EVALUATING LOCAL AREA PLANS AND THEIR EFFECT ON TRANSIT ORIENTED DEVELOPMENT

A STUDY FROM AHMEDABAD, INDIA

RICHA MAHESHWARI

Enschede, The Netherlands, February 2019

SUPERVISORS:

DR. ANNA GRIGOLON

IR. MARK BRUSSEL

EVALUATING LOCAL AREA PLANS AND THEIR EFFECT ON TRANSIT ORIENTED DEVELOPMENT

A STUDY FROM AHMEDABAD, INDIA

RICHA MAHESHWARI

Enschede, The Netherlands, February 2019

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
Specialization: Urban Planning and Management

SUPERVISORS:
DR. ANNA GRIGOLON
IR. MARK BRUSSEL

THESIS ASSESSMENT BOARD:
PROF. DR. KARIN PFEFFER (CHAIR)
PROF. MARK ZUIDGEEST (EXTERNAL EXAMINER, UNIVERSITY OF CAPE TOWN)
DR. ANNA GRIGOLON
IR. MARK BRUSSEL

ABSTRACT

The city of Ahmedabad in India, like many other mega-cities, is transforming rapidly and experiencing paralyzing traffic congestion, long travel times and a lack of last mile connectivity. To mitigate these issues and as an attempt to connect the ends of the city, the local government decided to introduce a metro rail by 2021 in addition to the existing AMTS (Ahmedabad Municipal Transport Service) and BRTS (Bus Rapid Transit System) transport systems. The metro construction in the first phase spans across north-south and east-west corridors covering 32 stations.

The local government has initiated Local Area Planning (LAP) for a 200 m zone on both sides of the metro corridor based on the widely acclaimed principles of Transit Oriented Development (TOD). LAP professes to redevelop and retrofit the existing brownfield area by incorporating six spatial planning strategies. However, Ahmedabad-LAP document lags as it does not satisfactorily discuss land-use and transport integration and lacks quantification of the indicators. Land-use and transport integration is required because it influences the travel demand and travel pattern of the people. A lack of integration may affect the ridership of the metro as seen in the case of Ahmedabad-BRTS. Moreover, in the absence of quantitative analysis, evaluation and comparison of indicators become difficult as no measurable performance can imply a good and bad threshold for TOD.

To this effect, the study aims to evaluate the effect of LAP's on the level of TOD in Ahmedabad (West). To achieve that, a mixed method approach is followed involving qualitative and quantitative analysis. The qualitative analysis deals with the narratives of the interviewees and the findings from the LAP planning document whereas the quantitative analysis features a geospatial approach to evaluate eleven built-environment factors in Pre-LAP and Post-LAP scenarios. The indicators were selected based on the literature but also adapted from the LAP document and site conditions. They were quantified using non-indexing and indexing method and a comprehensive value were computed for all the seven studied metro stations in both the periods; Pre and Post-LAP. These methods are suitable to quantify the eleven studied indicators, and therefore it helps in fulfilling the research aim and objectives.

The results demonstrate that the findings from the interviews, literature and LAP documents are not always in line with the findings from the quantitative analysis. This is because Ahmedabad-LAP has not considered few underlining principles which are essential for the success of the TOD and therefore it is a direct drawback of the LAP. On the other hand, the quantification analysis reveals that based on the eleven studied indicators, LAP proposals are improving the level of TOD in six out of seven studied metro stations. This indicates that LAP proposals are representative of TOD, but it is unable to bring all seven studied stations to the same level of TOD, and this was not anticipated by the experts involved in the LAP planning.

Lastly, this thesis makes a case by acknowledging and overcoming the gaps in Ahmedabad-LAP using policy recommendations that can improve the TOD index further and can strengthen the LAP. These recommendations are developed contextually but are not limited to the seven stations and can be extended to the remaining metro stations that are under preparation in Ahmedabad. In closing, any local area planning should incorporate land-use and transport integration and other operative principles to improve the level of TOD around the metro stations and to increase the ridership of the transit. The points thus raised can be taken up as a part of future research.

Keywords – Local area plan, Transit-Oriented Development, LAP, TOD, Land-use and transport integration, TOD index

ACKNOWLEDGEMENTS

I would like to use this platform and thank all the people who have extended their invariable support in fulfilling my piece of work. First and foremost, I would like to express my sincere gratitude to my supervisors: Dr. Anna B. Grigolon and Ir. Mark G. Brussel for their contribution and constant guidance during my thesis.

I am grateful to all the interviewees for their time, assistance and their valuable inputs in my work. I would like to thank AUDA and MEGA for sharing the data and required resources with me.

I am also indebted to Mr Andre Silva for his quick help with ArcGIS. I am also thankful to Dr Yamini Singh for her quick assistance. I would also like to express my appreciation to Vishesh, Anushka and Harshit for helping me out during my fieldwork.

Most of all, I would like to thank my friends Anshul, Anuja and Mitali, Sheeba, Nivedita, Harinish and Ashish for their endless support and my dearest parents and sister for their immense encouragement.

Finally, I would like to thank ITC for providing an excellent learning environment throughout my course.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

AMTS	Ahmedabad Municipal Transport Service
AUDA	Ahmedabad Urban Development Authority
BRTS	Bus Rapid Transit System
DCR	Development Control Regulations
LAP	Local Area Plan
LUTI	Land-use and transport integration
MEGA	Metro link Express for Gandhinagar and Ahmedabad
NMT	Non-Motorized Transportation
ROW	Right of Way
TOD	Transit Oriented Development
TOZ	Transit Oriented Zone
URDPFI	Urban and Regional Development Plans Formulation and Implementation

1. INTRODUCTION

1.1. Background and justification

The city of Ahmedabad in India like many other mega-cities has outgrown the pace of development and is transforming rapidly. It is now the seventh largest metropolitan area and third fastest growing city in India (World Population Review, 2018). The rapid transformation has resulted in a heterogeneous development that houses diversity concerning income groups, built typology and mixed-use development in every corner of the city. Earlier Ahmedabad had a distinct built form where the western part flourished as residential and commercial while industries dominated the eastern region. Nevertheless, with time the city engulfed the nearby areas and developed as an abode of diversity. The city also earmarks diversity concerning its transportation systems which are largely dependent on roadway systems. Around 46% of the people walk or use the bicycle, 26% use two-wheelers, 6% are dependent on autorickshaws, 11% use public transport, 6% use cars while remaining 6% either use rail, school buses or staff buses/cars (Center of Excellence in Urban Transport, 2018).

Regarding public transport, 10% are AMTS users (Ahmedabad Municipal Transport Service), which are oriented mostly to connect the central parts of the city whereas only 1% are BRTS users (Bus Rapid Transit System) which operate on dedicated lanes, covering 549 km and 82 km of road network respectively (Center of Excellence in Urban Transport, 2018). Even though the public transport systems covered a significant amount of the city's road network, the city still experiences paralyzing traffic congestion, long travel time, a lack of last mile connectivity, air pollution and low ridership. From 2004 till 2014, the motor vehicle population in Ahmedabad city mounted from 1.08 million to 3.66 million (Statista, 2016). According to NUMBEO (2018), out of 58 polluted cities in Southern Asia, Ahmedabad ranks at 33. To mitigate these issues and in an attempt to connect the ends of the city, the local government decided to introduce a metro rail (Center of Excellence in Urban Transport, 2018). The metro construction in the first phase spans across north-south and east-west corridors covering 28 elevated and 4 underground stations, which are planned to be operational by 2021 (Figure 1). The planning of the corridors and stations was decided based on two indicators; statistics of ridership and Peak Hour Peak Direction Traffic (PHPDT) (Center of Excellence in Urban Transport, 2018). Only these indicators are not appropriate as they lack input from spatial planning. Statistics of ridership and PHPDT helps in identifying potential corridors based on statistical analysis, however it fails to incorporate the effort of spatial analysis that seeks to integrate land-use and transport. Spatial planning considerations are essential because it deals with territorial organization of land-uses and the linkages between them in order to achieve a uniform economic growth for promoting sustainable development (Anonymous, 2008).

Having said that, it is possible that the metro may experience low ridership like BRTS (Kaushik, 2018) and becomes merely a mobility investment which does not effectively maximise ridership. An argument to support the low ridership of BRTS after nine years of its establishment could be the absence of land-use and transport integration and little attention to the physical integration of neighbourhoods with BRTS (Cervero, 2013b). Other factors that contributed to the low ridership of BRTS were incomplete last mile connectivity, subsidised road taxes, free parking, inadequate integration of BRTS with other public transport systems (Joshi, Joseph, Chandran, & Darji, 2017; Shaikh, 2018), a lack of technological integration (TNN, 2016), shuttle rickshaw operating parallel to the BRT (TNN, 2017), inefficient non-motorised transport (NMT) infrastructure (Joshi, et al., 2017) and a lack of spatial planning. Although BRTS in Ahmedabad just after its inception became a successful example because it earned worldwide acclaim and became a role model for public transport in India (Rizvi, 2014), with time its shortcomings started to register as it could not reach the expected ridership.

To avoid such situations with metro system and to maximise the return on investment, addressing the pitfalls of BRTS by integrating land-use and transportation (LUTI) is essential. For this, the Ahmedabad Urban Development Authority (AUDA) has prepared Local Area Plans (LAPs) for a 200 m zone on both sides of the metro corridor based on the principles of Transit Oriented Development (TOD). Various researchers have conceptualised TOD, but primarily it focuses on LUTI (Cervero, 2013b). Three LAPs are prepared for the western corridor which includes seven metro stations and remaining fifty-two LAPs are under preparation. These LAPs are currently with the state authority for scrutiny.

LAP professes to facilitate the inflow of the population and refurbishment of the existing infrastructure. They are built to improve the last mile connectivity, enhance accessibility and optimal utilization of land. It is an exercise of redevelopment as well as retrofitting. It not only discusses the existing conditions around the station areas, but it also focuses on improving the physical infrastructure and making TOD sustainable in the long run. A detailed plot level study was done to assess which plots will go for redevelopment at an early date. The focus was laid on effective use of front margin for better pedestrian movement, reducing the block size for encouraging walkability and creating active building frontage by introducing the public domain concept (AUDA, 2017). However, it was noticed that there was a lot of emphasises on road design and population density but the land use diversity aspect that is extremely important to Indian cities was not duly recognised. Proposal for redevelopment and retrofitting are stated but no proposals for land-use are made. Although some of the spatial planning issues in BRTS might be tackled through LAP, the foundation of LAP does not give due consideration to land-use and transport integration. Another drawback of LAP is much focus on qualitative discussions and lack of quantitative analysis. Quantitative analysis offers a platform to evaluate and compare indicators and their findings. In addition, it sets a measurable performance that can imply a good and bad threshold for TOD (Singh, Flacke, Zuidgeest, & Maarseveen, 2018).

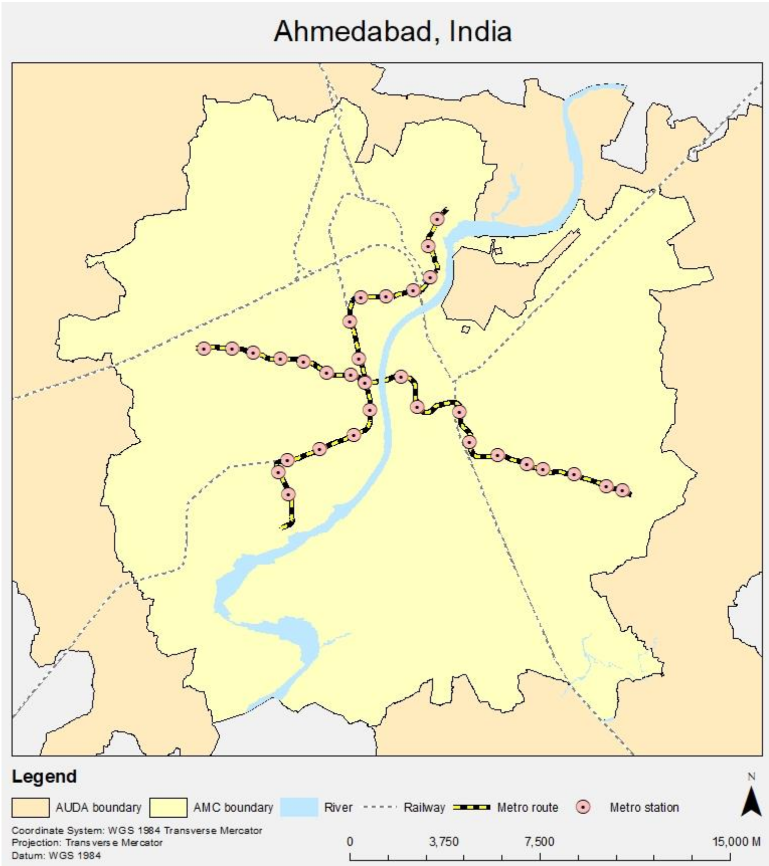

Figure 1: Map of Ahmedabad city with proposed metro corridor (Source: AUDA)

Thus, to overcome these issues, a TOD-LAP evaluation will be carried out. The outcome of the research will contribute to address the shortcomings and provide policy recommendations for strengthening the LAP. These recommendations might eventually help in increasing the ridership of the metro which is the direct output of efficient TOD planning (Guo, Nakamura, & Li, 2018; Higgins & Kanaroglou, 2016).

1.2. Research problem

In line with this justification, the proposed research problem is that the ambition to develop LAP along the metro corridors in Ahmedabad is not matched with the ambition of TOD because it lacks LUTI. Even though one of the foremost goals of TOD is to maximise its ridership (Higgins & Kanaroglou, 2016), it is not just about ridership but about linking land-use and transport to shape the development towards more transit. A project that only focuses on mobility lags because other aspects that are essential for the success of TOD are not given due consideration. Additionally, quantification of the LAP is also missing and should be addressed to determine which stations are moving towards TOD and which are not.

Therefore, this research will contribute to the whole discourse of TOD in relation to LUTI. In addition, to use this understanding in identifying relevant indicators that can aid in quantifying the Pre-LAP (existing situation) and Post-LAP (situation after implementation of LAP) levels of TOD of the proposed metro stations. This research presents its novelty by comparing two TOD indices and reflecting on them together with the local area planning practices and policies. Besides, there is no such study done in Ahmedabad on the metro system that looks at this comparison. The relevance of doing this is to identify if there are differences in the two TOD indices and if the post LAP is indicative of improvements towards making the areas more oriented towards transit. The findings from this study can draw lessons on how the other LAP should develop in the future.

1.3. Conceptual design

Figure 2 illustrates the conceptual diagram. It demonstrates the linkages between the central themes. LAP is prepared based on the widely applied principles of TOD however, all the principles of TOD are not incorporated in the LAP. Therefore, to evaluate LAPs, a mixed method approach is applied. The findings of qualitative and quantitative analysis will be synthesised to reflect on the gaps and draw policy recommendations from the gaps to strengthen the LAP and improve the TOD index.

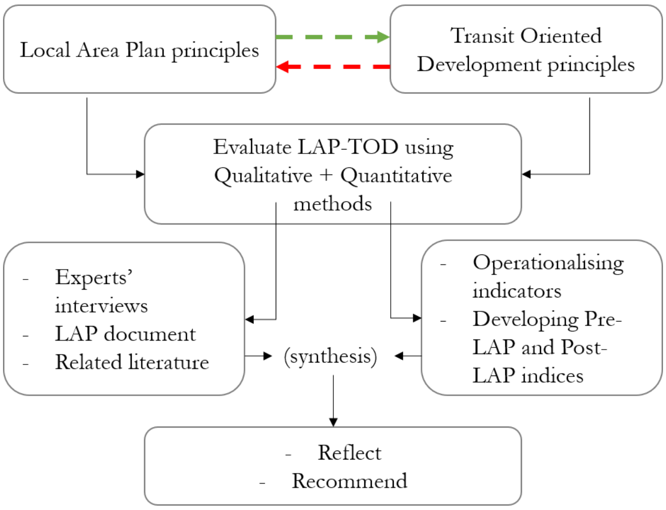

Figure 2: Conceptual design

1.4. Research objectives

The idea of this research is to understand the gap in the LAP planning and propose recommendations for strengthening the LAP. For this, land-use and transport indicators will be incorporated in the LAP prepared by AUDA (local government) which currently are not addressed. A general research objective thus formulated is: To evaluate the effect of LAPs on the level of TOD in Ahmedabad (West). Five specific objectives are formulated that are relevant to this research in the context of Ahmedabad.

1. To comprehend the relation between planning theories and their role on the LAP.
2. To extract relevant indicators adapted from LAP, TOD literature and site conditions.
3. To evaluate the LAP planning procedure in Ahmedabad using qualitative approaches.
4. To compute and compare Pre-LAP and Post-LAP TOD indexes to evaluate how planned interventions influence the characteristics of the transit stations.
5. To reflect and conclude on both qualitative and quantitative approaches and develop policy recommendations for strengthening the LAP towards better TOD.

1.5. Research questions

The following research questions are identified based on the respective sub-research objectives.

1. (A) What is the relation between land-use and transport? (B) How can TOD strategies strengthen this relationship? (C) How is TOD conceptualized in LAP?
2. (A) What are the indicators of TOD? (B) What are the indicators of LAP? (C) Which indicators are relevant in Ahmedabad? (D) What are the selected indicators for developing the TOD index?
3. (A) What are the qualitative approaches? (B) What are the elements of the interview? (C) What are the findings from the interviews? (D) What are the findings from the LAP document?
4. (A) What are the Pre-LAP TOD index values? (B) What are the Post LAP TOD index values? (C) What are the differences in the Pre-LAP and Post-LAP indices?
5. (A) What are the differences in the findings of the qualitative and quantitative analysis? (B) Which policy recommendation can strengthen the LAP towards a better TOD?

1.6. Anticipated results

At the end of the research, the following is anticipated.

- There will be differences in the Pre, and Post-LAP TOD index values and the Post-LAP values will improve the TOD because the LAP has undergone several planning interventions that would improve the TOD.
- There will be differences between the Post-LAP index values across the seven station areas. While some stations improve a lot, others will improve a bit. The variation in the improvement will be caused by the performance of different indicators. It will be interesting to study if this was on purpose or was a side effect of LAP planning that was not anticipated by the experts involved in the planning.
- From the comparison, sensible recommendations will be derived on TOD development in the station environments.
- The improvement in the TOD values might also improve the ridership of the metro in the future.

1.7. Thesis structure

The research is organised into five chapters. Chapter 1 sets the background and justification followed by the research objectives and questions. Chapter 2 examines the relevant literature that describes the theoretical discourse on the central concepts and their interrelationship. It also provides insights on LAP in Ahmedabad and the current gaps in the LAP. It concludes with an overview of indicators used to reflect TOD theoretically and empirically. Chapter 3 sets the research design and methodology of the thesis. Chapter 4 presents the results and discussion whereas Chapter 5 concludes the research and provides policy recommendations based on the findings of the analysis.

2. LITERATURE REVIEW

This section provides an overview of literature related to land-use and transport integration, transit-oriented development (TOD) and local area planning (LAP). Moreover, a comprehensive review on the conceptualisation of TOD in Ahmedabad through local area planning is discussed. This section is concluded by a literature summary that underscores key critical discussions of this section and provides a list of TOD indicators used by various researchers.

2.1. Land-use and transport integration

The land-use and transport integration has been widely recognised in shaping the development of cities, both conceptually and empirically (Acheampong & Silva, 2015). These are often called confounding factors because they affect both the land-use and travel (Litman, 2018). There are several types of studies done to understand the nexus between land use and transportation. For instance, according to Bertolini (1996), to evaluate integrated land-use and transport, a node place theory was developed for the station areas of Lisbon. The key finding of this study showed that a stable node-place is not automatically a transit-oriented development (TOD) and likewise. A complementary analysis of both factors is required to plan the development of the station areas towards TOD. According to Litman (2018), land use and transport interactions depend a lot on the geographical area, spatial scale and specific conditions. Cervero (2013) argues that LUTI is a solution to the rampant urbanisation in developed as well as developing countries. According to him, the mobility challenges for both the worlds are different and so are the challenges of linking land-use and transport systems. Newman and Kenworthy (1991) carried out a study of thirty-two cities to prove that transport and urban form of a city are tightly knitted. According to them, the foremost factor that has an impact on transport is direct policy instruments like provision of infrastructure, high density, reducing the level of dependence on automobiles and so on. To summarise, it is essential to link land-use and transport because it influences the travel patterns of the people. When land-use patterns are not integrated with the public transit system, awful effects are registered in terms of heavy congestion, longer travel time and lack of productivity (Dittmar & Ohland, 2004).

The strategies for integrating land-use and transport are transit-oriented development, smart growth, new urbanism and access management (Litman, 2018). Access Management refers to clustering all retail shops in a mall for better accessibility for shoppers as opposed to spanning them along a certain highway. While Smart Growth features infilling of employment and housing in an existing urban setting to increase transit system efficiency, New Urbanism features locating mixed of land-uses within a neighbourhood to improve access for the residents and employees and for enhancing their quality of life. Transit-oriented development, on the other hand, is referred to as walkable neighbourhoods, regional planning, city revitalisation and suburban renewal combined. It is a cross-cutting approach to development that is not only focused on diversifying transportation systems but also offers a new range of development patterns for housing, commerce and other activities (Dittmar & Ohland, 2004). Moreover, TOD is proved to be a useful planning technique in LUTI (Grigolon, Singh, Koeva, & Madureira, 2016; Taki, Maatouk, Qurnfulah, & Aljoufie, 2017). Various researchers like Curtis (2012) in Perth, Guo et al. (2018) in Japan, Singh (2015) in Arnhem and Nijmegen, Shastry (2011) in Ahmedabad, Schlossberg and Brown (2004) in Portland, Bonin and Tomasoni (2015) in France and Cervero and Murakami (2009) in Hong Kong, have empirically proven TOD to be an effective strategy for mounting challenges of the cities.

2.2. Transit Oriented Development (TOD)

Transit-oriented development (TOD) is an alternative to urban sprawl. It is a key strategy used to curb growth, reduce traffic congestion, provide transportation choice, and improve quality of life (Dittmar and Ohland, 2004). Calthorpe (1993) was the first to codify the concept of TOD. He defined TOD as a mixed, high-density development that encourages people to live near transit services for promoting walking environments which decrease the use of automobiles. Li, Lin, and Hsieh (2016) defined TOD as a combination of high-density development, mixed land-use, pleasant walking space environment and high quality of public highway transportation services. Parker, Mckeever, Arrington and Smith-Heimer (2002) associate TOD with moderate to high-density development which is located within an easy walking distance from a major transit stop and generally has a mix of residential, employment and shopping opportunities designed for pedestrians. Hale and Charles (2006) marked TOD as a vibrant, relatively dense, mixed-use development precinct characterised by quality public spaces and access to public transit whereas Higgins and Kanaroglou (2016) believe that TOD has championed as one of the ways to maximise return on its investment in the form of higher ridership. Maarseveen, Singh, Zuidgeest and Flacke (2012) relates TOD as a spatial planning tool for development around transit stations that is oriented towards the transit system. According to Dittmar and Ohland (2004), TOD has the ability to reduce car by increasing walking, bicycling and transit use.

2.2.1. TOD Principles

According to theoretical studies, TOD demands an area to be rich in diversity, high on density and supported by urban design techniques that promote walking and use of other non-motorized transport systems over automobiles. Vertical and horizontal diversity within land-uses create a balance in a region, increases interactions among different spaces and reduces the need to travel longer distances. High densities (population or employment) support the higher use of transit whereas a complete street design encourages more walking and cycling to and from a transit station.

In line with these ideas, Cervero and Kockelman (1997) explored the 3D's that characterises TOD as diversity, density and design. Ewing and Cervero (2010) added two other D's, i.e. destination accessibility (job accessibility by transit and distance to downtown) and distance to transit for measuring the level of TOD of an area and the innate qualities of a transit station and its adjoining development.

The empirical studies on TOD essentially focus on eight principles (Figure 3). Mix, walkable, densified, transit, compact, cycle friendly, and connected (ITDP, 2014). It has been accepted as a way to manage sustainable urban growth (Croese, 2016). However, it requires a strong vision, leadership, collaboration and commitment between multiple actors, consensus building and dedication for working together on a common goal. Therefore, the desired end-goals of TOD will not be achieved in one go, but rather step-by-step, with a number of interim goals (Bhatt, Paradkar, & Fliert, 2012).

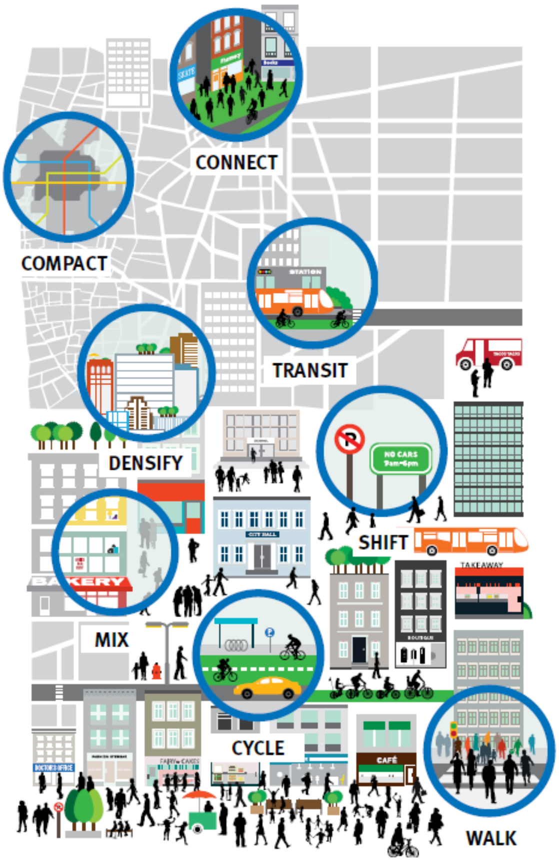

Figure 3: TOD principles (Source – ITDP)

Based on all this, it is evident that TOD comes with various ideas and concepts. The application and understanding of TOD combine the built environment, architecture, urban design, urban form, transportation planning, context-sensitive street design, changes in the development regulations and conventional policy.

2.2.2. TOD Actors, Goals and Precincts

A successful TOD requires an interdisciplinary approach where different stakeholders meet, communicate and formulate practical strategies with different desires. From the perspective of the state and regional government, the goal would be to increase ridership whereas, for private developers, the goal would be to increase the land values. Likewise, transit agencies would want to maximise monetary return on land or capture the value of transit whereas local government would aim at reducing congestion and dependency on cars. The other actors who are often involved in TOD development are the riders and communities who are either the actual users or the potential users of the transit service.

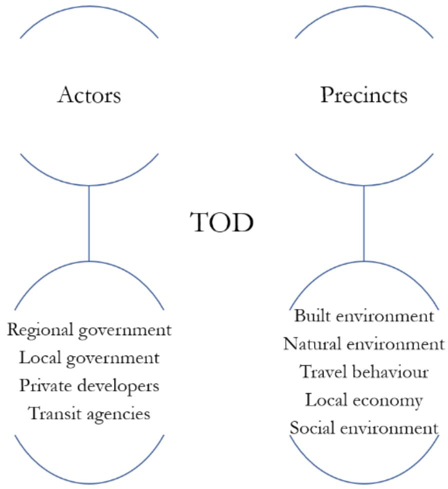

Figure 4: TOD actors and precincts (Source – author)

According to Renne (2007), there are five potential precincts where TOD type of development plays a role. These are built environment, natural environment, travel behaviour, the local economy and social environment (Figure 4). All these precincts have their own set of indicators to evaluate the performance of TOD by comparing their outcomes with the baseline data. The built environment is more about the internal and external factors surrounding the transit stations that influence the ridership. Internal factors include service quality, pricing, operational to name a few whereas external factors are the local economy, population, employment growth. According to Islam, Brussel, Grigolon and Munshi (2018), external factors have a relatively more significant effect on ridership than the internal factors.

Apart from the built environment, travel behaviour is another crucial and challenging precinct of TOD. It is a long-term commitment which expects behavioural change. It includes indicators like vehicles kilometres travelled, mode split, the frequency of public transit usage, resident commuting time, quality of transit service, vehicle ownership, transport-related perceptions of residents. The local economy is concerned with the number of jobs, vacancy rate, property value and so on whereas the natural environment is about transport energy consumption (computed), CO_2 emissions (computed), park space, per cent of land cover as greenspace, per cent of land cover as trees. The social environment deals with education, income, quality of life perception and policy context. Evaluating TOD based on these precincts can be claimed as a top-down approach and therefore interacting with the stakeholders, communities and potential users would bring in the diverse opinion that is also important to TOD thus, making it more bottom-up approach.

2.2.3. TOD Evaluation

Many authors have evaluated TOD differently. Cervero and Kockelman (1997) evaluate TOD based on the 3D's whereas Ewing and Cervero (2010) evaluated TOD based on 5D's. Singh (2015) used the method of indexing to evaluate the level of TOD of two cities in the Netherlands. She developed a Spatial Multi-Criteria Assessment (SMCA) framework to generate a holistic TOD value of train station areas. Evans and Pratt (2007) also used the technique of indexing for evaluating TOD. However, they argue that it is not just limited to evaluate the degree of TOD but is more about planning for a TOD.

There are two other approaches to evaluate the level of TOD namely regional performance approach (RPA) and community performance approach (CPA) (Curtis, Renne, & Bertolini, 2009). RPA focuses on comparing two or more TODs or TOD and a non-TOD within a region whereas CPA uses a bottom-up approach where different stakeholders are invited to track TOD indicators for indigenously developing and planning the communities. RPA evaluates how TOD compares to the rest of the region while CPA develops context-sensitive solutions to achieve the local goals.

2.2.4. TOD Benefits

TOD is one of those powerful tools which spreads its benefits not only in environmental and economic direction but also in a social sense. This makes TOD planning most important to achieve sustainability. Joshi et al. (2017) also believe that the three tiers of sustainability, which are intricately linked with TOD and policy recommendations are a way to connect TOD benefits to sustainable transport. Regarding social sustainability, higher levels of TOD will indicate a higher mix of uses which will reduce the commuting time. This will increase the socializing time for families as the need to travel to participate in activities will decrease. An enhanced and high-quality station environment will aid in stimulating social interactions and will reduce the amount of household income spent on transportation, which can be used elsewhere. It will also generate the need for people to walk (therefore healthier). In terms of economic sustainability, TOD helps in promoting vehicle efficiency. It reduces the need to travel which results in fewer cars, less congestion and less wastage of personal time. This time can instead be used for more productive tasks. Higher levels of TOD also attract ridership which in turn increases revenue for the city. Communities without cars emerge as more walkable and pedestrian friendly. Through the environment, one of the greatest benefits of TOD is a reduction in greenhouse gas emissions. Also, less air pollution and smog. However, these benefits can ripe only when TOD has a transit which efficient, safe, and reliable and is seamlessly connected to pedestrian infrastructure.

2.2.5. TOD Challenges

In the course of TOD study and its application, numerous challenges have evolved which need to be overcome to make TOD and local area planning a success. According to Dittmar and Ohland (2004), there are four challenges namely insufficient data on traffic and parking, the absence of a systematic and accepted method for modelling and evaluating TOD, the ineffectiveness of TOD due to inappropriate street and development standards and the reluctance of agencies towards reducing the parking standard.

Bhatt et al. (2012) argue that there are three other TOD challenges exist which are mainly observed in Indian cities. The first of these is the acceptance of the same place-based regulations for every station. Since each station has its intrinsic value and character, the place-based zoning regulations should also be different. The second is limited knowledge of the transfer of development rights (TDR) mechanisms and the third is the absence of area or micro level planning practices. States like Gujarat and Maharashtra have initiated Town Planning schemes (TPS) and area level planning. However, in many other metropolitan cities of India, area level planning is missing, and more concentration is laid on regional or city level master planning.

Moreover, there are other numerous challenges drawn out by Croese (2016). These apply to BRTS as well as other mass public transit systems. The challenges are related to the internal aspects of the station area like the high quality of transit performance, affordable and easy access to people from all income levels, the ability to function as an alternative to automobiles, level of satisfaction. Other external factors include the creation of effectively mixed, dense and diverse neighbourhoods, zoning regulations, gentrification, outward growth and capture changes in land use and values. According to Pardo (2006), the most critical challenge is awareness of sustainable urban transportation.

Above all of this, one of the foremost challenges particularly observed in Indian cities is the absence of a healthy environment within different municipalities and strict building bylaws that restrict the TOD kind of development. According to Joshi et al. (2017), TOD challenges are a conflict between transit node and desirable place, on-street and off-street parking, TODs degenerating into Transit Adjacent Development (TAD), gentrification and willingness from the stakeholders. Willingness from the stakeholders is required because TOD is developed on the land which is not owned by the government and requires dealing with the public at large.

2.3. Local Area Planning (LAP)

TOD planning tended to focus on rail-based transport systems until mid-2000 with BRT acting as a minor component of TOD (Currie, 2006). However, as cities are expanding, the transport system is also growing where BRTS and metro are more useful for travel within the city because of their high frequency and rapidness. Transport planners and government authorities have developed strategic plans to promote higher use of transit. This kind of planning which is centred around public transport is known as local area planning, station area planning, transit planning or corridor planning. The planning usually starts after the feasibility study. The plans entail an in-depth understanding of the context, characteristics of the area, the daily practices of the people and their travel behaviour. These plans are drafted based on TOD principles. The outcome of such plan includes the location of the transit stations, the area of influence around each station, a future plan which includes proposed designs based on TOD principles, context-sensitive recommendations and specific projects pertaining to the local areas (Bhatt et al., 2012). There are few examples of international and national local area planning described in the following section.

2.3.1. International examples

In the report of Brooks et al. (2008) on "Reconnecting America", station area planning is undertaken based on TOD principles. The importance of each principle in the context of America is explained using successful TOD examples. For instance, four cities in California found that residents of TOD are five times more likely to use transit than the people who live elsewhere. This indicates that a plan should acknowledge the increase in ridership within the TOD zone. Portland, one of the successful examples of TOD features streets for all the users where the convenience of the pedestrians and bicyclists were prioritised over the vehicles and fine grain network was developed to increase the connectivity within and outside Portland. Even the public spaces around the transit stations provided shaded, attractive and comfortable spaces that would welcome more transit users to spend quality time. In Plano, Texas, parking management techniques were implemented where minimum parking was promoted using shared parking and car-sharing. In addition, a TOD-friendly parking design was developed. The station in Bethesda, Maryland captures the value of transit by focusing on development and activity that generates revenue to fund station area improvements. For instance, property and sales taxes, farebox revenues, real estate lease and sales revenues, special assessment districts, fees on parking and business licenses, joint development and tax-increment financing.

TOD in Denver, Colorado is planned to be executed based on six principles: connect, innovate, efficient, place, mix and shift (Hancock et al., 2014). Connect focuses on achieving a high level of connectivity around stations areas by making it more walkable. Innovate refers to innovative thinking around TOD that can foster sustained, responsible and economic growth. Efficient features a place where people can work, live and play thereby reducing the number of trips. The place is marked by an area that can support safety and promote vibrant areas that can strengthen the liveability of the communities. Mix characterises diversity for the users regarding housing, shopping, jobs or transit options whereas shift indicates a car-free region. Croese (2016) critically discusses the international experience of Curitiba, Ottawa, Bogota, Ahmedabad, Guangzhou and Lagos. He shows that all the corridor developments are executed and implemented in different context-dependent ways, following local needs, characteristics and resources.

According to Sun (2013), sustainable transport is key to the development of sustainable cities. It can be done by integrated planning and development, demand management and integrated land and transport systems. The latter depends on three key strategies to develop a people-centred land transport system. More connection, better services and inclusive and liveable environment. More connection refers to connecting with agencies who are responsible for land and transport planning, a connection of the transport system with mixed-use building development and integrating existing and future public transport hubs. Better services cater to adding more feeder services parallel and perpendicular to the mass transit, planning priority lanes for buses, enhancing commuters experience by implementing walkways, providing travel information, smart cards and so on whereas inclusive, liveable environment features sheltered linkways, lift for overhead pedestrian crossings, enhancing overall walking experience, facilitating cycling and focusing on reducing carbon emission. These were the strategies incorporated in Singapore for encouraging a sustainable development with social inclusiveness, economic development and environmental protection.

2.3.2. National examples

Indian cities have the potential to develop transit-oriented developments. The "D" of TOD is always there in terms of intensity, a mix of land uses, network density and accessibility (Munshi, 2013). What they miss is quality. A good quality public transport can support the dense and diverse neighbourhoods. The cities with rampant urbanisation are facing multiple issues of traffic congestion, deteriorating air quality and increasing road accidents. This is an effect of the underdeveloped mass transit systems and rising population. To improve the mass transit systems, The National Urban Transport Policy stresses incorporating TOD strategy.

The Government of India has allowed an increase in the Floor space index (FSI) from 1.8 to 4 along the metro and BRTS corridor and 5.4 along the Central Business District (CBD) (Joshi, et al., 2017). When these areas undergo redevelopment, they can utilize the permissible FSI. However, the problem of Indian cities is the lack of informed planning and designing. The inadequate NMT, lack of integration of different modes with metro, and parking management are some of the challenges that lead to inefficient last mile connectivity Joshi et al. (2017). To address this situation, the government has made efforts in preparing for the TOD plan through development plans or standalone local area plans (LAP) in some cities like Delhi, Ahmedabad and Bengaluru. Among these, Delhi and Bangalore have incorporated a Station area planning (SAP) approach around the metro stations whereas Ahmedabad has demarcated Transit Oriented Zones (TOZ) under the development plan where the Local area plans (LAP) will be prepared. SAP and LAP are developed on similar principles and well rooted within the context of each city.

In Delhi, TOD is conceptualised as a tool that can restructure and redefine how people live, work and recreate within the city (Delhi Development Authority, 2015). The primary goals of TOD are to discourage private vehicle and provide easy access to public transport within walking distance. Planning for TOD is undertaken at three scales; Intense zone (300m), Standard zone (800m) and Transition zone (2000m). Each zone is studied in relation to six TOD principles. These principles are pedestrian and cycle-friendly environment, connectivity, multimodal interchange, modal shift, placemaking and safety and high-density mixed-income development. Policies, strategies and development norms for each principle are detailed in the master plan. This enables a realistic application and implementation of each principle on the ground. The development norms are detailed at the plot level making the vision of TOD close to reality.

In addition to the six principles, the core idea of TOD is inclusivity and sustainability. For inclusivity, Delhi has a strong policy for providing affordable housing within the TOZ zone for the economically weaker section (EWS) of the society. At the policy level, a residential percentage of 30% is included in the total FAR with a mandatory EWS FAR of 15% over and above the permissible FAR. For a sustainable TOD, Delhi has strict provisions for mixed use, mixed income development near stations with residential, commercial and civic uses as desirable uses. Apart from residential per cent, a minimum of 5% of FAR for commercial use and a minimum 10% of FAR for community facilities. At least 50% of the total FAR shall be as per zonal development plan (Joshi, et al., 2017; Singh, 2016). Delhi has made a great start to make the areas more inclusive with its design-based approach but dictating everything that comes within the TOZ might be difficult at times.

2.4. LAP for Ahmedabad using TOD

Ahmedabad has announced the planning and construction of metro transit after BRTS. The Ahmedabad Urban Development Authority (AUDA) looks after the planning of the metro corridor whereas, for the construction of the metro, Metro link Express Gandhinagar and Ahmedabad (MEGA) a Special Purpose Vehicle is designed (see appendix). AUDA has demarcated a 200m zone on both sides of the metro corridor as Transit Oriented Zone (TOZ). As per the verdict of the Government of India, all TOZ zones will be eligible for an increase in FSI. From FSI of 1.8, the new permissible FSI will be 4 for all Metro and BRTS corridors. Within these zones, AUDA has initiated local area planning (LAP) since 2015. LAP aims at developing a framework for improving the public realm (public spaces, areas under roads etc.) by enabling retrofitting and redevelopment of the existing built environment and preparation of a new layout with enhanced infrastructure provision (Ministry of Housing and Urban Affairs, 2018). LAPs are developed based on the principles of TOD. According to AUDA (2017), TOD is referred to as a high-density mixed-use development along the metro corridor that will encourage efficient use of ground and front margins. Following six key strategies were incorporated in the LAPs to make TOD sustainable in the long run:

1. Reducing block size
2. Increase in density around the metro stations
3. Adding parks and plazas near the metro stations
4. Complete street design guideline
5. Achieving last mile connectivity
6. Station area design

In addition to these six principles, an extensive study of the existing physical infrastructure is conducted. For funding and maintaining transit quality, the LAPs adopt a similar strategy of Delhi where the concept of value capture was used which indicates the use of chargeable FSI. Although, planning projects are never perfect, they are aimed to reach an optimum level which is the idea of the LAPs.

1. Reducing the block size

The metro will be accessed by people on foot and thus the urban fabric of the city needs to be geared towards a walkable environment. For this, smaller blocks are essential. A walkable distance is regarded as 5 to a maximum of 7 minutes to and from the metro station. In Ahmedabad, the number of buildings accessible within 400m (5 minutes' walk) from the metro stations is limited because of the larger block size of 800 - 1000m on an average. Therefore, it is preferable to have smaller blocks. In this parallel, LAPs incorporate four possibilities to disintegrate the block size.

Since LAP is a redevelopment exercise on a brownfield and the major part of the land is privately owned, there was not much scope for intervention. The first option was to provide more roads without disturbing the existing buildings by using the margin spaces. The current development control regulation in Ahmedabad is such that at least 50-60% of the private plot is open. These spaces could be used to connect to the existing public roads and a meaningful disintegration of blocks could take place. The second option was utilising the vacant areas. LAP proposes new roads that were carved out from the private plot. On the boundaries of the two adjacent plots, the new road was carved such that the original plot remains buildable. The third option was converting a private road into the public. Private roads are on most occasions already used by other vehicles during daytime and these roads could be integrated with the public road system with adequate compensation. The last option was using built land. The land would only be transformed into a new pedestrian connection or road if the owner intends on redeveloping its plot. Figure 5 shows a schematic of the effective utilization of margin spaces for the creation of new streets without demolishing any structure. The third schematic is converting the private road into the public.

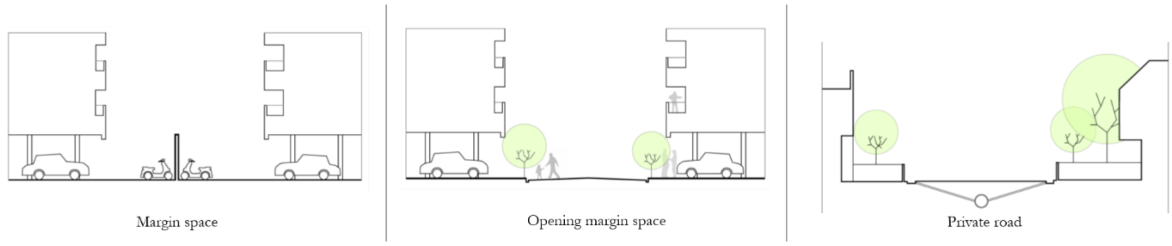

Figure 5: LAP – Reducing block size (Source - AUDA)

2. Increase in density around the metro stations

The more people living near public transport, the larger the share of people using public transport will be. Hence the increase in density around the metro station is essential for the optimal use of the metro. The western corridor of the transit-oriented zone has an average density of 400 people/ ha. An important concept in this regard is that of FSI (Floor Space Index). This index shows the amount of floor space per square meter of the plot area. The existing allowable FSI will go from 2.25 to 4.0, so it is possible to assume to the population will double. But with the increase in population, other supporting physical and social infrastructure is bound. Figure 6 illustrates the change in densities when FSI increases from 1.8 to 4. LAP has undergone an extensive property to property study to identify which plots can go for redevelopment at an early stage and which plots can consume FSI 4. This implies that instead of a uniform FSI of 4, an average FSI consumption study is considered.

Also, as per the population projection for Ahmedabad, in the next 10 years, 25 lakh people will be added to the city and by 2041 another 25 lakhs will be added (World Population Review, 2018). LAP is cautious of this increase and therefore has already planned to engulf this increase in density within the TOZ. All the plots that are more than 500 sq.m plot area and are touching an 18m or wider streets is allowed to build at FSI 4. Different plot sizes have different permissible limits as indicated in Table 1. This kind of regulation ensures that the high-density development is achieved in a planned and systematic manner.

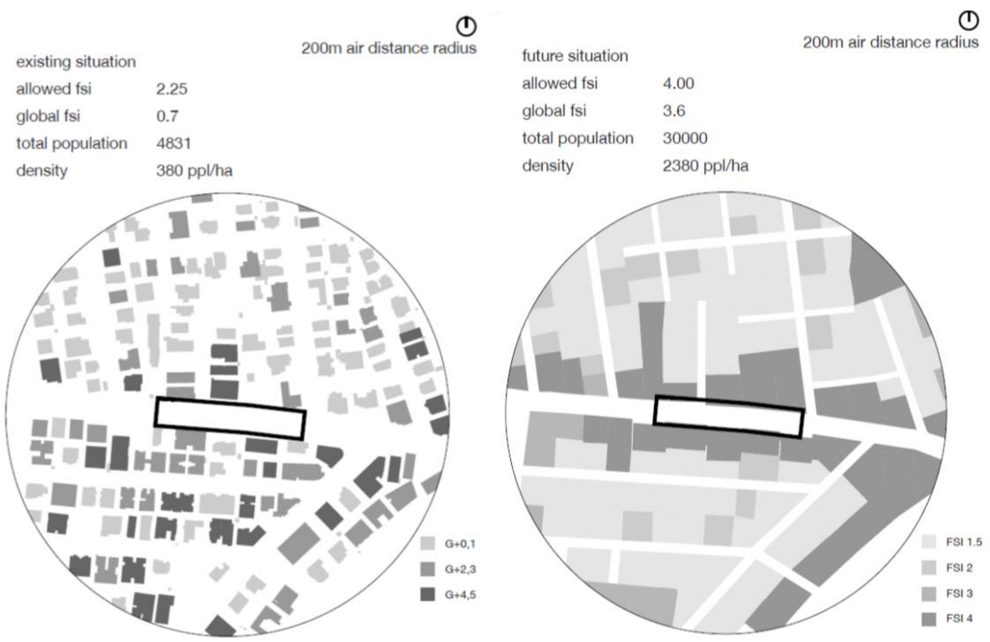

Figure 6: LAP – Increase in density (Source - AUDA)

Table 1: DCR - FSI

Road width/Plot size	< 150sq.m.	150-300sq.m.	300 to 500sq.m.	500 to 1000sq.m.	> 1000sq.m.
Less than 9m	at FSI 1.5	at FSI 1.5	at FSI 1.5	at FSI 1.5	at FSI 1.5
On 9m	at FSI 2	at FSI 2	at FSI 2	at FSI 1.5	at FSI 1.5
On 12m	at FSI 3	at FSI 3	at FSI 3	at FSI 2.7	at FSI 2.7
On 18m or more	at FSI 3	at FSI 3	at FSI 3	at FSI 4	at FSI 4

3. Adding parks and plazas near the metro stations

Nature is often overlooked in a rapidly growing economy because it is seen as a place that has 'no economic value'. In Ahmedabad, as per the URDPFI guidelines, 8-10 sq.m. per person open space should be available which at present is 0.37 sq.m. per person. This indicates a dire need for more green open spaces. Apart from this, open plazas and green spaces also offer other benefits like reduction in stormwater, recharge of groundwater, less pollution, beautification and so on. Trees also help in substantially lowering the temperature which is very important especially in a city like Ahmedabad. In a similar vein, AUDA and AMC have procured land closer to the proposed metro stations from the private owners for developing station level amenities and parks (Figure 7).

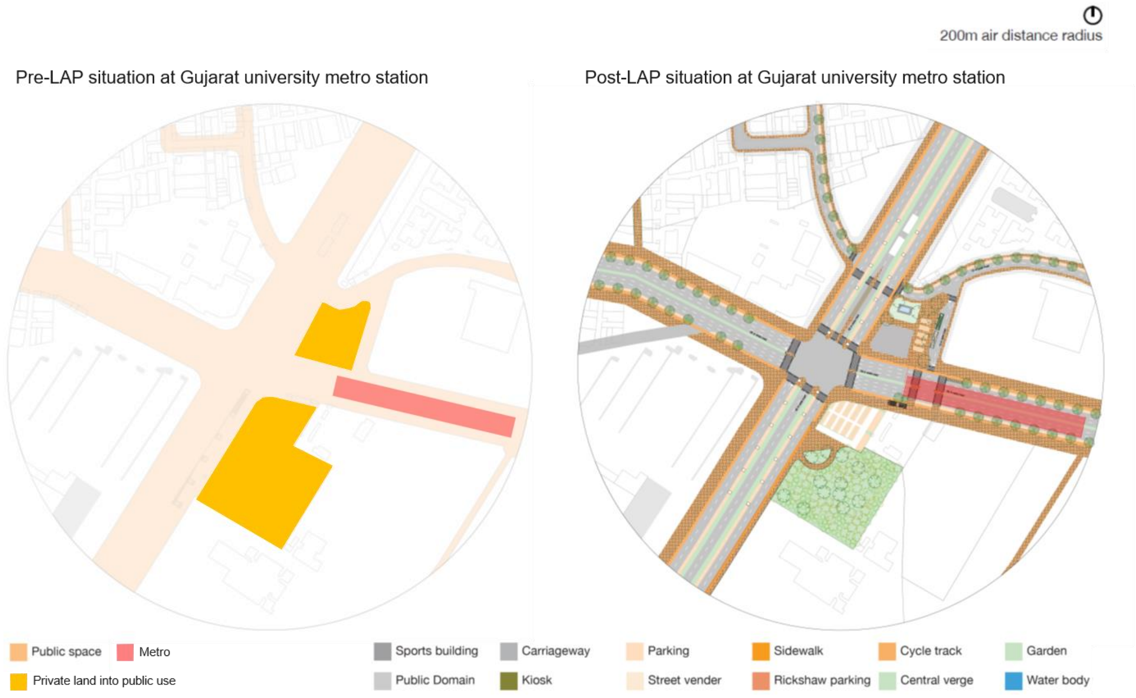

Figure 7: LAP – Public space (Source - AUDA)

4. Complete street design guideline

Ahmedabad presently has guidelines but no standards. Under the influence of American planning, Ahmedabad has developed streets for cars and not for people. Instead of lifting congestion, bridges and streets are added resulting in unsafe and undesirable spaces for the pedestrians. In the LAP, new street guideline has been proposed in accordance with the local and national standards. These guidelines focus on designing the streets to enhance the quality of life of people, provide safe contact between different modes of transportation and foster social interaction (Figure 8).

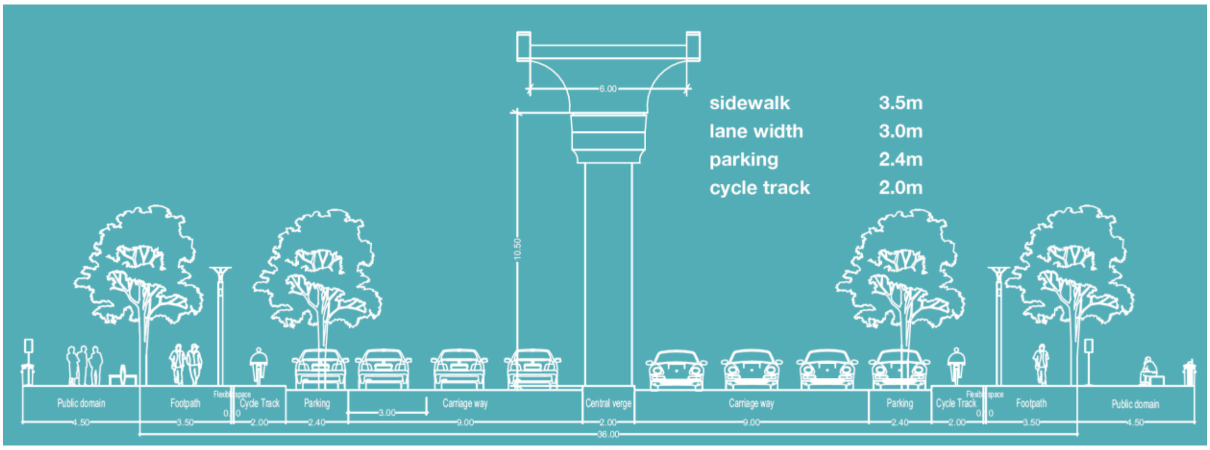

Figure 8: LAP – Complete street design (Source - AUDA)

Three scenarios were proposed in the new street design guideline. Streets that registered heavy movement of non-motorized vehicles were labelled as pedestrian-oriented streets where the dominant abutting land use was commercial or institution. Streets that encountered heavy parking demand were considered as parking-oriented streets where commercial or residential land use was dominant whereas streets that experienced heavy vehicular movement were termed as vehicular oriented streets which were mainly arterial streets. As per the DP, eleven street categories were used namely 6m, 7.5m, 9m, 12m, 15m, 18m, 24m, 30m, 36m, 40m, 60m. As the right of way increased, different street elements like a footpath, cycle tracks, multipurpose zone (trees, on-street parking, street furniture, hawkers), median, carriageway and street lights were added in different proportions (Table 2).

Table 2: LAP – Street design guidelines (Source – AUDA)

ROW/ Parameters	6m	7.5m	9m			12m			15m			18m			24m		
			PED	PARK	VEHI	PED	PARK	VEHI	PED	PARK	VEHI	PED	PARK	VEHI	PED	PARK	VEHI
Width of Access Lane (AL)			2.7	2.7	2.7	3.0	3.0	2.7	3.0	3.0	2.7	3.0	3.3	3.0	3.0	3.3	3.0
Number of lane			2	1	2	2	2	3	2	2	4	4	2	4	4	2	6
Carriage Way	S	S	5.4	2.7	5.4	6.0	6.0	8.1	6.0	6.0	10.8	12.0	6.6	12.0	12.0	6.6	18.0
Metro Access	H	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Service Lane (SL) (both side)	A R	A R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BRTS	E	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Central verge (both sides)	D	D	-	-	-	-	-	-	-	-	-	-	-	-	1.2	1.2	1.2
	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
On-street parking (both sides)	P A C	P A C	-	2.4	-	-	2.4	-	2.4	4.8		-	4.8	2.4	4.8	12	-
Cycle track (both side)	E	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sidewalk (both sides)			3.6	3.6	3.6	6.0	3.6	3.6	6.0	3.6	3.6	6.0	6.0	3.6	6.0	4.0	4.0
Total			9.0	8.7	9.0	12.0	12.0	11.7	14.4	14.4	14.4	18.0	17.4	18.0	24.0	23.8	23.2
Standard road width			9			12			15			18			24		
Flexible Space			0.0	0.3	0.0	0.0	0.0	0.3	0.6	0.6	0.6	0.0	0.6	0.0	0.0	0.2	0.8
Design Speed (km/h)	-	< 20	< 20			20			30			30			50		

ROW/ Parameters	30m				36m				40m					60m				Total no. of categories
	PED	PARK	VEHI	BRTS	PED	PARK	VEHI	BRTS	PED	PARK	VEHI	BRTS	METRO	PED	PARK	VEHI	BRTS	
Width of Access Lane (AL)	3.0	3.0	3.3	3.3	3.0	3.0	3.3	3.3	3.0	3.0	3.0	3.3	3.0	3.0	3.0	3.5	3.0	**4**
Number of lane	4	4	6	4	6	6	6	4	6	6	6	6	6	6	6	6	6	-
Carriage Way	12.0	12.0	19.8	13.2	18.0	18.0	19.8	13.2	18.0	18.0	18.0	19.8	18.0	18.0	18.0	21.0	18.0	-
Metro Access	-	-	-	-	-	-	-	-	-	-	-	-	9.0	-	-	-	-	**1**
Service Lane (SL) (both side)	-	-	-	-	-	-	-	-	-	-	7.0	-	-	12.0	12.0	12.0	12.0	**2**
BRTS	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0	7.0	-	-	-	7.0	**1**
Central verge (both sides)	1.2	1.2	1.2	-	2.0	2.0	2.0	-	2.0	2.0	2.0	-	2.0	2.0	2.0	2.0	-	**2**
	-	-	-	0.4	-	-	-	0.4	0.2	-	0.2	0.4	-	0.4	0.4	0.4	0.8	-
On-street parking (both sides)	4.8	12	4.8	4.8	4.8	12	4.8	4.8	4.8	12	4.8	4.8	-	12	12	12	4.8	**3**
Cycle track (both side)	4.0	-	-	-	4.0		4.0	4.0	4.0	4.0	4.0	4.0	-	4.0	4.0	4.0	4.0	**1**
Sidewalk (both sides)	7.0	4.0	4.0	4.0	7.0	4.0	4.0	4.0	11.0	4.0	4.0	4.0	4.0	11.0	11.0	7.0	11.0	**5**
Total	29.0	29.2	29.8	29.4	35.8	36.0	34.6	33.4	40.0	40.0	40.0	40.0	40.0	59.4	59.4	58.4	57.6	-
Standard road width	30				36				40					60				-
Flexible Space	1.0	0.8	0.2	0.6	0.2	0.0	1.4	2.6	0.0	0.0	0.0	0.0	0.0	0.6	0.6	1.6	2.4	-
Design Speed (km/h)	50				70				70					> 70				

In addition to the street classification, three types of street interventions are proposed. These are terms as future ROW – land identified as public ROW and to be developed as and when the plots undergo redevelopment, flexible ROW – Public ROW that can be flexibly located by the property owner connecting predefined network links on either side, Pedestrian ROW – Public ROW to used only for pedestrian activities and the last is public domain.

Public domain (Figure 9) is a space carved out from the front margin of the private plots regardless of their area and is added to the roadside margin identified in the LAP. This intervention was introduced because present footpaths are very narrow and to widen them, carriageway cannot be reduced. Therefore, a wise option is to expand on the outer side of the roads and intervene into the private plots. In exchange, the plot owners will get additional FSI or monetary compensation. The purpose of the public domain is to widen space for the pedestrians. Construction will be prohibited in this area and trees will be planted by the plot owners. This stretch will be painted differently and will be developed as and when the private plots undergo redevelopment. For all streets of between 9m and 12m width, 1.5m of the public domain will be carved out from the private plots that are abutting the road. For streets of 18m and less width, 3m of public domain will be developed whereas for all the roads wider than 18m, 4.5m of front margin will be carved out.

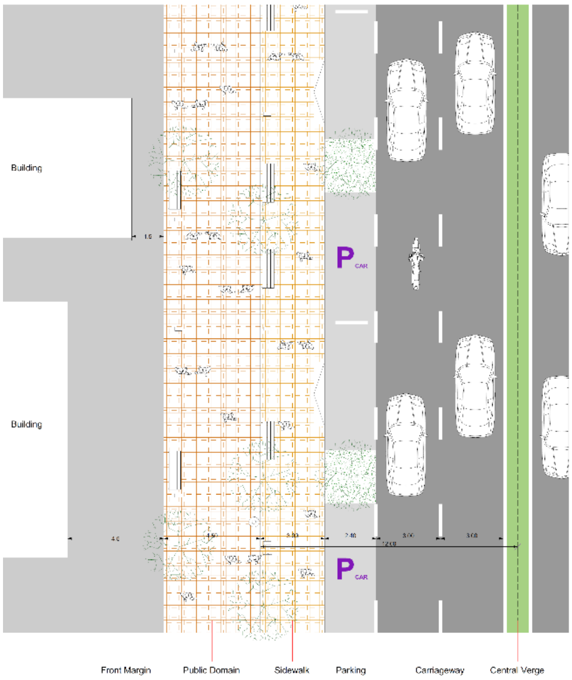

Figure 9: LAP – Public domain (Source - AUDA)

5. Achieving last mile connectivity

To achieve last mile connectivity, multiple modes are proposed near proposed metro station. In the land procured by the government, autorickshaw parking, docking station, private parking and feeder parking will be provided. The feeder bus is planned to work perpendicular to the proposed metro corridor in both directions. In addition, a BRTS and Metro interchange will be planned at one transit station.

6. Station area design

The station area planning would include parking facilities, pick up and drop in facilities and urban design elements like street furniture, public toilets, plaza etc, station building and space for local commercial development. Figure 10 gives an artist impression of a station building seamlessly integrating with the government plot that is procured to develop pedestrian infrastructure.

Figure 10: LAP – Last mile connectivity and Station area design (Source – AUDA)

Till now three LAPs (west) are prepared based on the above principles and are submitted to the State Government for scrutiny. Within these LAPs, seven metro stations are proposed. Once the state government approves the LAPs, implementation of the proposal will take place. A similar methodology will be incorporated for the remaining 52 LAPs. Paradoxically, the biggest wave of construction has taken place in the eastern corridor, but LAPs are prepared for the west. This is due to the misallocation between AUDA and MEGA and lack of TPS layout in the eastern corridor. As per the regulations, without the second tire (Town Planning Schemes -TPS) of development, the third tire cannot be prepared. Surprisingly, the eastern corridor is ready to function from March 2019.

All in all, the LAP provides proposals for the retrofitting and redevelopment but lack a proposal for land-use, implementation strategies, proposed timelines and little consideration to strengthening sustainability component (Joshi, et al., 2017). There are no incentives or proposals on how the land use should transform in the future. Since land use and transportation has a significant impact on the daily travel patterns of the people, it is one of the major drawbacks of the LAPs which must be addressed in due time.

Another drawback of LAP is that the indicators are not quantified and therefore it is difficult to state if planning interventions suggested in LAP will move towards TOD or away from TOD. Also, there is no comparative analysis of stations in LAP. Hence, a holistic picture of which station elements are absent cannot be drawn. Therefore, it fails to provide a complete perspective.

Methodology for Local Area Planning

By 2017, three LAPs in the western corridor of the metro were submitted to the state government for their approval. LAPs were prepared as an iterative process of negotiations and extensive discussions between various authorities, consultants and local inhabitants to ensure seamless integration of ideas and more rapid execution of plans. As a part of all the discussions and meetings, extensive site surveys were undertaken to document each physical element and infrastructure. With the help of the surveys, LAPs were prepared in collaboration between AUDA, AMC, MEGA and all consultants. Weekly meetings were organised where representatives of all authorities and consultants discussed on a common platform and developed the plans.

Owing to this, the plans were publicly presented, and the owners were invited to give their suggestions and objections at the time of the owners' meeting. The objections were mainly regarding margins of the public domain, station area plazas and new roads. These objections were taken into consideration, and changes were incorporated in the final plan accordingly. Post this, the notification of the draft LAP proposal was published in the Extraordinary Gazette of Gujarat Government and other leading newspapers. Eventually, it was sent to the state government for their final approval to confirm if the plan was feasible and compatible with state laws after which the implementation starts.

2.5. Literature summary

Based on empirical and theoretical studies, it can be said that TOD is an efficient technique to shape urban development towards transit and integrate it with the surrounding land-uses. TOD will improve the quality of life of the people, encourage them to use transit as an alternative mode of transport, improve the environmental quality by promoting public transport, walking and cycling and reduce travel distances.

TOD is a multidimensional and multi-disciplinary subject. It covers the built and natural environment, travel behaviour, the local economy and the social environment. For TOD to achieve sustainability, it needs to be carried out holistically. Holistically refers to the involvement of various actors and the integration of environmental, economic and social factors. Each actor comes with a specific goal and vested interest and therefore the whole idea is to develop a comprehensive solution where ideas and benefits can be shared across all the disciplines. It is a step by step tool to achieve sustainability and missing any step would distant it further from achieving a sustainable future.

The international and national examples of local area planning define the principles of TOD that need to be incorporated in the local area planning. While international models from the cities of global north focus on reducing car usage or reclaiming urban spaces from parking, making downtown areas car-free, cities in the global south are still struggling with issues of heavy congestion, long travel times, road accidents, inefficiencies of public transport and so on. International examples are helpful but should not be applied blindly because the contexts are entirely dissimilar. Moreover, the national example of local area planning provides a solution regarding policy recommendations, but these are still vague and need better clarity and to the point solutions.

Table 3 summaries the built-environment indicators suggested for TOD planning by numerous authors and in several local area plans both theoretically and empirically. This will be useful in selecting indicators for enhancing the local area plans (LAP) in Ahmedabad.

Table 3: TOD indicators and their sources.

Authors	Indicators
Litman (2018)	Regional accessibility, density, land-use mix, centeredness, parking and mobility management and road design.
Newman and Kenworthy (1991)	Provision of infrastructure, high density and dependence on automobiles.
Calthorpe (1993)	Mixed use, high-density, nearness to public transit, walking environments and use of automobiles.
Li, Lin, and Hsieh (2016)	High-density, mixed land-use, walking environment and high quality of public highway transportation services.
Parker, Mckeever, Arrington and Smith-Heimer (2002)	Moderate to high density, distance to transit, mix of residential, employment and shopping opportunities.
Hale and Charles (2006)	Vibrant, dense, mixed use, quality public spaces and access to public transit.
Higgins and Kanaroglou (2016)	Ridership
Cervero and Kockelman (1997)	Density (population density, employment density and accessibility to jobs).
	Diversity (dissimilarity index, entropy, vertical mixture, intensity of land use categories, activity centre mixture and proximities to commercial-retail uses).
	Design (street design, pedestrian and cycling provision and site design).
Ewing and Cervero (2010)	Destination accessibility (job accessibility by transit and distance to downtown).
	Distance to transit (distance to nearest transit stop).
Brooks et al. (2008)	Ridership, street design, public spaces, parking management, community involvement, affordable living, capture value of transit, station connectivity.
Hancock et al. (2014)	Connect, innovate, efficient, place, mix and shift.
Sun (2013)	Connectivity, Inclusivity, liveable environment.
Times of India (2018),	Subsidised road taxes, free parking, integration of public transport systems.
AUDA (2017)	FSI, road density, population density, ground coverage, public domain, built form, block size, pedestrian track, cycle track, public spaces and parks, hawkers, on-street car parking, off-street public parking, BRTS stops and feeder bus stop.
Self (local factors and daily practices of people of Ahmedabad)	Nearness to metro stations, building density, land-use diversity (vertical and horizontal), employment density, building height, building age, built typology, intersection density, AMTS stops, autorickshaw stops and cycle stations, street classification, property value and percentage of private parking.

Ahmedabad is rapidly transforming and has spread its prongs in all directions. Therefore, it is an interesting case to study where the micro level planning along the metro corridor might not be optimally planned because it does not consider land-use and transport interactions satisfactorily. Thus, this study dwells into evaluating the local area plans and identifies the existing and proposed levels of TOD around the metro stations where the LAPs are prepared.

3. RESEARCH DESIGN AND METHODOLOGY

This section explains the study area, explores the overall approach, provides an extensive methodology adopted to respond to the research questions and a research matrix to understand the operationalisation of each question. This research incorporates a case study approach (Gerring, 2018) where it investigates the properties of a single case of Ahmedabad city.

3.1. Study area

The study area is the western corridor of the proposed metro system which comprises of seven metro stations and three Local Area Plans. From left to right the stations are Stadium, Commerce six roads, Gujarat University, Gurukul road, Doordarshan kendra, Thaltej and Thaltej gam where Stadium is closest to the city centre and Thaltej gam is the most suburban metro station. The three LAPs are Part-13 Helmet Circle to Ashram Road, Part-9B Helmet Circle to S.G. Highway and Part-9A S.G. Highway to Thaltej. Part-13 contains Stadium, Commerce six roads and Gujarat University stations, Part-9B is constituted of Gurukul road and Doordarshan kendra stations whereas Part-9A features Thaltej and Thaltej gam metro stations.

The LAP boundaries are determined by a 200 m buffer on both the sides of the metro corridor. As shown in the Figure 11, all the final plots abutting within the buffer were considered for the LAP planning. However, in this research, only a part of each LAP surrounding 200 m from the metro station was studied. It was assumed that 200 m buffer around the metro station would give equivalent results as opposed to a buffer of 200 m around the metro corridor because the station areas have an influence on the spatial organisations of its surrounding areas. Figure 12 illustrates the existing site conditions and the proposed LAP interventions for each of the seven stations.

Part-13 LAP is closest to the city centre which caters to the old city and the Central Business District (CBD). A part of this LAP is well connected with BRTS lines. The area is characterised by 4 to 6 storey residential buildings and educational institutes. The plot size is made smaller and creates a fine-grained network of streets that form the basic structure on which urban development and social amenities can occur. Out of all the major intersections, traffic snarls at Gujarat university and Stadium crossroads during peak hours. Open green space is almost absent, except the Sabarmati river front which is outside the LAP area.

Part-9B LAP is one of the bustling areas of Ahmedabad. There are no BRTS lines running in this area. It connects to Part-13 in the west and Part-9A in the east. The area is characterized by high mix of residential, commercial and institution functions, attract many visitors. It also has large tracts of vacant land, often just behind the first line of buildings. The area also contains part of the greenbelt zone that has no approved TP scheme yet. The housing in the area is a mix of bungalows and mid-rise towers, arranged in gated communities. The area has many amenities and shopping malls, concentrated in small hubs.

Part-9A LAP is the most sub-urban area on the western corridor of Ahmedabad. This part of the city is still rapidly developing, and many plots are still unbuilt. There are no BRTS lines running in this area, but the proposed metro corridor includes the terminal station. The area mainly has residential developments with some pockets of commercial developments. There are 2 major and 1 minor water bodies. An important feature is a village that lies outside of the boundary. The village has its own character and growth pattern. Built densities are very high and so is the walkability inside village.

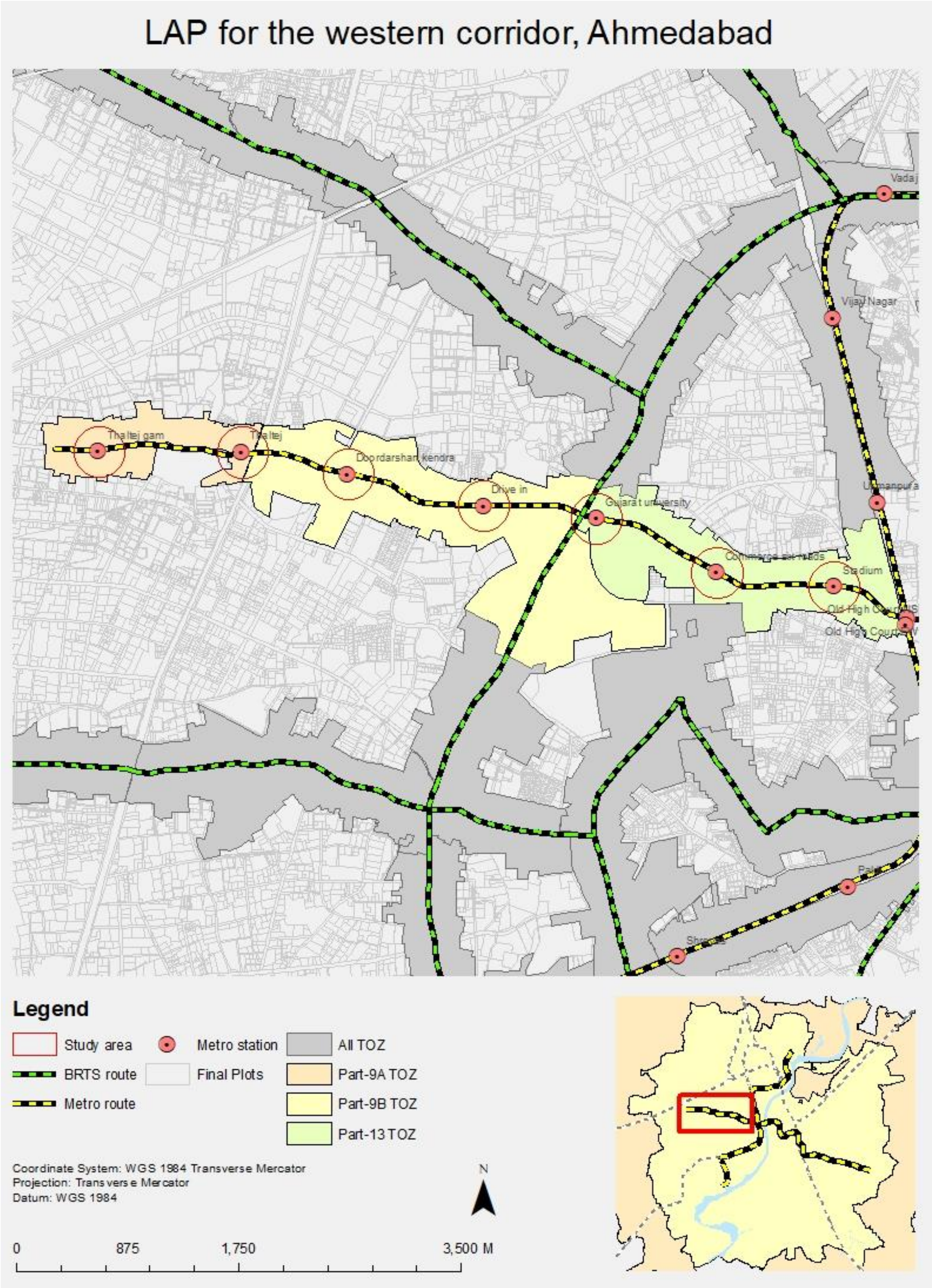

Figure 11: Study area

Figure 12: Study area - existing site conditions and proposed LAP interventions

3.2. Research Design

In this study, a LAP-TOD evaluation was undertaken for the three LAPs in the western corridor, which includes seven metro stations. Eleven built-environment indicators were quantified which were adapted from the LAP strategies, the TOD literature and available data. These indicators were implemented using geo-information-based approach and were computed with interval standardisation to derive comprehensive values depicting the Pre-LAP Index Score (baseline situation) and Post-LAP Index Score (situation after implementation of LAP) for all seven metro stations.

A mixed method (qualitative-quantitative) approach was adopted to explore each research objective extensively. Qualitative methods (direct site observations and expert interviews) were used for data collection. Qualitative method (coding interviews) and quantitative methods (non-indexing and indexing) were used for data analysing. Data processing was done for cleaning the secondary data, digitising the direct site observations and transcribing the experts' interviews.

- Direct site observations were collected for an area of 400 m around 22 metro stations. These observations were helpful because they captured the real-life situation and did not depend on other people's willingness to supply information (Taylor-Powell & Steele, 1996).
- Eight semi-structured interviews were conducted which provided a considerable amount of information relevant to this research. Upon completion of the report, the outcomes will be shared with the interviewees.
- Secondary data was collected from AUDA and MEGA. AUDA supplied with GIS shapefiles of LAP, and MEGA provided metro construction site pictures.
- Non-indexing and indexing are techniques used for quantification of the indicators.

Note: The entire metro system has 32 stations, but data was available only for 22 stations in the form of GIS shapefiles out of which only 7 stations in the western corridor had LAP proposal. Therefore, only those stations with the LAP proposal were studied.

Figure 13 explains the research design. The research commenced by formulating the research objectives and questions. A step by step approach was used to answer each objective. For the first objective, an extensive literature study was undertaken to understand the link between land-use and transport and their influence on TOD. To fulfil the remaining objectives, one-month fieldwork was required. Necessary preparation was undertaken including planning the interviews with the experts via e-mail, formulating open-ended questions (appendix 6.2) and printing Google Earth images of 400m radius from each metro station. Primary and secondary data were collected. Primary data included direct site observations for 400m radius around 22 metro stations and eight experts' interviews. Later, the interviews were transcribed and coded to fulfil the third research objective. The site observations were digitised and remaining secondary data was acquired from AUDA and MEGA for the computing the TOD indices as a part of the forth research objective. The final objective was to synthesis qualitative and quantitative analysis together to conclude and provide policy recommendations based on their findings of both the analyses. Table 4 provides an overview of the data acquired and their sources. The schedule of the fieldwork is provided in the appendix.

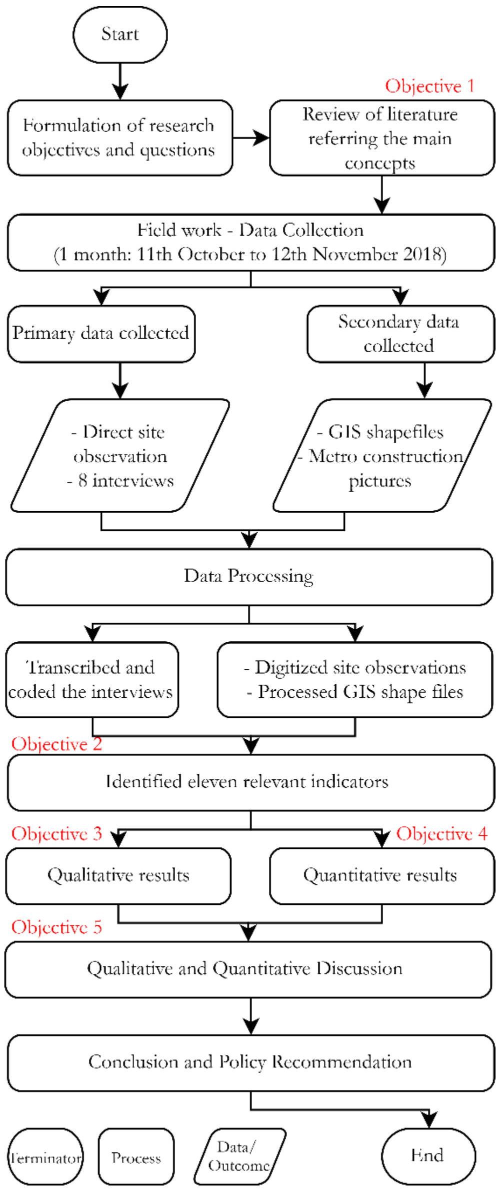

Figure 13: Research design

Table 4: Data acquisition and its source

Collection method	Data source	Indicators
Secondary	AUDA	Existing and proposed roads, existing footpaths, public domain, building footprint, building heights, government plots, TOZ boundary, metro route, metro stops, BRTS route, BRTS stops, final plot boundary, TP boundary, AUDA and AMC boundary, existing trees and survey file.
	MEGA	Site pictures of metro construction
Primary	On-site	Land-use, off-street parking, on-street car parking, hawkers, autorickshaw stops and cycle stations.
		Eight semi-structured experts' interviews

3.3. Methodology

3.3.1. Selecting indicators and dimensions

Before the fieldwork, few indicators were selected based on the literature review and LAP document. However, during the fieldwork, based on the available data and inputs from the interviews, a final selection of eleven indicators was made to fulfil the second research objective (Figure 14). From these indicators, six dimensions were formed namely (i) Physical form (ii) Connectivity (iii) Pedestrianisation (iv) Land-use (v) Parking (vi) First/Last mile. These dimensions were adapted from the six LAP strategies (refer 2.4.3). Block size deals with the physical form of the place. Therefore, it was studied under Physical form. The road and

Figure 14: Dimension and indicator chart

signalised intersection density were coupled with Connectivity dimension. Adding parks and plazas and complete street design strategies of LAP deals with pedestrians and how to ease their experience. Last mile connectivity and station area design were tied with First/Last mile dimension as they catered to the availability of para transits and park and ride system in the city.

Since LAP does not discuss land-use, it is considered as a separate dimension. Moreover, parking is a critical issue in Ahmedabad, and thus, it is also studied as an additional dimension. The LAP is concentrated only on the built environment factors and therefore, in this research, built environment indicators were studied. Most of the indicators do not reflect people and their behaviour in public spaces, but the analyses undertaken in the results section demonstrate if accessing metro will be convenient for people once the built environment factors are implemented.

3.3.2. Experts' interviews

Along with the data collection, eight experts' interviews were carried out during the field work. Interview is a qualitative approach used for understanding the challenges involved in the formulation of the LAP and the policy perspective behind LAP. Semi-structured experts' interviews were conducted to provide the experts with a platform where they could explore their knowledge and understanding of the issues. The interviews were audio recorded upon taking the consent of the interviewees. Later it was transcribed and coded using Atlas.ti, and a summary was prepared. The experts were asked to participate on volunteer basics. The experts interviewed were from a different background. While some were researchers, others were academicians or practitioners. The variety in their profiles gave valuable insights into the whole discourse of LAP-TOD in Ahmedabad.

The key elements of the interviews were regarding the existing land-use diversity, removal of illegal on-street parking, narrowing and encroachment on the footpaths, a lack of last mile, a lack of public spaces, financing and implementation of LAP. For the ease, the abovementioned topics were classified into the eleven indicators that were proposed in the previous subsection. It was explicitly noticed that while some experts had a complementing view, others had an utterly contrasting opinion. Basing on this and the literature, weights were distributed across all the dimensions after operationalising them.

3.3.3. Evaluating the LAP planning

Apart from the interviews, the qualitative analysis involved evaluating the LAP planning procedure based on the LAP documents and LAP literature. Positive approaches adopted in the LAP were underscored along with the gaps and contested spaces in the LAPs.

3.3.4. Operationalising the indicators

For the fulfilment of the forth research objective, the data were quantified and analysed using non-indexing and indexing techniques. Table 5 provides an overview of the methods used to examine the indicators and their measurements. The non-indexing method calculates one general value for the whole circular buffer.

As for indexing, a fishnet of 50m*50m was developed in ArcGIS and indicators were computed for each cell in the fishnet. The size of the fishnet was decided based on two criteria. It should not be too small otherwise its computation would be time-consuming and complicated, and it should not be too big otherwise it would not capture indicators like on-street car parking density whose granularity of the geospatial data is too small. It was important to represent all the indicators explicitly, and therefore such a decision was made. These two techniques were adopted because it was not possible to study each indicator using indexing. Non-indexing indicators did not generate meaningful values when they were analysed in indexing form. Therefore, two methods were used to quantify the indicators.

Out of 11 indicators, seven were computed using the non-indexing method whereas four were computed using indexing. The computation was done for all seven metro stations in the western corridor. For Pre-

LAP calculation, on-site survey, i.e. the existing situation of 11 indicators was inputted in ArcGIS whereas, for Post-LAP calculation, the proposed design of LAPs was used and computed in ArcGIS.

Table 5: Method for quantifying each indicator

Dimensions	Indicators	Method	Measurement
Physical form	Block size	Non-indexing	Average block perimeter per station
	Building footprint density	Indexing	Building footprint per cell
	Population density	Non-indexing	People per hectare
Connectivity	Road density	Indexing	Road area per cell
	Signalised intersection density	Non-indexing	Number of signalised intersections per hectare
Pedestrianization	Pedestrian and cycle track density	Indexing	Pedestrian and cycle track area per cell
	Public space density	Non-indexing	Area under public space per station
Land-use	Land-use diversity	Non-indexing	Entropy index
Parking	On-street car parking density	Indexing	Area occupied by cars per cell
First/Last mile	First mile connectivity	Non-indexing	Number of modes per station
	Last mile connectivity	Non-indexing	Number of modes per station

Dimension 1: Physical form

1. Block size

Since the metro will be accessed by people on foot, smaller block sizes are encouraged and are preferred for TOD. They allow for a fine grain of streets that are interconnected and scaled to the convenience of the pedestrians. A block is a piece of land covered by public roads from all the sides. Smaller blocks can be achieved by developing smaller plots - such kind of a physical form encourages a high density-low rise development model.

One value was generated for each station because calculation was done using the non-indexing method. Existing and proposed blocks were first digitised in ArcGIS based on the public roads network. Then the average block perimeter was calculated for each station in both the; Pre-LAP and Post-LAP scenario. The perimeter was used as a measure for block size. Then the maps were prepared, and the overall difference in each station was analysed for understanding the amount of decrease in the block size from existing to proposed. The smaller block size is more suitable for the general functioning of the city because they increase the ease of movement and thus accessibility (Lingzhu, Alain, & Yu, 2016). Therefore, it is considered as a cost indicator.

2. Building footprint density

It is assumed that positioning residential buildings near public transport will improve the patronage of the transport system. Footprint was considered as a single floor. For Pre-LAP calculation, indexing was adopted. Each grid was spatially overlaid with the buildings and then were summarised using the grid_ID. The summarised values of buildings were joined with the original grids. A new field was added to calculate building footprint density using the formula below, and then the final map using equal intervals was generated in ArcGIS.

In the LAP, there was no proposal for building footprint density, and therefore this indicator was not computed for Post-LAP. Building footprint density contributes positively to the TOD because higher densities can lead to a greater share of public transport (Ogra & Ndebele, 2014).

$$\text{Building footprint density} = \frac{\text{Building footprint area}}{\textit{Cell area}}$$

Additionally, to get an idea of the built percentage in each station area, the building footprint area was divided by the plot areas and then a calculation was made.

3. Population density

It is assumed that the more people living near public transport, the larger the share of people using public transport will be. Therefore, higher densities around the metro stations represents a better form of the city. With the help of non-indexing method, existing and proposed population densities were calculated.

For Pre-LAP, building heights data was used. Buildings higher than 1 floor were multiplied by 4 because it was assumed that irrespective of the size of the footprints, every residential and mixed-use buildings would have 4 units. Since bungalows (single floor detached housing) are one floor high, they were not multiplied with 4. For further calculation, the outcome was multiplied by 4.9 which is the current household size as per Census of India (2018). Only residential and mixed land-uses were selected using select by attribute and a total population was calculated. In case of mixed land-use, 80% was assumed to be under residential use. Finally, a single population value was developed for each station and was later divided by the whole area to find out the existing population density.

Regarding Post-LAP, Figure 15 was used to identify the FSI at which each plot can develop in the future. From this, a global FSI was calculated and was multiplied with the total station area to obtain the overall floorspace (in hectare) required to fit the future population. This was further multiplied with the existing residential area (including residential of mixed use). Later the output was divided by 20 sq.m which is per person residential space requirement. With this, future population was computed and for estimating the population density, population was divided by the circle area and converted into hectare.

Development Potential

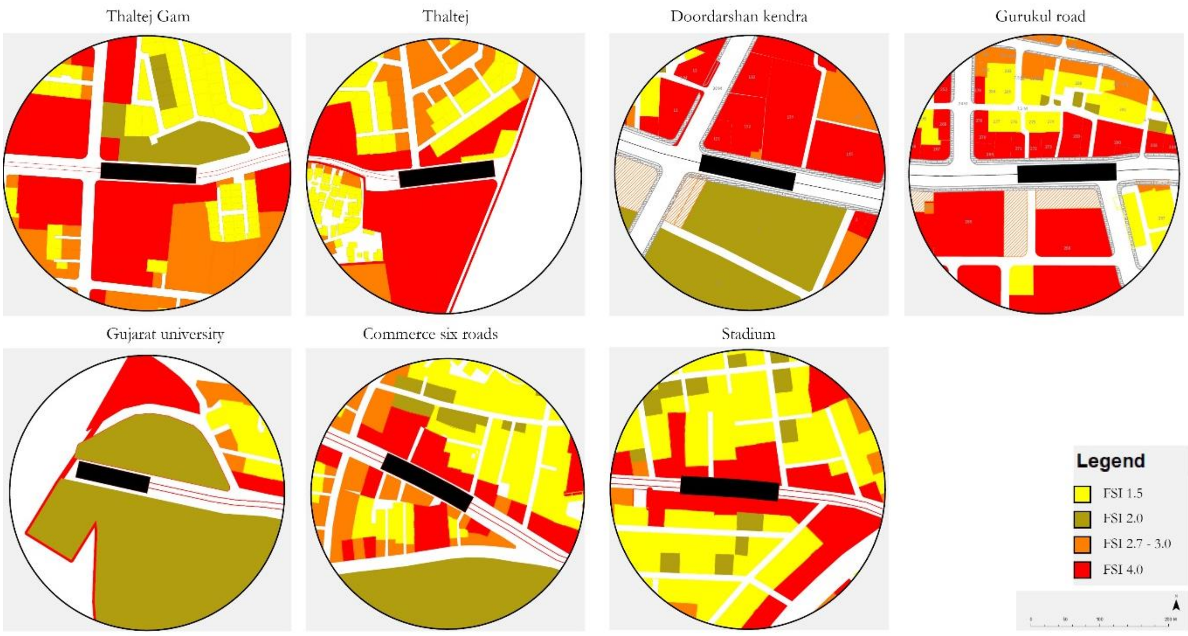

Figure 15: Development potential at plot level (Source – AUDA)

Dimension 2: Connectivity

1. Road density

An adequate area under roads is required to ensure comfortable movement of people and vehicles in an urban setting thereby ensuring connectivity. It is assumed that increase in road density increases accessibility between work and home by creating a dense network of streets and paths (Balachandran, Adhvaryu, & Lokre, 2006; ITDP, 2014). Therefore, it contributes positively to the TOD index.

For the Pre-LAP calculation, the existing public roads were used. Only public roads were used because private roads have limited access. It was calculated using indexing. First, a spatial overlay of existing public roads with the new grid was done, and then the streets were summarised using grid_ID. The summary was joined with the original grids, and existing road density was calculated using the following formula.

$$\text{Existing road density} = \frac{\text{Existing road area}}{Total\ cell\ area}$$

For Post-LAP calculation, new roads and new road widening as demonstrated in the LAP proposals were added to the calculation of the existing roads, and the same methodology as described previously was adopted. The formula is illustrated below.

$$\text{Proposed road density} = \frac{\text{New road area+Existing road area}}{Total\ cell\ area}$$

Based on the maximum value of road density, an equal interval classification was done, and a map was generated for Pre and Post LAP using ArcGIS. The last step was to analyse the overall difference in each station area. For this, the proposed road density values were subtracted and then divided from the existing road density values.

2. Signalised intersection density

Intersections at a regular distance would ensure a reduction in the speed of the vehicles and signalised intersections would create safer streets by reducing the conflicts between the road users (Drask, Hyd, & Planning, 1989). It improves the safety of the road network and thus enhances connectivity. Considering this, the increase in signalised intersection density would increase the level of TOD.

Signalised intersection density is represented as the number of intersections per station area. It is computed using non-indexing, and therefore one density value was generated for the whole station. The value was calculated using the following formula.

$$\text{Existing intersection density}= \frac{\text{Number of existing intersections}}{Total\ area} \times 10000$$

$$\text{Proposed intersection density} = \frac{\text{Number of existing+proposed intersections}}{Total\ area} \times 10000$$

To examine the overall difference in each station area, proposed density values were subtracted and then divided from the existing density values.

Dimension 3: Pedestrianization

1. Pedestrian and cycle track density

A complete street design provides well-designed, continuous and encroachment-free pedestrian and cycle tracks which prioritise the convenience of pedestrians and cyclists over automobiles. With this notion in mind, the more space dedicated to pedestrians and cyclists, the better it is for TOD.

Using the indexing method, existing and proposed densities were calculated. Since there are no cycle tracks in the immediate surrounding of the metro stations, only existing footpaths were used to calculate Pre-LAP values. At first, the existing footpaths were spatially overlaid with the grid and then their values were summarised using the grid_ID. It was later joined with the original grid. In the final step, the existing footpath density was calculated using the following formula and the maps were prepared using classes with equal interval.

$$\text{Existing pedestrian and cycle track density} = \frac{\text{Existing footpath area}}{Cell\ area}$$

For Post-LAP calculation, existing footpaths, new footpaths and cycle tracks, pedestrian roads and public domain areas were calculated and summed-up. If there was a cell which was untouched by the proposed plan, then existing footpath values were considered, and if the cell was touched by the LAP proposal, then the new value was considered. It was assumed that the old roads kept their old footpaths and they did not demolish them. The old roads do not have 20% of their road space as footpaths, but as per the new street design guideline in LAPs, approximately 20% of the road space will be used as footpath and cycle track. Therefore, it was assumed that 20% of the proposed road area was under footpath and cycle track and accordingly new footpaths and cycle tracks were calculated.

LAPs have many planning interventions including new pedestrian road connections and public domain. Pedestrian roads are 6m wide roads mainly carved out from the margin spaces to connect two roads and reduce the block size. These are open only for non-motorised activities. Using select by attribute tool on ArcGIS, pedestrian roads were selected and added to the overall calculation of proposed pedestrian and cycle track density.

Public domain, (refer 2.4.3) is a space carved out from the front margin of the private plots and is added to the roadside margin. The purpose of the public domain is to improve pedestrian activities and therefore, it was added in the calculation. Thus, the proposed pedestrian and cycle tracks have a public and a private part. The public part is the new footpaths and cycle tracks, and the private part is the public domain. It is termed as private because it will be carved out from the private land but will be used for public purpose. As a result, in the maps, there are two parts, and both are treated differently, but they still pertain to the pedestrian indicators. The following formula was used to generate the maps for the stations using classes with equal intervals standardisation.

$$\text{Proposed pedestrian and cycle track density} = \frac{\text{Existing footpath area+Proposed footpath and cycle track area+Pedestrian roads+Public domain}}{Cell\ area}$$

To find the overall difference in each station area, the proposed density values were subtracted from the existing density values and later divided by the existing density. In addition, another calculation was made where the pedestrian and cycle tracks were divided by the road area instead of the cell area to identify the contribution of non-motorised transport from the total road area.

2. Public space density

Public spaces near metro stations stimulate social interaction and make the pedestrian experience more rewarding (Jacobson & Forsyth, 2008). Therefore, this indicator contributes positively to the overall index score because higher scores will increase the level of TOD.

Everything within 200m which is not privately owned and is not a road is considered as a public space. Even then, in Pre-LAP scenario, only one station has a small area dedicated to public space. In the Post-LAP, AUDA has procured plots that were privately owned near the metro stations and will be used for developing station amenities. These plots are open for public use and therefore are considered under public space. This indicator was analysed using the non-indexing method, and thus one value was generated for the whole area. The area under public space was calculated as a percentage, and then an overall increase in the post scenario from the pre-scenario was computed.

Dimension 4: Land-use

A mix of uses and local serving stores provide an opportunity to reduce travel by internalising trips and also supports a high degree of walking and cycling (ITDP, 2014). It creates livelier, safer and vibrant areas with increased interaction among the people. The more diversity in and within the land-uses leads to a better TOD. To calculate land-use, the non-indexing method expressed by an entropy index was adopted.

Ritsema Van Eck and Koomen (2008) have defined entropy as a measure of diversity. It is understood as the share of specific land-use over the total area of all the land-uses. The formula to measure entropy is indicated below. It returns a 0 value when there is only a single land-use present which means there is no diversity and 1 when the diversity is maximum.

$$LU_d(i) = \frac{-\sum_i Q_{lu_i} \times \ln(Q_{lu_i})}{\ln(n)} \qquad Q_{lu_i} = \frac{S_{lu_i}}{S_i}$$

Where lu_i is the land-use classes from 1,2, … n. Qlu_i is the share of specific land-use. Slu_i is the total area of the particular land-use, and S_i is the entire area of the window.

Since the scale of the tessellation is too small, it made sense to calculate one entropy index value for the whole circle. With a moving window, only two or half a building would have been covered. Therefore, the analysis window was considered as the whole circle.

The existing land-use data were collected on-site and were processed in ArcGIS. Four categories were created. For calculating entropy, the total area of specific land-use was computed for each circle (Slu_i). Then it was divided by the sum of areas under all the land-use (S_i). This gave the share of specific land-use (Qlu_i). Then ln (Qlu_i) was calculated and was multiplied with Qlu_i. This was done for each land-use record. Followed by this, Qlu_i values were added and were divided by the log of total land-use classes (ln(n)). A negative sign is used in the formula to nullify the negative effect of ln (Qlu_i). From this, the relative importance of a certain land-use compared to other land-uses was derived. However, since there is no proposed design for land-use in the LAPs, no calculation was done for the Post-LAP value.

Dimension 5: Parking

Unless the public transport is as convenient, fast and reliable as cars, on-street car parking can hinder public transport usage (Balachandran et al., 2006). Considering this, on-street car parking density is attributed as a cost indicator. With the increase in the provision of on-street car parking, the propensity of people attracted towards the public transport decreases.

This indicator is computed using the indexing method. For Pre-LAP calculations, the parking locations were collected from the site. Since parking is a dynamic indicator and on-site observations were not conducted in the same time frame for all the stations, it was assumed that each location would have on average three cars. All existing parking locations were digitised in ArcGIS, and each location was multiplied by 3. Then based on the assumption of 15sq.m. (approx. 2.4m*6m) parking space requirement per car, the area under parking was calculated. In the last step, parking area was divided by the cell area and existing parking density was calculated.

$$\text{Existing on-street car parking density} = \frac{(\text{Existing car parking location} * 3 \text{ cars}) * 15\text{sq.m.}}{Cell\ area}$$

For Post-LAP, all new roads except for the pedestrian roads were selected and exported as a new shapefile. Pedestrian streets were eliminated because vehicles are not allowed to enter on these roads. The exported shapefile was overlaid with the new grid, and proposed parking supply was calculated using the street design guideline of LAP. As per the guidelines, on-street parking is provided on every street. For street narrower than 24m, parking was provided on any one side of the street whereas for streets wider than 24m, two sides parking was provided. For the ease of calculation, parallel parking dimensions (2.4m*6m) were used. Three types of parking categories were formed for calculating the parking provision in each cell area as indicated in the Figure 16. These three categories were divided by 16.8 which is derived from the street design guidelines which contains provision of a tree pit (2.4m*2.4m) followed by two parallel parking slots (2.4m*12m) followed by another trip pit. After calculating the new parking supply, it was summarised using grid_ID and joined to the original grids. The new parking supply was multiplied by 15sq.m. (parking area per car) and was later divided by the cell area.

$$\text{Proposed on-street car parking density} = \frac{One\ sided\ Type\ A\ or\ One\ sided\ Type\ B\ or\ Two\ sided * 15\ \text{sq.m.}}{Cell\ area}$$

Based on the maximum value of the proposed on-street car parking density, an equal interval classification was done, and maps were generated for Pre and Post LAP using ArcGIS. The last step was to analyse the overall difference in each station area. For this, the proposed on-street car parking density values were

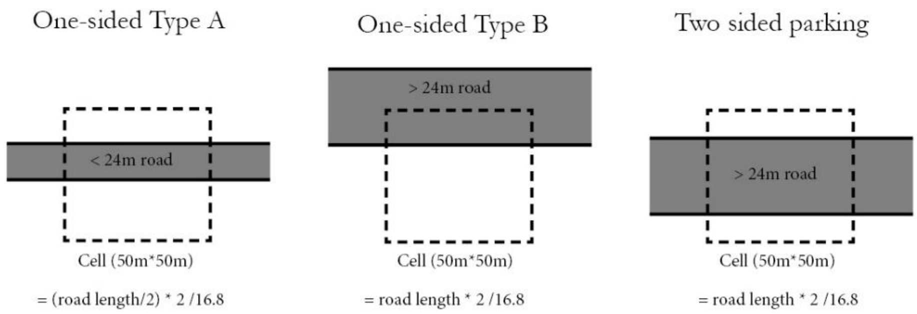

Figure 16: Formula for calculating on-street car parking

subtracted from existing on-street car parking density value and then divided by the same. Moreover, a calculation was computed to find out total area allocated to on-street car parking out of the total road area and is expressed as percentage in the maps.

Dimension 6: First/Last mile

BRTS and AMTS buses are envisaged as a feeder to the metro. The availability of these buses in addition to the autorickshaws, docking stations, off-street parking spaces and other feeder buses in the near vicinity to the metro station will ensure first and last mile connectivity.

Before aiming for the last mile, it is essential to start with the first mile. LAPs do not focus on the first mile, but it has been incorporated as an indicator in this study. First-mile connectivity (FMC) and last mile connectivity (LMC) have been distinguished between people who are travelling towards the station to get the metro (FMC) and people who are arriving by metro and need to get out of the station area to their destination (LMC). They are considered as a benefit in the TOD index because more variety and choices in the modes will attract more people to use the metro as the primary mode of transport.

The maps for FMC and LMC are discussed in relation to the metro station. Regarding FMC, since autorickshaws have notional drop off points, the passenger will be dropped next to the metro station but if AMTS or BRTS buses are used for FMC, then these buses will stop at their designated stop and the passenger has to walk to the metro station. For LMC, people alighting at the metro station will look for the nearest mode of transport to reach their destination.

Based on the site visit, the location of AMTS stops, BRTS stops, existing autorickshaw stops and docking stations were digitised. There was no off-street parking provision within these station areas. These were digitised in ArcGIS based on route perspective. For instance, to show one AMTS route, one stop that is closest to the metro station was digitised. Other AMTS stops for the same direction were not taken into consideration. Also, in the case of autorickshaws, only the locations of existing stops were marked and digitised and not the number of autorickshaws. If there are autos that run in different directions, then two locations were added on the map.

In the proposed plan, LAP has allocated space for autorickshaw stops, docking stations and off-street private parking and feeder buses. These parking spaces are aimed only for the metro users. Two feeder buses are planned at each metro station. They will run perpendicularly to the proposed metro corridor in order to bring more people to use the metro. Each bus will run to and from, and therefore two points were digitised at every station.

The transport system is quite complex, and therefore FMC and LMC were distinguished. For each Pre and Post LAP scenario, 2 FMC and 2 LMC maps were generated. Each map indicated the location of the modes at that metro station. This indicator was developed using the non-indexing method, and thus one value for each station representing the number of modes available was generated.

3.3.5. Comparing eleven indicators and seven stations

Each indicator was operationalised and was visualised using maps and charts. Maps helped in understanding the site context whereas charts helped in comparing the existing and proposed values for each indicator. However, there was no change observed in the building footprint density and land-use diversity because they do not have any proposed design in LAP.

For individual station analysis, a TOD index was computed for Pre-LAP and Post-LAP scenarios. An index is a way to aggregate the data and develop one single value for the whole station. It helps to identify station areas with high TOD values and with low TOD values (Singh, Fard, Zuidgeest, Brussel, & Maarseveen, 2014). For this analysis, a single value representing each indicator in each station was considered. The denominator was the cell area which was same across all the indicators to avoid overestimation or underestimation of any indicator.

The TOD index was developed using interval standardisation. Interval standardisation is a method to convert values to a scale from 0-1, based on their placement between the minimum and maximum values in the set. The minimum and maximum scores from both the periods; Pre-LAP and Post-LAP for each station are derived. All density values were transformed into a linear scale of 0 to 1 where 0 indicates the worst performance for TOD and 1 shows the best performance for TOD. The formula for interval standardisation is adopted from (Saitta, 2007).

$$\text{Interval standardisation} = \frac{value - minimum\ value}{maximum\ value - minimum\ value}$$

Since block size and on-street car parking density contribute negatively to the overall TOD-index, they were considered as cost indicators. Therefore, their scores were subtracted from 1 whereas, for benefit indicators, the interval standardised scores were used as is. Building footprint density, public space density and land-use were eliminated from this analysis because the values are the same in Post-LAP. For visual representation, spider diagrams were constructed. Spider diagram helps in identifying those indicators that score low and can be improved. The stations are the determinant and the indicators are the elements of the spider. This is in accordance with the maps which were prepared for each station area.

For computing the final overall Pre-LAP and Post-LAP value for each station, the dimensions and indicators were given a certain weight based on the experts' interviews and literature review. Physical form, Pedestrianisation and First/Last mile connectivity were considered relatively important than the other dimensions, i.e. 70:30 ratio. The weight of the dimension was divided by the number of indicators in that dimension. On incorporating this, Parking was given the highest weight whereas road and signalised intersection density was given the lowest weights. The remaining indicators had a same weight. Table 6 lists the weights for each indicator.

Table 6: Assigning weights to each indicator

Dimensions	Weight	Indicators	Weight
Physical form	23.33	Block size	0.11667
		Population density	0.11667
Connectivity	15.00	Road density	0.07500
		Signalised intersection density	0.07500
Pedestrianisation	23.33	Pedestrian and cycle track density	0.11667
		Public space density	0.11667
Parking	15.00	On-street car parking density	0.15000
First/Last mile	23.33	First mile connectivity	0.11667
		Last mile connectivity	0.11667

3.4. Limitations

- The time frame for the collecting data on different indicators and stations varied. However, an effort was made to cover all the studied stations during morning and evening hours.
- In absence of data, the total number of jobs accessible within 200 m radius from the stations was not considered.
- There are other principles which are important for the success of TOD but are not studied because LAP has not incorporated those principles.

4. RESULTS AND DISCUSSION

The following section is presented in two parts. The former focuses on the qualitative analysis whereas the latter features the quantitative analysis. The findings from both the analyses are discussed at the end.

4.1. Qualitative analysis of LAP planning

This section entails qualitative analysis for understanding and evaluating the local area plans and its relation to TOD through the findings from the interviews and from the literature and documentation of the local area plans as a part of the third research objective.

4.1.1. Findings from the interviews

The results of the eight interviews reflect a variety of perspectives regarding the preparation and planning procedure of the LAP. Nine broad themes emerged from the discussion. These themes are associated with nine indicators out of eleven indicators. For building footprint density and signalised intersection density, no opinion or concerns were expressed.

Indicator 1: Block size

Block size intervention in LAP has shown promising results according to all interviewees. Based on the opinion of an informant, Ahmedabad's TP scheme has done an excellent job in its network planning, and the LAP has further invested in improving the network hierarchy by disintegrating the existing blocks. A consequence of this has resulted in smaller blocks within the LAP-TOD zones which will ensure walkable neighbourhood.

Indicator 3: Population density

It was suggested by an interviewee that Ahmedabad's LAP has planned for containing the city rather than sprawling. According to him, the LAP vision is so futuristic that it has already made room for the influx of 3.8 million people in the city by the end of 2041. This inflow can be accommodated due to the increase in the FSI. However, another interviewee argued that there are no concrete plans or incentives to promote social housing in this zone like it was done in TP schemes. The absence of incentives will lead to a gentrified TOD, and the people who rely on public transport will be forced to stay away from the metro transit.

Indicator 4: Road density

In all the cases, the informants reported that Ahmedabad's existing road network is already promising due to the formulation of TP schemes. As stated by an interviewee, there are five separate ways of the same time to reach a destination in Ahmedabad. With such a convenient road network, manoeuvring within the city is comfortable and easy. He further stressed on the fact that the existing network planning is proper but not the design. Therefore, in LAP, the planning interventions have focused on improving the network design to improve the overall TOD level.

Indicator 6: Pedestrian and cycle track density

As suggested by all the interviewees, the road design has discontinuous pedestrian tracks and no cycle tracks. The absence of walking infrastructure has created an unsafe situation for non-motorised users. According to an interviewee, pedestrian tracks should be one of the foremost operative principles of a LAP which cannot be compromised in its planning. He further added that Ahmedabad-LAP has recognised this fact and has made provision for continuous and extended pedestrian tracks and cycle tracks in its street design guidelines. In general, all the interviewees agreed that Ahmedabad-LAP had prioritised the pedestrians and cyclists over cars leading the LAP towards a better TOD.

Another interviewee reported the meticulous brainstorming behind the street design guidelines where the concept of public domain is introduced. The public domain will be implemented as and when the private owners undergo redevelopment. Regarding the implementation, according to an interviewee, how to provide, when to provide and how to implement is a matter of timing. Provisioning and implementation are different things. A local area plan should reflect on the provisioning and provide a timeframe for implementing the suggestions. Ahmedabad's LAP specifies how much to provide, but the timeframe for implementing is missing. An absence of this makes the whole public domain process contested, problematic and tricky to implement.

Indicator 7: Public space density

While a minority mentioned that LAPs have contributed to public spaces, others counterargued this opinion. According to an interviewee, LAPs have not added much to the public spaces considering the high-density development. The land is limited, and public spaces are considered as a social facility which generates no revenue to the government, and therefore it often lags in the hierarchy of importance. Likewise, in TPS, the leftover spaces made in the process of demarcating a final plot from the irregular parcels are marked as open/public space. Currently, Ahmedabad has only Kankaria lake and Sabarmati riverfront as public spaces. Despite this, LAPs have not laid priority to address the dearth of public spaces around these stations. Of course, plots are acquired from private owners to develop station amenities and parks. However, this limited parcel under parks does not justify the percentage under public spaces for the populated city.

This view was echoed by another informant who further added that due to the removal of illegal on-street parking, the plots reserved for public space and station area amenities would instead be used to provide parking lots or multi-storied parking. He suggested that parking is not a social facility and therefore should not replace the parks and public spaces.

Indicator 8: Land-use diversity

The informants, on the whole, demonstrated that land-use and transport integration is a crucial aspect of any LAP planning. While some interviewees argued that land-use and transport integration is not satisfactorily considered in Ahmedabad-LAP, others suggested that it is recognised. According to few interviewees, there is no conclusive evidence on how mixedness within the land-use is planned to evolve in the future whereas according to few participants, it is left on the market speculation to decide which land-uses will flourish and therefore is not dictated in the LAP. They further added that since Ahmedabad has a history of mixed land-uses, it does not need any regulations to regulate land-use diversity with the LAP-TOD zone unlike Delhi SAP and therefore it will evolve naturally. However, another interviewee argued that unless there is a policy regarding the desirable mix of activities that LAP wants to incentivise, land-use and transport integration will not click in Ahmedabad.

Indicator 9: On-street car parking density

While some participants have a complementary view of on-street parking, others have a contradictory opinion. One interviewee alluded that LAP has given provision for excessive on-street parking which is even more than the existing on-street parking provision. He further suggested that to encourage TOD, use of non-motorised vehicles and paratransit should be encouraged instead of encouraging cars. With making use of cars more comfortable, a shift from cars to public transport will never be successful.

Two other interviewees have reported that a certain amount of on-street car parking is essential to uplift the local economy. The LAP should incorporate a parking management plan that mentions how much on-street parking should be provided and how much should be restricted. According to them, parking should not be provided for free as it is a private good. LAP should bring out a parking policy that decides on the parking charge such that parking is never over-utilised nor under-utilised.

Talking about this issue, another informant gave a contrasting opinion. He mentioned that on-street parking should be removed entirely from the LAP zone from a perspective of collective mobility. Only then people will be boosted to use mass transit. If on-street parking is provided, it will be convenient for people to mobilise in cars resulting in a car-oriented development.

Indicator 10 and 11: First and Last mile connectivity

Based on the result of an interviewee, even with AMTS and BRTS mass transits, Ahmedabad has not achieved last mile connectivity. With the metro system, the idea is to make AMTS and BRTS function as feeder services so that all the seven stations in the LAP can achieve first and last mile connectivity. She further added that the LAP had incorporated the first and last mile connectivity on paper. However, its implementation is questionable because there are no additional plans for technological integration and there is a lack of coordination between the various planning authorities.

In a similar vein, another interviewee argues that BRT cannot function as a feeder to metro because it is already misplaced. He further added that there are few underlining principles which are either ignored or not satisfactorily developed in BRT. These principles are the provision of pedestrian tracks, last mile connectivity, station area planning and active frontage. According to him, if these principles are not developed in BRT, then how does the municipal authority expect people to walk to the BRT system? In the absence of this, it cannot function as a feeder to the metro and will bring downfall to the whole metro system.

Similarly, another interviewee commented that BRT is still struggling with its transit quality. Also, it is competing with AMTS. Its coverage is less, and the pedestrian infrastructure is still absent. With these drawbacks, BRTS needs time to function as successful mass transit and then it might be able to develop itself as a feeder to the metro. Another opinion of an interviewee was that Ahmedabad's BRTS is dying and nobody wants it. It is kept just for taking advantage of FSI 4, and the actual feedback on the transport side is ignored. According to him, it is all about real estate and developing money-making proposals.

On the contrary, another interviewee has a positive take on BRTS. He believes that even though the ridership of BRTS has not increased in the past five years, it has at least reserved a 9m space in the centre of the roads. According to him, BRT is like money in the bank. It will earn interest once congestion increases to levels when private vehicles cannot move in the city. Then the value of BRTS will be appreciated.

4.1.2. Findings from the documentation of LAP and other literature

The results of the LAP documentation and findings from the literature reveal positive as well as negative characteristics in the LAP planning procedure. It also discusses the contested spaces of the LAP.

Positive characteristics of the LAP

Based on the results of the LAP document, Ahmedabad-LAP has undergone extensive land and physical planning in brownfield development. For the LAP-TOD zone, AUDA has specially curated **General Development Control Regulation (GDCR)** which are different from the regulations for the entire city. The codes will mandate an average density concept instead of applying a uniform density of FSI. This is a clear indication that the local government has aimed at extensive land planning for contained dense development instead of sprawling.

Moreover, since all the planning and physical interventions are suggested on private land, LAP is given a legal base after DP-TP. This makes LAP not an advisory but a **legal document**. Another positive intention revealed from the LAP is the concept of public domain where instead of not doing anything about the narrow and discontinuous footpaths, the government will carve out space from the front margin of the private plots to develop extended footpaths.

Additionally, Ahmedabad-LAP has adopted a **redevelopment and retrofitting** approach unlike Bhopal (India), which has demolished or await to demolish eleven schools, one hospital, 3000 government quarters, some hundreds of shops and two slums for redeveloping Bhopal into Bhopal smart city (Chowdhury, 2019). Furthermore, the street design guideline of LAP meticulously aims at prioritising pedestrians and cyclists over car users by providing more road space under them. Moreover, the component of owners' meeting is also a good intention of LAP as it indicates a bottom-up approach in the LAP planning.

Lastly, the location of these stations is seeded very strategically because they were famous destinations for commercial or institutional activities. For instance, Doordarshan kendra, named after a Doordarshan TV tower is a renowned old institution whereas Gurukul road station is named after a famous Gurukul temple. This approach of using making destinations or landmarks as station is called a **DOT (development-oriented transit)** approach (Moule and Polyzoides, 2017) which helps in significantly increasing the transit ridership.

In a nutshell, these positive physical planning interventions of LAP would aid in improving the level of TOD significantly. However, Ahmedabad-LAP is not just limited to this but also caters to certain gaps that bring down the sustainability component of the TOD. These are a lack of provision for affordable housing, lack of land-use and transport integration and a lack of parking management plan. These aspects emerged during the discussion with the experts and are linked to the eleven indicators.

Misplaced priorities of the LAP

It is important to discuss the negative aspects because they have a direct and indirect repercussion on the indicators and the overall TOD level. **Affordable housing**, a critical component of planning is recognised in the TP schemes but is not considered in the Ahmedabad's LAP. It is left on the market to decide which social group will live in the LAP-TOD zone and that is why there are no incentives or plans to provide social housing. However, affordable housing is a social welfare subject and should be the responsibility of the municipality. Unless they deliver prepare plans or incentives to encourage it within the TOD zones, no developer would be interested in building.

One of the most critical aspects of planning at any scale is **land-use and transport integration** which is another misplaced priority of Ahmedabad-LAP. According to Cervero (2013a), the biggest drawback of BRTS in Ahmedabad was non-existent land-use and transport integration. The BRTS has many gaps in its implementation because real estate's potential was not tapped at all. There was no focus on either planning the development along the BRTS corridor nor planning a corridor through high travel demand areas. Instead, the emphasis was laid on quickly building the BRTS due to political pressure and by suppressing land developing opportunities. That is why TOD did not grow to its potential, and similar records can be registered in the metro system if the LAPs are not strengthened by incorporating LUTI.

Moreover, the component of private **off-street parking** for the metro users in the FMC and LMC is not detailed. How much area to be allocated for private vehicle parking is ambiguous. Since LAP is a micro level planning document, such study needs to be a part of the LAP document to develop a holistic picture based on the demand and supply studies. Furthermore, new **roads** have been proposed in the LAP, but there are no plans indicating if the new intersections will be signalised or unsignalized. At least significant intersections should have a detailed traffic management study to avoid traffic collisions.

In total, these are the pitfalls of Ahmedabad-LAP. Additionally, according to Joshi et al. (2017), LAP also lacks implementation strategies, proposed timelines and gives little consideration to strengthening the sustainability component.

Planning of contested spaces

Within the planning aspect of the LAP, there are few uncontested and contested spaces. Indicators like block size, building footprint density, population density, signalised intersection density, public spaces, land-use diversity and first and last mile connectivity are uncontested aspects of LAP planning because their design and relevance to the overall TOD index are explicitly understood. However, road density, pedestrian and cycle track density and on-street car parking density are contested aspects of LAP planning because these indicators either deal with the use of private land or there are local demands that go against what is good for the success of the TOD.

In line with the literature on Ahmedabad-LAP, new **roads** are proposed under three categories. The first category deals with converting private road into the public to reduce the block size. From a perspective of the local body, this intervention is useful for the planning of a TOD zone; however, from the view of a plot owner, such an intervention can impede their safety. The second category is about carving pedestrian roads from the margin spaces. This intervention will again have a similar repercussion where it is arguable if private plot owners are willing to remove their compound wall and compromise on their safety by giving away their margin space. The last proposed road category is dependent on if the entire plot undergoes redevelopment. Looking at these parameters, the road planning as suggested in the LAP has become extremely tricky as it involves a lot of negotiations and discussions between the stakeholders and the local government. Even though these interventions can significantly improve the overall TOD index, their applicability is highly questionable.

Likewise, in pedestrian and cycle track density, there is a component of a **public domain** that deals with the use of private land. This intervention again raises similar concerns and questions. If all the plots do not go for redevelopment at the same time, what can happen is not anticipated in the LAP. Instead of becoming a good thing, because of the implementation, it could become an eyesore and lead to unsafe places. Some plots would go for redevelopment whereas some would not. Such irregular spaces would give rise to informality or encroachment or simply become crime sites. Instead of solving one problem of lack of space for pedestrians, another question has been mounted. It is blurry, and so is its implementation.

On-street parking is also contested because not everyone likes or dislikes it. From the perspective of shop owners, parking is essential as it increases their local economy, whereas from the standpoint of a government or a transport planner, on-street parking limits and reduces the growth of the public transport. Parking provision cannot be determined with the perspective of a single stakeholder. These are few aspects that go against the success of the TOD because they cannot be implemented quickly, and the negotiation process can bring the whole idea of TOD development to a standstill.

Within these contested spaces, a logical question to ponder upon is who will take the responsibility of developing and implementing components where multiple stakeholder's decisions are needed? Is the government taking responsibilities or are they making others share the responsibility? If not, then what responsibilities are they not taking and is it fair? These are the few unanswered questions that are coupled with the contested spaces in Ahmedabad-LAP.

4.2. Quantitative analysis of Pre-LAP and Post-LAP Indices

This section is in line with the fourth research objective. It deals with the quantification of Pre and Post-LAP indices where it demonstrates the variations in Pre and Post-LAP for each indicator and each station area and provides the overall Pre-LAP and Post-LAP index scores by assigning weights to each indicator. The findings of the quantitative analysis are augmented with the results from the interviews, literature and the LAP documentation.

4.2.1. Evaluating indicators

Indicator 1: Block size

Figure 17 presents the existing and proposed block size and highlights the variations in each station.

Pre-LAP findings

- Thaltej gam has the largest existing average block size whereas Thaltej has the smallest existing block size. Thaltej gam has large blocks because it is the farthest station from the city centre and therefore comprises of large tracts of undeveloped land.
- The large vacant parcels and large block sizes are also observed in Doordarshan kendra. This indicates that these stations are not suitable for TOD development.
- Likewise, Gujarat university and Commerce six roads station areas have the presence of institutions which cater to large plots and therefore have large blocks.
- Conversely, Thaltej, Gurukul road and Stadium have smaller block sizes because they have smaller plots, thereby a good representative of TOD. The small block size in Thaltej is due to its proximity to the village which has narrow streets and small buildings making it highly walkable.
- Likewise, Stadium is near the city centre and therefore witnesses smaller block size.
- Even though Thaltej gam and Thaltej stations are only 800m – 1000m apart, their context within the city is very distinct and so is their existing block size.

Post-LAP findings

- In line with the suggestion by all the interviewees, the proposed blocks have further disintegrated, and the level of TOD is improving.
- Thaltej gam has the highest proposed block size whereas Thaltej has the smallest.
- Even though a large part of Thaltej, Doordarshan kendra and Gujarat university is still unbuilt, planning interventions in LAP have managed to reduce the block size by one fifth.
- Additionally, the overall improvement from Pre-LAP to Post-LAP is maximum in Gurukul road station because its spatial condition allows for the reduction in block size whereas, in Stadium due to its densely built structure, the potential to decrease the block size is smaller.
- All in all, the proposed average block size of all the stations implies more walkability thus leading towards a better TOD.

Figure 17: Pre-LAP and Post-LAP Block size and overall difference

Indicator 2: Building footprint density

From Figure 18 the existing building footprint density for each station is illustrated. In absence of proposal for building footprint density in the local area plans, Post-LAP analysis is not reported.

<u>Pre-LAP</u>

- More than one-third of the area is covered by buildings in Stadium making it the highest contributor whereas Gujarat university ranks the lowest.
- Likewise, Thaltej and Commerce six roads also register one-third of their area under buildings.
- High-density pockets of buildings are formed in Gurukul road, Commerce six roads and Stadium station areas.
- Buildings are evenly spread in Gurukul road area except for the green field zone.

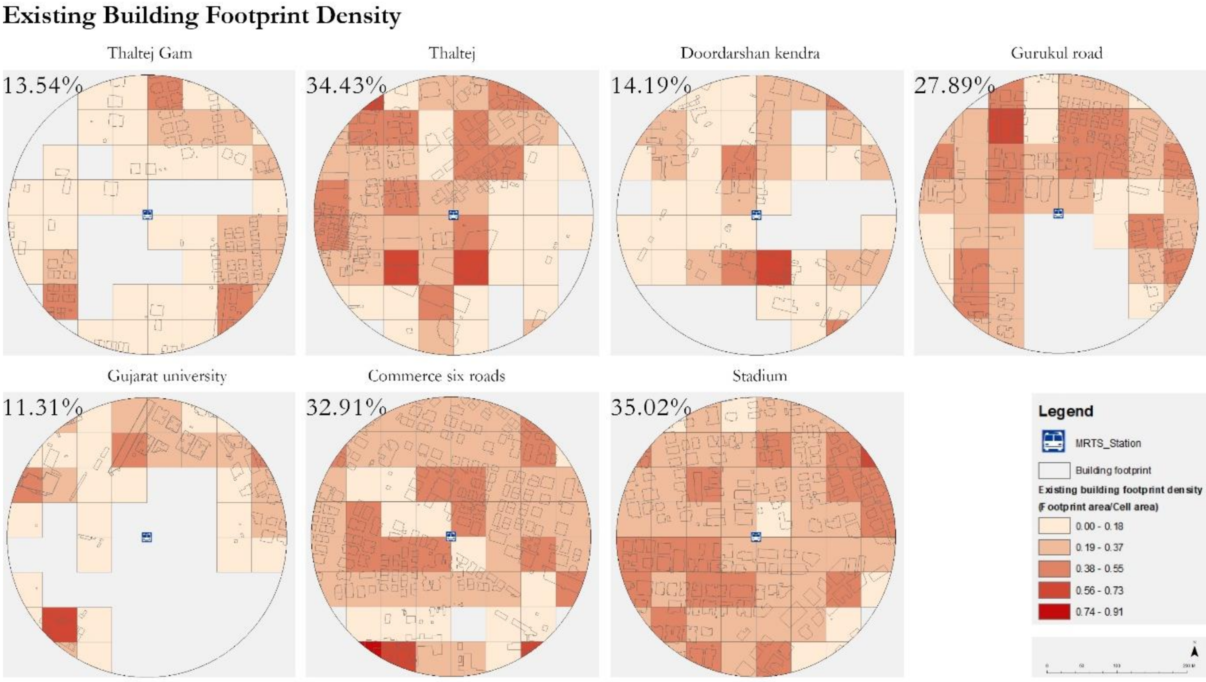

Figure 18: Pre-LAP Building footprint density

Indicator 3: Population density

Figure 19 demonstrate the results obtained for Pre and Post-LAP and the variation in the population density for each station area.

Pre-LAP

- Commerce six roads station has the highest existing population density whereas Doordarshan kendra has the lowest.
- One could expect that building footprint density and population density would outline a similar trend. However, this is not the case as the population density is dependent on the building height.

Post-LAP

- Thaltej gam contributes maximum to the proposed population density as opposed to Doordarshan kendra which has disparate islands of coverage.
- Followed by this, Gurukul road station experience the second highest inflow of population. Their proximity to the main arterials attracts more people in these areas.
- Likewise, Commerce six roads and Stadium stations are no exception and show a similar trend.
- Doordarshan kendra registers the highest overall increase in the population density.

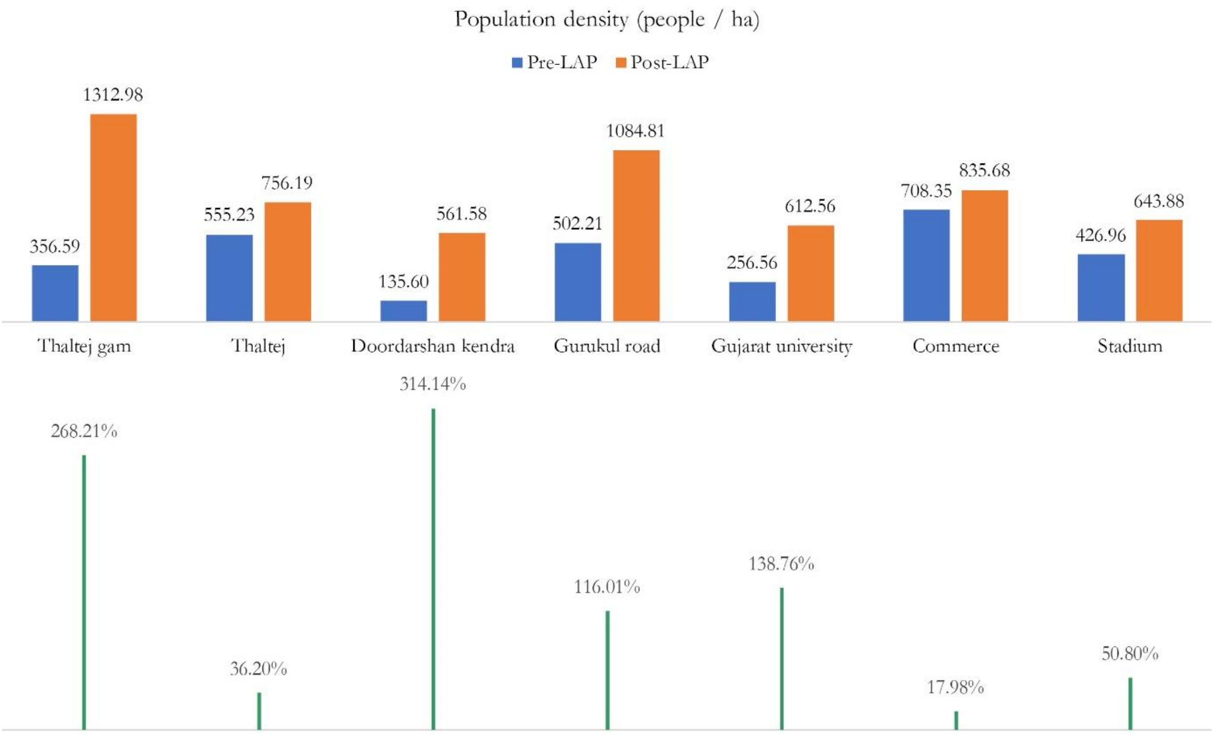

Figure 19: Pre-LAP and Post-LAP Population density

Indicator 4: Road density

Figure 20 compares the existing and proposed road densities and shows the variation in each station.

Pre-LAP findings

- Thaltej ranks highest in existing road density and outgrows other stations whereas Gurukul road and Thaltej gam rank the lowest.
- Gurukul road station contains a greenbelt zone in the south where development is prohibited whereas Thaltej gam has consequently less roads. Thereby not a good representative of TOD.
- Conversely, Thaltej area caters to a national highway towards and therefore experiences high-density pockets.
- Doordarshan kendra and Gujarat university also comprise of two major arterial connectors that run parallel to the national highway and therefore indicates high densities pockets.
- Commerce six roads and Stadium are fairly laid with public roads throughout however, their densities are low because they have narrow roads.
- From Figure 18 and Figure 20, it is apparent that areas where building footprint densities are low, road densities are high.
- Interestingly, the arterial road that caters to the metro does not record for high road density pockets because of the mismatch in the spatial location of the road and the placement of the cells.

Post-LAP findings

- The proposed design of roads in the LAP follows a systematic road pattern while clearly establishing a road hierarchy.
- The new roads are laid in the continuity of the existing roads thereby enhancing the connectivity and accessibility.
- For each road within the LAP-TOD zone, a comprehensive ROW design is proposed which prioritises the movement of pedestrians and cyclists over cars.
- With all these interventions, Thaltej still experiences the highest proposed road density whereas Stadium accounts for the lowest value.
- Despite being the lowest in existing road density, Gurukul road station has managed to increase its level by two third which is the highest increase amongst all the stations.
- To end, Post-LAP has significantly improved the accessibility in all the station areas expect for Stadium which records for a marginal increase due to the prominence of gated societies. However, proposed road density is leading towards a better TOD.

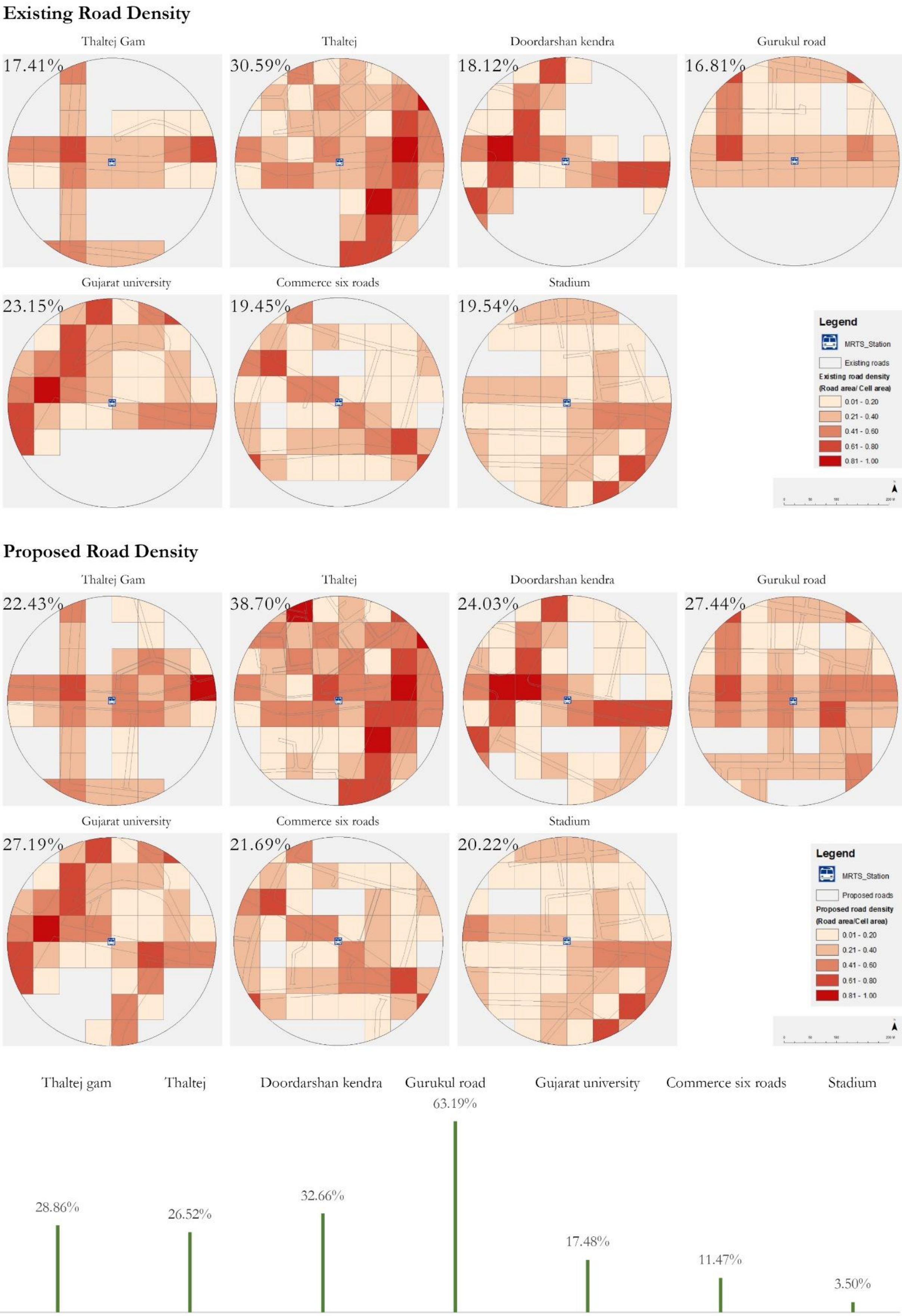

Figure 20: Pre-LAP and Post-LAP Road density and overall difference

Indicator 5: Signalised intersection density

Figure 21 illustrates the existing and proposed signalised intersection densities and the variation in all the stations.

Pre-LAP findings

- Even though the existing road density is around 20% in almost all the stations, the density of the existing signalised intersections is very low. Majority of the intersections are non-signalised which can create a chaotic and unsafe situation for all users.
- Commerce six road has the highest existing signalised intersection density.
- Thaltej gam comprises of a unsignalized intersection of two arterials that is creating unsafe situations for the road users.
- Most of the roads in Thaltej are narrow residential roads and therefore even if the signalised intersection density is less, the station area appears to be safe. Likewise, in Stadium, most of the streets are residential hence no signalised intersection is recorded.
- Doordarshan kendra, Gurukul road and Commerce six roads have arterial connections which are guarded with signalise intersection to avoid collision of vehicles and people.

Post-LAP findings

- Regardless of the increase in the percentage of the proposed road density, there is no change or increase in the proposed signalised intersection density in any station.
- There is a need for a cautious traffic management plan in the LAP which can ensure safety for all the users in the immediate surrounding of these station areas because, at the end, every citizen pays the price of unsafe roads.
- No change in the proposed signalised intersection densities is affecting the level of TOD in all the stations.

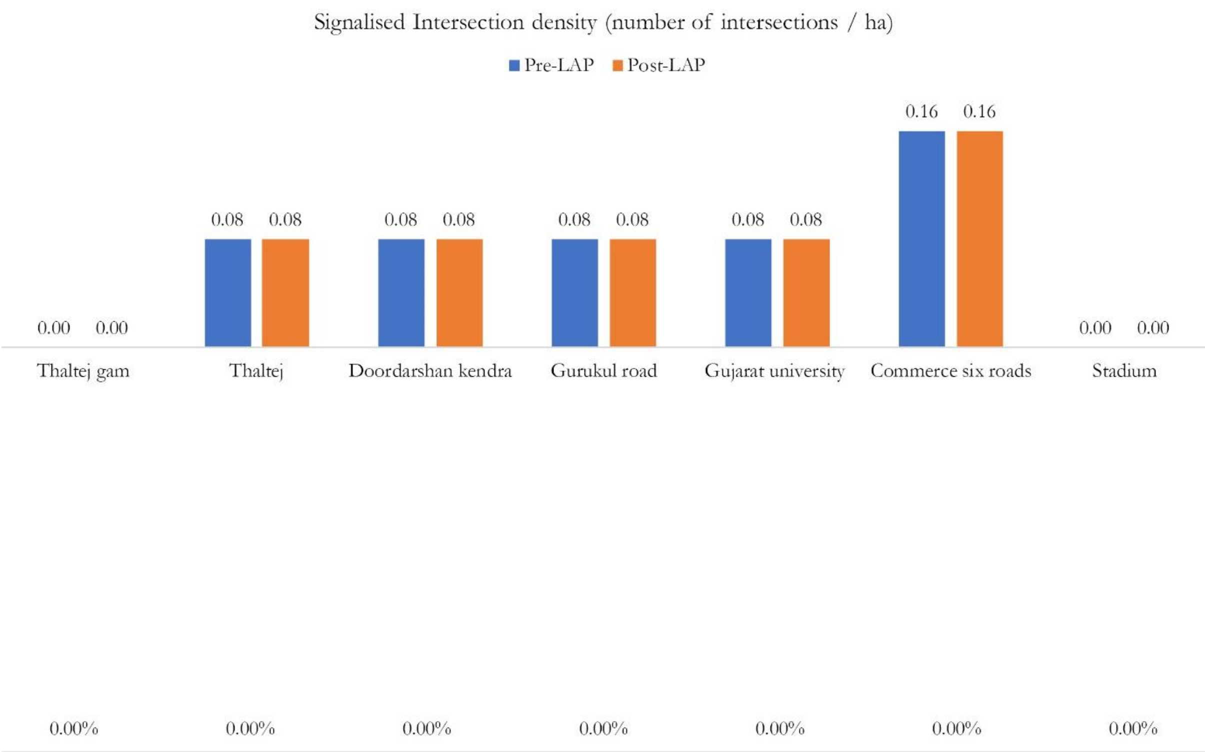

Figure 21: Pre-LAP and Post-LAP Signalised intersection density and overall difference

Indicator 6: Pedestrian and cycle track density

Figure 22 underscores the results obtained for Pre and Post-LAP of pedestrian and cycle track densities including the variation in each station area.

Pre-LAP

- In Stadium, one-fifth of the road area is covered with pedestrian tracks whereas Thaltej has no pedestrian tracks.
- Gujarat university, Stadium and Commerce six roads have continuous footpaths, but these are either very narrow in width or are encroached with hawking or on-street parking.
- Remaining stations have discontinuous and narrow footpaths which are not used by people to walk but are used for other stationary activities.
- In line with the qualitative analysis, all the stations are deprived of cycle tracks and the existing pedestrian track densities are also extremely low which is not a good demonstration of TOD.

Post-LAP

- In both; Pre and Post-LAP, Stadium ranks the highest and whereas Thaltej ranks the lowest.
- Stadium has half of its road area under pedestrian and cycle track density whereas Thaltej covers only one fifth of its area.
- Another station that performs well in this aspect is Commerce six roads.
- The high densities pockets in Thaltej, Doordarshan kendra, Commerce six roads and Stadium is due to the introduction of pedestrian streets and public domain.
- Mostly new pedestrian connections are planned in the village area within Thaltej station. Therefore, Thaltej has an inexplicable increase in its pedestrian and cycle track density.
- Gujarat university station has high and low values of pedestrian and cycle track densities whereas Gurukul road station has a flat map in its southern part. It is expected because this area contains the greenbelt zone.
- In a nutshell, all the stations are significantly improving and therefore they are a good representative of TOD. Amongst them, Stadium is the best illustrative of TOD. This result is also augmented with the findings from the interviews.

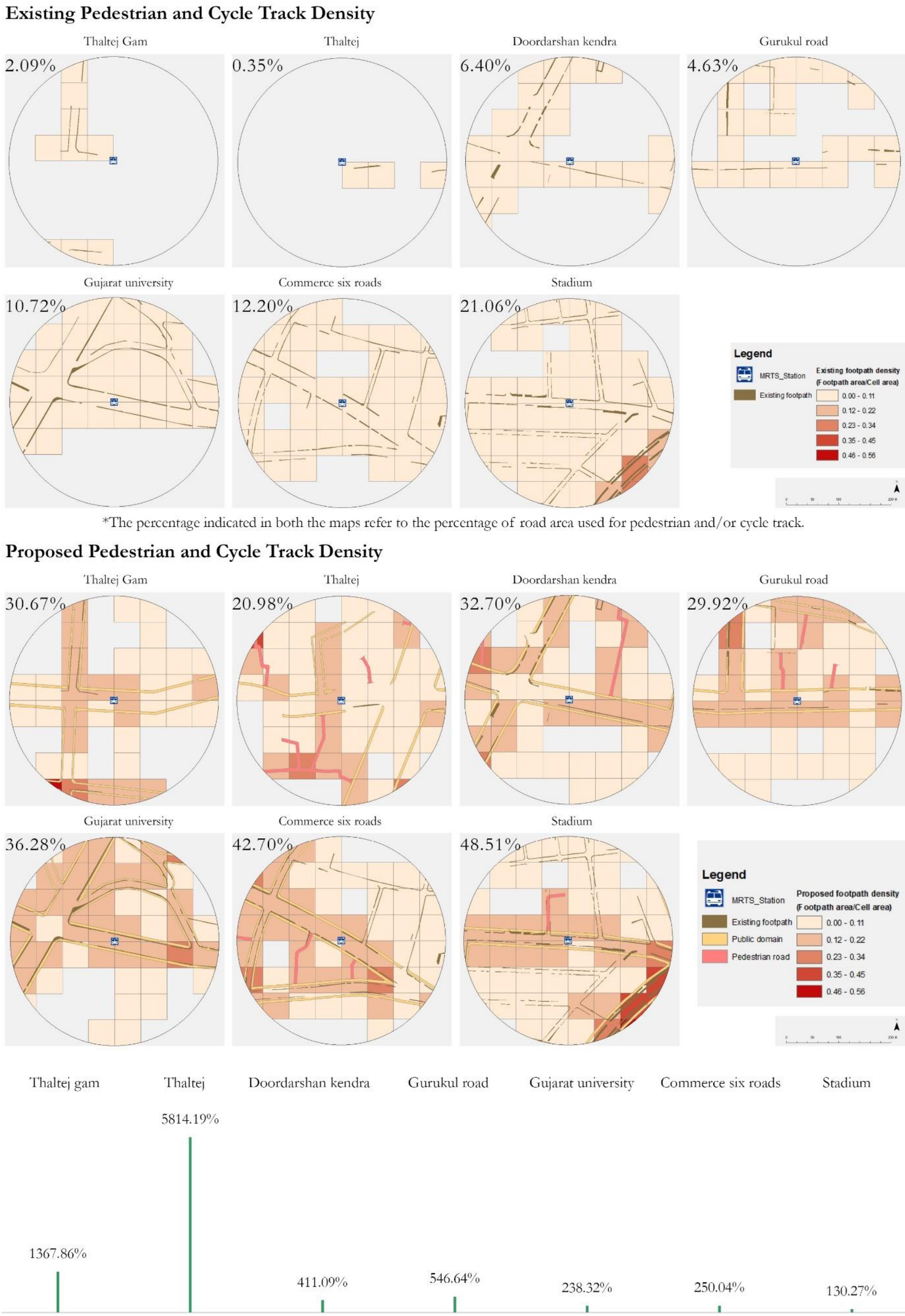

Figure 22: Pre-LAP and Post-LAP Pedestrian and Cycle track density and overall difference

Indicator 7: Public space density

Figure 23 shows the existing and proposed public space density and highlights the variation in the density.

<u>Pre-LAP</u>

- All the stations are penalised in terms of public space except for Gujarat University.
- Therefore, all the stations except for Gujarat University are a bad representative of TOD.

<u>Post-LAP</u>

- The local government has obtained land from private owners in exchange for money around the proposed metro stations to develop station level amenities. As per the proposed LAP design, these spaces will have room for parks and garden areas which will attract people to use the metro for the success of TOD.
- With this, Gujarat university registers the highest area under public space whereas Stadium is deprived of public space.
- Looking at this, it will be challenging for the planning and construction bodies to develop station amenities at Stadium and Commerce six roads which account for only 1% of the total area under public space.

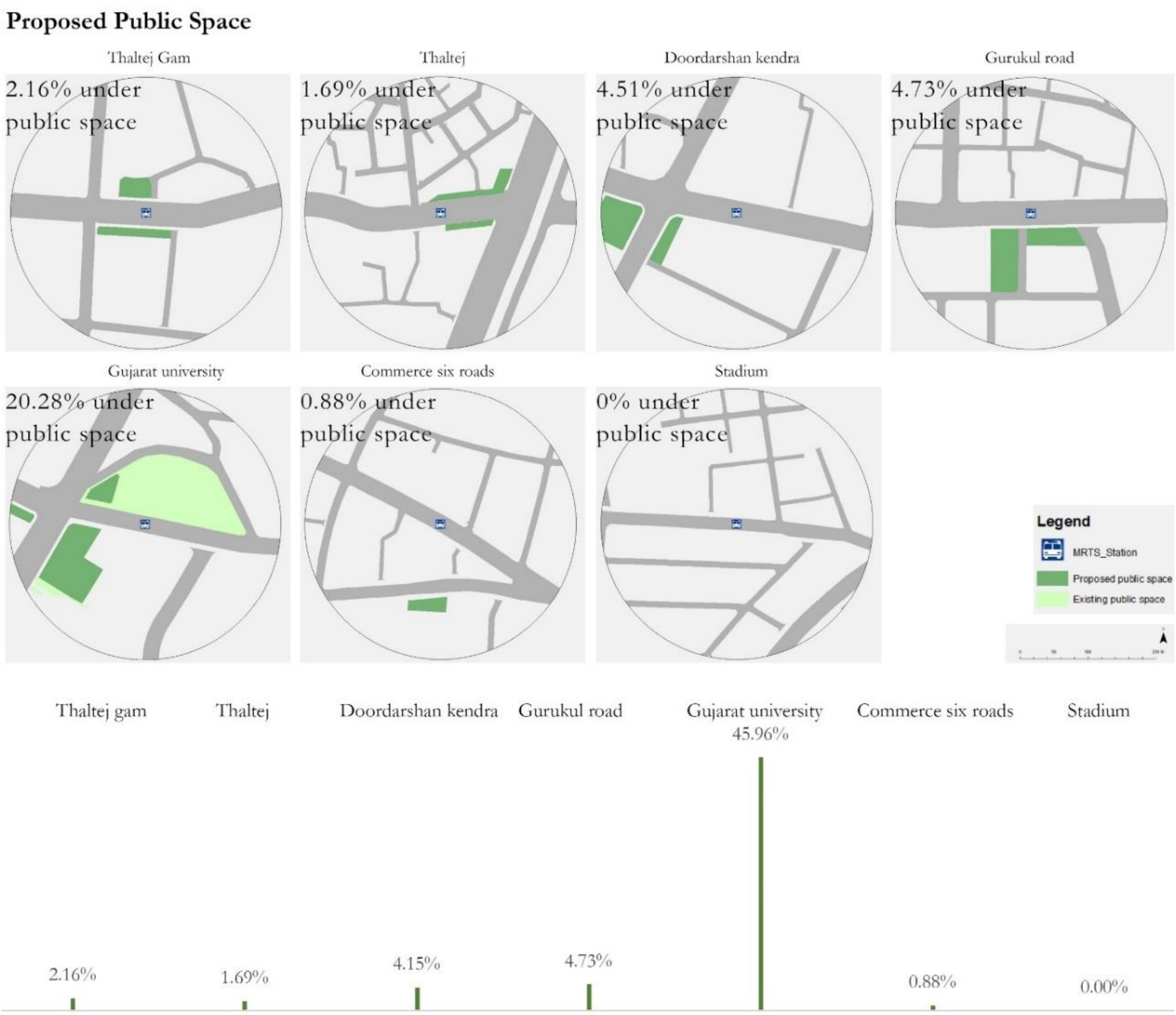

Figure 23: Pre-LAP and Post-LAP Public space density and overall difference

Indicator 8: Land-use diversity

From Figure 24, the existing diversity within the land-uses is illustrated. As LAP do not have proposal for the land-use, there is no Post-LAP analysis recorded which is the biggest drawback of LAP and is also expressed as a concern from the qualitative analysis.

Pre-LAP

- There is a variety observed in the land-use diversity where Doordarshan kendra underscores the highest whereas Thaltej gam stands out amongst others and ranks the lowest.
- Doordarshan kendra is surrounded by heavy commercial development.
- Similarly, Gurukul road station also experiences high diversity mainly because of the presence of local commercial.
- Thaltej being the adjacent station to Thaltej gam differs significantly because it is developed along the national highway with almost 40% as commercial.
- Despite Stadium being the closest to the city centre and to the existing commercial business district, it underscores less commercial development. The overall land-use diversity has decreased due to the dominance of residential in this area.
- Even Commerce six roads station has a similar urban fabric to Stadium but because of the prevalence of many educational institutions nearby, the diversity index has increased.
- The colocation of many compatible land-uses helps to reduce private trips and encourages walking, cycling and use of public transport thereby increase TOD levels.
- However, regardless of the land-use diversity being the highest as it does in Doordarshan kendra (0.96) or lowest (Thaltej gam 0.17) unless this diversity is complemented with public transport, efforts to integrate land-use and transport are incomplete.

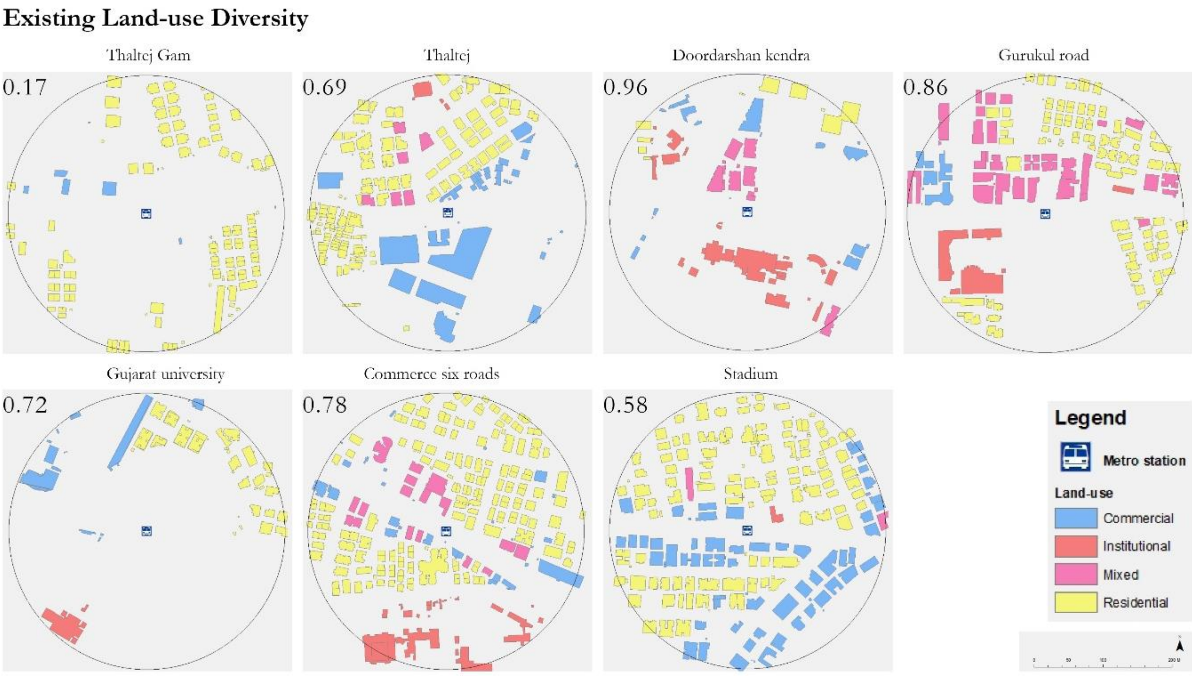

Figure 24: Pre-LAP Land-use diversity

Indicator 9: On-street car parking density

Figure 25 describes the existing and proposed on-street car parking densities and presents the variations in their densities.

Pre-LAP

- In absence of designated on-street parking spots, illegal on-street parking is recorded in all the station areas where Commerce six road station comprises of maximum existing on-street parking density and Gurukul road station comprises of the least amount.
- Maximum illegal parking translates into higher density pockets which were registered on the collector streets in all the stations. This is an effect of the current police patrolling in Ahmedabad. Since the police guards mainly the arterial roads, people have started to park on the inner streets.
- Additionally, in cases where off-street parking is not sufficiently provided, cars are illegally parked on the street which is another reason for higher on-street car parking densities on inner streets, especially in Stadium and Commerce six roads.
- In Thaltej gam, Thaltej, Doordarshan kendra and Gujarat university, existing parking is because of commercial and institutional land-use whereas in Gurukul road, Commerce six roads and Stadium, it is partly because of residential land-use as inferred from Figure 24.

Post-LAP

- In parallel to the qualitative results, excessive on-street parking is proposed in Post-LAP and the differences between the Pre and Post-LAP are striking.
- While Stadium accounts for highest proposed on-street car parking density, Doordarshan kendra accounts for the lowest.
- Since Stadium caters to many narrow and residential streets, its density is high. From Figure 24 it is apparent that the roads flunked with commercial also registers a huge area under on-street car parking density.
- Even though Doordarshan kendra has the highest land-use diversity, its parking density is the lowest.
- Despite having the highest road density, Thaltej station does not record for highest on-street car parking density. This is because of two reasons. Firstly, it has a national highway which is wider in width compared to the roads and so indicates high densities. The second reason is because it has relatively more pedestrian streets where parking is prohibited.
- Gurukul road station, on the other hand, experiences the highest overall increase in on-street car parking density.
- High densities pockets in the maps are a result of higher on-street car parking densities.
- According to the LAP proposal, the overall TOD has declined due to on-street car parking in all the stations.

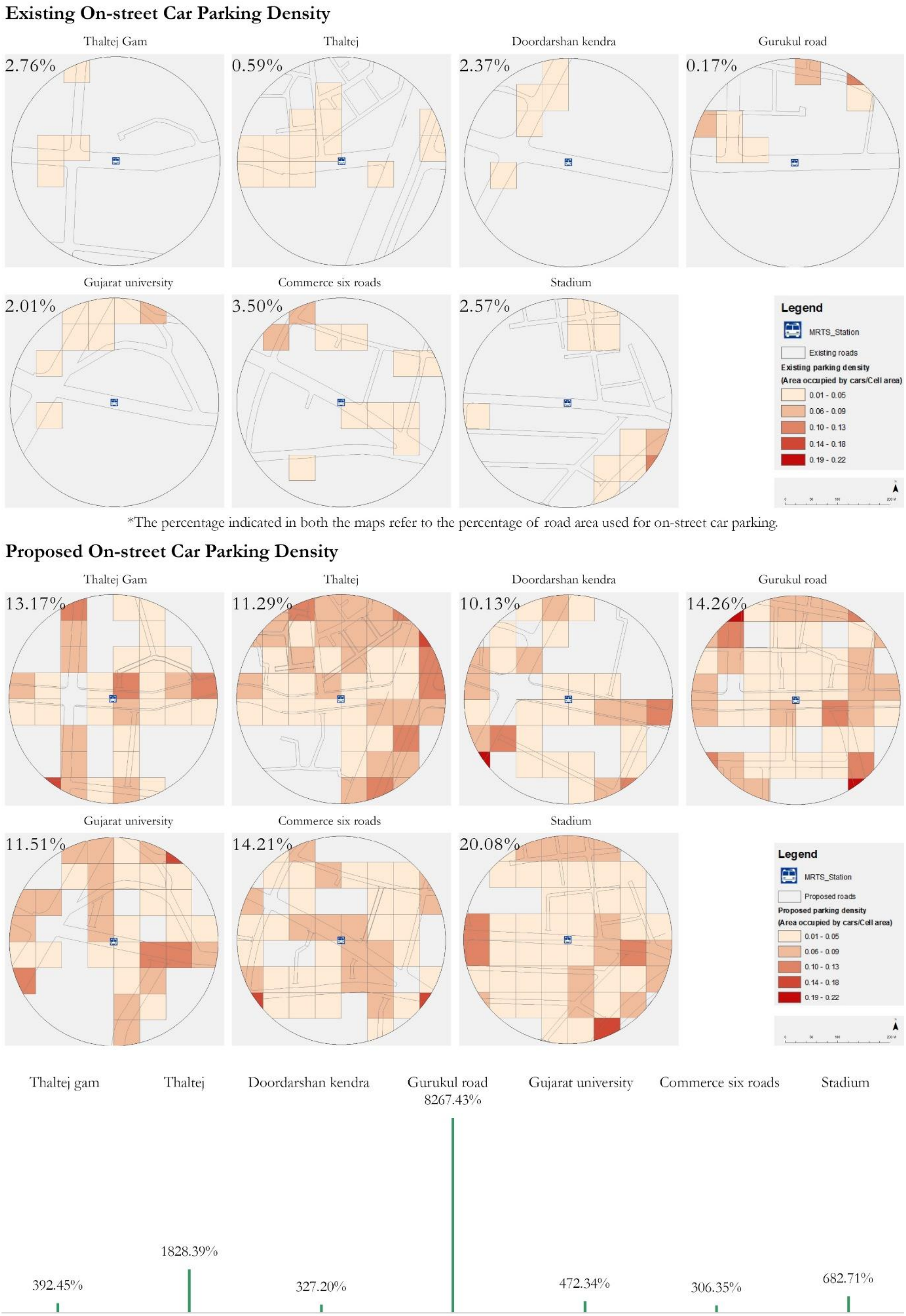

Figure 25: Pre-LAP and Post-LAP On-street car parking density and overall difference

Indicator 10: First mile connectivity

Figure 26 outlines the number of modes available at each station and indicates the variations from Pre to Post-LAP.

Pre-LAP

- All the stations are penalised than Gujarat university station because they have AMTS and autorickshaw stops but lag in terms of BRTS and bike sharing service.
- Gujarat university and Stadium have only one AMTS stop.
- In total, Gujarat university ranks highest and is a good representative of TOD.

Post-LAP

- Thaltej gam, Thaltej, Doordarshan kendra, Gurukul road and Gujarat university benefit from many choices of modes, while Commerce six roads and Stadium suffer from no change from the Pre-LAP situation.
- Amongst these, Gujarat university comprises of maximum mode choices.
- Thaltej gam, Thaltej, Doordarshan kendra and Gurukul road have shown more than 100% improvement. Metro users are expected to travel either using autorickshaw, AMTS, BRTS, bike or private vehicles. LAP has strategically developed areas to accommodate these modes in a systematic manner thus indicating a higher level of TOD in these stations.
- Compared to all the stations, there is no improvement in Commerce six roads and Stadium station due to their densely packed spatial considerations which restrict the establishment of any transport service near the metro station.
- In cities where public transport is constrained operationally, informal public transport services address the accessibility gaps. Therefore, along with the metro system, first-mile connectivity is also extremely important.

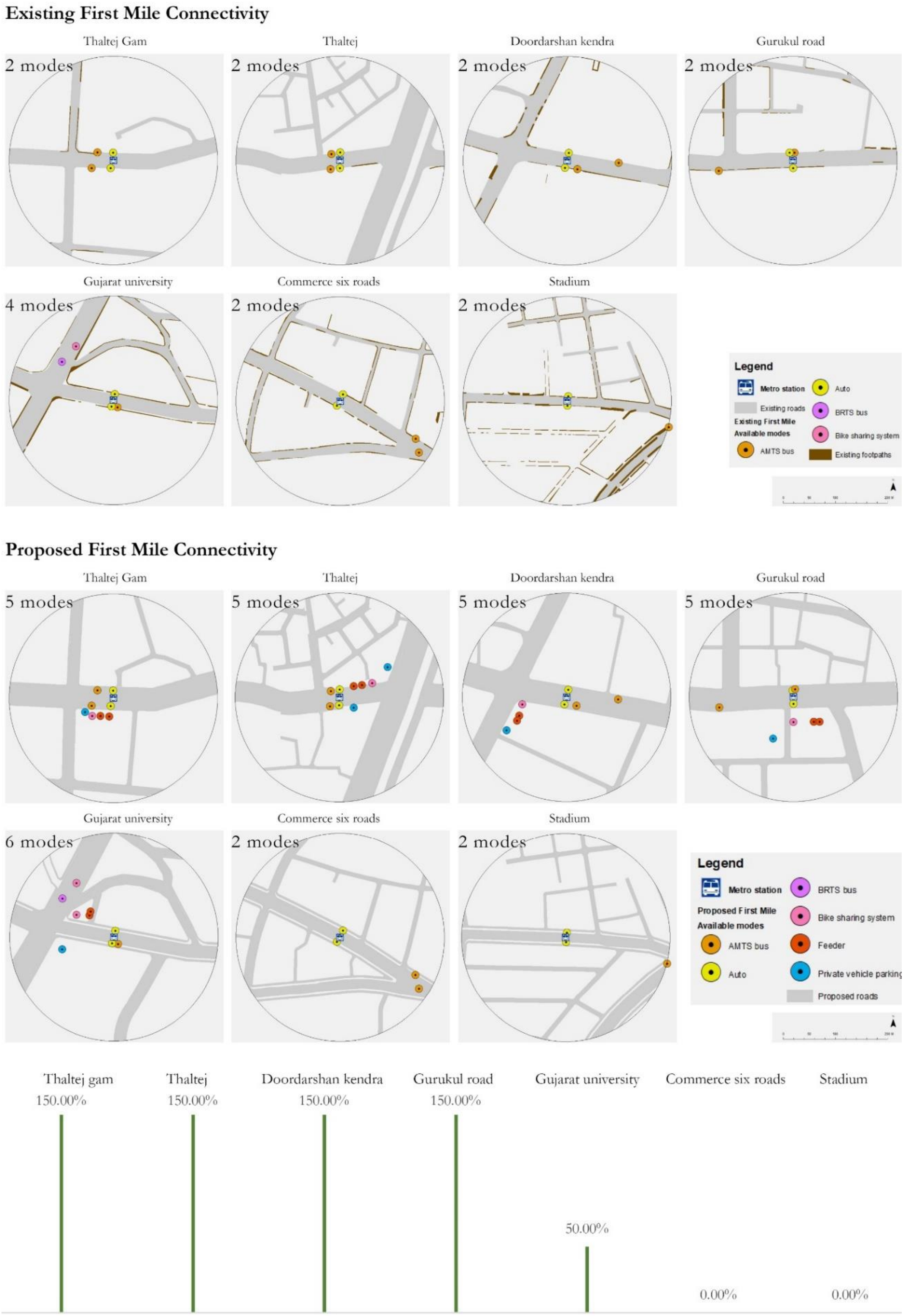

Figure 26: Pre-LAP and Post-LAP First mile connectivity and overall difference

Indicator 11: Last mile connectivity

Figure 27 reflects the existing and proposed last mile connectivity and demonstrate the variations in each station area in terms of mode choices.

Pre-LAP

- Like the first-mile connectivity, Gujarat university station comprises of maximum modes including BRTS and a bike sharing service whereas other stations are deprived of these services.
- The map highlights the tentative locations of all the autorickshaw stands. These are generally available at the intersection to attract more users. In this, metro users are expected to walk till the autorickshaw stand.
- All stations have AMTS bus service running in both directions except for Gujarat university and Stadium.

Post-LAP

- In line with proposed first-mile connectivity, Gujarat university contains the highest number of mode choices whereas Commerce six roads and Stadium rank the lowest.
- In addition to existing autorickshaw and AMTS stops, LAP has proposed a bike sharing system, feeder buses, and off-street parking areas for the metro users. These mode choices are expected to be integrated within the station area plaza design. However, LAP has no plans to provide additional AMTS stops in Gujarat university and Stadium station where only bus service is available only in one direction.
- Like the first mile, with only 50% increase in Commerce six roads and Stadium in achieving the last mile, the same figure stands at 150% for remaining stations other than Gujarat university.
- The fact that the buildings in Commerce six roads and Stadium are very clustered (Figure18), is indicative of a lack of space available for planning feeder services or any other transport option.

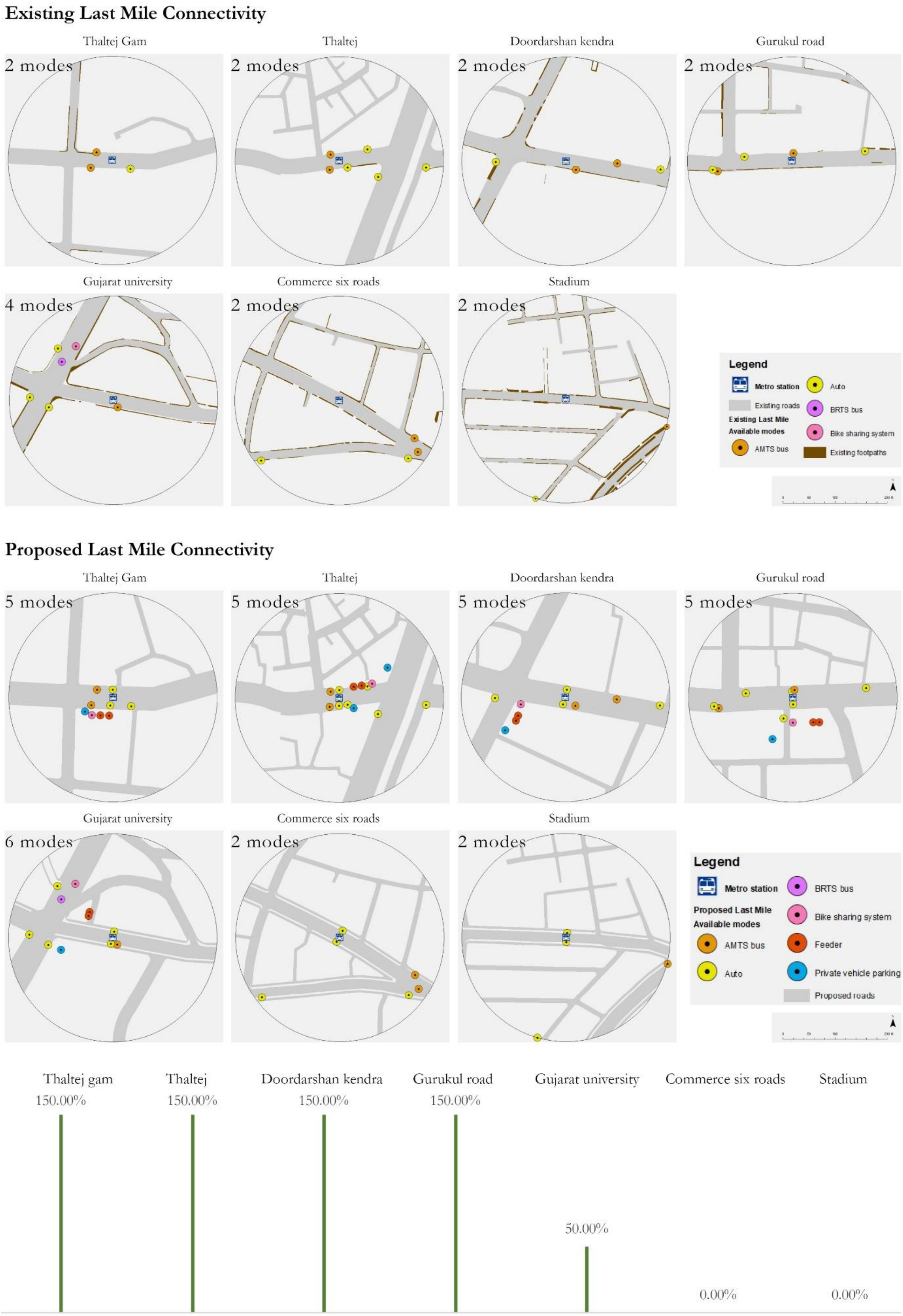

Figure 27: Pre-LAP and Post-LAP Last mile connectivity and overall difference

4.2.2. Evaluating metro stations

Overall TOD Index

Figure 28 illustrates the difference in the overall Pre and Post-LAP Index scores and the ratio where paradoxically, Thaltej gam, the most suburban station has improved the most in terms of TOD and Stadium station which is closest to the city centre registers decline in its improvement.

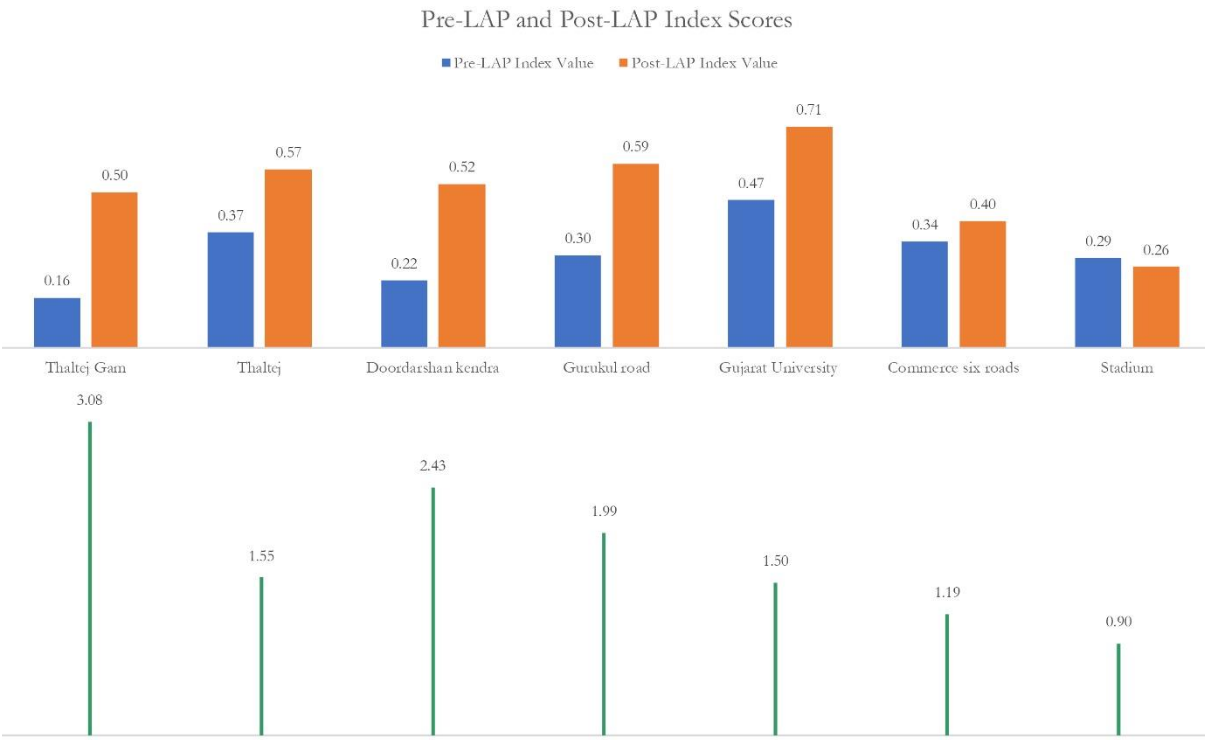

Figure 28: Pre-LAP and Post-LAP score for each station

Station 1: Thaltej gam

Figure 29 illustrates the Pre and Post LAP TOD Index scores where the latter has registered almost three times of improvement. Although the improvement in the index value from pre to post LAP is maximum in this station compared to others, it is not the station with the highest post-LAP TOD index. This is because the Pre-LAP Index scores were the smallest amongst all the stations and with various meaningful planning interventions, the overall score has managed to increase to 0.50.

<u>Pre-LAP Findings</u>

- Thaltej gam metro station is the most suburban station of the western corridor. Although this area is rapidly developing, many plots are still unbuilt, and therefore, the existing blocks are large.
- The lake is shunned from the city and is surrounded by refuse with absolutely no access to it which is a natural outcome of the low road density in this area.
- Although Thaltej gam has less building footprint and road density, its residential percentage is the highest across all the stations. this could be due to the low land value in this area.
- Moreover, due to the dominance of residential land-use, the land-use diversity is low. Commerce development is recorded in two pockets where on-street parking is also present.
- There are no cycle tracks and very few discontinuous pedestrian tracks. In general, there is no direct and continuous pedestrian access to the metro station.

- On-street parking is the lowest in this station which is a good representation of TOD. However, there are only two modes; AMTS buses and autorickshaws for first and last mile connectivity which is not sufficient.
- Accumulation of all these indicators has caused the lowest Pre-LAP Index score for this station.

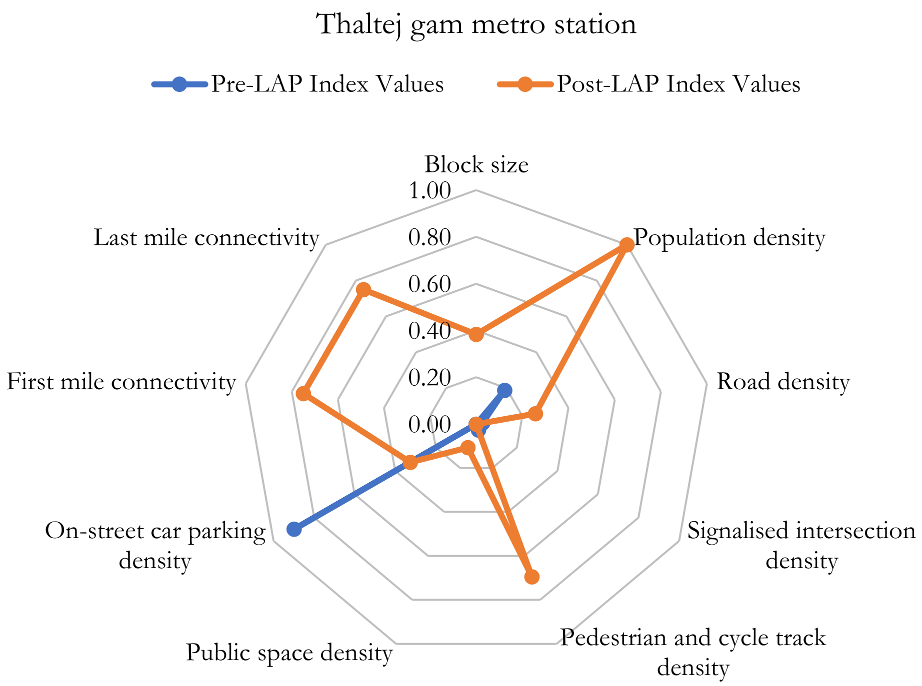

Figure 29: Pre-LAP and Post-LAP Index Values for Thaltej gam metro station

<u>Post-LAP findings</u>

- The change or improvement in block size, population density, pedestrian and cycle track density and first and last mile connectivity is high. However, on-street car parking density negates this improvement and results in low Post-LAP Index scores.
- Amongst all the stations, this station witnesses the highest increase in population density which could be due to the relatively low land value as it is the most suburban metro station.
- The road density has improved meaningfully which has enhanced the access to the previously shunned lake. Three new perpendicular roads are proposed in this area to improve access to the metro station.
- Even though the road density increases, there is no signalised intersections proposed in this station which can create an unsafe environment for the road users in the future.
- Moreover, pedestrian and cycle track also record for a significant increase, a large part of the increase is attributed to the public domain.
- Despite a large area unbuilt, the public space density is not so high.
- To support the first and last mile connectivity, Post-LAP shows a significant increase in the number of modes than the existing scenario. However, this station is still penalised compared to Gujarat university station because it has no BRTS stop.
- Building footprint density, and land-use diversity do not change, and the latter is one of the major drawbacks of the LAP.

Station 2: Thaltej

Thaltej station area has improved by one-fold and ranks third in the overall Post-LAP Index score. Figure 30 displays the Pre and Post-LAP Index scores. From this, it can be concluded that the Pre-LAP score performs relatively good in this station and Post-LAP interventions help in improving the overall TOD.

Pre-LAP Findings

- The blocks are smaller in size compared to other stations due to the closeness to the village area which has small plots and blocks.
- The smaller plot sizes have resulted in a dense building footprint which is the highest across all the stations. The buildings are evenly distributed with residential and commercial development. The latter has flourished due to the proximity of the highway and caters to a huge mall which provides for diverse city level amenities.
- The presence of the highway has resulted in the highest road density in this station, which has supported the movement of vehicles with the help of a signalised intersection.
- While the population density is high in this region, the public space density is zero.
- Even though the road density is the highest in this station, there are hardly any footpaths and no cycle tracks. Since this area caters to a different level of income groups, cycle track and footpaths are essential as they would enhance the mobility of these people.
- Similar to Thaltej gam, there is only AMTS and autorickshaw service available to support the mass transit in the existing situation. Considering the frequency of AMTS buses and their reliability, interventions are needed to support the first and last mile connectivity in this area.
- All in all, the Pre-LAP index score for this station is high mainly because of the low on-street car parking density score.

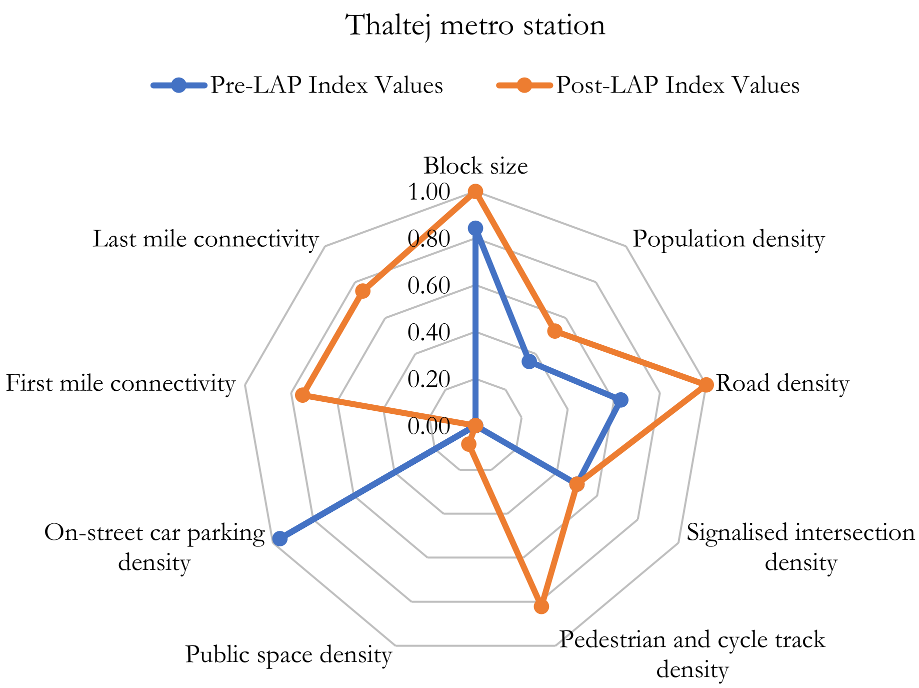

Figure 30: Pre-LAP and Post-LAP Index Values for Thaltej metro station

Post-LAP Findings

- Post-LAP interventions demonstration a positive impact on block size, population density, road density, first and last mile connectivity and pedestrian and cycle track density in particular.

- There is a marginal increase in the population density because this area caters to a high percentage of commercial development and densely organised buildings.
- The road density also does not seem to nudge much in the TOZ area but has targeted the accessibility in the village area by providing pedestrian roads that connect it with the commercial development nearby. This has also indicated a decrease in the block size making this station a highly walkable neighbourhood compared to all other station areas.
- Given the context of this metro station, it is important to increase the mobility of the people living in the village area. Considering this, Post-LAP has registered a maximum increase in the pedestrian and cycle track density in Thaltej station. In addition, three other modes are introduced next to the metro station to enhance the first and last mile connectivity for people belonging to different backgrounds.
- There is no change in the signalised intersection density and land-use diversity.
- The overall Post-LAP score has improved substantially.
- However, compared to other stations, the Post-LAP scores in Thaltej is higher and therefore, a good representative of TOD.

Station 3: Doordarshan kendra

The overall TOD index has documented a substantial increase from Pre-LAP to Post-LAP. As this is a transitional station, it contains characteristics of an urban as well as suburban area and therefore has the potential to grow rapidly in the future (Figure 31).

<u>Pre-LAP findings</u>

- It has accounted for a large block size which is evident from its low road density values.
- It is close to a major road that connects Ahmedabad and Gandhinagar cities, even then only one-fifth of the area is built.
- Moreover, it has the highest land-use diversity and therefore ranks lowest in population density.
- It is profusely diverse in terms of its land-use. It contains an old institution and is also marked by high commercial and mixed-use development. An argument to support the low population density could be the mixed-ness in its land-use.
- Since land-use diversity is the highest, the area needs integration with the transport system to support the travel needs of various people. For that, in connection to the metro, there are only two AMTS bus stops and autorickshaw located nearby. This indicates a lack of first and last mile connectivity and needs intervention to integrate land-use with transport.
- Out of the total area under roads, less than one-tenth of the area is covered by footpaths and absolutely no cycle tracks making it extremely difficult for people to walk around to access various land-uses.
- Surprisingly, given the diversity, on-street car parking is also very low. This can be due to the current police patrolling on the arterial streets. One good point is that the junction that connects the two arterials is signalised and therefore traffic flow is taken care of.
- All the indicators in the existing scenario do not push the TOD index much which is explicit from the low Pre-LAP TOD score for this station.

<u>Post-LAP findings</u>

- All indicators except for signalised intersection density and on-street car parking density have targeted improvement.
- Even though the block size has reduced by one fifth, the road density has increased by one third.

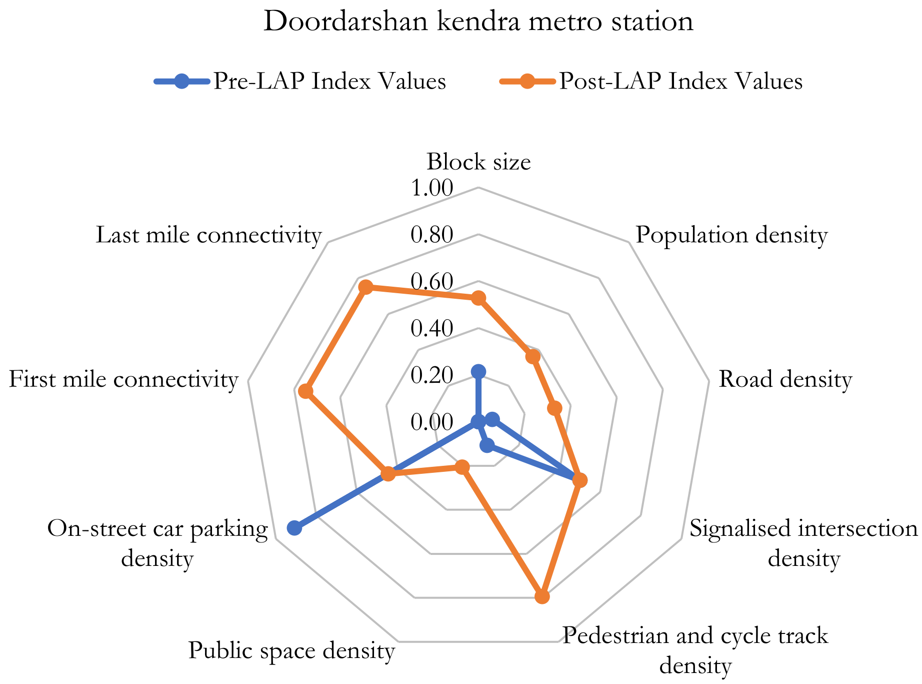

Figure 31: Pre-LAP and Post-LAP Index Values for Doordarshan kendra metro station

- Despite the increase in road density, the signalised intersection density does not increase.
- The pedestrian and cycle track density has increased significantly.
- The population density has increased sizably given the proximity to the major arterial.
- Out of the total road area, 10% is dedicated to on-street car parking.
- Two plots close to the metro station are identified for developing station level amenity.
- Building footprint density and land-use diversity do not record any change.
- Given the already diverse land-use, planning focus should be laid on increasing mode choices and this is exactly what the LAP has aimed at. There has been a 150% increase in the mode choices to enhance the first and last mile connectivity.
- To encapsulate, the Post-LAP has improved the overall level of TOD in this area.

Station 4: Gurukul road

Gurukul road station illustrates promising results as the level of TOD increases by two folds, ensuring the second rank in the Post-LAP index score across all the stations. Figure 32 elucidates the Pre and Post LAP values.

Pre-LAP findings

- The buildings are evenly distributed with one-third of the area built.
- No development is registered in the greenfield zone. Probably that can explain the absence of public roads in the southern part of the station area.
- Despite fewer roads, the block size is walkable but there are no public spaces.
- Additionally, there are no cycle tracks and with less road density, the pedestrian tracks are even lesser and discontinuous.
- Population density and land-use diversity are high with the dominance of residential land-use, plenty of mixed-use, the presence of a famous religious place and local commercial.

- The diverse land-use attracts a lot of traffic in this area. Signalised intersection helps in regulating the traffic movement but other junctions which are not signalised are frequented with pedestrian and vehicle conflicts.
- Like other stations, there is only AMTS and autorickshaw available to boost first and last mile connectivity.
- On-street car parking density is extremely low and has contributed the most in increasing the Pre-LAP Index value to 0.30.

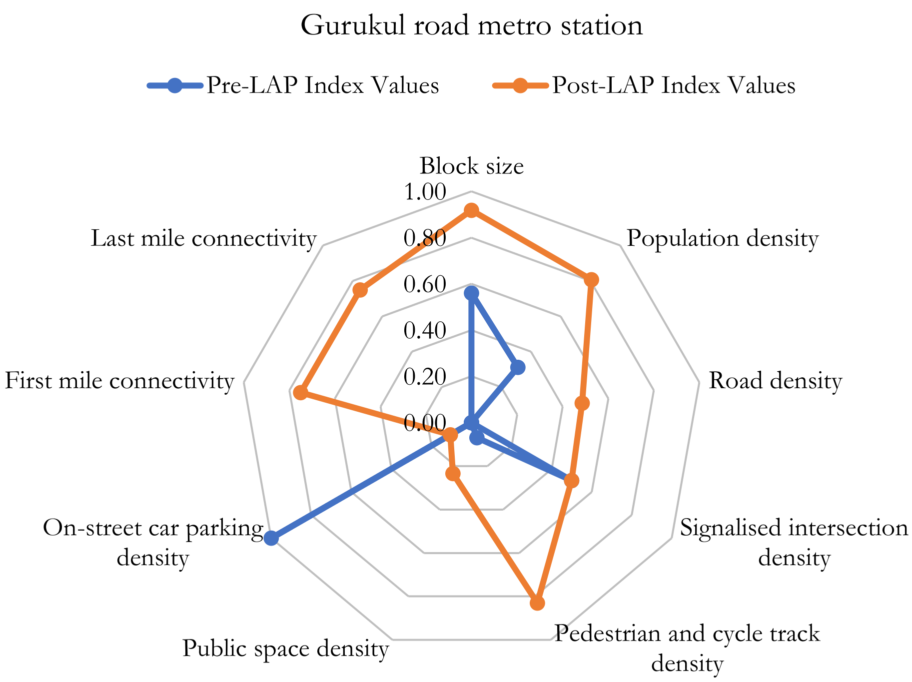

Figure 32: Pre-LAP and Post-LAP Index Values for Gurukul road metro station

<u>Post-LAP findings</u>

- This station experiences highest overall increase in the road density.
- A positive effect of this is the highest reduction in the block size across all the station areas.
- With this, the pedestrian and cycle track densities have also managed to grow with almost one-third of the road area dedicated to non-motorised activity thereby prioritizing people over vehicles.
- Although there are many new roads planned, there are no plans for providing signals at major intersections. This could be a critical issue which needs attention and intervention.
- The population density has drastically increased due to two third of the area under residential use.
- However, the increase in population is not supported by the creation of public spaces. Two relatively small pieces of land are acquired to create parks and station plazas.
- Considering the current land-use pattern and the need of the area, three mode choices are arranged to uplift the overall post-LAP index.
- Building footprint density and land-use diversity do not change. There is no projection for the change in the land-use which is one of the major pitfalls of LAP.
- Lastly, a high percentage of road area is dedicated for on-street car parking density.
- All in all, the overall Post-LAP Index has improved by two folds.

Station 5: Gujarat university

Gujarat university features promising results that has outshined all other stations concerning its Pre-LAP and Post-LAP score. There is a 1.5 times overall increase from Pre-LAP score (Figure 33).

Pre-LAP findings

- Being a university area, this station has a large public space that caters to several university events as well as city-level programs.
- It also contains a BRTS station that increases the mobility of the people and college students. As a part of a pilot project, the BRTS was supported by a bike sharing system.
- Major contributors of the high Pre-LAP scores are public spaces and first and last mile connectivity.
- The block size is large because there are large chunks of vacant land.
- Therefore, the built area is very less which is obvious due to the nature and characteristics of this station. This also explains the low population density.
- One-fifth of the area is covered by roads where the major contributor is the main arterial that runs parallel to the national highway. The high-density pockets in the maps are indicative of that.
- In a similar vein to other stations, there is only one signalised intersection which supports the movement of heavy traffic on the arterial roads.
- One-tenth of the road area is covered by broken and encroached footpaths.
- Even though this station promotes a bike sharing system, the use of bikes is negligible.
- On-street parking is low due to the police security.
- Considering all of this, the Pre-LAP scores are highest making this station a good illustrative of TOD.

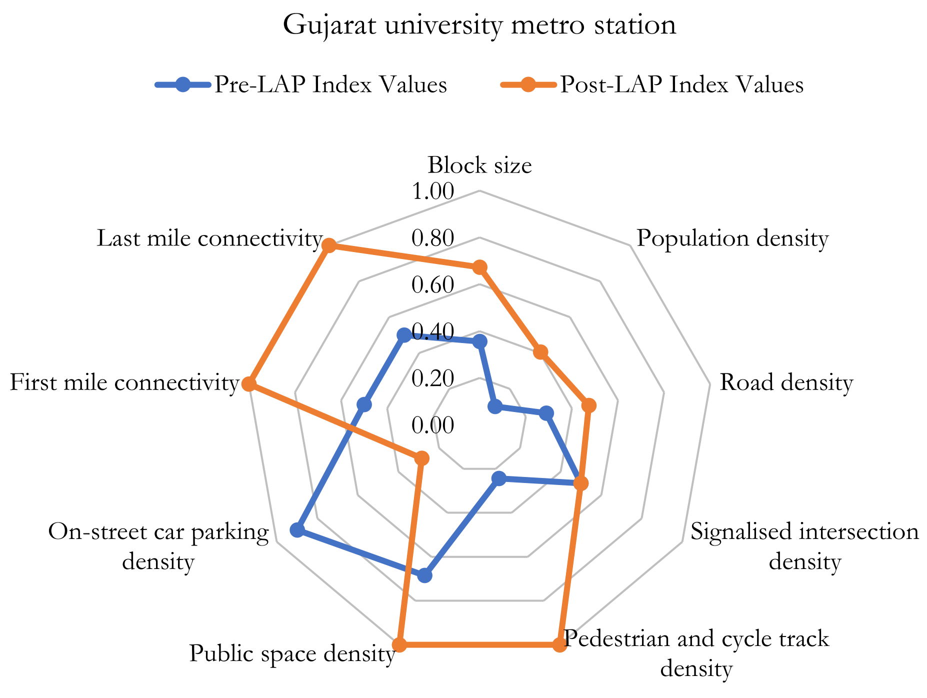

Figure 33: Pre-LAP and Post-LAP Index Values for Gujarat university metro station

Post-LAP findings

- The LAP interventions facilitate the already high TOD index scores by further improving the performance of all indicators except for building footprint density, land-use diversity, signalised intersection density and on-street car parking density.
- There are no proposals for the first three indicators whereas the latter negates the overall increase in the TOD index due to its negative relationship with TOD.

- Block size, pedestrian and cycle track density and public space density increases extensively whereas road density, population density and first and last mile connectivity have marginally improved.
- Even though the overall improvement in road density is 17%, the block size has reduced by 22%.
- More than one-third of the road space is earmarked to pedestrians and cyclists which gives the non-motorised users an edge.
- Next, to the already existing public space, the government has obtained land to develop public space spaces and station level amenities closer to the metro station.
- The increase in first and last mile connectivity is not as high as the other stations, even then this is the only station that has maximum mode choices and also BRTS connection.

Station 6: Commerce six roads

Figure 34 demonstrate the Pre-LAP and Post-LAP TOD Index scores. Despite the effort in increasing the level of TOD in Commerce six road station, the ratio does not seem to budge much as a lot of on-street car parking is proposed. This negates the overall increase in the Post-LAP TOD index which stands at 0.40 thereby not a good demonstrative of TOD development.

Pre-LAP findings

- Commerce six roads station area is categorized by a local commercial street with the presence of some institutions and the dominance of residential.
- The building density is high with more than 30% of the area built and is spread evenly. This has caused the highest population density in this area. Conversely, there are no public spaces.
- Even though the plots are smaller in size, the blocks are large questioning walkability.
- Regarding road density, one-fifth of the total area is covered by public roads. Out of which only one-tenth has broken and encroached footpaths. In addition, there are no cycle tracks.
- The station area comprises of two signalised intersections. These are important intersections where traffic snarls during peak hours.
- Since this area has the presence of a famous institution, BRTS is integrated with the university road. In addition to this, AMTS and autorickshaw stops are also available adding on to the first and last mile connectivity.
- Lastly, due to the presence of many residential streets, undesignated on-street car parking is observed which is the highest in this station area.
- Thereby, the overall Pre-LAP Index score is exceptionally low and not a good projection of a TOD development.

Post-LAP findings

- The overall increase from Pre to Post-LAP is marginal. This is attributed to the fact that first and last mile connectivity, signalised intersection density, building footprint density and land-use diversity records for no change.
- Public space has shown a slight improvement. Since the plot is away from the metro station, it cannot be used for developing station amenities but can act as a public open space.
- The block size has considerably reduced due to the introduction of pedestrian roads in this area and that is why the road density does not experience a major increase.
- The population density has earmarked an increase due to the dominance of residential land-use.
- A positive side is that more than 40% of the road area is provided for non-motorised activities.
- However, due to the poor performance of on-street car parking, the entire Post-LAP Index has registered a downfall.

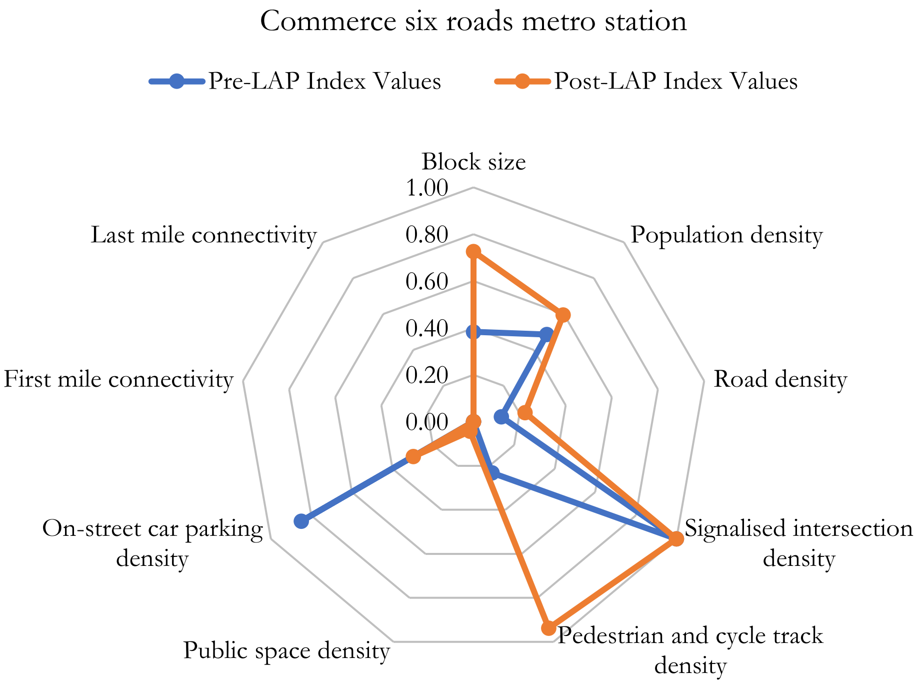

Figure 34: Pre-LAP and Post-LAP Index Values for Commerce six road metro station

Station 7: Stadium

Across all the stations, only Stadium records for a decrease in its index value from Pre-LAP to Post-LAP (Figure 35) and therefore the results are rather disappointing. Ironically this being the closest station to the city centre, near the Central Business District and near to the north-south and east-west metro interchange should have indicated improvement in the overall index score. The decrease is mainly caused by the excessive provision of on-street car parking density, no improvement in achieving first and last mile connectivity and a dearth of public spaces. Based on the results, this station is not a good indicator of TOD.

<u>Pre-LAP findings</u>

- The blocks are smaller in size due to the small size of the plots.
- This station records for the highest area under buildings. These buildings are evenly spread where commercial development has spurred on the first line of buildings whereas residential development has occurred on the inner streets.
- One-fifth of the total area is under roads. The higher densities pockets are observed in the southern area where pedestrian tracks are provided by are encroached with informal hawking.
- Since there is no major intersection in this area, signalised intersection density is zero. Similarly, public space density is also zero.
- Even though the building footprint density is the highest in this station, the population density is not so high. This is due to the built typology which promotes low rise buildings and bungalows.
- However, due to the presence of many residential streets, a significant amount of on-street car parking is recorded.
- To support the ridership of the metro, there is only one AMTS stop in the proximity and few undesignated autorickshaw stops.
- Accumulation of all these indicators have resulted in an overall Pre-LAP score of 0.29.

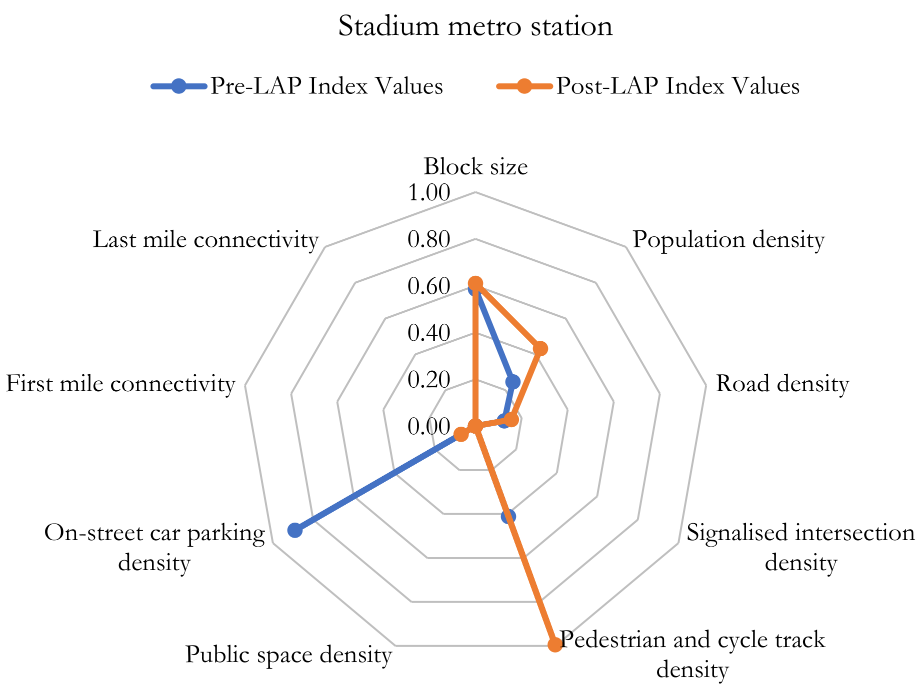

Figure 35: Pre-LAP and Post-LAP Index Values for Stadium metro station

<u>Post-LAP findings</u>

- The LAP fails to provide a proposal for building footprint density, land-use diversity, signalised intersection density, first and last mile connectivity and public space density. The LAP planning needs to acknowledge these indicators to improve the Post-LAP TOD index.
- The block size, road density and population density have registered marginal increases whereas pedestrian and cycle track density and on-street car parking density has recorded for a significant increase.
- Surprisingly, LAP has managed to dedicate almost half of the road space for pedestrian and cycle track density which is by far the highest across all the stations.
- Despite this increase, the overall index value does not indicate positive change because on-street car parking is also given one-fifth of the road space.
- Significant increase in on-street parking provision might affect the ridership of metro which is not good for the success of a TOD.
- In a nutshell, Stadium station is an exception and needs investigation on how to increase the Pre-LAP scores.

4.3. DISCUSSION

There is a relationship between the findings of the qualitative analysis and findings of the quantitative analysis. The **qualitative results** provide essential insights on the LAP planning procedure and its relation to the TOD. The general finding illustrates that Ahmedabad-LAP has indicated promising results and is geared towards making a successful TOD.

The **quantitative results** revealed that the local area planning would improve the level of TOD around six out of seven of the studied metro stations. In the exception, Stadium station, the potential for change is much smaller as its urban form is more consolidated and is also located near the centre of the city. This indicates that LAP is not able to bring all seven studied stations to the same level of TOD. The change in the improvement is because the level of improvement of each indicator is different and this is not in line with the suggestions of the interviewees. The experts involved in the LAP planning did not anticipate that each station area would be developed differently due to their spatial organisation and considerations.

A general discovery from the **quantification** is that the stations that are closer to the city centre have low levels of Post-LAP TOD. The excessive provision of **on-street parking** has resulted in a decline of the Post-LAP TOD index in all the station areas and a further decline in Commerce six roads and Stadium stations. This is also reported from the qualitative analysis.

In Post-LAP, **pedestrian and cycle track density** and **block size** tick all the boxes and show significant improvement in all the stations as opposed to Pre-LAP which is also revealed from the qualitative analysis. However, **public space density** does not show significant improvement in most of the stations. From the findings of the qualitative and quantitative analysis it is understood that the plots acquired near the metro stations will not only have space to develop parks, but they will also cater to various public amenities. Hence the effective green quality space will be much reduced. This is a pitfall of Ahmedabad-LAP as it is unable to contribute to creation of high-quality public spaces.

Building footprint density and **land-use diversity** were eliminated from the index calculations because there are no future projections for them. Had these indicators be inputted in the final score, the overall effect of LAP interventions would have been diluted. No conclusive plans and forecast for land-use is a direct drawback of the LAP because land-use and transport are confounding factors that impact not only the travel demand but also the travel pattern of the people. This was a general finding and suggestion from the interviews as well.

Even though **road density** is increasing, the **signalised intersection density** is not improving. It seems that LAP has not taken into consideration a traffic management plan for the proposed intersections. However, this should be incorporated in the LAP planning to avoid collision amongst various road users. On the other hand, **first and last mile connectivity** is indicating promising improvement in all the stations except for Commerce six roads and Stadium due to their dense urban form. This is a drawback of these stations because, in absence of feeder services, the access and egress from the metro are highly compromised. In total, most of the indicators score low or closer to zero in the Pre-LAP scenario, and this is reported in the spider diagrams as well.

In Commerce six roads and Stadium, the spatial constraints are such that high values of TOD cannot be achieved. This is expected because it is a brownfield approach and there is not much scope to intervene. In the remaining stations, the Post-LAP Index is improving which indicates success for the TOD and the ridership of the metro. However, there is still a scope of improvement in all the metro stations by developing policy recommendations that can strengthen the current gaps in the LAP and further improve the overall TOD.

Apart from this, in this research it was anticipated that there would be differences in the Pre-LAP and Post-LAP TOD index values and the Post-LAP values will improve the TOD because the LAP has undergone several planning interventions that would improve the TOD. The **anticipated result** stands out to be true and is augmented with the findings of the interviews, LAP document and the quantitative analysis.

Nevertheless, few informants opine and based on the **literature** of the Ahmedabad-LAP document; it is explicit that LAP has not satisfactorily acknowledged few operative principles that are extremely important for the overall increase of the TOD index. These principles are the following.

1. Land-use and transport integration
2. Provision of social housing

3. Policies for disincentivising car use
4. Parking management plan

Moreover, Ahmedabad-LAP has also failed to prepare a timeline for implementation of the planning projects and lacks quantification of the overall LAP proposal. These aspects are crucial for the success of any metro transit as **suggested by previous literatures** and **few experts**. If **affordable housing** will be allocated in LAP-TOD zone, then the actual users who are dependent on public transport will be able to use it like it was done in Curitiba. However, if affordable housing is provided elsewhere, then last mile connectivity should reach to these people as it was done in Bogota. **Land-use and transport** should be integrated to increase the ridership of metro transit, reduce the vehicles per mile travelled, shorten the trips and encourage more people to walk. Additionally, a **parking management plan** can ensure adequate location and amount of on-street as well as off street parking sports within the LAP zone to **disincentivising car use**.

Since **Ahmedabad-LAP has not duly considered** these aspects, the overall purpose of a local area plan has diluted. It has diluted because LAP planning is not only limited to providing a metro transit, but it is also about linking these aspects that have a direct repercussion on the ridership of the metro. Therefore, **policy recommendations** are required in this direction to strengthen the current LAPs.

In this study, these indicators are not incorporated because they are missing at source. However, had these indicators been incorporated, the **method** used to evaluate LAP is not suitable to address these aspects because it can deal with only quantitative indicators and not with qualitative indicators. Therefore, there is a need to **further investigate** in identifying a suitable method that can **synthesis qualitative aspects together with the quantitative aspects**. The points thus raised can be taken up as a part of future research.

5. CONCLUSION AND RECOMMENDATION

This study aimed to evaluate the effect of LAPs on the level of TOD in Ahmedabad (West). To achieve that, a suite of eleven indicators was developed. The indicators were selected based on existing literature but also adapted from the LAPs and other site conditions. These indicators were quantified using a geospatial approach, for Pre-LAP (baseline situation) and Post-LAP scenarios (situation after the implementation of the LAPs), and an evaluation was done for a 200-meter radius around the seven metro stations based on the comparison of these two situations. Additionally, eight experts were interviewed to get a variety of perspectives regarding the preparation and planning procedure of the LAP and the literature on the LAP document was studied as a part of qualitative analysis.

The indicators incorporated in this study were quantified using a non-indexing and indexing method. These methods are suitable to quantify the eleven studied indicators, and therefore it helps in fulfilling the research aim and objectives. Paradoxically, the results reveal that stations (Stadium) that are closer to the city centre have low levels of Post-LAP TOD index and stations (Thaltej gam) that are away from the city centre have high levels of Post-LAP TOD index. In the exception, Stadium station, the potential for change is much smaller as its urban form is more consolidated. This indicates that LAP is not able to bring all seven studied stations to the same level of TOD. It is improving but the improvement is not the same everywhere, and this is not in line with the findings of the qualitative results. The experts involved in the LAP planning did not anticipate that each station area would be developed differently due to their spatial organisation and considerations.

Additionally, the findings from the qualitative analysis reveal that Ahmedabad-LAP has not satisfactorily considered few underlining principles that are important for the success of the TOD. These principles are land-use and transport integration, disincentivising car use, parking management plan, and promoting affordable housing. Since these principles are missing in the LAP document, they were not quantified in this study. However, even if the LAP document had addressed these principles, the method adopted in this study is not suitable to operationalise these principles because it can only deal with quantitative data. Therefore, there is a need to find a method that can synthesis the qualitative and quantitative indicators together to study the overall impact of LAP.

Based on the qualitative and quantitative analysis, few policy recommendations are suggested to strengthen Ahmedabad-LAP and improve the TOD index further. These recommendations are structured under eleven aspects and are in line with the studied indicators.

1. <u>Land-use and transport integration</u> – Based on the analysis of land-use diversity which is described on page 48, most of the stations have high entropy value indicating diversity within the land-use. For stations with low diversity, Ahmedabad-LAP should incentivise a desirable mix of activities by allocating a certain percentage under mixed-use and commercial activities.
2. <u>Parking management plan</u> – In line with what was learnt from the literature and looking at the negative externalities, on-street parking has contributed to the Post-LAP index on page 49, there is a need to adopt a parking management plan. As an integral part of this plan, a parking survey needs to be carried out in the LAP zone to understand the parking demand. Post this, an appropriate charge for the on-street parking should be levied such that the parking never remains underutilised or overutilized.
3. <u>Public space density</u> – The Post-LAP score for public space density is low. To increase the green cover, plots reserved for public spaces within the LAP zone should be connected to the nearby open spaces which are at a walkable distance and these should be well integrated with the metro stations. Through a tree-lined corridor development, this should be done which in turn will encourage walkability and will create a seamless integration of metro stations with the pedestrian infrastructure of the city. These

corridors should be designed by using the available resources in a sustainable way. For instance, Thaltej gam and Thaltej metro stations are within 500 m distance from Thaltej lake. These three nodes can be linked together by developing a corridor that responds to the immediate surrounding and its neighbourhood such that it becomes a vibrant and lively space and may attract more people to use the space and thus the metro.

4. Tree plantation – Ahmedabad is climatically hot for 8-10 months in a year. Therefore, to complement the pedestrian and cycle track densities, it is essential to provide shade-giving trees alongside the roads. This will aid in encouraging walking and cycling within the LAP zone. Public domain should also be used as a public space with more trees.
5. Disincentivising car use – To discourage car use, on-street and off-street parking should be charged, and its provision should be made limited. In addition, robust pedestrian infrastructure should be developed and should be supported with multiple paratransit options so that manoeuvring via non-motorised transport or public transport becomes as convenient and comfortable as cars.
6. Road density – The Post-LAP road density values are a good representative of TOD. However, the roads can be complemented with tree-lined to improve the experience of walking.
7. Signalised intersection density – Ahmedabad-LAP needs to incorporate a traffic management plan for all the proposed intersections.
8. First and Last mile connectivity – As described on page 51 and 53, Post-LAP scores have significantly improved the FMC and LMC in all the stations except for Commerce six roads and Stadium. Since feeder buses are not proposed in these stations due to lack of space, it is recommended to identify a plot for parking away from the metro station and then connect the plot with the metro station via a feeder bus. Through this, the purpose of the feeder buses will be solved, and more people will be attracted to the metro station. Additionally, LAP should provide means through which the AMTS, BRTS and Metro can be technologically linked. LAP should also detail out how much off-street parking should be provided in each metro station area by conducting a parking survey.
9. Provision of affordable housing – It is evident from the qualitative analysis that Ahmedabad-LAP should invest in promoting social housing within the LAP zone. Since affordable housing is a social welfare subject, the local government should intervene in this matter. There are two recommendations for this. Firstly, the government can save a portion of the money produced by the chargeable FSI and deposit it in the housing fund. This fund can be used later by the government for developing social housing within the TOD zone in walking distance of public transport. Secondly, the government can give the land to the private sector at a low price, and through the Public Private Partnership (PPP), affordable housing can be developed. In a nutshell, the government needs to find out an innovative financial and sustainable model which can provide affordable housing in the TOD zone.
10. Coordination between multiple authorities – As studied in the literature and also from the qualitative analysis, it seems that there is a lack of coordination between the metro planning and construction authorities. For instance, the LAPs are prepared for the western corridor whereas the metro is constructed and is planned to function in March 2019 for the eastern corridor where LAPs are not yet prepared. It is required to have better coordination amongst these authorities for effective implementation and execution of LAPs and metro transit.
11. Method limitation – In this study, qualitative and quantitative analysis is undertaken. However, based on the policy recommendations, there are more things to the TOD that are important and are not analysed in this study because the method can deal with only quantitative analysis. There is a scope of taking this study and develop a method that can synthesis qualitative and quantitative results together

If these recommendations are incorporated in the current LAP planning, then the Post-LAP TOD index can improve especially for Commerce six roads and Stadium stations. Nevertheless, these recommendations are developed contextually but are not limited to the seven stations and can be extended to the remaining metro stations that are under preparation in Ahmedabad.

LIST OF REFERENCES

Acheampong, R. A., & Silva, E. A. (2015). Land use-transport interaction modeling A review of the literature and future research. *Source: Journal of Transport and Land Use*, *8*(3), 11–38. https://doi.org/10.5198/jtlu.2015.806

Anonymous. (2008). Spatial planning. *Cities*. https://doi.org/10.1016/S0264-2751(98)00028-6

AUDA. (2017). *Local area planning Part-9B. Unpublished manuscript.* Ahmedabad, India.

Balachandran, B. R., Adhvaryu, B., & Lokre, A. (2006). *Urban transport in India: Problems, responses and strategies*. Ahmedabad, India. https://doi.org/10.13140/RG.2.1.1798.0327

Bertolini, L. (1996). Nodes and places: Complexities of railway station redevelopment. *European Planning Studies*, *4*(3), 331–345. https://doi.org/10.1080/09654319608720349

Bhatt, C., Paradkar, P., & Fliert, N. van de. (2012). *Station area planning. Institute for Transportation and Development Policy*. India.

Bonin, O., & Tomasoni, L. (2015). Evaluation of a transit-oriented development scenario in a medium-sized French city by simulation models. *Science Engineering Research Support SoCiety*, *3*(1), 20. https://doi.org/10.14257/ijt.2015.3.1.07>

Brooks, A., Bleiweiss, P., Daggs, N., Watkins, A., & Sims, R. (2008). *Station area planning, TOD 202*. Oakland.

Calthorpe, P. (1993). *The next American metropolis : ecology, community, and the American dream*. Princeton Architectural Press.

Census of India. (2018). Office of the Registrar General & Census Commissioner, India. Retrieved February 3, 2019, from http://www.censusindia.gov.in/

Center of Excellence in Urban Transport. (2018). *Alternative analysis. Unpublished manuscript.* (Vol. 31). Ahmedabad, India.

Cervero, R. (2013a). BRT TOD:Leveraging Transit Oriented Development with Bus Rapid Transit Investments. *13th World Conference on Transport Research*. Retrieved from http://www.wctrs-society.com/wp-content/uploads/abstracts/rio/selected/1190.pdf

Cervero, R. (2013b). Linking urban transport and land use in developing countries. *Journal of Transport and Land Use (JTLU)*, *6*, 7–24. https://doi.org/10.5198/jtlu.v1.425

Cervero, R., & Kockelman, K. (1997). *Travel demand and the 3Ds: Density, Diversity and Design*. *Transpn Res.-D* (Vol. 2). Retrieved from https://ac.els-cdn.com/S1361920997000096/1-s2.0-S1361920997000096-main.pdf?_tid=6d8e2b69-b008-4892-b7e3-c23d63f2dfbf&acdnat=1533907334_0f60b9bd1aa75055b9074f6c31483f00

Cervero, R., & Murakami, J. (2009). Rail and property development in Hong Kong: Experiences and extensions. https://doi.org/10.1177/0042098009339431

Chowdhury, S. R. (2019). Smart Cities Mission: As Bhopal is redeveloped, poor residents worry if they will have a place in it. Retrieved February 6, 2019, from https://scroll.in/article/910434/as-bhopal-is-recast-as-a-smart-city-poor-residents-worry-if-they-will-have-a-place-in-it

Croese, S. (2016). *International case studies of transit-oriented development-corridor implementation*. Johannesburg.

Currie, G. (2006). *Bus transit oriented development - Strengths and challenges relative to rail. Journal of Public Transportation* (Vol. 9). Retrieved from https://www.nctr.usf.edu/jpt/pdf/JPT 9-4 Currie.pdf

Curtis, C. (2012). Delivering the "D" in transit-oriented development: Examining the town planning challenge. *Journal of Transport and Land Use*, *5*(3), 83–99. https://doi.org/10.5198/jtlu.v5i3.292

Curtis, C., Renne, J. L., & Bertolini, L. (2009). *Transit oriented development: making it happen*. (C. Curtis, J. L. Renne, & L. Bertolini, Eds.), *Transit*. England: Ashgate Publishing Limited A. https://doi.org/10.1068/a38377

Delhi Development Authority. (2015). *Masterplan of Delhi 2021 - Chapter 19 : Transit Oriented Development*. Delhi.

Dittmar, H., & Ohland, G. (2004). *The new transit town: Best practices in transit-oriented development*. (Hank Dittmar & Gloria Ohland, Eds.). London: Island Press. https://doi.org/na

Drask, M., Hyd, C., & Planning, T. (1989). Pedestrian safety measures - past and future, (1972), 86–96.

Evans, J. E., & Pratt, R. H. (2007). *Transit oriented development, TCRP's Traveler response to transportation system changes handbook series*. USA. Retrieved from www.TRB.org

Ewing, R., & Cervero, R. (2010). Travel and the built environment. *Journal of the American Planning Association*, (11). https://doi.org/10.1080/01944361003766766

Gerring, J. (2018). What is a case study and what is it good for? *American Political Science Review*, *98*(2). https://doi.org/10.1017/S0003055404001182

Grigolon, A., Singh, Y. J., Koeva, M., & Madureira, M. (2016). *Transit-Oriented Development (TOD) assessment using 3D visualisation and modelling Prospects and opportunities*. Enschede, The Netherlands.

Guo, J., Nakamura, F., & Li, Q. (2018). Efficiency assessment of transit-oriented development by data envelopment analysis : Case study on the Den-en toshi line in Japan. *Journal of Advanced Transportation*, *2018*. https://doi.org/https://doi.org/10.1155/2018/6701484 Research

Hale, C., & Charles, P. (2006). *Making the most of transit oriented development opportunities*. Australia. Retrieved from http://atrf.info/papers/2006/2006_Hale_Charles.pdf

Hancock, M. M. B., Shepherd, D. S., Faatz, D. J., Lopez, D. P. D., Lehmann, D. P., Burns, A., … Duffany, B. (2014). *Transit oriented development strategic plan*. Denver.

Higgins, C. D., & Kanaroglou, P. S. (2016). A latent class method for classifying and evaluating the performance of station area transit-oriented development in the Toronto region. *Journal of Transport Geography*, *52*, 61–72. https://doi.org/10.1016/j.jtrangeo.2016.02.012

Islam, M., Brussel, M., Grigolon, A., & Munshi, T. (2018). Ridership and the Built-form indicators: A study from Ahmedabad Janmarg Bus Rapid Transit System (BRTS). *Urban Science*, *2*(4), 95. https://doi.org/10.3390/urbansci2040095

ITDP. (2014). *The TOD Standard-2.1*. New York. Retrieved from www.itdp.org

Jacobson, J., & Forsyth, A. (2008). Seven American TODs: Good practices for Urban Design in Transit-Oriented Development projects. *Journal of Transport and Land Use*, *1*(2), 51–88. https://doi.org/10.5198/jtlu.v1i2.67

Joshi, R., Joseph, Y., Chandran, V. M., & Darji, V. (2017). *Transit-oriented development: Lessons from Indian experiences*. Ahmedabad, India.

Joshi, R., Munshi, T., Joseph, Y., Patel, K., Chandran, V. M., & Darji, V. (2017). *Links between Transit riders and Built form : The case of Ahmedabad (West)*. Ahmedabad, India.

Kaushik, H. (2018, July 6). BRTS: Ahmedabad bus users down 25% in a decade! *The Times of India*. Retrieved from https://timesofindia.indiatimes.com/city/ahmedabad/ahmedabad-bus-users-down-25-in-a-decade/articleshow/64877102.cms

Li, C.-N., Lin, C., & Hsieh, T.-K. (2016). TOD district planning based on residents' perspectives. *ISPRS International Journal of Geo-Information*, *5*(4), 52. https://doi.org/10.3390/ijgi5040052

Lingzhu, Z., Alain, C., & Yu, Z. (2016). Configurational accessibility study of road and metro network in

Shanghai, 1–33. https://doi.org/10.1111/j.1365-2745.2009.01572.x

Litman, T. A. (2018). *Land use impacts on transport - how land use factors affect travel behavior*. Canada. Retrieved from www.vtpi.orgInfo@vtpi.org

Maarseveen, M. F. A. M. Van, Singh, Y. J., Zuidgeest, M. H. P., & Flacke, J. (2012). A design framework for measuring transit oriented development. *Transactions on the Built Environment*, *128*, 719–730. https://doi.org/10.2495/UT120

Ministry of Housing and Urban Affairs. (2018). *Pilot on Formulation of Local Area Plan (LAP) & Town Planning Scheme (TPS) For selected Cities*. Delhi.

Moule and Polyzoides. (2017). *Transit-Oriented Development*. California. Retrieved from https://www.mparchitects.com/site/sites/default/files/content/MPA-TOD.pdf

Munshi, T. G. (2013). *Built form, travel behaviour and low carbon development in Ahmedabad, India. (Doctoral Dissertation)*. Faculty ITC, University of Twente, Enschede, The Netherlands. Retrieved from https://webapps.itc.utwente.nl/librarywww/papers_2013/phd/munshi.pdf

Newman, P., & Kenworthy, J. (1991). Transport and urban form in thirty-two of the world principal cities. *Transport Reviews*, *11*(3), 249–272.

NUMBEO. (2018). Southern Asia: Pollution Index by City 2018 Mid-Year. Retrieved September 29, 2018, from https://www.numbeo.com/pollution/region_rankings.jsp?title=2018-mid&region=034

Ogra, A., & Ndebele, R. (2014). The role of 6Ds: density, diversity, design, destination, distance, and demand management in transit oriented development (TOD). *Neo-International Conference on Habitable Environments*, (May 2013), 539–546.

Pardo, C. (2006). *Raising public awareness about sustainable urban transport*. Germany. Retrieved from http://www.sutp.org

Parker, T., Mckeever, M., Arrington, G., & Smith-Heimer, J. (2002). *Statewide transit-oriented development study factors for success in California*. California. Retrieved from http://www.dot.ca.gov/hq/MassTrans/Docs-Pdfs/TOD-Study-Final-Rpt.pdf

Renne, J. L. (2007). *Measuring the performance of transit-oriented developments in Western Australia*. Australia. Retrieved from http://www.vtpi.org/renne_tod_performance.pdf

Ritsema Van Eck, J., & Koomen, E. (2008). Characterising urban concentration and land-use diversity in simulations of future land use. *Ann Reg Sci*, *42*, 123–140. https://doi.org/10.1007/s00168-007-0141-7

Rizvi, A. (2014). *How planing process impacts bus rapid transit outcomes: A comparision of experiences in Delhi and Ahmedabad, India (Doctoral Dissertation)*. Columbia University.

Saitta, S. (2007). Standardization vs. normalization. Retrieved February 4, 2019, from http://www.dataminingblog.com/standardization-vs-normalization/

Schlossberg, M., & Brown, N. (2004). Comparing Transit-Oriented Development sites by walkability indicators. *Transportation Research Record: Journal of the Transportation Research Board*, *1887*, 34–42. https://doi.org/10.3141/1887-05

Shaikh, S. (2018, March 31). The missing last-mile link. *The Times of India*. Retrieved from https://timesofindia.indiatimes.com/city/ahmedabad/the-missing-last-mile-link/articleshow/63550839.cms

Shastry, S. (2011). *Spatial assessment of transit oriented development in Ahmedabad , India. (MsC Dissertation)*. ITC Faculty, University of Twente.

Singh, P. (2016). *Assessment of TOD Policies and Implementation Process. Cases of Delhi and Ahmedabad. (MsC Dissertation). CEPT University*. CEPT University.

Singh, Y. J. (2015). *Measuring transit-oriented development (TOD) at regional and local scales : a planning support tool. (Doctoral Dissertation).* Faculty of ITC, University of Twente, Enschede, The Netherlands. https://doi.org/10.3990/1.9789036539982

Singh, Y. J., Fard, P., Zuidgeest, M., Brussel, M., & Maarseveen, M. van. (2014). Measuring transit oriented development: a spatial multi criteria assessment approach for the City Region Arnhem and Nijmegen. *Journal of Transport Geography*, *35*, 130–143. https://doi.org/10.1016/j.jtrangeo.2014.01.014

Singh, Y. J., Flacke, J., Zuidgeest, M., & Maarseveen, M. van. (2018). GIS in sustainable urban planning and management: a global perspective. In M. Van Maarseveen, J. Martinez, & J. Flake (Eds.) (pp. 1–394). Enschede, The Netherlands: Taylor & Francis Group. Retrieved from https://www.crcpress.com/GIS-in-Sustainable-Urban-Planning-and-Management-Open-Access-A-Global/Maarseveen-Martinez-Flacke/p/book/9781138505551

Statista. (2016). Total number of vehicles across Ahmedabad, India. Retrieved September 29, 2018, from https://www.statista.com/statistics/665754/total-number-of-vehicles-in-ahmedabad-india/

Sun, G. (2013). Sustainable land transport system -Singapore's experience. Singapore: Land transport authority academy. Retrieved from https://sustainabledevelopment.un.org/content/documents/3756sun.pdf

Taki, H. M., Maatouk, M. M. H., Qurnfulah, E. M., & Aljoufie, M. O. (2017). Planning TOD with land use and transport integration: a review. *Journal of Geoscience, Engineering, Environment, and Technology*, *2*(1), 84. https://doi.org/10.24273/jgeet.2017.2.1.17

Taylor-Powell, E., & Steele, S. (1996). *Collecting evaluation data: An overview of sources and methods*. Madison. Retrieved from http://learningstore.uwex.edu/assets/pdfs/G3658-4.pdf

TNN. (2016, January 5). City's BRTS didn't enhance public transport usage. *The Times of India*. Retrieved from https://timesofindia.indiatimes.com/city/ahmedabad/Citys-BRTS-didnt-enhance-public-transport-usage/articleshow/50450129.cms

TNN. (2017, May 2). BRT System: BRT losses mount to more than Rs 73 crore. *The Times of India*. Retrieved from https://timesofindia.indiatimes.com/city/ahmedabad/brt-losses-mount-to-more-than-rs-73-crore/articleshow/58466373.cms

World Population Review. (2018). Ahmedabad population 2018 (Demographics, Maps, Graphs). Retrieved June 6, 2018, from http://worldpopulationreview.com/world-cities/ahmedabad-population/

APPENDIX

6.1 Description of the Interviewees

1. Himanshu Thakker – Deputy Town Planner, Ahmedabad Urban Development Authority (AUDA).
2. Dr. Rutul Joshi – Faculty in Planning, CEPT University.
3. AB Gor – CEO, Ahmedabad Urban Development Authority (AUDA)
4. Deepa Dave – Assistant Town Planner, Ahmedabad Urban Development Authority (AUDA).
5. Dr. Abhijeet Lokre - Faculty in Planning, CEPT University.
6. Dr. H M Shivanand Swamy – Faculty in Planning, CEPT University and Executive director, Centre of Excellence in Urban Transport.
7. IP Gautam, IAS, Managing Director, MEGA Consultancy
8. Niyati Thakkar, Senior Executive, MEGA Consultancy

6.2 Interview questions

Interview questions for the Government

1. Why was the metro conceived? How did the government decide on this routing?
2. What inspired the government to initiate local area planning with these specific indicators?
3. What is the goal of the LAP? Are all LAPs aimed at improving TOD-ness or is there any other objective associated with the LAPs? If TOD is the objective associated with the metro, then what are the objectives associated with the TOD?
4. What are your expectations from the LAPs? When do you think will the LAPs be implemented?
5. What kind of urban development is envisaged by the implementation of these LAPs? Is the optimum in reference to Ahmedabad?
6. Have you adopted a one-size-fits-all approach for all the LAPs? For instance, some stations need attention in terms of green spaces, or for some, it is more about commercial development While some, stations need more walking interventions, some need more feeder connections.
7. Do you think changes in planning interventions will improve the TOD index? How do you anticipate the stations to improve? Will the TOD improve everywhere in equal measure or will it be different? What do you think is causing the difference?
8. Do you believe LAP would make use of metro more attractive? Which elements would make it attractive amongst these (road density, FSI, built form, ground coverage, building height, block size, on-street and off-street parking, pedestrian and cycle track, pedestrian infrastructure, public domain, public spaces and park, road design, intersection design, BRTS and AMTS stops and feeder buses)?
9. How will you ensure implementation of these indicators along with the operation of the metro? Will it be station by station or indicator by indicator for the whole area?
10. What is the ideal threshold for these indicators in particular on-street and off-street parking, ground coverage, building height, block size and FSI in the context of Ahmedabad?
11. Why is land-use and transport integration not explicitly discussed in the LAP?
12. LAPs are qualitative in nature and are sort of a general planning guidelines. How do you think context sensitive implementations will be performed?
13. Do you think if everything gets implemented as per the LAP, Ahmedabad will become TOD?
14. Are there any other practices of the people or the characteristics of the city which makes the city diverse and are not included in the LAP? In other words, which other aspects/ indicators do you think can influence planning on the ground which can again influence the TOD and is not used in the LAP?
15. How do you want to address the LAP for the remaining stations?

16. Do you have any policy or planning suggestion on how to implement the LAPs or what more to add in the LAPs?
17. Are there any plans to have a technological/fare/schedule integration between BRTS, AMTS and the metro?
18. Does the government work in collaboration with mega and other consultants?
19. Does LAP encourage mixed land use or are there any incentives to promote mixed land use?
20. Is LAP contributing to high level of public spaces?
21. What is the main idea of LAP?
22. What is a way to limit parking?
23. Off-street parking laws are encouraging more cars. How do you think this will help public transportation?
24. What is the justification to the narrowing down of footpaths along BRT corridor?
25. How are the mistakes of BRTS addressed in the metro?
26. Parking is not social infrastructure. Why is SI space used for parking?
27. What about the affordable housing in TOD zone?

Interview questions for the Faculties

1. Have you heard about the local area planning around the proposed metro stations? If yes, what is your take on it?
2. Do you believe LAP would make use of metro more attractive? Which elements would make it attractive amongst these (road density, FSI, built form, ground coverage, building height, block size, on-street and off-street parking, pedestrian and cycle track, pedestrian infrastructure, public domain, public spaces and park, road design, intersection design, BRTS and AMTS stops and feeder buses)?
3. What is the ideal threshold for these indicators in particular on-street and off-street parking, ground coverage, building height, block size and FSI in the context of Ahmedabad?
4. Do you think if everything gets implemented as per the LAP, Ahmedabad will be become TOD?
5. Are there any other practices of the people or the characteristics of the city which makes the city diverse and are not included in the LAP? In other words, which other aspects/ indicators do you think can influence planning on the ground which can again influence the TOD and is not used in the LAP?
6. Do you have any policy or planning suggestion on how to implement the LAPs or what more to add in the LAPs?
7. Are you aware of any plans to have a technological/fare/schedule integration between BRTS, AMTS and the metro?
8. Footpath narrowing
9. What is your take on the new parking drive? do you think this can affect the mass transit's last mile connectivity?

Interview questions for MEGA

1. Why was the metro conceived? What inspired the government to initiate metro?
2. How did the government decide on the routing? Is there a political or equality perspective to it?
3. When will the metro start functioning? What will be its fare structure?
4. Does MEGA work in collaboration with other consultants? What is everyone's role? How often do they interact?
5. Who is the decision-making body? Government of MEGA? And how are the decisions made?
6. What is the estimated ridership of the metro? Are there any plans for last mile connectivity to increase the ridership?
7. Does MEGA work in conjunction with the LAPs prepared by AUDA?
8. How does MEGA perceive the station area planning and proposed feeder network in LAP?
9. What are the key elements of station area design?
10. What are the challenges on site?

11. What are your expectations from the metro?
12. What is the main work of MEGA? Do they talk about linking land-use and transport systems or is it more focused on land ownership and development?
13. Do you have any policy or planning suggestion on how to implement the metro?
14. Are there any plans to have a technological/fare/schedule integration between BRTS, AMTS and the metro?

6.3 Schedule during fieldwork

Table 7: Schedule during fieldwork

13th – 14th October	Welcome of Anna Grigolon and some sightseeing
15th October	Interview with Himanshu Thakker, Director of LG School of Architecture, former Deputy Town Planner AUDA (Ahmedabad Urban Development Authority) and Dr. Rutul Joshi, Head, Doctoral Office and Associate Professor at CEPT University
16th October	Interview with AB Gor, CEO AUDA and Dr. Abhijeet Lokre, Co-Founder of The Urban Lab and Visiting Professor at CEPT University
17th October	Interview with Deepa Dave, Assistant Town Planner AUDA and data acquisition at AUDA (start of the process)
18th October	Metro Site visits: East/West corridor
19th October	Identifying options for transcribing of the interviews. Departure of Anna Grigolon.
20th October	Transcribing of interviews
21st October	Site visit to Gandhigram and Paldi metro station
22nd October	Visit to MEGA (Gandhinagar) for Data collection and interview with Dr. I.P. Gautam, IAS, Managing Director, MEGA Consultancy).
23rd October	Transcribing of interviews and site visit to Stadium metro station
24th October	Visit to CEPT to meet Saswat Bandhopadhyan, Sejal Patel, Madhu Bharti and Anjana Vyas. Visit to Nilpa to meet Shivanand Swamy. Visit to Stantec requesting for data.
25th October	Interview with Dr. Shivanand Swamy, Executive Director, Centre of Excellence in Urban Transport, Visit to AUDA requesting for data and Transcribing of interviews
26th October	Visit to AUDA requesting for data, Visit to CEPT for meeting Anjana Vyas (absent), Visit to AUDA to collect secondary data and Attended the seminar on Higher FSI: A boon or a bane?
28th October	Coding of interviews in Atlas.ti and site visit to Vadaj and Ranip
29th October	Coding of interviews and site visit to Commerce metro station
30th October	Understanding the data, processing it in GIS and site visit to Gujarat university metro station.
31st October	Preparing interviews summary and processing data in GIS.
1st November	Processing data in GIS and site visit to Thaltej Gam metro station.
2nd November	Coding of interviews, prepared interview summary and attended a debate on Higher FSI: A boon or a bane?
3rd November	Processing data in GIS and site visit to Old High court metro station
4th – 6th November	Processing data in GIS
9th November	Site visit to Gurukul, Doordarshan and Thaltej metro stations.

6.4 Site pictures of metro construction

Figure 36: Metro construction pictures (Source – MEGA)