenario B

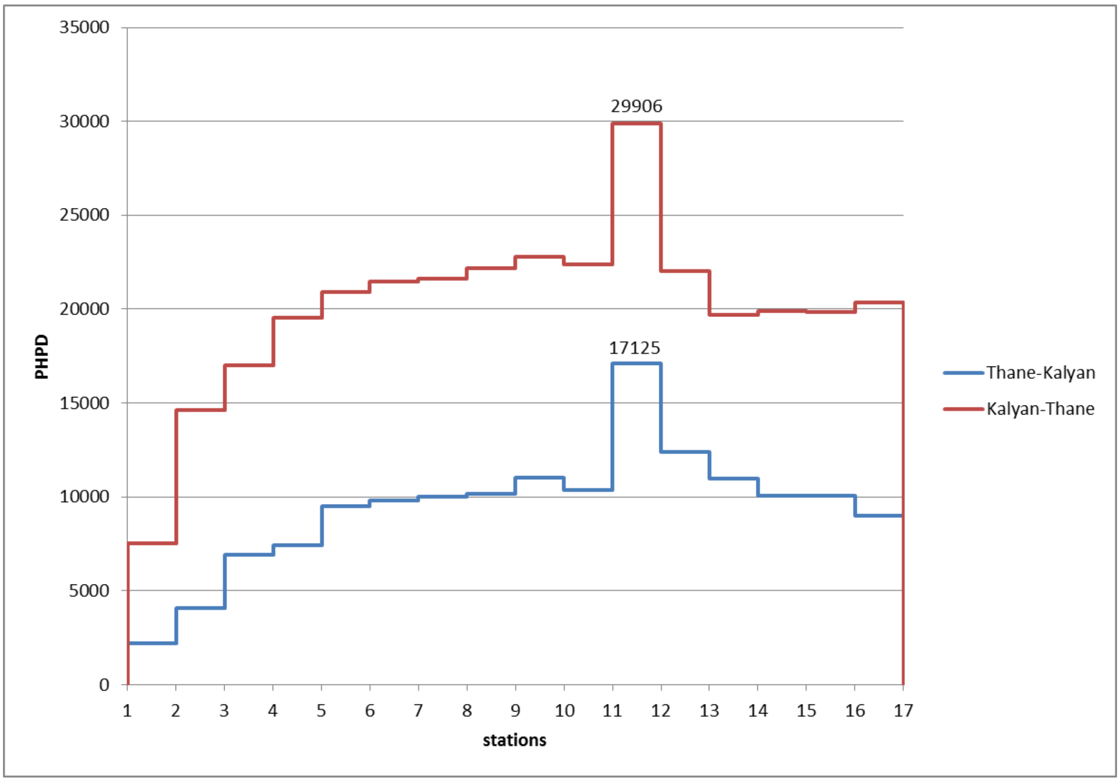

Figure 3.25:Load Diagrams regarding Simulation of 2031 Scenario C

In addition, boarding/alighting diagrams shown in the following tables give information about the attractiveness of each station.

As it can be seen, the most crowded stations are included in Thane and Kalyan areas, since simulation results highlight a great number of passengers boarding and alighting the MRTS line.

Furthermore, it is worth noting that, as already stated, station number 6 is extremely important to ensure the interchange with passengers of Central Railways lines. Indeed, many users travelling in both directions change transport mode so as to reach their destinations.

Stations belong to Bhiwandi area by contrast, host a considerable flow coming from Kalyan.

Table 3.22 Number of boarding/alighting passengers for the simulated scenarios, direction Thane-Kalyan (peak hour)

	SCENARIO 2021 A		SCENARIO 2021 B		SCENARIO 2031 A		SCENARIO 2031 B		SCENARIO 2031 C	
Station	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
17	8886	0	8880	0	8889	0	8891	0	8985	0
16	1251	244	1479	296	1295	362	1308	377	1432	362
15	578	879	580	900	583	905	591	868	899	905
14	113	82	166	112	503	77	504	83	1003	85
13	880	102	996	87	1010	105	1086	135	1553	110
12	7060	3303	7123	3466	7575	2947	7652	2181	8029	3314
11	1016	7421	1095	7390	1064	7680	1059	7724	1064	7840
10	2238	1870	2490	1913	2242	1583	2248	1590	2252	1583
9	657	1231	564	1339	695	1566	518	1589	725	1566
8	112	96	347	398	119	265	178	221	129	289
7	151	175	129	57	153	300	229	204	153	348
6	166	200	91	59	167	356	214	324	170	469
5	45	1916	225	1867	92	2009	181	1245	138	2224
4	83	329	151	269	99	462	129	496	102	634
3	116	1078	104	1146	118	1699	135	3025	127	2972
2	50	2155	52	2500	75	2084	78	2368	82	1963
1	0	2321	0	2673	0	2280	0	2570	0	2177

Table 3.23 Number of boarding/alighting passengers for the simulated scenarios, direction Kalyan-Thane (peak hour)

	SCENARIO 2021 A		SCENARIO 2021 B		SCENARIO 2031 A		SCENARIO 2031 B		SCENARIO 2031 C	
Station	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting	Boarding	Alighting
1	5780	0	5977	0	6459	0	6937	0	7519	0
2	5550	54	5740	55	6187	78	6665	81	7216.5	90
3	1394	67	1455	218	1919	478	1900	425	2479	104
4	2741	32	2506	295	3113	51	2505	148	3005	483
5	140	59	210	106	487	116	485	166	1419	69
6	703	606	168	340	671	138	665	125	705	136
7	148	263	325	166	567	134	163	49	280	138
8	730	3722	625	2203	1415	816	1257	744	769	201
9	2593	1967	2047	2076	2197	2586	1880	2435	1415	816
10	6321	1373	5900	1450	9240	1716	8988	1549	2197	2586
11	6704	7003	8848	9252	2875	10776	2851	9397	9240	1716
12	415	516	596	579	194	2525	184	2276	2875	10776
13	226	64	543	192	689	50	700	659	204	2525
14	890	4767	733	4606	1114	902	1117	907	964	768
15	918	931	818	1650	1537	722	1631	801	961	1003
16	241	3429	201	3348	407	10003	515	3860	1537	1018
17	0	10642	0	10157	0	7982	0	14822	0	20358

Table 3.24 Station to Station Link Flows for the simulated scenarios, direction Thane- Kalyan (peak hour)

		SCENARIO 2021 A	SCENARIO 2021 B	SCENARIO 2031 A	SCENARIO 2031 B	SCENARIO 2031 C
From	to	flow	flow	flow	flow	flow
17	16	8886	8880	8889	8891	8985
16	15	9893	10064	9823	9825	10055
15	14	9592	9743	9501	9503	10049
14	13	9623	9797	9926	9928	10967
13	12	10401	10706	10831	10833	12410
12	11	14158	14364	15459	15461	17125
11	10	7753	8069	8843	8845	10349
10	9	8122	8646	9502	9504	11018
9	8	7548	7871	8632	8634	10177
8	7	7563	7820	8485	8487	10017
7	6	7539	7892	8338	8340	9821
6	5	7505	7924	8149	8151	9522
5	4	5634	6282	6232	6234	7436
4	3	5389	6164	5870	5872	6904
3	2	4426	5121	4288	4290	4058
2	1	2321	2673	2280	2282	2177

Table 3.25 Station to Station Link Flows for the simulated scenarios, direction Kalyan- Thane (peak hour)

		SCENARIO 2021 A	SCENARIO 2021 B	SCENARIO 2031 A	SCENARIO 2031 B	SCENARIO 2031 C
From	to	flow	flow	flow	flow	flow
1	2	5780	5977	6459	6937	7519
2	3	11276	11662	12568	13521	14646
3	4	12603	12899	14009	14996	17021
4	5	15312	15109	17070	17353	19543
5	6	15392	15214	17442	17672	20892
6	7	15489	15042	17975	18213	21462
7	8	15374	15201	18408	18326	21604
8	9	12382	13623	19007	18840	22172
9	10	13009	13594	18619	18285	22771
10	11	17957	18044	26143	25724	22382
11	12	17658	17640	18242	19178	29906
12	13	17557	17657	15912	17086	22006
13	14	17719	18008	16551	17127	19685
14	15	13842	14135	16762	17337	19881
15	16	13830	13303	17577	18167	19839
16	17	10642	10156	7982	14822	20358

In conclusion, according to the simulated ridership levels provided by preliminary analysis (especially for 2031 scenarios), the most appropriate ***MRTS seems to be a metro system*** since it can carry passenger flows ***of approximately 30,000 PHPD.***

4 OVERVIEW OF DIFFERENT TRANSIT TECHNOLOGIES

A modern public transport system must be fast, frequent, reliable, and must be an improvement in capacity over local buses. It operates largely on its own right-of-way, meaning that it is not affected by regular car traffic.

Some rapid transit technologies are being considered, that can be classified on the basis of two key features:

- technology of motion and traction, i.e. as the motion of the vehicle and the sustenance are transmitted to the runway;
- Vehicle control system, mainly related to the presence on board of driving personnel.

For the first aspect, it is possible to define the following categories:

- **Rubber-Tyred Systems**

A rubber-tyred transport system uses a mix of road and rail technology: the vehicles have wheels with rubber tyres which have the function of motion and weight transfer, as well as traditional railway steel wheels with deep flanges on steel tracks have the function of guidance; most rubber-tyred vehicles are purpose-built and designed for the system on which they operate.

- **Rail Systems**

Rail transport is a means of conveyance, by way of wheeled vehicles running on rails; in contrast to road transport, where vehicles merely run on a prepared surface, rail vehicles are also directionally guided by the tracks on which they run.

- **Monorail**

A monorail is a railway in which the track consists of a single rail, typically elevated; the term is also used to describe the beam of the system, or the vehicles travelling on such a beam or track.

- **Magnetic Levitation**

Magnetic levitation is a method by which a vehicle is suspended with no support other than magnetic fields; this method has the potential to be faster, quieter and smoother than wheeled mass transit systems.

For the second aspect, vehicle control system could be:

- **With driver**, if at least one qualified operator is present on board, with function of vehicle movement control; this operator can be assisted by a supervision system, that is interfaced with a traffic management system (assisted driving) or not (manual driving);

- **Driverless**, no operator is on board; the control of each vehicle and the practicability of runway are remote and de-localised in a control room; in this case the system must be completely right-of-way.

On the basis of these key features, the public transport systems can be classified as indicated in the following table. For each technology a brief description is presented.

	With Driver	Driverless
Rubber-Tyred Systems	Bus Rapid Transit (BRT) Rubber-Tyred Tram Rapid Transit [metro, subway, underground]	Personal Rapid Transit (PRT) Rapid Transit [driverless metro]
Rail Systems	Tram (streetcar, trolley car, tram-train) Light Rail Transit (LRT) Rapid Transit [metro, subway, underground]	Rapid Transit [driverless metro]

4.1 BUS RAPID TRANSIT

Bus Rapid Transit (BRT) is a high-quality bus-based transit system; it does this through the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations.

There are five essential features that define BRT. These features most significantly result in a faster trip for passengers and make traveling on transit more reliable and more convenient.

- Dedicated Right-of-Way: bus-only lanes make for faster travel and ensure that buses are never delayed due to mixed traffic congestion;
- Busway Alignment: center of roadway or bus-only corridor keeps buses away from the busy curbside where cars are parking, standing, and turning;
- Off-board Fare Collection: fare payment at the station, instead of on the bus, eliminates the delay caused by passengers waiting to pay on board;
- Intersection Treatments: prohibiting turns for traffic across the bus lane reduces delays caused to buses by turning traffic. Prohibiting such turns is the most important measure for moving buses through intersections – more important even than signal priority;
- Platform-level Boarding: the station should be at level with the bus for quick and easy boarding. This also makes it fully accessible for wheelchairs, disabled passengers, strollers and carts with minimal delays.

4.2 RUBBER-TYRED TRAM

Guided buses are buses steered by external means, usually on a dedicated track or roll way that excludes other traffic, permitting the maintenance of schedules even during rush hours.

Guidance systems can be physical, such as kerbs or guide bars, or remote, such as optical (for example Irisbus Civis, with a device developed by Siemens Transportation Systems), or magnetic guidance (for example APTS Phileas).

A development of the guided bus is the “tramway on tyres”, in which a trolleybus is guided by a fixed rail in the road surface and draws current from overhead electric wires. Two incompatible systems exist, the Guided Light Transit (GLT) designed by Bombardier Transportation, and Translohr. There are no guide bars at the sides but there is a central guidance rail that, in the case of Translohr, is grasped by a pair of metal guide wheels set at

45° to the road and at 90° to each other. In the GLT system, a single double-flanged wheel between the rubber tyres follows the guidance rail. In both cases, the weight of the vehicle is borne by rubber tyres to which the guide wheels are attached. Power is supplied by overhead lines or by rechargeable batteries where there are no overhead wires.

The Bombardier system has been adopted in Nancy and Caen, France, while the Translohr system is in use in Clermont-Ferrand, France and Tianjin and Shanghai, China, and is under construction in Padua, L'Aquila (L'Aquila), and the mainland Mestre district of Venice in Italy. The Translohr system is intended for guidance-only operation, while with the Bombardier system the vehicles can be driven as normal buses as requirements dictate, such as journeys to the depot.

4.3 TRAM

A tram (also known as tramcar and in North America as streetcar, trolley or trolley car), is a rail vehicle which runs on tracks along public urban streets and also sometimes on separate rights-of-way.

Tram lines may also run between cities and/or towns (for example, interurbans, tram-train), and/or partially grade-separated even in the cities (light rail). The vehicles are usually lighter and shorter than conventional trains and rapid transit trains, but the size of trams (particularly light rail vehicles) is rapidly increasing. Some trams (for instance tram-trains) may also run on ordinary railway tracks, a tramway may be upgraded to a light rail or a rapid transit line, two urban tramways may be connected to an interurban, etc. in this way there are no changes of trains for passengers when travelling from the city centre to the suburbs.

Most trams today use electrical power, usually fed by an overhead pantograph; in some cases by a sliding shoe on a third rail or trolley pole. If necessary, they may have dual power systems - electricity in city streets, and diesel in more rural environments.

4.4 LIGHT RAIL TRANSIT

Light rail ranges from the traditional tramway through to fully segregated automated systems such as the Docklands Light Railway in London or Metro do Porto.

Light rail can run with all other traffic, alternatively road space can be shared, perhaps with busses, or be completely reserved. Sometimes a reserved right of way can be alongside a road or in the central reservation of a dual carriageway.

Railways which are underused can be converted to light rail and have on street extensions into town and city centers, providing additional stops.

4.5 PERSONAL RAPID TRANSIT

Personal rapid transit (PRT) is a public transport mode featuring small automated vehicles operating on a network of specially built guide ways. PRT is a type of automated guideway transit (AGT), a class of system which also includes larger vehicles all the way to small subway systems.

PRT vehicles are sized for small group travel, typically carrying no more than 50 passengers per vehicle. Guide ways are arranged in a network topology, with all stations located on sidings, and with frequent merge/diverge points. This allows for nonstop, point-to-point travel, bypassing all intermediate stations. The point-to-point service has been compared to a horizontal lift (elevator). This technology is commonly found at airports and occasionally as downtown circulators.

There is several type of guide way: proposals include beams similar to monorails, bridge-like trusses supporting internal tracks, and cables embedded in a roadway.

4.6 RAPID TRANSIT

Rapid transit (metro, subway, underground) is a type of high-capacity public transport generally found in urban areas. Rapid transit systems are electric railways that operate on an exclusive right-of-way, which cannot be accessed by pedestrians or other vehicles of any sort, and which is often grade separated in tunnels or on elevated railways.

Modern services on rapid transit systems are provided on designated lines between stations typically using electric multiple units on rail tracks, although some systems use guided rubber tyres, magnetic levitation, or monorail. The stations typically have high platforms, without steps inside the trains, requiring custom-made trains in order to avoid gaps. They are typically integrated with other public transport and often operated by the same public transport authorities, but does not exclude a fully segregated light rail transit.

With the aim of improving the frequency of service, many lines operate with ATO (Automatic train operation) technology, developed to enable trains to operate without a driver in a cab: either with an attendant roaming within the train, or with no staff on board.

According to the International Association of Public Transport (UITP), there are five Grades of Automation (GoA) of trains (IEC 62267):

- GoA0 is on-sight train operation, similar to a tram running in street traffic;
- GoA1 is manual train operation where a train driver controls starting and stopping, operation of doors and handling of emergencies or sudden diversions;
- GoA2 is semi-automatic train operation (STO) where starting and stopping are automated but a driver in the cab starts the train, operates the doors, drives the train if needed and handles emergencies;
- GoA 3 is driverless train operation (DTO) where starting and stopping are automated but a train attendant operates the doors and drives the train in case of emergencies;
- GoA 4 is unattended train operation (UTO) where starting and stopping, operation of doors and handling of emergencies are fully automated without any on-train staff.

Technology	Bus Rapid Transit	Rubber-Tyred Tram	Tram	Light Rail Transit	Personal Rapid Transit	Rapid Transit	Driverless Rapid Transit
Description	• Uses large rubber-tired buses • Runs in either dedicated bus lanes where regular traffic is prohibited or separate transit way	• Uses rubber-tired vehicles • Vehicles are guided by kerbs, guide bars or optical/magnetic devices • Runs in either dedicated bus lanes where regular traffic is prohibited or separate transit way	• Uses steel wheeled vehicles • Runs on steel rails embedded in the road surface or on a partially separate rail line	• Uses steel wheeled vehicles • Runs on steel rails embedded in the road surface or on a separate rail line	• Runs on an automated guide way • Small vehicles that carry 10÷50 people • No active systems in operation	• Provides frequent, high capacity services within urban areas • Typically uses steel-wheeled vehicles on steel tracks powered by electricity • Can run below or at-grade in a separate rail line	• Uses driverless, steel wheeled train vehicles running on rail tracks
Power Source / Propulsion	Mainly diesel engines but can also use alternative fuels like natural gas, propane,	Self-propelled, overhead electric wire and electric motor	Self-propelled, overhead electric wire and electric motor	Self-propelled, overhead electric wire and electric motor	Self-propelled units with electric motors or pulled by cables	Self-propelled units with electric motors	Self-propelled units with electric motors

Technology	Bus Rapid Transit	Rubber-Tyred Tram	Tram	Light Rail Transit	Personal Rapid Transit	Rapid Transit	Driverless Rapid Transit
	hybrid diesel-electric						
Typical Station Spacing	400 m ÷ 2 km	400 m ÷ 2 km	400 m ÷ 2 km	500 m ÷ 4 km	800 m ÷ 2 km	500 m ÷ 2 km	500 m ÷ 2 km
Typical Application	Urban/Suburban	Urban/Suburban	Urban/Suburban	Urban/Suburban	Urban/Suburban	Urban/Suburban	Urban/Suburban
Vehicles Seated Capacity	40 ÷ 85	65÷85	65÷85	65÷150	0÷10	70÷120	70÷120
Total Vehicles Capacity	100 ÷ 200	180÷300	180÷300	180÷600	10÷50	400÷1000	400÷1000
Frequency of Service	Less than 10 minutes	Less than 10 minutes	Less than 10 minutes	Less than 10 minutes	No Regular Schedule	Less than 5 minutes	Less than 5 minutes
Passengers per Hour per Direction	Exclusive right-of-way up to 10,000, Arterial up to 5,000	Exclusive right-of-way up to 12,000, Arterial up to 5,000	5,000 ÷ 9,000	Exclusive right-of-way up to 20,000, arterial up to 9,000	2,500 ÷ 7,500	10,000 ÷ 30,000	10,000 ÷ 30,000
Typical Capital Infrastructure Cost	$0.5 ÷ 22 M (higher end cost is for a separate transit way)	0$5 ÷ 15 M	$10 ÷ 25 M	$20 ÷ 35 M	$10 ÷ 25 M	$30÷50 M (at grade) $100÷160 M (subway)	$30÷50 M (at grade) $100÷160 M (subway)
Typical Vehicle Cost	$0.5 - 1.2 M	$2 - 3 M	$3 - 5 M	$3 - 5 M	Comprised in Infrastructure Cost	$5 - 8 M	$5 - 8 M

4.7 SUMMARY OF OPTIONS

On the basis of general characteristics of the above-mentioned transport systems, three options were selected and in the following paragraphs a summary of these options has presented.

Bus Rapid Transit (BRT)

- offers high-frequency and medium-capacity service with high-quality stop infrastructure;
- offers off-vehicle ticketing facilities and multiple-door, level boarding;
- uses rubber-tire, low-floor articulated buses that can run on diesel, compressed natural gas or electricity;
- operates along major routes in reserved lanes or on street-level dedicated rights-of-way separated from other traffic to improve travel time and reliability;
- runs exclusively on the surface, but can also be partially underground or elevated;
- uses signal priority at intersections and serves moderately-spaced stations at key destinations to improve journey times;
- can typically move 5.000 to 12.000 people each hour in each direction.

Light Rail Transit (LRT)

- offers high-frequency and high-capacity service with high-quality stop infrastructure;
- offers off-vehicle ticketing facilities and multiple-door, level boarding;
- uses driver-operated, electrically-powered rail systems;
- operates in the street in reserved lanes or on street-level dedicated rights of way separated from other traffic to improve travel time and reliability;
- has variants that include diesel light rail and tram-train; and
- can typically move 9,000 to 20,000 people each hour in each direction.

Rail Rapid Transit (RRT)

- offers high-frequency and high-capacity service with high-quality stop infrastructure;
- offers off-vehicle ticketing facilities and multiple-door, level boarding;
- comes in a variety of types (for example, automated, driverless systems, etc.);
- typically operates completely separated from traffic in a tunnel or on an elevated structure;
- surface level operation is possible, however it must be fully separated physically for safety; and
- typically moves over 20,000 people each hour in each direction.

4.8 SYSTEM SELECTION FOR THE PROPOSED CORRIDOR

With growing population and proposed BSNA and Kalyan development plans coming up in the regions, the travel demand is expected to grow steeply. Ridership values of the various simulated scenarios recommend construction of a new MRTS, which would be extremely attractive for a large group of people. The most likely peak traffic demand on Thane Bhiwandi Kalyan corridor has been assessed as 17500 PHPDT for 2021 and this is likely to increase to 25500 PHPDT by the year 2031. (See 14-1167-H2 rev2, 2015). Considering the Peak hour passenger demand traffic and the characteristics of transit systems described in the previous sections, there will be a need to introduce a Rail based Mass Rapid Transit System (MRTS) in the city to provide fast, safe, economic and environment friendly mode for mass movement of passengers.

4.9 ADVANTAGES OF A METRO SYSTEM

Metro systems are superior to other modes because they provide higher carrying capacity, faster, smoother and safer travel, occupy less space, and they are energy-efficient.

To summarise, a Metro system:

- requires 1/5th energy per passenger km compared to road-based system;
- causes no air pollution in the city;
- causes lower noise levels;
- occupies no road space if underground and only about 2 metres width of the road if elevated;
- carries same amount of passengers as 5 lanes of bus traffic or 12 lanes of private motor cars (either way), if it is a medium capacity system;
- is more reliable, comfortable and safer than road based systems;
- reduces journey time in comparison with other transport modes.

5 PLANNING & DESIGN PARAMETERS

5.1 GENERAL

This chapter describes various planning and design parameters recommended for proposed Thane-Bhiwandi-Kalyan Corridor metro system.

These parameters, which are collected in Table 5.1, are consonant with the basic requirements usually adopted for the design of the majority of metro systems spread all over the world.

Table 5.1: Basic Requirements for the Design of Metro Systems

Gauge	Minimum radius of curvature	Maximum slope	Average commercial speed	Maximum Operating speed	Average platform length	Average distance between consecutive stations
1435 mm	150 m	6%	35 km/h	80 km/h	180 m	1±2 km

5.2 STATION LOCATIONS

Locations of the stations play a vital role in the acceptance and success of any transit system. Stations have to be placed considering accessibility, catchment area and integration with other modes of transport. Stations have been located so as to serve passenger requirements and enable convenient integration with other modes of transport. The average spacing of stations is kept close to about 1.5 km as far as possible, to ensure the efficiency and enhanced operation. However some stations are spaced more than 2 km as there is no significant catchment. Total 17 stations are proposed for the corridor. Station Locations are dealt in detail in the coming chapter.

Table 5.2: Proposed Stations

Station No	Station Name	Chainage (from Kalyan (In Km)	Distance from Previous Stations (KM)	Remarks
1	Kalyan APMC	0.7		Elevated
2	Kalyan Station	0.296	0.700	Elevated
3	Sahajanand Chowk	1.06	0.764	Elevated
4	Durgadi Fort	1.694	0.634	Elevated
5	Kon Gaon	3.49	1.796	Elevated
6	Gove Gaon MIDC	5.791	2.301	Elevated
7	Rajnouli Village	6.794	1.003	Elevated
8	Temghar	8.58	1.786	Elevated
9	Gopal Nagar	10.36	1.78	Elevated
10	Bhiwandi	11.081	0.721	Elevated
11	Dhamankar Naka	11.998	0.917	Elevated
12	Anjurphata	13.838	1.84	Elevated
13	Purna	15.315	1.477	Elevated
14	Kalher	17.392	2.077	Elevated
15	Kasheli	18.833	1.441	Elevated
16	Balkum Naka	22.506	3.673	Elevated
17	Kapurbawadi	23.382	0.876	Elevated

5.3 PERMANENT WAY

5.3.1 Choice Of Gauge

Mumbai Metro Corridors I has been implemented with Standard Gauge (1435 mm) .With the objective of uniformity, this corridor is also proposed to be on Standard Gauge (1435mm). Apart from the uniformity feature, the standard gauge for Proposed Metro corridor is highly recommended for the following reasons:

The standard gauge is better as it allows a low turning radius as low as of 90 to 140 meters as against 175 meters for broad gauge and this reduces the requirement of land when the Metro has to take a curving turn. Metro alignment is passing through built-up areas for optimal commuter Utilization and this imposes severe restrictions on the selection of curves. As in most of the cities in India no 'right of way' has been reserved for metro systems, the alignments have to pass through already congested major arterial roads. These roads may have sharp curves and right-angle bends at many sections. In such a situation, adoption of Standard Gauge is advantageous, since it permits adoption of sharper curves compared to Broad Gauge to minimize property acquisition along the alignments;

Since all the major Metro systems adopt the standard gauge, quality is ensured because of mass production;

The adoption of standard gauge also ensures constant up-gradation to latest technologies in rolling stock, suspension, braking traction and propulsion in future as well, because of the availability of a very large market.

In Standard Gauge 1 in 7 and 1 in 9 turn-outs, which occupy lesser length, are feasible compared to 1 in 8 ½ and 1 in 12 turn-outs required for Broad Gauge. Length of cross-overs for Standard Gauge is thus lesser than for Broad Gauge. Land requirement for depots where a large number of lines connected together in the shape of ladder is also reduced. Standard Gauge is, therefore, more suited for use in built up environment where land availability is scarce especially in cities like Mumbai.

For Standard Gauge, optimized state-of-the-art rolling stock designs are available 'off the-shelf'. This is not so for Broad Gauge where new designs for rolling stock have to be specially developed, which entails extra time and cost.

Once technology for Standard Gauge coaches get absorbed and a manufacturing base for them is set up in India, there will be considerable export potential for the coaches, since almost all the countries use Standard Gauge for their metros. This is not so in case of Broad Gauge.

Main argument for that adoption of Broad Gauge for metros would enable interrunning of metro trains with Indian Railways since the railway uses Broad Gauge. Interrunning is, however, technically and / or operationally not feasible as the two systems have different Rolling Stock characteristics, Signalling Systems, Headways, Tariffs, and Loading standards. Since inter-running is not feasible, choice of gauge for a metro system should be based solely on technical and economic considerations on which Standard Gauge turns out to be superior.

5.3.2 Track Structure

Primary objective to select the track structure of a metro system is to ensure safety, reliability and comfort, with minimum noise and vibrations. The track structure should maintain stability, line and level under all conditions of applied load and temperature stresses. Furthermore, since tracks are subjected to rigorous usage and day-to-day maintenance time is also very less, it is necessary to select the track structure of long lasting, which should guarantee minimum maintenance.

The track structure has been proposed keeping the above philosophy in view.

5.3.3 General

Two types of track structures are proposed for Metro system. The normal ballasted track is suitable for At-Grade (surface) portion of Main Lines and in Depot (except inside the Workshops, inspection lines and washing plant lines. The ballast-less track is recommended on Viaducts and inside tunnels as the regular cleaning and replacement of ballast at such location will not be possible. Only in case of the depot normal ballasted track is proposed for adoption. From considerations of maintainability, riding comfort and also to contain vibrations and noise levels, the complete track is proposed to be joint-less and for this purpose even the turnouts will have to be incorporated in Long Welded Rails (LWR) /Continuous Welded Rails (CWR). The track will be laid with 1 in 20 canted rails and the wheel profile of Rolling Stock should be compatible with the rail cant and rail profile.

5.3.4 Rail Section

Keeping in view the proposed axle load and the practices followed abroad, it is proposed to adopt UIC-60 (60 kg. /m) rail section. Since on main lines sharp curves and steep gradients would be present, the grade of rail on main lines should be 1080 Head Hardened as per IRST- 12-96. As these rails are not manufactured in India at present, these have to be imported. For the Depot lines, the grade of rails should be 880, which can be manufactured in India.

5.3.5 Turnouts

From considerations of maintainability and riding comfort, it is proposed to lay the turnouts also with 1 in 20 cant. Further, it is proposed to adopt the following two types of turnouts:

i) On main lines, 1 in 9 type turnout with a lead radius of 300 metres and permissible speed on divergent track as 40 km/h

ii) On Depot lines, 1 in 7 type turnout with a lead radius of 140 metres and permissible speed on divergent track as 25 km/h

The proposed specifications for turnouts are given below:

- the turnouts should have fan-shaped layout throughout the turnout so as to have same sleepers/base-plates and slide chairs for both LH and RH turnouts;
- the switches and crossings should be interchangeable between ballasted and ballast less turnouts (if required);
- the switch rail should be with thick web sections, having forged end near heel of switch for easy connection with lead rails, behind the heel of switch. The switches should have anti creep device at heel of switch for minimizing the additional LWR forces transmitted from tongue rail to stock rail;
- the crossings should be made of cast manganese steel and with welded leg extensions;
- these crossings should be explosive hardened type for main lines and without surface hardening for Depot lines;
- the check rails should be with UIC-33 rail section without being directly connected to the running rails.

6 CIVIL ENGINEERING WORKS

6.1 ROUTE ALIGNMENT

6.1.1 General Description of the Route

The Alignment Option Report for the corridor was submitted by the Consultant during January 2016. It was recommended by the client to start/end the corridor from Kalyan Railway station (Gurudev Hotel Junction) to Thane Kapurbawadi Junction via Bhiwandi.

Consultant has investigated three options, the details of which are described in the following paragraph.

Finally, in Appendix A, B and C all the drawings regarding the plan and the longitudinal profile of the three options are collected.

Horizontal and Vertical Geometrics Description

For section Ch 0+000 to Ch 2+000

During the meeting with MMRDA Officials on 4th October 2016, it was deceded to extend the proposed alignment till Kalyan APMC which s around 800m from proposed Kalyan Station at Zero Chainage. The alignment starts from zero chainage at Bail Bazar Circle. It continues straight along the median of the existing Vallabh Bhai Patel road. (Kalyan Station) Station 2 at chainage 0+300 has been proposed. At chainage 0+492, the alignment crosses Shivaji Statue with a clearance of 5.5m. Land Acquisition will be an issue if the present alignmet shifted from median near statue, hence the statue of Chatrapati Shivaji Maharaj can be relocated accordingly in consultation with stakeholders, making the alignment feasible. The vertical alignment there is proposed to fly over the statue and height of guide way beam has been proposed as 8.5m accordingly. This is shown in Figure 6.1.

The alignment crosses Sahajanand Chowk at 0+900. Its vertical level at 0+900 is raised to 23.830m. The alignment continues on the median of the existing road and it approaches (Sahajanand Chowk) Station 3 at chainage 1+140 and (Durghadi Fort) Station 4 at chainage 1+700 and continues till Durgadi Chowk at chainage 2+000. There will be no land constraints in this section except acquisition of land for station facilities. This is shown in Figure 6.2. There are 6 number of curves fitted in this section of which the maximum radius of the curve is 4000m and minimum radius is 120m.

Figure 6.1: Section of Alignment From Kalyan Station to Kalyan APMC Market

Figure 6.2: Section of Alignment showing Start Chainage and Shivaji Chowk

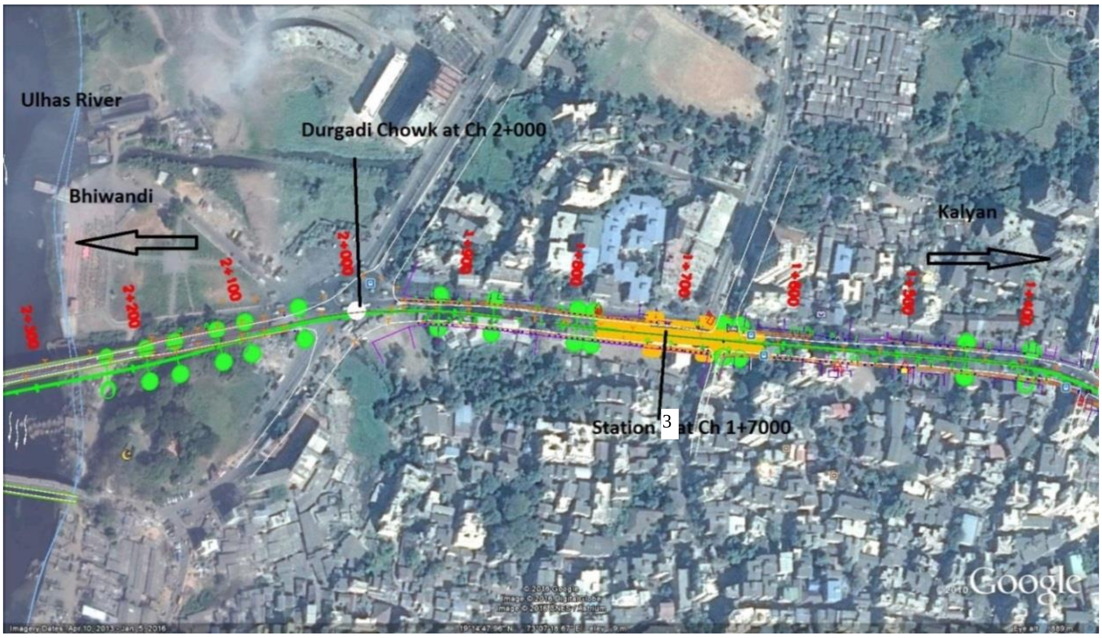

Figure 6.3: Section of Alignment showing Critical section of Durgadi Chowk

For section Ch 2+000 to Ch 7+500

The alignment gradually turns on the left before approaching Ulhas River at chainage 2+250. The alignment crosses Ulhas River at Ch 2+250 to Ch 2+600. The proposed metro alignment has been planned 13m away parallel towards the left side of the existing bridge and around 125 m (minimum) to 200m away from Durgadi Fort. As shown in Figure 6.4, the proposed metro alignment is The rail level of the metro is proposed as that of the existing bridge. After crossing the Ulhas River the alignment will turn right and will run along the median of the carriageway. This transition will be obtained providing longer span between the viaducts to avoid destruction to the through traffic on the Dhamtari Bridge

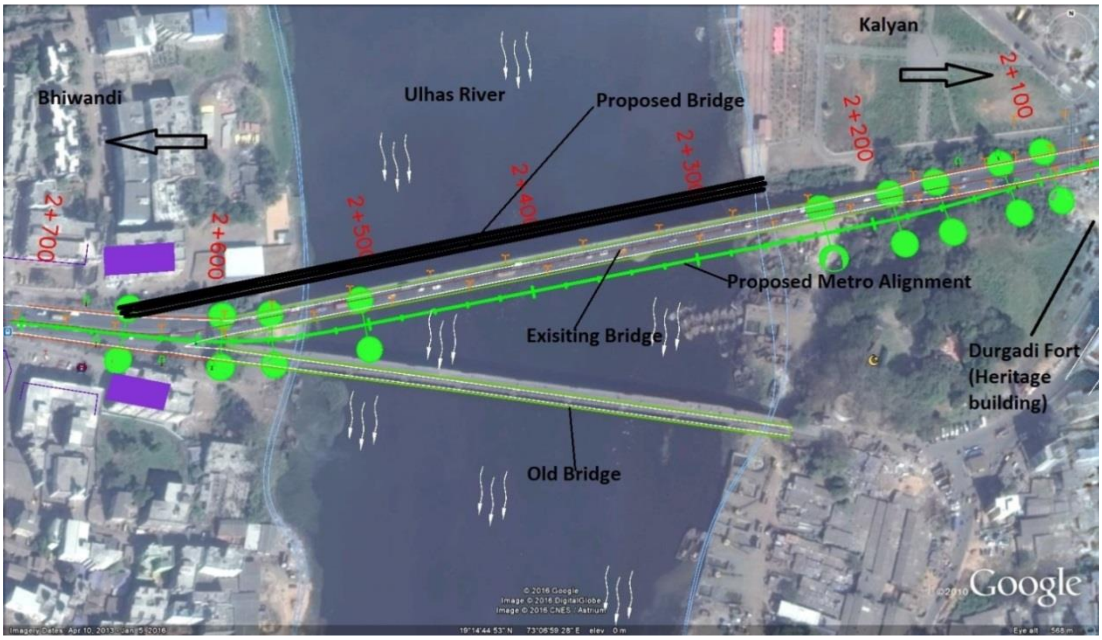

Figure 6.4:Section of Alignment showing Proposed Bridge over Ulhas River

The alignment continues to run along the median till the end of this section. i.e. Ch till 7+000. There are three stations along this section at Ch 3+500 (Kon Gaon) Station 5 is proposed, at Ch 5+800 (Gove Gaon MIDC) Station 6 is proposed and at Ch 6+800 (Rajnouli)Station 7 is proposed just before Bhiwandi By pass. After Station 7 the vertical alignment will fly over the proposed flyover at Rajnouli Junction from Ch 6+850- Ch 7+050. There are 14 number of curves fitted in this section of which the maximum radius of the curve is 8000m and minimum radius is 275m.

For Section Ch 7+500 to Ch 19+500

The Consultant has investigated three options in this particular section.

1. Option I (between Ch 7+500- 12+300) Alignment along the LHS of the proposed Flyover

In this option, the alignment is proposed to continue from Ch 7+500 along the right hand side of the flyover. The (Temghar) Station No 8 is at Ch 8+400. The alignment will continue on the right hand side of the flyover and as the slip road on both the side are too narrow; there will be land acquisition to be done for this particular option. The alignment will continue on right side parallel to the existing Rajiv Gandhi Flyover till the alignment takes a sharp left bent of 120m radius towards south west at Ch 10+500. The alignment will cross over the existing Rajiv Gandhi Flyover from Ch 10+500 - Ch 10+700. This portion of the alignment will run on the portal above the existing Rajiv Gandhi Flyover. The vertical alignment at Ch 10+500 is proposed to be 13.5m above the existing road level. The alignment will continue on the right side of the flyover from Ch 8+500- Ch 10+200 on the slip road.

From Ch 10+500- Ch 12+250, the alignment runs parallel to Rajiv Gandhi Flyover on the right hand side after which it slowly transits to the centre of the median of the existing road. This portion of the alignment from Ch 10+200- Ch 11+000 will involve 25901 sq. m of land acquisition. The proposed (Gopal Nagar) station 9 is located at Ch 10+350. The alignment continues to run through the median from Ch 11+100 - Ch 19+500. Between Ch 11+550-Ch 12+150, the alignment crosses through Dhamankar Flyover, which in this option is proposed to be dismantled. This is because the slip road available besides the flyover is too narrow to accommodate the portal frame and the area along it is densely populated. This may lead to sever land acquisition issues. The vertical alignment at Ch 14+60 is proposed to 13.5m as it is crossing a Railway Underpass. There are six other stations which are proposed in this particular section at different chainages. The proposed (Bhiwandi)station 10 is located at Ch 11+000, proposed (Dhamankar Naka)station 11 is located at Ch 12+000, proposed (Anjur Phata)station12 is located at Ch 13+850, proposed (Purna Village)station 13 is located at Ch 15+320, proposed (Kalher)station 14 is located at Ch 17+400, proposed (Kasheli)station 15 is located at Ch 18+850. There are 6 number of curves fitted in this section of which the maximum radius of the curve is 19000m and minimum radius is 120m.

2. Option II (between Ch 7+500- 12+300) Alignment along the RHS of the proposed Flyover

In this option, the alignment is proposed to continue from Ch 7+500 along the left hand side of the flyover. The (Temghar) Station No 8 is at Ch 8+400. The alignment will continue on the left side of the flyover from Ch 8+500- Ch 10+200 on the slip road. But as the slip road on both the side are too narrow, there will be land acquisition to be done for this particular option. Then the alignment will continue transit towards the left side parallel to the existing Rajiv Gandhi Flyover till the alignment will then take a sharp left bent of 120m radius towards south west at Ch 10+500. From Ch 10+500- Ch 10+850, the alignment runs parallel to Rajiv Gandhi Flyover on the left hand side after which it slowly transits to the centre of the median of the existing road. This portion of the alignment from Ch 10+200- Ch 11+000 will involve 25901 sq. m of land acquisition. The proposed (Gopal Nagar) station 9 is located at Ch 10+350. The alignment continues to run through the median from Ch 11+100 - Ch 19+500. Between Ch 11+550-Ch 12+150, the alignment crosses through Dhamankar Flyover, which in this option is proposed to be dismantled. This is because the slip road available besides the flyover is too narrow to accommodate the portal frame and the area along it is densely populated. This may lead to sever land acquisition issues. The vertical alignment at Ch 14+60 is proposed to 13.5m as it is crossing a Railway Underpass. There are six other stations which are proposed in this particular section at different chainages. The proposed (Bhiwandi)station 10 is located at Ch 11+000, proposed (Dhamankar Naka)station 11 is located at Ch 12+000, proposed (Anjur Phata) station12 is located at Ch 13+850, proposed (Purna Village)station 13 is located at Ch 15+320, proposed (Kalher)station 14 is located at Ch 17+400, proposed (Kasheli)station 15 is located at Ch 18+850. There are 6 number of curves fitted in this section of which the maximum radius of the curve is 19000m and minimum radius is 120m.

3. Option III (between Ch 7+500- 12+300) Alignment along the proposed flyover (on portal above the centre of the flyover)

In this option, the alignment is proposed to continue from Ch 7+500 along the median till it approaches the proposed flyover at Ch 8+500. The (Temghar) Station No 8 is proposed right before the proposed flyover i.e. at Ch 8+400. The alignment will continue on the portal above the centre of the flyover from Ch 8+500- Ch 10+200 as the slip road on both the side are too narrow. In Option I and II, the alignment runs through the right and left side of the slip road respectively. This will lead to blocking the slip road. These options will require land acquisition and will further make the option to be tough to execute and costly. Thus, the Option III of portal above the existing flyover seems more feasible. It was proposed during the meeting with MMRDA Officials to consider ROW of 30 m considering 3m land acquisition on both LHS and RHS of existing ROW of 24 m from Sai Baba Temple to Rajiv Gandhi Flyover. Then the alignment will transit towards the left side parallel to the existing Rajiv Gandhi Flyover till the alignment will then take a sharp left bent of 120m radius towards south west at Ch 10+500. From Ch 10+500- Ch 10+850, the alignment runs parallel to Rajiv Gandhi Flyover on left hand side after which it slowly transits to the centre of the median of the existing road. The vertical alignment on the portal is proposed to be 13.5m above road level between Ch 8+700- Ch 10+300. This portion of the alignment from Ch 10+200- Ch 11+000 will involve 4860 sq. m of land acquisition. The proposed (Gopal Nagar) station 9 is located at Ch 10+350 right after the alignment transits down from the Rajiv Gandhi Flyover. The alignment continues to run through the median from Ch 11+100 - Ch 19+500. Between Ch 11+550-Ch 12+150, the alignment crosses through Dhamankar Flyover, which in this option is proposed to be dismantled. This is because the slip road available besides the flyover is too narrow to accommodate the portal frame and the area along it is densely populated. This may lead to sever land acquisition issues. Hence it is proposed two–tier system in which proposed flyover shall be at Level-1 and proposed Metro shall be at Level-2. This will minimize the land acquisition in denslyn populated section of corridor. The vertical alignment at Ch 14+60 is proposed to 13.5m as it is crossing a Railway Underpass. There are six other stations which are proposed in this particular section at different chainages. The proposed (Bhiwandi) station 10 is located at Ch 11+000, proposed (Dhamankar Naka)station 11 is located at Ch 12+000, proposed (Anjur Phata) station12 is located at Ch 13+850, proposed (Purna) station 13 is located at Ch 15+320, proposed (Kalher)station 14 is located at Ch 17+400, proposed (Kasheli Village)station 15 is located at Ch 18+850. There are 6 number of curves fitted in this section of which the maximum radius of the curve is 19000m and minimum radius is 120m.

Figure 6.5: Section in which three Alignment Options are shown near MIDC Deport

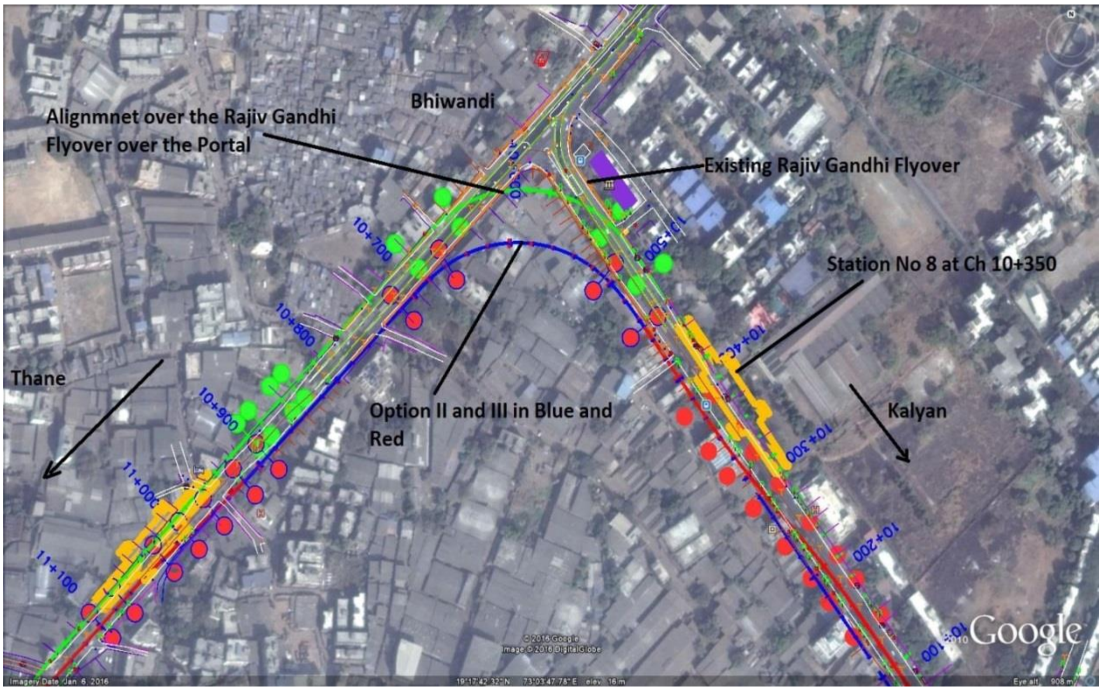

Figure 6.6: Section in which three Alignment Options are shown near Rajiv Gandhi Flyover

Comparison for between Ch 8+400 - Ch 10+200

For Option I and II, the alignment runs through the right and left side of the slip road respectively. This will lead to blocking the slip road. This is shown clearly in Figure 6.5 and Figure 6.6.These options will require land acquisition and will further make the option to be tough to execute and costly. Thus, the option III of portal above the existing flyover seems more feasible.

For section Ch 19+500 to Ch 23+600

The start of this section is at Kasheli Toll naka which is located at Ch 19+500. The alignment gradually turns on the right hand side. At Ch 19+700, the alignment runs parallel to the minor bridge over a small canal which meets Vasai creek. The alignment has been planned 3.65m parallel to the existing minor bridge. It continues on the right hand side of the existing carriageway of the road. At Ch 20+500, it crosses Vasai Creek parallel to Kasheli Bridge at 3.65m away. The alignment continues to run along the median till Ch 23+050. From Kasheli Bridge (Ch. 21+000) to Dhokali Naka (Ch. 22+250) two alignment options were expored viz. (i) **Option-1-** Proposed alignment after crossing Kasheli Bridge at Ch 21+350 runs at edge of existing RHS carriageway till Ch. 21+550 near temple . After crossing the temple the alignment transits through portal system along median of LHS and RHS existing carriageway from near temple upto Dhokali Naka 22+250 and; (ii) **Option-2-** Proposed alignment after crossing Kasheli Bridge at Ch 21+250 runs at edge of existing RHS carriageway upto Dhokali Naka upto Ch. 22+250. Comparing bothe the options in terms of number of trees required to be cut Option-1 is better as number of trees required to be cut is less as compared to Option-2. There after the alignment runs on the median of the carriageway till Ch. 23+400. From Ch. 23+400 the alignment slowly transits to the edge of existing ROW at RHS along the existing Kapurbawadi Flyover till the end chainage. There are two stations along this section at Ch 22+500 (Balkum Naka) Station 16 is proposed, at Ch 23+400 (Kapurbawadi) Station17 is proposed There are 14 number of curves fitted in this section of which the maximum radius of the curve is 1000m and minimum radius is 300m.

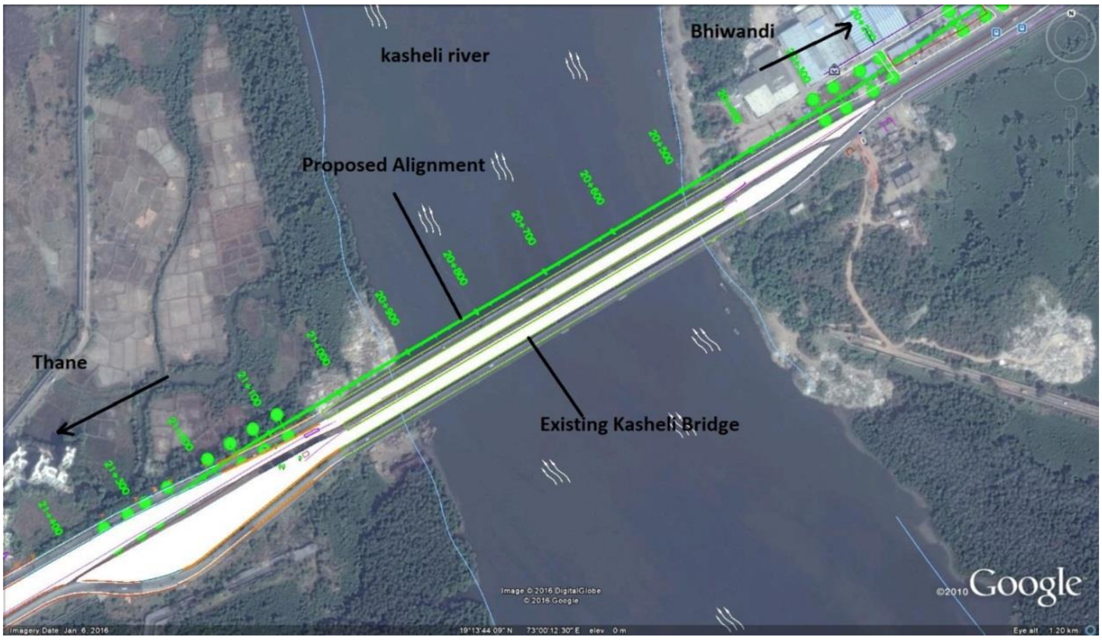

Figure 6.7: Section of Alignment showing proposed bridge over Vasai Creek

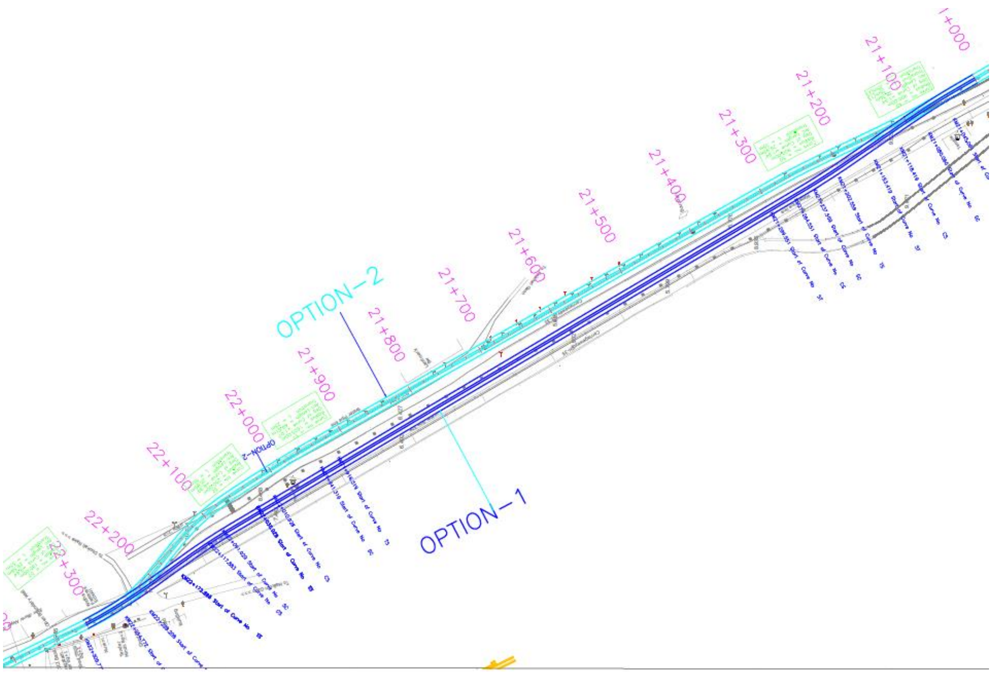

Figure 6.8: Section of Alignment showing proposed bridge over Vasai: Section of Alignment showing Option-1 and Option-2 between Kasheli Bridge (Ch 21+000) to Dhokali Naka (Ch. 22+200)

6.1.2 Major Roads along the Route

The major roads along and across the alignment are given in Table below.

Table 6.1: Major Roads Along/Across the Corridor

Road	Chainage (m)	Direction (LHS /RHS)	Name of major Roads across the Alignment	Road Width
Bhiwandi kalyan Road	0+300	RHS	To Kalyan Railway Station	18m
Bhiwandi Kalyan Road	2+000	LHS/RHS	Durgadi Chowk	20m
Bhiwandi Kalyan Road	6+930	LHS/RHS	NH3-(Mumbai Nashik Expressway) (Ranjnoli Junction)	35m
Old Agra Road	11+900	LHS	Dhamankar Naka Mansarovar Road	20m
Old Agra Road	14+100	LHS	Bhiwandi Station Road	12m
Old Agra Road	14+100	RHS	Chinchoti Anjurphata Road	12m

Road	Chainage (m)	Direction (LHS /RHS)	Name of major Roads across the Alignment	Road Width
Old Agra Road	14+550	LHS	To Mumbai Nashik Highway	20m
Old Agra Road	22+450	LHS	Saket Road	20m
Old Agra Road	23+050	RHS	Dhokali Balkum Road	27m

6.1.3 Horizontal Profile

The topology of the site is plain terrain along almost the proposed metro route. There are many sharp turns and curves along the road. This necessitates provision of curves for metro alignment also. The radius of curves is kept as low as 120 m to reduce the property acquisition. There are total 52 Nos. of curves provided for the Option I, 54 Nos of curves provided for Option II and 53 no's of curves provided for Option III. The details of curves and abstracts of horizontal curves for all three options are indicated in Table 6.2 to Table 6.4

Table 6.2: Horizontal Alignment - Proposed Metro Corridor Option I

Curve No.	CHAINAGE	Radius	Deflection Angle			Transition Length (m)		Hand of
		(m)	D	M	S			Curve
1	0+144	700	2	18	46	30	30	RIGHT
2	0+482	140	24	20	14	55	55	LEFT
3	0+858	120	30	13	45	55	55	LEFT
4	1+334	240	25	16	43	55	55	LEFT
5	1+714	4000	1	42	29	15	15	RIGHT
6	1+979	450	16	15	16	50	50	LEFT
7	2+172	750	2	7	32	40	40	RIGHT
8	2+572	275	6	6	19	55	55	RIGHT
9	3+113	360	19	28	36	55	55	RIGHT
10	3+323	1000	2	1	9	35	35	LEFT
11	3+498	1300	5	10	48	30	30	RIGHT
12	3+743	800	3	54	8	40	40	LEFT
13	4+055	1500	2	53	15	25	25	RIGHT
14	4+470	900	12	10	18	35	35	RIGHT
15	5+309	2000		41	14	15	15	RIGHT
16	5+594	500	3	48	38	45	45	LEFT
17	5+974	1200	3	51	28	30	30	RIGHT
18	6+242	350	4	27	47	55	55	RIGHT
19	6+630	500	3	27	42	45	45	LEFT
20	7+159	3000	8	33	47	15	15	RIGHT
21	7+545	800	1	57	12	40	40	LEFT
22	7+870	2000		53	36	15	15	LEFT
23	8+246	1200	1	32	29	30	30	RIGHT
24	8+467	1100	1	35	6	35	35	LEFT

Table 6.2: Horizontal Alignment - Proposed Metro Corridor Option I

25	8+757	350	8	23	15	55	55	RIGHT
26	9+001	350	9	1	49	55	55	LEFT
27	9+316	1000	3	12	31	35	35	RIGHT
28	9+536	1000	3	59	24	35	35	LEFT
29	9+842	2000	1	36	34	15	15	RIGHT
30	10+630	120	73	50	37	55	55	LEFT
31	12+169	750	2	23	8	40	40	LEFT
32	12+307	750	2	37	19	40	40	RIGHT
33	12+553	1800	5	33	14	20	20	LEFT
34	14+013	450	3	14	42	50	50	RIGHT
35	14+160	800	1	53	24	30	30	LEFT
36	14+304	1500	1	13	15	25	25	RIGHT
37	15+985	1200	3	35	44	30	30	LEFT
38	17+144	450	21	55	59	50	50	RIGHT
39	17+548	120	37	52	3	55	55	LEFT
40	17+811	450	4	40	8	50	50	LEFT
41	18+073	800	17	34	10	40	40	RIGHT
42	19+012	1050	3	32	40	35	35	LEFT
43	19+151	120	15	52	11	55	55	RIGHT
44	19+421	382.5	7	49	12	55	55	RIGHT
45	19+556	600	3	39	21	35	35	LEFT
46	20+047	1000	1	30	1	35	35	LEFT
47	20+250	1200	1	54	4	30	30	RIGHT
48	21+132	900	2	7	34	35	35	LEFT
49	21+295	900	1	41	14	35	35	RIGHT
50	22+181	700	2	40	33	30	30	LEFT
51	22+326	700	7	1	15	30	30	RIGHT
52	23+074	300	6	34	51	55	55	RIGHT

Table 6.3: Horizontal Alignment - Proposed Metro Corridor Option I

Curve No.	CHAINAGE	Radius	Deflection Angle			Transition Length (m)		Hand of
		(m)	D	M	S			Curve
1	0+144	700	2	18	46	30	30	RIGHT
2	0+482	140	24	20	14	55	55	LEFT
3	0+858	120	30	13	45	55	55	LEFT
4	1+334	240	25	16	43	55	55	LEFT
5	1+714	4000	1	42	29	15	15	RIGHT
6	1+979	450	16	15	16	50	50	LEFT
7	2+172	750	2	7	32	40	40	RIGHT
8	2+572	275	6	6	19	55	55	RIGHT
9	3+113	360	19	28	36	55	55	RIGHT
10	3+323	1000	2	1	9	35	35	LEFT
11	3+498	1300	5	10	48	30	30	RIGHT
12	3+743	800	3	54	8	40	40	LEFT
13	4+055	1500	2	53	15	25	25	RIGHT

Table 6.3: Horizontal Alignment - Proposed Metro Corridor Option I

14	4+470	900	12	10	18	35	35	RIGHT
15	5+309	2000	1	41	14	15	15	RIGHT
16	5+594	500	3	48	38	45	45	LEFT
17	5+974	1200	3	51	28	30	30	RIGHT
18	6+242	350	4	27	47	55	55	RIGHT
19	6+630	500	3	27	42	45	45	LEFT
20	7+159	3000	8	33	47	15	15	RIGHT
21	7+521	450	8	4	20	50	50	LEFT
22	7+700	450	3	53	30	50	50	RIGHT
23	7+872	2000	1	31	52	15	15	LEFT
24	8+248	1200	1	32	29	30	30	RIGHT
25	8+469	1100	1	35	6	35	35	LEFT
26	8+752	350	8	23	15	55	55	RIGHT
27	9+006	350	9	1	49	55	55	LEFT
28	9+318	1000	3	12	31	35	35	RIGHT
29	9+542	1000	4	32	37	35	35	LEFT
30	9+865	1000	2	9	54	35	35	RIGHT
31	9+984	1600	1	59	52	25	25	LEFT
32	10+593	120	70	52	39	55	55	LEFT
33	11+043	3000	2	25	15	15	15	LEFT
34	12+151	8500	1	11	31	15	15	RIGHT
35	12+485	1800	5	33	14	20	20	LEFT
36	13+944	450	3	14	42	50	50	RIGHT
37	14+091	800	1	53	24	30	30	LEFT
38	14+235	1500	1	13	15	25	25	RIGHT
39	15+917	1200	3	35	44	30	30	LEFT
40	17+075	450	21	55	59	50	50	RIGHT
41	17+479	120	37	52	3	55	55	LEFT
42	17+743	450	4	40	8	50	50	LEFT
43	18+005	800	17	34	10	40	40	RIGHT
44	18+943	1050	3	32	40	35	35	LEFT
45	19+082	120	15	52	11	55	55	RIGHT
46	19+352	382.5	7	49	12	55	55	RIGHT
47	19+488	600	3	39	21	35	35	LEFT
48	19+978	1000	1	30	1	35	35	LEFT
49	20+182	1200	1	54	4	30	30	RIGHT
50	21+064	900	2	7	34	35	35	LEFT
51	21+226	900	1	41	14	35	35	RIGHT
52	22+112	700	2	40	33	30	30	LEFT
53	22+258	700	7		15	30	30	RIGHT
54	23+006	300	6	34	51	55	55	RIGHT

Table 6.4: Horizontal Alignment - Proposed Metro Corridor Option III

Curve No.	CHAINAGE	Radius (m)	Deflection Angle D	M	S	Transition Length (m)		Hand of Curve
1	0+144	700	2	18	46	30	30	RIGHT
2	0+482	140	24	20	14	55	55	LEFT
3	0+858	120	30	13	45	55	55	LEFT
4	1+334	240	25	16	43	55	55	LEFT
5	1+714	4000	1	42	29	15	15	RIGHT
6	1+979	450	16	15	16	50	50	LEFT
7	2+172	750	2	7	32	40	40	RIGHT
8	2+572	275	6	6	19	55	55	RIGHT
9	3+113	360	19	28	36	55	55	RIGHT
10	3+323	1000	2	1	9	35	35	LEFT
11	3+498	1300	5	10	48	30	30	RIGHT
12	3+743	800	3	54	8	40	40	LEFT
13	4+055	1500	2	53	15	25	25	RIGHT
14	4+470	900	12	10	18	35	35	RIGHT
15	5+309	2000		41	14	15	15	RIGHT
16	5+594	500	3	48	38	45	45	LEFT
17	5+974	1200	3	51	28	30	30	RIGHT
18	6+242	350	4	27	47	55	55	RIGHT
19	6+630	500	3	27	42	45	45	LEFT
20	7+064	4000	4	35	16	15	15	RIGHT
21	7+869	2000	1	39	53	15	15	LEFT
22	8+246	1200	1	32	29	30	30	RIGHT
23	8+466	1100	1	35	6	35	35	LEFT
24	8+753	350	8	23	15	55	55	RIGHT
25	9+002	350	9	1	49	55	55	LEFT
26	9+316	1000	3	12	31	35	35	RIGHT
27	9+539	1000	4	32	37	35	35	LEFT
28	9+863	1000	2	9	54	35	35	RIGHT
29	10+103	2500	5	47	5	15	15	LEFT
30	10+340	900	2		27	35	35	RIGHT
31	10+591	120	70	52	39	55	55	LEFT
32	11+041	3000	2	25	15	15	15	LEFT
33	12+149	8500		11	31	15	15	RIGHT
34	12+483	1800	5	33	14	20	20	LEFT
35	13+943	450	3	14	42	50	50	RIGHT
36	14+089	800	1	53	24	30	30	LEFT
37	14+233	1500	1	13	15	25	25	RIGHT
38	15+915	1200	3	35	44	30	30	LEFT
39	17+073	450	21	55	59	50	50	RIGHT
40	17+477	120	37	52	3	55	55	LEFT
41	17+741	450	4	40	8	50	50	LEFT
42	18+003	800	17	34	10	40	40	RIGHT
43	18+941	1050	3	32	40	35	35	LEFT

Table 6.4: Horizontal Alignment - Proposed Metro Corridor Option III

44	19+081	120	15	52	11	55	55	RIGHT
45	19+350	382.5	7	49	12	55	55	RIGHT
46	19+486	600	3	39	21	35	35	LEFT
47	19+976	1000	1	30	1	35	35	LEFT
48	20+180	1200	1	54	4	30	30	RIGHT
49	21+062	900	2	7	34	35	35	LEFT
50	21+224	900	1	41	14	35	35	RIGHT
51	22+111	700	2	40	33	30	30	LEFT
52	22+256	700	7		15	30	30	RIGHT
53	23+004	300	6	34	51	55	55	RIGHT

6.1.4 Vertical Profile

The topology of the site is plain terrain along almost the proposed metro route. The difference from lowest point to highest point on is.0 m. The vertical profile of the proposed metro alignment will have vertical curves as there are RUB, flyovers along the alignment and also at few locations the alignment had to be planned off the roads in view of geometric constraints. The gradients observed for different options are given in Table 6.5 to Table 6.7

Table 6.5: Vertical Alignment - Proposed Metro Corridor Option I

Sl. NO.	CHAINAGE (m)	LEVEL OF PVI	LENGTH OF CURVE	TYPE OF CURVE	Grade IN (%)	Grade OUT (%)	Grade DIFF (%)	RADIUS (m)	CHAINAGE ST. OF CURVE	LEVEL AT START OF CURVE	CHAINAGE END OF CURVE	LEVEL AT END OF CURVE
1	0+000	17.4				1.5	1.5					
2	0+210	20.55	40	Hog	1.5	0	-1.5	-2666.67	0+190	20.25	0+230	20.55
3	0+475	20.55	20	Hog	0	-0.296	-0.296	-6752.29	0+465	20.55	0+485	20.52
4	0+659	20.005	50	Sag	-0.296	1.6	1.896	2637.313	0+634	20.079	0+684	20.405
5	0+965	24.9	40	Hog	1.6	0	-1.6	-2500.51	0+945	24.58	0+985	24.9
6	1+170	24.9	20	Hog	0	-0.588	-0.588	-3400	1+160	24.9	1+180	24.841
7	1+340	23.9	20	Sag	-0.588	0	0.588	3400	1+330	23.959	1+350	23.9
8	1+685	23.9	50	Hog	0	-1.891	-1.891	-2644.73	1+660	23.9	1+710	23.427
9	1+955	18.796	60	Sag	-1.891	0.463	2.353	2549.439	1+925	19.363	1+985	18.934
10	2+172	19.8	20	Hog	0.463	0.274	-0.189	-10566.8	2+162	19.754	2+182	19.827
11	2+574	20.9	20	Hog	0.274	0.094	-0.18	-11126.3	2+564	20.873	2+584	20.909
12	4+485	22.694	25	Hog	0.094	-0.867	-0.961	-2601.28	4+472.500	22.682	4+497.500	22.586
13	4+805	19.919	35	Sag	-0.867	0.489	1.356	2581.343	4+787.500	20.071	4+822.500	20.005
14	5+380	22.729	20	Hog	0.489	-0.187	-0.675	-2960.9	5+370	22.68	5+390	22.71
15	5+690	22.15	20	Sag	-0.187	0	0.187	10708.12	5+680	22.169	5+700	22.15
16	5+880	22.15	20	Hog	0	-0.629	-0.629	-3178.34	5+870	22.15	5+890	22.087
17	6+420	18.752	45	Sag	-0.629	0.999	1.629	2763.182	6+397.500	18.894	6+442.500	18.977
18	6+705	21.6	25	Hog	0.999	0	-0.999	-2501.76	6+692.500	21.475	6+717.500	21.6
19	6+890	21.6	40	Hog	0	-1.6	-1.6	-2500.42	6+870	21.6	6+910	21.28
20	7+263	15.633	65	Sag	-1.6	0.932	2.531	2567.811	7+230.500	16.153	7+295.500	15.936

21	8+016	22.648	55	Sag	0.932	2.998	2.066	2661.937	7+988.500	22.392	8+043.500	23.472
22	8+375	33.41	75	Hog	2.998	0.1	-2.898	-2588.2	8+337.500	32.286	8+412.500	33.448
23	8+755	33.79	45	Sag	0.1	1.74	1.64	2744.119	8+732.500	33.768	8+777.500	34.181
24	9+001	38.07	55	Hog	1.74	-0.444	-2.184	-2518.15	8+973.500	37.592	9+028.500	37.948
25	9+763	34.685	20	Hog	-0.444	-0.677	-0.233	-8593.46	9+753	34.729	9+773	34.617
26	10+260	31.32	20	Sag	-0.677	-0.1	0.577	3466.141	10+250	31.388	10+270	31.31
27	10+455	31.125	35	Hog	-0.1	-1.336	-1.236	-2831.71	10+437.500	31.143	10+472.500	30.891
28	10+785	26.716	20	Hog	-1.336	-1.733	-0.397	-5036.51	10+775	26.85	10+795	26.543
29	10+985	23.25	45	Sag	-1.733	0	1.733	2596.501	10+962.500	23.64	11+007.500	23.25
30	11+180	23.25	50	Hog	0	-1.987	-1.987	-2515.93	11+155	23.25	11+205	22.753
31	11+330	20.269	95	Sag	-1.987	1.8	3.788	2508.243	11+282.500	21.213	11+377.500	21.124
32	11+890	30.35	50	Hog	1.8	0	-1.8	-2777.5	11+865	29.9	11+915	30.35
33	12+090	30.35	40	Hog	0	-1.478	-1.478	-2705.62	12+070	30.35	12+110	30.054
34	12+391	25.9	35	Sag	-1.478	-0.268	1.21	2892.684	12+373.500	26.159	12+408.500	25.853
35	12+540	25.5	35	Hog	-0.268	-1.512	-1.244	-2814.48	12+522.500	25.547	12+557.500	25.235
36	12+831	21.1	80	Sag	-1.512	1.65	3.162	2529.89	12+791	21.705	12+871	21.76
37	13+740	36.1	45	Hog	1.65	0	-1.65	-2727	13+717.500	35.729	13+762.500	36.1
38	14+095	36.1	35	Hog	0	-2	-2	-1750	14+077.500	36.1	14+112.500	35.75
39	14+735	23.3	100	Sag	-2	2	4	2500	14+685	24.3	14+785	24.3
40	15+200	32.6	50	Hog	2	0	-2	-2500	15+175	32.1	15+225	32.6
41	15+420	32.6	50	Hog	0	-2	-2	-2499.73	15+395	32.6	15+445	32.1
42	15+880	23.399	60	Sag	-2	0.339	2.34	2564.429	15+850	23.999	15+910	23.501
43	16+346	24.981	85	Hog	0.339	-3	-3.339	-2545.55	16+303.500	24.837	16+388.500	23.706
44	16+651	15.832	85	Sag	-3	0.4	3.4	2499.963	16+608.500	17.107	16+693.500	16.002
45	17+180	17.95	20	Hog	0.4	-0.1	-0.5	-3996.98	17+170	17.91	17+190	17.94
46	17+435	17.695	25	Hog	-0.1	-1.089	-0.989	-2527.57	17+422.500	17.708	17+447.500	17.559
47	17+710	14.7	30	Sag	-1.089	0.099	1.188	2525.038	17+695	14.863	17+725	14.715
48	18+417	15.4	25	Sag	0.099	0.945	0.846	2954.691	18+404.500	15.388	18+429.500	15.518

49	18+745	18.5	25	Hog	0.945	0	-0.945	-2645.16	18+732.500	18.382	18+757.500	18.5
50	18+925	18.5	25	Hog	0	-0.831	-0.831	-3008.83	18+912.500	18.5	18+937.500	18.396
51	19+252	15.783	55	Sag	-0.831	1.293	2.124	2589.105	19+224.500	16.011	19+279.500	16.139
52	19+555	19.702	35	Hog	1.293	0.053	-1.24	-2822.53	19+537.500	19.476	19+572.500	19.711
53	21+050	20.5	25	Hog	0.053	-0.885	-0.939	-2663.6	21+037.500	20.493	21+062.500	20.389
54	21+550	16.074	30	Sag	-0.885	0.222	1.107	2710.681	21+535	16.207	21+565	16.107
55	21+824	16.681	45	Sag	0.222	2	1.778	2530.547	21+801.500	16.631	21+846.500	17.131
56	22+335	26.9	55	Hog	2	-0.1	-2.1	-2619.29	22+307.500	26.35	22+362.500	26.872
57	22+615	26.62	50	Hog	-0.1	-2	-1.9	-2631.18	22+590	26.645	22+640	26.12
58	22+965	19.619	65	Sag	-2	0.407	2.407	2700.51	22+932.500	20.269	22+997.500	19.751
59	23+280	20.9	20	Hog	0.407	0	-0.407	-4918.03	23+270	20.859	23+290	20.9
60	23+500	20.9	40	Hog	0	-1.6	-1.6	-2500	23+480	20.9	23+520	20.58
61	23+607.286	19.183			-1.6		1.6					

Table 6.6: Vertical Alignment - Proposed Metro Corridor Option II

Sl. NO.	CHAINAGE (m)	LEVEL OF PVI	LENGTH OF CURVE	TYPE OF CURVE	Grade IN (%)	Grade OUT (%)	Grade DIFF (%)	RADIUS (m)	CHAINAGE ST. OF CURVE	LEVEL AT START OF CURVE	CHAINAGE END OF CURVE	LEVEL AT END OF CURVE
1	0+000	17.4				1.5	1.5					
2	0+210	20.55	40	Hog	1.5	0	-1.5	-2666.67	0+190	20.25	0+230	20.55
3	0+475	20.55	20	Hog	0	-0.296	-0.296	-6752.29	0+465	20.55	0+485	20.52
4	0+659	20.005	50	Sag	-0.296	1.6	1.896	2637.313	0+634	20.079	0+684	20.405
5	0+965	24.9	40	Hog	1.6	0	-1.6	-2500.51	0+945	24.58	0+985	24.9
6	1+170	24.9	20	Hog	0	-0.588	-0.588	-3400	1+160	24.9	1+180	24.841
7	1+340	23.9	20	Sag	-0.588	0	0.588	3400	1+330	23.959	1+350	23.9
8	1+685	23.9	50	Hog	0	-1.891	-1.891	-2644.73	1+660	23.9	1+710	23.427
9	1+955	18.796	60	Sag	-1.891	0.463	2.353	2549.439	1+925	19.363	1+985	18.934
10	2+172	19.8	20	Hog	0.463	0.274	-0.189	-10566.8	2+162	19.754	2+182	19.827
11	2+574	20.9	20	Hog	0.274	0.094	-0.18	-11126.3	2+564	20.873	2+584	20.909
12	4+485	22.694	25	Hog	0.094	-0.867	-0.961	-2601.28	4+472.500	22.682	4+497.500	22.586
13	4+805	19.919	35	Sag	-0.867	0.489	1.356	2581.343	4+787.500	20.071	4+822.500	20.005
14	5+380	22.729	20	Hog	0.489	-0.187	-0.675	-2960.9	5+370	22.68	5+390	22.71
15	5+690	22.15	20	Sag	-0.187	0	0.187	10708.12	5+680	22.169	5+700	22.15
16	5+880	22.15	20	Hog	0	-0.629	-0.629	-3178.34	5+870	22.15	5+890	22.087
17	6+420	18.752	45	Sag	-0.629	0.999	1.629	2763.182	6+397.500	18.894	6+442.500	18.977
18	6+705	21.6	25	Hog	0.999	0	-0.999	-2501.76	6+692.500	21.475	6+717.500	21.6
19	6+890	21.6	40	Hog	0	-1.6	-1.6	-2500.42	6+870	21.6	6+910	21.28
20	7+263	15.633	65	Sag	-1.6	0.931	2.53	2568.889	7+230.500	16.153	7+295.500	15.935

21	8+016	22.64	55	Sag	0.931	3	2.069	2657.704	7+988.500	22.384	8+043.500	23.465
22	8+375	33.41	75	Hog	3	0.1	-2.9	-2586.21	8+337.500	32.285	8+412.500	33.448
23	8+755	33.79	40	Sag	0.1	1.695	1.595	2507.302	8+735	33.77	8+775	34.129
24	9+006.100	38.047	55	Hog	1.695	-0.444	-2.14	-2570.63	8+978.600	37.581	9+033.600	37.925
25	9+763	34.685	20	Hog	-0.444	-0.72	-0.276	-7238.98	9+753	34.729	9+773	34.613
26	10+230	31.32	20	Sag	-0.72	-0.126	0.595	3363.086	10+220	31.392	10+240	31.307
27	10+385	31.125	50	Hog	-0.126	-1.486	-1.36	-3676.36	10+360	31.156	10+410	30.754
28	10+915	23.25	40	Sag	-1.486	0	1.486	2692.063	10+895	23.547	10+935	23.25
29	11+140	23.25	20	Hog	0	-0.648	-0.648	-3085.97	11+130	23.25	11+150	23.185
30	11+350	21.889	65	Sag	-0.648	1.8	2.448	2654.895	11+317.500	22.1	11+382.500	22.474
31	11+820	30.35	50	Hog	1.8	0	-1.8	-2777.45	11+795	29.9	11+845	30.35
32	12+020	30.35	40	Hog	0	-1.478	-1.478	-2705.62	12+000	30.35	12+040	30.054
33	12+321	25.9	35	Sag	-1.478	-0.268	1.21	2892.684	12+303.500	26.159	12+338.500	25.853
34	12+470	25.5	35	Hog	-0.268	-1.512	-1.244	-2814.48	12+452.500	25.547	12+487.500	25.235
35	12+761	21.1	80	Sag	-1.512	1.65	3.162	2529.89	12+721	21.705	12+801	21.76
36	13+670	36.1	45	Hog	1.65	0	-1.65	-2727	13+647.500	35.729	13+692.500	36.1
37	14+025	36.1	35	Hog	0	-2	-2	-1750	14+007.500	36.1	14+042.500	35.75
38	14+665	23.3	100	Sag	-2	2	4	2500	14+615	24.3	14+715	24.3
39	15+130	32.6	50	Hog	2	0	-2	-2500	15+105	32.1	15+155	32.6
40	15+350	32.6	55	Hog	0	-2	-2	-2749.7	15+322.500	32.6	15+377.500	32.05
41	15+810	23.399	60	Sag	-2	0.339	2.34	2564.429	15+780	23.999	15+840	23.501
42	16+276	24.981	85	Hog	0.339	-3	-3.339	-2545.55	16+233.500	24.837	16+318.500	23.706
43	16+581	15.832	85	Sag	-3	0.4	3.4	2499.963	16+538.500	17.107	16+623.500	16.002
44	17+110	17.95	20	Hog	0.4	-0.079	-0.479	-4175.81	17+100	17.91	17+120	17.942
45	17+460	17.675	40	Hog	-0.079	-1.561	-1.482	-2699.14	17+440	17.691	17+480	17.363
46	17+650	14.71	45	Sag	-1.561	0.099	1.66	2711.624	17+627.500	15.061	17+672.500	14.732
47	18+347	15.4	25	Sag	0.099	0.945	0.846	2954.642	18+334.500	15.388	18+359.500	15.518
48	18+675	18.5	25	Hog	0.945	0	-0.945	-2645.16	18+662.500	18.382	18+687.500	18.5

49	18+855	18.5	25	Hog	0	-0.831	-0.831	-3008.83	18+842.500	18.5	18+867.500	18.396
50	19+182	15.783	55	Sag	-0.831	1.281	2.112	2603.847	19+154.500	16.011	19+209.500	16.135
51	19+488	19.704	35	Hog	1.281	0.053	-1.228	-2850.11	19+470.500	19.48	19+505.500	19.713
52	20+980	20.5	25	Hog	0.053	-0.885	-0.939	-2663.68	20+967.500	20.493	20+992.500	20.389
53	21+480	16.074	30	Sag	-0.885	0.222	1.107	2710.681	21+465	16.207	21+495	16.107
54	21+754	16.681	45	Sag	0.222	2	1.778	2530.547	21+731.500	16.631	21+776.500	17.131
55	22+265	26.9	55	Hog	2	-0.1	-2.1	-2619.29	22+237.500	26.35	22+292.500	26.873
56	22+545	26.62	50	Hog	-0.1	-2	-1.9	-2631.18	22+520	26.645	22+570	26.12
57	22+895	19.619	65	Sag	-2	0.407	2.407	2700.51	22+862.500	20.269	22+927.500	19.751
58	23+210	20.9	20	Hog	0.407	0	-0.407	-4918.03	23+200	20.859	23+220	20.9
59	23+430	20.9	40	Hog	0	-1.6	-1.6	-2500	23+410	20.9	23+450	20.58
60	23+538.641	19.162			-1.6		1.6					

Table 6.7: Vertical Alignment - Proposed Metro Corridor Option III

Sl. NO.	CHAINAGE (m)	LEVEL OF PVI	LENGTH OF CURVE	TYPE OF CURVE	Grade IN (%)	Grade OUT (%)	Grade DIFF (%)	RADIUS (m)	CHAINAGE ST. OF CURVE	LEVEL AT START OF CURVE	CHAINAGE END OF CURVE	LEVEL AT END OF CURVE
1	0+000	17.4				1.5	1.5					
2	0+210	20.55	40	Hog	1.5	0	-1.5	-2666.67	0+190	20.25	0+230	20.55
3	0+475	20.55	20	Hog	0	-0.296	-0.296	-6752.29	0+465	20.55	0+485	20.52
4	0+659	20.005	50	Sag	-0.296	1.6	1.896	2637.313	0+634	20.079	0+684	20.405
5	0+965	24.9	40	Hog	1.6	0	-1.6	-2500.51	0+945	24.58	0+985	24.9
6	1+170	24.9	20	Hog	0	-0.588	-0.588	-3400	1+160	24.9	1+180	24.841
7	1+340	23.9	20	Sag	-0.588	0	0.588	3400	1+330	23.959	1+350	23.9
8	1+685	23.9	50	Hog	0	-1.891	-1.891	-2644.73	1+660	23.9	1+710	23.427
9	1+955	18.796	60	Sag	-1.891	0.463	2.353	2549.439	1+925	19.363	1+985	18.934
10	2+172	19.8	20	Hog	0.463	0.274	-0.189	-10566.8	2+162	19.754	2+182	19.827
11	2+574	20.9	20	Hog	0.274	0.094	-0.18	-11126.3	2+564	20.873	2+584	20.909
12	4+485	22.694	25	Hog	0.094	-0.867	-0.961	-2601.28	4+472.500	22.682	4+497.500	22.586
13	4+805	19.919	35	Sag	-0.867	0.489	1.356	2581.343	4+787.500	20.071	4+822.500	20.005
14	5+380	22.729	20	Hog	0.489	-0.187	-0.675	-2960.9	5+370	22.68	5+390	22.71
15	5+690	22.15	20	Sag	-0.187	0	0.187	10708.12	5+680	22.169	5+700	22.15
16	5+880	22.15	20	Hog	0	-0.629	-0.629	-3178.34	5+870	22.15	5+890	22.087
17	6+420	18.752	45	Sag	-0.629	0.999	1.629	2763.182	6+397.500	18.894	6+442.500	18.977
18	6+705	21.6	25	Hog	0.999	0	-0.999	-2501.76	6+692.500	21.475	6+717.500	21.6
19	6+935	21.6	45	Hog	0	-1.7	-1.7	-2647.51	6+912.500	21.6	6+957.500	21.218
20	7+279	15.753	65	Sag	-1.7	0.756	2.456	2646.606	7+246.500	16.305	7+311.500	15.999
21	7+654	18.589	60	Sag	0.756	2.31	1.554	3862.202	7+624	18.362	7+684	19.282
22	8+165	30.392	60	Hog	2.31	1.865	-0.445	-13482.2	8+135	29.699	8+195	30.951

23	9+002	46	55	Hog	1.865	-1.724	-3.589	-1532.51	8+974.500	45.487	9+029.500	45.526
24	9+205	42.5	85	Sag	-1.724	1.491	3.215	2643.887	9+162.500	43.233	9+247.500	43.134
25	9+423	45.75	80	Hog	1.491	-2.414	-3.905	-2048.51	9+383	45.154	9+463	44.784
26	9+686	39.4	65	Sag	-2.414	0	2.414	2692.126	9+653.500	40.185	9+718.500	39.4
27	9+786	39.4	40	Sag	0	0.687	0.687	5823.389	9+766	39.4	9+806	39.537
28	10+030	41.076	100	Hog	0.687	-2.989	-3.676	-2720.57	9+980	40.733	10+080	39.582
29	10+182	36.533	45	Sag	-2.989	-1.37	1.618	2780.642	10+159.500	37.205	10+204.500	36.225
30	10+636	30.311	30	Hog	-1.37	-2.533	-1.16	-2585.45	10+621	30.517	10+651	29.931
31	10+898	23.674	70	Sag	-2.533	0.097	2.63	2661.883	10+863	24.561	10+933	23.708
32	11+156	23.923	50	Sag	0.097	2	1.903	2627.38	11+131	23.899	11+181	24.423
33	11+820	37.2	55	Hog	2	-0.1	-2.1	-2619.61	11+792.500	36.65	11+847.500	37.173
34	12+020	37	50	Hog	-0.1	-1.999	-1.899	-2632.3	11+995	37.025	12+045	36.5
35	12+791	21.584	95	Sag	-1.999	1.651	3.651	2602.096	12+743.500	22.534	12+838.500	22.368
36	13+670	36.1	45	Hog	1.651	0	-1.65	-2724.92	13+647.500	35.728	13+692.500	36.1
37	14+025	36.1	35	Hog	0	-2	-2	-1750	14+007.500	36.1	14+042.500	35.75
38	14+665	23.3	100	Sag	-2	2	4	2500	14+615	24.3	14+715	24.3
39	15+130	32.6	50	Hog	2	0	-2	-2500	15+105	32.1	15+155	32.6
40	15+350	32.6	55	Hog	0	-2	-2	-2749.7	15+322.500	32.6	15+377.500	32.05
41	15+810	23.399	60	Sag	-2	0.339	2.34	2564.429	15+780	23.999	15+840	23.501
42	16+276	24.981	85	Hog	0.339	-3	-3.339	-2545.55	16+233.500	24.837	16+318.500	23.706
43	16+581	15.832	85	Sag	-3	0.4	3.4	2499.963	16+538.500	17.107	16+623.500	16.002
44	17+110	17.95	20	Hog	0.4	-0.079	-0.479	-4175.81	17+100	17.91	17+120	17.942
45	17+460	17.675	40	Hog	-0.079	-1.561	-1.482	-2699.14	17+440	17.691	17+480	17.363
46	17+650	14.71	45	Sag	-1.561	0.099	1.66	2711.624	17+627.500	15.061	17+672.500	14.732
47	18+347	15.4	25	Sag	0.099	0.945	0.846	2954.642	18+334.500	15.388	18+359.500	15.518
48	18+675	18.5	25	Hog	0.945	0	-0.945	-2645.16	18+662.500	18.382	18+687.500	18.5
49	18+855	18.5	25	Hog	0	-0.831	-0.831	-3008.83	18+842.500	18.5	18+867.500	18.396
50	19+182	15.783	55	Sag	-0.831	1.293	2.124	2589.105	19+154.500	16.011	19+209.500	16.139

51	19+485	19.702	35	Hog	1.293	0.053	-1.24	-2822.53	19+467.500	19.476	19+502.500	19.711
52	20+980	20.5	25	Hog	0.053	-0.885	-0.939	-2663.6	20+967.500	20.493	20+992.500	20.389
53	21+480	16.074	30	Sag	-0.885	0.222	1.107	2710.681	21+465	16.207	21+495	16.107
54	21+754	16.681	45	Sag	0.222	2	1.778	2530.547	21+731.500	16.631	21+776.500	17.131
55	22+265	26.9	55	Hog	2	-0.1	-2.1	-2619.29	22+237.500	26.35	22+292.500	26.873
56	22+545	26.62	50	Hog	-0.1	-2	-1.9	-2631.18	22+520	26.645	22+570	26.12
57	22+895	19.619	65	Sag	-2	0.407	2.407	2700.51	22+862.500	20.269	22+927.500	19.751
58	23+210	20.9	20	Hog	0.407	0	-0.407	-4918.03	23+200	20.859	23+220	20.9
59	23+430	20.9	40	Hog	0	-1.6	-1.6	-2500	23+410	20.9	23+450	20.58
60	23+536.891	19.19			-1.6		1.6					

6.2 GEOTECHNICAL INVESTIGATIONS

6.2.1 GENERAL GEOLOGY & CHARACTERISTICS

6.2.1.1 Location

The Geotechnical investigations have been carried out along the proposed alignment to determine the strata, depth of foundation and safe bearing capacity of foundations required for the above proposed Metro corridor. Fifty four boreholes (BH-1 to BH-54) were completed at the site as illustrated on the Borehole Location Plan

Table 6.8: Borehole Location Plan

Borehole	Chainage	Borehole Termination Depths
BH-1	23+550	15.5m
BH-2	23+050	15.0m
BH-3	22+550	20.0m
BH-4	22+050	20.0m
BH-5	21+550	20.0m
BH-6	21+050	20.0m
BH-7	20+550	20.0m
BH-8	20+050	20.0m
BH-9	18+000	20.0m
BH-10	17+550	20.0m
BH-11	17+050	20.0m
BH-12	16+100	20.0m
BH-13	15+350	20.0m
BH-14	7+650	20.0m
BH-15	9+700	20.0m
BH-16	6+350	20.0m
BH-17	7+150	20.0m
BH-18	3+10	20.0m
BH-19	14+850	20.0m
BH-20	2+700	20.0m
BH-21	2+450	20.0m
BH-22	1+400	20.0m
BH-23	0+800	20.0m
BH-24	4+150	20.0m
BH-25	3+450	20.0m
BH-26	5+000	20.0m
BH-27	5+700	20.0m
BH-28	6+000	20.0m
BH-29	5+350	20.0m

BH-30	14+300	15.0m
BH-31	13+800	20.0m
BH-32	6+950	15.0m
BH-33	7+250	20.0m
BH-34	19+600	20.0m
BH-35	19+100	20.0m
BH-36	18+650	20.0m
BH-37	18+250	20.0m
BH-38	15+800	20.0m
BH-39	13+100	20.0m
BH-40	12+700	20.0m
BH-41	12+200	20.0m
BH-42	11+750	20.0m
BH-43	11+250	20.0m
BH-44	10+750	20.0m
BH-45	10+350	16.0m
BH-46	9+750	20.0m
BH-47	9+300	16.0m
BH-48	8+800	20.0m
BH-49	8+350	20.0m
BH-50	7+900	16.0m
BH-51	7+400	20.0m
BH-52	4+650	20.0m
BH-53	3+800	20.0m
BH-54	2+00	20.0m

6.2.2 FOUNDATION RECOMMENDATIONS

Recommended founding depths along with corresponding allowable bearing capacities for open spread foundations are given in Table below.

Table 6.9: Net allowable Bearing Capacity

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
BH-1	1.5m (WR)	50
	2.0m (HR)	80
BH-2	1.4m (WR)	50
	2.0m (HR)	80
BH-3	6.0m (HR)	80
BH-4	4.0m (Residual Soil)	20

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
	5.0m (HR)	80
BH-5	3.0m (Residual soil)	5
	6.0m (Residual soil)	10
	13.0m (HR)	80
BH-6	6.0m (Residual soil)	5
	8.0m (Residual soil)	35
	14.0m (HR)	80
BH-7	3.0m (Residual soil)	5
	8.0m (Residual soil)	35
	13.0 (HR)	80
BH-8	2.5m (Residual soil)	35
	4.0m (WR)	50
	5.0m (HR)	80
BH-9	3.0m (Residual soil)	35
	5.0m (WR)	50
	6.0m (HR)	80
BH-10	2.5m (Residual soil)	35
	3.0m (WR)	50
	5.0m (HR)	80
BH-11	3.5m (Residual soil)	35
	4.5m (WR)	50
	5.0m (HR)	80
BH-12	3.5m (Residual soil)	35
	4.0m (WR)	50
	5.0m (WR)	80
BH-13	3.5m (Residual soil)	35
	5.0m (WR)	50
	6.0m (HR)	80
BH-14	4.0m (Residual soil)	35
	4.0m (WR)	50
	8.0m (HR)	80
BH-15	4.0m (Residual soil)	35

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
	7.0m (WR)	50
	8.0m (HR)	80
BH-16	3.0m (Residual soil)	5
	5.0m (Residual soil)	10
	8.0m (WR)	50
	10.0m (HR)	80
BH-17	3.5m (Residual soil)	5
	5.5m (Residual soil)	15
	9.5m (WR)	50
	12.0m (HR)	80
BH-18	3.0m (Residual soil)	8
	9.0m (WR)	50
	12.0m (HR)	80
BH-19	3.0m (Residual soil)	8
	5.0m (Residual soil)	35
	7.0m (WR)	50
	10.0m (HR)	80
BH-20	4.0m (Residual soil)	8
	6.0m (Residual soil)	15
	9.0m (WR)	50
	12.0m (HR)	80
BH-21	2.5m (Residual soil)	15
	3.9m (WR)	50
	6.5m (HR)	80
BH-22	3.0m (Residual soil)	10
	4.9m (WR)	50
	5.5m (HR)	80
BH-23	3.0m (WR)	50
	5.0m (HR)	80
BH-24	2.0m (Residual soil)	15
	5.0m (WR)	50
	12.0m (HR)	80

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
BH-25	3.0m (Residual soil)	15
	4.5m (WR)	35
	13.0m (HR)	80
BH-26	3.0m (Residual soil)	15
	4.9m (WR)	50
	7.0m (HR)	80
BH-27	3.0m (Residual soil)	15
	5.9m (WR)	50
	9.0m (HR)	80
BH-28	3.0m (Residual soil)	20
	5.5m (WR)	50
	8.0m (HR)	80
BH-29	3.0m (Residual soil)	10
	5.0m (Residual soil)	35
	6.0m (WR)	50
BH-30	3.1m (WR)	50
	7.0m (HR)	80
BH-31	3.0m (Residual soil)	8
	6.0m (WR)	50
	8.0m (HR)	80
BH-32	3.5m (WR)	50
	5.5m (HR)	80
BH-33	3.0m (Residual soil)	15
	6.0m (WR)	50
	10.0m (HR)	80
BH-34	3.5m (Residual soil)	15
	5.0m (Residual soil)	35
	7.5m (WR)	50
	10.0m (HR)	80
BH-35	3.0m (Residual soil)	25
	4.0m (Residual soil)	35
	6.0m (WR)	50

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
	8.0m (HR)	80
BH-36	3.0m (Residual soil)	35
	6.0m (WR)	50
	10.0m (HR)	80
BH-37	4.5m (Residual soil)	35
	6.0m (WR)	50
	10.0m (HR)	80
BH-38	3.0m (Residual soil)	35
	5.0m (WR)	50
	8.0m (HR)	80
BH-39	3.0m (Residual soil)	20
	5.5m (WR)	50
	7.5m (HR)	80
BH-40	3.0m (Residual soil)	20
	6.0m (WR)	50
	9.0m (HR)	80
BH-41	3.0m (Residual soil)	35
	5.0m (WR)	50
	8.0m (HR)	80
BH-42	3.5m (Residual soil)	15
	6.5m (WR)	50
	10.0m (HR)	80
BH-43	3.0m (Residual soil)	10
	5.5m (WR)	50
	10.0m (HR)	80
BH-44	4.0m (Residual soil)	35
	6.0m (WR)	50
	10.0 (HR)	80
BH-45	3.0m (Residual soil)	35
	4.0m (WR)	50
	7.0 (HR)	80
BH-46	3.0m (Residual soil)	14

Boreholes	Depth to Foundation	Net Allowable Bearing Capacity (t/m^2)
	6.0m (WR)	50
	10.0 (HR)	80
BH-47	2.5m (Residual soil)	20
	4.5m (WR)	50
	8.5 (HR)	80
BH-48	3.0m (Residual soil)	35
	5.1m (WR)	50
	8.0 (HR)	80
BH-49	3.0m (Residual soil)	22
	5.0m (WR)	50
	8.0 (HR)	80
BH-50	2.5m (Residual soil)	35
	3.5m (WR)	50
	7.5 (HR)	80
BH-51	3.0m (Residual soil)	10
	6.0m (Residual soil)	35
	9.0m (WR)	50
	13.0 (HR)	80
BH-52	3.0m (Residual soil)	10
	5.5m (Residual soil)	35
	8.0m (WR)	50
	11.0 (HR)	80
BH-53	3.5m (Residual soil)	10
	7.5m (WR)	50
	8.5 (HR)	80
BH-54	3.0m (Residual soil)	35
	4.9m (WR)	50
	10.0 (HR)	80

Maximum settlement of foundations will be less than 25mm. Modulus of subgrade can be obtained as dividing bearing capacities as indicated in Table B above by corresponding footing settlement (0.025m). Excavation sides should be sloped at a maximum slope of 1:1 (horizontal: vertical) or flatter. Excavated soils can be used for backfilling.

6.2.3 Design Parameters of Rail Corridor

The proposed structure can be supported on bored piles socketed in bedrock. Piles should be socketed in 8D in weathered rock encountered at depths of 1.4m and 14.0m below ground surface in the boreholes and spacing shall be as per IS:2911. Piles can be terminated earlier if hard rock is encountered, which makes it practically impossible for piling equipment to penetrate further.

Pile termination depths and capacities of few representative pile sizes are given in Table below.

Table 6.10: Allowable Pile Capacities

Pile Diameter (mm)	Vertical Capacity of pile (tons)	Safe Lateral Capacity (tons)	Safe Uplift Capacity (tons)
1000	635	30	205
1200	905	44	290

Maximum settlement of foundations will be less than 12mm. Depth of fixity for lateral loads can be taken as 6m below pile cap.

6.2.4 RECOMMENDATIONS

Lateral Earth Pressures

Abutment/wing walls can be constructed of concrete, masonry or Gabions. Lateral pressure parameters for design of retaining walls at this site are provided in Table 6.11.

Additional surcharge lateral pressures will be exerted by vehicle loads. Weep holes with gravel filters can be provided in retaining walls to minimize hydrostatic pressures.

Table 6.11: Lateral static Earth Pressure Parameters (for vertical Walls and level Backfill)

Approximate Total Density	1.9 t/m^2
Approximate Friction Angle	30^o
Active Pressure Coefficient: Ka	0.33
Passive Pressure Coefficient: Kp	3.0
Sliding Friction Resistance at Base	(μ = tan ϕ=0.5)

Foundation Protection

Groundwater was not encountered in any of the borehole. A ‘normal’ Exposure Condition was assigned to this site. Hence, only following precautions shall be taken to protect concrete and reinforcement in foundations as per IS456-2000 / IRC21-2000 and updated amendments. Precautions for Subsurface Concrete is presented in Table 6.12.

Table 6.12: Precautions for Subsurface Concrete

	For Shallow Foundations	For Piles
Type of Cement	OPC or PPC	OPC or PPC
Minimum Cement Content	320 kg/m^3	400kg/m^3
Minimum Grade of Concrete	M30	M35
Maximum Water Cement Ratio	0.50	0.40
Minimum Cover for Foundations	50mm	50mm

For Bridges with spans more than 30m, or prestressed concrete or built with innovative design or construction.

6.2.5 TRAFFIC INTEGRATION

The objective of an integrated transport system and traffic movement is to offer maximum advantage to commuters and society from traffic and planning consideration. Various modes of transport need to be integrated in a way that each mode supplements the other. A large proportion of MRTS users will come to and depart from various stations by public, hired and private modes, for which integration facilities need to be provided at stations to ensure quick and convenient transfers.

In order to ensure that entire MRTS function as an integrated network and provides efficient service to the commuter, the following steps have been identified:

- -Suitable linkages are proposed so that various corridors of MRTS are integrated within themselves, with existing rail services and with road based modes.
- -Facilities needed at various stations are planned in conformity with the type of linkages planned there.

Traffic and transport integration facilities are provided for two different types of linkages:

- Feeder links to provide integration between various MRTS corridors and road based transport modes i.e. public, hired, and private vehicles.
- Walk links to provide access to the pedestrians.

6.2.6 APPROACH ADOPTED IN PLANNING TRAFFIC INTEGRATION FACILITIES

Integration facilities at MRTS stations include approach roads to the stations, circulation facilities, pedestrian ways and adequate circulation areas for various modes likely to come to important stations including feeder bus/mini-buses. Parking for private vehicles has not been proposed in view of the scarcity of land along the alignment.

6.2.7 OPERATIONAL INTEGRATION

Integration at operational level will be required to synchronize the timings of the MRTS services and the feeder service. For an efficient interchange, walking and waiting time at these stations will need to be minimized. Introduction of common ticketing and their availability at convenient locations will be necessary to ensure forecast patronage of the system. Last but not the least will be the need for an integrated passenger information system covering all the modes through the publication of common route guides, time tables and information boards at terminals and in the train coaches for providing updated information for users of the system.

6.3 CONSTRUCTION METHODOLOGY

6.3.1.1 Utility Diversion

It is suggested that all utilities falling within excavation area are diverted away in advance to avoid damage to such utilities during the excavation/ construction phase. The cross utilities, however has to be kept supported. It is suggested that pressure water pipelines crossing the proposed cut area are provided with valves on both sides of the cut so that the cut area can be isolated in case of any leakage to the pipeline to avoid flooding of the cut/damage to the works.

6.3.1.2 Support Walls

Most commonly used support wall is RCC Diaphragm Wall. The advantage of diaphragm wall is that the same can be used as part of permanent structure. The modern techniques are now available where water-stop can be inserted at the joints of two diaphragm wall panels to avoid seepage through the joints. It is also now possible to ensure the verticality of the diaphragm wall panels to avoid any infringement problem later on. Typically the diaphragm wall of 80 cm to 1 meter thickness is sufficient to do the cut and cover construction. The various advantages of diaphragm wall are as follows.

- It is rigid type of support system and therefore ensures the maximum safety against settlement to the adjacent structures.
- Can be used as part of the permanent structure and, therefore, considered economical.
- With diaphragm wall it is possible to construct an underground structure by top down method. In this method top slab is cast once the excavation is reached to the top slab level with rigid connections to the diaphragm wall which can be achieved by leaving couplers in the diaphragm wall reinforcement at appropriate level. This top slab then acts as strut between the two support walls and gives much more rigidity and safety to the construction. Excavation thereafter can be completed. This also helps in restoration of the surface faster without waiting for full structure to be completed.

The other support walls which can be used depending on the site conditions are as follows:

Sheet Piles: ‘Z’/ ‘U’ sheet piles cane be used as temporary support wall. This can be advantageous where it is possible to re-use the sheet pile again and again and therefore, economy can be achieved however the main concern remains, driving of sheet piles causes vibrations/noise to the adjacent buildings. This may sometimes lead to damage to the building and most of the time causes inconvenience to the occupants of the building. Situation becomes more critical if sensitive buildings are adjacent to the alignment like hospitals, schools, laboratories, etc. Silent pile driving equipments however are now available and can be used where such problems are anticipated.

Retaining Casing Piles: This is suitable for situation where the cut and cover is to be done partly in soil and partly in rocky strata. The top soil retaining structure can be done with the help of Casing pile which is then grouted with cement slurry. This is considered suitable in case of shallow level, non-uniform, uneven nature of rock head surface which render the construction of sheet piles/diaphragm wall impracticable. These are suitable up to 7-meter depth. The common diameter used for such casing pile is 2.00-2.50 mm dia.

Soldier Piles and Lagging: Steel piles (H Section or I section) are driven into the ground at suitable interval (normally 1-1.5 mtr.) centre-to-centre depending on the section and depth of excavation. The gap between two piles is covered with suitable lagging of timber planks/shot-creting /steel sheets/GI sheets during the process of excavation.

Secant Piles: are cast-in-situ bored piles constructed contiguously to each other so that it forms a rigid continuous wall. This is considered an alternative to diaphragm wall where due to soil conditions it is not advisable to construct diaphragm wall from the consideration of settlement during the trenching operation. 800 to 1000 mm dia piles are commonly used. Two alternate soft piles are driven and cast in such a way that the new pile partly cuts into earlier constructed piles. This new pile is constructed with suitable reinforcement. With this, alternate soft and hard pile is constructed. This has got all the advantages of diaphragm wall. However, this wall cannot be used as part of permanent structure and permanent structure has to be constructed in- side of this temporary wall.

6.3.1.3 Anchors

As an alternative to the struts, soil/rock anchors can be used to keep these support walls in position. This gives additional advantage as clear space is available between two support walls and progress of excavation & construction is much faster as compared to the case where large number of struts is provided which create hindrance to the movement of equipments and material & thus affects the progress adversely.

The combination of all the type of retaining walls, struts/anchors may be necessary for the project to suit the particular site. Based on the above broad principle, the support walls system for cut and cover shall be chosen for particular locations.

6.3.2 CHOICE OF SUPERSTRUCTURE

The choice of superstructure has to be made keeping in view the ease of constructability and the maximum standardization of the form-work for a wide span ranges. Following type of superstructures has been considered:

6.3.2.1 Segmental Balanced Cantilever Method

- Cast-in-situ Segmental Balanced Cantilever Method.
- Precast Segmental box girder using external unbonded tendons.
- Precast segmental U-Channel superstructure with internal pre-stressing. Cast-in-situ Segmental Balanced Cantilever Method

The formwork is supported from a movable form carrier. The form traveler moves forward on rails attached to the deck of the completed structure and is anchored to the deck at the rear. With the form traveler in place, a new segment is formed, cast and stressed to the previously constructed segment. A covering may be provided on the form carrier so that work may proceed during inclement weather.

Each segment is reinforced with conventional untensioned steel and sometimes by transverse or vertical prestressing or both, while the assembly of segments is achieved by longitudinal post-tensioning. One segment to the left of the pier is first constructed and then stressed against the crosshead, followed by the corresponding unit on the right, which will also be stressed against the crosshead. The sequence is then repeated. Additional pre stressing shall be provided for continuity to the overall frame structure.

The operation sequence in cast in place balance cantilever construction is as follows:

- Setting up and adjusting carrier
- Setting up and aligning forms
- Placing reinforcement and tendon ducts
- Concreting
- Inserting prestress tendons in the segment and stressing
- Removing the formwork
- Moving the form carrier to the next position and starting a new cycle

The limitation of the method is that the strength of concrete is always on the critical path of construction and it also influences greatly the structure's deformability, particularly during construction.

Pre Cast Segmental Box Girder

This essentially consists of precast segmental construction with external prestressing and dries joints and is by far the most preferred technique in fast track projects. In such construction the prestressing is placed outside the structural concrete (but inside the box) and protected with high density polyethylene tubes which are grouted with special wax or cement. The match cast joints at the interface of two segments are provided with shear keys as in traditional segmental construction. However, epoxy is dispensed with because water tight seal at the segment joints is not required in association with external tendons. The schematic arrangement is shown at Fig. 2.4.

The main advantages of dry-jointed externally prestressed precast segmental construction can be summarized as follows:-

- Simplification of all post-tensioning operations, especially installation of tendons.
- Reduction in structural concrete thickness as no space is occupied by the tendons inside the concrete.
- Good corrosion protection due to tendons in polyethylene ducts; the grout inspection is easier and leaks, if any, can be identified during the grouting process.
- Simplified segment casting. There is no concern about alignment of tendons.
- Increased speed of construction.
- The elimination of the epoxy from the match-cast joints reduces costs and increases speed of construction further.
- Replacement of tendons in case of distress is possible and can be done in a safe and convenient manner.

- Facility for inspection and monitoring of tendons during the entire service life of the structure.

Pre Cast Segmental 'U' Girder

The single U type of viaduct structure is also a precast segmental construction with internal prestressing and requires gluing and temporary prestressing of segments. The match cast joints at the interface of two segments are also provided with shear keys. The main advantages for this type of structural configuration of superstructure are:

- Built-in sound barrier.
- Built-in cable support and system function.
- Possibility to lower the longitudinal profile by approximately 1m compared to conventional design.
- Built-in structural elements capable of maintaining the trains on the bridge in case of derailment (a standard barrier design does not allow this)
- Built-in maintenance and evacuation path on either side of the track.

After studying all the feasible options, Pre-cast segmental box girder using external unbounded tendon had been adopted because of the advantages mentioned above. The schematic arrangement for this is shown in figure below.

Figure 6.9: Pre-cast segmental box girder

Span by Span Construction Method

Constructing the typical spans on an Advanced Launching Girder (ALG) with system formwork for span-by-span cast-in-situ construction:

Advanced Launching Girder with system formwork has been used in Singapore and it has demonstrated the effective use of this construction methodology in the viaduct construction to achieve quality finishes. The Advanced Launching Girder is a steel structure specially designed and fabricated for the cast-in-situ construction of the typical spans of the viaduct.

- Firstly, the piers and the cross heads are constructed in advance of the ALG. For the construction of every span, formwork units are adjusted, raised and suspended on the transverse trusses using Maccalloy bars (high tensile bars) in conjunction with the hollow ram jacks.
- After the formwork units are in place, fixing of reinforcement, placing of ducts and concreting will follow.
- When the structure achieves a concrete strength of 30 MPa, the stressing of the tendons will begin.
- Upon complete transfer of load to the starting elements and piers, the formwork units will be dismantled and placed on the working platform. The entire ALG will then be jacked to the next span. This cycle is then repeated.

The advantage of the span by span method of construction pertains to the pre- stressing steel requirement. Since the segments are supported by the form travellers, there are no cantilever stresses during construction, and pre-stress requirements are akin to those of conventional construction on false work.

The capital investment in the equipment for this type of construction is considerable. Taking into account total length of approximately 25.4 km of viaduct and the large number of equal spans, it may be economically justifiable for the equipment investment by the contractor.

Pre-Cast Construction

For the elevated sections It is recommended to have pre-cast segmental construction for super structure for the viaduct. For stations also the superstructure is generally of pre-cast members. The pre-cast construction will have the following advantages:-

- Reduction in construction period due to concurrent working for substructure and superstructure.
- For segmental, pre-cast element (of generally 3.0m length), transportation from construction depot to site is easy and economical.
- Minimum inconvenience is caused to the public utilising the road as the superstructure launching is carried out through launching girder requiring narrow width of the road.
- As the pre-cast elements are cast on production line in a construction depot, very good quality can be ensured.
- The method is environment friendly as no concreting work is carried at site for the superstructure.

Casting of Segments

For viaducts segmental pre-cast construction requires a casting yard. The construction depot will have facilities for casting beds, curing and stacking areas, batching plant with storage facilities for aggregates and cement, site testing laboratories, reinforcement steel yard, fabrication yard, etc. An area of about 2.5

ha to 3 ha is required for each construction depot (one per contract).

For casting of segments both long line and short line method can be adopted. However the long line method is more suitable for spans curved in plan while short line method is good for straight spans. A high degree of accuracy is required for setting out the curves on long line method for which pre calculation of offsets is necessary. Match casting of segments is required in either method. The cast segments are cured on the bed as well as in stacking yard. Ends of the segments are to be made rough through sand blasting so that gluing of segments can be effective.

The cast segment will be transported on trailers and launched in position through launching girders.

Launching Scheme

Launching girder is specially designed for launching of segments. The launching scheme is shown in the Figures 4.6 to 4.11. Initially, the launching girder is erected on pier head at one end of the work. The segments are lifted in sequence as shown in the figures and dry matched while hanging from the launching girder. After dry matching, the segments are glued with epoxy and pre-stressed from one end. The girder is lowered on the temporary / permanent bearings after pre- stressing. The launching girder then moves over the launched span to next span and the sequences continue.

6.3.2.2 Structural System of Viaduct

Superstructure

The superstructure of a large part of the viaduct comprises of simply supported spans. However at major crossing over or along existing bridge, special steel or continuous unit will be provided.

Normally the Box Girder having a soffit width of about 4.0 m (approx.) accommodates the two tracks situated at 4.2m center to center (c/c). The Box Girder superstructure for almost all the simply supported standard spans will be constructed by precast prestressed segmental construction with epoxy bonded joints.

The standard spans c/c of piers of simply supported spans constructed by precast segmental construction technique has been proposed as 28.0m. The usual segments shall be 3.0m in length except the Diaphragm segments, which shall be

2.0m each. The other spans (c/c of pier) comprises of 31.0 m, 25.0 m, 22.0 m, 19.0 m & 16.0 m, which shall be made by removing/adding usual segments of 3.0 m each from the center of the span.

- The pier segment will be finalized based on simply supported span of 31.0m and the same will be also kept for all simply supported standard span.
- For major crossing having spans greater than 31.0m, special continuous units normally of 3 span construction or steel girders have been envisaged.
- All these continuous units (in case provided at obligatory location) will be constructed by cast-in-situ balanced cantilever construction technique.

Substructure

The viaduct superstructure will be supported on single cast-in-place RC pier. The shape of the pier follows the flow of forces. For the standard spans, the pier gradually widens at the top to support the bearing under the box webs. At this preliminary design stage, the size of pier is found to be limited to 1.8m to 2.0 m diameter of circular shape for most of its height so that it occupies the minimum space at ground level where the alignment often follows the central verge of existing roads. To prevent the direct collision of vehicle to pier, a Jersey Shaped crash barrier of 1.0 m height above existing road level has been provided all around the pier. A gap of 25 mm has also been provided in between the crash barrier and outer face of pier. The shape of upper part of pier has been so dimensioned that a required clearance of 5.5 m is always available on road side beyond vertical plane drawn on outer face of crash barrier. In such a situation, the minimum height of rail above the existing road is 8.4 m. The longitudinal center to center spacing of elastomeric/pot bearing over a pier would be about 1.8 m. The space between the elastomeric bearings will be utilized for placing the lifting jack required for the replacement of elastomeric bearing. An outward slope of 1:200 will be provided at pier top for the drainage due to spilling of rainwater, if any. The transverse spacing between bearings would be 3.2 m (to be studied in more details).The orientation and dimensions of the piers for the continuous units or steel girder (simply supported span) have to be carefully selected to ensure minimum occupation at ground level traffic. Since the vertical and horizontal loads will vary from pier to pier, this will be catered to by selecting the appropriate structural dimensions.

6.3.2.3 Foundation Recommendation

Substratum consists of top 1 meter as filled up soil followed by sand, silty sand, silty sand mixed with gravel up to 30 meter depth. Pile foundations have been recommended for the foundations as per the stratum encountered. Hence, pile foundations with varying pile depths depending on soil characteristic have to be provided on a case-by-case basis.

Deck - Simple Spans

Salient features of the precast segmental construction method technique as envisaged for the project under consideration are indicated below:

- The superstructure shall be constructed “span by span” sequentially, starting at one end of a continuous stretch and finishing at the other end. Nos. of launching girders may be required so as to work on different stretches simultaneously to enable completion of the project in time.
- The number of “breaks” in the stretch can be identified by Nos. of continuous units & stations.
- The suggested method of erection will be detailed in drawings to be prepared, at the time of detailed design. The launching girder (or, more accurately, the “assembly truss”) is capable of supporting the entire dead load of one span and transferring it to the temporary brackets attached to the pier. The governing weight of the segments will be of the order of 50t (to be finalized). The launching girder envisaged will be slightly longer than two span lengths. It must be able to negotiate curves in conjunction with temporary brackets.
- Transportation of segments from casting yard to the point of erection will be effected by appropriately designed low-bedded trailers (tyre-mounted). The segments can be lifted and erected using erection portal gantry moving on launching girder.

- Box girder segments shall be match cast at the casting yard before being transported to location and erected in position. Post-tensioned cables shall be threaded in-situ and tensioned from one end. It is emphasized that for precast segmental construction only one-end pre-stressing shall be used.
- The pre-stressing steel and pre-stressing system steel accessories shall be subjected to an acceptance test prior to their actual use on the works. The tests for the system shall be as per FIP Recommendations as stipulated in the special specifications. Only multi-strand jacks shall be used for tensioning of cables. Direct and indirect force measurement device (e.g. Pressure Gauge) shall be attached in consultation with system manufacturer.
- The Contractor shall be responsible for the proper handling, lifting, storing, transporting and erection of all segments so that they may be placed in the structure without damage. Segments shall be maintained in an upright position at all times and shall be stored, lifted and/or moved in a manner to prevent torsion and other undue stress. Members shall be lifted, hoisted or stored with lifting devices approved on the shop drawings.

Epoxy Bonded Joints and Shear Keys

- A minimum compressive stress of 3 kg/sq cm shall be provided uniformly over the cross-section for the closure stress on the epoxied joint until the epoxy has set. The curing period for application of the compressive stress, method of mixing and application of epoxy and all related aspects including surface preparation shall be as per approved manufacturer's specifications.
- The purpose of the epoxy joint, which is about 1mm on each mating surface, shall be to serve as lubricant during segment positioning, to provide
- waterproofing of the joints for durability in service conditions and to provide a seal to avoid cross-over of grout during grouting of one cable into other
- ducts.The epoxy shall be special purpose and meet requirements of relevant
- provision of FIP (International Federation of Pre-stressed Concrete)
- The temporary compressive stress during the curing period shall be applied by approved external temporary bar pre-stressing (such as Macalloy or Diwidag bar systems or approved equivalent).

6.3.2.4 Construction of Stations

It is proposed to construct the elevated stations with elevated concourse over the road at most of the locations to minimize land acquisition. To keep the rail level low, it is proposed not to take viaduct through the stations. Thus a separate structural configuration is required (although this may necessitate the break in the launching operations at each station location). Sub-structure for the station portion will also be similar to that of viaduct and will be carried out in the same manner. However, there will be single viaduct column in the station area, which will be located on the median and supporting the concourse girders by a cantilever arm so as to eliminate the columns on right of way. Super-structure will consist of precast segmental box Girders for supporting the track structure and I Girder / Double T Girders for supporting the platform and concourse areas. A pre-cast or cast in situ prestressed cross girder will be required over the middle piers for supporting platform structure. Box shaped in situ prestressed cantilever cross girders are planned for supporting the concourse girders and escalators at mezzanine level. All the members will be pre-cast in a construction depot and launched at site through cranes.

6.3.2.5 Grade of Concrete

It is proposed to carry out construction work with design mix concrete through computerized automatic Batching Plants with following grade of concrete for various members as per design requirement/durability considerations.

- Piles - M -35
- Pile cap and open foundation - M -35
- Piers - M -40
- All precast element for viaduct and station - M -45
- Cantilever piers and portals - M -45- M -60
- Other miscellaneous structure - M -30

For all the main structures, permeability test on concrete sample is recommended to ensure impermeable concrete.

6.3.2.6 Reinforcement and pre-stressed Steel

It is proposed to use HYSD 415 or TMT steel as reinforcement bars.For pre-stressing work, low relaxation high tensile steel strands with the configuration 12 T 13 and or 19 K 15 is recommended (confirming to IS:14268).

6.3.2.7 Road width required during construction

As most of the construction is to be carried out on the middle of the road, central two lanes including median will be required for construction activities. During piling and open foundation work, a width of about 9 m will be required for construction and the same will be barricaded. It is proposed that two lanes are provided for traffic on either sides during construction by widening of roads, if necessary. In certain cases, one way traffic may be resorted to.

All these actions will require a minimum period of about 4 to 6 months. During this period, the implementing agency can go ahead with the following preliminary works:

- -Preliminary action for diversion of utility and preparation of estimates thereof.
- -Reservation of land along the corridor, identification and survey for acquisition.

6.4 UTILITY DIVERSIONS

6.4.1 INTRODUCTION

The alignment is been planned keeping the following factors into account. They are as stated e.g., transport demand analysis, route alignment, station locations, system design, viaduct structure, geo-technical investigations etc. However there are other engineering issues which we have looked up before finalizing the alignment.

Also following engineering items have been studied and described below:

- Existing utilities and planning for their diversion during construction, if necessary.
- Land acquisition necessary for the project including its break up between Government and private ownership.

6.4.2 UTILITY AND SERVICES

The proposed alignment is passing along through the major arterial roads which are serving commercial and residential areas. A large number of surface and sub-surface utility services e.g. sewers, water mains, storm water drains, telephone cables, electric poles, traffic signals etc. exist along the proposed alignment. Details of the existing utility services along the proposed alignment have been collected from the concerned authorities. The affected portions of the services with reference to the proposed alignment were identified are indicated below. Organizations/Departments with concerned utility services in Mumbai are mentioned in the table Table 6.13.

Table 6.13 Utility Responsibility Departments

SN	ORGANIZATION/DEPARTMENT	UTILITY SERVICES
1	Thane Municipal Corporation (TMC) (Kapurbawadi)	Water Pipe Lines
3	Thane Municipal Corporation (TMC) (Kapurbawadi)	Sewer Pipe Lines
4	Thane Municipal Corporation (TMC) (Kapurbawadi)	Water Pipe Lines
5	Thane Municipal Corporation (TMC) (Kapurbawadi)	Sewer Pipe Lines
6	Kalyan Development Municipal Corporation (KDMC)	Water Pipe Lines
7	Kalyan Development Municipal Corporation (KDMC)	Sewer Pipe Lines
8	MGL	Gas pipe lines

Assessment of the type and location of underground utilities running along and across the proposed route alignment between Kapurbawadi – Bhiwandi - Kalyan has been undertaken with the help of data available with concerned authorities, who generally maintain plans and data of such utility services. Particulars of main utilities i.e. trunk and main sewers, water mains, Telecom cable, gas pipe line etc. have been marked on alignment plans in Drawing

The proposed metro alignment is elevated running at the minimum height of 8.50 meter from existing road level. The alignment is running mostly on centre of the road. The entire corridor covers three Municipal Corporation Areas i.e. Thane Municipal Corporation (TMC), Bhiwandi Nizampur City Municipal Corporation (BNCMC) & Kalyan Dombivali Municipal Corporation (KDMC).

The major sewer lines and water mains running along & across the alignment and likely to be affected due to location of pier foundations, are proposed to be taken care of by relocating column supports of viaduct by change in the span configuration or by suitably adjusting the layout of pile foundations. Where, this is not feasible, utilities will be suitably diverted.

All the overhead lines need modifications, i.e. raising, shifting or converting into underground cables.

Details of water mains, Electrical Cables / Lines, Various underground utilities affected along the proposed alignment are listed in Table 6.14.

Table 6.14: Details of existing and proposed underground utilities

Sr no	Type of Utility	Existing/ Proposed	Chainage Affected	Diameter (m)	Position
1	Water Mains	Existing	7+100	2.5	Across
2	Water Mains	Existing	17+590	2.0	Across
3	Water Mains	Existing	22+300	2.0	Across
4	Sewer Line	Proposed	22+300-23+607	0.3 to 1	Along
5	MGL steel pipe line	Proposed	2+620	0.2 to 0.6	Across
6	MGL steel pipe line	Proposed	2+620-6+870	0.2 to 0.6	Along
7	MGL steel pipe line	Proposed	6+870	0.2 to 0.6	Across
8	MGL MP line	Existing	7+350-7+870	0.2	Along
9	MGL steel pipe line	Proposed	7+870-10+560	0.2 to 0.6	Along
10	MGL steel pipe line	Proposed+ existing	23+300	0.2 to 0.6	Across

6.4.3 SEWER LINES, STROM WATER DRAINS AND WATER LINES

The sewer/drainage lines generally exist in the service lanes i.e. away from main carriageway. However, in certain stretches, these have come near the central verge or under main carriageway, as a result of subsequent road widening.

The major sewer/drainage lines and water mains running across the alignment and likely to be affected due to location of column foundations are proposed to be taken care of by relocating on column supports of viaduct by change in span or by suitably adjusting the layout of pile foundations. Where, this is not feasible, lines will be suitably diverted. Provision has been made in the project cost estimate towards diversion of utility service lines. Investigations of underground utilities are in progress and details would be furnished during construction stage.

6.4.4 DETAILS OF UTILITIES - ABOVE AND UNDER GROUND

Above ground utilities namely street light, poles, traffic signal posts, telecommunication posts, junction boxes, trees etc., are also required to be shifted and relocated suitably during construction of elevated viaduct. Accordingly underground utilities will also needed to be shifted during construction of structures like piers, stations etc., since these will be interfering with the proposed alignment. Approximate numbers of utilities along the corridors are indicated in Table 6.15 to Table 6.17.

Table 6.15: DETAILS OF AFFECTED LIGHT AND SIGNAL POLES

DETAILS OF AFFCETED LIGHT/SIGNAL POLES				
S.No.	Start Chainage in (Km)	End Chainage (in Km)	No. of light poles	No signal poles
1	0.000	1.000	27	0
2	1.000	2.000	28	0
3	2.000	3.000	18	0
4	3.000	4.000	28	0
5	4.000	5.000	30	0
6	5.000	6.000	29	0
7	6.000	7.000	28	3 3
8	7.000	8.000	37	0
9	8.000	9.000	16	0
10	9.000	10.000	19	0
11	10.000	11.000	20	0
12	11.000	12.000	25	0
13	12.000	13.000	12	0 0
14	13.000	14.000	15	0 0
15	14.000	15.000	11	0
16	15.000	16.000	20	0
17	16.000	17.000	25	0
18	17.000	18.000	12	0
19	18.000	19.000	24	0
20	19.000	20.000	15	0
21	20.000	21.000	12	0
22	21.000	22.000	5	0
23	22.000	23.000	12	0
24	23.000	23.607	13	0

Table 6.16: Details of Telephone Poles

DETAILS OF AFFECTED TELEPHONE UTILITES				
S.No.	Start Chainage in (km)	End Chainage (in Km)	No. of Telephone poles	No. of telephone Junction box
1	0.000	1.000	31	-
2	1.000	2.000	30	-
3	2.000	3.000	27	-
4	3.000	4.000	24	-
5	4.000	5.000	29	-
6	5.000	6.000	28	1
7	6.000	7.000	46	-

DETAILS OF AFFECTED TELEPHONE UTILITES				
S.No.	Start Chainage in (km)	End Chainage (in Km)	No. of Telephone poles	No. of telephone Junction box
8	7.000	8.000	16	2
9	8.000	9.000	37	-
10	9.000	10.000	39	-
11	10.000	11.000	40	-
12	11.000	12.000	42	-
13	12.000	13.000	34	-
14	13.000	14.000	20	-
15	14.000	15.000	5	-
16	15.000	16.000	7	1
17	16.000	17.000	34	1
18	17.000	18.000	28	-
19	18.000	19.000	38	-
20	19.000	20.000	26	-
21	20.000	21.000	34	-
22	21.000	22.000	35	-
23	22.000	23.000	11	-
24	23.000	23.607	12	-

Table 6.17: Details of Affected Trees

SN	Corridor Name	Corridor Length(km)	No. of Trees
1	Option I	23.607	18
2	Option II	23.539	15
3	Option III	23.537	39

6.5 LAND REQUIREMENT FOR CORRIDORS

6.5.1 LAND REQUIREMENT FOR MAJOR COMPONENTS

Availability of land is one of the major prerequisites for a project in cities like Mumbai. As the Metro alignment has to be planned on set standards and parameters, it becomes difficult to follow the road alignment at all the locations. Apart from alignment the various structures like stations, parking facilities, traction sub stations, communication towers, etc. require large plots of land. The land being scare, costly and acquisition being complex process, the alignment is so planned that land acquisition is required is minimum. Land is mainly required for:

- Metro Structure (including Route Alignment), Station Building, Platforms, Entry/Exit Structures, Traffic Integration Facilities, etc.
- Receiving/Traction Sub-stations
- Radio Towers
- Property Development.
- Temporary Construction Depots and work sites.

- Depot

6.5.2 LAND REQUIREMENT FOR ELEVATED STRETCHES

For elevated section, single pier supporting the viaduct will be located on the middle of road for 90 % of the alignment, so that the existing roads remain in use as usual. Accordingly, necessary permission for using such right-of-way will have to be obtained from the concerned authorities. Elevated stations are generally proposed with elevated concourse so that land is required only for locating the entry/exit structures.

The normal viaduct structure of elevated Metro is about 2.5 m (edge to edge) wide. Ideally the required right of way is 12m. However, for reasons of safety a clean marginal distance / setback of about 6 m is necessary from either edge of the viaduct (or 6 m on both sides of the centre line) wherein no structures are to be located. In stretches, where the elevated alignment has to be located away from road, a strip of 12m width is proposed for acquisition, it ensures road access and working space all along the viaduct for working of emergency equipments and fire brigade.

6.5.3 LAND FOR DEPOT

As per the standards and requirements, about 15 Ha of land is required for construction of maintenance depot. This will include the area required for Stabling Purpose also. Area near Kon MIDC for maintenance depot and area near Kalyan APMC is suggested for Stabling Purpose.

Table 6.18: Land Requirement for Depots

Plot No.	Location	Land Area (Ha)	Ownership
1	Kon MIDC	12.57 Hectares	MIDC
2	APMC, Kalyan	1.6 Ha	KDMC
Total		14.17 Ha ≈ 15 Ha	

6.5.4 LAND REQUIREMENT FOR RUNNING SECTION

As indicated earlier, the ROW of the roads along which the alignment is planned is sufficiently wide except on few locations near proposed flyover before Rajiv Gandhi Flyover, Rajiv Gandhi Flyover, Dhamankar Flyover, and Anjurphata near RUB, hence minimal land acquisition is required. However, at curved portions, the alignment could not be kept at the centre of the road and acquisition of certain land is inevitable in spite of introduction of sharper radius curves in elevated sections. This is the most critical section of the proposed alignment (sharp bent of 120 m radius at Rajiv Gandhi flyover left turn) as can be seen in Figure 6.1.

To the extent possible the Entry and Exit points of stations (elevated) were planned on the foot paths wherever possible. But, for locating other station facilities such as chiller plants, ventilation shafts, underground water tanks, generator set room etc. and where entry & exit could not be accommodated on foot paths, land acquisition is proposed.

7 STATION PLANNING

7.1 GENERAL

7.1.1 Stations

Proposed Thane – Bhiwandi – Kalyan corridor runs Northward from Kapurbawadi Junction (Thane End) to APMC Market (Kalyan) covering a total distance of about 24.9 km. Total 17 stations are proposed along the Corridor taking in to account of the catchment area , inter spacing between stations , land availability, and connectivity. All stations are proposed as elevated stations. Stations are generally located at an average distance of 1.5 km apart.

7.1.2 Rail Levels and Alignment

Alignment is planned as elevated and is governed by minimum ground clearance of 5.50 m. In order to keep the land acquisition to minimum, alignment is planned generally in middle of the road. Wherever necessary, roads are aligned to match the alignment of rail tracks of proposed Metro to place the viaduct on median of the road.

7.1.3 Platforms

All the stations have two side platforms. Care has been taken to locate stations on straight sections of the alignment. The platform level is determined by the rail level and is generally 13.5 m above ground to cater concourse. Entry/exit and other above ground structures have been planned along the sidewalks in the open spaces available near the stations keeping the acquisition of private property to the minimum. The sequence of stations along with their respective chainage, are presented in the Table 7.1.

Table 7.1: Sequence of Stations and their Respective Chainage

Station No	Station Name	Chainage (from Kalyan (In Km)	Distance from Previous Stations (KM)	Remarks
1	Kalyan APMC	0.7		Elevated
2	Kalyan Station	0.296	0.700	Elevated
3	Sahajanand Chowk	1.06	0.764	Elevated
4	Durgadi Fort	1.694	0.634	Elevated
5	Kon Gaon	3.49	1.796	Elevated
6	Gove Gaon MIDC	5.791	2.301	Elevated
7	Rajnouli Village	6.794	1.003	Elevated
8	Temghar	8.58	1.786	Elevated
9	Gopal Nagar	10.36	1.78	Elevated
10	Bhiwandi	11.081	0.721	Elevated
11	Dhamankar Naka	11.998	0.917	Elevated
12	Anjurphata	13.838	1.84	Elevated
13	Purna	15.315	1.477	Elevated
14	Kalher	17.392	2.077	Elevated
15	Kasheli	18.833	1.441	Elevated
16	Balkum Naka	22.506	3.673	Elevated
17	Kapurbawadi	23.382	0.876	Elevated

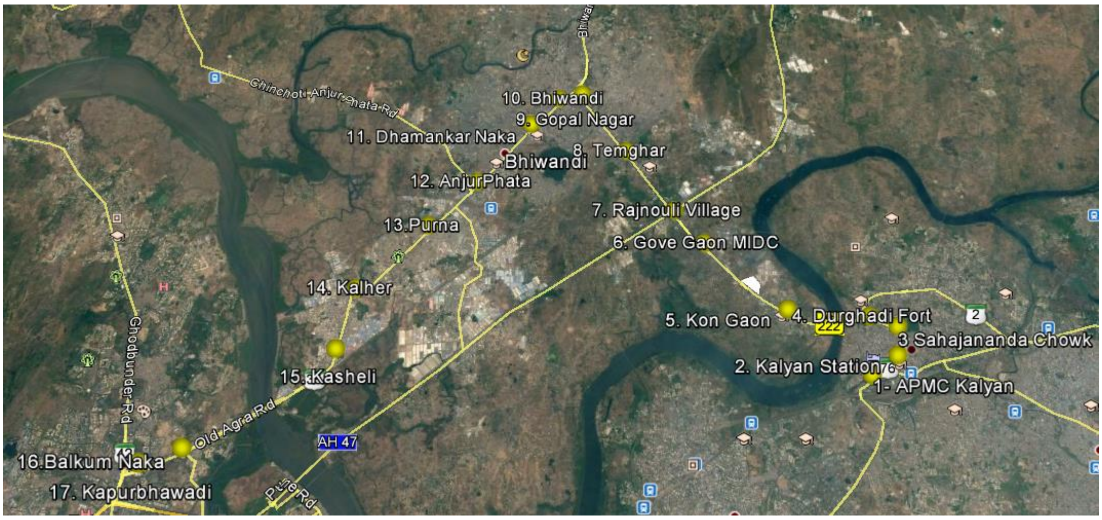

Figure 7.1: Proposed Station Locations

7.2 PLANNING AND DESIGN CRITERIA FOR STATIONS

Following design criteria have been taken into consideration for station planning:

Typical station layout is shown in Figure 7.2.

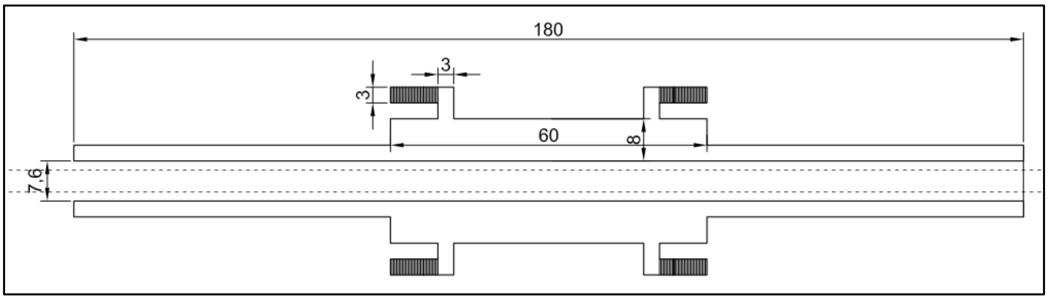

Figure 7.2: Typical Station Layout

- The stations can be divided into public and non-public areas (those areas where access is restricted).The public areas can be further subdivided into paid and unpaid areas.
- The platform level has adequate assembly space for passengers for both normal operating conditions and a recognized abnormal scenario.
- The platform level at elevated stations is determined by a critical clearance of 5.5 m under the concourse above the road intersection, allowing 3.5 m for the concourse height, about 1 m for concourse floor and 1.5 m for structure of tracks above the concourse. Further, the platforms are 1.09 m above the tracks. This would make the rail level in an elevated situation at least 13.5m above ground.
- The concourse contains automatic fare collection system in a manner that divides the concourse into distinct areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area', which includes access to the platforms.

- The arrangement of the concourse is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However, it is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, automatic fare collection (AFC) gates, stairs and escalators.
- Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed at the ticketing gates.
- Station entrances are located with particular reference to passenger catchment points and physical site constraints within the right-of-way allocated to the MRTS.
- Office accommodation, operational areas and plant room space is required in the non-public areas at each station.
- The DG set, bore well pump houses and ground tank would be located generally in one area on ground.
- The system is being designed to maximize its attraction to potential passengers and the following criteria have been observed:
  - minimum distance of travel to and from the platform and between platforms for transfer between lines,
  - adequate capacity for passenger movements,
  - convenience, including good signage relating to circulation and orientation,
  - safety and security, including a high level of protection against accidents;
- Following requirements have been taken into account:
  - Minimum capital cost is incurred consistent with maximizing passenger attraction.
  - minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers,
  - flexibility of operation including the ability to adapt to different traffic conditions changes in fare collection methods and provision for the continuity of operation during any extended maintenance or repair period, etc.,
  - provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety,
  - Provision of display of passenger information and advertising.
- The numbers and sizes of staircases/escalators are determined by checking the capacity against AM and PM peak flow rates for both normal and emergency conditions such as delayed train service, fire etc.
- In order to transfer passengers efficiently from street to platforms and vice versa, station planning has been based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross-flows between incoming and outgoing passengers.
- Passenger handling facilities comprise of stairs/escalators, lifts and ticket gates required to process the peak traffic from street to platform and vice-versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit).

7.3 TYPICAL STATION

The station is generally located on the road median on central piers as far as possible. Total length of the station is 180 m. All the stations are two-level stations. Staircases /Escalators are proposed from either side of the road. Passenger facilities like ticketing, information etc. as well as operational areas are provided at the on course level. Typically, the concourse is divided into public and nonpublic zones. The non-public zone or the restricted zone contains station operational areas such as Station Control Room, Station Master's Office, Waiting Room, Meeting Room, UPS & Battery Room, Signaling Room, Train Crew Room & Supervisor's Office, Security Room, Station Store Room, Staff Toilets, etc. The public zone is further divided into paid and unpaid areas. Auxiliary Service station is provided on the ground nearby as per availability of land. Since the stations are in the middle of the road, minimum vertical clearance of 5.5 m has been provided under the concourse. Platforms are at a level of about 13.5 m from the road.

With respect to its spatial quality, an elevated Metro structure makes a great impact on the viewer as compared to an At-grade station. The positive dimension of this impact has been accentuated to enhance the acceptability of an elevated station and the above ground section of tracks. Structures that afford maximum transparency and are light looking have been envisaged. A slim and ultra-modern concrete form is proposed, as they would look both compatible and modern high-rise environment as well as the lesser-built, low-rise developments along some parts of the corridor.

Platform roofs, that can invariably make a structure look heavy, have been proposed to be of steel frame with aluminum cladding to achieve a light look. Platforms would be protected from the elements by providing an overhang of the roof and sidewalls would be avoided, thereby enhancing the transparent character of the station building. In order to allow unhindered traffic movement below the stations, structure is supported on a central row of columns, which lies unobtrusively on the central verge.

Typical elevated station building is presented in Figure 7.3.Station plans are presented in "Appendix D"

Figure 7.3: Typical Elevated Station Building

7.4 PASSENGER AMENITIES

Passenger amenities such as ticketing counters/automatic ticket vending machines, ticketing gate, etc. are provided in the concourse. Uniform numbers of these facilities have been provided for system wide uniformity, although the requirement of the facilities actually varies from station to station. The same applies to provision of platform widths and staircase/escalators. Maximum capacity required at any station by the year 2031 for normal operation has been adopted for all stations. For this purpose, peak minute traffic is assumed to be 2% of the peak hour traffic. For checking the adequacy of platform area, stair widths and requirement additional of emergency evacuation stairs, a maximum accumulation of passengers in the station has been considered to be comprising waiting passengers at the platform (including two missed headways) and section load expected to be evacuated at the station in case of an emergency.

7.5 CONCOURSE

Concourse forms the interface between street and platforms. In stations, this is contained in a length of 70 - 80 m in the middle of the station. All the passenger amenities are provided at concourse area. The concourse contains automatic fare collection system in a manner that divides the concourse into distinct paid and unpaid areas. The 'unpaid area' is where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates, the passenger enters the 'paid area’, which includes access to the platforms. The concourse is planned in such a way that maximum surveillance can be achieved by the ticket hall supervisor over ticket machines, Automatic Fare Collection (AFC) gates, stairs and escalators. Ticket machines and AFC gates are positioned to minimize cross flows of passengers and provide adequate circulation space. Sufficient space for queuing and passenger flow has been allowed in front of the AFCs.

7.6 TICKETING GATES

Ticketing gates’ requirement has been calculated taking the gate capacity as 30 persons per minute per gate. Passenger forecast for the horizon year 2031 has been used to compute the maximum design capacity. At least two ticketing gates shall be provided at any station even if the design requirement is satisfied with only one gate. Uniform space has been provided in all stations where gates can be installed as and when required.

7.7 TICKET COUNTERS AND TICKET ISSUING MACHINES (TIMS)

It is proposed to deploy manual ticket issuing in the beginning of the operation of the line. At a later stage, automatic TIMS would be used for which space provision has been made in the concourse. At present, ticket counters would be provided, which would be replaced with TIMS in future. Capacity of manual ticket vending counters is taken to be 10 passengers per minute and it is assumed that only 40% of the commuters would purchase tickets at the stations while performing the journey. The rest are expected to buy prepaid tickets or prepaid card, etc. Accordingly, the requirement of ticket counters has been calculated and the same provided for in the plans.

7.8 PLATFORMS

A uniform platform width 4.5 m wide side platforms are proposed for the elevated stations. These platform widths also have been checked for holding capacity of the platform for worst-case scenario.

7.9 STAIRS, ESCALATORS AND LIFTS

Provision has been made for escalators in the paid area i.e. from concourse to platforms. On each platform, one escalator has been proposed. In addition, two staircases with a combined width of 6 m are provided on each platform connecting to the concourse. These stairs and escalator together provide an escape capacity adequate to evacuate maximum accumulated passengers in emergency from platforms to concourse in 5.5 minutes. Lifts have been provided one each on either platform, to provide access for elderly and disabled. Since the rise to road from the concourse is about 8m, it is proposed to provide lifts in addition to stairs for vertical movement of passengers from street to concourse.

7.10 STATION LOCATIONS

This section deals with the stations planned for proposed Thane Bhiwandi Kalyan Corridor. Proposed corridor runs Northward from Kapurbawadi Junction (Thane End) to APMC (Kalyan) covering a total distance of about 24.9 km. Total 17 stations are proposed along the Corridor taking in to account of the catchment area , inter spacing between stations , land availability, and connectivity. All stations are proposed as elevated stations. Stations are generally located at an average distance of 1.5 km apart.

7.11 PROPOSED STATIONS

Locations at which stations are proposed along the corridor are presented in Figure 7.1 and Table 7.1. Details of the locations are described in the subsequent sections.

7.11.1 Kalyan APMC

During the meeting with MMRDA Officials on 4th October 2016, it was deceded to extend the proposed alignment till Kalyan APMC which s around 800m from proposed Kalyan Station at Zero Chainage

Station is planned near APMC and Sarvodaya Mall at Kalyan. It is estimated that the station will attract high boarding and alighting of passengers, therefore, the platform is planned to be wider at 4.5 m. Entry and exit stairs are provided along the both sides of proposed station on footpaths. This station would serve the activity nodes in the station area and also it will attract nearby shopping malls .The catchment of the station would serve Bail Bazar, Sarvodaya Mall, APMC Market etc.

Figure 7.4: Kalyan APMC Metro Station

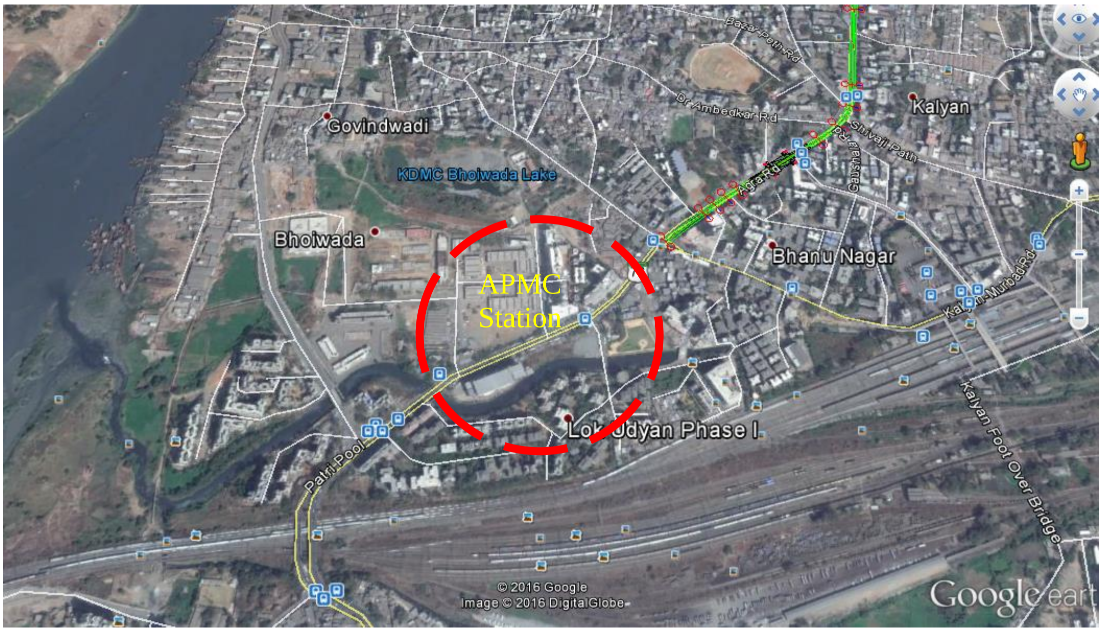

Figure 7.5: Location of Kalyan Metro Station

7.11.2 Kalyan Metro Station

Kalyan Station is planned near Shivaji Chowk at Kalyan. It is estimated that the station will attract high boarding and alighting of passengers, therefore, the platform is planned to be wider at 4.5 m. Entry and exit stairs are provided along the both sides of proposed station on footpaths. For easy changeover with Central Railway Station, it is proposed to be integrated Kalyan station Skywalk. This station would serve the activity nodes in the station area. The catchment of the station would serve Bail Bazar, Sarvoday Mall, Kalyan Station Jija Mata Colony, Joshibaug, area near Subhash Maidan. This may also serve the area up to RamBaug.This station would even act as a feeder station to Kalyan Railway station.

Figure 7.6: Kalyan Metro Station

Figure 7.7: Location of Kalyan Metro Station

7.11.3 Sahajanand Chowk

This station would mainly serve the residential and commercial establishments on Vallabh Bhai Patel Road. The catchment may also extend upto the residential colonies of Beturkar pada, Swanand Nagar, Tilak Nagar and Vishu Nagar. National Hospital being a major activity node in the area, a station is planned about 200 m from it for the easy accessibility of visitors. Since it is estimated that it will attract high passenger volumes, the station area is comparatively proposed to be larger than other stations. The width of the platform is kept 4.5 m against the standard width of 3 m on other stations. Entry and exit stairs are provided along the both sides of proposed station on footpaths.

Figure 7.8: Sahajanand Chowk

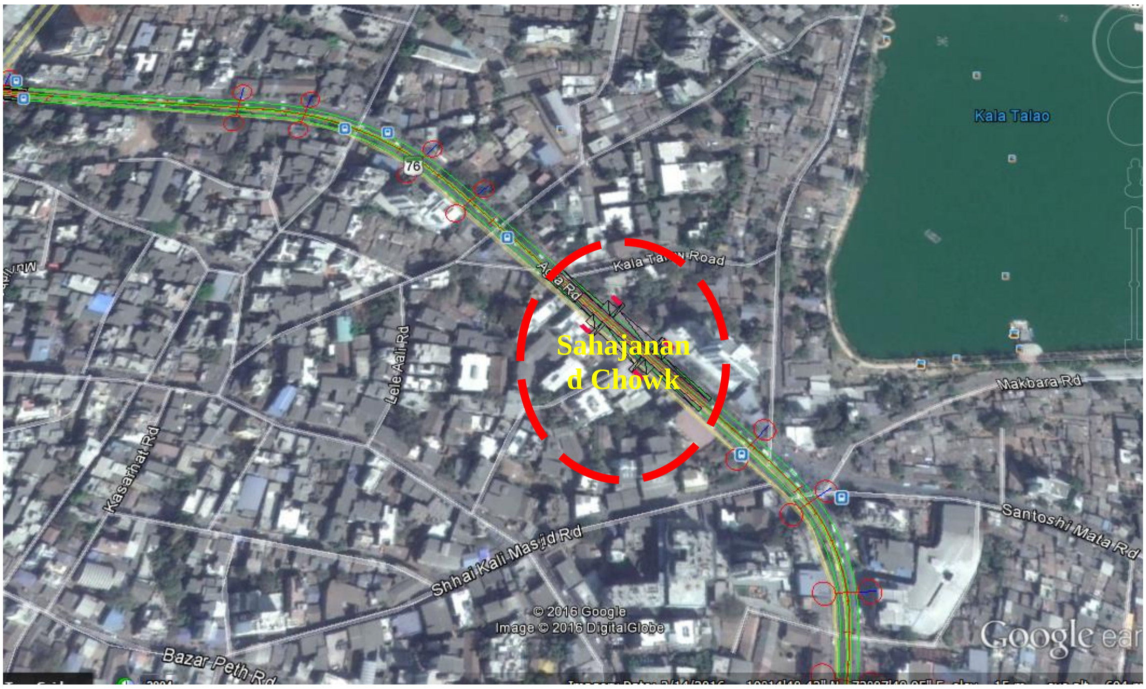

Figure 7.9: Location of Sahajanand Chowk

7.11.4 Durgadi Fort/Lal Chowki

Durgadi Fort is the first station within the Kalyan Municipal Corporation's Administration area. Entry and exit stairs are provided along the both sides of proposed station on footpaths. This station would mainly attract residents of Subhash Nagar, Wadeghar, Tilak Nagar etc. and the demand from commercial establishments

Figure 7.10: Durgadi Fort/Lal Chowki

Figure 7.11: Location of Durgadi Fort/Lal Chowki

7.11.5 Kongaon

Kon Gaon station is the next station proposed to be developed which is about 1.5 km from the previous. This station would mainly serve the population of Kongaon and future developments.

Figure 7.12: Kon gaon Station

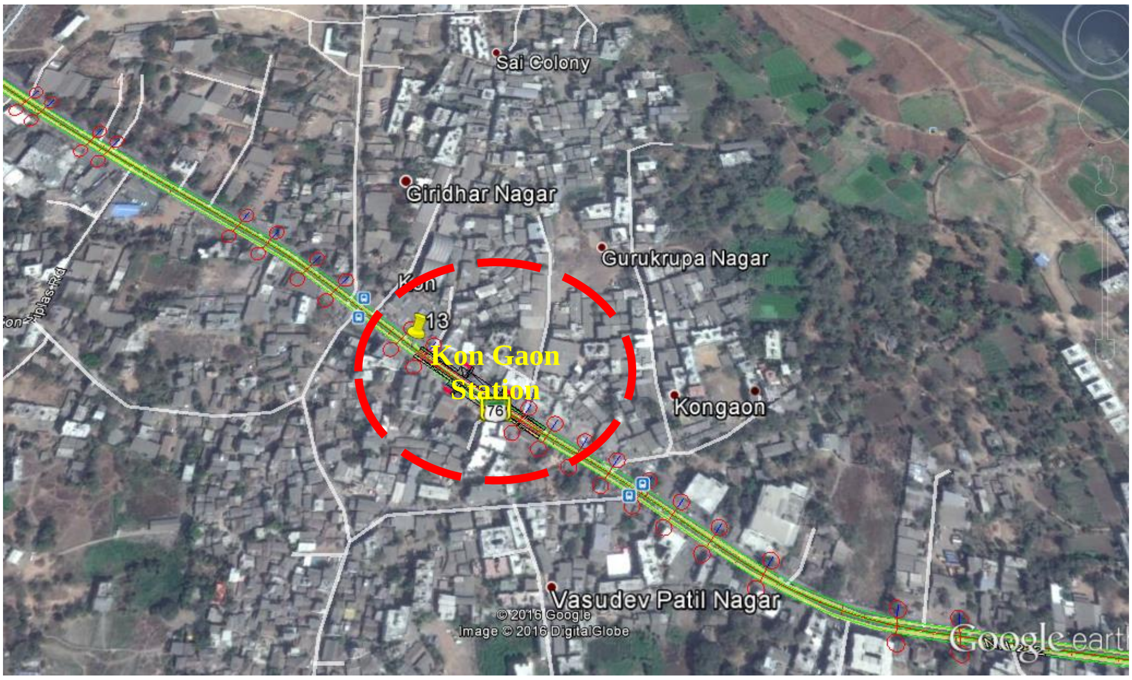

Figure 7.13: Location of Kon gaon Station

7.11.6 Gove Gaon MIDC

This station is about 1.8 km from the previous station with side platforms 13.5 m (minimum) above the ground level. Entry and exit stairs are provided along the both sides of proposed station on footpaths. This station would serve the population of near the toll gate and other future developments. Also this would serve the MIDC Area

Figure 7.14: Gove Gaon MIDC Station

Figure 7.15: Location of Gove Gaon MIDC Station

7.11.7 Rajnouli

Rajnouli station is planned about 0.8 km from the previous station with side platforms. Entry and exit stairs, Lifts, and Escalators are provided along the both sides of proposed station on footpaths. This station would serve the population of Rajnouli, Saravali and other future developments.

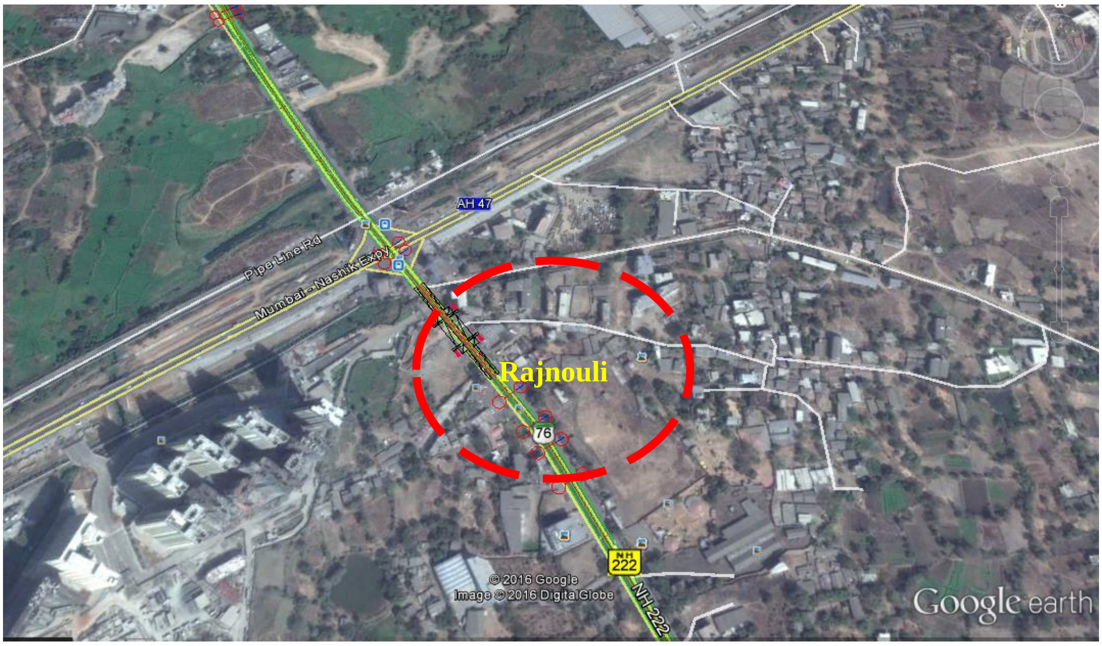

Figure 7.16: Location of Rajnouli Station

7.11.8 Temghar

This station is about 2.1 km from the previous station This station would serve the future developments.

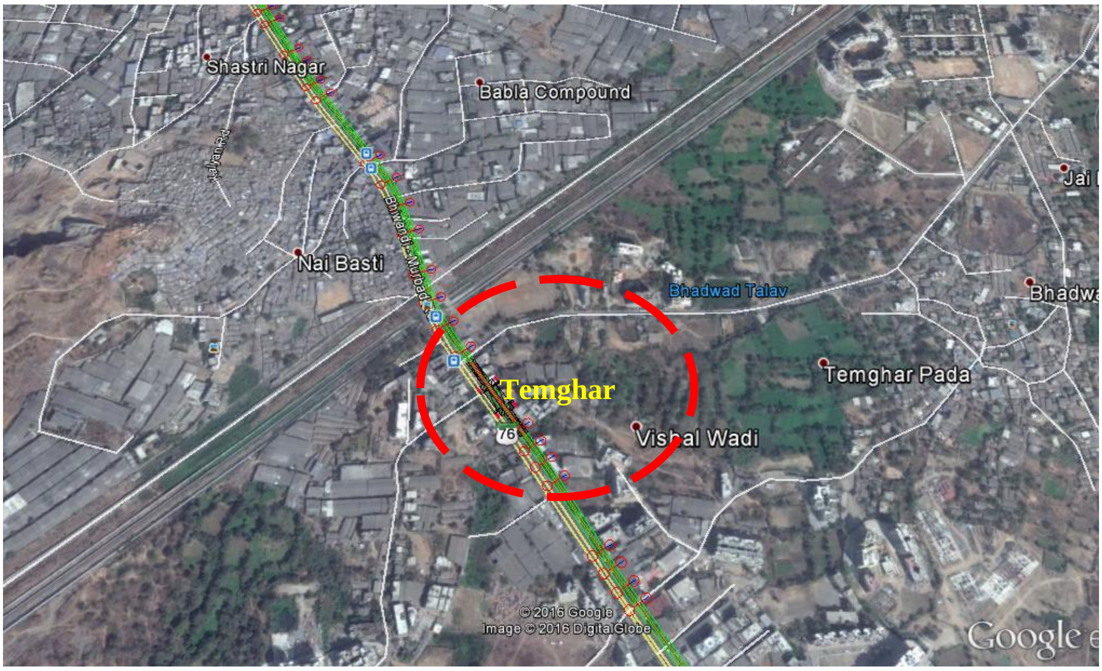

Figure 7.17: Location of Temghar/Pipeline

7.11.9 Gopal Nagar

Gopal Nagar Station is planned about 2.16 km from the previous station with side platforms 13.5 m (minimum) above the ground level. Entry and exit stairs are provided along the both sides of proposed station on footpaths. Catchment of station would serve a large extent of outgrowth of Bhiwandi and Residents of Punit Nagar, Gopal Nagar and Ashok Nagar

Figure 7.18: Gopal Nagar

Figure 7.19: Location of Gopal Nagar

7.11.10 Bhiwandi

This station is about 0.8 km from the previous station with side platforms. Entry and exit stairs are provided along the both sides of proposed station on footpaths. Catchment of station would serve the population of Bhiwandi, Kaneri, Mandai Samarth Nagar, Punit Sagar Complex and Samad Nagar.Also there are many small commercial establishments which would also attract commuters

Figure 7.20: Bhiwandi Station

Figure 7.21: Location of Bhiwandi Station

7.11.11 Dhamankar Naka

This station is about 1.2 km from the previous station with side platforms Stairs, Escalators, and Lifts are provided along the both sides of proposed station on footpaths. Catchment of station would serve the population of Keshav Nagar, Dhamankar Naka, Narpoli Village, Balaji Nagar and New Taware Compund.

Figure 7.22: Dhamankar Naka

Figure 7.23: Location of Dhamankar Naka

7.11.12 Anjur Phata

Anjur Phata is planned about 2 km from the previous station, Purna Village Station as the area between these stations is yet to be developed. Entry and exit stairs are provided along the both sides of proposed station on footpaths. Proposed station would majorly serve the population of Ajiwada, Val and Rahnal.

Figure 7.24: Anjur Phata

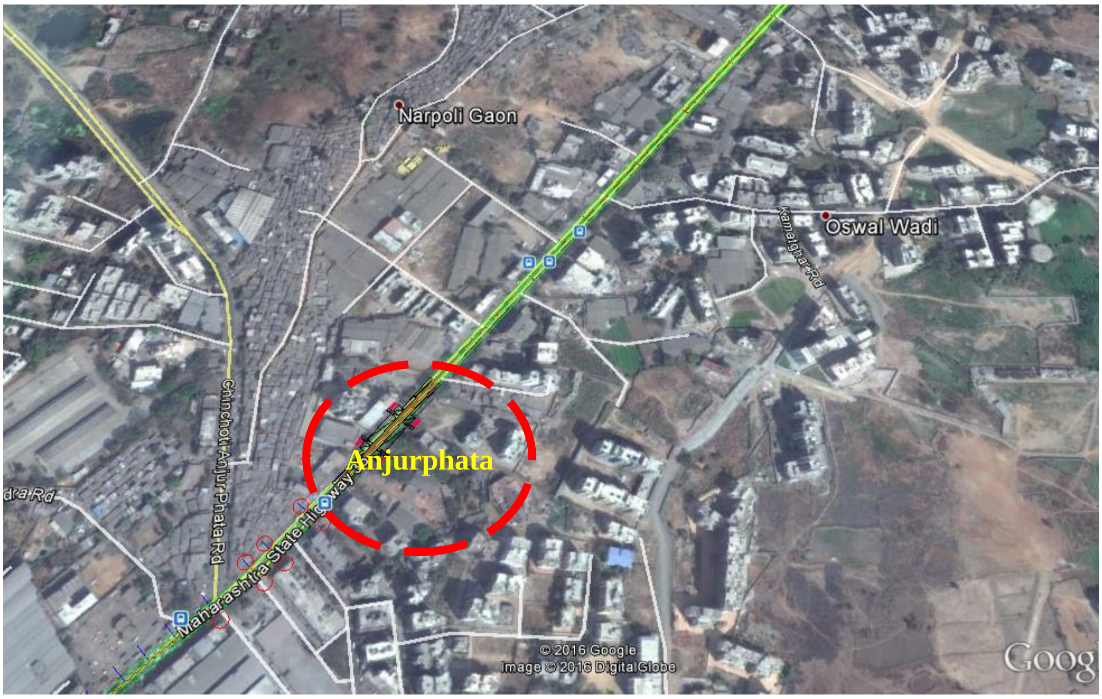

Figure 7.25: Location of Anjur Phata

7.11.13 Purna

This station is planned at about 1.5 km from the previous station. Station is proposed with side platforms. Entry/Exit Stairs Lifts and Escalators are proposed along both sides of station on footpaths. This area is surrounded with small and medium industries. Thus, this station would mainly serve the employees and the residents from Purna Village, Rahnal and Kailasnagar.

Figure 7.26: Purna

Figure 7.27: Location of Purna

7.11.14 Kalher

This station is planned about 2 km from the Purna Station with side platforms. Entry/Exit Stairs Lifts and Escalators are proposed along both sides of station on footpaths. Area is surrounded by mainly medium and small scale industries and transport companies. Thus, it would majorly serve the employees and the residents of Arihant Complex and Kopar Village.

Figure 7.28: Kalher

Figure 7.29: Location of Kalher

7.11.15 Kasheli

This Station would mainly serve the travel demand from Kasheli Village and commercial spaces near Kasheli. Considering the future development, next station is planned at about 3.3 km from the Kalher Station. Platforms are planned at minimum 13.5 m from the ground level. Entry/Exit Stairs Lifts and Escalators are proposed along both sides of station.

Figure 7.30: Kasheli

Figure 7.31: Location of Kasheli

7.11.16 Balkum Naka

Next station is proposed near Balkum Naka Station at a distance of about 1 km from Kasheli Station. This station would mainly serve the residential settlements of Balkum Naka, Ashok Nagar, Runwal City Etc. It has two side platforms. Entry/Exit Stairs Lifts and Escalators are proposed along both sides of station.


Figure 7.32: Balkum Naka

Figure 7.33: Location of Balkum Naka Station

7.11.17 Kapurbawadi Station

Proposed corridor starts from Kapurbawadi Junction at Thane and passing through Bhiwandi area and ends at Shivaji Chowk at Kalyan. Kapurbawadi Station is the starting point of the proposed corridor. Station is planned on the east of proposed Kapurbawadi Flyover i.e. towards Big Bazar on Old Agra Road. This station is proposed to be integrated with the proposed Kapurbawadi Metro station on Godhbandar Road. It has two side platforms. Entry/Exit Stairs Lifts and Escalators are proposed along both sides of station. This station would mainly serve the employees of the industrial establishments. Also Big bazar is also a major demand generation for this station. Apart from those mentioned, station would also serve few residential areas namely, Kapurbawadi, Balkum, Kailash Nagar, Srinagar Colony Yashaswi Nagar and Sainath Nagar.

Figure 7.34: Kapurbawadi Station

Figure 7.35: Location of Kapur Bawadi Station

8 ROLLING STOCK

8.1 GENERAL

This chapter defines the Rolling Stock characteristics recommended for the proposed Thane Bhiwandi Kalyan Metro corridor. Projected Peak hour per direction (PHPD) is the primary factor for selecting the type of Rolling Stock. Considering the Peak hour passenger demand traffic and the characteristics of various transit systems described in the Chapter 2, there will be a need to introduce a Rail based Mass Rapid Transit System (MRTS) in the city to provide fast, safe, economic and environment friendly mode for mass movement of passengers.

Typical Rolling stock is shown in Figure 8.1.

Figure 8.1: Typical Rolling Stock

8.2 PASSENGER CARRYING CAPACITY

In order to maximize the passenger carrying capacity, longitudinal seating arrangement is recommended as similar to Line 1 Metro, whose coach characteristics are presented in Table 8.1.

Table 8.1: Coach Dimensions

Particulars	Length (m)	Width(m)	Height(m)
Driving Trailer Car (DTC)	21.64	2.9	3.9
Trailer Car (TC)/Motor Car (MC)	21.34	2.9	3.9

Therefore, Medium Rail Vehicles (MRV) with 2.9 m maximum width and longitudinal seat arrangement, conceptually the crush capacity of 43 seated, 204 standing, a total of 247 passengers for a Driving Trailer Car, and 50 seated, 220 standing, a total of 270 for a Trailer/ Motor Car is envisaged.

Following train composition is recommended:

6-car Train: DTC+TC+MC+MC+TC+DTC

8.3 COACH DESIGN AND BASIC PARAMETERS

The primary controlling criteria for rolling stock selection are reliability, low energy consumption, lightweight and high efficiency leading to lower annualized cost of service. Apart from those, the coach should have high rate performance indices measures like acceleration and deceleration. Major features for selecting the rolling stock are as listed below:

- Proven equipment with high reliability;
- Passenger safety feature;
- Energy efficiency;
- Light weight equipment and coach body;
- Optimized scheduled speed;
- Aesthetically pleasing Interior and Exterior;
- Low Life cycle cost;
- Flexibility to meet increase in traffic demand;
- Anti-telescopic.

The coaches should be fire retardant, air-conditioned and designed to reduce noise and vibration, and should feature both high seating capacity and ample space for standing passengers. They should be outfitted with a number of features for safety and convenience, including LCD screens, 3D route maps, first-aid kits, wheelchair facilities, fire-fighting equipment and intercom systems permitting communication with the train driver. Each coach should have a black box to assist in accident investigations. The interior view of coach is shown in Figure 8.2.

For rapid evacuation of the passengers in short dwell period, four doors of adequate width, on each side of the coach have to be considered. These doors shall be of such dimensions and location so that all passengers inside the train can evacuate within the least possible time without conflicting movements. As the alignment passes through elevated section at 10 to 12 meters above ground, automatic door closing mechanism is envisaged from consideration of passenger safety. Passenger doors are controlled electrically by a switch in Driver cab. Electrically controlled door operating mechanism has to be preferred over pneumatically operated door to avoid cases of air leakage and sluggish operation of doors. The door shall be of bi-parting, as in the existing coaches Mumbai Line 1.

Figure 8.2: Typical Coach

Figure 8.3: Passenger Doors

The specifications of the rolling stock and its procurement may be decided on the basis of the project implementation mechanism during implementation period. However the broad features of Rolling Stock which may be followed for the Corridor are presented in Table 8.2.

Table 8.2: Rolling Stock Features

Salient Features of Rolling Stock for Medium Rail Transit System		
S.No.	**Parameter**	**Details**
1	**Gauge** (Standard)	1435mm
2	**Traction system**	
2.1	Voltage	25 KV AC
2.2	Method of current collection	Overhead Current Collection System
3	**Train composition**	
3.1	4 car :	DTC + MC + MC + DTC
3.2	6 car:	DTC + TC + MC + MC + TC + DTC
4	**Coach Body**	Stainless Steel
5	**Coach Dimensions**	
5.1	Height	3.9 m

Salient Features of Rolling Stock for Medium Rail Transit System		
5.2	Width	2.9 m
5.3	Length over body (approx.)	
	- Driving Trailer Car (DTC)	21.64 m
	- Trailer Car (TC)	21.34 m
	- Motor Car (MC)	21.34 m
	Maximum length of coach over couplers/buffers:	*22 to 22.6 m (depending upon Kinematic Envelop)*
5.4	Locked down Panto height (if applicable)	4048 mm
5.5	Floor height	1100mm
6	**Designed - Passenger Loading**	
6.1	Design of Propulsion equipment	8 Passenger/ m^2
6.2	Design of Mechanical systems	10 Passenger/ m^2
7	**Carrying capacity- @ 6 standees/sqm**	
7.1	Coach carrying capacity	
	DTC	282 (seating - 42 ; standing - 240)
	TC	298 (seating - 50 ; standing - 248)
	MC	298 (seating - 50 ; standing - 248)
7.2	Train Carrying capacity	
	4 car train	1160 (seating - 184 ; standing - 976)
	6 car train	1756 (seating - 284 ; standing - 1472)
8	**Weight (Tonnes)**	
8.1	Tare weight (maximum)	
	DTC	39
	TC	39
	MC	39
8.2	Passenger Weight in tons	@ 0.065 T per passenger
	DTC	16.055
	TC	17.55
	MC	17.55
8.3	Gross weight in tons	
	DTC	55.055
	TC	56.55
	MC	56.55
9	**Axle load(T)(@ 8 persons per sqm of standee area)**	15.32
	System should be designed for 16T axle load	
10	**Maximum Train Length (6 car)-Approximate**	136. m
11	**Speed**	
11.1	Maximum Design Speed	95 Kmph
11.2	Maximum Operating Speed	85 Kmph
12	**Wheel Profile**	**UIC 510-2**
13	**Noise Limits (ISO 3381 and 3058 -2005)**	
13.1	Stationary (Elevated and at grade)	
13.1.1	Internal (cab and saloon)	LpAFmax 65 dB(A)
13.1.2	External (at 7.5 mtr from centre line of track)	LpAFmax 68 dB(A)

Salient Features of Rolling Stock for Medium Rail Transit System		
13.2	Running at 85 kmph (Elevated)	
13.2.1	Internal (cab and saloon)	LpAeq,30 72 dB(A)
13.2.2	External (at 7.5 mtr from centre line of track)	LpAFmax 85 dB(A)
13.3	Stationary (Underground)	
13.3.1	Internal (cab and saloon)	LpAFmax 72 dB(A)
14	**Traction Motors Ventilation**	**Self**
15	**Acceleration on level tangent track**	**0.82 m/sec^2**
16	**Deceleration on level tangent track**	**1.1 m/sec^2 (>1.3 m/sec^2 during emergency)**
17	**Type of Bogie**	**Fabricated**
18	**Secondary Suspension springs**	Air
19	**Brakes**	• An electro-pneumatic (EP) service friction brake. •A fail safe, pneumatic friction emergency brake. •A spring applied air-release parking brake •An electric regenerative service brake •Provision of smooth and continuous blending of EP and regenerative braking.
20	**Coupler**	Auto
	Outer end of 2-car Unit (except DT cab front side)	Automatic coupler with mechanical, electrical & pneumatic coupling
	Front cab end of DT car	Automatic coupler with mechanical & pneumatic coupling but without electrical
		coupling head
	Between cars of same Unit	Semi-permanent couplers
21	**Detrainment Door**	Front
22	**Type of Doors**	Sliding
23	**Passenger Seats**	Stainless Steel
24	**Cooling**	
24.1	Transformer	Forced
24.2	CI & SIV	Self/Forced
24.3	TM	Self-ventilated
25	**Control System**	Train based Monitor & Control System (TCMS/TIMS)
26	**Traction Motors**	3 phase VVVF controlled
27	**Temperature Rise Limits**	
27.1	Traction Motor	Temperature Index **minus** 70 deg C
27.2	CI & SIV	10 deg C temperature margin for Junction temperature
27.3	Transformer	IEC specified limit **minus** 20 deg C

Salient Features of Rolling Stock for Medium Rail Transit System		
28	**HVAC**	- Cooling, Heating & Humidifier (As required) - Automatic controlling of interior temperature throughout the passenger area at 25°C with 65% RH all the times under varying ambient conditions up to full load.
29	**PA/PIS including PSSS (CCTV)**	Required
30	**Passenger Surveillance**	Required
31	**Battery**	Lead Acid Maintenance free
32	**Headlight type**	LED
33	**Coasting**	8% (Run time with 8% coasting shall be the 'Run Time in All out mode **plus** 8%')
34	**Emergency Operating Conditions**	- One serviceable fully loaded 4-car train shall be capable of pushing a fully loaded defective 4-car train without parking brakes applied on all sections including section of 3% gradient up to next station. Thereafter, after passenger detrainment, the healthy train shall push the defective train till terminal station. - A 4-car or 6-car fully loaded train shall be capable of clearing the section with the traction motors of one 2-car unit cut out.
35	**Gradient (max)**	4%
36	**Insulated Mat on roof**	Required

9 TRAIN OPERATION PLAN

This chapter defines the objective, features and various components of the Operation Plan for the proposed Thane Bhiwandi Kalyan Metro system.

9.1 BACKGROUND

Primary objective of the operation plan is to provide reliable, safe and accessible connectivity by minimizing the waiting time of passengers. The key operation philosophy is to make the proposed Thane-Bhiwandi-Kalyan MRT System more attractive and economical. Main features of operation plan are as follows:

- recommending most optimum frequency to cater the envisaged passenger demand during peak hours;
- recommend the most economical and at the same time optimum train service frequency throughout the hourly operations;
- ensure a reliable, convenient and a safe system operation;
- consider the future growth potential along the corridor and the development plan proposals in Kalyan Bhiwandi Regions so as to meet the demands of population and employment growth.

9.2 TRAIN OPERATION PLAN

The assessment of the train operation plan is vital for the estimation of the rolling stock requirements, whose technical features have to guarantee good levels of service quality.

More details on this analysis are included in the following sub-paragraphs.

9.2.1 Basic Features

Following features are considered for the train operation plan:

- Trains will be running for 16 hours of the day (6 AM to 10 PM);
- Station dwell time of 30 seconds;
- Make up time of 5-10 % with 8-12% coasting;
- Commercial speed for this corridor is assumed as: 35 kmph.

9.2.2 Traffic Demand

Rolling stock requirement and train operation plan is based on Peak hour per direction traffic demand (PHPDT). As described in detail in the chapter 2 regarding the “Traffic and Demand Assessment”, for each time horizon (i.e. 2021 and 2031), more than one scenario have been simulated so as to evaluate the expected ridership for future years taking into consideration different assumptions regarding the demographic growth rates of the study area.

The expected values of PHPDT resulting from the macroscopic simulations for both the 2021 and the 2031 scenario are collected in Table 9.1.

Table 9.1: Ridership on Thane – Bhiwandi – Kalyan Metro Corridor

HORIZON 2021	maximum PHPD
Scenario A	17957
Scenario B	18044
HORIZON 2031	
Scenario A	26143
Scenario B	25724
Scenario C	29906

9.2.3 Train Composition

In order to meet the expected traffic demand, it is necessary to examine the fleet composition of running trains (4 cars and 6 cars) with different headway combinations.

Generally, a metro train is composed of three types of cars:

- DTC: Driving Trailer Car;
- MC: Motor Car;
- TC: Trailer Car.

Common train compositions in practice are as follows:

- 4 Car Train Composition : DTC + MC + MC+ DTC (Extendable);
- 6 car Train Composition : DTC + TC + MC + MC + TC+ DTC.

The following values regarding the capacity of each car can be considered:

- DTC : 282 Passengers (Sitting-42, Crush Standing-240);
- TC/MC : 298 Passengers (Sitting-50, Crush Standing-248).

As a consequence, the total capacity of the train is:

- 4 Car Train: 1160 Passengers (Sitting-186, Crush Standing-848);
- 6 Car Train: 1756 Passengers (Sitting-284, Crush Standing-1472).

9.2.4 Train Operation Plan

The assessment of the train operation plan consists of estimating the fleet composition and the service frequency according to the forecasted ridership for both time horizons (i.e. 2021 and 2031).

Table 9.2: Train Requirement for 2021 Scenarios

Particulars	Year	
	2021 A	2021 B
Cars/trains	6	6
Peak Headway (Minutes)	5	5
Train capacity (6 cars)	1756	1756
Max. PHPDT Demand	17957	18044
PHPDT Capacity Available	21072	21072
	21600*	21600*
No of trains Required (fleet + 20% of reserve)	23	23

** @ 8 persons per square meter of standee area is assumed.*

In particular, on the basis of the traffic demand levels shown in Table 9.2, trains composed of 6 cars with a service frequency of 12 trains per hour (i.e. headway 5 minutes) are necessary to meet the expected demand for 2021 (both Scenario A and B).

The total number of trains required is calculated considering an additional 20% of the total fleet as a reserve for ordinary maintenance programs or in case of disturbances to the service (e.g. spare locomotives). As a consequence the resulting number of trains for 2021 is **23**.

Table 9.3: Rake Requirement for 2031 Scenarios

Particulars	Year		
	2031 A	2031 B	2031 C
Cars/trains	6	6	6
Peak Headway (Minutes)	4	4	3
Train capacity (6 cars)	1756	1756	1756
Max. PHPDT Demand	26143	25724	29906
PHPDT Capacity Available	26340	26340	35120
	27000*	27000*	36000*
No of trains required	29	29	38

** @ 8 persons per square meter of standee area is assumed.*

For the more distant scenario by contrast (i.e. 2031), a higher frequency is necessary. In particular, headway of 4 minutes and trains composed of 6 cars should meet the peak demand expected for Scenario A and B, while headway of 3 minutes should guarantee good levels of service quality for the simulated demand projections of Scenario C (i.e. Scenario 2031 A, B and C). Therefore, in order to keep a safety margin, in the following calculations (i.e. Hourly operation plan, number of rakes required as well as power requirement), the results of Scenario C are considered. As a consequence, the number of trains required amounts to **38**.

Table 9.4: Hourly Operation Plan

Time of Day	2021			2031		
	Headway In Minutes	N. of Trains		Headway In Minutes	N. of Trains	
		UP	Down		UP	Down
6 to 7	10	6	6	5	12	12
7 to 8	10	6	6	5	12	12
8 to 9	5	12	12	3	20	20
9 to 10	5	12	12	3	20	20
10 to 11	5	12	12	3	20	20
11 to 12	10	6	6	3	20	20
12 to 13	10	6	6	5	12	12
13 to14	10	6	6	5	12	12
14 to15	10	6	6	5	12	12
15 to 16	10	6	6	5	12	12
16 to 17	10	6	6	5	12	12
17 to 18	10	6	6	5	12	12
18 to 19	5	12	12	3	20	20
19 to 20	5	12	12	3	20	20
20 to 21	5	12	12	3	20	20
21 to 22	10	6	6	5	12	12
Total No. of train trips per day		264			496	

The complete daily train operation plan for the corridor is presented in

Table 9.4. As it can be seen, for both time horizons, the operational service considered is from 6:00 to 22:00.

10 MAINTENANCE DEPOT

10.1 GENERAL

This section defines the various components of Maintenance Depot Facility recommended for the proposed Thane Bhiwandi Kalyan Metro system.

Following functions will be served at proposed depot- cum- workshop

- Major overhauls of all the trains.
- All minor schedules and repairs.
- Lifting for replacement of heavy equipment and testing thereafter.
- Repair of heavy equipments.

10.2 DEPOT PLANNING ASSUMPTIONS

Assumptions considered for Depot Planning are summarised as follows:

- Enough space should be available for establishment of a Depot- Cum workshop;
- All inspection lines, workshop lines, stabling lines are designed to accommodate one train set of 6- Car each and space earmarked for future provision;
- All Stabling lines are designed to accommodate one trains of 6- Car each;
- All stabling lines are planned in the proposed depot-cum-workshop assuming adequate space availability. In case of space constraints, if any, stabling facilities may need to be created at terminal stations or elsewhere to cater to the required stability facilities.

Two locations are identified for Depot Location. One is near Gove Gaon (Kon MIDC) area and the second one is near APMC Market Kalyan near Sarvoday Mall. Approximate area required for the maintenance facility is about a minimum of 12 hectares. However considering the future developments recommended area for maintenance depot is 15 Hectares. The locations are shown in the following figures.

Figure 10.1: Depot Site Near MIDC

Figure 10.2: Depot Location Near Kon MIDC

Figure 10.3: Depot Site Near Kalyan APMC

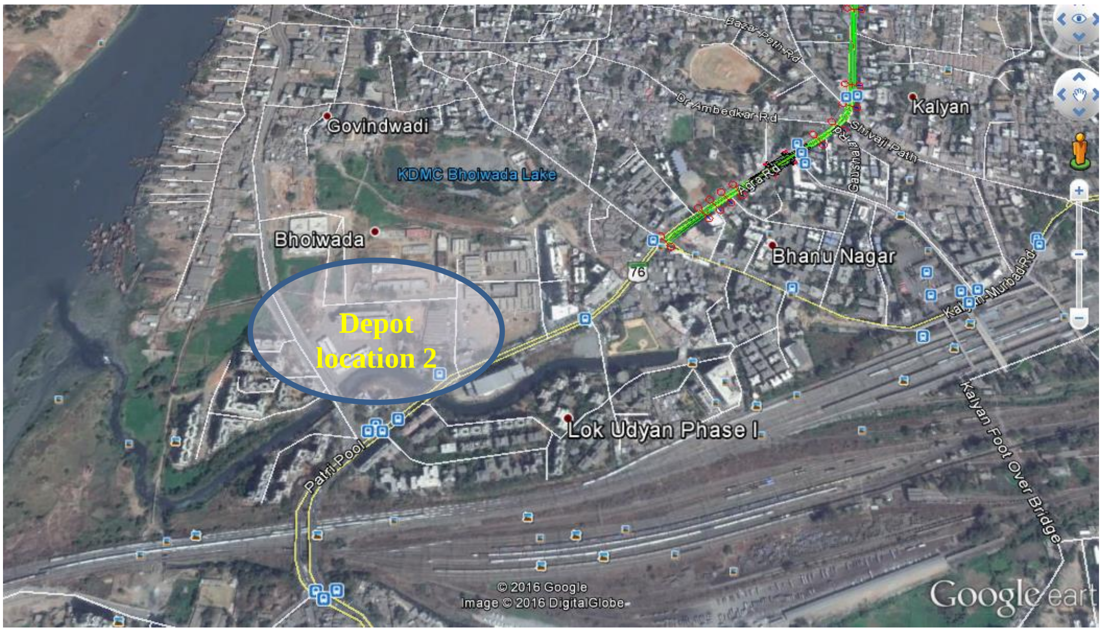

Figure 10.4: Depot Location Near Kalyan APMC

10.3 MAINTENANCE PHILOSOPHY

Recommended Maintenance Philosophy for depot cum workshop is listed as follows:

Monitoring of the performance of equipment by condition monitoring of key parameters. The concept is to evolve the need based maintenance regime, which can be suitably configured in the form of schedules like daily check, "A" checks, "B" type checks, "IOH" and "POH".

Labor intensive procedures are kept to the minimum. Automation with state of the art machinery to ensure quality with reliability.

Multi skilling of the Maintenance staff to ensure quality and productivity in their performance.

- Energy conservation is given due attention.

Typical Depot Layout is shown in Figure 10.5 and in "Appendix E"

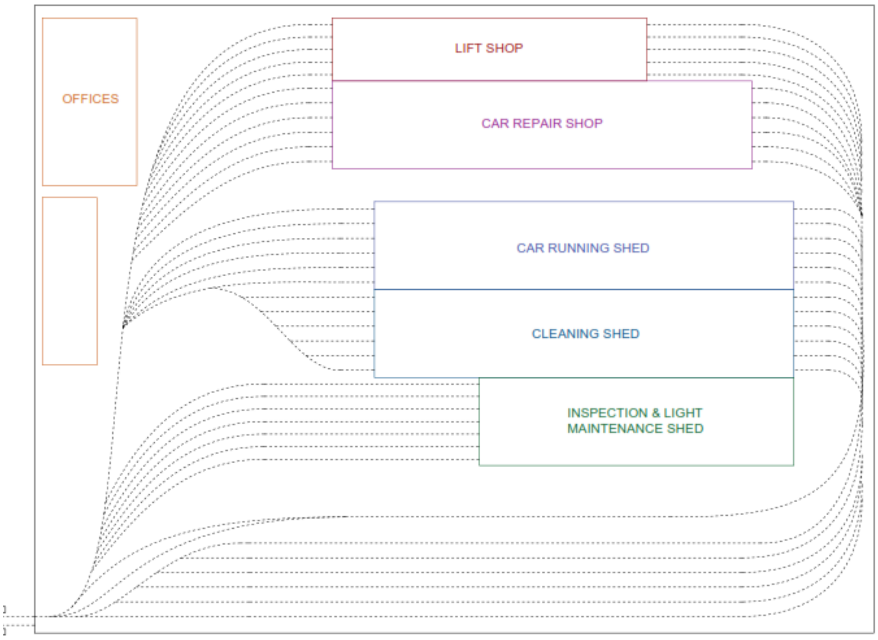

Figure 10.5: Depot Layout

10.4 ROLLING STOCK MAINTENANCE NEEDS

10.4.1 Maintenance Schedule

The following maintenance (Table 10.1) schedule has been envisaged for conceptual design of depots assuming approximately 275 kms running per train per day, taking in consideration the passenger load of 2021 and 2031 respectively.

Table 10.1: Maintenance Schedule

Type of Schedule	Interval	Work Content	Locations
Daily	Daily	Check on the train condition and function at every daily service completion. Interval cleaning/mopping of floor and walls with vacuum cleaner.	Stabling Lines
"A" Service Check	5,000 Km (approx. 15 days)	Detailed inspection and testing of sub - systems, under frame, replacement/ topping up of oils & lubricants.	Inspection Bays
"B" Service Check	15,000 Km (approx. 45 days)	Detailed Inspection of 'A' type tasks plus items at multiples of 15,000 Km ('B' type tasks)	Inspection Bays

Type of Schedule	Interval	Work Content	Locations
Intermediate Overhaul (IOH)	420,000 Km, (3 and half Years approx.)	Check and testing of all sub-assemblies (Electrical + Mechanical). Overhaul of pneumatic valves, Compressor. Condition based maintenance of sub-systems to bring them to original condition. Replacement of parts and rectification, trial run.	Workshop
Periodical Overhaul (POH)	840,000 Km, (7 Years approx.)	Dismantling of all sub-assemblies, bogies suspension system, traction motor, gear, control equipment, air-conditioning units etc. Overhauling to bring them to original condition. Checking repair and replacement as necessary. Inspection and trial.	Workshop
Heavy Repairs		Changing of heavy item such as bogies, traction motor, axles, gear cases & axle boxes etc.	Workshop

The above Schedule may need slight revision based on the actual earned kilometers per train and the specific maintenance requirements of Rolling Stock finally procured.

10.4.2 Washing Needs of Rolling Stock

Cleanliness of the trains is essential. Following schedules (Table 10.2) are recommended for Indian environment.

Table 10.2: Washing Needs of Rolling Stock

S.N.	Kind Inspection	Maint. Cycle	Time	Maintenance Place
1.	Outside cleaning (wet washing on automatic washing plant)	3 Days	10 mins.	Single Pass through Automatic washing plant of Depot
2.	Outside heavy Cleaning (wet washing on automatic washing plant and Front Face, Vestibule/Buffer area. Floor, walls inside/outside of cars and roof. Manually)	30 days	2 – 3 hrs.	Automatic washing plant & cleaning & washing shed

Year-wise planning of maintenance facility setup at depot cum workshop based on planned Rolling Stock requirement in Train Operation Plan is tabulated below.

Table 10.3: No of Coaches

(i) Planned rakes as per TOP:

Year	Headway in minutes	No. of Rakes	No. of coaches
2021	5	23	138
2031	3	38	228

10.4.3 Requirement of Stabling Lines (SBL),Inspection Lines (IBL) and Workshop Lines(WSL) in the Depot

Table 10.4: Requirement of Stabling Lines

Year	No. Of Trains	SBLs	IBLs	WSLs
2021	23	12 lines x two 6-car	3 lines x one bay of 3 lines with two trains of 3-cars each in each line	3 lines x one bay of 3 lines with two trains of 3-cars each
2031	38	19 lines x two 3-car	3 lines x one bay of 3 lines with two trains of 3-cars each in each line	-do-

- All lines shall be suitable for placement of two 6-car trains on each line.

- Provision of space shall be made for additional 8 stabling lines x two 3- car

Considering the fleet requirement for different scenarios , we propose, approximate land requirement for stabling yard will be around **1.6 Ha and 2.1 Ha** for 2021 and 2031 scenarios.

10.4.4 Requirement of maintenance / Inspection lines for depot-cum-workshop:

Table 10.5: Requirement of maintenance / Inspection lines

Schedule	Maintenance Requirement No.of Cars)	Lines Needed
i) Year 2021 - Maximum no. of rake holding is 23 TS x6 (= 138Cars)		
'A' Checks (5000 km) approx. 15 days	(23*6) Cars = 138 Cars	1 Line x two 3- cars (with Sunken Floor)
'B' Checks (15000 km) approx. 45 days	(23*6) Cars = 138 Cars	1 Line x two 3- cars (with Sunken Floor)
Unscheduled line & adjustment lines	For minor repairs, testing and after IOH/POH adjustments	1 Line x two 3- cars (with sunken Floor)

Table 10.5: Requirement of maintenance / Inspection lines

Requirement		1 bay of 3 lines with provision of space for additional bay of 3 lines for work load in 2025
ii) Year 2031 - Maximum no. of rake holding is (38 TS x6 = 228 Cars)		
'A' Checks (5000 km) approx. 15 days	(38X6) Cars = 228 Cars	1 Lines X two 3- Cars (with sunken floor)
'B' Checks (15000 km) approx. 45 days	(38X6) Cars = 228 Cars	1 Lines X two 3- Cars (with sunken floor)
Unscheduled line & adjustment lines	For minor repairs, testing & adjustments post major repairs / IOH & POH	1 Line X two 3- Cars (with sunken floor)
Requirement		1 bay of 3 lines with provision of space for additional bay of 3 lines for work load in 2025

10.5 INSPECTION REQUIREMENTS AT DEPOT

Facilities for carrying out inspection activities shall be provided in the inspection bay for the following Systems / Equipments of a train:

- Electronics; PA/PIS
- Mechanical components, couplers etc
- Batteries
- Air conditioner
- Brake modules
- Bogie
- Traction Motor
- Vehicle doors, windows and internal fittings
- Power system including converter, circuit breaker etc.

10.5.1 Car Delivery Area

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

However in case of newly procured coaches, which are transported by road, these shall reach the Depot-cum Workshop by the road on trailers. To unload the coaches and bring them to the track, provision of space, along the side of shunting neck, has to be made for unloading of cars and other heavy materials. This area shall have an insulated track embedded in the floor facilitating the movement of road trawler, which brings in the cars. The length of the track embedded area shall be about 40m long. There should be enough space available for movement of heavy cranes for lifting of coaches. The unloading area should be easily accessible for heavy duty hydraulic trailers.

10.5.2 Operational Features

The rake induction and withdrawal to main line will be primarily from the stabling shed. Further, provisions are there for direct rake induction and withdrawal to main line from Inspection Shed/workshop area. Movement from depot to the main line is so planned that the headway of main line is not affected. Simultaneous receipt and dispatch of trains from depot to main line is feasible in the present site scenario. Both of these activities will be done effectively without effecting the train operation on the main line. The stabling lines would be interlocked with the main line thereby induction of train from the stabling would be safe and without loss of time. The proposition for a transfer track on the incoming line as well as on the outgoing line to facilitate the movement of rake in the depot by Operation Control Centre (OCC) even though the further path inside the depot is not clear shall be explored in the detailed design stage depending on the actual availability of land.

An emergency line is also provided from which an emergency rescue vehicle may be dispatched to main line in the event of emergency if necessary

10.5.3 Infrastructure Facilities

Inspection and Workshop facilities:

Stabling Lines in Depot:

a. The requirement of lines shall be in accordance with the details indicated in previous sections above. A part of the stabling siding in the depot shall be covered with a roof in order to facilitate testing of air conditioning of trains and their pre-cooling under controlled condition of temperature.
b. Separate toilets adjustment to stabling lines shall be provided with small room for keeping cleaning aids and for utilization by the working staff.

Automatic Coach Washing Plant (AWP)

Provision to be made for Rolling Stock exterior surfaces to be washed using a fully automated Train Washing System, with a throughput capacity of approximately ten trains per hour. The AWP shall be situated at such a convenient point on the incoming route so that incoming trains can be washed before entry to the depot and undesirable movement/shunting over ingress and egress routes within the depot is avoided. Additional space for plant room for AWP system shall be earmarked alongside the washing apron as indicated at S. No. 6 of Annexure I.

10.5.4 Train Operators Booking Office

Suitable office facility adjacent to the stabling lines at each depot should be provided so that train operators reporting ‘On’ duty or going ‘Off’ duty can obtain updates regarding ‘Special Notices’, ‘Safety Circulars’ and other technical updates/information in vogue. These offices should have an attached a cycle/scooter/car stand facility for convenience of the train operating staff.

10.5.5 Test Track

A test track of 1000 mts. in length covered & fenced should be provided beside workshop in the depot. It shall be equipped with signaling equipments (ATP/ATO). It shall be used for the commissioning of the new trains, their trials and testing of the trains after the IOH and POH. Entry into the test track shall be planned for a 3-car train. In compliance to safety norms, the boundary of the track shall be completely fenced to prevent unauthorized trespassing across or along the track.

10.5.6 Heavy Cleaning Shed

Monthly heavy cleaning of interior walls, floors, seats, windows glasses etc., outside heavy cleaning, Front/rear Face, Vestibule/ Buffer area, outside walls and roof shall be done manually in the interior cleaning plant designed for cleaning of one at a time. A line adjacent to inspection shed should be so provided that placement of rakes is possible from workshop or inspection lines & vice – versa conveniently and with ease.

10.5.7 Power Supply

Auxiliary substations are planned for catering to the power supply requirement of the whole depot and workshop. Details of connected load feeder shall be worked out. Taking diversity factor of 0.5 the maximum demands shall be computed. Two Auxiliary substations are proposed, as the demand by machines in Workshop area would be very large. The standby power supply is proposed through DG set with AMF panel. The capacity of DG set will be adequate to supply all essential loads without over loading.

10.5.8 Compressed Air Supply

Silent type compressor units shall be suitably installed inside the depots at convenient location for the supply of compressed air to workshop and Inspection sheds. Thus, the pneumatic pipeline shall run within the workshop and inspection bays as to have compressed air supply line at all convenient points.

10.5.9 Water Supply, Sewerage and Drainage Works

In house facilities shall be developed for the water supply of each depot. Sewerage, storm water drainage shall be given due care while designing the depots for efficient system functioning. Past records of Municipal Corporation shall be used to design the drainage system. Rainwater harvesting would be given due emphases to charge the underground reserves.

10.5.10 Ancillary Workshop

This workshop will have a line at floor level with provision of pits. Arrangement for repairs of Shunters, Rail Road Vehicles and other ancillary vehicles will be provided. These vehicles will also be housed here itself. Heavy lifting works can be carried out in main workshop.

Ancillary workshop will be used for storing OHE/rigid OHE parts and their maintenance/ repair for restoration of 25 kV feed system.

10.5.11 Watch Towers

There shall be provision of adequate number of watchtowers for the vigilance of depot boundary.

10.5.12 Administrative Building

An administrative building close to the main entrance is planned. It can be suitably sized and architecturally designed at the detailed design stage. A time and security office is also provided close to main entrance. It shall be equipped with suitable Access control system for all the staff working in the complex.

10.5.13 Shed and Buildings

The shed and buildings normally provided in the depot in the detailed design stage depending upon the land availability, the decision to locate these buildings can be taken. These can then be architecturally and functionally grouped.

10.5.14 Plant and Machinery

A separate building is planned for housing pit wheel lathe (PWL), approachable from workshop, inspection bay and stabling lines through rail and road for placement of cars for re- profiling of wheels within the depot along with space for depot of scrap.

Following Safety features should be incorporated in the design of the Maintenance Depot-cum-Workshop.

1.5 EOT cranes in the inspection bay should be interlocked with 25 kV ac OHE in such a way that, the cranes become operational only when the OHE is isolated and grounded.

Red flasher lights should be installed along the inspection lines at conspicuous location to indicate the OHE is ‘Live’.

Multi level wheel and TM stacking arrangement should be an inbuilt feature at the end of Workshop Lines.

Pillars in the inspection bay & workshop should have provision for power sockets.

Placement of rakes from inspection/workshop lines on to washing lines for interior cleaning on their own power should be possible. Linking of OHE and its isolation at the cleaning area should be provided. Necessary requirements of safety should be kept in view.

The roof inspection platform should have open-able doors to facilitate staff to go up the roof for cleaning of roof. Suitable safety interlock should be provided to ensure maintenance staff are enabled to climb on the roof inspection platform only after the OHE is isolated.

Control Centre, PPIO & store depot must be close to Workshop.

Width of the doors of the sections wherein repairs of equipments are done should be at least 2 meters wide to allow free passage of equipment through them.

Provision of water hydrants should be done in workshops & stabling yards also.

Compressed air points along with water taps should be available in interior of buildings for cleaning.

Ventilation arrangement inside the inspection shed and workshop should be ensured.

Arrangement for natural cross ventilation from one side to another of inspection & workshop bays to be incorporated along with optimum availability of natural light at floor level.

11 POWER REQUIREMENTS

11.1 GENERAL

This chapter defines the various components of power requirements for the proposed Thane Bhiwandi Kalyan Metro system.

Electricity/power is required for operation of Metro system for various activities such as running of trains, station services which include lighting, lift operation, escalators, signalling & telecom processes, firefighting activities, workshops/depots and other maintenance infrastructure. In order to estimate the power demand, peak hour power requirement for traction and auxiliary applications have to be assessed.

Table 11.1: Power Demand Estimation (MVA)

Traction power requirements	Year 2021	Year 2031	Units
Number Of Cars	6	6	
Passenger Weight	67.2	67.2	ton
Train Tare	156	156	ton
Total Train Weight	223.2	223.2	ton
Section Length	23.6	23.6	km
Headway	**5**	**4**	min
Specific Consumption	70	70	kwh/GTPK
Number Of Trains In Both Directions	24	40	
Peak Traction Power Requirement	9.0	15.1	MW
Regeneration (30%)	2.7	4.5	MW
Depot Power Requirement	1.5	2	MW
Total Traction Power Requirement	7.8	12.5	MW
Total Traction Power Requirement Assuming 5% Of Loss And 0.95 Of Pf	8.6	13.8	MW
Station Auxiliary Power Requirements			
Elevated Station Power Consumption	0.2	0.3	MW
Number Of Elevated Stations	17	17	
Total Station Aux Power Requirement	3.4	5.1	
Depot Aux Power Requirement	1.5	2	MW
Total Aux Power Requirement	4.9	7.1	MW
Total Auxiliary Power Requirements Assuming 5% Energy Losses And 0.95 Pf For Aux Loads	5.4	7.8	MW
Total Traction And Auxiliary Power Requirement	**14.0**	**21.6**	MW

Auxiliary and traction power demand is analysed according to the following components:

- Specific energy consumption of rolling stock;
- Regeneration of about 30% by rolling stock;
- Elevated station load;

- Depot auxiliary load.

On the basis of the train operation plan, the rolling stock requirements as well as the auxiliary demand for the stations and the depot, the estimated power requirements expected for the year 2021 and 2031 are summarized in Table 11.1.

11.2 NEED FOR HIGH RELIABILITY OF POWER SUPPLY

The proposed metro system is being designed to cater peak hour per direction traffic of about 25500 passengers with headway of 3 minutes in 2031. Effect on signal and communication may affect train operation and passenger safety issues. Incidences of any power interruption will not only affect the train running, but it will also cause congestion at stations. Also interruption of power at night will cause signage visibility issues, disruption of operation of lifts/escalators etc. These situations will surely create inconvenience to commuters and thus the attractiveness of the system may be affected. Hence it is necessary to provide a reliable, uninterrupted power supply to ensure the efficiency and reliability and even the safety of the system.

To ensure reliability of power supply, it is essential that both the sources of Supply and connected transmission & distribution networks are reliable and have adequate redundancies built in. Therefore, it is desirable to obtain power supply at high grid voltage of 220kV or 132kV from stable grid sub-stations and further transmission & distribution is done by the Metro Authority itself.

11.3 SOURCES OF POWER SUPPLY

The Electrical Power is required for operation of metro system for running of trains, station services including illumination of buildings, lifts, escalators, signalling system.

The major component of power supply is the traction requirement and auxiliary load requirements for elevated section.

The high voltage power supply network of Mumbai city was studied in brief. The city has 220, 110 and 22 kV network to cater to various types of demand in vicinity of the proposed corridors. Keeping in view the reliability requirements, two Receiving Sub-stations are proposed to be set up for the line. This is an economical solution without compromising reliability. It is proposed to avail power supply for traction as well as auxiliary services from the following grid sub-stations of TATA Power Company Limited at 110 kV voltages through cable feeders.

The main source for power is from M/S TATA Power Co. Ltd. or MSEDCL. Unit rate of power (Tariff) varies from company to company.

11.3.1 Location of Receiving Substations:

In order to ensure a reliable Power Supply, more than one Receiving Sub Stations are planned, each of which should be capable of taking on the load of entire Network in case of failure of one of the RSS, thus building redundancy in the system.

The following RSS are proposed:

Purna RSS will supply power to the proposed corridor from Kapurbawdi to Gopal Nagar, which will be fed at 25 kV from MSEB’s 110kV/22kV grid substation located in Temghar. This RSS will also supply power to maintenance depot in emergency.

Tollgate RSS will be exclusively for maintenance Depot and will receive power from Temghar receiving substation of MSEDCL (MSEB).

Kalyan RSS located between Kongaon and Sahajanand Chowk will supply power to the proposed corridor from Kalyan to Shanti Nagar, which will be fed at 25kV from MSEB's 110kV/25 kV grid substation located in Kalyan.

The 110 kV power supply will be stepped down to 33 kV level at the RSS's of metro authority. The 33 kV power will be distributed along the alignment through 33 kV Ring main cable network for feeding traction and auxiliary loads. These cables will be laid in dedicated ducts/cable brackets along the viaduct.

In case of tripping of One RSS of the line on fault or input supply failure, train services can be maintained from stand-by source of the same line. But if one more RSS fails, only curtailed services can be catered to.

However, in case of total grid failure, all trains may come to a halt but station lighting, fire and hydraulics & other essential services can be catered to by stand-by DG sets. However, no train services can be run with power supply received from DG Sets. Therefore, while the proposed scheme is expected to ensure adequate reliability, it would cater to emergency situations as well, except for the train running.

Figure 11.1: Typical Receiving Sub Station

11.3.2 Various options of Traction system:-

Available options for power supply system for MRTS are as follows:

25 kV & 2X25 kV AC Overhead Catenary system;

750 V DC third rail system;

1500 V DC Overhead Catenary system.

11.3.3 Merits and Demerits of various traction systems

11.3.3.1 25 kV AC with OCS (Flexible/rigid):-Merits

Reduced cost - Unlike dc traction, this system does not require substations at frequent intervals due to high voltage, reduced current levels and lower voltage drops. As a result, there is substantial reduction in cost. Cost of 25 kV AC traction systems is about 30% less as compared to 750V DC 3rd rail traction system;

Energy regeneration & line losses - Energy regeneration is more than 30% in 25 kV AC traction system as compared to 18% in 750V DC 3rd rail traction system. In 25 kV AC traction system line losses are 12% less as compared to 750V DC 3rd rail traction system;

Cost of rolling stock - The cost of rolling stock & maintenance cost of traction system are comparable;

Capacity - The system can cater to traffic needs even in excess of 75000 PHPDT, which, however, is restricted on account of other constraints;

Easy of capacity enhancement - Capacity enhancement can be easily achieved by simply enhancing the transformer and its associated equipment at the receiving substation;

Higher efficiency of operation - The efficiency of regeneration is substantially more than DC systems and line losses are very less of the order of 5%. 100% recovery of regenerated energy is possible in the case of 25 kV AC traction compared to a figure of 75% in the case of 1500 V DC systems and 60% in the case of 750 V DC systems.

Less Fire hazards - AC system poses lesser fire hazards as current levels are much lower than DC system.

Stray current - There are no problems of stray currents and hence nearby metallic structures are not affected by corrosion. However there are problems of EMC / EMI which can be controlled by using return conductor & screened cables in signalling applications & fibre optic cable in telecommunication system without using booster transformer as per recent developments. This also helps in avoiding use of booster transformer which causes 2% line loss and excessive voltage drops besides involving maintenance & reliability issues.

Traction equipment in 25 kV AC system is standardized & mostly indigenously available.

11.3.3.2 600-850 V DC third rail traction system: -Demerits

High operating currents and High voltage drops necessitating reduction in spacing of sub-station - This lead to larger voltage drops along the Third Rail distribution system, which necessitates closer spacing of sub-stations at an interval of almost every 2 Km, leading to higher costs of construction;

Low levels of regeneration- 60% of re-generated energy in a 750 V DC system is possible to be retrieved;

Safety hazards with use of high voltage at ground level- Due to existence of the “live” third rail at ground level, this system can be hazardous to safety of commuters and maintenance personnel if they fail to adopt safety precautions;

Line losses- Line losses are more due to higher current. Transmission line losses on 750 V DC traction systems are around 21% as against 5% of 25 kV AC traction system;

Phenomenon of stray current - In a third rail system, where the running rails are used as a return path, a part of the return current leaks into track structure. This current is called stray current. It is necessary to manage the stray current to ensure minimal corrosion effect and consequent damages to metallic components in the track structure as well as metallic reinforcement and metal pipes of building of metro and public areas adjacent to the Metro alignment.

11.3.3.3 1500 V dc system with Overhead Catenary System: -Demerits

Higher maintenance requirement and costs as compared to 750V DC third rail system;

Theoretical traffic capacity with 1500 V traction system is less as compared to 25 kV AC system;

Line losses are more due to higher current as compared to 25 kV AC. It may be in the range of 10 to 12% as against 5% of 25 kVAC system.

In view of above techno-economic considerations, 25 kV AC traction system is recommended.

11.4 ELECTROMAGNETIC INTERFERENCE (EMI) AND ELECTROMAGNETIC COMPATIBILITY (EMC)

25 kV AC traction currents produce alternating magnetic fields that cause voltages to be induced in any conductor running along the track. Booster Transformer and Return Conductor (BT/RC) System is proposed for EMI mitigation. Concrete structures of elevated viaducts are not good electrical earths and therefore, Earthing and Bonding of the traction system shall be in accordance with the latest standards EN50122-1, IEEE80 and other relevant standards. Two earth conductors –Overhead Protection Cable (OPC) and Buried Earth Conductor (BEC) are proposed to be laid along with elevated viaduct and all the metallic structures, structural reinforcement, running rails etc. will be connected to these conductors to form an equiv-potential surface & a least resistance path to the fault currents. The overhead protection cable will also provide protection against lightning to the 25 kV OHE and the elevated viaduct.

Detailed specification of equipment e.g. power cables, transformer, switchgear, E&M equipment etc. shall be framed to reduce conducted or radiated emissions as per appropriate international standards. The Metro system as a whole (trains, signalling & telecomm, traction power supply, E&M system etc.) shall comply with the EMC requirements of international standards viz. EN50121, EN50123, IEC61000 series etc. A detailed EMI/EMC plan will be required to be developed during project implementation stage.

11.5 AUXILIARY SUPPLY ARRANGEMENTS FOR STATIONS

Auxiliary sub-stations (ASS) are envisaged to be provided at each station. The ASS will be located at mezzanine or platform level inside a room. The auxiliary load requirements have been assessed at 500 kW for stations. Accordingly, two dry type cast resin transformers (33/0.415 kV) of 630 kVA capacity are proposed to be installed at the stations (one transformer as standby).

11.6 AUXILIARY SUPPLY ARRANGEMENTS FOR DEPOT

A separate ASS is required at the depot. The Depot ASSs will also be provided with 2x2500 kVA auxiliary transformers.
The Following major plant and machinery are to be provided within the depot:

- RRV for carrying re railing equipment;
- Road vehicles (pick up van/ truck);

- Flat wagon for carrying material;
- Diesel/Electric battery powered locomotive with traction battery charger;
- Under floor Pit wheel lathe, chip crusher and conveyor for lathe on pit, Electric tractor for movement over under floor wheel lathe;
- Travelling O/H crane workshop 15T/3T,1.5T capacity(IBL),ETU shed 5T crane;
- Mobile Jib crane.

11.7 SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

The entire system of power supply (receiving, traction & auxiliary supply) shall be monitored and controlled from a centralized Operation Control Centre (OCC) through SCADA system. Modern SCADA system with intelligent remote terminal units (RTUs) shall be provided. Optical fibre provided for telecommunications will be used as communication carrier for SCADA system.

Digital Protection Control System (DPCS) is proposed for providing data acquisition, data processing, overall protection control, interlocking, intertripping and monitoring of the entire power supply system consisting of 33 kV AC switchgear, transformers, 25 kV ac switchgear and associated electrical equipment. DPCS will utilize microprocessor-based fast-acting numerical relays & Programmable Logic Controllers (PLCs) with suitable interface with SCADA system

11.8 ENERGY SAVING MEASURES

Energy charges of any metro system constitute a substantial portion of its operation & maintenance (O & M) costs. Therefore, it is imperative to incorporate energy saving measures in the system design itself. The auxiliary power consumption of metros is generally more than the traction energy consumed by train movement during initial years of operation. Subsequently, traction power consumption increases with increase in train frequency/composition in order to cater more traffic. The proposed system of Mumbai Metro includes the following energy saving features:

- Modern rolling stock with 3-phase VVVF drive and lightweight stainless steel coaches has been proposed, which has the benefit of low specific energy consumption and almost unity power factor;
- Rolling stock has regeneration features and it is expected that 30% of total traction energy will be regenerated and fed back to 25 kV AC OHE to be consumed by nearby trains;
- Effective utilization of natural light is proposed. In addition, the lighting system of the stations will be provided with different circuits (33%, 66% & 100%) and the relevant circuits can be switched on based on the requirements (day or night, operation or maintenance hours etc.);
- Machine-room less type lifts with gearless drive has been proposed with 3-phase VVVF drive. These lifts are highly energy efficient;
- The proposed heavy-duty public services escalators will be provided with 3-phase VVVF drive, which is energy efficient & improves the power factor. Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used by passengers;
- The latest state of art and energy efficient electrical equipment (e.g. transformers, motors, light fittings etc.) has been incorporated in the system design;

- Efficient energy management is possible with proposed modern SCADA system by way of maximum demand (MD) and power factor control;
- LED lights to be used in the station area and Depot area.

11.9 ELECTRIC POWER TARIFF

Electricity cost is a significant part of Operation & Maintenance (O&M) charges of the Metro System, which constitutes about 25-35% of total annual working cost. Therefore, it is the key element for the financial viability of the Project. In addition to ensuring optimum energy consumption, it is also necessary that the electric power tariff are kept at a minimum in order to contain the O& M costs. Therefore, the power tariff for Mumbai Metro should be at effective rate of purchase price (at 110 kV voltage level) plus nominal administrative Charges i.e. on a no profit no loss basis. The power tariff of Maharashtra Electricity Regulatory Commission for TATA power Company, FY 2015 – 16 demand charges Rs 200/ kVA per month and energy charges Rs 7.63/ kWh. Therefore it will be in the about Rs 8.46 per unit. It is proposed that Government of Maharashtra takes necessary steps to fix power tariff for Mumbai Metro at “No Profit No Loss” basis. Similar approach has been adopted for Delhi Metro.

12 TELECOMMUNICATION AND AUTOMATIC FARE COLLECTION

12.1 TELECOMMUNICATION SYSTEM

The telecommunication system acts as the communication backbone for Signalling systems and other systems (such as SCADA, AFC, etc.) and provides telecommunication services to meet operational and administrative requirement of metro network. The telecommunication facilities proposed are helpful in meeting the requirements for:

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

The proposed telecom system will cater to the following requirements:

- Train Traffic Control;
- Assistance to Train Traffic Control;
- Maintenance Control;
- Automatic Fare Collection;
- Security system;
- Emergency Control;
- Station to station dedicated communication;
- Telephone Exchange;
- Integrated Passenger Announcement System and Passenger Information;
- Display System within the station and from Central Control to each station;
- Centralised Clock System;
- Train Destination Indicator;
- Instant on line Radio Communication between Central Control and Moving;
- Cars and maintenance personnel;
- Data Channels for Signalling, SCADA, Automatic Fare Collection etc.;
- E&M SCADA ;

12.2 TELECOMMUNICATION SYSTEM AND TRANSMISSION MEDIA

This section describes the various system components.

12.2.1 Fibre Optic System (FOTS) - Main Telecommunication Bearer

The main bearer of the bulk of the telecommunication network is proposed with optical fibre cable system. Considering the channel requirement and keeping in view the future expansion requirements a minimum 48 Fibre optical cable is proposed to be laid in ring configuration with path diversity.

SDH (minimum STM-16) based system shall be adopted with SDH nodes at every station and OCC. Access 2MB multiplexing system will be adopted for the lower level at each node, equipped for channel cards depending on the requirement of channels in the network. Further small routers and switches shall be provided for LAN network at stations. Alternatively a totally IP Based High Capacity, highly reliable and fault tolerant, Ethernet Network (MAN/LAN) can be provided in lieu of SDH/MUX.

12.2.2 Telephone Exchange

For an optimized cost effective solution Small exchanges of 30 port each shall be planned at each station and a 60 Port Exchange at the Terminal Stations shall be provided. The exchanges at Central Control and Depots shall be of larger sizes as per the actual number of users. The Exchanges will serve the subscribers at all the stations and Central Control. The exchanges will be interconnected at the channel level on optical backbone. The exchanges shall be software partitioned for EPABX and Direct Line Communication from which the phones shall be extended to the stations. Alternatively only for non-operational (other than Direct Line Communication) a separate IP Based Phone System can be implemented.

12.2.3 Mobile Radio Communication

Mobile Radio communication system having minimum 8 logical channels is proposed for on-line emergency communication between Motorman (Front end and Rear end) of moving train and the Central Control. The system shall be based on Digital Trunk Radio Technology to TETRA International standard. This system now is widely adopted for mobile radio communication in metro / rapid transit services abroad. All the stations and the OCC will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets. These persons will be able to communicate with each other as well as with central control. The frequency band for operation of the system will be that for TETRA in 400/800 MHz band, depending on frequency availability. The system shall provide mobile radio communication between the motorman of the moving cars from any place and the Central Control. The motorman can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during detailed Design stage, base stations for the system will be properly located. In addition to the TETRA Radio Coverage for the internal use of the Metro, the city is also likely to have Mobile Coverage from Private Operators. In the elevated sections it is expected that coverage shall be available from the adjoining sites of the Mobile Operators.

12.2.4 Passenger Announcement System

The system shall be capable of announcements from the local station as well as from OCC. Announcements from Station level will have over-riding priority in case of emergency announcements. The System shall be linked to Signalling System for automatic train actuated announcements.

12.2.5 Passenger Information Display System

These shall be located at convenient locations at all stations to provide bilingual visual indication of the status of the running trains and will typically indicate information such as destination, arrival/departure time, and also special messages in emergencies. The boards shall be provided at all platforms and concourses of all stations. The System shall be integrated with the PA system and available from same MMI.

12.2.6 Centralized Clock System

This will ensure an accurate display of time through a synchronization system of slave clocks driven from a Master Clock at the operation control center. The Master Clock signal shall also be required for synchronization of FOTS, Exchanges, Radio, Signalling, etc. The System will ensure identical display of time at all locations. Clocks are to be provided at platforms, concourse, Station Master's Room, Depots and other service establishments.

The Closed Circuit Television (CCTV) System shall provide video surveillance and recording function for the operations to monitor each station. The monitoring shall be possible both locally at each station and remotely from the OCC. The CCTV system backbone shall be based on IP technology and shall consist of a mix of Fixed Cameras and Pan/Tilt/Zoom (PTZ) Cameras. Cameras shall be located at areas where monitoring for security, safety and crowd control purpose is necessary.

12.2.7 Network Monitoring and Management

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a network management system (NMS), which will help in diagnosing faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance. The proposed NMS system will be covering radio communication, Optical Fiber Transmission, Telephone Exchange and summary alarms of PA/PIDS, CCTV and Clock System.

12.3 TECHNOLOGY

The Technologies proposed to be adopted for telecommunication systems are shown in Table 12.1.

Table 12.1: Telecommunication Technology Features

System	Standards
Transmission Media	Optical Fibre system as the main bearer for bulk of the telecommunication network
Telephone Exchange	EPABX of minimum 30 ports is to be provided at all Stations, an Exchange of 60 Ports to be provided at Terminal Station
Train Radio System	Digital Train radio (TETRA) communication between motorman of moving cars, stations, maintenance personnel and central control.

Table 12.1: Telecommunication Technology Features

Train Destination Indicator System	LED/LCD based boards with adequate visibility to be provided at convenient location at all stations to provide bilingual visual indication of the status of the running trains, and also special messages in emergencies.
Centralized clock system	Accurate display of time through a synchronisation system of slave clocks driven from a master clock at the OCC and sub – master clock in station. This shall also be used for synchronisation other systems.
Passenger Announcement System	Passenger Announcement System covering all platform and concourse areas with local as well as Central Announcement.
Redundancy (Major System)	Redundancy on Radio's in the Base Stations, Path Redundancy for Optical Fibre Cable by provisioning in ring configuration
Environmental Conditions	All equipment rooms to be air-conditioned.
Maintenance Philosophy	• System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. • Philosophy of preventive checks of maintenance to be followed. System should be connected with NMS for diagnosing faults and co-ordination. • Card/module level replacement shall be done in the field and repairs undertaken in the central laboratory/manufacture's premises.

12.3.1 Space Requirement for Telecom Installations

Adequate space for proper installations of all Telecommunication equipment at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for Signal & Telecom equipment shall be generally 30 sqm. each for Telecom Room and 50 sqm. for UPS Room (common for signal, telecom and AFC). These areas shall also cater to local storage and space for maintenance personnel to work. At the OCC , the areas required shall be as per the final configuration of the equipment and network configuration keeping space for further expansion.

12.3.2 Maintenance Philosophy for Telecom systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipment shall be followed as per the Operation and Maintenance Manual.

Card / module / sub-system level replacement shall be done in the field.

Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station. The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located on the section. This lab will be equipped with appropriate diagnostic and test equipment to rectify the faults and undertake minor repairs. Cards / modules / equipment requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

12.4 AUTOMATIC FARE COLLECTION

12.4.1 Introduction

This section details out the fare collection system standards and performance requirements for the Automatic Fare Collection (AFC) System to be designed, installed, commissioned and operated.

Mass rapid Public Transport Systems are designed for large number of passengers. One of critical responsibility of transit authorities is cash management. Fare collection methods and system play a key role in the efficient and proper operation of the transit system. To achieve this objective, ticketing system should be simple, easy to use/operate and maintain, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. In view of above, computer based automatic fare collection system is proposed.

12.4.2 Automatic Fare Collection System (AFC)

Automatic Fare Collection system (AFC) is a contactless smartcard-based end-to-end solution for fare collection and payment. The state-of-the-art solution is uniquely designed with the demand of revenue services for modern transit operation in mind. Furthermore, with the advent of smartcard technology and its business applications, AFC also enables transit operators to expand revenue opportunities, exploit the benefits of payment integration with other transit operators as well as non-transit service providers.

Benefits of Smartcard-Based System are as listed below:

- Improve efficiency and reduce operating and maintenance cost of fare collection for transit operators;
- Ease-of-use for commuters, increased passenger flow in and out of stations and transit vehicles and almost 100% ticket checking at entry / exit;
- Open up proactive marketing opportunities. Multi-application capability and interoperability;
- enable effective targeted pricing, loyalty programmes, cross-marketing with other services etc.;
- Reduce fare-related fraud and revenue loss through open standard, secured transaction technology.

For Multiple Journey, the Store Value Smart Card shall be utilized and for the Single Journey, the media shall be as utilized as Contactless Smart Token. AFC system proves to be cheaper than semi-automatic (manual system) in long run due to reduced manpower cost for ticketing staff, reduced maintenance in comparison to paper ticket machines etc. AFC systems are the worldwide accepted systems for LRT/Metro environment.

The proposed ticketing system shall adopt Contactless Smart Card type for multiple journeys and Token for Single Journey. The equipment for the same shall be provided at each station Counter/Booking office and at convenient locations and will be connected to a local area network with a computer in the Station Master's room.

12.4.3 Control Gates

Retractable flap type Control Gates/Paddle Type Gates are proposed which offer high throughput, require less maintenance and are latest in modern metros internationally. Tripod turnstile type gates offer less throughput and require more maintenance and hence, they are not proposed. Typical AFC gate is shown in Figure 12.1.

Figure 12.1: AFC Gate

12.4.4 Passenger Operated Machine (POM)

At all stations, two Passenger Operated Machines (Automatic Ticket Vending Machines) are proposed. The POM's will provide convenience to passengers to avoid standing in queues at ticket booths and provide them international standard of service.

12.4.5 AFC equipment Requirement

Tentative AFC gates requirement at each station is calculated according to the expected numbers of boarding/alighting passengers at each station (see Table 12.2).

The exact number and type shall depend on the final station layout. However, <u>as minimum requirements</u>, following equipment can be considered:

- 2 entry gates, 2 exit gates, 2 EFO, 2 TOM, 4 T, 2 TVM;
- At least 1 disabled gate at each station;
- Throughput of gate 30 passengers per minute, TOM 10 transaction per minute.

Table 12.2: AFC Gates Requirement (projection for 2021)

Sr. No	Station Name	Hourly Boarding	Hourly Alighting	Entry Gate	Exit Gate	Disabled	TOM	EFO	TR	TVM
1	Kalyan Station	11527	5606	6	6	2	6	2	4	4
2	Sahajanand Chowk	2036	571	3	3	1	3	2	4	2
3	Durgadi Fort	2338	1899	3	3	1	3	2	4	2
4	Kon Gaon	120	132	3	3	1	3	2	4	2
5	Gove Gaon MIDC	296	167	3	3	1	3	2	4	2
6	Rajnouli Village	157	155	3	3	1	3	2	4	2
7	Temghar	1202	5647	3	3	1	3	2	4	2
8	Gopal Nagar	5101	2229	3	3	1	3	2	4	2
9	Bhiwandi	8647	8714	6	6	2	6	2	4	4
10	Dhamankar Naka	7855	4505	3	3	1	3	2	4	2
11	Anjurphata	7001	6502	3	3	1	3	2	4	2
12	Purna	1613	694	3	3	1	3	2	4	2
13	Kalher	1660	185	3	3	1	3	2	4	2
14	Kasheli	1402	5890	3	3	1	3	2	4	2
15	Balkum Naka	2335	1597	3	3	1	3	2	4	2
16	Kapurbawadi	8523	15552	6	6	2	6	2	4	4

12.4.6 Technology

The technology proposed for AFC systems are presented in Table 12.3 .

Table 12.3: AFC System Standards

Standards	Description
Fare media	a) Contactless smart card – For multiple journeys. b) Single Journey: Contactless smart token captured at exit gates.
Gates	Computer controlled automatic gates at entry and exit. There will be following types of gates: • Entry • Exit • Reversible (if required as per final station layout) can be set to entry or exit • Reversible Handicapped Gate -gate for disabled people.
Station computer, Central computer and AFC Network	All the fare collection equipment shall be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control centre through the optic fibre communication channels. The centralised control of the system shall provide real time data

Standards	Description
	of earnings, passenger flow analysis, blacklisting of specified cards etc.
Ticket office machine (TOM/EFO)	Manual Ticket Counters offices shall be installed in the stations for selling tickets to the passengers. Also POM's shall be provided for Automatic Ticket Vending.
Ticket reader and portable ticket decoder.	Ticket reader shall be installed near EFO for passengers to check information stored in the ticket.
UPS (uninterrupted power at stations as well as for OCC).	Common UPS of S&T system will be utilised**.**

13 SIGNALLING AND TRAIN CONTROL:

13.1 OVERVIEW

The signalling system shall provide the means for an efficient train control, ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on the network. Metro carries large number of passengers at a very close headway requiring a very high level of safety enforcement and reliability. At the same time heavy investment in infrastructure and rolling stock necessitates optimization of its capacity to provide the best services to the public. These requirements of the metro are planned to be achieved by adopting 'CATC' (Continuous Automatic Train Control System) based on "CBTC" (Communication based Train Control System) which includes ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems using radio communication between Track side and Train.

This will:

- Provide high level of safety with trains running at close headway ensuring continuous safe train separation for bidirectional working.
- Eliminate accidents due to driver passing Signal at Danger by continuous speed monitoring and automatic application of brake in case of disregard of signal / warning by the driver.
- Provides safety and enforces speed limit on section having permanent and temporary speed restrictions.
- Improve capacity with safer and smoother operations. Driver will have continuous display of Target Speed / and other information in his cab enabling him to optimize the speed potential of the track section. It provides signal / speed status in the cab even in bad weather.
- Increased productivity of rolling stock by increasing line capacity and train speeds, and enabling train to arrive at its destination sooner. Hence more trips will be possible with the same number of rolling stock.
- Improve maintenance of Signalling and telecommunication equipment by monitoring system status of trackside and train born equipment and enabling preventive maintenance.

Signalling & Train Control system on the line shall be designed to meet the required headway during peak hours. Radio for CBTC shall work in License free ISM band.

13.1.1 System Description and Specifications

The Signaling and Train Control system shall be as explained in the following sub-paragraphs. Sub-system/ components will conform to international standards like CENELEC, IEC, IEEE, IS, ITU-T etc.

13.1.2 Continuous Automatic Train Control

Continuous Automatic Train Control based on CBTC will consist of ATP (Automatic Train Protection), ATO (Automatic Train Operation) and ATS (Automatic Train Supervision) sub-systems. The Train-borne Automatic Train Control System will consist of Automatic

Train Operation (ATO) and Automatic Train Protection (ATP). This will work on moving block principle.

13.1.3 Automatic Train Protection (ATP)

Automatic Train Protection is the primary function of the train control systems. This sub-system will be inherently capable of achieving the following objectives in a fail-safe manner. Line side signals will be provided at diverging routes (i.e. at points & crossings) as well as other required locations, which shall serve as backup signalling in case of failure of ATP system.

- Cab Signalling
- Moving block
- Track Related Speed Profile generation based on line data and train data continuously along the track
- Continuous monitoring of braking curve with respect to a defined target point
- Monitoring of maximum permitted speed on the line and speed restrictions in force
- Detection of over-speed with audio-visual warning and application of brakes, if necessary
- Maintaining safety distance between trains
- Monitoring of stopping point
- Monitoring of Direction of Travel and Rollback

The cab borne equipment will be of modular sub-assemblies for each function for easy maintenance and replacement. The ATP assemblies will be fitted in the vehicle integrated with other equipment of the rolling stock.

13.1.4 Automatic Train Operation (ATO)

This system will operate the trains automatically from station to station while remaining within the safety envelope of ATP & open the train doors. Driver will close the train doors and press a button when ready to depart. In conjunction with ATP/ ATS, ATO can control dwell time at stations and train running in accordance with headway/ timetable.

13.1.5 Automatic Train Supervision (ATS)

A train supervision system will be installed to facilitate the monitoring of train operation and also remote control of the station. The train supervision will log each train movement and display it on the workstations with each Traffic Controller at the OCC and on one workstation placed in the Station Control room (SCR) with each Station Controller.

The centralized system will be installed in the Operation Control Centre. The OCC will have a projection display panel showing a panoramic view regarding the status of tracks, points, signals and the vehicles operating in the relevant section/ whole system. ATS will provide following main functionalities:

- Automatic Route setting
- Automatic Train Regulation

- Continuous Tracking of train position
- Display Panel & Workstation interface
- Link to Passenger Information Display System for online information
- Computation of train schedules & Timetable.

13.1.6 Computer Based Interlocking (CBI)

The entire line including turn back track, transfer track, sidings will be equipped with CBI system for operation of points and crossings and setting of routes.

The setting of the route and clearing of the signals will be done by workstation, which can be either locally (at station) operated or operated remotely from the OCC.

This sub-system is used for controlling vehicle movements into or out of stations automatically from a workstation. All stations having points and crossings will be provided with workstations for local control. Track occupancy, point position, etc. will be clearly indicated on the workstation. It will be possible to operate the workstation locally, if the central control hands over the operation to the local station. The interlocking system design will be on the basis of fail-safe principle.

The equipment will withstand tough environmental conditions encountered in a Mass Transit System. Suitable IS, IRS, BS standards or equivalent international standards will be followed in case wiring, installation, earthing, cabling, power supply and for material used in track circuits, axle counters, relays, point operating machines, power supply etc.

13.1.7 Track Vacancy Detection

Primary mode for track vacancy detection system on main line may be through radio and for secondary detection, can be through Track circuit / Axle Counter.

13.1.8 Signals

Multi Aspect Colour Light (LED) type Line side signals shall be installed on the Main Line and depot entry/ exit.

13.1.9 Point Machines

Non-Trailable Electrical Point Machine capable of operating with 3-phase, 50 Hz.

380V AC will be used on main line and the depot point machine will be trailable/non trailable type electrical point machine capable of operating with either 3 phase, 50 Hz. 380V AC or 110V DC.

13.1.10 Train Depot: Signalling

All depot lines except the one which is used for shunting and in the workshop shall be interlocked. A workstation shall be provided in the Depot Control Centre for electrical operation of the points, signals and routes of the depot yard. Audio Frequency Track Circuits/ Axle Counter will be used in the depot as well. A test track with similar Signalling and Train control system as adopted in Main Line shall be provided at Depot.

13.1.11 Interface for PSD

Interface for PSD should be provided at all stations which can be utilized as and when PSDs are provided.

13.1.12 Standards

The standards to be adopted with regard to the Signaling system is presented in the Table 13.1.

Table 13.1: Signaling System Standards

Description	Standards
Interlocking	Computer based Interlocking adopted for station having switches and crossing. All related equipment as far as possible will be centralised in the equipment room at the station. The depot shall be interlocked except for lines mainly used for workshop lines, inspection shed lines etc.
Block Working	Moving Block working concept may be followed.
Operation of Points	Non-Trailable Electrical Point Machine capable of operating with 3-phase, 50 Hz. 380V AC will be used on main line and the depot point machine will be trailable/ non -trailable type electrical point machine capable of operating with either 3 phase, 50 Hz. 380V AC or 110V DC.
Track Vacancy Detection System	Primary mode for track vacancy detection system on main line and test track in depot may be through radio and for depot and secondary detection it can be through Track circuit / Axle Counter.
Signals at Stations with point & crossings	Line Side signals to protect the points (switches). LED type signals for reliability and reduced maintenance cost.
UPS (uninterrupted power at stations as well as for OCC)	For Signalling, Telecommunications and AFC.
Train protection system	Train Protection system shall be based on CBTC (Communication based Train Control) System. The system architecture shall provide for redundancy. The system will conform to IEEE 1474 standards.

Description	Standards
Train Describer System	Automatic Train Supervision system. Movement of all trains to be logged on to a central computer and displayed on workstations in the Operational Control Centre and at the SCR. Remote control of stations from the OCC. The system architecture shall provide for redundancy.
Cables	Outdoor cables will be steel armored as far as possible.
Fail Safe Principles	SIL-4 safety levels as per CENELEC standard for Signal and Train Control System.
Immunity to Externa Interface.	All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables as per standard. CENELEC standards to be implemented for EMC.
Train Working under emergency	Running on site with line side signal with speed automatically restricted between 15-25 kmph.
Environmental Conditions	Air-conditioners for all equipment rooms.
Maintenance philosophy	Philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling equipment shall be followed. Card / module / sub-system level replacement shall be done in the field and repairs undertaken in the central laboratory/ manufacturer's premises.

13.1.13 Space Requirement for Signaling Installations

Adequate space for proper installations of all signalling equipment and platform screen doors at each of the stations has to be provided keeping in view the case of maintenance and use of instrumentation set up for regular testing and line up of the equipment/system. The areas required at each of the stations for Signalling equipment shall be generally 60 sqm. for UPS Room (common for signalling and telecom). For Signalling Equipment Room the area required 50 sqm. at depot and all the stations having crossovers and for remaining stations 20 sqm. These areas shall also cater to local storage and space for maintenance personnel to work. At the OCC and the Depot, the areas required shall be as per the final configuration of the equipment and network configuration keeping space for further expansion.

13.1.14 Maintenance Philosophy for Signalling systems

The philosophy of continuous monitoring of system status and preventive & corrective maintenance of Signalling and telecommunication equipment shall be followed. Card / module / sub-system level replacement shall be done in the field. Maintenance personnel shall be suitably placed at intervals and they shall be trained in multidisciplinary skills. Each team shall be equipped with a fully equipped transport vehicle for effectively carrying out the maintenance from station to station.

The defective card/ module / sub-system taken out from the section shall be sent for diagnostic and repair to a centralized S&T repair lab suitably located in the section/depot. This lab will be equipped with appropriate diagnostic and test equipment to rectify the faults and undertake minor repairs. Cards / modules / equipment requiring major repairs as specified in suppliers documents shall be sent to manufacturer's workshop.

14 DISASTER MANAGEMENT

14.1 INTRODUCTION

Disaster is a sudden accident or a natural catastrophe that causes great damage or loss of life. As per the disaster management act, 2005 "disaster" is a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area”. As this is catastrophe, one need to manage the resources and responsibilities for which disaster management is essential.

Disaster Management can be defined as “the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters” as per IFRC.Disaster Management Process is graphically presented in the Figure 14.1.

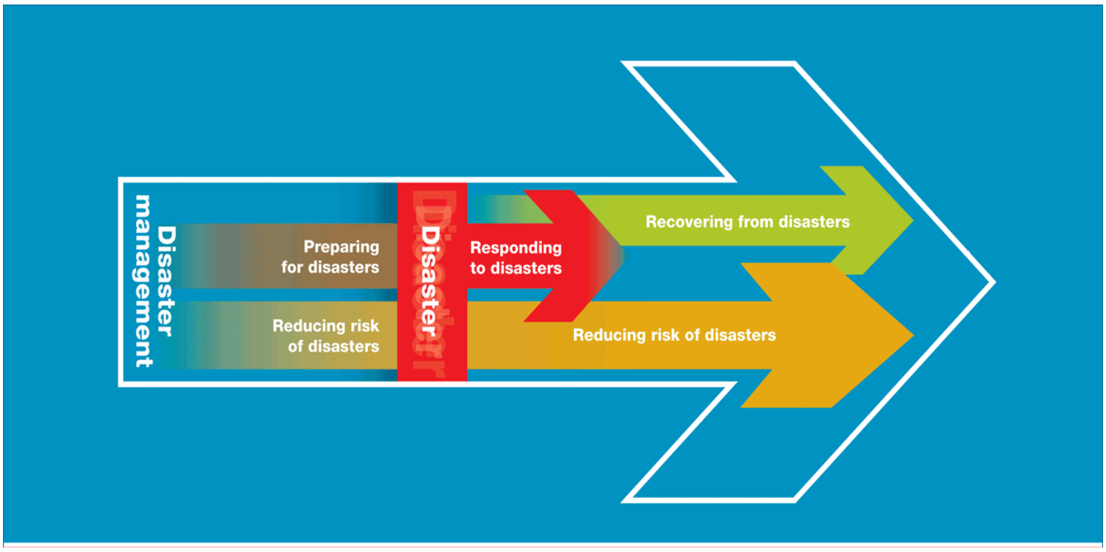

Figure 14.1: Disaster Management Process

And as per disaster management act, 2005, “disaster management means” a continuous and integrated process of planning, organising, coordinating and implementing measures which are necessary or expedient for:

- prevention of danger or threat of any disaster;
- mitigation or reduction of risk of any disaster or its severity or consequences;
- capacity building;
- preparedness to deal with any disaster;
- prompt response to any threatening disaster situation or disaster;
- assessing the severity or magnitude of effects of any disaster;
- evacuation rescue and relief;
- rehabilitation and construction.

Disater Management Measures are shown in Figure 14.2.

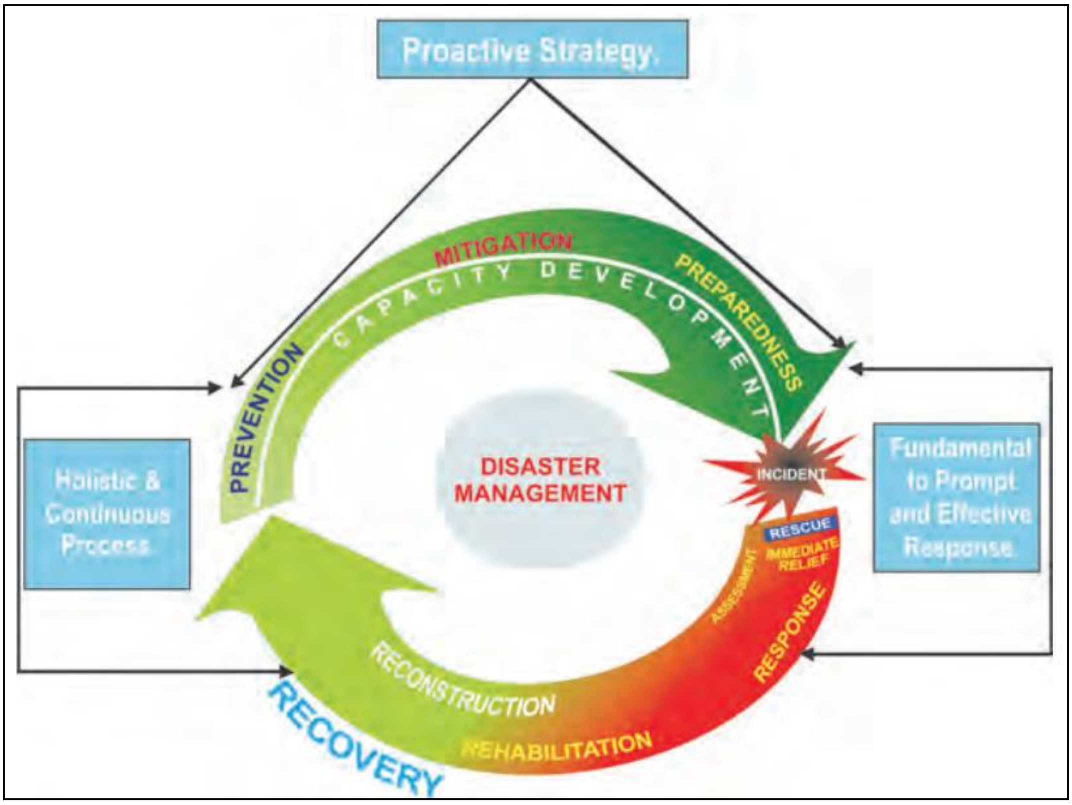

Figure 14.2:Disaster management measures

14.2 PURPOSE OF DISASTER MANAGEMENT MEASURES

A disaster is a sudden occurrence of events which incur economical disruption, huge human loss, deterioration of health, damage to infrastructure, increase the pollutants etc. The presently proposed Thane-Bhiwandi-Kalyan metro corridor will accommodate plentiful passenger load daily commuting for various purposes. The metro stations, infrastructure of the metro line and the commuters are going to get effected due to various disasters or such conditions which may lead to major human and economic loss.

There is no city that is immune from disaster, though vulnerability to disaster varies. There are four main types of disaster.

- **natural disasters**: including floods, hurricanes, earthquakes and volcano eruptions that have immediate impacts on human health and secondary impacts causing further death and suffering from (for example) floods, landslides, fires, tsunamis;
- **environmental emergencies**: including technological or industrial accidents, usually involving the production, use or transportation of hazardous material, and occur where these materials are produced, used or transported, and forest fires caused by humans;
- **complex emergencies**: involving a break-down of authority, looting and attacks on strategic installations, including conflict situations and war;

- **pandemic emergencies**: involving a sudden onset of contagious disease that affects health, disrupts services and businesses, brings economic and social costs.

Still there are many unpredictable disasters which affect the public. Considering all these huge effects of disasters, there is vital need to have a proper disaster management plan to the present metro system. Though the complete prediction and prevention of the incidence of any disaster is not possible, a state of preparedness and ability to respond quickly to a disaster can be considerably done. This helps to mitigate loss of life, property and the human suffering and thus restore normality to the earliest.

It is therefore of paramount importance that a plan of action for dealing with contingencies that arise in the wake of disasters needs to be implemented.

14.3 OBJECTIVES OF DISASTER MAANGEMENT MEASURES

The main objectives of Disaster Management measures to mitigate its effects are as follows:

Put the maximum efforts to save life and reduce the deterioration

Protect the MMRDA metro railway property and infrastructure

Educate the passengers and metro staff of how to react and handle the catastrophic situations

Make ensure that all the commuters are provided with proper and accurate information regarding different provisions provided in the metro stations to mitigate some of the risks incurred due to disasters

Provide provisions for easy escape of the passengers during the high peak time without causing any confusion and chaos

Accelerate the renovation works needed to restart the stopped metro services

For proper management of disasters Government of India has taken initiative and commenced Disaster Management Act, 2005. The following sections details about the various provisions of the act.

14.4 PROVISIONS UNDER DISASTER MANAGEMENT ACT, 2005

Under the Disaster Management Act (2005), there shall be various establishment of authorities at different levels, that is at

- national level;
- state Level;
- district level.

14.4.1 The National Disaster Management Authority (NDMA)

Establishment of National Disaster Management Authority:-

1. With effect from such date as the Central Government may, by notification in the Official Gazette appoint in this behalf, there shall be established for the purposes of this Act (The Disaster Management Act, 2005), an authority to be known as the National Disaster Management Authority.
2. The National Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the Central Government and, unless the rules otherwise provide, the National Authority shall consist of the following:-

- the Prime Minister of India, who shall be the Chairperson of the National Authority, ex officio;
- other members, not exceeding nine, to be nominated by the Chairperson of the National Authority.

3. The Chairperson of the National Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the National Authority.
4. The term of office and conditions of service of members of the National Authority shall be such as may be prescribed.

14.4.2 State Disaster Management Authority

Establishment of State Disaster Management Authority:-

1. Every State Government shall, as soon as may be after the issue of the notification under sub-section (1) of section 3, by notification in the Official Gazette, establish a State Disaster Management Authority for the State with such name as may be specified in the notification of the State Government.
2. A State Authority shall consist of the Chairperson and such number of other members, not exceeding nine, as may be prescribed by the State Government and, unless the rules otherwise provide, the State Authority shall consist of the following members, that is:-
   - The Chief Minister of the State, who shall be Chairperson, ex officio;
   - Other members, not exceeding eight, to be nominated by the Chairperson of the State Authority;
   - The Chairperson of the State Executive Committee, ex officio.
3. The Chairperson of the State Authority may designate one of the members nominated under clause (b) of sub-section (2) to be the Vice- Chairperson of the State Authority.
4. The Chairperson of the State Executive Committee shall be the Chief Executive Officer of the State Authority; the Chief Minister shall be the Chairperson of the Authority established under this section.
5. The term of office and conditions of service of members of the State Authority shall be such as may be prescribed.

14.4.3 Command & Control at the National, State & District Level

The mechanism to deal with natural as well as manmade crisis already exists and that it has a four tier structure as stated below:-

1. National Crisis Management Committee (NCMC) under the chairmanship of Cabinet Secretary
2. Crisis Management Group (CMG) under the chairmanship of Union Home Secretary.
3. State Level Committee under the chairmanship of Chief Secretary.
4. District Level Committee under the Chairmanship of District Magistrate. All agencies of the Government at the National, State and district levels will function in accordance with the guidelines and directions given by these committees.

14.4.4 Plans by Different Authorities at District Level and their Implementation

Every office of the Government of India and of the State Government at the district level and the local authorities shall, subject to the supervision of the District Authority:-

1. Prepare a disaster management plan setting out the following, namely:-
    - provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
    - provisions for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
    - the response plans and procedures, in the event of, any threatening disaster situation or disaster;
2. Coordinate the preparation and the implementation of its plan with those of the other organizations at the district level including local authority, communities and other stakeholders;
3. Regularly review and update the plan; and
4. Submit a copy of its disaster management plan, and of any amendment thereto, to the District Authority.

Under the Disaster Management Act (2005), every office of the Government of India shall prepare a disaster management plan which includes out the following, namely:

- provisions for prevention and mitigation measures as provided for in the District Plan and as is assigned to the department or agency concerned;
- PROVISIONS for taking measures relating to capacity-building and preparedness as laid down in the District Plan;
- the response plans and procedures, in the event of, any threatening disaster situation or disaster

Further proper coordination of the plan should be done with the other organisations at the district level and eventually review and update the plan. A copy of the disaster management plan needs to be submitted to the District Authority.

15 DISABILITY FRIENDLY FEATURES

15.1 INTRODUCTION

The disability friendly feature presented in this chapter has been worked out to make disability friendly features in Indian mass transport facilities which can ensure accessibility to the key target groups.

The target group is composed of five major categories:

- wheelchair users;
- people with limited walking abilities;
- the sightless;
- the partially sighted;
- the hearing impaired.

15.2 TACTILE PAVERS[5]

Person with vision impairment need guidance in using pedestrian area. Tactile pavers are used for guiding or warning. Wherever tactile pavers are used same kind of paver types should be used consistently to avoid confusion.

15.2.1 Tactile Guiding Paver (Line type)

Guide blocks line type has straight continuous line and indicate the correct path/route to follow, leading to building entrances, an amenity, bus stop etc. It should be laid in a simple and logical manner and not be located close to manholes or drains, to avoid confusion for persons with vision impairments. A continuous path of guide blocks in the direction of pedestrian travel, which has a different texture to the rest of the footpath, can provide this guidance.

15.2.2 Tactile Guiding Paver (Dot type)

It is provided for warning signal to screen off obstacles, drop-offs or other hazards, to discourage movement in an incorrect direction and to give warning of a corner or junction. It should be provided at intersections, turnings, building entrances etc. It should be placed 300 mm at the beginning and end of the ramps, stairs and entrance to any door. It should be laid 600mm wide across the entire footpath where the crossing occurs. A warning block strip should be provided along the inner edge of a footpath where there is a break in the line of the corridor, e.g. at a garage forecourt or a gap in a building facade for an archway.

15.3 STEPS & STAIRS

- uniform riser of 150 mm and tread of 3006 mm should be adopted for the stairs.
- the steps should have an unobstructed width of 1200mm minimum;
- flight and landings should have a clear unobstructed width of at least 1000mm;
- the rise between landings should not exceed 1200mm;

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[5] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.4 pg no18
[6] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.8.2 pg no40

- the stair covering and nosing should be slip-resistant, non-reflective, firmly-fixed and easy to maintain;
- the staircase should be adequately and uniformly illuminated during day and night(when in use);
- noise should be avoided;
- there should be a suitable and continuous handrail on each side of the flights and landings.

15.4 HANDRAILS[7]

- handrails should be circular in section with a diameter of 38-40mm and formed from materials which provide good grip such as timber, nylon or powder coating, matt finish metal finishes;
- the handrail should contrast in colour (preferably yellow/orange) with surrounding surfaces;
- at least 50mm clear of the surface to which they are attached and should be supported on brackets which do not obstruct continuous hand contact with the handrail;
- the handrail should be positioned between 760mm and 900mm above the ramp and landing surfaces;
- handrail should extend 300mm beyond the ramp and steps at the bottom and at the top, and terminate in a closed end that does not project into path of the travel.

15.5 RAMPS

- ramps gradient should ideally be 1 in 20 and no greater than 1 in 12.
- width of the ramp should not be less than 1200 mm;
- the steeper the gradient, the shorter the length of ramp between landings;
- on long ramps, a horizontal resting space should be provided every 6 meters;
- surface materials should be slip-resistant, non-reflective, firmly-fixed and easily maintained;
- the edge of the ramp should have an edge protection with a minimum height of 100mm to prevent person from falling through;
- landings every 750mm of vertical rise should be provided;
- a tapping or lower rail should be positioned so that its bottom edge is no higher than 200mm above ground level;
- landing should be at least 1500mm*1500mm;
- a row of tactile warning tile should be placed 300mm to indicate change in gradient;
- on long ramp, one can provide passing bays, 1800mm*1800mm every 20 m.

15.6 ELEVATORS/LIFT

- Lift location should be clearly signposted from main pedestrian route.

[7] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.8.3 pg no47

- minimum car space should be 1500 mm*1500mm with door opening of minimum 900mm wide;
- the call buttons and control panels should be placed at a level between 800 mm-1000mm;
- min 1500 mm*1500mm clear landing area in front of the lift doors should be provided;
- handrail is to be fixed on both side as well as rear of the lift at a height of 900mm from the floor level;
- buttons with Braille and raised letter in sharp contrast from the background should be provided;
- Lift should be fitted with voice announcement system along with a visual display to indicate the floor level.

15.7 WASHROOM AND TOILETS

15.7.1 Signages

- accessible toilets with international symbol of accessibility displayed outside for wheelchair access;
- opening of the doors should be of minimum 900mm width;
- the toilet door should be an outdoor opening or two way opening or a sliding type;
- it should have a horizontal pull-bar, at least 600mm long, on the inside of the door, located so that it is 130mm from the hinged side of the door and at a height of 1000mm.

15.7.2 Wc Compartment Dimensions[8]

- minimum dimension of the compartment should be 2200mm*2000mm which allows use by both manual and motorised wheelchair users;
- layout of the fixtures in the toilet should be such that a clearing maneuvering space of 1500mm x 1500mm in front of the WC and washbasin.

15.7.3 Water Closet (WC) Fittings[9]

- top of the WC seat should be 450-480mm above finished floor level, preferably be of wall hung or corbel type as it provides additional space at the toe level;
- an unobstructed space 900mm wide should be provided to one side of the WC for transfer, together with a clear space 1200mm deep in front of the WC;
- WC should be centred 500mm away from the side wall, with the front edge of the pan 750mm away from the back wall. Have a back support. The WC with a back support should not incorporate a lid, since this can hinder transfer;
- l-shape grab bar at the adjacent wall and on the transfer side (open side) swing up grab bar shall be provided;
- the cistern should have a lever flush mechanism, located on the transfer side and not on the wall side and not more than 1000mm from the floor.

[8] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.14.1 pg no50
[9] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.14.2 pg no50

15.7.4 Grab Bars[10]

- it is essential that all grab rails are adequately fixed, since considerable pressure will be placed on the rail during maneuvering. Grab bars should sustain weight of 200kgs minimum;
- a hinged type moveable grab bar should be installed adjacent to the WC on the transfer side. This rail can incorporate a toilet tissue holder. A distance of 320mm from the centre line of the WC between heights of 200-250mm from the top of the WC seat. It should extend 100-150mm beyond the front of the WC;
- a fixed wall-mounted L- shape grab bar (600mm long horizontal and 700mm long vertical) on the wall side should be provided. It should be placed at a height of 200-250mm above the WC seat level.

15.7.5 Wash Basin

- hand washbasins should be fitted on cantilevered brackets fixed to the wall;
- the basin should be fixed no higher than 750 mm above the finished floor level;
- the dimension of wash basin 520 mm and 410 mm, mounted such that the top edge is between 800-900mm from the floor; have a knee space of at least 760 mm wide by 200mm deep by 650-680mm high;
- the position of the basin should not restrict access to the WC i.e. it should be located 900mm away from the WC;
- a lever operated mixer tap fitted on the side of the basin closest to the WC is useful as it allows hot and cold water to be used from a seated position on the WC;
- the hand drying facilities should be located close to the hand washbasin between 1000-1200mm;
- lever type handles for taps are recommended.

15.7.6 Fixtures and Fittings

- contrast between fittings and fixtures and wall or floor finishes will assist in their location;
- towel rails, rings and handrails should be securely fixed to the walls and positioned at 800-1000mm from the floor;
- the mirror should be tilted at an angle of 300 for better visibility by wheelchair users;
- mirror’s bottom edge should be 1000mm above floor finish;
- hooks should be available at both lower-1200mm and standard heights- 1400mm, projecting not more than 40mm from the wall;
- where possible, be equipped with a shelf of dimensions 400mm x 200mm fixed at a height of between 900mm and 1000mm from the floor;
- light fittings should illuminate the user's face without being visible in the mirror. For this reason, most units which have an integral light are unsatisfactory;

[10] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.14.3 pg no51

- alarms must be located so that assistance can be summoned both when on the toilet pan i.e. at 900mm height and lying on the floor i.e. at 300mm, from floor surface. Alarms should be located close to the side wall nearest the toilet pan, 750mm away from rear wall and at 900mm and 200mm above floor finish.

15.7.7 Signage of Accessible Toilets

- a distinct audio sound (beeper/clapper) may be installed above the entrance door for the identification of the toilets.
- for the benefits of the persons with visual impairment, all general toilets should have mail pictogram in triangle or female pictogram in circle, marked on plates with raised alphabets and put on walls next to door and on the door as well.

15.7.8 Accessible Urinal

- a stall-type urinal is recommended
- urinals shall be stall-type or wall-hung, with an elongated rim at a maximum of 430mm above the finish floor;
- urinal shields (that do not extend beyond the front edge of the urinal rim) should be provided with 735mm clearance between them;
- grab bars to be installed on each side, and in the front, of the urinal;
- the front bar is to provide chest support; the sidebars are for the user to hold on to while standing;
- urinals having grab bars is to support ambulant persons with disabilities (for example, people using mobility aids like crutches).

15.8 PEDESTRIAN FACILITIES- PARKING

15.8.1 Accessible Parking11

- designated car parking spaces may be arranged perpendicular or parallel to the kerb;
- dropped kerb will facilitate access to the footpath for person using wheelchair;
- two accessible parking lots with overall minimum dimension 3600mm * 5000mm, should be provided;
- when parallel parking is the only option, some person prefer to transfer on the road side to avoid the kerbs. In such cases, a clear space of 1200mm must be allowed at the ends of the car to allow them to gain access of the footpath;
- directional guiding sign should be provided to guide people to the accessible parking;
- international signage should be painted on the ground and also on a signpost/board near it;
- wheel stopper should be provided to avoid vehicles to occupy spaces on the pedestrian footpath.

[11] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.16.2 pg no56

15.8.2 Drop-Off / Boarding Points[12]

- drop-off/boarding point should be provided near to the entrance. It should be marked by wheelchair (access) symbol painted on the floor and put on a pole of height 2m;
- the drop-off point should be level, with a firm surface;
- drainage gullies, siting manholes etc should be avoided as it could become hazardous;
- direct transfer onto footpath must be avoided, if not possible. Footpath of at least 2000mm wide must be provided at the drop-off point.

15.8.3 Street Design

15.8.3.1 Footpath

- height of the kerb at the edge should not exceed the height of standard public step riser , i.e. 150mm;
- clear walking zone should be at least 1800mm wide in order to accommodate wheelchair user;
- the minimum 1.8 m (width) *2.2 m (height) walking zone should be clear off all the obstructions- both horizontally and vertically;
- within the “walking zone” there should not be any utility ducts, electric, water or telecom boxes, signage and any kind of obstruction;
- a clear height of 2.2m is required for entire width of the footpath walking zone.

15.8.3.2 Kerbs

- maximum height of the pavements including kerbs, walking surface, top-of-paving should not exceed 150mm from the road level;
- Maximum corner radius of kerb should be 12m;
- kerb ramps are cut back into the footpath (flush with roadways), at a gradient not greater than 1:12;
- width of the kerb ramp should not be less than 1200mm;
- kerb ramp should have a flared sides providing transition in three directions;
- at street intersection and turnings kerb ramps should be provided;
- tactile warning strip should be provided on the kerb edge of the slope , so that person with vision impairment do not accidently walk into the road.

15.8.3.3 Subway and Foot Over Bridge

- provision of signage at strategic location;
- provision of slope ramps or lifts at both the ends to enable wheelchair accessibility;
- ensuring that the walkway is at least 1500 mm wide;
- provision of tactile guiding and warning paver along the length of the walkway;
- keeping the walkway; free from any obstructions and projections; and

[12] IRC 103:2012, Guidelines for Pedestrian Facilities. 6.16.3 pg no59

- providing for seats for people with ambulatory disabilities at regular intervals along the walkway and at landings.

15.8.3.4 Car Park

- international symbol of accessibility (wheelchair sign) should be displayed at approaches and entrances to car parks to indicate the provision of accessible parking lot for persons with disabilities within the vicinity;
- directional signs shall be displayed at points where there is a change of direction to direct persons with disabilities to the accessible parking lot. Where the location of the accessible parking lot is not obvious or is distant from the approach viewpoints, the directional signs shall be placed along the route leading to the accessible parking lot;
- accessible parking lot should be identifiable by the International Symbol of Accessibility. The signs should not be obscured by a vehicle parked in the designated lot;
- vertical signs shall be provided, to make it easily visible, the sign should be at a minimum height of 2100 mm.

15.8.3.5 Accessible Car Parking Lot

- the accessible car parking lot should: Have minimum dimensions 5000 mm × 3600 mm;
- have a firm, level surface without aeration slabs; Wherever possible, be sheltered;
- Where there are two accessible parking bays adjoining each other, then the 1200 mm side transfer bay may be shared by the two parking bays;
- the transfer zones, both on the side and the rear should have yellow and while cross-hatch road markings;
- two accessible parking lots shall be provided for every 25 no of car spaces.

15.8.3.6 Drop Off and Pick Up Areas

- designated drop-off and pick-up spaces, to be clearly marked with international symbol of accessibility;
- kerbs wherever provided, should have kerb ramps.

16 SECURITY MEASURES FOR A METRO SYSTEM

16.1 INTRODUCTION

Metro system functions in inherently open environments and is becoming increasingly important for urban areas to prosper in the face of fact challenges such as reducing congestion and pollution. It also provides ease of access gathers huge volume of people in limited areas to provide passengers with efficient and convenient transportation system through various regions. These unique attributes make metro system more vulnerable to adversarial targeting and threats. Hence, security plays vital role in helping public transport system to become the mode of choice and manage the risk of their environments. Quality in security is prerequisite for Metro system for mounting its ridership. Security model has to keep pace with new metro network and changing security scenario.

16.2 PURPOSE OF SECURITY PLANNING AND MEASURE

This defines the process for addressing safety, security and emergency preparedness as:

- **System Security** – The application of operating policies and procedures to reduce vulnerability to security threats.
- **Emergency Preparedness** – The system of policies and procedures that assure rapid, controlled, and predictable responses to a wide variety of safety and/or security incidents.
- **System Safety** – The application of operating policies and procedures to reduce vulnerability to safety-related hazards.

16.3 STAGES OF SECURITY

There are four stages of security for resolving critical incidents in and around metro system. Critical Incidents could include accidents, natural disasters, sabotage, civil unrest, hazardous materials spills, criminal activity, or acts of terrorism. Regardless of the cause, critical incidents require swift, decisive action to protect life and property. The figure below (Figure 16.1) shows the various stages of security requirements while critical incidents.

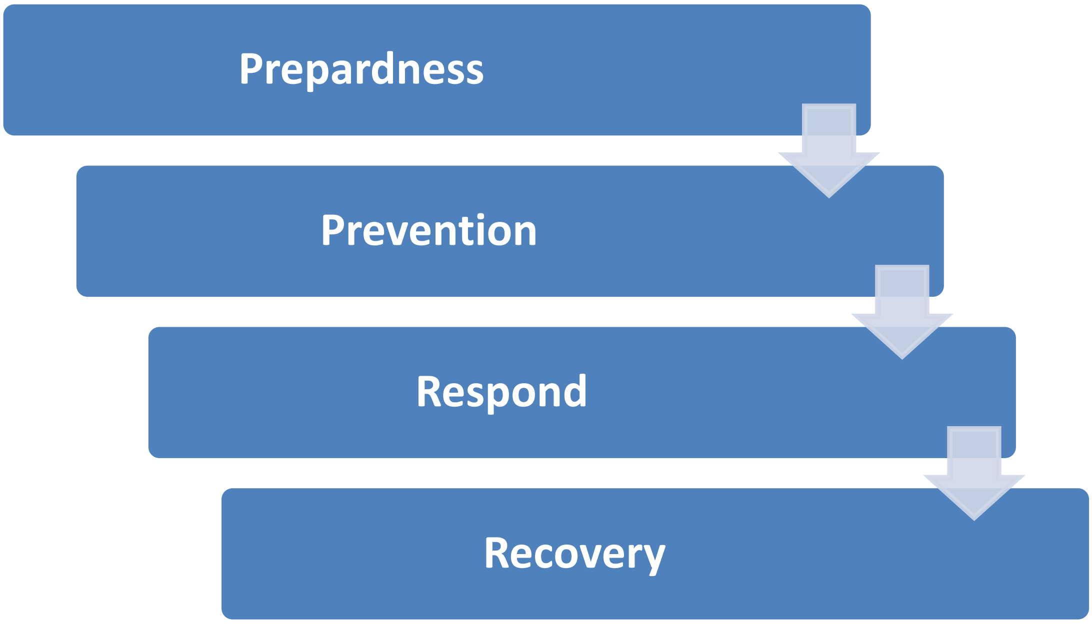

Figure 16.1: Flow Chart of Various Stages

16.3.1 Stage 1- Preparedness

Safety addresses the day-to-day problems of commuting passengers in the metro system safely and without accidents. All the safety measures and plans must be prepared to respond to critical incidents and identify assets essential for completion of incident. Security should deals with whole transit system and the potential for threats against it.

16.3.2 Stage 2- Prevention

There are various measures which can eliminate a security incidence from taking place. The various risks can be identified by conducting risk assessment and gathering intelligence. And other major prevention method is through risk reduction. Risk reduction reviews current methods of threat and vulnerability resolution and establish procedures to

- eliminate;
- mitigate;
- transfer, and/or
- accept specific risks.

Prioritization of security remediation measures are based on risk analysis. Prevention starts with the good operations of security within metro system.

16.3.3 Stage 3- Response

React quickly and decisively to critical incidents by focusing on life safety, property protection and Stabilization of Incident.

Security team should make all efforts to ensure that, they are confronted with a major emergency. Team personnel will respond effectively, using good judgment, ensuring due diligence, identify procedures and exercise through drills and training. The response preparation shall also include the following

- One shall coordinate with local law enforcement agencies and other public safety agencies to handle response to any incident that occurs on a transit vehicle or at transit stations, and
- Process for integrating resources and capabilities shall be identified to support the management of a major safety or security event affecting the community.

16.3.4 Stage 4- Recovery

Quick recovery of service from critical incidents is very important for metro system operations as well as it should reassure the passenger's confidence to continue the usage of system by replacing and repairing the critical assets. Recovery should also assess incident response and make changes based on lessons learned for future. Recovery process needs to address about the disaster recovery process, which will include the following:

- establishing continuity of operations;
- resumption of normal operations;
- preparation of an after action report;
- counselling for impacted employees, and
- initiation of long term recovery.

16.4 MEASURES FOR SECURITY SYSTEM

Security measures are going into place to help keep passengers safe on TBK metro system.

Availability of dedicated security force. The police force should be flexible to approach and meet different stations by maintaining balance between facilitation and control;

Provision of Multi-tier security check at all stations for metal detection;

Dedicated bomb detection and disposal squads and quick reaction team for effective response during emergencies/ contingencies need be available with security agency.

Deployment of security personnel shall be at outer access point, concourse level, checking points, platforms, station control rooms and tracks for security of passengers.

All metro stations need to be under CCTV surveillance (Figure 16.2). With provision of monitoring in centralised security control room along with station security room, with computer access to internet.

Figure 16.2: CCTV surveillance

At least one baggage scanner (Figure 16.3) has to be provided at all the entry gates of station for proper screening of baggage's. Depending on footfall at stations and interchanges, additional requirement of baggage scanner can be determined.

Figure 16.3: Baggage scanner

Multi-zone Door Frame Metal Detector (MDFMD) (see Figure 16.4) is empowered with state of the art technology, which facilitates detection of both ferrous and non-ferrous metals. These walk through metal detectors can easily detect metal that is concealed on human body as well as concealed in containers. All the crucial technical components like Search Coil, Control Modules etc. are embedded in door frames. MDFMD is based upon the principals of electromagnetic induction. Minimum 3 per entry or 2 per AFC array. The number can vary on level of footfall at stations.

Figure 16.4: Multi-zone Door Frame Metal Detector

Provision of Hand held metal detectors (HHMD) (see Figure 16.5) plays a vital role in deducting metal inclusions hidden within the object or presence of metal nearby. General features of it are designed for low enforcement security & policing, detect all Metals both ferrous and non-ferrous, auto balancing with push button operation, highly sensitive & auto tune to every application. Minimum two HHMD per entry is required for both men and women queues, which varies from station to station with at leasr 1.5 per DFMD installed at stations.

Bomb detection equipments are required at all the station with security agencies for to determine whether a container or object contains explosive material. For every 25 to 30 metro stations one bomb deduction security team will be required.

Figure 16.5: Hand Held Metal Detectors

In all metro stations, terminals, depots at least one bomb Suppression blanket (BSB) (see Figure 16.6) and Blast Containment Ring (BCR) need to be provided which will protect from explosion.

Figure 16.6:Blast Containment Ring

Search lights (see Figure 16.7) are required at all the stations to use at the time of critical incidents.

Figure 16.7: Search Lights

For all the member in security team, wireless sets need to be provided.

Bullet Proof Steel Morcha (BPSM) (Figure 16.8) is majorly used for the protection from bullets and it replaces the Sand Bags. In all the metro stations for every security check point at point of entry one BPSM is required.

Figure 16.8: Bullet Proof Steel Morcha

Bullet proof jackets and helmets for quick reaction team are required. One team for every 5 stations.

For senior security officers and control rooms provisions like mobile phones, land lines and EPBX phone connections shall be provided.

One ladies frisking booth for security check along with bullet proof morcha.

Physical barriers for queue managing at ticketing areas to avoid bunching.

At main entrance staircases for proper segregation has to be provided through iron grills

Proper design of emergency staircases and fireman entry to prevent unauthorised entry and exits.

Dedicated panel of police force for all the stations with security arrangements is required to tackle crimes related issues.

All the entry and exit of the stations should be under surveillance of CCTV cameras.

Lighting patterns should overlap so that no area is dependent on a single luminaire and to eliminate dark spaces, corners and shadows.

Security lighting layout and the maintenance, inspection and repair protocols should be incorporated into the facility’s security plan.

Illuminate objects, people and spaces to allow observation and identification.

Protect lighting by installing protective covers over lamps, and place lamps on poles out of the reach of passengers.

Provide primary, auxiliary or redundant power sources to lighting.

Landscape design, fences and other facility features should not obstruct lighting. Trees and other landscaping should be coordinated with the lighting system and pruned to permit illumination below the canopy.

Illuminate all vehicle and pedestrian entrances in parking facilities.

Building doorways should be individually illuminated to reduce or eliminate shadows that may be cast by other light sources.

Use the minimum light levels required and choose efficient luminaires and lamps.

Reduce light pollution, sky glow, light trespass and glare as much as possible.

Protective lighting should be installed to protect areas and critical infrastructures, such as communications and power systems.

16.5 MANAGEMENT AUTHORITY AND LEGAL RESPONSIBILITIES

Security would be the responsibility of the State as it is a sovereign function. Security in public places requires clear policies and governance framework. In this development of new metro system, the responsibility of the state government to ensure the public for secured travel in the MMRDA metro system.

17 ENVIRONMENTAL IMPACT ASSESSMENT

17.1 BACKGROUND

Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse.

17.2 OBJECTIVE

The objective of EIA study is to assess the following components.

- To determine the baseline quality of various environmental components along the proposed corridor.
- To establish the general nature and categorization of potential impacts due to the project activities.
- To identify suitable Mitigation measures for all the potential impacts envisaged due to the proposed project
- To formulate an effective Environmental Management Plan for ensuring successful implementation of all the measures suggested during various stages of the project to avoid, mitigate or minimize the adverse impact due to the project.
- To prepare an Environmental Impact Assessment Report containing the above points

17.3 METHEDOLOGY

The EIA study mainly comprises of three stages as presented in Table 17.1.

Table 17.1: EIA Study Stages

Stage 'A'	Determination of Baseline conditions.
Stage 'B'	Assessing the impacts on the environment due to the construction and operation of the project and recommendations on preventive measures to be taken to minimize the impact on the environment to acceptable levels
Stage 'C'	Preparation of EIA document containing Environment Management Plan

17.3.1 Baseline Data

The compilation of environmental baseline data is essential to assess the impact on environment due to the project activities. The environment includes water, land, air, ecology, noise, socio – economic issues etc. The baseline environmental conditions are reviewed by collecting data through literature survey, desk research and other secondary sources. Most of the data on water quality, soil, vegetation, meteorology, air and noise quality had been collected for the year 2015 and 2016. Following major components of field are studied:

- **Physical Environment**

Physical presence of environmental components such as land use pattern, water resources, drainage condition, historical and archaeological sites, polluting industries, sensitive areas, plantations, etc were marked. Strip map database is prepared by precisely locating the details along the corridor of impact to characterise the environmental sensitivity of the feature for the EIA.

- **Natural Environment**

Trees on the corridor which may be affected due to proposed cut were counted. Other details such as type of trees and girth size have been collected. Any impacts on movement of animals, breeding grounds are also noted.

- **Measurement Of Environmental Quality**

Study of existing ambient air quality, surface and ground water quality, ambient noise level and soil characteristics at various locations along the existing alignment have been carried out.

- **Ambient Air Quality**

The Ambient Air Quality in terms of Suspended Particulated Matter (SPM), Respirable Particulated Matter (PM10), Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx), has been collected from MPCB (Maharashtra Pollution control board) for major locations along the Project corridor from August 2015 to February 2016 by following the guidelines of CPCB and the requirement of MoEF.

- **Water Quality**

Water Quality for surface water has been measured at various locations along project corridor has been collected from MPCB (Maharashtra Pollution control board) published data following the guidelines of CPCB and IS: 10500 for drinking water standard.

- **Ambient Noise Level**

Noise levels data was collected from MPCB published data for various locations in Thane, Bhiwandi and Kalyan along project corridor for normal and festival days.

17.3.2 Assessing The Impact

Impact Analysis includes the following stages.

- **Analysis of Data**

The collected data was then analysed comparing with different statutory norms. The impact of the project on environment was assessed in relation to this existing environmental quality.

- **Impact Identification**

Impact during construction and operation phase due to different project activities was identified and expressed through matrix methods.

- **Mitigation Measures and EMP**

The project document was reviewed from environmental perspective both for construction phase and operation phase. Mitigation measure for environmental control was studies and then further activities have been suggested as appropriate for the case. An Environmental Management Plan has been developed based on the above studies and mitigation measures.

EMP defines the responsibilities for different project groups and present documentation details.

17.3.2.1 Legislation, Policies and Legal Frame Work

The Government of India has enacted nearly 30 ‘Environment Conservation Laws and Acts’. Some of these are: Wildlife (Protection) Act 1972; Forest (Conservation) Act 1980; Water (Prevention and Control of Pollution) Act 1974, Air (Prevention and Control of Pollution) Act 1981; 1988 Amendment of Motor Vehicle Act (M.V.) Act, 1939 and Environment (Protection) Act (EPA) 1986.

Environment (Protection) Act, 1986 is widely regarded as a comprehensive / umbrella legislation for environment in its entity and it provides measures for protection of environment and aims at loopholes in the other related Acts. The other Acts and Rules related to environment in India, such as Air and Water Acts were brought under this umbrella legislation.

17.4 STUDY AREA CHARACTERISTICS

17.4.1 PRESENT TRANSPORT SCENARIO OF THANE – BHIWANDI - KALYAN

With rapid strides in economic development particularly in urban areas, the need for rationalising and upgrading the transport system is imperative. In the process of development, there has been intensive use of natural resources. Very often the process of development has adversely affected the environment, leading to ecological imbalances. The importance of conserving and enhancing the environmental assets has assumed urgency. The conservation of flora and fauna and planning urban transportation is an important aspect of eco development.

Thane is located at Latitude 18o 42’ 20’’N, Longitude 72o45’73’’E in northern Maharashtra state in western India. The headquarters of the District is the City of Thane. Other major cities in the District are Navi Mumbai (formerly New Bombay), Kalyan-Dombivali, Mira-Bhayander, Bhiwandi, Ulhasnagar, Ambarnath, Kulgaon-Badlapur, Dahanu, Shahapur, Wada and Vasai-Virar. This is the third-most industrialized District in Maharashtra. The area of the District is 9558 km². It has coastal line of about 113 Km. The shape of the District is triangular. The District is bounded by Pune and Ahmadnagar on the east, Nashik on the east and northeast, Valsad District of Gujarat state and Union Territory of Dadra and Nagar Haveli on the north. The Arabian Sea forms the western boundary, while it is bounded by Mumbai City District and Mumbai Suburban District on the southwest and Raigad District on the south. Thane is about 25 Km from the international airport and 35 Km from the main down town of Mumbai City. The location map of proposed project area is shown below.

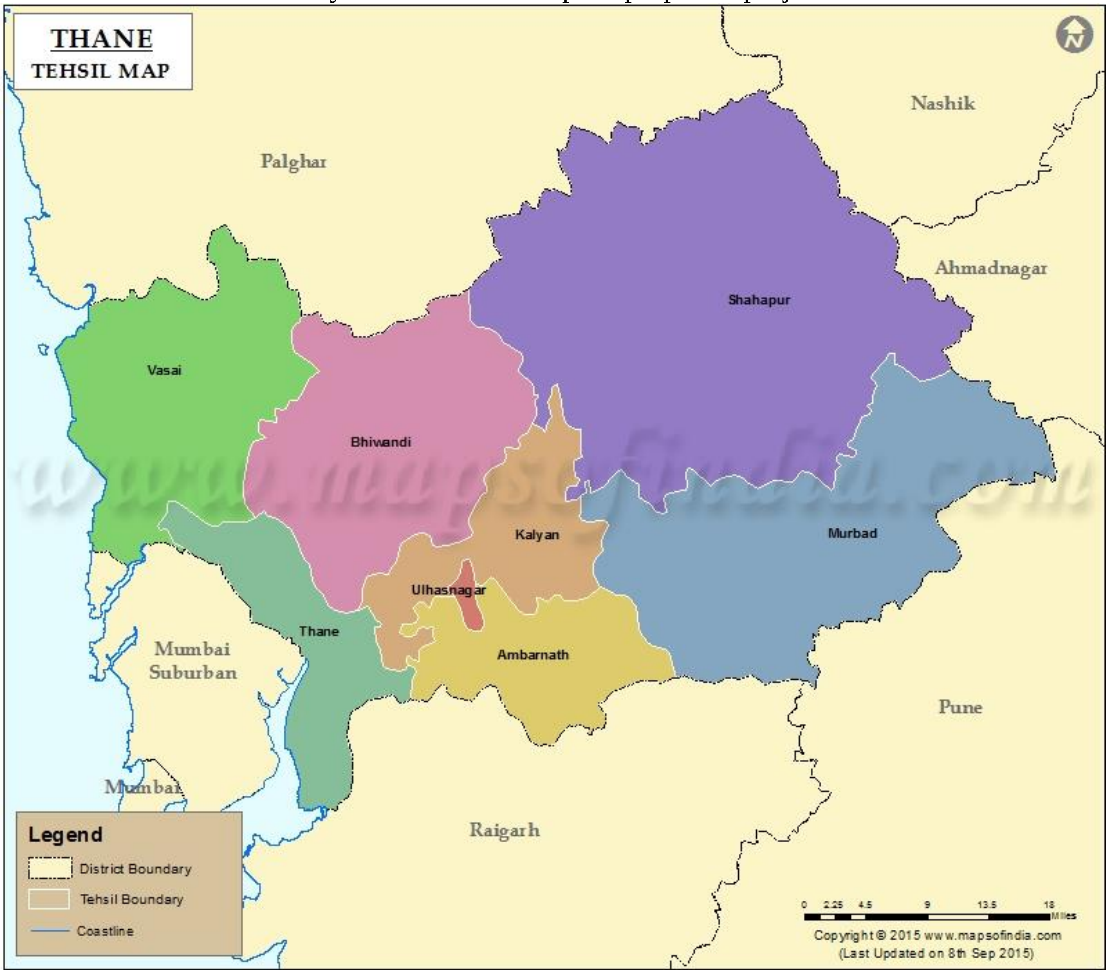

Figure 17.1:Project Location Map

The Thane Municipal Corporation started its own public transport service known as the Thane Municipal Transport (TMT) from February 9, 1989. The TMT has a fleet of 289 buses which ply on 45 routes from 2 bus-depots and 8 bus-stands ferrying approximately 2.8 lakhs commuters daily. The Kalyan Dombivali Municipal Corporation also runs its own Kalyan-Dombivali Municipal Transport (KDMT) service. Maharashtra State Road Transport Corporation (MSRTC) buses connect Thane city to different parts of the district and also to other districts. BEST provides services to Suburban Mumbai, Thane city and Mira Bhayander. Local trains have now started plying from Chhatrapati Shivaji Terminus, Mumbai to Panvel on this network. Dahanu, Satpati, Mahim. Kalyan, Vasai, and Uttan are the ports on the Arabian Sea coast. Ferry services are available between these ports. Metered Auto Rickshaws ply in Thane, Mira-Bhayander and several other towns. Metered Taxi services are also available in Thane, Mira-Bhayander and some other towns.

17.5 BASELINE DATA OF ENVIRONMENT

17.5.1 Seismicity

In the seismic zone map of India prepared by Bureau of Indian Standards (BIS code: IS 1893: Part-1:2002), The seismic zoning map of India divides India into 5 seismic zones (Zone 1, 2, 3, 4 and 5). According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity. The city of Thane – Bhiwandi - Kalyan falls in Zone 3 (Figure 17.2). This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII. The IS code assigns zone factor of 0.16 for Zone 3. MSK scale describes the impact as ‘Felt by most indoors and by many outdoors.

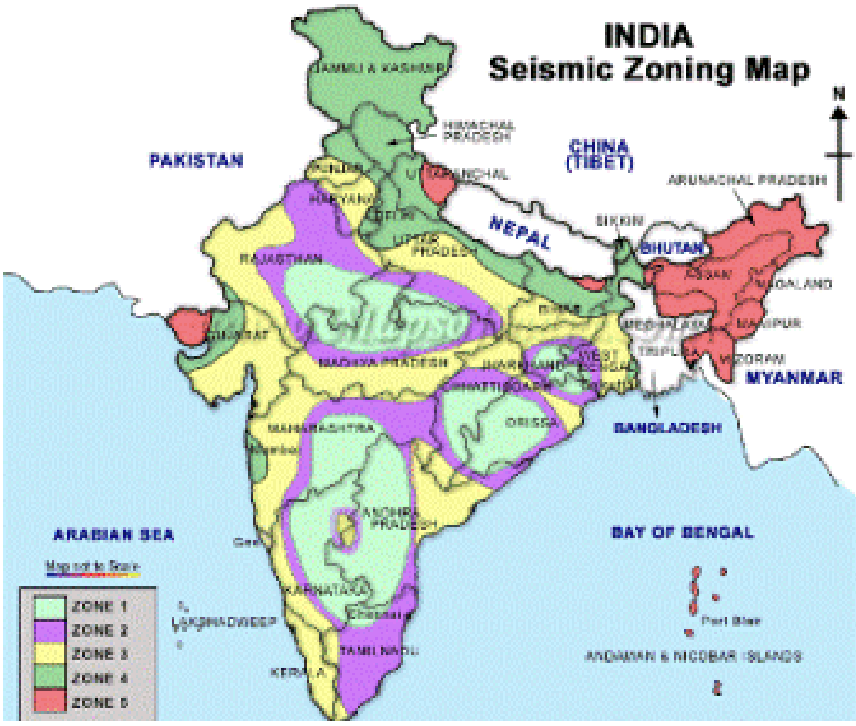

Figure 17.2: Seismic Zoning Map of India

A few persons lose their balance. Many people are frightened and run outdoors. Small objects may fall and furniture may be shifted. Dishes and glassware may break. Farm animals may be frightened. Visible damage to masonry structures -cracks in plaster. Isolated cracks on the ground’. Comparing with Modified Mercalli intensity scale, Zone 3 can have earthquake of 5 to 5.9 Richter magnitudes near the epicentre of the earthquake.

A mild earthquake struck the Ambarnath-Kalyan Region near Mumbai, Maharashtra, on 14 June 2005. It had a magnitude of M 3.7 and was felt in many towns of the Region as well as in suburban Mumbai. It was the strongest earthquake in the Mumbai Region since the M 3.8 Taloje earthquake of 1998 which was felt strongly in the Mumbai and Navi Mumbai areas. Suitable seismic factor of recommended civil engineering designs need to be appropriately incorporated while finalizing civil structures.

17.5.2 Meteorology

Meteorology is an important parameter in environmental impact assessment exercise. It is responsible for the movement of air and air pollutants. The main parameters are: temperature, humidity, rainfall, winds and cloud cover. A brief description of meteorological data and air environment of the area is discussed in subsequent sections. The meteorological data collected from Indian Meteorological Department (IMD) and other secondary sources to represent the metrological conditions of the project area has been reviewed and presented in subsequent paragraphs.

Climate: There are two distinct climates in the district, one on the western coastal plains and the other on the eastern slopes of Sahyadri. The climate on the western coastal plains of Thane, Vasai, Palghar and Dahanu talukas is tropical, very humid and warm. The climate on the plains at the foot of the slopes (Kalyan, Bhiwandi, Vada, Ulhasnagar, Ambarnath and Talasari talukas) and on the eastern slopes of Sahyadri (Murbad, Shahapur, Jawhar, Vikramgad and Mokhada talukas) is comparatively less humid. The temperature variation is more in the eastern part of the district comparing to the western coastal areas.

Season: The district has four seasons. Winter is from December to February, followed by summer from March to June. The southwest monsoon season is from June to September. October and November months constitute the post-monsoon season, which is hot and humid in the coastal areas.

Temperature: In the coastal area, the average daily maximum temperature in summer is 32.9 °C (maximum recorded at Dahanu is 40.6 °C on 19 April 1955) and in winter average mean daily minimum temperature is 16.8 °C (minimum recorded at Dahanu is 8.3 °C on 8 January 1945). But in the interior parts of the district, the average daily minimum temperature is slightly lower in the winter season and the average daily maximum temperature is higher in the summer.

Relative Humidity: In the monsoon (June – September), the relative humidity varies from 76.60% to 91.10%. Between November to January i.e. during winter, the relative humidity varies from 47.68% to 77.23%. Owing to the proximity of the sea the District is on the whole very humid nearly all the year round.

Rainfall: The average annual rainfall in the district is 2293.4 mm. The rainfall in the district increases from the coastal areas to the interior. The rainfall varies from 1730.5 mm at Mahim on the coast to 2588.7 mm at Shahapur in the interior. The rainfall during the southwest monsoon season, June to September, constitutes about 94% of the annual rainfall. July is the wettest month with a rainfall of about 40% of the annual total. The variation in the annual rainfall from year to year in the district is not large.

17.5.3 Air Quality

The Ambient Air Quality in terms of Suspended Particulated Matter (SPM), Respirable Particulated Matter (PM10), Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx), has been collected from MPCB (Maharashtra Pollution control board) for major locations along the Project corridor from August 2015 to February 2016.

The data has been collected from various locations in Thane, Bhiwandi and Kalyan as shown in Table 17.2.

Table 17.2: Locations for Air Quality

City	Number of location	Locations
Thane	3	1) Balkum, 2) Naupada, 3) Kopri
Bhiwandi	2	1) Prematai Hall, 2) IGM Hospital
Kalyan	1	1) MPCB RO Kalyan office

The data show that desirable limits for particulate matters were crossed rarely and the average values nearly all remained within limits. Sulphur dioxide levels remained very low, highest value being 53 µg/m3 for one day only with an average being 34 µg/m3. Nitrogen oxide levels were optimum near the 50% level of the permissible limit. But the RSPM has crossed the limits with an average around 120 µg/m3 in Thane district while it is around 60 µg/m3 in Bhiwandi and Kalyan districts. SPM has also crossed the desired limits in Bhiwandi and Kalyan districts with an average of 130 µg/m3. The National Ambient Air Quality Standards laid down by Ministry of Environment and Forest (MoEF) in 16th November 2009 are compiled in Table 17.3.

The air quality standards along with the project site air quality statistics with respect to prior specified locations is given below from Table 17.4 to Table 17.6.

Table 17.3: Air Quality Standards

Pollutants	Time-weighted average	Residential, Rural & other Areas	Ecologically Sensitive Areas Notified by GOI
SulphurDioxide (SO_2)	24 hours	80 µg/m^3	80 µg/m^3
Oxides of Nitrogen as (NOx)	24 hours	80 µg/m^3	80 µg/m^3
Respirable Particulate Matter (RPM) (size less than 10 microns)	24 hours	100 µg/m^3	100 µg/m^3
PM 2.5 microns	24 hours	60 µg/m^3	60 µg/m^3

Table 17.4: Ambient Air Quality in Thane

Naupada				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
August				
1	05-08-2015	31	56	62
2	06-08-2015	28	61	91
3	12-08-2015	26	58	94
4	13-08-2015	28	63	67
5	19-08-2015	25	55	76
6	20-08-2015	26	58	73
7	26-08-2015	29	62	59
8	27-08-2015	29	56	63
September				
9	02-09-2015	27	59	98
10	03-09-2015	31	57	88
11	09-09-2015	31	66	71
12	10-09-2015	34	60	66
13	16-09-2015	34	61	48
14	17-09-2015	31	62	55
15	23-09-2015	30	67	68
16	24-09-2015	29	65	101
17	30-09-2015	30	67	97
October				
18	01-10-2015	27	66	98

Balkum				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
August				
1	01-08-2015	23	51	74
2	07-08-2015	26	58	85
3	08-08-2015	25	59	75
4	14-08-2015	24	58	92
5	21-08-2015	24	56	54
6	22-08-2015	28	57	67
7	28-08-2015	27	61	52
8	29-08-2015	26	54	56
September				
9	04-09-2015	24	57	104
10	05-09-2015	24	56	112
11	11-09-2015	26	61	85
12	12-09-2015	26	58	83
13	18-09-2015	27	59	66
14	19-09-2015	27	61	87
15	25-09-2015	26	62	95
16	26-09-2015	27	59	90
October				
17	02-10-2015	27	61	79
18	03-10-2015	26	60	83

Kopri				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
August				
1	03-08-2015	23	56	89
2	04-08-2015	29	55	79
3	10-08-2015	26	66	55
4	11-08-2015	30	62	93
5	17-08-2015	27	65	58
6	18-08-2015	31	59	71
7	24-08-2015	27	63	62
8	25-08-2015	34	61	40
9	31-08-2015	25	57	70
September				
10	01-09-2015	29	57	104
11	07-09-2015	29	64	78
12	08-09-2015	33	60	73
13	14-09-2015	32	64	53
14	15-09-2015	36	66	54
15	21-09-2015	30	66	52
16	22-09-2015	34	63	61
17	28-09-2015	27	64	76
18	29-09-2015	30	63	87
October				

Naupada				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
19	07-10-2015	31	60	108
20	08-10-2015	30	63	109
21	14-10-2015	34	67	93
22	15-10-2015	32	62	89
23	21-10-2015	31	65	75
24	22-10-2015	34	64	94
25	28-10-2015	35	67	116
26	29-10-2015	35	68	85
November				
27	04-11-2015	29	59	111
28	05-11-2015	30	62	91
29	16-11-2015	25	57	147
30	17-11-2015	28	56	164
31	18-11-2015	24	52	123
32	25-11-2015	26	49	111
33	26-11-2015	23	53	116
December				
34	02-12-2015	28	55	109
35	03-12-2015	25	54	90
36	09-12-2015	30	58	117
37	10-12-2015	28	57	103
38	16-12-2015	29	58	129
39	17-12-2015	28	55	115

Balkum				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
19	09-10-2015	26	57	70
20	10-10-2015	23	55	75
21	16-10-2015	24	57	142
22	17-10-2015	25	58	137
23	23-10-2015	23	61	129
24	24-10-2015	29	59	138
25	30-10-2015	30	64	128
November				
26	06-11-2015	25	55	163
27	07-11-2015	28	59	131
28	14-11-2015	23	54	128
29	19-11-2015	25	50	131
30	20-11-2015	28	51	172
31	21-11-2015	25	52	120
32	27-11-2015	24	53	174
33	28-11-2015	24	49	153
December				
34	04-12-2015	23	50	206
35	05-12-2015	26	48	243
36	11-12-2015	22	42	215
37	12-12-2015	21	45	165
38	18-12-2015	25	44	199
39	19-12-2015	23	52	326

Kopri				
Concentration of Air Pollutants				
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3
Standards		80	80	100
19	05-10-2015	28	63	53
20	06-10-2015	29	67	69
21	12-10-2015	28	65	78
22	13-10-2015	27	67	77
23	19-10-2015	31	59	130
24	20-10-2015	28	62	149
25	26-10-2015	34	63	130
26	27-10-2015	29	62	130
November				
27	02-11-2015	27	57	139
28	03-11-2015	26	56	121
29	09-11-2015	26	57	125
30	10-11-2015	28	29	266
31	11-11-2015	33	47	320
32	12-11-2015	27	52	321
33	23-11-2015	23	53	118
34	24-11-2015	30	48	128
35	30-11-2015	27	54	180
December				
36	01-12-2015	27	46	180
37	07-12-2015	24	52	134
38	08-12-2015	27	49	168
39	14-12-2015	25	50	251

Naupada				
Concentration of Air Pollutants				
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**
Standards		**80**	**80**	**100**
40	23-12-2015	26	65	116
41	24-12-2015	23	61	123
42	30-12-2015	24	71	155
January				
43	06-01-2016	24	68	136
44	07-01-2016	24	69	144
45	13-01-2016	26	65	208
46	14-01-2016	26	71	114
47	20-01-2016	24	71	92
48	21-01-2016	27	72	106
49	27-01-2016	22	72	124
50	28-01-2016	27	70	159
February				
51	03-02-2016	24	76	136
52	04-02-2016	26	76	168
53	10-02-2016	26	73	162
54	11-02-2016	25	68	121
55	17-02-2016	23	84	132
56	18-02-2016	26	69	107
57	24-02-2016	24	78	108
	Minimum	22	49	48
	Maximum	35	84	208
	Average	28	63	107

Balkum				
Concentration of Air Pollutants				
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**
Standards		**80**	**80**	**100**
40	25-12-2015	22	57	165
41	26-12-2015	24	64	213
January				
42	01-01-2016	22	64	147
43	02-01-2016	20	60	243
44	08-01-2016	17	56	224
45	09-01-2016	20	60	230
46	15-01-2016	18	60	167
47	16-01-2016	24	75	125
48	22-01-2016	20	63	201
49	23-01-2016	21	63	186
50	29-01-2016	19	62	253
February				
51	05-02-2016	22	63	206
52	06-02-2016	22	63	251
53	12-02-2016	23	67	126
54	13-02-2016	24	64	127
55	19-02-2016	20	64	142
56	20-02-2016	22	62	121
57	26-02-2016	19	68	182
	Minimum	17	42	52
	Maximum	30	75	326
	Average	24	58	142

Kopri				
Concentration of Air Pollutants				
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**
Standards		**80**	**80**	**100**
40	21-12-2015	21	51	196
41	22-12-2015	24	65	189
42	28-12-2015	20	58	214
43	29-12-2015	23	71	240
January				
44	04-01-2016	19	68	229
45	05-01-2016	21	73	235
46	11-01-2016	21	71	245
47	18-01-2016	20	71	131
48	19-01-2016	22	66	169
49	25-01-2016	22	72	200
50	26-01-2016	23	68	179
February				
51	01-02-2016	22	66	270
52	02-02-2016	21	75	195
53	08-02-2016	23	78	179
54	15-02-2016	24	75	213
55	16-02-2016	26	73	198
56	22-02-2016	24	72	127
57	23-02-2016	25	66	139
	Minimum	19	29	40
	Maximum	36	78	321
	Average	27	62	142

Table 17.5: Ambient Air Quality in Bhiwandi

Prematai Hall						IGM Hospital					
Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3	S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3
Standards		80	80	100	60	Standards		80	80	100	60
August						August					
1	06-08-2015	33	43	82	128	1	01-08-2015	32	42	79	132
2	07-08-2015	34	44	77	132	2	02-08-2015	33	40	81	133
3	13-08-2015	35	39	78	129	3	08-08-2015	35	38	81	134
4	14-08-2015	33	39	81	132	4	09-08-2015	33	39	79	126
5	20-08-2015	32	42	79	134	5	16-08-2015	33	38	83	127
6	21-08-2015	33	41	80	135	6	17-08-2015	34	42	79	126
7	27-08-2015	33	43	77	134	7	22-08-2015	34	41	83	123
8	28-08-2015	34	41	81	133	8	23-08-2015	33	39	78	128
September						September					
9	05-09-2015	35	47	68	135	9	03-09-2015	37	51	66	136
10	06-09-2015	35	47	66	125	10	04-09-2015	36	53	67	137
11	12-09-2015	35	47	68	121	11	08-09-2015	36	51	69	139
12	13-09-2015	35	47	67	115	12	09-09-2015	36	50	68	137
13	17-09-2015	33	47	67	124	13	19-09-2015	36	51	69	138
14	18-09-2015	35	48	67	123	14	20-09-2015	35	52	69	139
15	25-09-2015	35	47	67	139	15	22-09-2015	36	52	68	141
16	26-09-2015	36	48	67	125	16	23-09-2015	36	51	67	138
October						October					
17	04-10-2015	39	47	65	129	17	01-10-2015	30	51	64	136
18	05-10-2015	38	47	65	134	18	02-10-2015	31	53	61	137
19	10-10-2015	38	47	66	134	19	08-10-2015	31	51	61	139

Prematai Hall						IGM Hospital					
Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3	S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3
Standards		80	80	100	60	Standards		80	80	100	60
20	11-10-2015	37	47	65	134	20	09-10-2015	30	50	62	137
21	17-10-2015	37	47	65	135	22	16-10-2015	32	52	62	139
22	18-10-2015	37	48	65	134	23	21-10-2015	31	52	61	141
23	26-10-2015	35	47	67	138	24	22-10-2015	32	51	62	138
24	27-10-2015	37	48	66	136	26	29-10-2015	32	30	62	138
November						November					
25	04-11-2015	38	42	66	133	27	06-11-2015	37	41	76	136
26	05-11-2015	36	39	62	126	28	07-11-2015	35	43	75	137
27	08-11-2015	36	42	59	121	29	11-11-2015	36	43	79	138
28	09-11-2015	33	42	63	117	30	12-11-2015	36	44	79	136
29	15-11-2015	36	40	63	124	31	20-11-2015	36	41	74	138
30	16-11-2015	38	42	63	123	32	21-11-2015	36	39	77	139
31	23-11-2015	32	42	61	138	33	27-11-2015	35	42	78	141
32	24-11-2015	37	43	59	125	34	28-11-2015	36	42	78	137
January						December					
33	01-01-2016	30	40	65	131	35	03-12-2015	29	41	66	131
34	02-01-2016	27	43	64	131	36	04-12-2015	28	41	65	133
35	10-01-2016	30	42	62	132	37	08-12-2015	29	41	66	131
36	11-01-2016	26	44	64	130	38	09-12-2015	28	41	65	133
37	17-01-2016	29	41	64	130	January					
38	18-01-2016	35	45	64	133	39	03-01-2016	30	41	62	131
39	22-01-2016	30	41	64	131	40	04-01-2016	28	41	65	133
40	23-01-2016	29	40	61	132	41	08-01-2016	53	42	66	141

Prematai Hall						IGM Hospital					
Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**	**S.No.**	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**
Standards		**80**	**80**	**100**	**60**	**Standards**		**80**	**80**	**100**	**60**
41	29-01-2016	29	44	64	130	42	09-01-2016	29	42	64	130
42	30-01-2016	28	42	64	130	43	15-01-2016	29	42	62	125
	-	-	-	-	-	44	16-01-2016	30	42	65	121
	-	-	-	-	-	45	24-01-2016	34	42	66	131
	-	-	-	-	-	46	25-01-2016	29	40	65	134
	Minimum	26	39	59	115		**Minimum**	28	30	61	121
	Maximum	39	48	81	139		**Maximum**	53	53	83	141
	Average	34	44	67	130		**Average**	33	44	69	134

Table 17.6: Ambient Air Quality in Kalyan at MPCB RO Kalyan office

Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**	**S.No.**	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**
Standards		**80**	**80**	**100**	**60**	**Standards**		**80**	**80**	**100**	**60**
August						**November**					
1	04-08-2015	35	43	76	130	27	02-11-2015	31	36	67	133
2	05-08-2015	35	41	74	128	28	03-11-2015	32	36	66	134
3	10-08-2015	34	43	77	129	29	13-11-2015	36	36	66	130
4	11-08-2015	33	42	75	132	30	14-11-2015	35	36	63	131
5	18-08-2015	34	42	74	133	31	18-11-2015	30	36	66	135
6	19-08-2015	35	43	77	128	32	19-11-2015	29	35	63	134
7	25-08-2015	34	42	74	128	33	26-11-2015	27	36	66	138

Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**	**S.No.**	**Date**	**SO2 µg/m3**	**Nox µg/m3**	**RSPM µg/m3**	**SPM µg/m3**
Standards		**80**	**80**	**100**	**60**	**Standards**		**80**	**80**	**100**	**60**
8	26-08-2015	35	42	75	133	34	27-11-2015	26	37	63	130
September						35	29-11-2015	27	36	66	138
9	01-09-2015	24	34	64	136	**December**					
10	02-09-2015	26	35	66	137	36	05-12-2015	29	41	66	131
11	10-09-2015	27	34	65	132	37	06-12-2015	28	41	65	133
12	11-09-2015	26	34	63	132	38	10-12-2015	29	41	66	131
13	14-09-2015	26	34	67	139	39	11-12-2015	28	41	65	133
14	15-09-2015	24	34	67	135	**January**					
15	28-09-2015	25	33	66	140	40	05-01-2016	29	41	66	131
16	29-09-2015	22	34	67	140	41	06-01-2016	27	43	64	132
October						42	13-01-2016	27	41	65	125
17	06-10-2015	31	36	63	136	43	14-01-2016	29	40	63	132
18	07-10-2015	29	37	63	134	44	19-01-2016	32	39	64	131
19	12-10-2015	27	38	64	130	45	20-01-2016	26	44	65	129
20	13-10-2015	26	37	63	131	-	-	-	-	-	-
21	19-10-2015	26	38	67	139	-	-	-	-	-	-
22	20-10-2015	31	34	65	134	-	-	-	-	-	-
23	23-10-2015	30	36	66	140	-	-	-	-	-	-
24	24-10-2015	31	36	65	140	-	-	-	-	-	-
25	30-10-2015	32	36	69	140	-	-	-	-	-	-
26	31-10-2015	31	38	71	141	-	-	-	-	-	-
	Minimum	22	33	63	128		**Minimum**	26	35	63	125
	Maximum	35	43	77	141		**Maximum**	36	44	67	138

Concentration of Air Pollutants						Concentration of Air Pollutants					
S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3	S.No.	Date	SO2 µg/m3	Nox µg/m3	RSPM µg/m3	SPM µg/m3
Standards		80	80	100	60	Standards		80	80	100	60
	Average	30	38	69	135		**Average**	29	39	65	132

17.5.4 Water Quality and Resources

Thane District has vast natural water resources in the form of perennial Rivers which are major source of drinking water supply. The two primary sources of water in thane district are from the river Ulhas and the Vaitarna. Ulhas River is 135 km long. Ulhas originates from the north of Tungarli near Lonavala, flows for a short distance before descending near Bhor ghat. It meets the sea at Vasai creek. The River has many tributaries; two important ones (within the boundaries of this District) are Barvi and Bhatsa. Vaitarna River is 154 km long and has a drainage area that practically covers the entire northern part of the District. It has also a number of tributaries; the most important of them are Pinjal, Surya, Daherja and Tansa. Vaitarna, the largest of Konkan Rivers rises in the Tryambak hills in Nashik District, opposite to the source of Godavari, The River flows across Shahapur, Vada and Palghar talukas and enter the Arabian Sea through a wide estuary off Arnala.

Many small creeks are found all along the western coast. The bigger creeks are Bhiwandi, Chinchani, and Dahanu creeks. The Thane creek is not a creek in the true sense, but a depression overwhelmed by the sea. In Thane district wells, lakes, reservoirs and Rivers are the sources of water supply. The District has several lakes, but a number of artificial lakes have been constructed mainly to important dams in the District are Vaitarna, Tansa and Bhatsa where there are reservoirs. Water from the Rivers Ulhas and Barbi is supplied to the industrial belt in the south and to New Mumbai. Vaitarna Lake on the River Vaitarna has been formed behind a huge dam and feeds the City with drinking water. Another huge lake is the Tense Lake across the Tense River formed in the hills north of Bhiwandi. The entire Thane Municipal Corporation is divided into three zones for water supply. Each zone has provided the water by separate source. The water supply is through Shahad Temghar water Authority (STEM) and the current water demand in Thane Municipal Corporation is 328 MLD.

To collect the baseline data on existing quality of water resources in Thane district along the proposed transit alignment various data has been collected MPCB (Maharashtra Pollution control board) published data for the year 2015 from January to August and analysed as per the guidelines of CPCB and IS:10500 for drinking water standard. The water quality standards for surface water are provided for comparison in Table 17.7. The physio-chemical analysis of water quality from three creeks and three nallas along the project corridors was gathered. The results are given in Table 17.8.

Table 17.7: Primary Water Quality Criteria as laid down by the Central Pollution Control Board

SN	Water quality characteristics	Water Quality Class*				
		A	B	C	D	E
1	Dissolved oxygen (DO) mg/1 Min	6	5	4	4	-
2	Biochemical oxygen demand (BOD) mg/l Max	2	3	3	-	-
3	Total coliforms organism**MPN/100ml,Max	50	500	5,000	-	-
3	PH value	6.5-8.5	6.5-8.5	6.	6.5-8.5	6.5-8.5
4	Free ammonia (as N)mg/1,Max	-	-	-	1.	-
5	Electrical conductivity,	-	-	-	-	2,250
6	Sodium adsorption ratio (SAR) Max	-	-	-	-	2
7	Boron, mg/1 max	-	-	-	-	2

Class A Drinking Water Source without Conventional Treatment but after Disinfection
Class B Outdoor Bathing
Class C Drinking Water Source with Conventional Treatment Followed by Disinfection
Class D Fish Culture and Wild Life Propagation
Class E Irrigation, Industrial Cooling or Controlled Waste Disposal

Ref: Central Pollution Control Board (Ministry of Environment & Forest, Govt. of India) Environmental Standards (water quality criteria)

Table 17.8: Water quality in Thane- Bhiwandi - Kalyan

Month	pH	Dissolved Oxygen (mg/l)	B.O.D (mg/l)	C.O.D (mg/l)	Nitrate (mg/l)	Fecal Coliform (MPN/100 ml)
	Parameters					
Rabodi Nalla						
January	7.3	BDL	90	152	1.5	250
February	6.9	BDL	110	256	1.9	425
March	7	BDL	60	120	3.8	350
April	7.3	2	32	68	2.2	550
May	7.1	BDL	70	232	65.4	225
June	7.5	1	4	120	5.6	80
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.3	1.5	35	108	1.4	2.9
Colour Chem Nalla						
January	7.3	1.5	88	188	1.4	550
February	7.2	BDL	96	236	1.6	900
March	N/A	N/A	N/A	N/A	N/A	N/A
April	7.4	0.2	42	72	3.6	900
May	7.3	0.4	60	184	74.7	900
June	7.2	BDL	115	304	1.6	110
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.5	2.4	40	180	1.4	3.7
Sandoz Nalla						
January	7.4	BDL	65	144	4.4	550
February	6.9	BDL	115	288	5.6	900
March	7.4	BDL	56	144	6.3	550
April	7.7	BDL	60	116	3.9	900
May	7.4	BDL	105	312	24.9	425
June	N/A	N/A	N/A	N/A	N/A	N/A
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.4	4.4	12	44	1.9	540
Ulhas Creek at Mumbra Reti Bunder						
January	7.7	3.6	12	148	6.5	170
February	7.4	3.1	12	192	2.7	550

Month	pH	Dissolved Oxygen (mg/l)	B.O.D (mg/l)	C.O.D (mg/l)	Nitrate (mg/l)	Fecal Coliform (MPN/100 ml)
	Parameters					
March	7.4	3.8	12	128	4.3	350
April	7.6	4	12	156	6.3	425
May	7.7	4.5	12	184	63.2	250
June	N/A	N/A	N/A	N/A	N/A	N/A
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.5	5.6	7	44	2.4	140
Thane Creek at Kalwa Road Bridge						
January	7.7	3.7	11.5	176	6.9	170
February	7.9	4.4	10	208	2.6	350
March	7.7	3.5	12	136	4.5	350
April	7.6	3	14	160	6.2	250
May	7.7	5.2	12	192	66.8	250
June	N/A	N/A	N/A	N/A	N/A	N/A
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.5	5.6	7	36	2.5	220
Ulhas Creek at Kolshet Reti Bunder						
January	7.7	3.3	14.5	184	6.7	550
February	7.4	4.1	11	184	2.9	350
March	7.2	3.7	12	128	6.4	350
April	7.7	5.2	10	168	5.6	425
May	7.9	5.4	12	196	49.5	425
June	N/A	N/A	N/A	N/A	N/A	N/A
July	N/A	N/A	N/A	N/A	N/A	N/A
August	7.5	5.4	8	48	2.5	130

The water test result indicates that water is slightly alkaline with pH varying from 7.0 to 7.9 and lies within the permissible limits. Dissolved oxygen contents are slightly lower than the desired minimum content and Fecal Coliform is also in the desired limits. The results show that the water from these various Creeks/Nallas can be used for outdoor bathing purpose.

17.5.5 Geology and Soil

The hill ranges in the Area are predominantly aligned north-south and have more or less steep escarpments. Basalt flows, popularly known as Deccan traps, form the predominant formation. It is capped by laterite on a few high plateaus and covered by shore sands along the coast. A general geological sequence is Shoresand-recent, Laterite- Pleistocene and Basalt- ecocene. A generalized section of the basalt flows shows a thin amygdular flow with pipe amygdules followed by a comparatively thick massive flow capped by a highly vesicular and amygdular flow. The basalts show exfoliation by weathering into spheroidal cores. The flows at Thane were differentiated on their textural and mineralogical variations and at places by the presence of baked, reddish horizon forming the top of the flow. The flows vary from fine, to medium grained, grey to black basalts. Porphyritic flows are common. There are numerous dykes criss-crossing the area. The general trend is, however, north-northwest-south-southeast and north-northeast-south-southwest, dipping steeply to the east. The drainage is controlled by the Vaitarna, Surya and Ulhas Rivers and their tributaries.

The three main types of soils are black coloured soils occurring on plains, the lighter coloured coarse soils occupying hill-slopes (also known as varkas) and black coloured soils along the coast in the District. The coastal soils are further divided into sweet lands supporting the garden crops and the khar or saline lands which grow coarse varieties of paddy after partial reclamation. The soil of the District in general is almost neutral in reaction, free from calcium carbonate and is sandy in texture. The colloid complex is low in bases and divalentions account for more than 90 per cent of the total exchangeable bases. The soil is fairly well supplied with nitrogen but is low in phosphate and potash contents. The soil all along the coast and particularly in parts of Dahanu, Palghar and Vasai talukas, is blackish and contains sand. It is very suitable for garden crops. Towards the east the soil is red and brown. It is not very deep but is suitable for rice. Further east on the hill-slopes, the soil is poor and is used only for growing grass and coarse grains, viz., nagli and vari. In the valleys there are patches of black soil in Bhiwandi, Kalyan, Mokhada and Shahapur talukas where rice is grown in ample quantity.

As far as agriculture is concerned the soils in the District are mainly classified into three main classes, viz., coastal soils, mid-plane soils and varkas type soils. Coastal soils are further sub-divided into bagayat, sandy loam and salt paddy soils near creeks. Midplane soils are mainly derived from the trap rock and are sub-divided into late soils and mid-late soils. Varkas soils are mostly found in the far eastern part of the District.

17.5.6 Noise

Ambient Noise level quality data has been collected during the festivals of Diwali and Ganesh festival which are considered as the most noise producing festivals, from MPCB published data for various locations in Thane, Bhiwandi and Kalyan along project. It could be concluded that the noise levels recorded are higher than prescribed permissible levels during these festival time in Residential and rural areas of Thane, Bhiwandi and Kalyan. The ambient noise quality criteria laid down by CPCB has been given in Table 17.9. Noise levels for ganesh and diwali festivals are given in Table 17.10 and Table 17.11.

Table 17.9: National Ambient Noise Standards

Area Code	Category of Zones	Limits of Leq in dB(A)	
		Day*	Night*
A	Industrial	75	70
B	Commercial	65	55
C	Residential and rural	55	45
D	Silence Zone **	50	40

Day time- 6 am to 10 pm, night time - 10 pm to 6 am

Ref: Central Pollution Control Board (Ministry of Environment & Forest, Govt. of India) Environmental Standards

Rule 3(1) and 4(1) published in Gazette of India, vide S.O 123(E) dated 14.02.2000 and latest amendment on 11.10.2002 vide S.O.1088 (E), under environmental protection act.

Table 17.10: Noise Levels for Diwali Festival, 2015

	Diwali																	
	11-Nov-15						12-Nov-15						13-Nov-15					
Location	Day Time (6 am - 10 pm)			Night Time (10 pm - 6 am)			Day Time (6 am - 10 pm)			Night Time (10 pm - 6 am)			Day Time (6 am - 10 pm)			Night Time (10 pm - 6 am)		
	Leq	Min	Max	Leq	Min	Max	Leq	Min	Max	Leq	Min	Max	Leq	Min	Max	Leq	Min	Max
Shiv Mandir-in front of kopineshwar Mandir	79.4	54.6	87.6	79.6	64.5	87.3	77.4	57.3	85.3	69.4	50.3	76	75.1	48.7	84.3	68.2	46.7	73.6
Tembhi Naka - Four Way Road (Junction)	74.7	56.3	80.8	77	63.5	83.5	68.6	62.7	73.7	69.5	52.7	74.7	79.7	72.4	83.8	62.5	52.2	66.6
Pokharan - Vartak Nagar	78.8	56.8	88.2	66.9	57.2	74.6	72.3	67.2	78.2	79.4	50.3	86.3	69.7	60.7	73.4	58.5	42.3	65.2
Wagle Estate	81.4	68.3	90.7	63.1	48.2	69	75.2	57.5	80.9	69.2	57.8	74.6	77.3	57.2	83.4	68.7	54.6	75

Table 17.11: Noise Levels for Ganesh Festival, 2015

Ganesh festival															
	17-Sep-15			18-Sep-15			21-Sep-15			23-Sep-15			27-Sep-15		
Location	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Gokhale Road-Malhar Cinema	83.6	58.9	72.9	70.5	51.3	60.9	77.6	73.7	75.3	80	70.6	75.4	94.8	72.4	84
Jambli Naka- Lake immersion Point	82.3	54.7	74.3	79.6	58.3	68	82.3	73.8	78	78.8	73.1	75.3	106.3	75.6	88.3
Main Road- Gaondevi Mandir, Naupada	80.4	62.1	74.5	77.3	55.9	68.3	75.7	70.7	73	83.6	72.2	78.2	86.4	73.6	80
Pokhran Road- Vartak Nagar Chowk	83.6	63.6	75	74.5	59.6	67.2	78.9	67.9	73.8	81.2	71.5	76.5	88.6	61	75.2

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Ganesh festival															
	17-Sep-15			18-Sep-15			21-Sep-15			23-Sep-15			27-Sep-15		
Location	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**
Wagle Estate- Raila Devi Lake	78.4	58.3	66.7	71.3	54.3	63.5	81.6	65	75	76.3	66.1	72.5	92.3	70.5	78.8
Court Naka	83.9	64.9	76.9	71.9	55.5	64	83.1	71.3	77.3	78.3	71.3	74.5	86.6	61.7	74.6
Bedekar Hospital	78.6	58.4	68	77.5	52.9	62	76.4	66.8	70.8	72.6	65.4	68.7	72.6	53.6	65.1

17.5.7 Ecology

The forest area is negligible in Thane district.

17.5.8 Culture and Religious Facility

Over the whole stretch of project corridor 4 temples are covered. The chainage wise details of the temples affected are given below:

- 2 Temples at chainage 7 + 600 to the left of the corridor
- 1 Temple at chainage 22 + 050 in the middle of the corridor
- 1 Temple at chainage 23 + 300 to the left of the corridor

17.6 ENVIRONMENTAL IMPACT ASSESSMENT

17.6.1 Introduction

This section identifies and assesses the probable impacts on different environmental parameters due to planning, construction and the operation of the proposed development. After studying the existing baseline environmental scenario, initial field surveys, reviewing the process and related statutory norms, the major impacts have been identified and assessed during the design, construction and the operation phases. Metro construction related impacts occur at three stages of the project:

- Planning and Design
- Construction
- Operation

Planning and Design includes planning of the metro railway corridor alignment, elevated sections, construction details, materials of construction etc. which ultimately decides the impact during later phases. Most of the impacts are during construction and operation phase. While some of the construction phase impacts are temporary, some also are permanent. Operation phase impacts are continuous in nature. To identify these impacts broadly on physical, ecological and social environment Impact Identification Matrix are developed.

Other important criteria for identification of impact are identification of the impact zone. For present screening studies, a Corridor of Impact (COI) of 30 m width from the central alignment has been considered.

Environmental parameters are broadly classified into three groups.

- Physical Environment
- Biological Environment
- Human Environment

Physical environment includes:

- Water Resources, Water Quality, Air Quality, Noise and Land environment
- Biological Environment includes:
- Flora, Terrestrial fauna, Avifauna, Aquatic flora & fauna, Plantation

An Impact Identification Matrix for all the phases of the project is presented in Table 17.12.

Table 17.12: Impact Matrix

Project Activity Environmental Component	Realignment of Utility Lines	Earth moving	Removing trees & vegetation	Construction work	Sanitation & disposal of water from tunnel	Vehicle & machine operation & maintenance	Vehicle operation
Air & Noise		Dust Pollution		Noise, dust, air pollution	Odour	Air pollution	Noise, air pollution
Water Resources & quality	Contamination of water line, disturbance in sewerage and drainage line	Impact due to Soil Erosion	Reduced water quality	Impact on Water use, Contamination by fuel & lubricants	Contamination of local water sources	Contamination of local water sources	
Land		Dumping of earth		Solid Waste	Contamination from wastes		
Trees	Impact on trees	Impact on trees	Loss of trees & vegetation				
Cultural & Religious facility		Damage to structure		Disturbance to religious function			

17.7 Impact due to Design Phase

The major impact associated with Design or Pre-construction phase deals with loss of land, properties and livelihood due to acquisition of properties. The design phase also decides the temporary acquiring of land for construction, shifting of different utilities. These issues were studied by environmental and social specialists to minimize the impact. Besides the impact on environment and social factors, there should also be consideration for legal issues so that the project can be operated with ease.

The utilities to be impacted have been identified. The land to be acquired permanently has been identified and its impact is covered under social impact. The permanently acquired land does not include any forest land or environmentally sensitive area. The temporarily acquired lands for construction purpose and near stations have been identified and it is of around 6 hectares.

17.7.1 Impact During Construction Phase

Following sections describes the impacts during construction Phase.

17.7.1.1 Air Quality

Impacts on air quality during construction are due to generation of dust due to earth moving activities on road side, generation of dust due to excavation and handling of construction materials, emission of gaseous pollutants like sulphur dioxide, nitrogen oxides, hydrocarbon, particulates, carbon monoxide etc. from heavy vehicles and generation of dust due to movement of these vehicles. Transportation of earth and establishment of the material will involve use of heavy machinery like compactors, rollers, water tankers, and dumpers. This activity is machinery intensive resulting in dust generation.

As the construction will be carried out inside the city and mostly along the busy road sections, a large number of people will be exposed to the pollution. So mitigation of air pollution should be given priority.

17.7.1.2 Soil Erosion

Soil erosion also takes place during construction activities which involve soil excavation from the runoff from excavated areas, and underground tunnel faces. Especially construction works during monsoon season can cause such erosions more.

The prevention measures require proper guarding of excavated areas, timing of activities and proper drainage arrangements. Dumping of construction materials without planning also cause much soil erosion, choking in local drainage and pollution of water bodies. Land is also impacted from oil residues, lead and other components from running of vehicles and construction machineries. The excavated earth shall be used for landfills and can be dumped in open grounds. The disposal location will be identified later.

17.7.1.3 Noise

Noise pollution is of major concern during construction phase. Noise will be generated during construction phase from operation of heavy machineries, movement of heavy vehicles. The construction equipment will have high noise levels, and can affect the personnel operating the machines. Major part of this problem can be reduced by proper mitigation measures. Also construction phase noise is a very much temporary affair. Each type of activity can generate different type and level of noise but that continue for a short period during the construction phase.

The acceptable limits (for 8 hour duration) of the equivalent noise level exposure during one shift is 90 dB(A). Hence, noise generated due to various activities in the construction camps may affect health of the workers. For reasons of occupational safety, exposure to impulses or impact noise should not exceed 140 dB (A) (peak acoustic pressure). Exposure to 10,000 impulses of 120 dB (A) is permissible in one day. A typical Noise generation due to different activities has been given in Table 17.13.

Table 17.13: Noise Generation due to various Construction Activities/Equipments [Db(A)]

CLEARING	
Bulldozer Front end loader Dump truck Jack hammer Crane with ball	80 72 - 84 83 - 94 81 - 98 75 - 87
EXCAVATION AND EARTH MOVING	
Bulldozer Backhoe Front end loader Dump truck Jack hammer	80 72 - 93 72 - 84 83 - 94 81 - 98 80 - 93
STRUCTURE CONSTRUCTION	
Crane Welding generator Concrete mixer Concrete pump Concrete vibrator Air compressor Pneumatic tools Bulldozer Cement and dump trucks Front end loader	75 - 77 71 - 82 74 - 88 81 - 84 76 74 - 87 81 - 98 80 83 - 94 72 - 84 83 - 94
GRAND AND COMPACTING	
Grader Roller	80 -93 73 - 75
PAVING	
Paver Truck Tamper	86 - 88 83 - 94 74 - 77
LANDSCAPING AND CLEAN UP	
Bulldozer Backhoe Truck Front end Loader Dump Truck Paver	80 72 - 93 83 - 94 72 - 84 83 - 94 86 – 88

From the above given table it is evident that the operation of construction machinery e.g. hot-mixer, bulldozer, loader, backhoes, concrete mixer, etc will lead to rise in noise level to the range between 80-95 dB (A). Vehicles carrying construction materials will also act as the noise sources. The magnitude of impact from noise will depend upon types of equipment to be used, construction methods and also on work scheduling. However, the noise pollution generated due to different construction activities is a temporary affair. Each type of activity can generate different type and level of noise that continue for a short period during the operations of those activities.

Considering the stationary construction equipment as a point source generating 90 dB (A) at a reference distance of 2 m, computed distance require to meet the permissible limits during day time for different land use categories are given below in Table 17.14.

Table 17.14: Minimum Distance (m) of Operation from Stationary Construction Equipment

Category	Permissible limits in day time (CPCB)	Distance required (m)
Silence zone	50 dB (A)	200
Residential	55 dB (A)	113
Commercial	65 dB (A)	36
Industrial	75 dB (A)	11

From the above table it may be noted that residence within 113 m from the road will be exposed to a noise higher than the permissible limit. The impacts will be significant on construction workers, working close to the machinery.

17.7.1.4 Water Quality

Water is a very important resource required for flushing of piles during excavation, concreting, curing etc. The source for water supply is mainly the water from different nallas and creeks (Ulhas creek, Thane creek etc) and nearby rivers from the project site. However, proper permission from the relevant statutory authority needs to be obtained to avoid any unwanted impact on the water resource and subsequent impact on other users.

Water will also be required for human uses including drinking for the workers at workers' camp and at construction sites. This water has to be acquired from the municipal supply or from boring well to have ground water. This also will require permission from the relevant statutory authority. Laying of pavement within the formation width may lead to reduction in the ground water recharge capacity. But as the area involved in the construction is very less, the chances of this influence will be non-significant.

No permanent impact is anticipated on water quality due to the project. Construction activity may temporarily deteriorate surface water quality near the proposed alignment through increase in turbidity as well as in oil and grease. These impacts are temporary in nature and can be handled through the proposed mitigation measures. Water may have to be pumped out during excavation work to facilitate underground work. The pumped water may contain high amount of suspended solids which can pollute outside water body. This needs special care so that pumped water is settled before discharge or some filtration applied.

Two bridges over the Ulhas Creek have been proposed. The construction activities e.g. well foundation and sinking, foundation of piers etc can impact water quality due to spillage of construction materials, debris, oil from machines etc. This should be taken care during construction. The improper sanitation at work camps, depots and waste disposal can also pollute local water body

17.7.1.5 Plantation/Trees

The project corridors have trees and plantations on sides or in some stretches on the middle of the project corridor. Construction and maintenance activities can cause severe impact on these trees and plantations by removing them. This will cause also induced impact on local fauna and ecology. The loss of trees is also important for road users as these trees provide shade to the road users. The impact will depend on the number, density, and types of species of trees on each road.

The major finding of the survey is that 18 trees can be impacted in the corridor for the proposed alignment 1. Compensatory plantation near the project area needs to be carried out as detailed out in mitigation measures. With the proposed mitigation measures, there can be more trees planted as compared to existing one.

17.7.1.6 Utilities

Different types of utilities serving local and regional needs are falling under COI will need to be relocated from their present position due to the proposed widening alignment. These services are mainly lamp posts, electric poles, transformers, telephone poles, gas lines and optical fibre cables. The magnitudes of impact in each corridor on these services are presented below in Table 17.15 and Table 17.16. Such types of impacts are unavoidable.

Table 17.15: Details of Affected Light and Signal Poles

S.No.	Start Chainage in (Km)	End Chainage (in Km)	No. of light poles	No signal poles
1	0.000	1.000	27	0
2	1.000	2.000	28	0
3	2.000	3.000	18	0
4	3.000	4.000	28	0
5	4.000	5.000	30	0
6	5.000	6.000	29	0
7	6.000	7.000	28	33
8	7.000	8.000	37	0
9	8.000	9.000	16	0
10	9.000	10.000	19	0
11	10.000	11.000	20	0
12	11.000	12.000	25	0
13	12.000	13.000	12	0
14	13.000	14.000	15	0
15	14.000	15.000	11	0
16	15.000	16.000	20	0
17	16.000	17.000	25	0
18	17.000	18.000	12	0
19	18.000	19.000	24	0
20	19.000	20.000	15	0
21	20.000	21.000	12	0
22	21.000	22.000	5	0
23	22.000	23.000	12	0
24	23.000	23.607	13	0

Table 17.16: Details of Affected Telephone Poles

S.No.	Start Chainage in (km)	End Chainage (in Km)	No. of Telephone poles	No. of telephone Junction box
1	0.000	1.000	31	-
2	1.000	2.000	30	-
3	2.000	3.000	27	-
4	3.000	4.000	24	-
5	4.000	5.000	29	-
6	5.000	6.000	28	1
7	6.000	7.000	46	-
8	7.000	8.000	16	2
9	8.000	9.000	37	-
10	9.000	10.000	39	-
11	10.000	11.000	40	-
12	11.000	12.000	42	-
13	12.000	13.000	34	-
14	13.000	14.000	20	-
15	14.000	15.000	5	-
16	15.000	16.000	7	1
17	16.000	17.000	34	1
18	17.000	18.000	28	-
19	18.000	19.000	38	-
20	19.000	20.000	26	-
21	20.000	21.000	34	-
22	21.000	22.000	35	-
23	22.000	23.000	11	-
24	23.000	23.607	12	-

17.7.2 Impact During Operation Phase

After the completion of construction and the rail services along the project corridors are started, the operation phase get started. Though this rapid transport system will have significant beneficial impact on people's mobility in the city, it also will have some impact on different environmental components.

17.7.2.1 Noise

The noise will impact the people outside on the elevated part of the corridor.

17.7.2.2 Air Quality

It is expected that air quality of the city will improve and people will depend on Metro service and there will be less increase in numbers of car and buses. As Metro operation will not locally emit any air pollution, ambient air quality will be better in future.

17.7.2.3 Refuse from Stations

The station will generate solid waste from different uses of the passengers. All wastes from stations need to be disposed properly to avoid any local pollution

17.7.2.4 Traffic problem near the Stations

There will be increased traffic near the stations. All stations also will not have parking spaces. If this traffic is not managed properly it can cause both noise and air pollution locally. This should be considered for long term planning.

17.8 ENVIRONMENTAL MANAGEMENT PLAN

17.8.1 Introduction

Environmental Impact Mitigation Plan plays a vital role to ensure that the environmental qualities of the project surrounding area will not get deteriorate due to the construction and operation of the project. The set of measures to be taken during implementation and operation to avoid or offset adverse environmental impacts or to reduce them to acceptable levels, together with the action which needs to be taken to implement them are enumerated in this section. The Mitigation Plan covers all aspects of the construction and operation phases related to environment.

17.8.2 MITIGATION MEASURES

The mitigation plan needs to be implemented right from the conception stage and should continue till the end. The Plan has been divided into three phases:

- Design phase
- During construction phase and
- During operational phase.

17.8.2.1 Design Phase

During the design phase of the project, the design of different elements of the project corridor should be done with proper concern and knowledge on the impacts of the design over the existing environmental components (water supply, sewage disposal, drainage, trees, sensitive locations etc) and social components (school, hospitals, places of worship, residential areas, commercial place etc). While finalising alignments and deciding on corridor of impact, these data has been considered to minimize the impact on environment Planning shall also be done for the realignment of the underground public utility lines e.g. water supply, sewage and storm water disposal, electricity, gas, telephone lines etc at planning stage. This will be done in consultation with the relevant authorities.

Table 17.17: Mitigative Measures for various Impacts

Impacts	Mitigation Measures
Land Acquisition	Alignment design to minimize the land acquisition
Removal of Trees	Alignment design to reduce the number of trees to be cut, further compensatory plantation to be planned.
Impact on public utilities	Alignment design to consider lower interference. In case of removal alternate arrangement to be done before.
Impact on Archaeological and Cultur Sites	Alignment design to consider minimum impact
Access Restriction	Required alternatives, underpasses, proper signposts for people should be included in design

Impacts	Mitigation Measures
Environmental Specifications for contractors	Environmental qualifications specification should be included in pre-qualification packages for the contractors

17.8.2.2 Construction Phase

Mitigation plan needs to be implemented during construction phase are as described in the following sections.

17.8.2.2.1 *Air Pollution Control*

Construction activities at different phases can generate significant air quality problems. The project corridor has educational and medical institutions. There are also temples and mosques along the corridors. Mitigation measures suggested to reduce the impact are as follows:

- Water will be sprayed during construction phase if required for suppression of dust
- Dust emission from piles during excavation etc, will be controlled by spraying water
- Regular maintenance of vehicles and machineries
- Proper care provided to the workers (uniform, masks, safeguards, shoes, gloves etc) to resist the polluted air during construction activities

17.8.2.2.2 *Noise Control*

There may be an increase in noise level in ambient air due to construction. However, noise levels in the core city may slightly go down. The increase in levels is marginal; hence, local population will not be adversely affected. However the exposure of workers to high noise levels especially, near the engine, vent shaft etc. need to be minimized. Mitigation measures suggested to reduce the impact are as follows:

- This can be achieved by job rotation, automation, protective devices, noise barriers, and soundproof compartments, control rooms etc
- The workers employed in high noise level area could be employed in low noise level areas and vice-versa from time to time
- Automation of equipment and machineries, wherever possible, should be done to avoid continuous exposure of workers to noise
- Workers exposed to noise are provided with protective devices.
- Workers shall not be exposed to noise level more than permitted for industrial premises, i.e. 90 dBA (Leq) for 8 hours
- Construction work generating noise pollution near the medical institution and residential areas should be stopped during night.
- The noise levels during pile driving could be reduced by using a suitable sound absorbent, which can reduce the noise levels upto 70 dB (A) at a distance of 15m from the piles
- Noise level from loading and unloading of construction materials can be reduced by usage of various types of cranes and placing materials on sand or sandy bag beds.

17.8.2.2.3 *Water Pollution Control*

The project work may have some impact on water environment and also the requirement of water for construction activities may have some impact on local water resources. Mitigation measures to be taken to reduce the negative impact are as follows:

- If there is any requirement for closure or stoppage of access to public water taps on the roadside, alternative arrangements for the users will be made accordingly
- Excavated earth and other construction materials should be stored away to prevent washing away
- Vehicle maintenance to be carried out in confined areas away from water bodies
- All practical measures should be taken to prevent any uncontrolled effluent discharge to the water sources

17.8.2.2.4 *Platation/Trees*

Field survey found about 18 trees may be cut for the project. Mitigating measures to reduce the impact due to cutting down of trees are as follows:

- Restricted tree felling
- 5 times the number of trees cut will be planted
- Plantations on road side, parks, gardens, open spaces and housing complexes

17.8.2.2.5 *Traffic diversion*

During the construction activities the traffic that will be needs to be diverted onto some other route. A proper traffic diversion plan should also be established during the construction period. Following measures to be followed to provide proper welfare facilities to the workers:

17.8.2.2.6 *Worker's Welfare*

During the construction phase of any project, worker's safety and welfare is a very important concern to the project organisation.

- Cautionary camp and facilities to be provided
- The contractor should comply with all the precautions required for workmen's safety
- Adequate precautions to be trained to the workers
- First Aid kits to be placed at every workplace

17.8.2.3 Operation Phase

Environmental issues change during operation phase and its mitigation plan also has to be looked for a longer period of time.

17.8.2.3.1 *Noise*

The noise will impact the people outside on the elevated part of the corridor. Mostly upper stories of the buildings close to the corridor may face additional noise level. In case the elevated track goes too close to any sensitive building, noise barrier may be constructed there.

17.8.2.3.2 *Refuse from Stations*

The station will generate solid waste from different uses of the passengers. All wastes from stations need to be disposed properly to avoid any local pollution. The Metro authorities should have special group to work on this.

17.8.2.3.3 *Traffic problem near the Stations*

There will be increased traffic near the stations. All stations also will not have parking spaces. If this traffic is not managed properly it can cause both noise and air pollution locally. This should be considered for long term planning. Proper traffic signs and special traffic lights may be required near the station area. This needs to be coordinated with city police and traffic authorities.

18 COST ESTIMATES

18.1 INTRODUCTION

The cost of the design and construction of the Metro is an important means of comparing alternatives and determining the affordability of the investment. The selected alignment, chosen system technology and preferred rolling stock are mentioned in the previous chapters.

This section describes the capital cost components and estimates for the selected alignment and the chosen technology

The cost estimate for the Thane-Bhiwandi-Kalyan Corridor at March 2016 prices is shown in Table 18.1.

Table 18.1: Cost estimation

Name of the Corridor	Thane-Bhiwandi-Kalyan Corridor
Length of Corridor (km)	24.9
Capital Cost (with Land) in Rs. (Crores)	5313.39
Taxes & Duties in Rs. (Crores)	1308.84
Total Cost (with Land) in Rs. (Crores)	6622.23

18.2 CAPITAL COST CRITERIA

Two major cost elements are included in the cost estimates for Thane- Bhiwandi-Kalyan corridor:

1. Direct costs (costs associated directly with building the capital infrastructure);
2. Indirect costs (contingencies, professional services). Indirect costs are expressed as a percentage of the direct costs.

Also, while calculating the capital cost elements following key parameters were used:

1. Route km length of alignment is 24.9 km;
2. All track costs are for dual-tracked alignment;
3. Total number of Stations are 17;
4. Stations used for estimating costs are of the dimensions 185mx21m;
5. Ballasted Track length inside the maintenance depot is 5 km;
6. Length of tracks leading to/from maintenance Depot is 1 km;
7. The number of vehicles was estimated based on the operating scenario and round-trip time for technology and alignment length;
8. Rolling Stock used for the base year is 23 considering 6 cars for each rake;
9. Staff Quarters & OCC building are part of the cost estimation;
10. No Tunnel structure is recommended for the Thane-Bhiwandi-Kalyan corridor.

18.3 CAPITAL COST ESTIMATION

This section provides the preliminary cost estimates for Thane- Bhiwandi- Kalyan corridor. The preliminary costing includes the following main components:

- Land
- Civil Works;

- Machinery & Plant Works;
- General works;
- Traction & Power Supply,
- Road works, Signages etc. ;
- Signaling & Telecommunications works;
- Rolling Stocks;
- Environmental and R&R;
- Staff & OCC buildings.

Some of the documents that were referred to arrive at the capital costs for Thane-Bhiwandi-Kalyan Metro corridor are:

1. DPR of Agra Metro;
2. DPR of Lucknow Metro;
3. DPR of Nagpur Metro;
4. DPR of Kochi Metro;
5. DPR of Delhi Metro Phase-III;
6. DPR of Delhi Metro Phase-IV.

The criteria and basis of rates that were used for estimating the cost of the corridor is given below:

1. **Land-** Land requirements have been worked out on area basis and effort has been made to keep the land requirements to the barest minimum. Elevated alignment is proposed for the entire project corridor. Also, most of the alignment runs along the central verge of the road. However, some land would be needed to be acquired for running section at few locations where alignment runs outside the Right of Way. Total permanent land requirement has been worked out to be 17.42 Hectares. Cost of Government land is is 1.5 times of ready reckoner rate of identified government land location . Private land for MRTS project is proposed to be acquired by MMRDA. For this project following are the quantities and rate that has been taken for calculations: Land requirement for the project is presented in Table 18.2.

Table 18.2: Land Requirement

Land Requirement in Hectres			
	Pvt Land	Govt Land	Total
Stations	0.65		0.65
RSS	0.6		0.6
Other	2		
Depot Facilities		14.17	14.17
Total Land	**3.25**	**14.17**	**17.42**
Rate (in Rs. Crores)	**3**	**16**	
Temporary Land Requirement	6		

2. **Alignment -** The whole alignment of the project corridor is elevated viaduct and the rates adopted are based on the completion works of phase-II and ongoing phase-III Metro corridors of Delhi. Also, DPR for Lucknow Metro was used for validating cost to the current levels. Estimated rates are based upon accepted work of elevated priority corridor of LMRC suitable escalations to bring the costs to March 2016 price level.
3. **Stations-** All the stations on the corridor are elevated. The basis of rate is the awarded rates of Phase III Delhi Metro Project and a suitable escalation factor has been applied to bring these costs to March 2015 price level. The cost includes the general services at the stations and includes the cost of lifts & escalators. An escalation of 10% is used for Mumbai. Mainly two types of stations are proposed i.e. Intermediate stations and Terminal stations, for the elevated alignment & rates are proposed accordingly.
4. **Maintenance Depot-** Estimated rates are based upon LMRC Depot LAR, April'15, excluding taxes and duties. The rates are calculated for various items of building, elevated structures, tracks, boundary wall & plants machinery etc.
5. **Permanent Way-** For elevated sections, ballast-less track and for Depot ballasted track has been planned. The basis of rate is recently awarded rates of Phase IV Delhi Metro Project & Lucknow Metro and a suitable escalation factor has been applied to bring these costs to March 2016 price level.
6. **Traction & Power Supply-** Provisions have been made to cover OHE, SCADA augmentation, sub stations and other miscellaneous items. The basis of rate is recently awarded rates of Kochi metro and suitable escalations to bring the costs to March 2016 price level.
7. **Signaling & Telecommunication Works-** The basis of the rate for Signaling is the latest awarded rate for Kochi Metro, whereas for Telecommunication is for Phase III Delhi Metro, For Automated Fare Collection, awarded rates of Jaipur Metro were used for reference. All these rates were suitably escalated for bringing the costs to March 2016 price level.
8. **Rolling Stock-** The estimated cost per coach at March 2016 price level exclusive of taxes and duties has been taken as Rs. 11.09 crores per coach. Estimated rates are based upon the accepted rates of LMRC suitably escalated for bring to the price levels of March 2016. Total number of coaches is assumed to be 120 coaches considering 6 cars per rake.
9. **Environmental and R& R-** Provision for environmental impacts of the proposed corridors has been made to cover various protection works, additional compensatory measures, compensation for loss of trees, compensatory afforestation and fencing, monitoring of water quality, air/noise pollution during construction, establishment of Environmental Division. Provision towards compensation/rehabilitation of structure likely to be affected has been assessed. Sufficient provision is kept in the estimate to cover the cost of shifting of structures. A provision of Rs. 90 Crores has been kept. A more detailed analysis would be done at the DPR stage after the completion of preliminary Environmental assessment has been carried out.
10. **Miscellaneous Utilities, road-works, other civil works such as median. Signages, environmental protection & traffic management-** Estimated rates for both civil and electrical works are based upon average of escalated rates of DMRC Ph-IV DPR May'14 & LMRC DPR May'13.
11. **Capital Expenditure on Security-** Estimated rates are based upon average of escalated rates of DMRC Ph-IV DPR May'14. The expenditure is required to cover the civil and Electrical items, equipments (X-Ray machine, Metal detector etc.)

12. **Staff Quarters -** Estimated rates are based upon average of escalated rates of DMRC Ph-IV DPR May'14 and escalated suitably for March-2016 price levels.
13. **OCC Building-** Estimated rates are based upon average of escalated rates of DMRC Ph-IV DPR May'14 and suitably escalated for March-2016 price levels.
14. **Platform Screen Doors(PSD) cost-** Estimated cost are taken from Delhi metro stations PSD cost.
15. **Multi Modal Integration-** 2% of the total capital costs minus land cost is used for estimation and provision of inter modal integration at stations.

All rates and cost estimates are validated and revised based on Line 4 DPR.

Capital cost estimates for the project is presented in

Table **18.3** .

Table 18.3 Capital Cost Estimates for the Thane-Bhiwandi-Kalyan Metro Corridor

S No.	Description	Unit	Rate (Base price Mar-16)	Quantity	Amount (Rs. In Crores)
1	**Land**				
	Government Land (in hectares)	ha	3	14.17	42.51
	Private Land	ha	16	3.25	52
	Temporary Land for Construction depot	ha	3	6	18
	R&R Including Hutments	R KM	3.874	24.9	96.4626
	Sub Total-1				**208.97**
2	**Alignment**				
	Elevated Section including station length	Rkm	38.15	24.9	949.94
	Entry to Depot	R km	38.15	0.5	19.08
	Special Span at Dhamankar Flyover	LS			75.00
	Sub Total-2				**1044.01**
3	**Stations**				
	Elevated Station- Civil Works including viaduct	Per Station	29.43	15	441.45
	Elevated Station- EM works including lift and escalators	Per Station	8.33	15	124.95
	Terminal Station- Civil	Per Station	33.53	2	67.06
	Terminal Station- EM works including lift and escalators	Per Station	8.33	2	16.66
	Providing half height platform screen doors (PSD) at all stations	Each	2.53	34	86.02

S No.	Description	Unit	Rate (Base price Mar-16)	Quantity	Amount (Rs. In Crores)
	OCC Building				
	Civil Works	LS	55.00		55.00
	EM Works	LS	25.00		25.00
	Sub Total-3				**816.14**
4	**Depot**				
	Civil Works	Lumpsum	100.00		100.00
	EM works etc	Lumpsum	150.00		150.00
	Sub Total-4				**250.00**
5	**P-Way**				
	Ballastless track	R km	8.87	24.9	220.86
	Ballasted track for Depot	Track km	4.88	5	24.40
	Sub Total-5				**245.26**
6	**Traction & Power Supply incl. OHE, ASS etc.**				
	Elevated section	R km	10.50	24.9	261.45
	Sub Total-6				**261.45**
7	**Signaling & Telecom**				
	Signaling & Telecom	R km	15.99	24.9	398.15
	Automatic Fare Collection	Each	5.68	17	96.56
	Sub Total-7				**494.71**
8	**Misc. Utilities, roadworks, other civil works such as median stn. Signages, environmental protection & traffic management**				
	Civil Works (4.65Cr/Km) + Em Works (3.62 Cr/KM)	R km	8.27	24.9	205.92
	Diversion and Shifting of Overhead HT Lines	LS			20.00
	Sub Total-8				**225.92**
9	**Rolling Stock**	Each	9.80	120	1176.00
	Sub Total-9				**1176.00**
10	**Capital Expenditure on Security**				
	Civil Works	RKM	0.07	24.9	1.74
	EM Works	RKM	0.30	24.9	7.47
	Sub Total-10				**9.21**
11	**Staff Quarters**				

S No.	Description	Unit	Rate (Base price Mar-16)	Quantity	Amount (Rs. In Crores)
	Civil Works	R km	1.80	24.9	44.82
	EM Works	R km	0.45	24.9	11.21
	Sub Total-11				**56.03**
12	**Capital Expenditure on Multimodal Integration**				
	Capital Expenditure on Multimodal Integration	Each	2.40	17	40.80
	Sub Total-12				**40.80**
13	**Total of all Items Except Land**				**4716.00**
14	**General Charges including Design Charges on all items except land(7% of total except land)**				330.12
15	**Total of all Items including G charges except land**				**5046.12**
16	**Contengencies @3%**				151.38
17	**Gross Total**				**5197.50**
18	**Cost without Land**				**5198.00**
19	**Contengencies on land (3%)**				**3.38**
20	**Cost with Land including contigencies on Land and R&R**				**5313.39**

18.4 TAXES & DUTIES

Basic cost is exclusive of various taxes and duties viz. custom duty, excise duty, VAT, Octroi and service tax and details of taxes and duties are worked out separately. Current rates of various taxes and duties have been taken into consideration and taxes / duties have been applied as per prevalent practice Details of taxes and duties as applied on the corridor are shown in Table 18.4.

Table 18.4: Details of Taxes and Duties

Type of Tax/duty levied	Rate
Customs Duty	23.42%
Excise Duty	12.50%
Vat	13.50%
Octroi	4.25%

A detail of taxes and duties have been worked out separately and is shown Table below

Table 18.5: Taxes and Duties								
`S No.	Description	Total cost without Taxes & Duties (INR Crores)	Taxes, Duties and Octroi					Total Taxes & Duties (INR Crore)
			Custom Duties (INR Crore)	Excise Duty (INR Crore)	VAT (INR Crore)	Service Tax	Octroi (INR Crore)	
1	**Alignment**							
	Elevated at grade & Entry to Depot	1044.0		91.34	100.22	39.15	21.46	252.18
2	**Stations**							
	Elevated Station- Civil Works	508.5		44.49	48.82	19.07	10.45	122.83
	Elevated Station- EM works etc.	141.6	9.94	12.39	13.59	5.31	2.91	44.15
	OCC Building Civil Works	55.0		4.81	5.28	2.06	1.13	13.29
	OCC Building EM Works	25.0	1.76	2.19	2.40	0.94	0.51	7.79
3	**Maintenance Depot**							
	Civil Works	100.0	7.02	8.75	9.60	3.75	2.06	31.18
	EM Works	150.0	10.53	13.12	14.40	5.62	3.08	46.77
4	**P-Way**	245.3	17.22	21.46	23.55	9.20	5.04	76.47
5	**Traction & Power Supply incl. OHE, ASS etc.**							
	Traction & Power Supply incl. OHE, ASS etc.	261.5	18.36	22.88	25.10	9.80	5.37	81.51
6	**Signaling & Telecom**							
	Signaling & Telecom	398.2	27.96	34.84	38.22	14.93	8.18	124.13
	AFC	96.6	6.78	8.45	9.27	3.62	1.99	30.10
	PSD	86.0	6.04	7.53	8.26	3.23	1.77	26.82
7	**R&R Hutments**	96.5			1.06		3.75	4.81

8	**Misc. Utilities, roadworks, other civil works such as median stn. Signages, environmental protection & traffic management**							
	Civil Works	115.8		10.13	11.12	4.34	2.38	27.97
	EM Works	90.1		7.89	8.65	3.38	1.85	21.77
	Diversion and Shifting of Overhead HT Lines	20.0		1.75	1.92	0.75	0.41	4.83
9	**Rolling Stocks**	1176.0	82.58	102.89	112.90	44.10	24.18	366.64
10	**Capital Expenditure on Security**							
	Civil Works	1.7		0.15	0.17	0.07	0.04	0.42
	EM Works	7.5		0.65	0.72	0.28	0.15	
11	**Staff Quarters**							
	Civil Works	44.8		3.92	4.30	1.68	0.92	10.83
	EM Works	11.2		0.98	1.08	0.42	0.23	2.71
12	**Capital Expenditure on Multimodal Integration**	40.8		3.57	3.92	1.53	0.84	9.86
Total		**4716.0**	**188.20**	**404.18**	**444.53**	**173.21**	**98.72**	**1308.84**

Derived Project Completion cost presented in below table

Table 18.6: Project Completion Cost

S. No.	Items	Cost (In Crores)
1	Total civil cost (excluding taxes)	3,212.34
2	Total systems cost (excluding taxes)	2,946.56
3	Total taxes including escalation (Central)	908.42
4	Total taxes including escalation (State)	751.09
4	Total Design Charges	431.13
5	Total land cost	146.93
6	IDC	20.00
7	**Project completion cost**	**8,416.51**
	Total Escalation Cost	**1,774.28**

19 ECONOMICAL ANALYSIS

19.1 INTRODUCTION

The Major difference between financial analysis and economic analysis are involved cost segment assigned to both of them. While one is purely deals with financial aspect of the study which are debt, grant and various other terms associate to it. Economic analysis is a logical representation attached to social and environmental changes in terms of money i.e. benefits.

Economic benefit are basically derived from with and without project scenario same as road projects. Suppose, a metro line is introduced, then the difference between benefits and cost components like capital and recurring cost for a metro system are obtained by adjusting cost component in accordance with economic prices i.e. Cost involved in economic analysis are without central taxes and duty. The net benefit values are negative during initial period of assessment as huge impact of capital cost during construction period. But get slowly normalize with period due to intervention of obtained benefits. Table 19.1 presents project completion cost with and without central taxes.

Table 19.1: Total Project Cost with and without central taxes

Financial Year	Cost at March -2016 Price Level	Completion Cost including land cost and all taxes
2017-18	344	350
2018-19	863	945
2019-20	1669	1964
2020-21	1441	1822
2021-22	1152	1567
2022-23	577	843
2023-24	575	904
Total	6622	8396

The length of Thane-Bhiwandi-Kalyan corridor is 24.9 Km. It starts from Thane (Kapurbawadi Junction) and terminates at Kalyan (APMC Market) and looks out to be a very viable option considering existing crowding at suburban rails. In future, no doubt will prove to major route connecting this 3 cities having utmost importance in terms of their proximity to financial capital of India.

Economic benefits basically divided into 7 types and each of them are explained below

19.1.1 Time Saving of Metro Passengers

Proposed MRTS, there will reduce traffic congestion on the roads and correspondingly, there will be saving in time of commuters travelling by various modes of road transport. Similarly, MRTS System itself being faster than conventional road transport modes will also lead to considerable saving in time of commuters traveling on MRTS. With the implementation of the project, the passenger time savings are estimated at Rs. 623.66Cr. for the year 2021-2022.

19.1.2 Fuel Saving by Metro Passengers

Savings in fuel consumption with the introduction of proposed MRTS have already been included in savings of vehicle operating cost. The effect of MRTS on fuel savings alone has been calculated separately. The main fuels used in vehicles are diesel and petrol. The saving because of fuel alone from the savings in vehicle operating costs and savings due to decongestion effect for the year 2021 works out to Rs 201.72 Cr.

19.1.3 Saving In VOC (Capital and Operational cost saved by metro passengers)

MRT will contribute towards reducing the congestion and journey time on roads because of diversion of some traffic to MRTS. Reduction in traffic congestion will save the necessary capital investment and vehicle operating cost as well as increase in time saved per vehicle. With the implementation of this MRTS corridor, the savings from operating costs due to decongestion effect is estimated at Rs 70.27 Cr. in year 2021.

19.1.4 Saving due to Emission

Introduction of MRTS will result in significant drop in concentration of various harmful gases and hence to reduce in air pollution. at Rs. 22.93Cr. for the year 2021-2022.

19.1.5 Saving due to reduce in number of accidents

The reduction in traffic volumes on roads brought about by modal transfer to the proposed MRTS is expected to reduce number of accidents. Any reduction in number of accidents will involve savings from damage to vehicles and savings towards medical and insurance expenses to persons involved in accidents. The benefits because of accidents prevented with the introduction of this MRTS corridor works out to Rs.67.59 Cr. in the year 2021-2022.

Cost saving due to decongestion effect, i.e. due to increase in mobility amongst vehicles travelling on road is very significant in terms of fuel and time saving.Traffic Parameters derived from transport demand assessment is enlisted in the

Table 19.2: Traffic Parameters

Item	Year 2021	Year 2031	Year 2041
Daily Total Trips on the corridor	347607	463900	626265
Daily Trips on MRT	230438	301042	405547
Daily Trips by other modes	117169	162858	220718
Average Trip Length	10.14 Km		

Various Assumptions and Values were derived by thoroughly reviewing DPRs prepared by various consultants and through desktop research.

Table 19.3: VOC/VOT Parameters

Modes	Average Speed in Km	VOC/KM in Rs	VOC/hr	VOT (passenger/hr) in Rs
Bus	16	91.60	1373.89	40.63
Car+Taxi	20	26.89	404.08	97.51
2 Wheeler	13	9.01	134.74	65.01
3Wheeler	12	12.56	188.52	73.13
MRTS				40.63

Table 19.4: Speed and Travel Time Parameters

Modes	Without MRTS Vehicle Speed Km/hr	With MRTS Vehicle Speed Km/hr	Time for Per km without MRTS in minutes	Time for unit km with MRTS in minutes
Bus	10	12	6.00	5.00
Car	15	20	4.00	3.00
2 Wheeler	15	25	4.00	2.40
3 Wheeler	13	17	4.62	3.53
TAXI	15	20	4.00	3.00
MRTS		33		1.82
train	40	40	1.50	1.50

Table 19.5: Fuel Consumption and Pollution Parameters

Mode	Fuel consumption (Litre/Km.)	Reduction in fuel consumption due to decongestion effect (Lt./Km.)	Pollution Emission (Kg./1000 Litres)
Bus	0.392581018	0.09596425	85.8894098
Car	0.108346733	0.04038378	309.111821
2 Wheelers	0.040805912	0.01350816	326.109594
3Wheelers	0.081611825	0.02701633	303.244212

Source:Dahisar-Charkop-Bandra-Mankhurd DPR by RITES

Values are escalated by 5% to derive price at March 2021 level

Values are escalated by 5% to derive price at March 2021 level. Accident Cost Parameters are presented in Table 19.6.

Table 19.6: Accident Cost Parameters

Type of Accident	No. of accidents/cr veh km	average cost in RS
All	1.82	230000
Fatal	0.22	1026000

Conversion Factor to convert passenger km into vehicle km is derived from average lead and trip length Conversion factor to convert passenger km into Veh Km is 0.143.

Above mentioned parameters are considered and detailed cost benefit analysis is carried out and the same is presented in the Table 19.7.

Table 19.7: Cost Benefit Analysis

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Annual Time Cost Saved by Metro Passengers in Cr. Rs.	Annual Fuel cost Saved By metro passengers in Cr Rs	VOC (Capital + operation Saved by metro passengers in Cr RS	Emission cost benefits	Saved in accident cost in cr Rs	Annual Time cost saved by road passengers in cr Rs	Annual Fuel cost saved by road passengers in cr RS	Total Benefits	Net Benefits
2017-2018	322				322								0	-322
2018-2019	807				807								0	-807
2019-2020	1561				1561								0	-1561
2020-2021	1348				1348								0	-1348
2021-2022	1077		157		1234	623.5662	201.7167	70.2735	22.93084	67.5958	21.4993	16.2972	1023.88	-211
2022-2023	539		170		709	654.74451	211.8025	73.78718	24.07738	70.9756	22.5743	17.112	1075.074	366
2023-2024	538		183		722	687.48174	222.3927	77.47654	25.28125	74.5244	23.703	17.9676	1128.827	407
2024-2025			198		198	721.85582	233.5123	81.35036	26.54532	78.2506	24.8882	18.866	1185.269	987
2025-2026			214		214	757.94861	245.1879	85.41788	27.87258	82.1631	26.1326	19.8093	1244.532	1030
2026-2027			232		232	795.84604	257.4473	89.68877	29.26621	86.2713	27.4392	20.7998	1306.759	1075
2027-2028			251		251	835.63835	270.3197	94.17321	30.72952	90.5848	28.8112	21.8398	1372.097	1121
2028-2029			271		271	877.42026	283.8357	98.88187	32.266	95.1141	30.2517	22.9318	1440.701	1170
2029-2030			293		293	921.29128	298.0274	103.826	33.8793	99.8698	31.7643	24.0783	1512.736	1220
2030-2031			317		317	967.35584	312.9288	109.0173	35.57326	104.863	33.3525	25.2823	1588.373	1272
2031-2032		680	408		1088	1015.7236	328.5753	114.4681	37.35193	110.106	35.0202	26.5464	1667.792	580
2032-2033			440		440	1066.5098	345.004	120.1915	39.21952	115.612	36.7712	27.8737	1751.182	1311
2033-2034			476		476	1146.4981	370.8793	129.2059	42.16099	124.283	39.529	29.9642	1882.52	1407
2034-2035			514		514	1232.4854	398.6953	138.8963	45.32306	133.604	42.4937	32.2115	2023.709	1510
2035-2036			555		555	1324.9218	428.5974	149.3136	48.72229	143.624	45.6807	34.6274	2175.487	1620
2036-2037			600		600	1424.2909	460.7422	160.5121	52.37646	154.396	49.1068	37.2245	2338.649	1738

2037-2038			649		649	1531.1128	495.2979	172.5505	56.3047	165.976	52.7898	40.0163	2514.048	1865
2038-2039			701		701	1645.9462	532.4452	185.4918	60.52755	178.424	56.749	43.0175	2702.601	2002
2039-2040			758		758	1769.3922	572.3786	199.4037	65.06712	191.806	61.0052	46.2438	2905.296	2148
2040-2041			819		819	1902.0966	615.307	214.3589	69.94715	206.191	65.5806	49.7121	3123.193	2304
2041-2042			885		885	2044.7538	661.4551	230.4359	75.19319	221.655	70.4991	53.4405	3357.433	2472
2042-2043			957	645	1602	2198.1104	711.0642	247.7185	80.83267	238.279	75.7866	57.4486	3609.24	2008
2043-2044			1034	670	1704	2362.9687	764.394	266.2974	86.89512	256.15	81.4706	61.7572	3879.933	2176
2044-2045			1118		1118	2540.1913	821.7235	286.2697	93.41226	275.362	87.5809	66.389	4170.928	3053
2045-2046			1208		1208	2730.7057	883.3528	307.74	100.4182	296.014	94.1494	71.3682	4483.748	3275
2046-2047			1270		1270	2935.5086	949.6043	330.8205	107.9495	318.215	101.211	76.7208	4820.029	3550
Total	6193	680	14677	1315	22865	36714	11877	4138	1350	3980	1266	960	60284	17.092%

19.2 SENSITIVITY ANALYSIS

A sensitivity analysis of the EIRR with 10% cost overrun and 10% reduction in traffic materialization (separately) has been carried out. The EIRRs under these scenarios are given in below Table 19.8.

Table 19.8: Sensitivity Parameters

Sensitivity Parameter	
Basic EIRR	**17.09%**
With Increase in 10 percent cost	**15.44%**
With decrease in 10 percent traffic(trips)	**15.27%**
With Increase in 10 percent cost and decrease in 10 percent traffic(trips)	**13.67%**
With Increase in 20 percent cost	**13.97%**

20 FINANCIAL ANALYSIS

20.1 INTRODUCTION

The financial analysis for the project has been worked out taking into consideration the completion cost, operation and maintenance cost as well as the additional expenditure to be incurred in coming years for additional rolling stock, signaling and telecom and augmentation of power supply system.The Thane Bhiwandi Kalyan Metro Corridor is proposed to be constructed at an estimated cost of Rs 5313.39 Crores which also includes the land but excluding taxes. The total cost for the proposed Metro corridor is estimated at Rs 6622.23 Crores which also includes taxes and other duties. Cost elements are depicted in following table.

Table 20.1: Construction Cost of Thane Bhiwandi Kalyan Metro Corridor at March 2016 price level

Length of Metro Corridor (km)	24.9
Capital Cost (with Land) in Rs. (Crores)	5313.39
Taxes & Duties in Rs. (Crores)	1308.84
Total Cost in Rs. (Crores)	6622.23

20.2 COSTS

Various cost components are discussed in the sections below.

20.2.1 Investment Cost

It is assumed that the construction work will start on 01.10.2017 and is expected to be completed on 31.03.2021 with Revenue Opening Date (ROD) as 01.04.2021 for the corridor. The total completion costs duly escalated and shown in the table have been taken as the initial investment. However, the actual project completion cost is shown in the table below. With escalation factor of 7.5% per annum, the completion cost of the project is estimated at Rs. 8416 Crores including IDC. The taxes and duties consist of Custom Duty (CD), Excise Duty (ED), State Value Added Tax (VAT) and Octroi levied by the Brihanmumbai Municipal Corporation (BMC)

Total project Completion Cost is estimated and the same is presented in Table 20.2.

Table 20.2: Total Project completion cost

Financial Year	Cost at March -2016 Price Level	Completion Cost including land cost and central taxes
2017-18	344	350
2018-19	863	945
2019-20	1669	1964
2020-21	1441	1822
2021-22	1152	1567
2022-23	577	843
2023-24	575	904
Total	6622	8396

20.2.2 Operation & Maintenance (O&M) Costs

The Operation & Maintenance costs have been divided into three major parts:

- Staff costs
- Maintenance cost which include expenditure towards upkeep and maintenance of the system and consumables
- Energy costs

The requirement of staff has been assumed @ 35 persons per kilometer. The escalation factor used for staff costs is 9% per annum to provide for both escalation and growth in salaries. Assumptions considered for calculating Operation and maintenance are as follows:

- The requirement of staff has been assumed @ 35 persons per kilometre.
- The escalation factor used for staff costs is 9% per annum to provide for both escalation and growth in salaries.
- The cost of other expenses is based on the actual O & M unit cost for the Delhi Metro Phase-II project.
- The prevailing rate of electricity in Mumbai is Rs. 8.46 per unit which has been used for all calculations.

O& M Cost is calculated and the same is presented in Table 20.3.

Table 20.3:Operation & Maintenance Cost for Thane Bhiwandi Kalyan Metro Corridor

YEAR		Rs in Crores			
		Staff	Maintenance Expenses	Energy	Total
2021	2022	61.97	40.9	54.15	157.02
2022	2023	67.55	43.97	58.21	169.73
2023	2024	73.63	47.27	62.58	183.47
2024	2025	80.26	50.81	67.27	198.34
2025	2026	87.48	54.62	72.32	214.42
2026	2027	95.35	58.72	77.74	231.81
2027	2028	103.94	63.12	83.57	250.63
2028	2029	113.29	67.86	89.84	270.98
2029	2030	123.49	72.94	96.58	293.01
2030	2031	134.60	78.42	103.82	316.83
2031	2032	146.71	84.30	176.55	407.56
2032	2033	159.92	90.62	189.79	440.33
2033	2034	174.31	97.41	204.03	475.75
2034	2035	190.00	104.72	219.33	514.05
2035	2036	207.10	112.57	235.78	555.45
2036	2037	225.74	121.02	253.46	600.22
2037	2038	246.06	130.09	272.47	648.62
2038	2039	268.20	139.85	292.91	700.96
2039	2040	292.34	150.34	314.87	757.55
2040	2041	318.65	161.62	338.49	818.75
2041	2042	347.33	173.74	363.88	884.94
2042	2043	378.59	186.77	391.17	956.52
2043	2044	412.66	200.77	420.51	1033.94
2044	2045	449.80	215.83	452.04	1117.67
2045	2046	490.28	232.02	485.95	1208.25

20.2.3 Additional Investment

Total Investment provided in the FIRR calculation towards requirement of additional rolling stock and has been duly escalated @ 5% per annum. Total additional investment cost of Rs. 610 crore has been provided in the year 2032. These costs have been provided to take care of increased requirement of Rolling Stock and related equipment on account of the increased traffic since the existing rolling stock would be insufficient to carry the traffic estimated in these years. Cost for 34 half height Platform Screen Doors (PSD) with installation i.e. 86.02 Crores have been added in the cost estimate considering 2 PSDs for each station.

20.2.4 Replacement Cost

These costs are associated for requirement of replacing equipment due to continuous wear and tear because of use when metro is operational. The replacement costs are provided for meeting the cost on account of replacement of equipment due to wear and tear. For Thane Bhiwandi Kalyan Metro, it is expected that only 50% of the equipment comprising signaling and telecom would require replacement after 20 years. Further, 25% of the electrical works would be replaced in 20 years. These costs have been provided duly escalated @ of 5% per annum.

20.3 REVENUES

20.3.1 Fare Box

The fare box collection is the product of projected ridership per day and applicable fare structure based on trip distribution at different distance zones.

20.3.2 Traffic

The projected ridership for years are as indicated in table:

Table 20.4:Traffic Ridership for proposed Thane Bhiwandi Kalyan Metro Project corridor

Item	Year 2021	Year 2031	Year 2041
Daily Total Trips on the corridor	347607	463900	626265
Daily Trips on MRT	230438	301042	405547
Daily Trips by other modes	117169	162858	220718

20.3.3 Fare Structure

For calculation of fare structure, a comparison between fares of Delhi Metro and rates used by MMRDA has been used. After having discussion with client, MMRDA fare structure have been finalised for fare box revenue calculation. The Fare Structure for 2021-22 is shown below:

Table 20.5:Fare Structure for base year of operations

Fare	0-3	3-8	8-12	12-15	15-20	20-25	25-30	30-35	>35
2021	12	14	18	22	27	30	33	37	41

The fare structure used for Thane-Bhiwnadi-Kalyan Metro corridor is shown below in the table:

Table 20.6:Proposed Fare Structure for Thane Bhiwandi Kalyan Metro corridor

Fare	0-3	3-8	8-12	12-15	15-20	20-25	25-30	30-35	>35
2021	12	14	18	22	27	30	33	37	41
2022	12	14	18	22	27	30	33	37	41
2023	12	14	18	22	27	30	33	37	41
2024	13	16	20	24	30	33	37	41	46
2025	13	16	20	24	30	33	37	41	46
2026	13	16	20	24	30	33	37	41	46
2027	14	18	22	27	33	37	41	46	51
2028	14	18	22	27	33	37	41	46	51

Fare	0-3	3-8	8-12	12-15	15-20	20-25	25-30	30-35	>35
2029	14	18	22	27	33	37	41	46	51
2030	16	20	24	30	37	41	46	51	57
2031	16	20	24	30	37	41	46	51	57
2032	16	20	24	30	37	41	46	51	57
2033	18	22	27	33	41	46	51	57	63
2034	18	22	27	33	41	46	51	57	63
2035	18	22	27	33	41	46	51	57	63
2036	20	24	30	37	46	51	57	63	70
2037	20	24	30	37	46	51	57	63	70
2038	20	24	30	37	46	51	57	63	70
2039	22	27	33	41	51	57	63	70	78
2040	22	27	33	41	51	57	63	70	78
2041	22	27	33	41	51	57	63	70	78
2042	24	30	37	46	57	63	70	78	87
2043	24	30	37	46	57	63	70	78	87
2044	24	30	37	46	57	63	70	78	87
2045	27	33	41	51	63	70	78	87	97
2046	27	33	41	51	63	70	78	87	97
2047	27	33	41	51	63	70	78	87	97

20.3.4 Other Revenue

Other revenues from Property Development and advertisement have been estimated at 10% of the fare box revenues during operations and Rs. 1500 Crores upfront. Other revenues from Property Development and advertisement have been assumed @ 10% of the fare box revenues during first five years of operations and thereafter @ 20% of the fare box revenues. Apart from development of property on metro stations and depot it is possible to raise resources through leasing of parking rights at stations, advertisement on trains and tickets, advertisements within stations and parking lots, advertisements on viaducts, columns and other metro structures, co-branding rights to corporate, film shootings and special events on metro premises. Revenues from Advertisement screens placed beside PSD has been added in financial analysis. Similarly Considering 160 sqm commercial spaces available on each station lease rate have been worked out.

20.4 FINANCIAL INTERNAL RATE OF RETURN

The financial rate of Return (FIRR) FOR 30 year model is produced for both scenarios; viz. without property development and with property development and is reproduced in the tables below. The calculations for FIRR also include the requisite central taxes and duties as estimated in previous sections.

Table 20.7:FIRR with Central Taxes (Without Property Development),all figures are in INR Crores

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2017-2018	350				350						-350
2018-2019	945				945						-945
2019-2020	1964				1964						-1964
2020-2021	1822				1822						-1822
2021-2022	1567		157		1724	255	45	3	13	316	-1408
2022-2023	843		170		1013	265	49	3	14	331	-681
2023-2024	904		183		1088	307	60	3	14	385	-703
2024-2025			198		198	319	62	3	15	400	202
2025-2026			214		214	373	75	3	16	467	253
2026-2027			232		232	388	154	4	17	562	331
2027-2028			251		251	454	186	4	18	662	411
2028-2029			271		271	471	195	4	18	689	418
2029-2030			293		293	547	234	4	19	804	511

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2030-2031			317		317	568	244	4	20	837	521
2031-2032		680	408		1088	663	289	5	21	978	-109
2032-2033			440		440	679	302	5	22	1009	568
2033-2034			476		476	786	362	5	24	1176	701
2034-2035			514		514	804	371	5	25	1205	691
2035-2036			555		555	925	439	6	26	1396	840
2036-2037			600		600	947	450	6	27	1430	830
2037-2038			649		649	1089	529	6	29	1653	1004
2038-2039			701		701	1116	544	6	30	1697	996
2039-2040			758		758	1290	639	7	32	1967	1210
2040-2041			819		819	1322	656	7	33	2018	1199
2041-2042			885		885	1516	776	7	35	2334	1449
2042-2043			957	645	1602	1531	795	8	37	2370	769
2043-2044			1034	670	1704	1750	934	8	38	2731	1027
2044-2045			1118		1118	1767	943	9	40	2759	1641

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2045-2046			1208		1208	2001	1099	9	42	3152	1943
2046-2047			1270		1270	2018	1110	10	44	3182	1912
Total	8396	680	14677	1315	25068	24151	11544	144	671	36510	5.2%

Table 20.8:FIRR with Central Taxes (WithProperty Development),all figures are in INR Crores

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2017-2018	350				350						-350
2018-2019	945				945						-945
2019-2020	1964				1964						-1964
2020-2021	1822				1822						-1822
2021-2022	1567		157		1724	255	45	3	13	316	-1408
2022-2023	843		170		1013	265	-249	3	14	34	-979
2023-2024	904		183		1088	307	-178	3	14	147	-940
2024-2025			198		198	319	-96	3	15	241	43
2025-2026			214		214	373	34	3	16	426	212
2026-2027			232		232	388	219	4	17	627	395
2027-2028			251		251	454	260	4	18	735	485
2028-2029			271		271	471	292	4	18	786	515
2029-2030			293		293	547	339	4	19	909	616
2030-2031			317		317	568	372	4	20	965	648

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2031-2032		680	408		1088	663	422	5	21	1111	24
2032-2033			440		440	679	548	5	22	1254	814
2033-2034			476		476	786	599	5	24	1413	938
2034-2035			514		514	804	624	5	25	1458	944
2035-2036			555		555	925	681	6	26	1637	1082
2036-2037			600		600	947	709	6	27	1690	1090
2037-2038			649		649	1089	777	6	29	1901	1252
2038-2039			701		701	1116	810	6	30	1963	1262
2039-2040			758		758	1290	888	7	32	2216	1459
2040-2041			819		819	1322	923	7	33	2285	1466
2041-2042			885		885	1516	1016	7	35	2575	1690
2042-2043			957	645	1602	1531	1058	8	37	2633	1031
2043-2044			1034	670	1704	1750	1164	8	38	2961	1257
2044-2045			1118		1118	1767	1203	9	40	3019	1901
2045-2046			1208		1208	2001	1321	9	42	3374	2165

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commercial Space Rent	Revenue from Advertising on PSD Advt Screen	Total Revenue	IRR
2046-2047			1270		1270	2018	1364	10	44	3435	2165
Total	8396	680	14677	1315	25068	24151	15145	144	671	40111	6.02%

Transport Mass Transit projects is generally considered to be viable when FIRR is generally in the range of 3%, this project shall require govt. support for implementation. It is essential to note that the Government involvement in the funding of metro systems is a foregone conclusion and the practice has been such not only in India but across various countries spread across different continents.

20.5 SENSITIVITY ANALYSIS

Sensitivity Analysis has been carried out for increase and decrease in the following main components of revenue and costs:

- Construction Cost
- Fare Box Collection
- Operation & Maintenance Cost

This analysis has been carried out for the scenario of property development and the various sensitivities have been carried out independently for all the factors above and FIRR calculated is shown in the table below.

Table 20.9:FIRR sensitivity analysis with Property Development

Description	FIRR
10% decrease in the construction cost	6.7%
10% increase in the construction cost	5.4%
20% decrease in the construction cost	7.5%
20% increase in the construction cost	4.9%
10% decrease in Fare box	5.3%
10% increase in Fare box	6.7%
20% decrease in Fare box	4.5%
20% increase in Fare box	7.3%
10% decrease in O&M cost	6.4%
10% increase in O&M cost	5.6%
20% decrease in O&M cost	6.8%
20% increase in O&M cost	5.1%

FIRR sensitivity with the scenario of property development suggests that the lowest FIRR would be 4.5% and would result in when there is a 20% decrease in the fare box revenue. Under all scenarios the FIRR is above 3% which is a fairly good number for mass transit projects.

20.6 FINANCING OPTION

Transport infrastructure is a public good and the services benefit a large number of people. Hence, it is not just the financial returns but also social returns that need to be considered when planning such projects. The cost of rail projects, both the upfront land acquisition and construction, as well as the ongoing operations and maintenance, is considerable. Thus, it is of utmost importance that planning, structuring and implementation of Metro projects are ensured so that they deliver value for money when implemented.

Metro system requires heavy capital investments and certainly requires involvement of central and state government in terms of financial support as well as in terms of political will for creating a sustainable metro system. A review of the financial scenario, world over and in India, reveals significant capital contribution from the government. Phase-I, Phase II and Phase III of Delhi metro have been funded with a mixture of equity and debt by Government of India (GoI) and Delhi State Government. Similarly, metro projects in Chennai, Bengaluru and Mumbai have been funded by a combination of contribution by GoI and respective state governments and the balance amount being funded by JICA through loans. It is also worth noticing that a Single Purpose Vehicle was adopted for construction of metro rail system in all these cities.

However, Maharashtra State Government had opted for Build, Operate & Transfer model for construction of Line-1 from Versova-Andheri-Ghatkopar. The work has been awarded to private operator for construction and operation by giving Viability Gap funding by Government of India and Government of Maharashtra.

20.6.1 SPV Model

The financing option will depend on the dedicated agency created to implement the project. SPV model of financing is proposed project of Thane Bhiwandi Kalyan Metro. The State Government has already formed a fully owned SPV in the name of Mumbai Metro Rail Corporation (MMRC), which is responsible for the implementation of all the metro rail corridors under the Mumbai Metro rail project. It is assumed in the calculation that JICA would extend a modified step loan. The interest rate that JICA will extend the loan has been taken as 0.30 % per annum. The tenure of the loan has been assumed as 40 years with 10 years as moratorium period. The funding pattern for the project is shown in the table below:

Table 20.10:Funding Pattern under SPV model (all figures in INR Crores)

Funding Pattern under SPV Model		
Description	**Amount**	**Percentage of Contribution**
Equity by GOI	1127	14.55%
Equity by GOM	1127	14.55%
SD for CT by GOI	422	5.45%
SD for CT by GOM	422	5.45%
Loan from JICA	4649	60%
Total	**7748**	
SD for Land by GOM	648	
Total	**8396**	
Interest during Construction	20	
Total	**8416**	

20.6.2 BOT Model

In this model, the private firm will be responsible for financing, designing, building, operating and maintaining of the entire project. The contribution of Government of Maharashtra will be limited to cost of land only. Such a project become eligible for Viability Gap Funding (VGF) up to 20% from the Central Government provided the state government also contribute same or more amount towards the project. The metro being a social sector project not much private parties are available to bid for such a project. Besides quite expectedly the private operator may demand assured rate of return in the range of 16% to 18% or a comfort of guaranteed ridership.

Table 20.11:Funding Pattern under BOT model without property development (all figures in INR Crores)

Funding Pattern under BOT Model without Property Development		
Description	**Amount**	**Percentage of Contribution**
VGF by GOI	1550	20.00%
VGF by GOM	3262	42.10%
Equity by Concessionaire	938	12.10%
Concessionaire's debt	1999	25.80%
Total	**7748**	100.00%
Free Land by GOM	648	
Total	**8396**	
Interest during Construction	18	
Total	**8414**	

Table 20.12:Funding Pattern under BOT model with property development (all figures in INR Crores)

Funding Pattern under BOT Model with Property Development		
Description	**Amount**	**Percentage of Contribution**
VGF by GOI	1550	20.00%
VGF by GOM	2189	28.25%
Equity by Concessionaire	1093	14.10%
Concessionaire's debt	2917	37.65%
Total	**7748**	100.00%
Free Land by GOM	648	
Total	**8396**	
Interest during Construction	59	
Total	**8455**	

The total fund contribution by Government of India and Government of Maharashtra is depicted in the table below:

Table 20.13:Fund contribution by State and Central Government

Funding Source	SPV Model	BOT without PD	BOT with PD
GOI	1550	1550	1550
GOM	2198	3910	2837
Total	3747	5460	4387

Considering the difference in funding, it is recommended to implement the project under SPV model (completely Government Funded). The detailed cash flow statement for SPV model for both the scenarios i.e. without property development and with property development is given below.

Table 20.14:SPV Model without Property Development

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commecial Space Rent	Revenue from Advertising on Panel beside PSD	Total Revenue	Net Cash Flow	Equity from GOI & GOM	Avalaibility of Cash	Cumulative Cash	Cum. Loan	Loan	Repayment of Loan	IDC	Cumulative Loan incl. IDC	Interest	Profit before Tax	Cash Balance	CumulativeCash
2017-2018	350				350					0	-350	484	134	134	0	0	0	6	6				
2018-2019	945				945					0	-945	808	-137	-3	0	0	0	0	6				
2019-2020	1964				1964					0	-1964	966	-998	-1002	1212	1212	0	3	1221				
2020-2021	1822				1822					0	-1822	938	-884	-1886	2456	1243	0	11	2476				
2021-2022	1567		157		1724	255	45	3	13	316	-1408	551	-609	-2494	3615	1160	0		3635	42		-291	-291
2022-2023	843		170		1013	265	49	3	14	331	-681	0	-776	-3270	4128	513	0		4148	54		-222	-513
2023-2024	904		183		1088	307	60	3	14	385	-703	0	-521	-3791	4649	521	0		4669	61		-243	-756
2024-2025			198		198	319	62	3	15	400	202	0	0	0	0	0	0		4342	60		142	-615
2025-2026			214		214	373	75	3	16	467	253	0	0	0	0	0	0		4342	60		193	-422
2026-2027			232		232	388	154	4	17	562	331	0	0	0	0	0	0		4342	60		271	-151
2027-2028			251		251	454	186	4	18	662	411	0	0	0	0	0	325		4017	60		25	-126
2028-2029			271		271	471	195	4	18	689	418	0	0	0	0	0	325		3691	56		36	-90
2029-2030			293		293	547	234	4	19	804	511	0	0	0	0	0	325		3366	52		133	44
2030-2031			317		317	568	244	4	20	837	521	0	0	0	0	0	325		3040	48		147	191
2031-2032		680	408		1088	663	289	5	21	978	-109	0	0	0	0	0	325		2715	44		-479	-288
2032-2033			440		440	679	302	5	22	1009	568	0	0	0	0	0	325		2389	39		204	-84
2033-2034			476		476	786	362	5	24	1176	701	0	0	0	0	0	325		2064	35		340	256
2034-2035			514		514	804	371	5	25	1205	691	0	0	0	0	0	325		1739	31		335	591
2035-2036			555		555	925	439	6	26	1396	840	0	0	0	0	0	325		1413	27		488	1079
2036-2037			600		600	947	450	6	27	1430	830	0	0	0	0	0	325		1088	23		482	1561
2037-2038			649		649	1089	529	6	29	1653	1004	0	0	0	0	0	139		948	19		846	2407
2038-2039			701		701	1116	544	6	30	1697	996	0	0	0	0	0	139		809	17		839	3246
2039-2040			758		758	1290	639	7	32	1967	1210	0	0	0	0	0	139		669	15		1055	4301
2040-2041			819		819	1322	656	7	33	2018	1199	0	0	0	0	0	139		530	13		1046	5348
2041-2042			885		885	1516	776	7	35	2334	1449	0	0	0	0	0	139		390	11		1299	6647
2042-2043			957	645	1602	1531	795	8	37	2370	769	0	0	0	0	0	139		251	9		620	7267
2043-2044			1034	670	1704	1750	934	8	38	2731	1027	0	0	0	0	0	139		111	8		879	8146
2044-2045			1118		1118	1767	943	9	40	2759	1641	0	0	0	0	0	139		-28	5		1496	9643
2045-2046			1208		1208	2001	1099	9	42	3152	1943	0	0	0	0	0	139		-168	4		1800	11443
2046-2047			1270		1270	2018	1110	10	44	3182	1912	0	0	0	0	0	139		-307	2		1770	13213
Total	8396	680	14677	1315	25068	24151	11544	144	671	36510	5.2%					4649	4649			855		13213	

Table 20.15: SPV model with property development

Year	Total Project Completion Cost	Additional Cost	Running Expenses	Replacement Cost	Total Cost	Fare Box Revenue	Revenue from Advertisement & PD	Revenue from Commecial Space Rent	Revenue from Advertising on Panel beside PSD	Total Revenue	Net Cash Flow	Equity from GOI & GOM	Avalaibility of Cash	Cumulative Cash	Cum. Loan	Loan	Repayment of Loan	IDC	Cumulative Loan incl. IDC	Interest	Profit before Tax	Cash Balance	Cumulative Cash
2017-2018	350				350					0	-350	484	134	134	0	0	0	6	6				
2018-2019	945				945					0	-945	808	-137	-3	0	0	0	0	6				
2019-2020	1964				1964					0	-1964	966	-998	-1002	1212	1212	0	3	1221				
2020-2021	1822				1822					0	-1822	938	-884	-1886	2456	1243	0	11	2476				
2021-2022	1567		157		1724	255	45	3	13	316	-1408	551	-609	-2494	3615	1160	0		3635	42		-291	-291
2022-2023	843		170		1013	265	-249	3	14	34	-979	0	-776	-3270	4128	513	0		4148	54		-520	-811
2023-2024	904		183		1088	307	-178	3	14	147	-940	0	-521	-3791	4649	521	0		4669	61		-481	-1292
2024-2025			198		198	319	-96	3	15	241	43	0	0	0	0	0	0		4342	60		-17	-1309
2025-2026			214		214	373	34	3	16	426	212	0	0	0	0	0	0		4342	60		152	-1157
2026-2027			232		232	388	219	4	17	627	395	0	0	0	0	0	0		4342	60		335	-822
2027-2028			251		251	454	260	4	18	735	485	0	0	0	0	0	325		4017	60		99	-722
2028-2029			271		271	471	292	4	18	786	515	0	0	0	0	0	325		3691	56		133	-589
2029-2030			293		293	547	339	4	19	909	616	0	0	0	0	0	325		3366	52		239	-351
2030-2031			317		317	568	372	4	20	965	648	0	0	0	0	0	325		3040	48		274	-76
2031-2032		680	408		1088	663	422	5	21	1111	24	0	0	0	0	0	325		2715	44		-346	-422
2032-2033			440		440	679	548	5	22	1254	814	0	0	0	0	0	325		2389	39		449	27
2033-2034			476		476	786	599	5	24	1413	938	0	0	0	0	0	325		2064	35		577	605
2034-2035			514		514	804	624	5	25	1458	944	0	0	0	0	0	325		1739	31		588	1192
2035-2036			555		555	925	681	6	26	1637	1082	0	0	0	0	0	325		1413	27		730	1922
2036-2037			600		600	947	709	6	27	1690	1090	0	0	0	0	0	325		1088	23		741	2663
2037-2038			649		649	1089	777	6	29	1901	1252	0	0	0	0	0	139		948	19		1094	3757
2038-2039			701		701	1116	810	6	30	1963	1262	0	0	0	0	0	139		809	17		1105	4862
2039-2040			758		758	1290	888	7	32	2216	1459	0	0	0	0	0	139		669	15		1304	6167
2040-2041			819		819	1322	923	7	33	2285	1466	0	0	0	0	0	139		530	13		1313	7480
2041-2042			885		885	1516	1016	7	35	2575	1690	0	0	0	0	0	139		390	11		1540	9020
2042-2043			957	645	1602	1531	1058	8	37	2633	1031	0	0	0	0	0	139		251	9		883	9903
2043-2044			1034	670	1704	1750	1164	8	38	2961	1257	0	0	0	0	0	139		111	8		1109	11012
2044-2045			1118		1118	1767	1203	9	40	3019	1901	0	0	0	0	0	139		-28	5		1756	12768
2045-2046			1208		1208	2001	1321	9	42	3374	2165	0	0	0	0	0	139		-168	4		2022	14790
2046-2047			1270		1270	2018	1364	10	44	3435	2165	0	0	0	0	0	139		-307	2		2024	16814
Total	8396	680	14677	1315	25068	24151	15145	144	671	40111	6.02%					4649	4649			855		16814	

20.7 CONCLUSIONS

Conclusions of the Financial analysis is summarised as follows.

1. The total project cost including the cost of land that has to be provided for the project is Rs. 6622.23 Crores. This cost includes the cost of both the private land as well as government land that would need to be available for this project corridor. It has been proposed that MIDC land would be required for the maintenance depot.
2. The project completion cost for Thane Bhiwandi Kalyan Metro corridor is Rs. 8416 Crores (including IDC). This has been calculated by using an escalation factor of 7.5% per annum.
3. It is assumed that the construction work will start on 01.10.2017 and is expected to be completed on 31.03.2021 with Revenue Opening Date (ROD) as 01.04.2021 for the Thane Bhiwandi Kalyan metro corridor.
4. The FIRR of the project with property development works out to be 6.02% with the proposed construction cost and proposed fare structure as detailed in this chapter.
5. The sensitivity analysis also suggests that the project is financially viable with support from State government of Maharashtra and Government of India.
6. It is necessary that both central and state government provide support for the construction and operation of the metro project and it is recommended that the Thane Bhiwandi Kalyan metro project be implemented on SPV model for which cash flow statement has been provided in this chapter.
7. As per the current practice, it has been assumed that the central government would provide equity support for the 20% of the project cost and equal contribution would be provided by the state government. The aggregated equity contribution from the central and state government is estimated to be 40%of the project cost.

21 IMPLEMENTATION PLAN

21.1 INTRODUCTION

The proposed metro corridor of Thane –Bhiwandi - Kalyan Metro Corridor has a route length of 24.9Kms. The cost of the metro along with the breakup of taxes is shown below in the Table 21.1.

Table 21.1: Cost of the Metro

Name of the Metro Corridor	Thane-Bhiwandi-Kalyan Corridor
Length of the Metro Corridor (km)	24.9
Capital Cost (with Land) in Rs. (Crores)	5313.39
Taxes & Duties in Rs. (Crores)	1308.84
Total Cost in Rs. (Crores)	6622.23

21.2 FINANCING MODELS FOR METRO PROJECT:

1. Build, Operate & Transfer (BOT)
2. A Private Public Partnership (PPP) and
3. Fully through Government funding i.e. Government mobilizing all the funds required for the project through equity, grants or loans borrowed by the Government.

Possibilities and implications of the 3 models mentioned above are discussed below:-

21.2.1 Build, Operate & Transfer (BOT)

In BOT model, the project will be handed over to a private Consortium for a specified period of time, selected through competitive bidding. The consortium will receive a concession from the MMRDA.

Consortium will be duly involved in the project for a specified period of time, selected through competitive bidding. The consortium will bring in all the funds required for the project, appoints consultants for design, planning and project implementation, execute the project fully and then operate and maintain the same during concession period. All the revenues from the project, fare box collections as well as non-fare box collections will go to the Consortium and in all the concession period the project is handed over to the Consortium. Here the Government responsibility is only to make available the required land and right of way and monitor the quality of services and safety standards. Building the system to the specified safety standards and obtaining the safety certificate from the competent authority will be the responsibility of the BOT operator. In this model the Government has no financial liability and all the risks are carried by the BOT operator. The Government may or may not stipulate the fares to be levied.

21.2.2 PPP model:

There are essentially two variants under this model.

Alternative 1:- Here the Government funds the fixed infrastructure cost such as land and basic civil structures and private investor funds all the systems such as rolling stock, signalling, power supply, traction, track, fare collection system and E&M works including station architectural design. An example for this is Delhi Metro Airport line and Versova-Andheri-Ghatkopar (VAG) corridor, Mumbai. Under this arrangement, the Government's investment will be about 40 to 45% of the total cost and the PPP Operator funds the remaining cost. The operator is selected again on competent bidding with viability gap funding who operates and maintains the system to the specified service safety levels. All the Revenues will accrue to the Operator in all the concession period till the project is handed over to the owner. Ridership for this is taken by the Operator fully or shared between the operator and the owner.

Alternative 2:- Under this the Government acquires the required land and offers to the concessionaire free of cost. The private partner funds all the rest of the project, operates and maintains the system taking all the revenues and risks. His expected losses are made good through a viability Gap Funding (VGF), by the Government arrived at based on competitive bidding. At the end of concession period the system reverts to the owner. Under the PPP model, Sweeteners are sometime offered to the operator in the form of lands for commercial exploitation. Private management generally ensures better efficiency in the execution and operation of the system compared to a Government agency.

When the project is taken up on BOT or PPP model the total cost of the project generally gets hiked up by the Concessionaire adding the availing additional costs.

- As bulk of the funds will be through borrowings. Interest during construction period will get added on to the projects costs.
- The funds are available to a private party to which borrowing costs compared to the Government and additional funding cost will get factor to the cost of the project.
- When a private party executes the project the refunds of the taxes and duties of the two Governments may not be possible. This alone will increase the cost of project by 18 to 20%.
- Metro projects by themselves will not be financially viable. Commercial exploitation of surplus lands and identified Governments lands along the route has to be necessary to augment the Capex as well as revenue earnings. Making available normal land free to the Concessionaire for commercial exploitation will lead to public criticism and often end up in scandals.

Nowhere in the country a complete BOT or PPP model has so far found successful or attractive for the main reason that the fare levels have to be kept low and affordable to the common citizens.

21.2.3 Fully through government funding:

Here, the Government takes full responsibility for funding the project either from its own resources or through borrowings. For convenience, Special purpose vehicle has been implemented as MMRC (MUMBAI METRO RAIL CORPORATION LTD). The Operation and maintenance of the system can be either directly by the SPV or they can engage an operator for the purpose. Usually a debt equity ratio of 2:1 is followed but there can be variations depending upon the tender's terms and the Government's ability to provide funds. The government's own investment will be in the form, of shareholdings in the SPV and borrowings can be either from a Consortium of local banks or from infrastructure funding organizations such as IIFCL, IDBI, etc. or through an external bilateral loan from institutions such as ADB, World Bank, JICA etc. All the loans will need Governmental guarantee to reduce the borrowing cost. The Government can also assist the SPV with interest free subordinate loans. The SPV will have responsibility to service and pay back the loan and if SPV fails the responsibility will then devolve on the Government.

21.3 RECOMMENDED FINANCIAL MODEL FOR THANE- BHIWANDI- KALYAN CORRIDOR:

World over Metro projects are not financially viable and depend upon generous concessions and subsidies. The financial rate of return for the Thane- Bhiwandi- Kalyan Corridor is 6.02% with property development option.

The metros which have been implemented on BOT model so far are the Rapid Metro in Gurgaon and Versova-Andheri-Ghatkopar (VAG) corridor, Mumbai. Out of the 3 PPP models in the country, Delhi Airport Line has been a total failure since the Concessionaire has voluntarily withdrawn with claims through arbitration. In the case of Mumbai Metro Line No.1 which is only 11 Kms length had taken more than 6 years for completion and the cost had gone up 2 times. Concessionaire is representing to government for allowing him to charge very high fare in spite of very good ridership leading to loading the public financially.

In the case of the Hyderabad Metro the PPP Concessionaire withdrew from the project and another Concessionaire namely L&T is implementing the project. The financial performance of this project is yet to be assessed as even one section of the project is still not opened for traffic. Considering the global scenario and the experience in our own country DMRC does not recommend either the BOT model or PPP route for implementing the Thane- Bhiwandi- Kalyan Corridor.

It is therefore recommended that the project is implemented fully as a Government initiative. By this route the project can be completed at the shortest time and at the lowest cost. This is important because then only ticket can be priced low, affordable to the common citizens and make the system truly a popular public transport.

21.4 INSTITUTIONAL ARRANGEMENTS

The State Govt. of Maharashtra will have to approve the implementation of the project by Mumbai Metro Rail Corporation Ltd or MMRDA.

21.5 IMPLEMENTATION STRATEGY

When the project is taken up as a Government initiative there are two ways the projects can be implemented. One is – Mumbai Metro Rail Corporation Ltd. (MMRC) /MMRDA handling the project directly with the help of General Consultants (G.C.). Further bilateral lending agencies generally insist of international consultants to engage as G.C. for assisting for the implementation of the project. International G.C. is required for planning, design, drawing up specifications, preparation of tender documents, and finalization of contract and supervision of the project during execution. To engage the G.C. globally tenders would be necessary. For finalizing such a global contract and positioning the Consultants it takes about 9 to 12 months. G.C. will generally cost about 3½ to 4% of the project cost. Even if G.C. is engaged, still MMRC/MMRDA will need a fairly big organisation to oversee the G.C. work. It will be difficult for MMRC/MMRDA to mobilize required technical persons with experience and knowledge and the establishment cost of MMRC/MMRDA itself would be about another 3½ to 4%. Thus about 7 to 8% of the project cost will be spent on total establishment alone.

The 2nd option is MMRC/MMRDA for this project can be a very small lean organisation responsible for land acquisition and mobilisation of funds. The entire Metro project can be entrusted on turnkey basis and on deposit terms to an experienced organisation such as DMRC who has the experience and track record and competency of technical manpower. DMRC is implementing on similar basis Jaipur Metro for Rajasthan Government and Kochi Metro for Kerala Government and Greater Noida Metro project for the Greater Noida Authority. The same way the Thane-Bhiwandi-Kalyan Corridor can also be handed over to DMRC on a turnkey basis for implementation. DMRC generally charges 6% of the project cost for the total turnkey implementation. This will be the cheapest and quickest way of completing the project in time.

21.6 CONTRACT PACKAGES FOR IMPLEMENTATION OF THE THANE-BHIWANDI-KALYAN CORRIDOR PROJECT

- **Package –1:** Starting from Thane to Kalyan proposed metro station via Bhiwandi.
- **Package-2:** Detailed design consultant for both the corridors including Depot.
- **Package-3:** Construction of boundary wall for depot, earth work filling and construction of workshop, inspection bay, stabling lines etc.
- **Package-4:** System Contracts: Supply and installation of traction power system (3rd bay) including sub-station.
- **Package-5:** Supply and installation of signaling system (CBTC)
- **Package-6:** Supply and installation of AFC System.
- **Package-7:** Supply and commissioning of rolling stock.
- Any other small package may be decided at the time of implementation of the Project.

21.7 IMPLEMENTATION SCHEDULE

A suggested project implementation schedule for Project Implementation on Turnkey Basis (Deposit Terms) is given in Table 21.2.

Table 21.2: Implementation Schedule

Item of Work	Completion Date
Submission of Final DPR to State Govt.	D
Approval of DPR by State Government	D+15 days
Submission of DPR for Approval of Ministry of Urban Development (MoUD).	D+30 days
Sanction of Project by GOI	D+60 days
Appoint an agency on deposit terms	D+30 days
Implementation of the project	D+43 months
Testing and Commissioning	D+44 months
CMRS Sanction	D+45 months
ROD	D+ 45 months

21.8 HIGH POWER COMMITTEE

During the implementation of the project several problems with regard to acquisition of land, diversion of utilities, shifting of structures falling on the project alignment, rehabilitation of project affected persons, etc. are likely to arise. For expeditious resolution of these problems, an institutional mechanism needs to be set up at the State Government level. Towards this end, it is recommended that a High Power Committee under the chairmanship of Chief Secretary, Maharashtra should be set up. Other members of this Committee should be Secretaries of the concerned Departments of the State Government and Heads of civic bodies who will be connected in one way or the other with the implementation of the project. This Committee should meet once a month and sort out all problems brought before it by MMRC Ltd. It is reliably learnt that for the Delhi Metro also such a High Power Committee was set up and it proved very useful in smooth implementation of the Delhi Metro Rail Project.

21.9 CONCESSION FROM GOVERNMENT

Metro rail projects need very heavy investment. Loans have invariably to be taken to fund a part of the capital cost of the projects. These projects yield low financial internal rate of return. With reasonable fare level, servicing of these loans often pose problems. To make the project financially viable, therefore, the fares need to be substantially increased to socially un-acceptable levels. This results in the ridership coming down significantly, as it is sensitive to increases in the fare level. Thus the very objective of constructing the metro rail system to provide an affordable mode of mass travel for public is defeated. It, therefore, becomes necessary to keep the initial capital cost of a metro project as low as possible so that the fare level of the metro system can be kept at reasonable level. Following are the taxes and duties, which have to be borne by a metro project:

- Custom Duty on all imported rolling stock and other equipment needed for the project.
- Excise Duty on all indigenously manufactured rolling stock and other indigenously finished goods required for the project.
- Sales Tax on all purchases made for implementation of the project whether directly by the project implementation authority or by the contractors executing the project.
- Sales Tax on works contracts to be executed for the implementation of the project.
- Tax on electricity required for operation and maintenance of the metro system.
- Municipal Taxes.

As in the case of Delhi Metro, the State Government should exempt/reimburse the Maharashtra Value Added Tax (VAT) to this Metro project. It should also exempt the following:

As per the present policy 50% of the Central Taxes will be paid by GOI as subordinate Debt and balance 50% will be paid by the concerned State Government. Maharashtra State Government may pursue the Central government to extend the same benefit to MMRC.

In the case of Delhi Metro project, the Union Government has granted exemption from payment of Custom Duty and Excise Duty while the Delhi Government has agreed to give exemption from payment of Sales Tax and on works contracts. Delhi Metro Rail Corporation is also pursuing with the Government for exemption from tax on electricity being consumed by Delhi Metro for its operation and maintenance.

It is recommended that similar exemptions from taxes and duties be granted by the Central Government/Maharashtra Government for TBK Metro. In this connection it may be mentioned that the Central Government has been encouraging infrastructure projects in the country through fiscal and non-fiscal concessions. Cities have emerged as the engines of growth and mass transport systems today are one of the most important pre-requisites for the balanced growth of the city. The Government can demonstrate the importance it attaches to this sector by granting the above concessions which would not only help reduce the initial cost of the project so that TBK Metro remains commercially viable during its operation phase but also send strong signals to the effect that it is committed to a safer and pollution free city. Moreover, public transport is employment-friendly and favours social balance in a sustainable way since it allows access to jobs and services to all.

21.10 LEGAL COVER FOR MUMBAI METRO

Implementation of proposed Thane-Bhiwandi-Kalyan Metro can now be done under "The Metro Railways (Amendment) Act 2009". The copies of the Gazette notification and the amendment are put up enclosure to this chapter.

22 CONCLUSIONS AND RECOMMENDATIONS

22.1 INTRODUCTION

Government of Maharashtra (GoM) and Mumbai Metropolitan Region Development Authority (MMRDA) intend to improve transport scenario in the Mumbai Metropolitan Region (MMR). MMRDA has completed Comprehensive Transportation Study (CTS) for MMR that has identified transport infrastructure for horizon year 2031. There are various ideas of CTS which are recommended of which few are being implemented in phased manner.

MMRDA has carried out Technical Feasibility Study on Thane - Bhiwandi – Kalyan monorail (approx. 25 kms) corridor in December, 2011 which is displayed in Figure 1.1.(Chapter1) The CTS data used for the estimating the ridership is more than a decade old. As per Feasibility study, Thane (Kapurbawdi) -Bhiwandi- Kalyan Monorail corridor may not turn out to be economically viable on fare box, advertisement and other revenues.

MMRDA entrusted D'Appolonia S.p.A. and TATA Consulting Engineers Limited to carryout fresh travel demand estimation for Thane (North), Bhiwandi, Kalyan sub region and to prepare Techno-Economic Feasibility and Detailed Project Report (DPR) for appropriate MRT system for the Thane-Bhiwandi-Kalyan sub region.

Thane and Kalyan are major trip generating locations in Mumbai Metropolitan Region (MMR). Considerable population of working class is living in Thane and Kalyan. Bhiwandi is a hub for warehouses and small industries, which leads into major trip attraction zone. Though in terms of time based mobility and accessibility, there is lack of connectivity between them. Secondly, besides having railway stations at Thane and Kalyan, most of the time suburban rails have passenger volume which is far more than the crush load and hence causes high level of discomfort to the commuters. In light of above, it is necessary to review the status of public transportation in Thane, Bhiwandi and Kalyan.

22.2 STUDY SUMMARY AND RECOMMENDATIONS

Major Study summary and recommendations are listed as below

- With growing population and proposed BSNA and Kalyan development plans coming up in the regions, the travel demand is expected to grow steeply. Ridership values of the various simulated scenarios recommend construction of a new MRTS, which would be extremely attractive for a large group of people The most likely peak traffic demand on Thane Bhiwandi Kalyan corridor has been assessed as 18000 PHPDT for 2021 and this is likely to increase to 26000 PHPDT by the year 2031 Considering the Peak hour passenger demand traffic and the characteristics of transit systems described in the previous sections, there will be a need to introduce a Rail based Mass Rapid Transit System (MRTS) in the city to provide fast, safe, economic and environment friendly mode for mass movement of passengers.
- Proposed peak hour headway for 2021 is 5 minutes and Train capacity is 1756 passengers.
- Proposed Thane – Bhiwandi – Kalyan corridor runs Northward from Kapurbawadi Junction (Thane End) to Shivaji Chowk (Kalyan) covering a total distance of about 24.9 km. Total 17 stations are proposed along the Corridor taking in to account of

the catchment area , inter spacing between stations , land availability, and connectivity. All stations are proposed as elevated stations. Stations are generally located at an average distance of 1.5 km apart. Proposed Station are presented in Figure 22.1. Average station length would be 180 m.

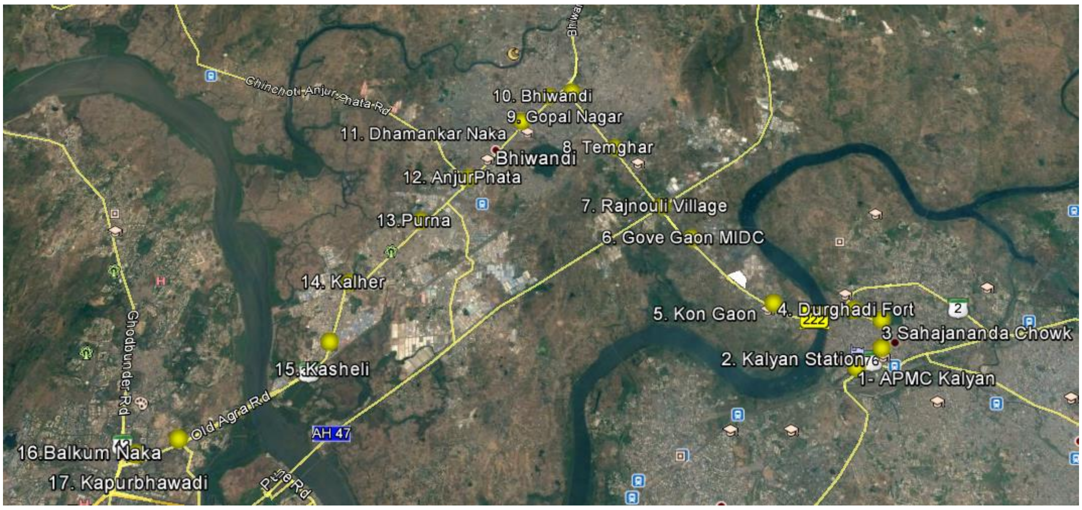

Figure 22.1:Proposed Stations

- A detailed Environmental Impact Assessment Study was carried out. As a part of this Study, environmental baseline data was collected, and both positive and negative impacts of the project were assessed in detail. The project has many positive environmental impacts like reduction in traffic congestion, saving in travel time, reduction in air and noise pollution, lesser fuel consumption, lesser road accidents etc, with a few negative impacts (especially during implementation phase of the project) for which Environmental Management Plan has been suggested.
- The total project cost including the cost of land that has to be provided for the project is Rs. 6622.23 Crores. This cost includes the cost of both the private land as well as government land that would need to be available for this project corridor.
- The project completion cost for Thane Bhiwandi Kalyan Metro corridor is Rs. 8416 Crores. This has been calculated by using an escalation factor of 7.5% per annum.
- It is assumed that the construction work will start on 01.10.2017 and is expected to be completed on 31.03.2021 with Revenue Opening Date (ROD) as 01.04.2021 for the Thane Bhiwandi Kalyan metro corridor.
- The FIRR of the project with property development works out to be 6.02% with the proposed construction cost and proposed fare structure.
- While the Financial Internal Rate of Return (FIRR) for the project has been assessed as 6.02 %, the Economic Internal Rate of Return (EIRR) works out to 17.09%
- The sensitivity analysis also suggests that the project is financially viable with support from State government of Maharashtra and Government of India.

- It is necessary that both central and state government provide support for the construction and operation of the metro project and it is recommended that the Thane Bhiwandi Kalyan metro project be implemented on SPV model
- As per the current practice, it has been assumed that the central government would provide equity support for the 20% of the project cost and equal contribution would be provided by the state government. The aggregated equity contribution from the central and state government is estimated to be 40%of the project cost.
- For the remaining 60%, it has been assumed that a loan would be needed from international institutions like JICA. Other sources which could also provide soft loans are World Bank and Asian Development Bank. JICA provides loan at an interest of 1.4% per annum and World Bank at about 2.5% per annum.

REFERENCES

14-1167-H1 (2015). Inception report of Techno-Economic Feasibility and Detailed Project Report for Thane-Bhiwandi-Kalyan for appropriate Mass Rapid Transit System (MRTS). D'Appolonia & Tata Consulting Engineering (TCE);

CTS (2015). Comprehensive Transportation Study for Mumbai Metropolitan Region;

Cantarella, G.E. (1997). A general fixed-point approach to multi-mode multi-user equilibrium assignment with elastic demand. Transportation Science, 31, 107-128;

DPBSNA (2008). Development Plan 2008 – 2028 for Bhiwandi Surrounding Notified Area. Institute for Spatial Planning and Environment Research, India Panchkula;

DPKAT (2011). Development Plan for notified area of 27 villages of Kalyan and Ambarnath Tehsils of Thane district. Mumbai Metropolitan Region Development Authority;

MMC (2011). Techno- economic and financial feasibility study for development of a mutlimodal corridor from techno economic feasibility Virar to Alibaug. The Louis Berger Group, Inc.;

Nielsen, O. A. (1993). A new method for estimating trip matrices from counts. Institute of Roads, Traffic and Town Planning, The Technical University of Denmark;

Sheffi, Y., & Powell W.B. (1981). A comparison of stochastic and deterministic traffic assignment over congested networks. Transportation Research B, 15, 53-64;

Sheffi, Y., & Powell W.B. (1982). An algorithm for the equilibrium assignment problem with random link times. Networks, 12, 191-207;

Spiess H. (1987). A maximum likelihood model for estimating origin-destination matrices. Transpn. Res. B 21, 395-412;

TEFS (2011). Technical feasibility study for monorail Thane – Bhiwandi – Kalyan corridor. RITES Ltd. Mumbai, India.

APPENDIX A

APPENDIX A: PLAN AND LONGITUDINAL PROFILE OF OPTION I

APPENDIX B

APPENDIX B: PLAN AND LONGITUDINAL PROFILE OF OPTION II

APPENDIX C

APPENDIX C: PLAN AND LONGITUDINAL PROFILE OF OPTION III