Summer 2019

Connecting the Nodes: A better relationship between Transit-Oriented Development and Pedestrian Connectivity

Tanvi Halde

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CONNECTING THE NODES

A better Relationship between TOD and Pedestrian Connectivity

By

Tanvi Sharad Halde

A creative component submitted to the graduate faculty in

Partial fulfillment of the requirements for the degree of

MASTER OF COMMUNITY AND REGIONAL PLANNING

MASTER OF URBAN DESIGN

Major: Community and regional planning and Urban Design

Program of Study Committee:
Professor Carlton Basmajian, Major Professor
Professor Sungduck Lee, Major Professor
Professor Biswa Das, Committee Member

Iowa State University

Ames

Iowa

2019

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CURRENCY EQUIVALENTS
(as of 23 March 2019)

Currency unit rupee (₹)

₹ 1.00 $0.014
$1.00 ₹ 69.17

LIST OF ABBREVIATIONS

ADB - Asian Development Bank
AFC - Automatic Fair Collection
BEST - Brihanmumbai Electricity Supply and Transport
CTS - Comprehensive Transport Study
DMRC - Delhi Metro Rail Corporation
DP - Development Plan
IIT - Indian Institute of technology
ITDP - Institute for Transportation and Development Policy
L&T - Larsen and Toubro
MCGM - Municipal Corporation of Greater Mumbai
MMOPL - Mumbai Metro One Pvt Ltd
MMR - Mumbai Metropolitan Region
MMRDA - Mumbai Metropolitan Region Development Authority
MOOPL - Metro One Operation Private Limited
NMT - Non-Motorized Transport
PHPDT - Peak Hour Peak Direction Traffic
RInfra - Reliance Infrastructure
SVP - Special Purpose Vehicle
TCS - Tata Consultancy Services Limited
TOD - Transit Oriented Development
VGF - Visibility gap funding
ACKNOWLEDGEMENTS

I would like to take this opportunity to express my thanks to those who helped me with various aspects of conducting research and writing of this report. I would like to thank, my major professors and committee member, Carlton Basmajian, Sungduck Lee and Biswa Das for their guidance patience and support throughout the research and writing my creative component. It was a great learning opportunity for myself while working under your guidance.

I would like to thank my friends and family who in a way or other have shared their support, either emotionally and physically.

The completion of this undertaking would not have been possible without the support and assistance of many people whose names may not be enumerated. Their contributions are appreciated and gratefully acknowledged.
Chapter 1: Introduction

1.1 Background

India’s growing economy and major advancements in vehicle affordability has caused a significant increase in the private ownership of vehicles. Mumbai Metropolitan Region (MMR) is one of the fastest growing regions in India. The MMR consists of 7 municipal corporations, 13 councils and 996 villages extended over a total area of 4,355 sq. km. The current Population of MMR is 21.3 million. MMR is projected to have a population of 34.0 million and employment of 15.3 million by the year 2031. In the city of Mumbai, there is a dominance of passenger movement accompanied by overwhelming dependence of travel of public transport modes and walk. The city currently consists of overcrowded public transport systems and a congested road network system due to a large gap between demand and supply. The city has observed a large population growth since 1951 and is accommodated mostly in the suburbs while the high concentration of the jobs lies in the downtown of MMR (South Mumbai). The physical characteristics of the city are such that the suburbs have been constrained to spread northwards only, and all transport facilities are concentrated within three narrow corridors.\(^1\) MMR is historically heavily dependent on public transport and walking as a mode of transport. Over 40% of workers in MMR reach their workplace on foot resulting in almost 52% of the total trips per day using walking as a primary mode of transport.\(^2\) Suburban local trains form the lifeline of Mumbai’s North-South transport. The Mumbai Suburban Railway network covers about 248.54 miles (400km) with 7 million average weekday passenger trips with extremely low fares. The buses contribute to 26% mode of public transport with 3.55 million trips. Brihan Mumbai Electric Supply and Transport (BEST) along with other private transport provide the bus transport in Mumbai. Intermediate transport like auto-rickshaws and taxis play an

\(^1\) India: Mumbai Metro Rail Systems Project, Mumbai Metropolitan Region Development Authority, Government of India for the Asian Development Bank

\(^2\) Mitigation Policy packages for Transport sector- Mumbai Metropolitan region
important role in accommodating the transport demands to provide access to busses and trains in the
city.

The demand for vehicular transport is significantly higher than the existing capacity of the roads in
Mumbai, India leading to severe congestion. Transit oriented development is one of the effective tools
which can bring a shift from the use of private vehicles to public transport. In highly populated
metropolitan city like Mumbai, residents face many problems in terms of compact housing, scarcity of
open space, crowded public transport and heavy traffic congestion on daily basis. As the existing transport
system in the city is failing to meet the demands of the commuters, Metro rail system has been introduced
in congested areas to reduce the traffic congestion. (MMRDA) is planning to implement TOD along the
newly introduced METRO network. Transit-oriented development (TOD) can directly benefit a transit
agency through increases in ridership and revenues. TODs can also have a positive impact on society by
reducing auto use and reducing the volume of vehicles and congestion on the highway network. However,
its success aspects are unknown and yet to be explored. It is important to evaluate whether the area
where TOD is planned will give the above desired effects and to what extent. Hence, this study focuses on
understanding the relationship between TOD and pedestrian connectivity, before implementing plans for
proposed metro lines in the city. An analysis of the existing metro Line 1 needs to done in terms of street
design parameters which influence the pedestrian behavior. These parameters include sidewalks, off-
street parking, elevated walkways, street vending and accessibility to the transit nodes.
This study includes the Andheri Metro Station on Mumbai Metro Line 1 as a pilot study area which will be observed to understand the problems faced by the pedestrian to commute to the existing station for metro line 1. The selected area lies around the Andheri Metro Station and covers half-mile radius area. The parameters of street design will be observed for the station for existing metro station for Line 1 (Node A) and area dedicated for proposed metro line 2 (Node B). The results from the observations will set the guidelines for a better pedestrian connectivity to the transit nodes and to define successful TOD in Mumbai. The findings from this study will be useful for decision makers, practitioners and policy makers to predict the passenger behavior before the station has been designed. The recommended street
Interventions will help to develop better TOD policies based on the predictions and study for the existing station for metro line 1.

1.2 Research questions and study objectives

This research explores on the relationship between TOD and pedestrian connectivity at neighborhood scale in Mumbai metropolitan area. TOD is a straightforward concept: concentrate a mix of moderately dense and pedestrian-friendly development around transit stations to promote transit riding, increased walk and bicycle travel, and other alternatives to the use of private cars (Shirke, C., Joshi, G. J., Kandala, V., & Arkatkar, S. S., 2017).

This research investigates the relationship between TOD and pedestrian connectivity. This study addresses two research questions: 1) What is the level of urban pedestrian connectivity that is related to TOD in Mumbai, India? 2) How do we implement successful TOD strategies for urban pedestrian connectivity in Mumbai, India?

The research questions focus on the objective to study:

1) The level of pedestrian connectivity to the existing metro station for line 1 in Mumbai, India.

2) The factors that are involved to promote a better street connection and promote walking modes.

3) To suggest changes in the street design templates mentioned in the manual for India and provide recommendations for streetscape for the proposed metro line 2 in Mumbai.

4) To suggest the policies that needs to be revised and new policies that needs to be introduced to have a successful TOD system in Mumbai, India.

1.3 Overview of Data and Methodology

1) What is the level of urban pedestrian connectivity that is related to TOD in Mumbai, India?

Observation method will be used as a methodology to answer the first research question. The existing Metro Line 1 of Mumbai has 12 stations, out of which 1 station (Andheri station) is selected as a Node A
for observation. The Node A is observed in terms of pedestrian connectivity to get results that provide street design and planning policy recommendations for Node B (Proposed Metro Line2). The selected Node A and Node B are observed at different times of the weekdays and weekends in to understand the pedestrian connectivity to the existing Metro Station for line 1 and the area where the proposed metro line 2 is expected to be constructed. The observation is done by the author by clicking pictures and videos on site. A mapping analysis is done to understand the existing scenario for Metro station for line 1(Node A) and proposed line 2 (Node B). The results from the observation method are used to answer the first question and are used as a base for answering the second research question.

2) How do we implement successful TOD strategies for urban pedestrian connectivity in Mumbai, India?

The results from the analysis for the first research questions, set the general guidelines for my design suggestions for the proposed metro station (Node B) in Mumbai in terms of planning policies, urban design implications, city infrastructure. A mapping analysis is done for Node A and Node B which identifies the pedestrian and vehicular activity in both the nodes and based on the results from the mapping analysis, the Node A and Node B are narrowed done to a street Section of 0.62 mile (1 km) in length to define the street design interventions.

1.4 Study Area

The paper focuses on the Metro System in Mumbai, India and explores the relationship between TOD and pedestrian connectivity. The current situation in India indicates that people are preferring to use private vehicles than public transport. The main objective of the Mumbai Metro is to provide mass rapid transit services to people within an approach distance of between 1 and 2 kilometers, and to serve the areas not connected by the existing Suburban Rail network. The Metro Line 1 and 2 is located in the city of Mumbai of state of Maharashtra in India. The selected nodes for the existing metro line 1 and proposed metro line 2 will be observed and analyzed. The focus of the study is to observe the pedestrian accessibility in terms of modes like car, bus, bike and walk to the transit station within a buffer of half- mile radius. TOD has a
major principle which aims to increase the pedestrian access and reducing the use of private vehicles in densely populated areas. The observation is done at different times of the day and are analyzed using mapping analysis. ITDP EPC manual for street design in Urban India and Street design guidelines for Mumbai provide a set of standards that need to be followed while designing street. These guidelines will be used as base for recommending future street interventions for proposed metro line 2. The goal is to observe existing metro line 1 (Node A), analyze it and provide recommendations in terms of urban design and planning policy for the proposed metro line 2. The street design guidelines are provided in terms of street sections in reference to the analysis and observations done for both Nodes A and B.

1.5 Organization of the Study

The paper is organized in sections as follows: Literature review, Study Area, analysis and discussion and conclusion. Chapter 2 talks about the benefits and challenges of TOD and explains the concepts of TOD. It explores the issues related to TOD in general and the introduction of TOD in India. The chapter explores the current debate of TOD in India and the initiatives taken by the government of India for a better TOD system in India. The chapter narrows down to the rational objective of TOD in city of Mumbai and explores the metro rail system in Mumbai in terms of connectivity. This chapter explains the Draft development Plan for Greater Mumbai 2014-2034 and identifies the strategies mentioned for a better TOD system in Mumbai. It also explores the financial structure of the Metro Line 1, Line 2 and Line 3 which will be studied further in chapter 4. Chapter 2 identifies the two research questions of the paper and the objectives of study.

Chapter 4 is study area which explains the methodology that will be used for the selected site. It describes the objective of the study and methodology used to achieve these objectives. It provides a detailed explanation of study area and data collection method. The observation method as a methodology is explained in detail for existing metro line 1 (Node A) and proposed metro line 2 (Node B). The results from the observation method are explained through mapping analysis and site images to understand the
current issues and provide suggestions for street interventions for proposed metro line 2. Chapter 5 is Analysis, which uses the results from the study area and provides a detailed design proposal in form of street sections and illustrations. It uses street design guidelines to provide changes in street design and implement it for the proposed metro line 2 (Node B). Chapter 6 is about discussion, contribution, limitations and scope of future research for the paper. This chapter discusses the planning policy recommendations based on the analysis which contribute to have a better relationship between TOD and Pedestrian connectivity. The paper identifies the considerations that needs to be made in the draft development plan for Mumbai which includes street design to promote TOD in terms of pedestrian connectivity. The paper is concluded with the scope of future research.
Chapter 2: Literature review

2.1 Benefits and Challenges of Transit oriented development (TOD):

TOD has impacts on social, environmental, economic and individual aspects leading to benefits. The characteristics of successful Transit Oriented Development (TOD) are outlined: 1) A strategic policy for nodes: TOD requires the nodes to be developed in order to reduce the external costs on car dependence and save travel time in traffic congestion; 2) A strategic policy for rapid transit: TOD requires repackaging of land parcels, re-design of roads and re-orientation towards the rail system. Proactive planning processes that create these land packages and do the detailed urban design are usually beyond local government resources; and 3) A public-private partnership mechanism to build rail linked to nodes: Tod requires the public and private transit system to work simultaneously to get an efficient utilization of the Metro system.

One of the biggest challenges is that the regulatory framework of most municipalities is not supportive of TOD. It is common for cities to have zoning ordinances and land development codes designed for automobile-oriented, single-purpose, suburban-scale development. The key to balancing the development mix is in understanding the station’s role in the transit network and metropolitan economy. The imperative for successful TOD of any size or location remains ensuring the walker has precedence (Curtis 2008).

Parking: Developments where car parking ratios for residents, shoppers and commuters remain generous, and private car use continues at former levels, will struggle to develop the sense of place and community to which genuine TOD aspires. Research results show that TOD parking supply and pricing policy seldom are structured to support transit ridership goals Parking policy is an important determinant of travel behavior, regardless of proximity to transit.
Gentrification: As most cities continue to sprawl, many young families especially from the middle class prefer returning to the central city resulting in an increase in demand for housing in upmarket neighborhoods which are usually located around newly ordained public transit projects. It is generally agreed that in the American context, average prices for homes near transit may be at least 10 per cent costlier than in the suburbs. In the resultant competition for housing limited by development regulations, invariably those with poor purchasing power may get replaced by the newly arrived richer households through the process of gentrification. Gentrification may also result in the exclusion of the low-mobility, low-income groups that were located on the TOD corridor who may be considered captive groups for public transit. These groups may then be replaced by middle-income or high-income groups that already own cars and would be reluctant to use public transit in the absence of adequate push factors in the form of high taxation and fuel prices.

Stakeholders: It is imperative for stakeholders to actively take part and integrate between various departments within a city to make a TOD successful. In the Indian context, political will acts as a major factor in the completion of TOD projects because of the age-old discussions and policies mostly leading into private vehicle-oriented policies, it is a shift which needs to be backed by willingness from the citizens as well as the government.

2.2 TOD in India:

Indian cities face a multitude of issues such as severe congestion; deteriorating air quality; increasing greenhouse gas (GHG) emissions from the transport sector; increasing road accidents; and an exploding growth in the number of private vehicles (largely motorcycles). With the urban population projected to more than double in the next generation, the situation could easily get out of control and thwart India’s economic development efforts unless remedial measures are soon taken. The state of public transport in the majority of Indian cities has degraded over the years. Rising population and
underdeveloped mass transport have led to a rapid rise of personal vehicles, traffic congestion and an increase in pollution levels. Moreover, most people do not use public transport simply because of the lack of it and inaccessibility to the transit. Therefore, while augmenting public transport, planning for accessibility is the need of the hour. Increased density and improved connectivity through TOD can help achieve that. But, one of the most important reasons for thinking about TOD for Indian cities is the recent emphasis on public transport at all levels of government (EPC 2012). Scholars have argued that transport sector in India is extremely energy intensive and needs massive investments in mass transit to quell the rise of private motorised mobility (Rizvi Transit-Oriented Development: Lessons from Indian Experiences 2013; Yedla 2015). Post the announcement of mission-based programs like Jawaharlal Nehru National Urban Renewal Mission (JNNURM) in 2005, Atal Mission for Rejuvenation, and Urban Transformation (AMRUT) and Smart Cities in 2015, there has been huge emphasis on investments in public transport. Transit systems like metro rail and Bus Rapid Transit (BRT) have found their way into many cities including Delhi, Mumbai, Kolkata, Chennai. Bengaluru, Hyderabad, Ahmedabad, Rajkot, Surat, Pune, Pimpri-Chinchwad, Hubli, Dharwad, Lucknow, Kochi, Jaipur, Bhopal and Indore among many others. In western countries, TOD was used for densifying certain areas but in India the cities already have higher densities. Hence TOD in Indian cities should be looked at as a tool for improving quality of life and financial means to provide infrastructure facilities (Petkar and Hamand 2013).

Current debate on TOD in India:

Additionally, the level of diversity of use in these areas is also high, presenting an ideal case for TOD. Many of the mainstream debates around TOD have centred on the development potential of the areas along transit corridors The National Urban Transport Policy (NUTP) of 2006 was a response to the massive issues of congestion and resultant loss of productivity in Indian cities. While it mentioned progressive concepts like “cities for people” and “encouraging greater use of public transport and non-motorized modes,” it
also talked of mass transit systems only in the context of using “land as a resource for financing investments” (Ministry of Urban Development 2006). It also encouraged cities to pursue the integration of land use and transport plans. It must be noted that the draft NUTP (Ministry of Urban Development 2014) stresses on TOD as means to bring about high-density urban growth with a view to promoting high levels of accessibility and shortening trip lengths. “The Government of India would encourage Transit Oriented Development (TOD) with increased [Floor Area Ratio] FAR along transit corridors with high density of population should form a part of planning”. Additionally, the reports recognize the need for Transportation Demand Management (TDM) and controlling the use of personal vehicles in line with the philosophy behind TOD. The Detailed Project Reports (DPR) for metro rail in cities like Kochi (DMRC 2011), Jaipur (DMRC 2012) and Pune (DMRC 2013) take inspiration from national policy only sparingly as only integration of different modes with the metro rail is proposed. Cities like Delhi have had the lead in the adoption of mass transit from the early 2000s. Overall, the debates have largely centered on realizing the value of land through which the metro rail corridor runs and integration of private modes with metro stations. Concrete attempts towards preparation of TOD plans through development plans or standalone local area plans has not been explored in most cities.

Rational Objectives of Mumbai Metro:

One of the major challenges for the city is to improve the quality of life of the residents by providing connectivity and promoting growth by providing inputs to the infrastructure. As described in Figure 2.1, Comprehensive Transportation Study (CTS) for Mumbai Metropolitan Region estimates that a there is a total daily demand of 34.3 million trips by all modes 50% contributes to walking and 50% contributes to uses of mechanized modes of transport- 73% trips are by public transport, 9% are by para transit mode and 18% are private transport mode. The currently existing Mumbai Suburban Rail system are the major
source of long distance inter-intra travel in the city, supported by BEST buses to provide cross connection transport in the city and para transit modes.

![Pie chart showing modes of transit in Mumbai Preferred by Commuters. Source: Author, 2019.]

The Mumbai Suburban Rail System suffers severe overcrowding due to extensive reach across the Mumbai Metropolitan Region and intensive use by the local urban population. The capacity of the 9-car rail is 1700 but over 4500 passengers travel during peak hours and has a dense crush load of 14 to 16 standing passengers per square meter of floor space. To decongest the existing suburban rail system and to provide connectivity at macro and micro level within MMR, MMRDA envisaged a transit network of about 667 km in 32 transit links. This includes 1) Metro Network (251 km), 2) Monorail Network (179 km) and 3) suburban Rail network (237 km). MMRDA prepared a Master Plan of Mumbai Metro network in 2003 which includes 9 corridors covering a length of 146.5 km, out of which 32.5 km is underground and 114 km is elevated. The Master Plan for the Mumbai metro along with its progressive implementation
was developed by Delhi Metro Rail Corporation (DMRC), in collaboration with TATA Consultancy Services (TCS) and the Indian Institute of Technology (IIT).

MMRDA has set aims for Metro Rail project\(^3\), which are: 1) Providing environmentally sustainable transport means by mitigating the climate change and air and noise pollution, 2) Reducing the urban congestion in the city and thus, increasing labor productivity which will contribute to the economic growth and 3) Enhancing the mobility of the socially disadvantaged population to improve livelihood and increase their access to education, jobs and other services.

This paper will be focusing on the AIM 2 which is reducing the urban congestion in the city and AIM 3 enhancing the mobility of the socially disadvantaged population to improve livelihood and increase their access to education, jobs and other services of the Metro Rail Project which is further discussed in Chapter 2.3 which identifies the strategies and goals for TOD in Mumbai.

\(^3\) India: Mumbai Metro Rail Systems Project, Mumbai Metropolitan Region Development Authority, Government of India for the Asian Development Bank
2.3 Development 2014-2034, Greater Mumbai:

Mumbai is a city located in India with a population of 18.41 million. The Municipal Corporation for Greater Mumbai has prepared Draft Development Plan 2034 following the provisions of The Maharashtra Region & Town Planning Act, 1966. The DP 2034 covers the jurisdiction of the Municipal Corporation of Greater Mumbai, excluding the areas under Special Planning Authorities appointed under section 40 of the MR&TP Act 1966. The comprehensive plan is called as Development plan or DP in Mumbai, India. Greater Mumbai is witnessing trends of stabilizing population growth rate combined with decreasing household size, increasing workforce participation rate, and increasing per capita income. Greater Mumbai has also experienced marginal increase in proportion of formal sector employment and growing aspirations and increasing demand for space and infrastructure. Mumbai has also experienced significant transformation of its economy. Manufacturing has declined considerably, and services particularly financial services have expanded. Now the aspiration is to become international center for finance, commerce and entertainment. This would need to be enabled by the proposed spatial structure. On the other hand, there is limited availability of land in Greater Mumbai. The City is characterized by inequitable distribution of space, amenity and infrastructure demand, given its vast population that resides in slums. Further, the significance of its eco-system under pressure from urbanization and its protection is imperative. DP 2034 therefore needs to find strategies, which promote holistic and inclusive city renewal and redevelopment, improved access to transportation and amenities, and preservation of its ecology and environment. Further, provision of amenities and infrastructure required to sustain growth is one of the key challenges of the DP 2034. The vision and objective section of includes the goals and objectives that the city will implement for the time span of 2014-2034. The vision projects the 12th Five Year Plan for the City of Mumbai and aims to make Mumbai a center for economic growth over next two decades and expecting a GDP growth of 9%-10%. The three major goals of the DP 2034 for greater Mumbai are competitive city, Inclusive city and sustainable city providing a good quality for life.
DP 2034 adopts a multi-pronged approach that integrates the vision for Greater Mumbai with bottom-up perspectives as under:

![Diagram showing DP 2014-34 Objectives]

Figure 2.3 Objectives of DP 2014-2034. Source: Draft Development Plan 2034, Greater Mumbai.

In the figure 2.3, it demonstrates the Six objectives of Draft Development plan for Mumbai 2014-2034. The objective 1 is Enabling Urban Transformation, Objective 2 is ensuring equitable development, objective 3 is strengthening the environmental networks, objective 4 is ensuring efficient mobility for all, objective 5 is reinforcing Mumbai’s diversity and Objective 6 is Formulating effective Implementation Plan. Each objective has strategies which will help to achieve the objectives. The paper focuses on Objective 1 which is Enable Urban Transformation and Objective 4 which is Efficient Mobility for all as in focuses on TOD in the city.
The Figure 2.4 demonstrates the objectives and related strategies of the objectives mentioned in the DP 2014-2034 which aim to achieve an efficient TOD system and better street connections. Objective 1: Enable Urban Transformation includes Strategy 01 which is Promote Polycentric Development. DP 2034 aims to continue and promote the ongoing polycentric growth in the city. The DP 2034 aims to create a multiple intensive, compact, walkable and mixed-used growth nodes by strengthening the existing and upcoming commercial and employment nodes. Strategy 02 which is Strengthen Transit Oriented Development (TOD) aims to establish a better connection better the transport networks and development patterns. Strengthening the influence zone of the important public transport nodes like railway stations and existing and proposed metro station is one of the major strategies. The nodes are identified in the DP 2034 which have the potential for Polycentric Development.

The DP 2034 aims to channelize the redevelopment of the existing, emerging and potential growth nodes across the city into high-intensity, compact business, employment and activity nodes. This
policy would work towards further enhancing the economic primacy of Greater Mumbai in the region. The following nodes have been identified and shown in Figure 2.5:

a) Established CBDs and employment nodes include Fort & Ballard Estate, Nariman Point, the inner city bazaars, World, BKC, SEEPZ & MIDC at Andheri. These nodes are highlighted as employment nodes buffer in Figure 2.5 and represented in orange shade in the figure 2.5. b) Areas that have recently emerged, which are developing through the processes of industrial transformation; these include areas such as the mill lands redevelopment in Lower Parel. Renewals that have occurred in response to new infrastructure investments, such as at Mindspace at Goregaon, areas along Andheri-Kurla road, Powai, Bhandup, Mulund, Vikroli and Kanjur marg. These locations are highlighted as employment node and marked in red color in figure 2.5. These nodes have been further categorized as per the order of their prominence and correspondingly their existing, as well as, expected influence areas have been defined, in order to ensure compatible planning of places around them.

• Nariman Point, BKC, SEEPZ, MIDC, Mill Lands area at Lower Parel, Fort and Ballard Estate have been identified in the DP 2034 as major nodes with a 1 km to 2 km influence zone;
• Areas around Andheri – Kurla road, Andheri Link Road, Bhandup, Mulund, Chembur, Powai, Vikroli-Kanjur marg, Worli, Mindspace, have been considered as minor nodes with a 0.5 km influence zone. These nodes are marked as CBD buffer and are highlighted in purple and light purple for 1km and 2km radius respectively. The following Figure 2.5 indicates the broader spatial strategy for polycentric development in Greater Mumbai.
Figure 2.5: Identified growth nodes and their influence areas

Source: Draft Development Plan 2034, Greater Mumbai.
The objective 04 of the DP 2014-2034 is Efficient Mobility for all. This objective includes strategies that includes augmentation of the public transit as well as access to public transit, optimizing the network of street grids, managing on-street and on-plot parking, improving walkability, and suggesting design of streetscapes that are inclusive, adhere to barrier free codes, and cater to different types of mobilities. As seen in Figure 2.4, the strategy 12 mentioned is Transit first. It envisages the Transit Oriented Zones as dense, compact, efficient & vibrant mix-use clusters with quick and easy access to public transit, where access of private vehicles is regulated and minimized. It suggests station area improvement guidelines through which suggest multi-modal integration. Strategy 14 of objective 04 is to create inclusive streets. The DP prioritizes pedestrian movement as walking contributes to large modal share in the city. This strategy includes facilitation of bus movement, regulation of carriageway space, on-street parking space, as well as inclusion of street-vending spaces in high pedestrian traffic & mixed-use areas. Strategy 15 of objective 04 is to adopt a parking demand management approach. The DP views parking as a private good and suggests rationalized on-plot parking provision norms, which also vary based on location depending on availability of public transit access. It attempts to promote different tools to manage public parking spaces in the city, which includes variable regulations and management mechanisms for on-street parking and public car parks within private plots. Create Poly-centric growth nodes around public transit stations, reduce use of cars, promote sustainable development, decongest roads & promote efficient travel and Promote affordable housing stock around station area. In the Figure 2.6, the map shows the areas identifies in the DP 2014-2034 which have the potential to be developed as TOD nodes (areas marked in blue). The circle highlights the area selected as study area and will be discussed in Chapter 3.
Figure 2.6: Transit Oriented Development Zones

Source: Draft Development Plan 2034, Greater Mumbai.
2.4. Project Features of Existing Metro line 1 and 2:

The city of Mumbai, Maharashtra is served by a rapid transit system of Mumbai Metro Line. The Mumbai metro system is designed with an aim to reduce the traffic congestion in the city and develop a suburban connection in the city. The proposed Metro system consist of 8 lines and currently Metro Line 1 is functioning and 5 metro lines are under construction consisting of Line 2- A and B, Line 3, Line 4, Line 6 and Line 7. The selected nodes for the research work lie on Line 1 Andheri Metro Station\(^4\) and junction of Line 2 and 3 which is B.K.C station\(^5\)

Table 1: Table shows the Phase wise construction of Metro Lines in Mumbai and their total length.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Line</th>
<th>Name of Corridor</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I (2006-2011)</td>
<td>1</td>
<td>Versova – Andheri- Ghatkopar</td>
<td>11.04</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Colaba- Bandra- Seepz</td>
<td>38.24</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Bandra- Kurla - Mankhurd</td>
<td>13.37</td>
</tr>
<tr>
<td>Phase II (2011-2016)</td>
<td>4</td>
<td>Charkop - Dahisar</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Ghatkopar - Mulund</td>
<td>12.4</td>
</tr>
<tr>
<td>Phase III (2016-2021)</td>
<td>6</td>
<td>BKC – Kanjurmarg via airport</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Andheri (E)- Dahisar(E)</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Hutatma Chowk - Ghatkopar</td>
<td>21.8</td>
</tr>
</tbody>
</table>

Source: [https://propstory.com/mumbai-metro/](https://propstory.com/mumbai-metro/)

The Metro Line 1 came into function in 2014 and is operated by Metro One Operator Private Limited (MOOPL) which is a joint venture of RATP Development and Transdev (50:50) which contributes to 70%

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\(^4\) The Yellow circle on Figure 2.6.

\(^5\) The Red Circle on Figure 2.6.
ownership and Reliance Infrastructure which contributes to 30% ownership. Reliance Infrastructure and RDTA are planning to extend the operation contract and into bidding for metro rail projects in other Indian cities. 5% of Mumbai Metro One Pvt Ltd (MMOPL) is owned by RDTA, which is a special purpose vehicle set up in December 2006, which owns the line and was in charge of its construction. Reliance Infrastructure owns 69% of the MMOPL, and Mumbai Metropolitan Region Development Authority (MMRDA) owns 26%.\(^6\) The total length of the Existing Metro Line one is 11.40 km and it is elevated. The line consists of 12 station. The metro consists of 6 coaches and the maximum capacity and is 1792 passengers. The metro Line 1 has interchange facilities with metro line 2 (D.N. Nagar, Proposed), Existing Railway station (Andheri), Metro Line 3 (Marol Naka, Proposed) and central railway (Ghatkopar). The maximum ridership recorded on a single day was 312,215.\(^7\) The estimated ridership for the Metro Line 1 in 2021 is 6.65 lakhs per day (PHPDT – 23321) and 2031 is 8.83 lakhs per day (PHPDT – 30491). The minimum and maximum fares on the line are ₹10 and ₹40 respectively, which is roughly 1.5 times the bus system in the city. Line 1 utilizes an Automatic Fare Collection System (AFC) which is powered by Datamatics.\(^8\)

The total length of the proposed Metro Line 2A one is 18.58 km and it is elevated. The line consists of 17 stations. The metro consists of 8 coaches and the maximum capacity is 2244 passengers. The metro Line 2 has interchange facilities with metro line 1 (Ghatkopar, Existing) and Line 7 (Dahisar, Proposed). The estimated ridership for the Metro Line 2A in 2021 is 4.07 lakhs per day (PHPDT – 11560) and 2031 is 6.09 lakhs per day (PHPDT – 15565). The total length of the proposed Metro Line 2B one is 23.64 km and it is elevated. The line consists of 22 stations. The metro consists of 8 coaches and the maximum capacity is


2244 passengers. The metro Line 2B has interchange facilities with Metro Line 1 and Metro Line 2A (D.N. Nagar, Existing), Metro Line 3 (B.K.C, Proposed), Monorail and Metro Line 4 (Eastern Express Highway).

The estimated ridership for the Metro Line 2B in 2021 is 8.90 lakhs per day (PHPDT – 35142) and 2031 is 10.49 lakhs per day (PHPDT – 38509). The corridor is expected to be operational by the year 2020.

The MMRDA appointed Reliance Infrastructure (RInfra), in consortium with SNC Lavolin Inc Canada and Reliance Communication, through an international competitive bidding process to carry out this phase of the project, and the concession agreement was signed with the RInfra-led consortium in January 2010. Mumbai metro line underwent a bidding process amongst ten infrastructure developers and was bagged by 7 contractors. The Metro line 2 is divided in 4 packages out of which 2 packages are owned by Reliance Infrastructure and Italy based Rizzani de Eccher S.p.A (RdE) and 2 packages are owned by L&T.

The ADB bank co-financing with Shanghai’s New Development Bank and the Government of India have signed a US $926 million Loan agreement to operationalize metro line 2 and metro line 7 in the city.

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**Figure 2.7: Financial structure for Metro Line 2, Source: Government documents, Edelweiss research**

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9 Reliance Infra wins Rs 11,000-cr Mumbai Metro-II project - Economic Times India Times. Retrieved 3 April 2014

10 "Another R-Infra project heads for termination" Business standard. 18 December 2012.
Figure 2.8: Financial Structure for Metro Line 3, Source: Government documents, Edelweiss research
Chapter 3: Objectives and Research Questions:

The primary objective of the paper is to understand the relationship between TOD and pedestrian connectivity in Mumbai, India. The study focuses on the parameters that influence a better pedestrian connectivity to the transit nodes in the city. The literature review suggests that in a Metropolitan city like Mumbai, the demand for connectivity to the existing transport in the city is increasing. The connectivity to transport modes like bus, trains and metro is provided by para transit modes and by walk. The city aims to achieve TOD and one of the major factors to achieve this is by having a better pedestrian connectivity. Hence, the study focuses on two research questions:

1) What is the level of urban pedestrian connectivity that is related to TOD?

2) How do we implement successful TOD strategies for urban pedestrian connectivity in Mumbai, India?

The research questions will be answered by using the methodology and study area by observation method which is discussed in the next chapter. This research questions helps to understand the current scenario of the streets around the Metro Station for existing line 1. In particular, with TOD it is intended to increase transit patronage, active travel and reduce car travel, raising revenues, enhance livability and widen housing choices, by increasing the multimodal access conditions of the city, considering the transit network as the key transportation infrastructure of the city (Cervero et al., 2004). Despite there is not a single universally accepted definition of a TOD, it is often described in a purely physical description way: a mixed-use place, with a certain urban density and high-quality walking environment, located within half-mile (800 m), i.e. 10 min walk, of a transit stop. However, the physical characteristics of these places are essential but not sufficient to achieve the extensive goals of TOD, which are not focused in creating physical forms but instead in creating vibrant, rich and livable urban places.

11 Transit-oriented development, integration of land use and transport, and pedestrian accessibility: Combining node-place model with pedestrian shed ratio to evaluate and classify station areas in Lisbon.
The research questions focus on the objective to study:

5) The level of pedestrian connectivity to the existing metro station for line 1 in Mumbai, India.

6) The factors that are involved to promote a better street connection and promote walking modes.

7) To suggest changes in the street design templates mentioned in the manual for India and provide recommendations for streetscape for the proposed metro line 2 in Mumbai.

8) To suggest the policies that needs to be revised and new policies that needs to be introduced to have a successful TOD system in Mumbai, India.

In the next Chapter 3 Methodology, we will be discussing about the nodes that are identified as study area for the research and the methodology used to answer the research questions.
Chapter 4: Study area and Methodology

To answer the research questions of the study observation method will be used as a method. The study area will be selected for existing metro line 1 and proposed metro line 2 which will be observed and analyzed. The study area includes 2 nodes- Node A: existing metro line 1 within buffer of half mile radius and Node B- Proposed metro line 2 within a buffer of half mile radius. Chapter 3 introduces the study area used for observation method and explains the results of observation method. These results will be analyzed in order to provide answers to the research questions.

Study Area:

The paper focuses on the Metro System in Mumbai, India and explores the relationship between TOD and pedestrian connectivity. The current situation in India indicates that people are preferring to use private vehicles than public transport. The main objective of the Mumbai Metro is to provide mass rapid transit services to people within an approach distance of between 1 and 2 kilometers, and to serve the areas not connected by the existing Suburban Rail network. The city of Mumbai has an existing metro line implemented in 2006 and began to function in 2014. The existing Metro line 1 consist of 12 stations and is 7.1 miles in length. There upcoming 2 metro lines in the city currently, namely Line 2 and line 3. Line 2 consists of two sub lines: Line 2A consist of 17 stations (11.55 miles) and Line 2B consists of 22 stations (14.69 miles). Line 3 consists of 27 stations (20.82 miles). One of the reasons for lack of use of public transport is that the metro-stations and bus stations are not easily accessible. One of the principles of TOD is to increase pedestrian access and reduce the use of private vehicles in densely populated areas. The capacity of the user to access the transit stop is a core component of TOD. The goal of the paper is to observe the existing metro station (Node A) and based on my analysis making recommendations in terms of urban design and planning policy for the proposed metro station (Node B).
Project Location: The Metro Line 1 and 2 is located in the city of Mumbai of state of Maharashtra in India. Figure 4.1 shows the layout of the overall Mumbai Metro Rail Network showing the locations of the project lines. The map also shows the location of the stations of the metro lines. The black line corresponds to existing Line 1, blue line corresponds to proposed Line 2 and Green line corresponds to proposed Line 3. The existing Line 1 and proposed Line 3 provides East west connection in the City and Line 2 provides North south as well as east west connection to the city. The metro Line 1 (Black Line) consist of 12 stations, Metro line 2A consists of 17 stations and 2B consists of 22stations while Metro line 3 (green line) consists of 27 stations. As seen in the Figure 4.1 Metro Line 1 provides an east-west connection in the city, metro line 2 provides a North-south connection and diverts to east-west connection on intersection with line 3. Metro line 3 provides a North south connection in the city. The existing Railway line in the city provides north-south connection in the city and fails to establish a cross connection throughout the city. With the help of the Metro lines, the city will be able achieve a cross connection which will reduce travel time. In order to have a successful TOD system in Mumbai, the city has introduced metro and mono rail systems and aims to achieve a better public transportation system. The issues need to be identified which are affecting the level of pedestrian connections to the transit systems in the city like railways, metro and monorail. For this study two major nodes will be selected as seen in Figure 4.2 which are identified as TOD zones and growth nodes in the Draft Development Plan for Greater Mumbai as shown in Figure 2.6.
Figure 4.1: Map showing the Proposed Mumbai Metro Rail Lines.


The nodes are selected on the following criteria:

1) Cross-Connections for railways: The existing and the proposed metro lines intersect each other to provide transit connections to the areas not connected by the suburban railway. I have selected the nodes where the lines intersect each other.
2) Population density: A mass rapid transit service needs to be provided on the region with moderately dense population. The nodes selected lie in the region with moderate to high population density.

![Map showing the selected nodes along the existing and proposed metro line in Mumbai, India.](http://www.loginmumbai.org/map.html#)

Figure 4.2: Map showing the selected nodes along the existing and proposed metro line in Mumbai, India.


In figure 4.2, the map indicates the nodes that are selected for the analysis of the relationship between TOD and pedestrian connectivity in Mumbai. The Node A highlighted in blue circle is a buffer of half-mile radius and includes existing railway station (Andheri Station) and metro station (Andheri) within the selected buffer. The area is a densely populated area (see population density Figure 4.3e in APPENDIX). The metro line 1 is currently operating and will be observed to understand the causes of hinderances between TOD and pedestrian connectivity. The selected Node B is a buffer of half-mile radius and includes
the intersection of proposed metro line 2 (Income Tax Office station) and metro line 3 (Bandra Station).
The area is selected as it provides a cross connection between two metro lines and lies in a densely populated area. A detailed study of Node A and Node B is done by observation method as discussed in Methodology section.

I would like to focus on the accessibility mode like car, bus, bike and walk to the transit station within a buffer of half-mile radius. I would like to focus on the selected Node A and Node B as seen in Figure 4.2 of metro station in the city to understand how TOD transforms the urban fabric around a metro station. I will be focusing on the streetscape, the physical setting and the urban structure around the metro station.

Methodology

Observation method is used to answer the first research question, ‘What is the level of urban pedestrian connectivity that is related to TOD in Mumbai, India?’ Mapping Analysis based on the observation method is used to answer the second research question, ‘How do we implement successful TOD strategies for pedestrian connectivity in Mumbai, India?’.

The first research question is, what is the level of urban pedestrian connectivity that is related to TOD in Mumbai, India? To understand the level of urban pedestrian connectivity I have used observation method. Pedestrian behavior is the way the user accesses transit-station nodes by walk, bicycle, car or bus within the half-mile radius. On my visit to India, I observed the two transit nodes - Existing Metro Station1 (Node A) and proposed Metro Station 2 (Node B) at different times of day during weekends and weekdays and analyze the pedestrian behavior of the commuters.

Based on the above measures at the existing metro station in Mumbai, I have done Network Classification analysis (Schlossberg, M., & Brown, N., 2004) and street section analysis. Network Classification: An evaluation and categorization of street type and purpose along the road network within the TODs, which
provides insight into the basic quality of certain paths for walkability purposes and reflects the hierarchy of road types and the function of the road network. A mapping analysis categorizing of the street network as primary, secondary and tertiary street to understand the street network which helps to define the pedestrian street network. The street section analysis is done by using the guidelines mentioned in ITDP EPC manual of street design for urban India and Street design guidelines for Mumbai.

The level of pedestrian connection is analyzed by street design parameters at the existing metro station 1 (Node A) and Proposed Metro Line 2 (Node B). I have focused on different parameters in terms of pedestrian connectivity for observation, which are:

1) Sidewalks: Availability of the sidewalks for the commuters to access the existing station. In India, most of the trips which are below 1.25 miles (2 km) are done by foot. A Better sidewalk design promotes safety and comfortable pedestrian mobility. Sidewalks act as a primary feature of street design and are accessible to all the users regardless of age, gender or special needs. The paper identifies the sidewalks in Node A and Node B which need to be redesigned to provide a better pedestrian connectivity to Metro Station.

2) Accessibility to metro-Station: Accessibility by mode of car, bicycle, bus, elevated walkway or walking within half-mile radius.

3) Elevated walkway to commute: The city of Mumbai has elevated walkway that connects the commuters to different nodes within the city. Observing the availability of the elevated walkway for the commuters to access the existing station.

4) Carriageway and Bus-Rapid Transit System: The primary purpose of the carriageway and BRTS is to provide vehicular mobility. The purpose of the road needs to be identified in terms of speed of vehicle, major and minor roads, narrow lanes, traffic-calming lanes and pedestrian lanes. Since
the streets in India do not provide spaces for walking, cycling and vending spaces, all these activities tend to be performed on the carriageways. A separated carriageway and BRT lane is demanded to reduce congestions and improve the user experience.

5) On-street Parking: In City of Mumbai, it is very common to observe streets where cars are parked without actual provision of parking space. On-street parking is clearly designated, managed, charged, and restricted in volume, enabling access to nearby properties without disturbing the flow of motor vehicles, pedestrians, and cyclists. When footpaths and cycle tracks are provided, they often become parking lots for cars and two-wheelers unless physical barriers or law enforcement prevent such encroachment. The lack of an adequate parking fee gives the impression to users that parking is a deemed right. Instead on-street parking should be treated as a premium service. A high charge encourages short duration parking, thereby allowing multiple users to access the same spot. It also promotes the use of off-street parking.

6) Spaces for Street Vending: Well-planned spaces for street vending provide citizens with secure and dignified areas for the trade of goods and services. Existing street design fails to address street vending. Very few streets in India in have spaces designated for vending. As a result, vendors end up using spaces intended for others such as footpaths or the carriageway.

7) Landscaping elements and Pedestrian Refuge: A good median reduces conflict between opposite directions of traffic and acts as pedestrian refuge but has frequent enough breaks to discourage motor vehicle users from driving in the wrong direction. Medians improve safety for pedestrians by functioning as refuge islands, which allow pedestrians to cross one direction of travel at a time. Landscaping improves the livability of streets. It plays a functional role in providing shade to pedestrians, cyclists, vendors, public transport passengers, and other street users. It also enhances the aesthetic qualities of streets.
Observations on Node A and Node B:

I began my observation at Node A (Existing Metro Line 1). The area selected for observation was half-mile in radius and the major streets approaching the Transit- Node were selected. The highlighted streets in the Figure 4.2a shows the streets that were observed. The stretch of the street is 0.6 mile (1km). As an observer, I selected different times on weekend and weekdays to understand the level of pedestrian connection at the Node A. The observations were made on time slots: 1) Peak hours: 8am-11am, 2) Moderate hours: 11am-4pm, 3) Rush hours: 4pm-9pm and 4) Night Hours: 9pm-11pm.

Table 4.2a: Observations made at Node A, Source: Author, 2019.

The observations made are represented in Table 4.2a at the four distinct hours based on pedestrian and vehicular activity at Node A. The Table 4.2a represents Peak hours 8am-11am, it is observed that the pedestrian activity and the vehicular activity is high at the peak hours. The commuters travel by rickshaws, cars, taxis, bike and by walking towards the Node A. As observed at peak hours, there is traffic congestion
due to lack of space for parking of cars, waiting areas for auto-rickshaws, taxis and buses. The sidewalks are utilized by the vendors and hawkers which forces the pedestrians to use the road. The commuters mostly comprise of office goers and shop owners / Workers who utilize the Metro to reach commercial and office spaces. The Table 4.2a represents Moderate hours 11am-4pm, which shows that the pedestrian activity is less during this time. The number of cars, taxis and auto-rickshaws that are parked on the street are moderate. The pedestrian crowd mostly comprises of residents in the Node A who come out for vegetable shopping and college students and office goers who use eateries near the Node A. The Table 4.2a represents Rush hours 4pm-8pm, which demonstrates that the pedestrian and vehicular activities increases as there are people commuting back to their home from offices, commercial areas and nearby colleges. The vending activity and street food areas are also active at this time. Again, there is lack of parking spaces for auto-rickshaws, taxis and buses. The people standing for the bus queues use the roads as the sidewalks cannot accommodate all the pedestrians. The Table 4.2a represents Night hours 8pm-11pm, which demonstrates that the area has less pedestrian and vehicular activity at night hours.

The Figure 4.3e represents the issues identified at different location near the Metro Station 1 which caused hinderance in pedestrian connectivity. The issues will be further discussed in the following section mapping analysis on Page 44.

The observations for Node B were also made on time slots: 1) Peak hours: 8am-11am, 2) Moderate hours: 11am-4pm, 3) Rush hours: 4pm-9pm and 4) Night Hours: 9pm-11pm. The Table 4.2b demonstrates the pedestrian and vehicular activity at Node B. The Table 4.2b represents Peak hours 8am-11am, it is observed that the pedestrian activity and the vehicular activity is moderate at peak hours. The road is 113.18 ft wide and currently accommodates 4-way lanes on both sides which is divided by planters in between. There cars are also parked along the sidewalks and pedestrians are currently utilizing the sidewalks efficiently. The condition is similar at the rush hours for pedestrian and vehicular activity shown
in Table 4.2b However, when the metro will be constructed the area will expect to be crowded by pedestrians and vehicular activity. The expected activity is demonstrated in the Table 4.2b which highlights the need of street design template that needs to be followed. The issues are shown in Figure 4.4e and will be further discussed in the following section mapping analysis on Page 51.

Table 4.2b: Observations made at Node B, Source: Author, 2019.

The observations method can be summarized as:

1. Street design focuses on vehicular transport over pedestrian movement: The observation from Node A shows that 10-12% of the road is dedicated to pedestrian activity on the existing streets. As per the ITDP EPC: A manual for street design in urban India 20-25% of the street should be dedicated to pedestrian activities depending upon the type of street. The roads observed in Node A are major and minor collector road and sub-arterial roads which needs to be redesigned with a provision of 20-25% of pedestrian movement. If pedestrian activities are prioritized over vehicular transport a better connection will be provided to the Node A (Metro Station 1).
2. Street design elements like pedestrian areas, utilities, landscaping, street vending, social activities and cyclist mobility are given less importance: Currently the streets observed at Node A consists of 10% of area occupied by sidewalks and remaining 90% as vehicular road. The sidewalk is used by street vendors and hawkers, cars are being parked on it, with lack of amenities like benches, landscaping elements and no cyclist mobility facilities. A provision should be made for the essential amenities by widening the streets which will provide space for the commuters to walk on sidewalks and will also accommodate the street activities.

3. Existing streets are uncomfortable and inconvenient for pedestrian movement: As per the first observation, pedestrian activities need to be prioritized, as the sidewalk currently doesn’t accommodate all the commuters due to which the commuters tend to walk on the vehicular road. This makes both the pedestrians as well as transportation drivers uncomfortable and inconvenient. Pedestrians are also prone to accidents to improper sidewalk facilities. In order to improve the quality of the streets, the sidewalks should be widened, the location of the railings should be reconsidered, a planned space should be provided for the street vendors, along with parking facilities for cars, auto-rickshaw’s and taxis and parking management is required.

4. Lack of car parking management: The observations show that there is no parking management in Node A. The cars are parked on streets and sidewalks which occupies the area dedicated for pedestrian. Car parked on the sidewalks indicates that there is lack of parking spaces near the transit node and also, it causes hinderances for the commuters in terms of accessibility. A concept of off-street and on-street parking should be introduced by understanding the commuter pattern at peak hours and parking fees should be charged to make the citizens more aware about the parking management.

5. Increasing traffic congestion: Traffic congestion is one of major issues in city of Mumbai and it is observed in Node A as well. Lack of width of sidewalks, lack of space of street vendors, lack of traffic and
parking management, least preference for street landscaping and pedestrian activities are issued observed in node A as the planning policies have not identifies the need of future commuters while designing the Metro Station. A planning policy focusing on street design elements and parking management should be considered while redesigning streets for Node B (Proposed Metro Line 2) in order to accommodate the need of the future commuters.

All the five factors observed cause interruptions in the pedestrian connection to the Node A (Existing Metro Station 1). These observations from Node A are used to analyses and find the design proposals for upcoming Metro Station 2 (Node B). The analysis method mentioned above is done for Node A and Node B. This method helps to understand the level of urban pedestrian connection to the existing metro station (Node A) and will help to prepare the policy and planning suggestions for the proposed metro station (Node B).

The second research question is, how do we implement successful T.O.D strategies for pedestrian connectivity in Mumbai, India?

The success of TODs significantly rests on the capacity of pedestrians to navigate and access the range of land uses in proximity of transit stations (Schlossberg, M., & Brown, N., 2004). Thus, it seems that understanding the opportunities for pedestrian movement should be a key component in understanding and evaluating TODs. The first research question helped to identify how the level of pedestrian connectivity is related to TOD in Mumbai, India. The results from the analysis for the first research questions, set the general guidelines for the suggestions for the proposed metro station (Node B) in Mumbai in terms of planning policies, urban design implications, city infrastructure. A mapping analysis is done for Node A and Node B which identifies the pedestrian and vehicular activity in the nodes and based on the results from the mapping analysis, the Node A and Node B are narrowed done to a street Section of 0.62 mile (1 km) in length to define the street design interventions. The results derived from the
mapping analysis of Node A and Node B assist to identify the changes that need to be recommended for the proposed metro Line 2 (Node B). This analysis discovers the change in urban form around a metro station. The results identify the factors like landscaping and street interventions that will provide a better pedestrian connectivity to the proposed metro stations at Mumbai, India.

Mapping Analysis: 4.3: Existing Metro line 1

1) Pedestrian Analysis:

Figure 4.3 a: Pedestrian Analysis for Existing Metro Line 1 (Node A).

Figure 4.3a shows the buffer (blue circle) for the existing metro station. The inner radius is 0.5 mile and the outer radius is 1 mile. The lines in the map indicate the pedestrian activity in the selected region. The thickness of the line in the above figure represents the number of pedestrians in selected node. The high line weight represents high pedestrian activity in the area and the tapering line represents reducing pedestrian activity. The location of existing Metro Station as seen in Figure 4.3a shows that it experiences a high level of pedestrian activity.

Land-Use with parcels:

Figure 4.3b: Land Use Map For Node A.

Source: [http://mohua.gov.in/](http://mohua.gov.in/)

Figure 4.3b shows the existing Land-Use map for the Node A (existing metro line 1). The Node A lies in the K/W ward of the city of Mumbai. The K/W ward has a total population of 7,48,688 and the area of the
ward is 8.98 sq. mile (23.28 sq. m). As seen in the figure, the selected node has mostly residential area (yellow region) and commercial areas (blue region).

2) Street Type and circulation:

Figure 4.3c: Street Type and circulation


Figure 4.3c shows the buffer (blue circle) for the existing metro station. The inner radius is 0.5 mile and the outer radius is 1 mile. The lines in the map indicate the vehicular activity in the selected region. The
thickness of the line in the above figure represents the vehicular traffic in selected node. The high line weight represents high vehicular traffic in the area and the tapering line represents reducing vehicular traffic. The location of existing Metro Station as seen in Figure 4.3c shows that it experiences a high level of vehicular traffic. On comparison of Figure 4.1.1 and Figure 4.1.2, it demonstrates that the station for Existing metro Line 1 experiences a high pedestrian and vehicular activity. This overlap of pedestrian and vehicular activity demands a better street connection to have an efficient TOD system.

3) Selected area:

![Figure 4.3d: Selected area for Street intervention.](http://www.loginmumbai.org/map.html#)

Figure 4.3d shows the street highlighted in yellow is the selected area for analysis of the existing street condition. The street is selected on basis of the high pedestrian and vehicular activity. The street is 0.62 mile (1 km) in length. The sections of the streets will be further analyzed in Chapter 4 and recommendations will be provided for the proposed metro line 2.

Existing Site Images:

Figure 4.3 e: Observations for Node A, Source: Author, 2019.
Figure 4.4 is clicked from the Metro Station for Line 1 and it overlooks the street which approaches towards the station. The image is clicked during daytime and represents the pedestrian and vehicular activity on street. The Figure shows that the vendors are utilizing the sidewalks for selling items and the pedestrians are forced to utilize the carriageway for walking. The street doesn’t include a pedestrian island which will accommodate the pedestrians and the vendors. The road doesn’t include a divided carriageway and leads to disorganization of vehicular traffic.

In figure 4.5 shows the quality and width of the sidewalks in Node A. The width of the sidewalk is 6.56 ft (2 m). It shows that the landscaping and tiling is not properly planed. Vehicles are parked right next to the sidewalk which causes obstruction for a pedestrian friendly street. The sidewalks need to be redesigned to accommodate vendors, pedestrians and cyclist (if applicable).

Figure 4.6 is showing the piers of the elevated Metro Line 1 and the street below the elevated metro line. The street leads to the metro station. As seen above, cars are parked below the metro line and the sidewalks are utilized by the hawkers and vendors. This causes the pedestrians to walk on the carriageway and also affects the vehicular traffic to be disorganized.

In Figure 4.7 shows the entry point of the metro station which is blocked by the vendors around the station. Both figures explain the need to redesigning the road in terms of sidewalks, carriageway and street vending facilities.

Figure 4.8 shows the area around the metro station during night time. It shows the congestion outside the railway station on the road leading to the Metro because unorganized parking of auto-rickshaws. The auto-rickshaws are not provided with a proper space for parking. The commuters are utilizing road for walking. In figure4.9 the passengers are waiting for the bus on street as the wide of the sidewalk is too narrow and utilized by stores nearby. The image shows the need of provision of proper waiting areas and redesigned bus stops along with widened sidewalks. The road lacks a bus rapid transit lane.
4.4: Proposed Metro Line

1) Pedestrian Analysis:

Figure 4.4a: Pedestrian Analysis for Existing Metro Line 1 (Node A).


Figure 4.4a shows the buffer (blue circle) for the existing metro station. The inner radius is 0.5 mile and the outer radius is 1 mile. The lines in the map indicate the pedestrian activity in the selected region. The thickness of the line in the above figure represents the number of pedestrians in selected node. The high
line weight represents high pedestrian activity in the area and the tapering line represents reducing pedestrian activity. The location of proposed Metro Station as seen in Figure 4.4a shows that it experiences a high level of pedestrian activity.

2) Land-Use with parcels:

Figure 4.4b: Land-use map for Node B.


Figure 4.4b shows the existing Land-Use map for the Node B (Proposed metro Line 2). The Node A lies in the H/E ward of the city of Mumbai. The H/E ward has a total population of 5,57,239 and the area of the ward is 7.15 sq. mile (18.53 sq. m). As seen in the figure, the selected node has residential area (yellow region) and commercial areas (blue region). The area also includes SPA zone, which is area dedicated for private and office development. The area also includes government buildings (Highlighted in orange).
3) Street Type and circulation:

Figure 4.4c shows the buffer (blue circle) for the existing metro station. The inner radius is 0.5 mile and the outer radius is 1 mile. The lines in the map indicate the vehicular activity in the selected region. The thickness of the line in the above figure represents the vehicular traffic in selected node. The high line weight represents high vehicular traffic in the area and the tapering line represents reducing vehicular traffic.

traffic. The location of existing Metro Station as seen in Figure 4.4c shows that it experiences a high level of vehicular traffic. On comparison of Figure 4.1.1 and Figure 4.1.2, it demonstrates that the station for proposed metro Line 2 experiences a high pedestrian and vehicular activity. This overlap of pedestrian and vehicular activity demands a better street connection to have an efficient TOD system.

4) Selected Area:

Figure 4.4d: Selected area for Street intervention.

Figure 4.4d shows the street highlighted in yellow is the selected area for analysis of the proposed street condition. The street is selected on basis of the high pedestrian and vehicular activity. The street is 0.62 mile (1 km) in length. The sections of the streets will be further analyzed in Chapter 4 and recommendations will be provided for the proposed metro line 2.

Images for the existing site Proposed Metro Line 2:

Figure 4.4e: Observations for Node B, Source: Author, 2019.
Figure 4.10 and figure 4.11 shows the existing road in the selected area. The sidewalks are not utilized by pedestrians as they are blocked by railing and parked cars. The railing needs to be positioned in a way which will encourage the pedestrian will use the sidewalk. Th car parking space next to sidewalk needs to be planned and located alternately and provide openings for sidewalks to be more accessible.

Figure 4.12 and figure 4.13 shows the existing underutilized sidewalks. The car parked on the sidewalk shows that there is lacking of parking space in the area which is forcing the owners to park on sidewalks. This alarms for redesign of street as well as a strict policy recommendation for street parking charges to avoid such incidents.

Based on the results of the observation method, a street analysis is done for the Existing Metro Line 1 (Node A) and Proposed metro Line 2 (Node B) in terms of sections and plans. This analysis will be done using the guidelines mentioned in street design manual for India and design recommendations will be provided in next chapter.
Chapter 5: Analysis

This chapter includes three typical street sections of the selected street of 0.62-mile (1 km) length for the existing Metro line 1 which are analyzed based on the Street design guidelines in mentioned in the Street Design Guidelines for the City of Mumbai and ITDP EPC A manual for Street Design in Urban India. Based on the results of the analysis of the selected street section for existing metro line 1, design intervention proposals will be suggested for selected street section for Proposed Metro Line 2. The design recommendations for the proposed Metro Line 2 consists of two typical street sections for selected street of 0.62-mile (1km) length and are supported by plans. The analysis is done by understanding the typical site section which corresponds to the existing site scenario, which will provide recommendations for street design for proposed Metro Line 2. This chapter is divided in two sections, Section A: Understanding the guidelines mentioned in the existing manual and Section B: Design Interventions.

Section A: Understanding the guidelines mentioned in Street design guidelines for city of Mumbai and ITDP EPC a manual for street design in urban India.

Section A explores the guidelines for street design and templates in the 2 manuals namely, Design Guidelines for the City of Mumbai and ITDP EPC A manual for Street Design in Urban India. The figures included in this section are extracted from the manual to understand the layout and street design elements that needs to be considered for roads with varying lanes. 5 images will be discussed from the manual to understand the street design guidelines.

The guidelines used for determining the street interventions are based on the manual as follows:

1) Street design Guidelines for the city of Mumbai: The objective of this document is to propose a non-motorized transport strategy for Mumbai along with pedestrian oriented street design
guidelines to enable safe and comfortable walking environments.\textsuperscript{12} These are conceptualized under the umbrella of the National Urban Transport Policy (2006), which states that “people occupy center-stage in our cities and all plans would be for their common benefit and well-being”. The document identifies the Non-Motorized Transport (NMT) strategies and Street Design guidelines. The street design Guidelines consist of road classification based on the road with which are: 1) Arterial roads range from 120-150 feet (36.61-45.70 m), 2) Sub-arterial roads range from 100-120 feet (30.51-36.60 m), 3) Major collector roads 60-100 feet (18.31-30.50 m), 4) Minor collector roads range from 46-60 feet (14.10-18.30 m), 5) local streets are up to 14m. and 6) NMT streets routes can be classified as pedestrian routes, cycling routes. The street hierarchy is used for setting up the street elements for design which includes footpaths, traffic calming, on-street parking, median, bus stops and shelter, plot entrance, street lights, vending and other activities, landscaping, utility boxes and bollards. Based on these elements street design templates are proposed for different set of roads. These street design templates are supported by Street Sections with the help of color coding and dimensions for the design elements. This document doesn’t include any existing pictures of the street that implement these strategies in Mumbai or the street that have the potential for implementation. Also, a supporting plan for the sections will make it easier to relate to the guidelines.

\textsuperscript{12} Street Design Guidelines for the City of Mumbai
2) ITDP EPC, A manual for street design in Urban India: The Institute for Transportation and Development Policy sets a manual for street design in India. The document includes the principles
for complete street, street design elements like footpaths, cycle tracks, carriageways, Bus-rapid transit, Landscaping, service lanes, on street parking, spaces for street vending, bus stops and street furniture and amenities. The document also gives examples for intersection of roads and the design process involved for complete streets.

![Symbol & colour key](image)

Figure 5.3: Standard for Symbol and Color key for street design guideline.

Source: ITDP EPC A manual for Street Design in Urban India.

The Figure 5.3 is extracted from the ITDP EPC, A manual for street design in India. The figure5.3 includes a plan which is color coded, where yellow indicates Footpath/ sidewalk, orange indicates median track or cyclist lane, grey indicates carriageway, dark grey indicates parking, purple indicates shared pedestrian road, red indicates Bus- Rapid Transit Lane, and green indicates...
landscaping. This design template will be used in the paper as a reference for color and symbols for design interventions.

Figure 5.4: The illustration demonstrates the design template for a 42 m wide Road including a Bus rapid transit lane.

Source: ITDP EPC A manual for Street Design in Urban India.

The figure 5.4 demonstrates the design template that can be used for a Bus - rapid Transit road supported by a plan and 3 sections. As per the design template, the street is divided in sections namely heavy traffic lanes, moderate traffic lanes and non- motorized transit lanes. The bus-rapid transit lane which consists heavy traffic activity should be placed in the central part of the road with the bus stop in the middle. After the Bus Rapid Transit Lane, a moderate traffic lane consists of a carriageway which should be provided which can be 5.50-6.50 wide depending upon the length of street and traffic congestion. The Pedestrian Lane or Non-motorized traffic lane is the
following lane which can be 2.4-4m wide, including sub-categories like the sidewalks, cycle tracks, vending spaces and landscaping. To provide accommodation for passing lanes in narrow profile the pedestrian sidewalk, cyclist tracks and informal activity lanes can be separated by offset platforms in each direction. The layout consists of sidewalks and cyclist tracks along the sides of the road with vending counter at specific location. The parking spots for cars are located in the areas between the carriage lane and sidewalks which acts as a buffer between the traffic lane and the pedestrian lane. Landscaping elements like grass and trees also act as a buffer between the traffic lanes and pedestrian lanes as well as adds to the visual aesthetics of the road and provides shade to the pedestrians. This strategy will be used for the Proposed Metro Line 2 as it lies in the similar category of the road which will be explained in the Section B.

Figure 5.5: Street Design layout including vending facilities.
In the Figure 5.5, illustration shows different options for location the vending facilities on the street. Mumbai is a metropolitan city where street vendors and hawkers are commonly seen in different parts of the city which often leads to traffic congestion, as they occupy spaces which are dedicated for vehicular transit. In Figure 4.5, design template is provided for accommodating the Vendors depending upon the width of the street. In example 1 and 2, the street is 29.5 ft (9 m) wide and 39.37 ft (12 m) wide respectively. The design template suggests that the pedestrian islands can be places alternatively on the meandering streets at regular intervals by placing the vending sections towards the edge of the street and middle of the street alternatively. This design template helps to reduce the traffic congestion and also diverts the direction of the traffic. The pedestrian island acts as a platform for informal activities and a speed breaking lane for the vehicular activity. In example 3, the design template includes a street which is 60-100 ft (18-30.20 m) in width and includes bulb-outs in the parking lane which are located near the pedestrian crossing to make it more accessible for the vendors and pedestrians. In example 4, a service lane is interrupted for making space for a large vending platform which can be used as a standard for designing streets with width more than 120 ft (36.61m). Example 5, consists of a pedestrian island located at the center of the street with cycle tracks on either side. Figure 5.5 includes sections of the space utilized for vending facilities depending upon the level of investment and formalization which includes a simple elevated concrete platform, a fully enclosed shelter, a platform doubling as lockable storage and a concrete platform with a roof doubling up as a display window. These design guidelines will be used for street interventions for proposed Metro Line 2 in the Section B of analysis.
Section B: Design Interventions.

The section B of analysis uses the guidelines explored in the Section A of analysis as a standard for design interventions and proposals. Section B includes Three typical street sections of existing Metro Line 1 which are analyzed by using the street design guideline manuals as explored in section A and design proposals are made for proposed metro line 2 with help of sections and plans. The DCR for Mumbai, Street Design Guidelines for the City of Mumbai and ITDP EPC A manual for Street Design in Urban India includes street design templates for different types of traffic lanes, however none of the document includes street design templates for roads with TOD or Metro Lines. As city of Mumbai, is planning to have 9 Metro lines in near future, Section B provides street design recommendations that can be considered as a guideline for roads and streets with Metro lines and stations.

Site Section analysis for Existing Metro Line 1:

Figure 5.7: Site Section for Existing Metro Line 1

Source: Author, 2019.
The Figure 5.7, represents the existing condition of the street in terms of pedestrian and vehicular activity. Based on the Street Guidelines for Mumbai, this street can be categorized as Major Collector Road (60-100 feet / 18.31-30.50 m). In the figure 5.7, the section represents a 75.45 ft (23m) wide two-way lane with Metro Line 1 passing through the center of the road. The Metro Line 1 is elevated and the piers of the Line occupies around 6.5 ft (2m) of the road. The road has 3.93 ft (1.2m) wide sidewalk on either side of the road which is utilized by the pedestrian and the vendors, causing the pedestrians to walk on the
road instead of the sidewalk. The carriageway is 27.23 ft (8.3m) wide (one-way) on both sides of the median track. Cars are parked on the 27.23 ft wide road. This leads to traffic congestion on the street.

The Figure 5.7a represents a street design template based on the guidelines explored in Section A of analysis. Option 1 of figure 5.7 b, consists of sidewalk, parking and vending facilities along with carriageway and landscaping. As per the design standards, the sidewalk is 8.20 ft (2.5m) wide with shared space for vending and pedestrian walking. The railings should be removed from locations of vending facilities to provide more accessibility to the pedestrians. The sidewalks in the existing scenario should widened from 3.93 ft to 8.20ft. Adjacent to the sidewalk, parking lane of 6.56 ft (2m) width should be provided. The parking space acts as a buffer between the pedestrian and informal activity and the carriageway. A divided carriageway of 19.68 ft(6m) is provided on either sides of the road divided by 6.656ft (2m) wide landscaping element.

Option 2 of Figure 5.7 b consists of sidewalk, parking and vending facilities along with carriageway and landscaping. As per the design standards, the sidewalk is 8.20 ft (2.5m) wide with shared space for vending and pedestrian walking. The sidewalks in the existing scenario should widened from 3.93 ft to 8.20ft. Adjacent to the sidewalk is 21.32 ft (6.5m) wide carriageway on either side of the road. In the center of the road lies a 16.40ft (5m) wide pedestrian island which accommodates the vending facilities and car parking at alternate locations.
The figure 5.8a, represents the existing condition of the street in terms of pedestrian and vehicular activity. Based on the Street Guidelines for Mumbai, this street can be categorized as Minor Collector Road (46-60 feet / 4.10-18.30 m). Figure 5.8a represents the existing station for Metro Line 1 which includes a 59.05 ft (18m) wide road. The site section consists of 9.84 ft (3m) wide sidewalk which leads to
the staircase of the metro station. The pedestrian activity is blocked by the motorcycle parked on the sidewalk. The carriageway is 29.52 ft (9m) wide for one-way traffic which has cars parked at unwanted locations. Motorcycle should be parked in dedicated spaces and car parking on the road should be restricted in order to reduce the traffic congestion on a 29.52 ft wide one-way lane. Figure 5.8brepresents a design recommendation that should have been followed while designing the street with a metro station, based on the street design manual. The Street section should have 9.84ft (3m) wide sidewalk without any motorcycles parked on it. Figure 5.8b demonstrates a sidewalk which is 9.84ft (3m) wide with a 6.56 ft(2m) wide motorcycle parking adjacent to sidewalk on either side. Car parking should be restricted in narrow road under the station to avoid congestion. The one-way street is 26.24 ft(8m) wide.

Figure 5.9a: Site Section for Existing Metro Line 1
Source: Author, 2019.
Figure 5.9b: Site Section for Existing Metro Line 1

Source: Author, 2019.

Figure 5.9a represents the existing condition of the street in terms of pedestrian and vehicular activity. Based on the Street Guidelines for Mumbai, this street can be categorized as Minor Collector Road (46-60 feet / 4.10-18.30 m). Figure 4.12 consists of a road which is 53.14 ft (16.2m) wide one-way lane with undivided carriageway. The street consists of a 6.5ft (2m) wide sidewalk on one side which connects to the elevated skywalk and on the other side of the road 3.93ft (1.2m) wide sidewalk. The road is a minor collector road and consists of bus stop on the sidewalk which is 6.5ft (2m) wide. However, the commuters occupy the sidewalk as well as the road while waiting for the bus. This forces the pedestrian to walk on the street as the width of the sidewalk is not sufficient for accommodating the commuters and pedestrians as per the standards mentioned in the manual. The road consists of 42.65ft (13 m) wide one-way carriageway, which is occupied by unorganized car parking and pedestrian’s activity leading to traffic congestion. Figure5.9b consist of street analysis as per the guidelines for a 53.14 ft (16.2m) wide road. As per the street analysis, the road should consist of 27.88 ft (8.5m) wide divided carriageway which includes a bus-rapid transit lane. The sidewalk which has a bus stop located on it should be 8.85 ft (2.7m) wide
having a adjacent parking lane which is 6.56 ft (2m) wide. The parking lane should have bulb-out at the location of bus stops to accommodate the commuters and bus stop. On the rare side of the road, the sidewalk should be widened from 3.93ft (1.2m) to 7.87ft (2.4m) with a buffer of 1.96 ft (0.6m) landscape between the road and sidewalk. This will avoid the pedestrian from walking on the street and causing traffic congestion.

The analysis for the Node A (Proposed Metro Station 1) can summarized as:

A. The Five major issues identified after the analysis are:

1. Poorly maintained sidewalks: As shown in figures 5.7, 5.8 and 5.9, the sidewalks are not maintained in terms of pedestrian management. The location of the staircases for entry/ exit of the commuters to the metro station needs to be planned. The sidewalks tend to end abruptly at certain locations due to which the pedestrians need to use the vehicular road instead of sidewalks which causes congestion and safety issues. The width of the sidewalk is not efficient to accommodate the commuters, pedestrians and street vendors.

2. Lack of parking management: As shown in figures 5.7, 5.8 and 5.9, there is lack of parking management which obstructs the pedestrian connectivity. Cars are parked right outside the entry/ exit location to the Metro station 1 which adds up to the commute time as the passenger needs to divert his direction of walking. Specific areas need to be identified as parking zones and parking hours should be mentioned on the streets based on the analysis.

3. Absence of Bus rapid transit lane: The analysis demonstrates that the vehicular lane doesn’t provide any division for Bus rapid transit lane and small/ heavy vehicular lane. As per the ITDP EPC: A manual for street design in Urban India, the roads consists of divisions like- a carriageway with heavy vehicular traffic in the center of the road, with small traffic lanes on either sides, BRTS lanes towards the sidewalk which will be easily accessible by the bus stops, a buffer through
landscaping elements like trees, shrubs and plants, a sidewalk which can consists of pedestrian way, cycle track or shared lane. The redesign of Node B (Proposed Metro Station 2) should consider these street design elements in order to provide pedestrian friendly street designs.

4. No dedicated space for vendors: The analysis indicates that the vendors are not provided any dedicated spaces on the streets in Node A. Street vending and street hawking are major activities in India which demands a consideration in planning policies for street design elements. As the street lacks the provision for the vendors, it causes hinderance for a free pedestrian movement around the Metro station. Pedestrian islands should be provided at possible locations to accommodate street activities.

5. Street design lacks space for future commuters: The analysis shows that future expansion of rail and metro corridors is not considered while designing the Metro Station 1. The elevated skywalks which lead to the Metro Station 1 occupy the land which reduces the areas for activities like street parking, street vending and commuter activities. Most of the commuters access the metro station by modes of transportation like rail, auto-rickshaw, bus and taxis. There is no dedicated space around the metro station 1 to accommodate the areas where autos, buses and taxis can be parked. The location of an auto, bus and taxi stand should be reconsidered while designing the proposed Metro Line 2 in order to accommodate the future commuters.

B. The design recommendations that can solve these five major issues mentioned above are:

1. Improved Mobility: The widening of the sidewalks will lead to improved mobility for the pedestrians as well as the vehicular traffic. Improved mobility will help to reduce the commuter travel time in terms of walkability and it will reduce the congestion on the streets caused because of mis-management of the pedestrian and vehicular traffic. Improved mobility should be
considered as a design guideline for Node B (Proposed Metro Line 2) which will accommodate the existing and future commuters.

2. Improved pedestrian accessibility: Pedestrian buffer spaces and pedestrian islands should be provided at locations like street crossing, waiting areas near the entry/exit to the Metro station and street vending stations. The pedestrian accessibility should include accessibility to areas like Metro station, nearest amenities, street vendors and bus stops. As per the analysis for Metro Line 1 accessibility to Metro station is only given preference neglecting other areas near the station like shops, vendors, restaurants, offices, residential and commercial areas. A design template should consider for Node B (Proposed Metro Line 2) which includes accessibility which responds to the Land-use.

3. Livability: The existing conditions for Node A indicates that vehicular transit is a priority for street design. Livability is an important element for street design as it adds the life to the street. On Indian streets activities like vending and street artists and performers are commonly found. In order to accommodate these activities, Urban Design policies should be considered while designing a street. Elements like water fountain, street furniture, interactive walls and street landscapes adds livability to the street. They also promote walking over use of vehicular transport.

4. Sensitivity to local context: The street design currently in Node A doesn’t respond to the existing Land-use. The Node B falls in an area where there is a mix of residential and commercial areas. This indicates that the street will be used by residents as well as office goers at different times of the day. Addition of a Metro Station indicates that the residential neighborhood will increase street activity from 8am-8pm. It also indicates that there will be certain time when the street will be under-utilized. Hence, the street design for Node B should consider that fact to be sensitive to the future Land-Use. Rail and Metro corridor expansions should be considered while designing a street which will accommodate the future commuters.
5. Creative uses of spaces: Sustainable use of street needs to be considered as a planning policy recommendation. Transit streets, curb extensions, storm-water management, creative placement of plants as a buffer rather than installing railings and buffer areas for informal street activities are some strategies than promote creative uses of street spaces. This will attract more pedestrian activities on the street as well as promote walking.

The next section utilizes these five design recommendations mentioned above as a street design guideline along with recommendations from the two manuals- Design Guidelines for the City of Mumbai and ITDP EPC A manual for Street Design in Urban India. The street design template is provided in form of section and plan for Node B (Proposed Metro Line 2) which demonstrates the future street design recommendations.

Site Sections for Proposed Metro Line 2:

Figure 5.10a: Site Section for Proposed Metro Line 2.
Source: Author, 2019.
Figure 5.10b: Site Section for Proposed Metro Line 2.
Source: Author, 2019.

Figure 5.10a represents the existing condition of the street where metro Line 2 will be proposed in the future. Based on the Street Guidelines for Mumbai, this street can be categorized as Sub Arterial Road (100-120 ft /30.51-36.60 m). The road is 113.18 ft (34.50m) wide which consists of 48.39 ft (14.75m) wide two-way lanes divided by median 6.56ft wide in the center of the road. On the either side of the road lies sidewalk which is 4.92 ft (1.5m) wide. Currently, the road does not allot any provision for parking space. The road doesn’t include any bus rapid transit lanes as per the guidelines. Figure 5.10b is an illustration
for the street once the metro line 2 is constructed fully and working. Figure 5.10b provides the guidelines that can be considered as a street design template. The metro line 2 will occupy 6.56 ft (2m) wide in the center of the street. It will also demand more space for pedestrian sidewalks as the no. of commuters using the metro line will be increasing. The design template in Figure 5.10b consist of a pedestrian island which is 24.60ft (7.5m) wide in the center of the road. The pedestrian island will be accommodating the staircase that will be leading to the elevated metro station, pedestrian sidewalk, street furniture, cycling lane and bus stop. On the either side of the pedestrian island a bus rapid transit lane should be provided which is 9.84 ft (3m) wide. Following the bus transit, carriageway should be provided which is 18.04 ft (5.5m) wide. 6.56 ft (2m) wide car parking area should be placed next to the carriageway, which acts as a buffer between the sidewalk and the road. The existing sidewalk should be widened from 4.92ft (1.5m) to 9.84 ft (3m) wide in width. The sidewalk will include pedestrian walkway along with street furniture and landscaping elements. The aim of the design strategy is to increase the pedestrian connectivity to the public transit and design walkable streets.

Figure 5.11a: Site Section for proposed metro line2.

Source: Author, 2019.
Figure 5.11b: Site Section for proposed metro line 2.

Source: Author, 2019.

Figure 5.11a represents the existing condition of the street in terms of pedestrian and vehicular activity. Based on the Street Guidelines for Mumbai, this street can be categorized as Minor Collector Road (46-60 feet / 4.10-18.30 m). The existing street is 50.19ft (15.3m) wide two-way street with undivided carriageway. The road has 3.93ft (1.2m) wide sidewalk one side and creek on the other side. The proposed metro line 3 will be constructed on the side towards the creek. The street does not include any space for car parking. Figure 5.11b is an illustration that shows how the street will look like once the metro line 3 is constructed and working. The road should consist of a 17.71ft (5.4m) wide pedestrian lane below the...
elevated metro line 3. The pedestrian lane should consist of 7.87ft (2.4m) wide sidewalk and 9.84 ft(3m) wide shred lane with street furniture and cycle track. The sidewalk will have bulb- out which will accommodate the bus stop below the elevated metro line 3. Adjacent to the sidewalk should be a 9.84ft (3m) wide bus-rapid transit lane. The road should consist a carriageway which is 18.04 ft (5.5m) wide. Alongside the carriageway, a 6.56ft (2m) wide parking space should be provided on one side of the road. The existing sidewalk should be widened from 3.93ft (1.2m) to 7.87 ft (2.4m) wide. The sidewalk will be used as a shared space with landscaping elements and street furniture. These recommendations for street design can be considered as a guideline for transit-oriented development projects.

The street design templates provided for the selected street sections can be used as an addition to the manual of street design guidelines for India. The manual should include illustrations including 2-D and 3-D illustrations of how the street will look, when these interventions are used. In the following Chapter 5, the strategies are discussed that need to be considered for street designing for TOD to promote pedestrian connectivity and walkability.
Chapter 6: Discussion and Conclusion

The street design guidelines can be implemented on the upcoming metro lines in Mumbai. The problems identified in the existing streets can be avoided using the street design templates.

The Policy recommendations based on the analysis area as follows:

The Development Control Regulations (DCR) 2034 is a document created by Municipal Corporation of Greater Mumbai in relation to the Development Plan 2034. The Draft Development Plan (DP) for Greater Mumbai (2014 – 2036) identifies the potential T.O.D zones within the city as seen in Figure 2.6. However, it can be supported with a separate document / section where it categorizes the areas at a micro scale for TOD development. The DP redirects to DCR which set guidelines for streetscape in written format which can be improvised by adding plans, sections and existing site pictures to make the document more readable and adaptable. The DCR includes guidelines in terms of administration, development permission, Land-Uses and Manners of development, FSI, general building requirements and urban safety requirements. The design guidelines included in the DCR provide standards that needs to be considered while designing a street which elaborates on streetscapes for public street, road intersections, median refuge, traffic signals, subways and foot over bridges. The following are the design guidelines mentioned for streetscapes of public street. The pedestrian crossings should benefit the physically abled and people with visual impairments by constructing the guide strips to indicate the position of the pedestrian crossings and have curb ramps. The raised median refuges should be cut through and levelled with the street level and should have curb ramps. In order to guide the pedestrians who are physically abled and have visual impairments, a colored tactile marking strip which is at least 1.9 feet (0.6m) wide should be marked at the beginning and end of the traffic island. The pedestrian traffic lights should be located at the point of the origin of the crossings and not at the point of destination. The traffic lights should be provided with clear audible signals and acoustic devices. Signages should be provided for foot over bridges and
subways. To enable wheelchair accessibility a provision of slope ramps or lifts should be made at both ends of the road. The document does not support the guidelines with any sections or plan for Streets. The document also fails to provide any reference to the existing street guidelines for Urban India created by ITDP. The document can be improvised by addition of illustrations which provide street design templates for physically abled and elderly people.

Street Design Guidelines for Greater Mumbai should include the reference images of the street similar to the guideline created by ITDP for urban streets. The guidelines can include suggestions for Land-use annexation if required and provide with list of scenarios where the Land-use can be modified. The DCR and the street Guidelines should be relatable to in terms of Land-use policies. A scoreboard can be created to grade the quality of the street corresponding to the street guidelines, which will further help to identify the T.O.D zones within the city. Looking at the financial structure of the Metro lines in Mumbai as shown in Table 1, a comparative analysis can be made to understand which Model of financial structure worked better and can be used as a model for other cities in India.

A transport Infrastructure development policy needs to be adopted which promotes Transit oriented development. The factors that need to be considered are shown in Figure 6.1 1) Connection to transit: Elevated walkways and Widening of sidewalks, 2) Restricted car use: car restricted zones and car free zones, car-pooling, promoting cycling and congestion pricing,, 3) Parking policy: Park and Ride, ensuring parking space at home and office, congestion pricing, and parking management, 4) Road Infrastructure: improvement of NMT infrastructure, better Bus rapid transit system, expansion of rail and metro corridors and online ticketing and tracking system.

Planning and Urban design Policy recommendations
Connection to Transit: Figure 6.2 represents the Urban design policy 1 recommendation which is connection to transit that will lead to a better pedestrian connection and will promote TOD in Mumbai. TOD can be successful in a city of Mumbai only if it is supported by and efficient connection to transit mode. Currently the street demands a better connection to the Metro station through the means of elevated walkways and widened sidewalks. This policy aims to improve the existing network conditions and provide quality ridership to public transport users. This policy will improve the functioning of the road, rail, metros and buses in the city which will encourage people to use public transport. A better connection to transit and an improved road network will avoid congestion in Mumbai.
Restricted Car use: Figure 6.3 represents the Urban design policy 2 recommendation which is connection to transit that will lead to a better pedestrian connection and will promote TOD in Mumbai. A non-profit organization in Mumbai initiated the concept of car free day from the year 2010-2014. However, this initiative failed due to lack of promotion and awareness amongst the dwellers. A policy should be introduced which identifies the location in the city and the time of the day when cars can be restricted for few hours. Based on the commuter traffic and ridership data, areas around the metro station need to be identified which can have restricted car parking time which will make more space for pedestrian on the street. Carpooling is a new concept in India began in 2006, and several apps are being developed to promote carpooling in India. The city of Mumbai should create awareness about car-pooling through print media and advertising sources. Cabs like OLA, Meru and Uber also offer carpooling options at affordable
rates. People using private vehicles should be encouraged to use apps for carpooling which will reduce the traffic congestion on the streets.

Figure 6.3: Policy Recommendations  Source: Author, 2019.

Parking Policy: Figure 6.4 represents the Urban design policy 3 recommendation which is connection to transit that will lead to a better pedestrian connection and will promote TOD in Mumbai. Car ownership in Mumbai is fairly low (32 cars per 1000 persons) as compared to other Asian cities with similar densities (LEA Associates 2008). One street parking has become a major concern as it results to traffic jams and congestion on the streets. Off-street parking is easily available in Mumbai but it does not mean that it fuels to encourage paper for owning a car. Hence, the regulations of parking policy have become an important issue and the transport policy of Mumbai needs to be revised. Mumbai has an extremely high

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13 Mitigation Policy packages for Transport sector- Mumbai Metropolitan region
public transport ridership as compared to other Indian cities and it is essential to provide proper parking spaces. Parking system needs to be improved near the rail and metro stations while considering the fact of congestion.

Figure 6.4: Policy Recommendations   Source: Author, 2019.

Road Infrastructure: Figure 6.5 represents the Urban design policy 4 recommendation which is connection to transit that will lead to a better pedestrian connection and will promote TOD in Mumbai. In the city of Mumbai, there is restricted space for new roads which causes traffic congestion on existing roads. In order to improve connectivity in Mumbai and attract more commuters the city needs to implement plans for Bus Rapid Transit System (BRTS) with a dedicated bus lane. Based on the standards mentioned in the guidelines for Street Design in India, bus lanes need to be provided on multi-lane highways in the city. The bus rapid transit system will provide a comfortable and faster alternative to private cars thus reducing the
number of cars in the city and also encouraging the use of public transport at a cheaper rate. BRTS will increase the capacity and reduce the delays by promoting more reliability among the bus commuters. The city currently has autos and taxis as a para-transit mode of transport. Non-Motorized modes (walking and cycling) needs to be improved in the city. The transport planning system in Mumbai has given more preference to vehicular transport over pedestrian movement. The majority of low-income classes still prefer walking and cycling to reach their destination in Mumbai for distances less than 3-4 km.\(^{14}\) Non-motorized transport (NMT) modes provide flexibility and affordability as well as they are environmentally friendly. Pedestrian footpaths, sidewalks, traffic signals, cycle lanes, cycle routes, cycle signals, cycle parking and cycle sharing need immediate attention at planning and policy levels. NMT guidelines mentioned in the ITDP EPC manual for street design should be considered as a policy recommendation.

The rail and metro corridors should be expanded to accommodate future commuters in Mumbai. The sidewalks and pedestrian islands near the rail and metro stations needs to be redesigned and expanded in order to provide a better pedestrian connection. BEST provides public bus system in the city of Mumbai and has made plans to develop apps for the bus commuters where the commuters can book bus tickets online through their mobile and track their buses real time. An online app needs to be developed for both public bus transport system in Mumbai. This will make transit easier and also promote sustainable, high-occupancy of the bus transport. Ola and Uber systems are very successful in the city and a similar online app strategy should be used for the public bus system in Mumbai. cashless transactions will promote more reliability and convenience for bus commuters (Indian Express, 2016)\(^{15}\).

\(^{14}\) Mitigation Policy packages for Transport sector- Mumbai Metropolitan region

\(^{15}\) Mitigation Policy packages for Transport sector- Mumbai Metropolitan region
One of the major issues of policy recommendations is the process of evaluation and monitoring. In order to develop a successful TOD system, it is necessary to identify the organizations who will be responsible to monitor the entire process of street designing based on the planning and urban design policies. The key actors responsible for policy development are:

1) Developers and elected officials: MMRDA and Reliance Infra are the primary stakeholders who are responsible as the developer of the Metro Lines in Mumbai, India. The Metro line is owned by MMRDA and is developed by private agency Reliance Infra. Reliance Infra has divided the entire metro length of 1 mile and further appointed contractors for each mile for construction. It is mandatory for the developer and elected officials to co-ordinate with the transit planner in order to identify ideal locations for the Metro Stations to promote TOD. MMRDA and Reliance Infra are responsible to develop the planning stages of TOD and the timeline for different activities. During the implementation process, developers and elected officials should look at the profits made from...
the investments and understand the pattern to be followed for future investments. MMRDA looks at the TOD for city as a whole and is responsible for obtaining financial benefits as the TOD development will lead to increase in Land value and increased tax revenue.

2) Urban planners and designers: The urban planners and designers should ensure that the TOD project leads to livable and walkable neighborhoods, economic well-being of the community, diverse land-use, community development and pedestrian friendly street design. Urban planners and designers develop master plans which corresponds to the population growth, ridership data and transit needs.

3) Financiers: Financiers look after the funding of the Metro station for TOD development. The financiers should look after the revenue flows and profit returns from the investments made. Financers can be both public and private agencies.

4) Public: The citizens of Mumbai, India are responsible in maintaining the street life. Waste management issues, following the parking management rules and payment of parking fees, taking acre of the ambience of the area and acting publicly responsible are the duties of an ideal citizen. The citizens should make sure that the maintenance of walkable neighborhood is their duty. Citizens should make less use of private transport whenever possible to promote pedestrian activity in the neighborhood. Car-pooling options can be used in order to reduce the vehicular congestion which will provide more space for street activities.

If the monitoring and evaluation shows progress in the development of TOD nodes in city of Mumbai, the results will show mobility, economic environmental and social benefits.

1) Mobility benefits: Implementation of TOD nodes with positive results will provide mobility benefits as people will prefer pedestrian modes over vehicular modes of transport. In terms of
walking distance to the Transit nodes will be reduced and people will prefer public transport over private transport in Mumbai, India. A better pedestrian connectivity will improve access to jobs, schools, colleges, and other amenities supported by a better access to public transportation, walkable urban spaces, bicyclist infrastructure which will reduce the use of vehicular transport. TOD can lead to increase in the use of public transport economies which will lead to improvement in quality of services.

2) Economic benefits: TOD can encourage economic resilience as it helps in development of local economic activity. The property values of the areas with better TOD will increase which will lead to increase in housing and infrastructure development in Mumbai, India. TOD’s will promote mixed-used development which will be easily accessible by the residents within half-mile distance radius. As the transportation costs reduces, TOD’s can lead to other economic opportunities.

3) Environmental benefits: Less use of auto-mobiles and vehicles will lead to reduction in air pollution, lower green house gases emissions and less energy consumption. The reduction of auto-dependency will promote conservation of nature. Addition of landscaping elements like trees and shrubs will provide fresh air and reduce pollution in the city.

4) Social Benefits: Neighborhood revitalization, social activities will increase due to successful TOD system in the city. Walkable neighborhoods will provide accessibility to public spaces, parks, community gathering areas and entertainment zones within the city. This will result in bringing the people outside the house in a mixed-used neighborhood which will lead to mental and health benefits. TOD’s will promote happiness due to increased interactions and physical activities like bicycling, dog-walking and street activities.
Contribution and Future Research

Contribution

This paper contributes to the urban design and planning policy recommendations for streetscaping in city of Mumbai. Findings of the study show the relationship between TOD and pedestrian connectivity. The study focuses on the aim of Mumbai to develop a TOD system and helps to find solutions to existing scenario by looking at one of the essential factors which is pedestrian connectivity. The goal of this research paper is to provide street templates which can be a part of the of the street design manual for Urban India. The study provides simple street design templates supported by plans and sections which include street design elements like sidewalks, carriageways, Bus rapid transit lanes, vending facilities, street furniture, car parking facilities and landscaping. The study suggests additions that can be made to develop a better TOD system and encourage the use of public transport by prioritizing street infrastructure. The paper identifies the existing metro station in Mumbai, India and analysis the existing infrastructure in terms of roadways and transport. This study will help to determine the need of considering the development of road infrastructure in terms of pedestrian streets and connectivity for the upcoming metro stations in Mumbai, India. The results obtained from the analysis will set a benchmark for street design guidelines for the metro lines which yet proposed and expected to be developed in future.

The study also provides recommendations for the policies that needs to be considered as a planning objective. The study suggests transport infrastructure development policies that should be a part of the planning policy for Mumbai to have an efficient TOD system in the city. The paper explores the benefits of the policies like connection to transit, restricted car use, parking policy and road infrastructure. The study highlights the policies the ability of a better pedestrian connectivity to improve a strong and
successful TOD system in the city of Mumbai by the improvement in the policies related to street and transport infrastructure.

Limitations and Future Research

The study focuses on two specific nodes mentioned in the Draft development Plan of Mumbai 2014-2034. The study is limited to one node of existing metro line 1 and one node of proposed Metro line 2. To have a better TOD system in Mumbai, all the major nodes mentioned in the Draft Development Plan of Mumbai 2014-2034 needs to be explored by using similar methodology. The paper used the methodology of observation method to understand the level of pedestrian connectivity required to have an efficient TOD system at selected nodes. The recommendations suggested in Chapter 4 of analysis in terms of street design needs to be adjusted for other street design interventions in the city. In future, similar methodology should be used to understand pedestrian connectivity which includes street design elements, Bus rapid transit system and Non-motorized transport system. The study should look after pedestrian catchment areas and intersection analysis. Pedestrian a catchment area includes analysis of walkable zone within a half-mile radius of selected node while intersection analysis includes the intersections of different types of road which looks after the dead ends that limits the pedestrian access. A GIS based analysis identifies the intersections of different roads within selected buffer. It will help to understand the street crossings that pedestrian use and are affected by vehicular traffic.

The study is limited to city of Mumbai and can be extended to other cities in India which are planning to have Metro system in future. Currently 10 cities in India namely, Kolkata, Delhi, Chennai, Bengaluru, Hyderabad, Jaipur, Gurgaon, Mumbai. Kochi and Lucknow have metro rail system which is working. The cities like Pune, Kanpur, Surat, Coimbatore, Nagpur are planning to have metro line by the year 2025. A study can be done similar to the areas explored in the paper to provide better urban design and planning recommendations for the country in terms of pedestrian connectivity. There are also plans for
underground metro line system in Mumbai and other major cities in India. The study can be extended to focus on the factors of light and ventilation, platform design, storage facilities supported with plans, layouts and 3-D views. The ITDP EPC A manual for Street design in urban India, identifies the elements that needs to be considered for street design above the ground and a section can be added for design of public spaces below the ground like metro stations. A separate manual can be made for design guidelines templates which includes climate control requirements, lighting, buffer spaces, specific materials and utility location which are not similar to streetscaping for metro stations above ground.

As the concept of carpooling is new in Indian cities, it demands a policy consideration as well. Most of the dwellers of Mumbai are familiar with Carpooling and private providers like OLA and Uber. The city has traditional bus stops, auto-rickshaw and taxi stands. Ola auto-rickshaw are recently launched in the city. This means that there should be separate provision for OLA auto-rickshaw pickup and drop off stands. Currently, the city does have a dedicated zone for private cabs which forces the pedestrians to come on the road and access the vehicle. A pedestrian island should be created where commuters can access private cabs or car-pooling facilities. The city needs to develop apps which will encourage carpooling services in Mumbai and this will help to reduce the use of private vehicles thus, reducing traffic congestion on the roads.

Transit Oriented Development (TOD) requires a commitment to nodes and a commitment to rail as its core ingredients. TOD demands a strategic policy framework that asserts where nodes need to occur and in the context of diversity of Land-Use, a policy planning base that requires development to occur at the necessary density and design in each node, preferably by a state government development agency, a public-private partnership mechanism that enables the rail to be built or refurbished through a linkage to the nodes it will service and a metro station that is linked to the residential areas around which will help to reduce car dependence and reduces travel time.
In conclusion, a fully designed complete street should improve pedestrian and cyclable connectivity in the city which will have a significantly less use of vehicular transport. New urbanism, transit-oriented design and traditional town planning have common transportation objectives that are reduce in the number of motorized trips, non-motorized transport and reduce travel distance. New urbanists, Neo-Traditionalists and other reform-minded designers argue for changing three dimensions or the 3D’s of built environment – Density, Diversity and Design to achieve the objectives of transportation. Livability in today’s urban streets is about a balance among all modes of travel.\textsuperscript{16} The day of the streets myopically oriented to serve vehicle is fading into the past, while complete streets balancing the needs of all users are the future.\textsuperscript{17} In future, we need should be able to solve the debate between auto-oriented design and transit-oriented design by implementing street design and planning policies for a better pedestrian connections to transit modes in Mumbai, India.

\textsuperscript{16} Travel demand and the 3Ds: Density, diversity, and design.
\textsuperscript{17} Travel demand and the 3Ds: Density, diversity, and design.
References:


2) Construction Update, Edelweiss Aug 15

3) Construction Update, Edelweiss June 17


7) EPC (2012). *Station Area Planning: A Guide to Planning and Implementing Transit Oriented Development in Indian Cities*, Environmental Planning Collaborative, Ahmedabad

8) ET online. (2009, Aug 04). Reliance Infra wins Rs. 11,000-cr Mumbai Metro -II project. Retrieved from: "Reliance Infra wins Rs 11,000-cr Mumbai Metro-II project - Economic Times".


11) India: Mumbai Metro Rail Systems Project, Mumbai Metropolitan Region Development Authority, Government of India for the Asian Development Bank

12) Institutional and financial framework for implementing Metro Projects- MMRDA experience

13) ITDP EPC A manual for Street design in urban India.


16) Line 1 (Mumbai Metro), (2018, December 18)


21) Mitigation Policy Packages for transport sector- Mumbai Metropolitan Region

22) NACTO. Urban Street Design Guide


34) Street Design Guidelines for Greater Mumbai.

Figure 2.9: Identified Transit Oriented Zones around Rail Stations

Source: Draft Development Plan 2034, Greater Mumbai.
Table 4: Salient Features of Mumbai Metro Line 2A

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Trip</th>
<th>Average Lead (Km)</th>
<th>PHPDT</th>
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<tr>
<td>2016</td>
<td>270215</td>
<td>6.02</td>
<td>8270</td>
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<tr>
<td>2019</td>
<td>352782</td>
<td>6.25</td>
<td>10213</td>
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<td>2021</td>
<td>407826</td>
<td>6.41</td>
<td>11560</td>
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Train Operation:

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<td>Max. PHPDT Demand</td>
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<tr>
<td>PHPDT Capacity Available</td>
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<td>19156*</td>
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* @ 6 Persons Per Square Meter of Standee Area

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<th>Year</th>
<th>Headway (Min)</th>
<th>No. Of Rakes</th>
<th>No. Of Car Per Rake</th>
<th>No. Of Coaches</th>
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<td>2031</td>
<td>5.5</td>
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Table 5: Salient Features of Mumbai Metro Line 2B

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<th>Total Trip</th>
<th>Average Lead (Km)</th>
<th>PHPDT</th>
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<td>2021</td>
<td>89043</td>
<td>11.09</td>
<td>35141</td>
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<td>2031</td>
<td>1049100</td>
<td>9.71</td>
<td>38509</td>
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Train Operation:

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<th>2031</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars/Trains</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Head Way (Minutes)</td>
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<td>5.5</td>
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<tr>
<td>Max. PHPDT Demand</td>
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<td>PHPDT Capacity Available</td>
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* @ 6 Persons Per Square Meter of Standee Area

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<th>No. Of Rakes</th>
<th>No. Of Car Per Rake</th>
<th>No. Of Coaches</th>
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<td>39</td>
<td>6</td>
<td>234</td>
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<tr>
<td>2031</td>
<td>5.5</td>
<td>40</td>
<td>6</td>
<td>240</td>
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</table>

Figure 4.3e: Population density of ward K/E.


Figure 4.4e: Population density of ward K/E.

## Table 1: FINANCIAL FRAMEWORK FOR IMPLEMENTING METRO PROJECTS

<table>
<thead>
<tr>
<th>Metro Line 1</th>
<th>Metro Line 2, 4 and 7</th>
<th>Metro Line 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Public-Private Partnership metro project in India. Started Under Indian Tramways Act, later brought under Metro Act.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length: 11.4 km, Elevated</td>
<td>Length: 118 km, Elevated</td>
<td>Length: 33.5 km, Underground</td>
</tr>
<tr>
<td>Total Costs: Estimated Rs.2,356 Crore, Actual Rs.4,321 Crore.</td>
<td>Total Costs: Estimated Rs.40,000 crore</td>
<td>Total Costs: Estimated Rs.23,136 Crore</td>
</tr>
<tr>
<td>Implementing Agency: MMOPL (R Infra and MMRDA)</td>
<td>Implementing Agency: MMRDA o Inviting Bids o Deposit Work by DMRC</td>
<td>Implementing Agency: MMRC an SPV of Govt. of India and Govt. Of Maharashtra</td>
</tr>
<tr>
<td>Financing Pattern: o VGF by Govt. of India Rs.471 Crore o VGF by Govt. of Maharashtra Rs.179 crore o Equity Rs.521 Crore o Debt Rs.1194 Crore</td>
<td>Financial Pattern: o State govt. to provide sub- debt for central taxes (50%), state taxes (100%) and land costs. o Loan assistance for systems Funding Agencies (80%) and MMRDA (20%)</td>
<td>Financial Pattern: o Equity by centre 11% o Equity by MMRC and state 11% o Sub debt by centre 4% o Sub debt by State 7% o Property development and Impact Fee 4% o Stakeholder contribution (MIAL) 3% o MMRDA grant 3% o JICA loan 57%</td>
</tr>
<tr>
<td>Sharing Pattern:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Percentage</th>
<th>Company</th>
<th>Bidding Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>69%</td>
<td>R Infra and Veolia</td>
<td></td>
</tr>
<tr>
<td>26%</td>
<td>MMRDA</td>
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</tr>
<tr>
<td>5%</td>
<td>RDTA</td>
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Reliance Industries Limited won the bid with 27.6% VGF demanded. Reliance Infrastructure and L&T won the bidding process by having 2 packages each.

<table>
<thead>
<tr>
<th>Year</th>
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<td>2006-2014</td>
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<td>2014-2020</td>
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**Observation Images for Node A:**

![Figure 4.14: Bikes parked in vacant spaces around the station.](image1)

![Figure 4.14: No dedicated lanes as mentioned in street design guidelines causing congestion.](image2)
### Figure 5.6: Intersection of two major streets explaining pedestrian connection

Source: ITDP EPC A manual for Street Design in Urban India.
In the Figure 5.6, illustration shows the level of pedestrian connection at an intersection of two major roads. The proposed Metro Line 2 and 3 consists of a road intersection which needs to be designed using a similar design approach in Figure 5.6. Figure 5.6 shows the location of pedestrian crossings (white strips) which are marked for a dedicated pedestrian movement. These crossings help to stop the vehicular activity before the pedestrian crossings, so that the pedestrian and cyclist can cross lane without any disturbance. The zebra crossings (white strips) are located at the intersection of the streets and a speed bump can be placed before the zebra crossings to reduce the vehicular speed at the intersections. Shrubs, trees, street vending facilities and street parking should not be placed close to the intersections as it blocks the visibility of the pedestrian and may cause accidents. Queuing space for the vehicles should be provided at the intersections supported by round-about to provide a smooth vehicular traffic at the junctions. It helps to widen the carriageway lane and reduces the stop time at traffic signals. The extra lane can be occupied from the parking lane on regular street.